FARM CROPS

BY MANY SPECIALISTS

UNDER THE EDITORSHIP OF

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PASTURES AND HAY

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PASTURE PLANTS

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Pasture plants are usually considered in three main groups, viz.: grasses (*Gramineæ*), clovers and allied plants (*Leguminosæ*), and miscellaneous (plants belonging to other natural orders).

GRAMINEÆ. GRASSES

General Characteristics of Grasses.

In describing grasses, the following terms are frequently used: *tufted*, when all the shoots or tillers are above ground and growing in a more or less dense tuft; *creeping*, when some of the shoots take a horizontal course either in the soil or on the surface; when such shoots grow underground they are known as *rhizomes*, when they grow above ground they are known as *stolons* or *runners*.

The grass leaf consists of two main parts: the *sheath* (or the lower portion which remains surrounding the shoot or stem even when the leaf is fully expanded), and the *blade* (the green, strap-shaped upper portion, standing at an angle to the shoot or stem when the leaf is fully expanded). The sheath is *split* when it does not form a complete tube around the shoot or stem, although the margins may meet or may even overlap to some extent. It is *entire* when, at least for the greater part of its length, it forms such a complete tube. Whether a sheath is split or entire can be seen by cutting a section across the shoot or stem: if split, the section of the sheath will form an incomplete enclosure; if entire, the enclosure will be complete.

The leaf blade is *rolled in the bud* when one margin only of the leaf can be seen as it emerges from the bud. The arrangement is similar to a long sheet of paper rolled up lengthwise. It is *folded in the bud* when the two halves lie on each other with the margins touching but not overlapping as the young leaf emerges. This arrangement is similar to a long sheet of paper folded lengthwise along the middle.

Either the sheath or the blade may be more or less *keeled.* The keel is a prominent ridge running lengthwise along the sheath or along the middle of the under surface of the blade.

At the bottom end of the leaf-blade, where it joins the sheath, the two sides of the blade are sometimes produced downwards into more or less prominent *auricles.* In some grasses these completely clasp the shoot or stem.

The *ligule* is a longer or shorter membranous outgrowth of the leaf at the point where the blade and sheath meet. It is erect, and in a straight line with the inner surface of the sheath. In some grasses it is very prominent, while in others it is very short. It can best be seen by drawing the blade gently away from the stem or shoot. The leaves of a grass are arranged in two rows on the stem. In the vegetative state, the leaves are set very closely together, so that they appear to originate almost at the same point. When flowers and " seeds " are to be produced, the stem lengthens, and the leaves become much more widely set apart. The points at which the leaves arise are known as the *nodes*, and here the stem is solid. In the spaces between the nodes, the *internodes*, the stem is usually hollow.

The stem branches quite close to the ground and also towards the top. The branching at the top part gives rise to the *inflorescence* or *ear*, and is of various types, as may be readily seen by comparing the ears of barley and oats. The oat inflorescence consists of many relatively long branches carrying *spikelets*. A ripe spikelet of the oat consists of the two chaffy scales, or *glumes*, enclosing one or more " grains ". The grain again is made up of the two *paleæ*, or husks, and the *caryopsis*, or kernel. The outer palea (sometimes called the lower pale) almost surrounds the caryopsis, so that the inner palea, or upper pale, is not very easily seen in the ripe grain. It is much more easily seen before the grain is ripe. In a few cases the inner palea is absent. For practical purposes, therefore, the presence of a pair of paleæ, and in rare cases of only one palea, indicates the presence at flowering time of a *floret*, so that a spikelet may be described as consisting of glumes and florets.

When the spikelets are arranged singly and directly on the main axis, as in wheat and rye grasses, we have the arrangement known as a *compound spike*. In this case there is no branching of the main axis, except directly into the spikelets. In other cases, as in oats, the spikelets are placed far apart on long branches. This arrangement is known as the *panicle*. In yet other cases the branches are very short, so that, although the inflorescence is really a panicle, its appearance is often somewhat similar to a compound spike. This arrangement is known as a *compressed panicle*.

When a grass is ripe, it very rarely happens that the paleæ open to allow the kernel to drop out, as they do in wheat. In most cases the axis of the spikelet breaks just below each individual floret, so that the grain is similar to that of oats, and consists of the paleæ enclosing the kernel. This is usually the commercial "seed". For the identification of such seeds, the shape and character of the small piece of axis (now known as the *rachilla*) still left attached to each seed are sometimes important. This is found adjacent to the inner palea at the base of the seed. In some cases the commercial seed consists either of the whole spikelet (as in Meadow Foxtail) or the greater part of a whole spikelet (as in Tall Oat Grass).

The outer palea, and in some cases other parts of the spikelet, may be *awned*. The awn is a more or less strong and prominent hair-like attachment, which sometimes occurs as a continuation of the outer palea at its tip as in barley. In other cases, it arises behind the tip, about the middle, or near the base, when it is known as *sub-terminal*, *dorsal*, or *basal* respectively, according to its position.

It should be pointed out that some pasture plants which are popularly regarded as "grasses" are not really such, but belong to other families. Those most easily confused with the true grasses belong to the sedge family (Cyperaceæ) and to the rush family (Juncaceæ). Deer's Grass (*Scirpus cæspitosus*), Carnation Grass (*Carex* spp.), and Cotton Grass (*Eriphorum* spp.) belong to the sedge family, whilst the Wood Rushes (*Luzula* spp.) and Heath Rush (*Juncus squarrosus*) belong to the rush family.

In the vegetative state, plants belonging to the sedge family differ from the true grasses, chiefly in that:

1. The leaves are arranged differently. In grasses, they are arranged in *two* rows along the stem. This arrangement is well shown in Cocksfoot. In the sedges, they are arranged in *three* rows.

2. When a grass shoot is cut across, it is found to be circular or oval, whereas a sedge shoot similarly cut across is usually found to be more or less triangular.

3. In many cases the leaf-sheath of a grass is split; in the sedges the leaf-sheath is entire.

In the flowering and fruiting stages the two families are usually more easily distinguished. The inflorescence varies in form within each family, but in the sedges, far more often than in the grasses, the inflorescence is so divided that on the same flowering stem a number of apparently individual and complete inflorescences are found. Very often also in the sedges these are found in the axils of well developed leaves, while in grasses well developed leaves are very rarely found in the inflorescences. This difference is, however, far from absolute, since in certain members of the sedge family the inflorescence is as simple and free from leaves as in the grasses.

The "floret" is distinctly different in the two families. That of the true grasses has already been described. In the sedges, there is only one glume, and in the case of the seed-bearing florets, the " seed " is enclosed within a membranous vessel—there is nothing exactly similar to the outer and inner paleæ of the true grasses.

Further, whereas the flowering stem in grasses is usually hollow except at the nodes, that of the sedge is usually solid.

Most of the rushes are easily distinguished from the grasses, but the Wood Rushes have distinctly grass-like leaves. The most common is the Field Wood Rush, a small, grass-like plant, frequently occurring in pastures. In the vegetative state, this agrees with the grasses in that the shoot when cut across is circular or oval and the sheath resembles that of Yorkshire Fog in having longitudinal pink lines. It differs from most grasses in having an entire sheath, but most markedly in having long silky hairs at the mouth of the sheath and along the margins of the leaves.

The inflorescence in the Wood Rushes is made up of clusters of florets. These florets differ very markedly from both those of the true grasses and those of the sedges. Each floret consists on the outside of a ring of six segments, dry, and about equal in length. Within a chamber in the centre of the floret three seeds are produced. The plan of the floret rather closely resembles that of a lily, the six segments referred to corresponding to the coloured petals of the lily.

It will be understood that below no attempt is made to describe *all* British grasses. Moreover, the descriptions given are general in character, and do not take into consideration to any great extent the rather wide variation that is found within the same class of plant (species). It must be admitted also that even within such a main class of grasses as the Bent Grasses (*Agrostis* spp.) our present knowledge is far from satisfactory, even in the matter of classification, and it is expected that further research will make a reclassification necessary.

CLASSIFICATION OF THE MOST IMPORTANT GRASSES, BASED UPON VEGETATIVE CHARACTERS

A. Leaves Rolled in the Young Shoot.

1. MORE OR LESS HAIRY

Agropyron repens. COUCH GRASS.—Rare in fairly old pastures; chiefly an arable land weed, but may be present to some extent in young pastures; upper surface of leaf-blade slightly hairy or not, ribs not prominent; under surface dull; ligule very short; auricles long and clasping; creeps widely underground.

Anthoxanthum odoratum. SWEET VERNAL.—Leaf-blade fragile but fairly broad, varying from distinctly hairy to almost glabrous, tufts of fairly long hairs in the position of the auricles; sweet scented.

Arrhenatherum elatius. TALL OAT GRASS.—Leaf-blade fragile, broad, varying in hairiness, sometimes glabrous, dull on lower surface; ligule prominent, blunt; no auricles; roots yellow; sheath with few or many rather long hairs.

Arrhenatherum elatius, var. *bulbosum.* ONION COUCH.—As preceding, but lower stem internodes (at the ground), distinctly bulbous.

Bromus hordeaceus. SOFT BROME.—Sheath entire white, usually densely hairy; leaf-blades also fairly densely hairy on upper surface.

·*Festuca elatior.* TALL FESCUE.—Sheaths reddish at ground; leaves strong and rather harsh; a few stiff and short hairs on the auricle ledges only.

Holcus lanatus. YORKSHIRE FOG.—Entire plant softly downy; hairs short and dense; sheath split, with pink longitudinal veins.

Molinia cœrulea. PURPLE HEATH GRASS.—Usually found in wet or peaty soils; sheath usually free from hairs; blades harsh, more or less hairy on upper surface, especially towards the base; ligule usually represented merely by a tuft of hairs.

Trisetum flavescens. GOLDEN OAT.—Sheath split, rather densely hairy with rather long outstanding hairs: leaf-blades hairy, dull on under surface; roots yellowish.

2. GLABROUS

Agrostis canina. BROWN BENT.—Usually growing on peat; leaf-blade narrow; ligule prominent and rather pointed. Sheaths smooth.

Agrostis alba. WHITE BENT.—Sheaths roughish; blades broader than in preceding; ligule rather long; some types creeping by means of strong underground stems.

Agrostis tenuis. COMMON BENT.—Chiefly on rather dry soils; leaf-sheaths smooth, blade relatively narrow; ligule very short—much shorter than width of leaf-blade.

Agrostis nigra. BLACK BENT.—Resembles *A. alba*, but leaf-sheaths usually less rough and ligule considerably shorter, but longer than in *A. tenuis*; creeps by means of underground stems.

Alopecurus pratensis. MEADOW FOXTAIL.—Living sheaths at ground white or tinged with red; old sheaths in similar position, chocolate coloured; old roots dark, purplish; tufted or slightly creeping by means of short rhizomes; ligule short and blunt; no auricles.

Alopecurus myosuroides. SLENDER FOXTAIL.—A weed of arable land.

Alopecurus geniculatus. FLOATING FOXTAIL.—In moist places; not very common.

Briza media. QUAKING GRASS.—Margins of leaves sometimes slightly hairy; leaf-sheaths entire; living sheaths a fairly bright yellow at the ground; leaf-blade with flat ribs on upper surface, dull underneath; very shortly creeping by means of rhizomes.

Deschampsia cæspitosa. TUFTED HAIR GRASS.—In rather wet places; very strongly tufted; leaf-blades stiff, very harsh, very strongly ribbed on upper surface, and tips of leaves sharp; ligule long.

Festuca pratensis. MEADOW FESCUE.—Leaf-blades fairly long and broad, not very stiff, margins rough, under surface glossy, ribs on upper surface rather prominent; ligule very short and blunt; prominent auricle ledges but usually not produced into points; *no stiff hairs on margins of auricle ledges*; living sheaths tinged with red at the ground.

Festuca elatior. TALL FESCUE.—Very similar to *F. pratensis* but leaves distinctly more stiff and harsh and plant usually more densely tufted; *auricle ledges with a few short stiff hairs on margins.*

Lolium perenne, var. *multiflorum* (= *L. italicum*). ITALIAN RYEGRASS.—Very similar to *Festuca pratensis* in vegetative state but rarely found except in young pastures; leaf-blades usually longer and softer; ligule more prominent; auricle ledges usually prolonged into clasping points.

Phleum pratense. TIMOTHY.—Most easily confused with *Alopecurus pratensis*, but old sheaths at ground a much lighter brown; leaf-blades paler green, and when held up to light showing much more distinct and regular parallel white lines; lower internodes of stem in most cases with a distinct tendency to become bulbous; old roots a distinctly lighter colour than in *Alopecurus pratensis.*

B. Leaves Folded in the Young Shoot.

1. MORE OR LESS HAIRY

Bromus erectus. UPRIGHT BROME.—Would usually be placed in this class, but the leaves sometimes have a tendency to become rolled in the young shoot; sheaths not split; margins of leaf-blades with rather long hairs; not common except on calcareous soils.

Festuca rubra. RED FESCUE.—When growing in fairly dense herbage, this species generally comes under class C (p. 8) as the leaf-blades are then usually bristle-like; individual plants of some types of *F. rubra* when given sufficient space may have well-expanded leaf-blades even at the ground; leaf-blade when expanded with prominent ribs on upper surface; under surface slightly glossy, may be slightly hairy on under surface towards base; ligule short in middle but longer at one of the corners; no auricles; old sheaths near ground usually bright brown with the veins showing up as whitish lines; living sheaths may be densely hairy, slightly hairy, or even completely glabrous, so that *F. rubra* does not always fall into Class B1; often (but not always) creeping by means of longer or shorter underground stems.

Sieglingia decumbens. SMOOTH HEATH GRASS.—Not common except on poor soils, but may occur on good soils to a slight extent; in the vegetative state, is most easily confused with *Anthoxanthum* owing to the distinct tufts of rather long hairs in the position of the auricles, but is easily distinguished from it by the fact that the shoot is cylindrical and the leaves rolled in the bud in *Anthoxanthum*; in *Sieglingia* the shoot is flattened and the leaf-blade is folded in the bud, while the leaf-blade is also hard and is keeled, and there are no prominent ribs on the upper surface. It may also be confused with *Poa* spp., but in the latter there are no hairs in the position of the auricles.

2. NOT HAIRY

Cynosurus cristatus. CRESTED DOGSTAIL.—Leaf-blade usually rather short and tapering from fairly broad at the base; upper surface prominently ribbed, under surface glossy; sheaths split, living sheaths distinctly yellow at the ground. Owing to the colour of the sheaths, this grass is not readily confused with other grasses except *Briza media*, and these two grasses differ distinctly in other characters. *Cynosurus* is much the more common pasture grass. (See *Briza media* under A2 above.)

Dactylis glomerata. COCKSFOOT.—Shoots greatly flattened at the ground, distinctly tufted (compare *Poa* spp. below); leaf-blade very strongly keeled; ribs not prominent, margins rough, under surface not glossy; no auricles; ligule fairly prominent; living sheaths usually white at ground. Small or weak plants might be confused with *Poa* spp.

Festuca rubra. RED FESCUE.—Some types would come under this class as they are quite free from hairs. In other characters they agree with the description given under B1.

Lolium perenne. PERENNIAL RYEGRASS.—In the vegetative state, most easily confused with *Festuca pratensis* and *Cynosurus cristatus*. Differs from *F. pratensis* in that the leaves are much more distinctly folded in the young shoot, the young shoot itself is more flattened, the leaf-blades are more narrow, ligule slightly longer, auricles usually more pointed.

From *Cynosurus cristatus* it usually differs quite markedly in that the colour of the living sheaths at the ground is a distinct red; the leaf-blades are also longer, and the margins more parallel.

Poa annua. ANNUAL MEADOW GRASS.—Usually small leaf-blade, margins generally wrinkled especially towards base; ligule fairly prominent. Most easily confused with *Poa trivialis*, and non-flowering specimens of the two plants cannot very easily be distinguished in certain stages of growth. *Poa annua* does not occur in any quantity in old pastures; it is more often found filling up gaps in young pastures and in open waste places such as along paths.

Poa nemoralis. WOOD MEADOW GRASS.—Found in shady places; not very common; somewhat resembles *Poa trivialis* but is much more tufted, and the ligule is much shorter.

Poa pratensis. SMOOTH-STALKED MEADOW GRASS.—Strongly creeping by means of underground stems; leaf-blades a dull green, margin parallel to near the tip, then shorter than midrib so that the tip becomes strongly boat-shaped; ligule short; ribs not prominent on upper surface; under surface somewhat glossy; living sheaths sometimes tinged with red.

Poa trivialis. ROUGH-STALKED MEADOW GRASS.—Creeping by means of surface stems, but these not strong; leaf-blades a much brighter green than in *Poa pratensis*, and narrower except where the plants are given plenty of space; blades also less distinctly boat-shaped at tip and glossy on under surface.

C. Leaves Bristle-like; Hairy or not.

Deschampsia flexuosa. WAVY HAIR-GRASS.—Not found except in very poor pastures; leaf-blades usually long, very dark green, permanently rolled (really nearly solid); ligule long and usually pointed; creeping by means of underground stems. Most easily confused with some types of *Festuca rubra*, but type of ligule usually quite distinct in the two species.

Festuca rubra. RED FESCUE.—In dense pastures, the ground leaves are usually permanently rolled (really folded), otherwise descriptions given under B1 and B2 stand; sheaths hairy or not.

Festuca ovina. SHEEP'S FESCUE.—Leaf-blade and ligule very similar in appearance to *F. rubra*, but usually more slender; distinctly tufted and not creeping, and therefore not easily confused with most types of *F. rubra*; old sheaths greyish (not the bright brown of *F. rubra*) and in decaying not becoming fibrous.

Festuca ovina varies; generally forming very dense tufts, but in a mountain fescue pasture these tufts not so prominent; sheaths rarely hairy and then more downy than in *F. rubra*.

Festuca ovina, var. *tenuifolia*.—Not often met with in this country and then not very easily distinguished from other types of *F. ovina*.

Festuca ovina, var. *duriuscula*.—Not often met with in old pastures; leaf-blades stouter than in wild types of *F. ovina*, and colour a more hoary green than in most types; tuft usually much less dense with fewer tillers.

Nardus stricta. MAT GRASS.—Not common except in poor pastures; forms dense tufts of hard bristle-like leaves, with a tendency to be open over the centre; most easily distinguished by its short, strong rhizomes, densely covered with old leaf-sheaths from which a few green leaves arise; these rhizomes give off a few strong stringy roots.

GENERAL DESCRIPTION OF MOST IMPORTANT GRASSES

Agropyron repens. COUCH GRASS.—Creeping widely underground; rhizomes thick, long, and strong. Sheaths whitish, generally somewhat hairy; leaf-blade slightly hairy or not, upper surface with indistinct ribs, under surface dull; ligule extremely short; auricles pointed and often very long and clasping.

Flowering stem usually tall; inflorescence, a compound spike with the spikelets in two rows on alternate sides of the main axis. Spikelets set on with the broad side towards the main axis (as in wheat, not as in Ryegrasses); spikelets large, with two glumes at base; seed, two paleæ with kernel, about $\frac{3}{8}$ in. long; outer palea whitish; awn very short and terminal or absent; rachilla broadening upwards from the base.

This grass rarely occurs in considerable quantity in old pastures. It is typically a bad weed of arable land, and pasturing conditions discourage it.

Agrostis spp. BENT GRASSES.—These grasses are rather difficult to distinguish from each other, but are fairly easily distinguished from other grasses. General characters: usually more or less creeping, either by means of stolons or rhizomes; flowering stems often bent at the base, and then erect; plants not hairy; leaf-sheaths sometimes slightly rough; inflorescence, a distinct, generally widely spreading panicle with the branches of the panicle usually rough; leaf-sheaths split; leaf-blade rolled in the bud, with the margins usually finely toothed; ribs on upper surface of leaf-blade fairly prominent; no pointed auricles; spikelets very numerous, 1-flowered, about $\frac{1}{10}$ in. long. The branches of the panicle at first glance appear to occur in whorls around the main axis of the stem. The panicles are late to appear, and the grasses are usually in flower in July and August.

Bent Grass (*Agrostis tenuis*)

Agrostis canina. BROWN BENT.—Leaf-blade narrow; ligule long and pointed; outer palea only present, with an awn inserted below its middle; the awn is about equal in length to the palea itself; sheaths smooth.

This grass is chiefly found in poor heath and mountain pastures, especially where the soil is peaty. It appears to have no agricultural value except where it grows naturally.

Agrostis alba. WHITE BENT.—Leaf-blade usually much broader, in some cases reaching $\frac{1}{4}$ in. in breadth, but in other cases not more than $\frac{1}{8}$ in.; ligule prominent, and in stem leaves long and more or less pointed; sheaths roughish; panicle rarely completely spread in such a way that all the spikelets are separated; when in flower the branches are widely spread, but they again close later; two paleæ present; not awned.

This grass is of common occurrence except in pastures on the drier and poorer soils.

A variety, *Agrostis stolonifera* (Fiorin) has been considered to be of considerable agricultural value, especially for meadows and heavy soils generally. The plants produced from seeds sold under this name are robust and productive, with relatively very broad leaf-blades, but they have the disadvantage of producing strong rhizomes, at least on fairly dry soils. This makes the grass undesirable in short leys, and even in pastures of considerable duration.

Agrostis tenuis. COMMON BENT. — This grass varies considerably according to the conditions under which it grows. Leaf-sheaths smooth; blade relatively narrow; ligule very short—much shorter than the width of the blade; panicle much branched, open both while in flower and after; two paleæ present, the outer one rarely awned. Typically, the flowering stem of this grass is considerably shorter than that of *Agrostis alba*; where most prevalent, its height is rarely above 12 in., and is usually less.

This grass is of very wide distribution, but is generally more abundant in poor dry pastures. In such neglected pastures, it may form over 90 per cent of the total herbage. On arable land, this and other *Agrostis* spp. may become troublesome weeds, as they are difficult to eradicate. In pastures which are not well attended to, Common Bent is very poorly grazed and becomes very objectionable. Under suitable treatment, however, its objectionable character disappears; and, although it may then be even more abundant, it is quite evenly grazed. Basic slag, ground mineral phosphate, and superphosphate with lime have been found to be suitable manures under various conditions.

Agrostis nigra. BLACK BENT.—This grass is variously classified as a distinct species, as a variety of White Bent, and as a variety of Common Bent. In size it resembles White Bent, but its leaf-sheaths are usually less rough, the ligule considerably shorter, and the panicles do not close up after flowering. The ligule is, on the other hand, usually longer than that of Common Bent. It creeps by means of rhizomes, and, as it is favoured by shade, it flourishes in arable land, where it may become a very troublesome weed.

None of the Bent grasses can be considered of much agricultural value except under extreme conditions. Under haying conditions, they are usually decreased by the application of " complete " manures (unless the combination includes much sulphate of ammonia) and by farmyard manure.

Alopecurus pratensis. MEADOW FOXTAIL.—One of the largest meadow grasses, sometimes 3 ft. high or even more; almost strictly tufted in habit, but the tufts are rather loose, and the grass sometimes creeps to a slight extent. The plant is not hairy except in the spikelets; living sheaths near the ground, white or slightly tinged with red; old sheaths purplish brown or chocolate; sheaths split the greater part of their length; no pointed auricles; ligule short, blunt; leaf-blade rolled in the bud, broad when expanded, dull on both surfaces, ribs on upper surface flat and not prominent, margins toothed.

The spikelets are arranged on very short branches, so that the panicle has a cylindrical spike-like appearance. This compressed panicle is about $1\frac{1}{2}$ to $2\frac{1}{2}$ in. long, and before flowering has a purplish sheen, and is silky to the touch.

The commercial seed consists of the whole spikelet—the two glumes, which are very strongly keeled, and have relatively long hairs (especially along the sharp keels), enclosing a single palea with the caryopsis. When the spike-like ear is examined, it is found to be distinctly hairy. The obvious hairs are the awns, which are protruded from the glumes, and are inserted low down towards the base of the paleæ. The seed is about $\frac{3}{16}$ in. long.

Meadow Foxtail (*Alopecurus pratensis*)

This grass is fairly widely distributed, but occurs chiefly in permanent hay-fields, where there is a fair depth of good soil. It is most common at low elevations, but where the land is liberally treated with farmyard manure, or where nitrate of soda is freely applied, it may flourish at elevations well above 500 ft., provided the soil conditions are also favourable. Under grazing conditions it is much less prominent. Even on the best old pastures, it forms but a small proportion of the total herbage, and it rarely succeeds well when sown except when the field is given over to meadow conditions. As it is a very early grass, it is worth encouraging for spring grazing, and its produce later is also valuable.

Alopecurus myosuroides (= *A. agrestis*). SLENDER FOXTAIL, BLACK GRASS.—An annual; chiefly an arable land weed of heavy soils; inflorescence, a compressed panicle, but more slender and more tapering than in Meadow Foxtail; glumes almost free of hairs and joined together in the lower half. It comes into flower later than Meadow Foxtail, but different plants continue to flower throughout the summer. It rarely exceeds 2 ft. in height; flowering stalks rough.

Important only as a weed.

Alopecurus geniculatus. FLOATING FOXTAIL.—Widely distributed in moist places at relatively low elevations, but rarely plentiful; spikelets much shorter than in Meadow Foxtail; glumes blunt and slightly outcurved at the top of the spikelet; stem semi-prostrate and bent at the lower nodes; ligule is long.

The grass is of no agricultural value.

Anthoxanthum odoratum. SWEET VERNAL GRASS.—A tufted, more or less hairy, perennial grass, varying considerably in size and appearance. In grazed pastures, its flowering stem is often only a few inches high, but in meadows it sometimes reaches 18 in. or even more. The sheaths are split, often slightly hairy; no pointed auricles, but even in plants which are otherwise free of hairs a few fairly long and prominent hairs are found in the position of the auricles, while in more hairy specimens these hairs are also quite prominent; ligule fairly prominent but blunt; leaf-blade rolled in the bud, fragile, sometimes distinctly hairy especially along the margins, but often nearly free from hairs, under surface dull or very slightly glossy, margin toothed in upper half; inflorescence, a loosely compressed panicle up to about 2 in. long, tapering rather irregularly at both ends, more lax than in Meadow Foxtail; spikelets consist of a single floret enclosed in a pair of paleæ and *two pairs of glumes*; the flower has *only two stamens*; when ripe, the paleæ are perfectly smooth and glossy, of a rich brown colour, closely enveloping the kernel; inner pair of palea also a rich brown when ripe; these inner glumes are both hairy and are awned—the awn of the lower glume is straight and relatively short, while that of the upper glume when the seed is ripe is twisted and much longer and stronger. The lower pair of glumes are thin, free from hairs, straw-coloured, and do not fall away when the seeds are ripe. The commercial seeds consist of the awned glumes, the paleæ, and the kernel, and have therefore a rich brown colour; in bulk, they are very spongy.

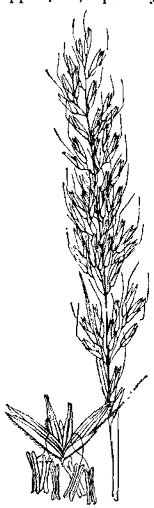
Sweet Vernal Grass
(*Anthoxanthum odoratum*)

The green plant, when drying, emits the familiar odour observed when hay is mown.

This grass is very widely distributed, and usually occurs in relatively small amounts in most pastures. It is a very early grass, flowering in April, and in a mixed pasture it is well grazed, but its produce as hay is relatively small. Opinions as to its value differ, but it appears to be of very considerable value on uplands and sheep-walks, and its occurrence in small quantities in other situations is not objectionable. Its behaviour in pastures under manuring is uncertain, and apparently few manures influence it very strongly under meadow conditions. The continuous use of sulphate of ammonia, either alone or in combination with other manures, usually causes a considerable increase in the proportion of the grass, although an excess of this manure with a complete mineral dressing may have the opposite effect.

Arrhenatherum elatius. Tall Oat Grass, False Oat.—A tufted.

strong-growing perennial, found chiefly in hedgerows; it is rather coarse, and the flowering stems sometimes reach a length of 4 ft.; roots yellow; stem not bulbous near the ground in typical plants (see var. ***bulbosum*** below); sheaths split, white or slightly purplish near the ground, not obviously keeled, often hairy near the margins in the upper part, especially in stem leaves; no pointed auricles; ligule prominent but blunt, with an irregular margin; leaf-blade rolled in the bud, thin, long, dull but not hairy on under surface, often hairy on upper surface especially in stem leaves, ribs not prominent; margin toothed. Inflorescence, a large, lax panicle, spreading when in flower but otherwise rather narrow and slightly drooping; spikelets about ½ in. long, upper glume about twice as long as the lower, both very thin; generally two florets per spikelet, but only one kernel is usually formed owing to the absence of the egg-chamber in the lower floret;[1] outer palea of lower floret with a strong arm arising well below its middle; outer palea of second floret often awnless, or with an awn arising near the tip and then very short and slender, or again with an awn arising lower down and then both longer and stronger.


Tall Oat Grass
(*Arrhenatherum elatius*)

The commercial seed consists of the whole spikelet except the glumes. The lower pair of paleæ are usually empty, and the four paleæ with the single kernel form a somewhat oat-like seed, with the long awn of the lower floret much twisted and bent. The seed is about ⅜ in. long, and the rachilla is not seen.

The grass will grow on a variety of soils, but when sown it usually disappears rapidly under grazing conditions. It persists much better under mowing conditions, and is then encouraged by quick-acting manures such as nitrate of soda with superphosphate, and by the use of complete mineral fertilizers with ammonium salts, and to some extent by the continuous use of farmyard manure.

The quality of the herbage is generally considered to be poor, but it is often very productive of hay. When grown alone, it is much neglected by stock except in the early spring.

Arrhenatherum elatius, var. ***bulbosum***. BULBOUS TALL OAT, ONION COUCH.—This differs from the typical Tall Oat Grass described above

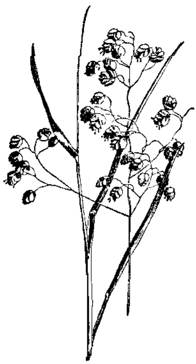
[1] Cases have been met with where the spikelets consist of three florets, and also where more than one of the florets may produce a kernel.

chiefly in the fact that the lowest internodes near, or often in, the soil are very much swollen. The grass is a bad arable land weed, especially in some hill districts where the soil is a thin brashy loam and the land is imperfectly cleaned. When such land is laid down to pasture, the grass gives some bulk of hay under meadow conditions, but is of very little value in grazed pastures.

Briza media. QUAKING GRASS.—A slightly creeping perennial; flowering stalk up to about 18 in. high; inflorescence, a spreading panicle with drooping spikelets on rather long, slender branches; spikelets of two glumes with six or seven florets; lower palea inflated; upper seeds shorter than the lower ones, often giving the spikelet a bluntly triangular appearance; leaf-sheaths a fairly bright yellow near the ground, entire; leaf-blade rolled in the bud, under surface of blade dull, ribs on upper surface very flat; no pointed auricles; ligule very short and blunt; plant usually free from hairs.

The seeds, which are not obtainable commercially, consist of the two paleæ enclosing the kernel. They are relatively very broad and hollow, about $\frac{1}{8}$ in. long or less; not awned.

The grass is fairly widely distributed on poor land, but more especially on or near limestone or chalk. Its presence seems to indicate an impoverished soil, as whenever land on which it is prevalent is improved by manuring, the grass decreases rapidly.



Quaking Grass
(Briza media)

Brome Grass
(Bromus mollis)

Bromus spp. BROME GRASSES.—The common Brome grasses are usually more or less hairy; leaf-sheaths usually not split; inflorescence, generally a loose panicle with large prominent spikelets; outer palea usually with an awn arising just behind a cleft tip.

Bromus erectus. UPRIGHT BROME.—A tufted or very slightly creeping perennial, with an erect panicle of many large spikelets (up to $1\frac{1}{2}$ in.) containing five to nine florets; outer glume 1-nerved, upper 3-nerved; awn practically terminal; sheaths entire, hairy; leaf-blade rather narrow.

The seed consists of two paleæ and the kernel. It is about $\frac{3}{8}$ in. long with a fairly long awn.

The grass is generally found on dry calcareous soils, and is favoured by haying conditions. It provides a large bulk of hay, but is not regarded as a particularly valuable grass. Farmyard manure and also guano decrease it under haying conditions.

Bromus hordeaceus (= *B. mollis*). SOFT BROME.—A tufted annual or biennial, chiefly found in hay-fields especially at fairly low elevations. The whole plant is softly downy; sheaths entire; leaf-blade rolled in the bud; panicle fairly compact and erect; with large plump spikelets (over $\frac{1}{2}$ in. long); seeds not distinctly separated in spikelet when ripe, about $\frac{1}{4}$ in. long, with an awn shorter than the length of the seed arising just behind the distinctly cleft tip of the broad outer palea. The upper glume reaches to the middle of the outer palea of the sixth floret of the spikelet.

The plant ripens relatively early, so that it often persists or even increases in hay-fields by self-seeding. It is not greatly affected by manures, but excess of nitrogen (especially nitrate of soda) may cause it to increase greatly.

Bromus Schraderi (SHRADER'S BROME) and *Bromus inermis* (AWNLESS BROME, HUNGARIAN FORAGE GRASS) have been tried in this country although not native. Neither of them has so far been found to be of any particular value for cultivation.

Crested Dogstail
(*Cynosurus cristatus*)

Cynosurus cristatus. CRESTED DOGSTAIL.—A glabrous, tufted perennial, with relatively short basal shoots; sheaths bright yellow near the ground (cf. *Briza media*), split; no pointed auricles; ligule very short; leaf-blade folded in the bud, under surface glossy, upper surface dull and distinctly ribbed, margins not toothed in greater part. Flowering stems up to 2 ft. high, smooth, wiry, erect; inflorescence, a rather one-sided compressed panicle, 1 to 3 in. long (usually about $1\frac{1}{2}$ in.). The arrangement of the inflorescence is peculiar in that what appears to be a sterile spikelet (producing no flowers) occurs close to each fertile spikelet. The spikelet itself consists of two almost equal glumes and usually about five florets.

The commercial seed consists of two paleæ and the kernel. It is about $\frac{1}{8}$ to $\frac{3}{16}$ in. long, usually bright yellow; outer palea not markedly keeled, rough in upper half, and pointed or sometimes produced to a very short awn.

The grass is very widely distributed, and contributes a considerable proportion of the herbage of many grazed pastures. It is more especially a grazing plant, which assists greatly in the formation of a dense bottom, but when sown it contributes considerably to the hay crop in the second year and later. Under permanent haying conditions it does not flourish, and, when such fields are well manured, it practically disappears. It is undoubtedly a valuable grass, even in considerable quantities on all but the very best soils, as, although the withered stalks may remain uncropped unless a field is heavily grazed in the early summer, the leaves are well eaten down. Where strongly indigenous, and where the land is under long rotations, it generally comes in fairly rapidly in a young pasture, but not so rapidly as to make it unnecessary or undesirable to include the seed in a seeds mixture. On reclaimed dry heath land it is particularly valuable when sown. Where it occurs in small quantity in a poor neglected pasture, it is considerably increased when the pasture is improved by manuring.


Cocksfoot (*Dactylis glomerata*)

Dactylis glomerata. COCKSFOOT.—A strongly tufted, rather coarse perennial, usually quite free from hairs; young shoots very much flattened at the base; sheaths whitish near the ground, entire the greater part of their length, strongly keeled; leaf-blade long, folded in the bud, keeled, dull on both surfaces, flat on each side of the midrib on the upper surface, margins sharply toothed; no pointed auricles; ligule prominent. In old tufts the leaves have a bluish tinge, but the rapidly growing blades are a light green.

Flowering stems strong, up to 4 ft. high, upper part rough; inflorescence, a clustered panicle, the clusters widely spread at flowering, but partly or completely closed up later, lower branches of panicle distant; spikelets in dense clusters, each spikelet of two nearly equal glumes and about five florets; spikelet flattened and curved.

The commercial seed ideally consists of the two paleæ with the kernel; but very often the individual seeds do not separate, so that sometimes almost entire spikelets are included. Sometimes also a proportion of the kernels becomes free. The seed is about $\frac{3}{16}$ in. long, almost triangular when cut across, owing to the keel of the outer palea; keel of outer palea sharp and extended into a sharp point or a short awn. The seed is of a whitish colour and is bent sideways in the upper half.

As this is a strong-growing grass which forms coarse tufts in a pasture when neglected, it is sometimes objected to by farmers. It is, however, a very valuable grass both in hay meadows and in pastures, as the immature roduce is nutritious and is well liked by stock. Neglect of it by stock , usually due to its surroundings, as in the same field it is generally ound to be present in the well-grazed parts. Where it becomes coarse, e ground needs attention. It yields well in hay meadows, especially here farmyard and nitrogenous manures are applied, but hay-fields which it is abundant should be mown early. It flourishes in widely ifferent situations, but, even where indigenous, it is a very slow colonizer grazed pastures, so that where its presence is desired it is always advangeous to include the seed in a seeds mixture. On thin soils it tends to ecrease fairly rapidly after the second year in a young pasture, but it still one of the best grasses on such land and on land reclaimed from ry grass heath, as, with a fairly heavy seeding, it persists in some quantity r a number of years if the land be moderately well treated.[1]

Deschampsia cæspitosa. TUFTED HAIR-GRASS, BULL FACE.—A coarse, rongly tufted perennial, usually growing on heavy soils and in moist wet places; not hairy; sheaths split, whitish; leaf-blade rolled in the ud, long, relatively narrow, hard, flat or with the margins incurved, pper surface very deeply ribbed and very harsh, point acute and hard; gule long and pointed; no pointed auricles.

Flowering stem up to about 4 ft. high; inflorescence, a widely spread anicle up to about 9 in. long; spikelets purplish, shiny, very small (about in. long), and very numerous on very slender rough branches; spikelet sually of two slightly unequal glumes and two florets, the glumes almost closing the florets. The seed consists of the paleæ and kernel; outer lea bears a hair-like awn arising near its base and about equal in length itself; the base of the seed and the rachilla are hairy.

The grass is of no agricultural value. It indicates excessive moisture d usually that better drainage is the first essential in the improvement the pasture in which it occurs.

Deschampsia flexuosa. WAVY HAIR-GRASS.—A creeping perennial, with aracteristic long, slender, permanently folded (apparently permanently lled, but really almost solid) leaves. The leaves are somewhat similar appearance to those of the fine-leaved fescues (see *Festuca* spp. below), it the ligule is long and pointed. Flowering stems usually reddish, to 2 ft. high; panicle spreading, purplish and shiny; spikelets about in. long, shiny, erect, containing two florets; seed consists of the paleæ d kernel, about $\frac{3}{16}$ in. long; outer palea with a hair-like awn inserted ar its base and slightly longer than itself; rachilla not hairy but tuft of irs at base of seed.

The grass is widely distributed, but rarely occurs in open pastures cept in heath land. It has no known agricultural value.

Festuca spp. FESCUE GRASSES.—These grasses are of two main types:

[1] Recent investigations have shown that the ordinary commercial seed, such as French, duces a much less leafy herbage than some types of New Zealand seed.

(*a*) Leaves usually slender, folded in the bud, ground leaves apparently more or less cylindrical, especially when growing in a dense herbage. These are usually known as "fine-leaved" or "bristle-leaved" fescues, and include such grasses as Sheep's Fescue, Hard Fescue, and Red Fescue (see below).

(*b*) Leaves rolled in the bud, flat and broad when mature. These include Meadow and Tall Fescues (see below).

Festuca ovina. SHEEP'S FESCUE.—A tufted perennial, free from hairiness or nearly so; sheaths whitish near the ground, split; no pointed auricles; ligule usually quite short, never pointed at the centre, but one or both corners often slightly prolonged; leaf-blades slender, and those of ground leaves, and usually those of the stem, permanently folded and very narrow; the inflorescence and other characters vary considerably in different varieties. In typical plants the flowering stem is only a few inches high, but it may reach 18 in. or even more; upper stem node much below the middle of the stem; panicle narrow and almost spike-like although considerably branched, usually 1 to 2 in. long, but often longer in protected plants; spikelets numerous, three- to eight-flowered, with two unequal glumes at the base; the seed consists of the paleæ enclosing the kernel, $\frac{1}{8}$ to $\frac{3}{16}$ in. long; outer palea hairy or not, usually produced at the tip into a short awn; rachilla short, cylindrical, standing away from the seed so that the latter tends always to lie on its "back".

Grasses of this general type, but which vary in certain respects, are widely distributed in this country, but they are almost confined to heath conditions at various elevations. They do not thrive in open competition on good soils, but they may be the dominant grasses on poor dry soils. They are valuable for sheep-walks on uplands and downs, but plants of this general type are seldom, if ever, obtained from seed sold as that of Sheep's Fescue.

Festuca ovina, var. *tenuifolia*. FINE-LEAVED SHEEP'S FESCUE.—The seed of this variety of Sheep's Fescue has been obtainable commercially. The leaves are even finer than those of the plant described above, and the plant is altogether smaller; not hairy; spikelets small, about $\frac{1}{8}$ to $\frac{3}{16}$ in. long, but with up to seven florets per spikelet. The commercial seed consists of the paleæ with kernel, outer palea smooth, straw colour when ripe, about $\frac{1}{8}$ in. long, very rarely produced into a short awn, not hairy.

This grass is much less common in this country (probably rare) than the variety described above, and it has yet to be proved that seeds obtainable commercially are valuable for agricultural purposes.

Festuca ovina, var. *duriuscula* Koch. HARD FESCUE.—Seeds sold under this name were extensively used in seeds mixtures for permanent pastures prior to 1915. When sown this seed generally produced a fairly uniform type of plant which may be briefly described as follows: a tufted perennial.

usually free from hairs; leaf-sheaths whitish or slightly tinged with red near the ground, split; no pointed auricles; ligule short, more or less produced at one or both corners; blades of ground leaves usually less tightly folded than in typical Sheep's Fescue, more rigid, often bluish green or sometimes almost hoary; produce of leafy herbage much smaller than in typical Sheep's Fescue under similar conditions; flowering stem usually 6 to 18 in. high, but sometimes more; panicle more spreading than in typical Sheep's Fescue when in flower, and panicles appearing considerably earlier; spikelet about $\frac{1}{4}$ to $\frac{3}{8}$ in., with five to seven florets; seed similar to that of Sheep's Fescue in most respects, but larger (usually $\frac{3}{16}$ to $\frac{1}{4}$ in. long), and with a somewhat longer awn; outer palea rarely hairy.

The plant is altogether less attractive than typical Sheep's Fescue, but it usually seeds more freely. Although apparently early, its early produce is very scanty. When sown in seeds mixtures, it disappears very apidly on most soils, but it has been found to persist to some extent on 'ery light soils and on very thin, dry, brashy loams for some years. It ppears to be of relatively very little value.

Festuca rubra. RED FESCUE.—Various types or varieties of this grass re found in this country, but they are generally found at lower altitudes, on moister soils, and on better land than Sheep's Fescue. The most ommon type is a perennial creeping by means of rhizomes. Owing to he fact that several creeping varieties are met with, only a general description can be given.

Old leaf-sheaths brown and fibrous at the ground; living sheaths often reddish, split, hairy or not; leaf-blades of ground shoots usually long, folded fairly closely or more or less open and flat, and then strongly ribbed on the upper surface, with a fairly distinct keel underneath, not hairy or very slightly so; blades of stem leaves usually open and flat, strongly ribbed, but sometimes folded (so-called " rolled "); ligule short; no pointed auricles; flowering stems up to $2\frac{1}{2}$ ft. high, usually smooth below the panicle; panicle large, often lax, more or less spreading when in flower and then almost erect; spikelets about $\frac{1}{4}$ to $\frac{1}{2}$ in. long, with up to eleven florets per spikelet, but usually five to seven; outer palea rarely hairy, usually produced terminally into an awn about a third to half its own length.

The seed of the creeping variety of Red Fescue is not obtainable commercially. In bulk it differs considerably from that of Sheep's Fescue, but individual seeds may be indistinguishable. The seed of Red Fescue is generally larger, about $\frac{1}{8}$ to nearly $\frac{5}{16}$ in. long; the back of the seed often straight or even concave longitudinally; outer palea hairy or not; awn terminal, $\frac{1}{16}$ to $\frac{1}{8}$ in. long.

These creeping varieties of Red Fescue occur to a considerable extent in some of the best permanent pastures, where they are well grazed and assist considerably in forming a dense turf. On some heavy soils and alluvia, a coarse variety with harsh leaves occurs, and, when such a pasture is neglected, the grass may assume an objectionable form. The widely creeping varieties are also objectionable on arable land, and are not likely to be useful except where the rotation is a long one.

A non-creeping variety of Red Fescue is also fairly widely distributed. This forms very dense tufts when grown alone, and when not well grazed (as seems to be more often the case than with the creeping varieties) the withered leaf-sheaths persist, forming an objectionable fog. Otherwise this variety differs but little from the creeping forms in appearance, but the panicle is often more lax, more spreading, longer and more drooping, while the number of florets per spikelet is often less and the seeds slightly shorter and more slender.

Meadow Fescue (*Festuca pratensis*)

This grass seems to be very near to, if not actually the same as New Zealand or Chewings' Red Fescue, the seed of which is obtainable commercially. Owing to the fact that New Zealand Red Fescue seeds usually germinate but poorly, this grass has probably not yet had a fair trial in this country. It has been known to show up well under haying conditions, in the third year from sowing, but under these conditions its produce is not leafy, although when grown alone it is quite attractive. It appears to do best on medium soils in good condition at fairly low altitudes, but it does not seem to be suitable for land on which Sheep's Fescue would thrive.

Sulphate of ammonia usually, and nitrate of soda sometimes increase Red Fescue considerably under haying conditions. Under pasturing conditions the creeping varieties often increase considerably where there is an obvious improvement in the herbage following the application of manures.

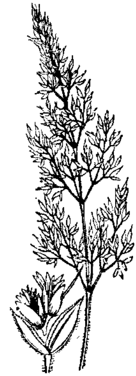
Festuca pratensis. MEADOW FESCUE.—A tufted perennial, not hairy; shoot cylindrical at the base; sheaths split, generally red near the ground; no pointed auricles; no stiff hairs on margin of auricle ledges (compare Tall Fescue below); ligule very short and blunt; blade rolled in the bud, shining and almost flat underneath, prominently ribbed and rough on the upper surface, margins toothed.

Flowering stems usually 1 to 2½ ft. high; panicle well branched and more or less spreading; panicle branches rather slender, nearly smooth;

spikelets relatively large; commercial seed, the paleæ enclosing the kernel; outer palea rather broad, not hairy, rounded or somewhat flattened (not keeled), about $\frac{1}{4}$ in. long, membranous at tip (not pointed); *rachilla cylindrical.*

This grass, although fairly widely distributed in the lowlands of this country, is rarely prominent in old grazed pastures. When sown on fairly good soils at low elevations, it usually does well at from three to five years from sowing, and even later under haying conditions, especially where the land is dressed with farmyard manure. Under grazing conditions it usually forms but a small proportion of the total herbage after the fifth year. It is, however, one of the best grasses, and sometimes succeeds in districts to which it is exotic, up to an altitude of 600 ft.

Festuca elatior. TALL FESCUE.—In general characters, this grass is very similar to Meadow Fescue, but the plant is altogether more robust. The leaf-blades are larger, stiffer, and more harsh, and the auricle ledges carry fairly short stiff hairs on the margin. These hairs are completely absent in Meadow Fescue. The flowering stems are as a rule taller, the panicle larger, more branched, and more drooping, while the outer palea of the seed is more pointed.



Yorkshire Fog
(*Holcus lanatus*)

This grass, in spite of its harshness, is fairly well grazed, but on good soils it is less valuable than Meadow Fescue. It is more hardy than the latter grass, and succeeds better on the poorer and drier types of soils and at higher altitudes.

Holcus lanatus. YORKSHIRE FOG.—A tufted, downy perennial; sheaths split, very slightly keeled, pink parallel longitudinal lines on sheaths near the ground; leaf-blade rolled in the bud, soft and thin, greyish green, ribs not prominent; ligule prominent, blunt but uneven. Flowering stem up to 2 ft. high; inflorescence, a panicle, spike-like before flowering, with a purplish sheen; spreading when in flower, but rather dense; closed after flowering and becoming whitish when ripe. When the grass is ripe, the *spikelets* are shed, and are therefore regarded as seeds. The spikelet consists of two nearly equal, strongly keeled and flattened, softly downy (not so distinctly hairy as in Meadow Foxtail) glumes, with two small florets. The lower floret produces a kernel, but the upper one does not. The inferior palea is much shorter than the glumes, is smooth, white, and shiny, compressed sideways, so that the ripe grain lies on its side; it tapers almost equally from both ends so that the grain is widest (when lying on its side) about the middle; not awned. The outer palea of the upper floret (the paleæ of which are also within the glumes) is smaller and bears an awn which arises above its middle and becomes hooked when the plant is ripe.

This grass is widely distributed, and although generally considered to be of very inferior value, it often forms a relatively high proportion of the herbage of some of the best grazing pastures. It is also often increased when a poor pasture is improved by manuring.

It is undoubtedly of inferior value iu hay-fields, as it ripens early and it makes but poor quality hay. Where a young pasture is continuously mown it often increases very rapidly for some years. Under haying conditions it may be considerably increased by nitrogenous manures, but alternate dressings of farmyard manure and artificial manures, including phosphates, appear to keep it in check.

Perennial Ryegrass (*Lolium perenne*)

Lolium perenne. PERENNIAL RYEGRASS.—A tufted perennial, not hairy; leaf-sheaths split, usually red near the ground; auricles variable, sometimes pointed; ligule rather short and blunt; leaf-blade folded in the bud, under surface glossy, somewhat keeled; upper surface prominently ribbed; margins rarely toothed in lower half.

Flowering stem up to about 2 ft. high; inflorescence, a compound spike, with spikelets set closely on the main axis on alternate sides, usually at considerable distances apart, especially towards the base. The branching of the spikelets is apparently in the same plane as that of the main axis, so that a section cutting all the paleæ of a spikelet in half longitudinally would also split the main axis longitudinally in half. Thus the whole ear has a flattened appearance. The terminal spikelet consists of two glumes and up to eight or more florets, but the other spikelets usually have only a single glume, and the spikelet seems to stand in the angle made by this glume and the main axis.

The seed is very similar to that of Meadow Fescue, except that it is usually slightly longer and that in Perennial Ryegrass seed the rachilla is flattened, and widening out from its base upwards (not cylindrical as in Meadow Fescue).

The grass is very widely distributed, but is usually completely absent from old upland pastures. It forms a high proportion of the herbage of some of the best grazing pastures; but, although not completely absent from poorer pastures, its place seems often to be taken by Crested Dogstail. It usually yields well on most soils and in many situations in the first and even the second hay crop from sowing, but then often decreases fairly rapidly under either haying or grazing conditions unless the land is well attended to. Farmyard manure seems to check its decrease under mowing conditions, and often increases its proportion in the herbage of old hay-fields in which it is not plentiful, and most manures seem to have the same effect. Where plentiful, manures may have a stronger influence on other plants and may cause an apparent or real decrease of this grass.

Lolium perenne, var. *multiflorum* (= *L. italicum*). ITALIAN RYEGRASS. —This differs from Perennial Ryegrass in the following respects: (1) it is a biennial; (2) it is taller and more luxuriant; (3) the leaf-blades are rolled in the bud and are broader; (4) the shoots are more cylindrical; (5) the auricles are usually prominent; (6) the outer palea is produced into an awn, often equal in length to the palea itself.

The grass is rarely found except in young pastures. Its seed is often included in seeds mixtures, however, even for permanent pastures chiefly for the sake of the grazing it affords during the first winter and spring, and especially for the sake of the yield it gives in the first year's hay crop. It is very largely used in seeds mixtures for pastures of short duration, although in some cases it has been found to give a less satisfactory yield than Perennial Ryegrass.

It is a particularly valuable grass for stubble grazing, owing to its rapid growth and winter greenness. Sown with a corn crop, it gives valuable keep in autumn and spring.

The growth of Italian Ryegrass is rapid, and it responds well to the application of nitrogenous manures.

A variety known as "Westernwolth's Italian Ryegrass" is still more rapid in growth. This is chiefly used for forage purposes, as on soils in good condition it gives a heavy yield in the year it is sown. It is, however, a short-lived plant, and usually does not survive a winter.

Molinia cœrulea. PURPLE HEATH GRASS, MOOR GRASS.—A perennial which is so shortly creeping that it forms very dense tufts. It is widely distributed, but at the same time is almost completely confined to peaty soils. It occurs on moors, fens, and shallow hill-peat, and is often associated with *Calluna vulgaris* (Ling). In upland pastures, especially in a wet climate, it is often dominant over wide areas.

The roots are very strong and penetrate deeply; leaf-sheath split, free from hairs; no pointed auricles; ligule usually merely a tuft of hairs; leaf-blade rolled in the bud, flat, tapering both above and below the middle, dull underneath, more or less hairy on the upper surface, especially towards the base; flowering stems up to 4 ft. high, but usually much shorter, wiry, slightly swollen at the ground; inflorescence, a narrow, erect, purplish panicle; spikelets numerous, one- to three-flowered; glumes unequal; seed, the paleæ with the kernel, about $\frac{1}{8}$ in. long, not hairy; outer palea widening sharply in lower third and then tapering, but not awned; rachilla long and prominent; the inner palea stands a little apart from the outer palea at the tip of the seed.

The grass is peculiar in that the leaves have an absciss layer about 2 in. from the ground. In autumn they die down as far as this layer, and during the winter storms they often break away at this joint, leaving the stock as if cut across.

The grass is considerably grazed in the young stage, and in upland districts is often mown for hay. The hay, when properly made, is reputed to be sweet, palatable, and nutritious.

Manures have been found to have little effect on *Molinia* pastures.

Nardus stricta. MAT GRASS.—A very shortly creeping perennial, free from hairs. It forms tufts of very fine, hard, bristle-like leaves; roots very strong and infrequent on a rhizome densely covered with old leaf-sheaths. The young leaves also arise from within a mass of such old sheaths; living leaf-sheaths white near the ground; no pointed auricles; ligule short and blunt; leaf-blade very narrow and almost cylindrical, and solid, hard, and stiff.

Flowering stems up to about 9 in. high; inflorescence, erect and spike-like with the spikelets, consisting of a single seed each, apparently along one side; seed very narrow, but nearly $\frac{1}{4}$ in. long; outer palea produced into a short awn. The seed has a nearly parallel outline almost its entire length, and then tapers sharply towards the tip.

The grass is chiefly found on moors and grass-heaths. In zones intermediate between the *Molinia* pasture and the drier *Agrostis-Festuca* pasture, and also in places flushed by acid peat drainage it is often dominant, and here it forms a useless pasture, as the grass is very little grazed even in a mixed herbage. Under exceptional conditions, when scattered in a pasture where White Clover is also found, it may be closely grazed when the clover is encouraged by the application of alkaline phosphates, but a single dressing has little if any direct effect on the grass.

Phleum pratense. TIMOTHY, CATSTAIL.—A tufted perennial of tall habit and broad leaf-blades, not hairy; leaf-sheaths split, not keeled, white near the ground; no pointed auricles; ligule relatively short and blunt; leaf-blade rolled in the bud, broad, dull underneath, slightly keeled, upper surface with broad flat ribs, margins toothed; shoots cylindrical, often bulbous at the ground.

Flowering stem varies in height, often short in grazed pastures, but in hay reaching 4 ft. in height; inflorescence, a cylindrical compressed panicle, the main axis being uniformly covered all round, outline nearly parallel most of its length, blunt at both ends, usually 2 to 4 in. long, but often either shorter or longer, harsh to the touch; spikelets small, flattened, one-flowered: glumes strongly keeled, prolonged into a short stiff awn and with short harsh hairs along the keels, glumes wider apart at tips than elsewhere; paleæ shorter, very glossy, thin, not hairy, no awn; outer glume very broad. The inflorescence is late in appearing and the grass is rarely in flower before July.

The commercial seed usually consists of the kernel enclosed in the paleæ, but generally a greater or smaller proportion of the seed in a sample consists of the kernels without the paleæ. The seed, which is very small (about $\frac{1}{12}$ in. long), is somewhat similar in appearance to a miniature barley grain, but the paleæ are white and glossy, and it is so circular in cross section that it rolls on a sloping surface. The kernel is somewhat egg-shaped, but is pointed at one end, and it is of a dirty light brown colour. It is but little shorter than the entire seed.

Timothy is widely distributed, but it is rarely, if ever, abundant in old grazed pastures. When sown it generally yields well in the hay of the second season even on land which may be regarded as light, but the most suitable soils are good loams, heavy soils, and well-drained peat. It succeeds well under haying conditions, but tends to disappear on most soils under pasturing conditions. It may persist to some extent for about ten years from sowing, even on land which is rather dry and poor, if the climate is moist. Under such conditions, however, its chief value lies in its produce during the first few seasons.

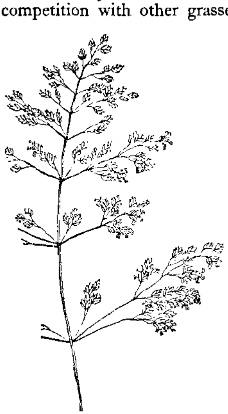
It is sometimes grown alone for hay, but in such cases it should be mown relatively early, as it becomes hard as it ripens. The grass withstands cold well, but may be injured by heavy grazing with sheep in winter. It has been found to be very resistant to drought, and it responds well to dressings of farm-yard manure.

Phleum pratense, var. *nodosum*.—This appears to be quite a distinct type of Timothy. While the typical Timothy is generally found wild on heavy soils, this variety occurs chiefly on chalk, and in such situations it may be very abundant. It differs from the usual type of Timothy in that even when grown under the same conditions, it is much dwarfer, the base leaves are much more narrow, and the inflorescences are both shorter and more narrow; it also usually forms much more densely leafy tufts, especially than the usual commercial Timothy.

Poa annua. Annual Meadow Grass.—A small, tufted, short-lived grass, free from hairs. In a fairly dense herbage it somewhat resembles *Poa trivialis* in its vegetative characters (see below), but its leaf-sheaths are more deeply split; the leaf-blade is broader and its margins are often wavy. It differs also in its tufted habit.

Flowering stem usually a few inches, but sometimes a foot high; inflorescence, a loose open panicle which varies much in size; both flowering stem and branches of the panicle smooth; spikelet of two glumes and usually three to six florets; glumes slightly unequal; upper margin of outer palea membranous. The seed of this grass is of little interest except that it is sometimes found as an impurity in other grass seeds.

The grass is a true vagabond, being usually found in abundance along paths and roadsides, as well as on almost any ground which is sparsely colonized by other plants. Thus, it is often abundant in a young pasture where the seeds mixture has not been very effective, and in such places it can hardly be considered objectionable, as it readily gives way in competition with other grasses and the little herbage it produces is of good quality.


Smooth-stalked Meadow Grass (*Poa pratensis*)

Poa nemoralis. WOOD MEADOW GRASS.—A tufted or slightly creeping perennial of little agricultural importance. It succeeds well only in shady places, and is found chiefly in woods. Leaf-sheaths split and slightly keeled; leaf-blades narrow, folded in the bud; ligule very short; no pointed auricles.

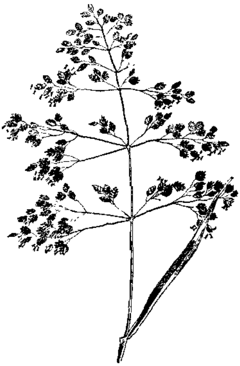
Flowering stem 1 to 2 ft. high; nodes very short; panicle usually finely spreading; spikelets numerous, small, rather slender, flattened, with two to five florets.

Commerical seed, the paleæ and kernel; outer palea distinctly keeled and rather pointed, not awned, when seed has not been cleaned, with a line of silky hairs along the sides and on the keel; seeds fall off from the spikelet readily when ripe, as the seed is almost quite bald at the base.

Poa pratensis. SMOOTH-STALKED MEADOW GRASS.—A perennial, free from hairs, creeping by means of rhizomes; shoot flattened; leaf-sheaths whitish near the ground, entire, keeled; no pointed auricles; ligule short, blunt; leaf-blade dark green or sometimes almost glaucous, folded in the bud, keeled below, flat each side of the midrib on upper surface; margins almost parallel practically their entire length, shorter than midrib so that the leaf is concave at the tip.

Flowering stem usually 9 to 24 in. high, smooth to the tongue; inflorescence, a spreading panicle; spikelets broader than in *Poa nemoralis*, with about four florets per spikelet. In the uncleaned condition, the seed (paleæ with kernel) has a web of hairs at the base and long hairs along the keel and along the two outer veins of the outer palea, so that the seeds cling together when ripe and readily become attached to objects coming into contact with them. The commercial seed has been cleaned so that these hairs are rarely found. The seed has a roughly triangular section when cut across, as the outer palea is keeled; outer palea also not awned, 5-nerved, but the veins on the sides are not prominent; rachilla strong; entire seed about $\frac{1}{12}$ in. long.

This grass rarely forms a considerable proportion of the herbage of a pasture. It often flourishes in rather dry banks and on light soils, and it is often found in small quantities in other old pastures. It appears to be a very poor colonizer, but when a plant is established it may spread rapidly, forming a short but dense turf especially in the absence of strong competition. It is most suited to rather poor light soils, but even on such soils results obtained from sowing commercial seeds are often disappointing. It has sometimes been found to increase rapidly on peaty soil. It can hardly be regarded as of great value in this country, as although it is of some value for spring grazing, it is not very productive. It is, at most, only valuable for permanent pastures. For practically all situations *Poa trivialis* (see below) is a much more valuable grass.



Rough-stalked Meadow Grass (*Poa trivialis*)

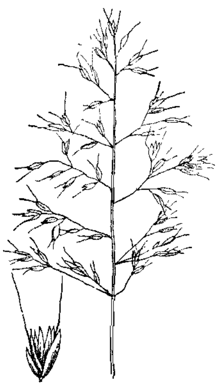
Poa trivialis. ROUGH-STALKED MEADOW GRASS.—This grass differs from *Poa pratensis* (see above), in that it creeps by means of stolons, the ligule is long and pointed especially in the stem leaves, the leaf-blade is a lighter green, and tapers more gradually, the flowering stem is rough to the tongue, and the spikelets are usually somewhat smaller, more widely spread in the panicle.

It differs considerably in appearance according to the situation in which it grows.

The seed differs in the natural state from that of *Poa pratensis* in that there are no long hairs along the sides. The outer palea is also more sharply keeled, the lateral nerves are more prominent, and the rachilla is more slender.

This grass rarely occurs in poor old pastures on dry soils. Where the land is well treated, however, it often flourishes on rather dry soils if the climate is moist. It is undoubtedly a valuable grass, as it assists greatly in the formation of a dense nutritious sole, but it is apt to suffer greatly in severe droughts. It is especially encouraged by dressings of farmyard manure under haying conditions, and as it is a rapid colonizer it often increases considerably when a pasture is improved. Commercial seeds usually give good results.

Sieglingia decumbens. Blue Heath Grass, Smooth Heath Grass.—A rather small tufted perennial; roots very strong; leaf-sheaths whitish near the ground, flattened; *no pointed auricles; ligule not membranous,* but hairs present in its position and these also extend to the position of the auricles in fairly prominent tufts; leaf-blade usually bluish green, hard, usually sparsely hairy, especially along *the margins, very flat on the upper surface on each side of the midrib.*



Yellow Oat Grass (*Trisetum flavescens*)

Flowering stem usually 6 to 12 in. high, but sometimes shorter or taller; inflorescence, a *narrow panicle* with but a few branches and spikelets; spikelet of two glumes and two or three florets; seed about $\frac{3}{16}$ in. long, and about $\frac{1}{12}$ in. broad, *with a distinct tuft of short hairs on each* side at the base; kernel about half the length of outer palea; back of seed rounded; outer palea not awned, but apex notched into three very short teeth, white and very shiny, but slightly hairy at the sides in lower half; rachilla very short.

The grass occurs on various types of poor soils—on light dry soils, on wet clay soils, and also on peat, but rarely on the better soils. It is of very little agricultural value.

Trisetum flavescens. Yellow Oat Grass, Golden Oat Grass.—A tufted or slightly creeping, hairy perennial, most common on or near limestone soils; roots fibrous, yellow; leaf-sheaths split to near base, softly hairy; no pointed auricles; ligule fairly prominent but blunt; leaf-blade rolled in the bud, usually narrow, hairy on both surfaces, ribs well marked on upper surface.

Flowering stems usually 1 to 2 ft. high; inflorescence, a much-branched panicle, with very numerous spikelets, spreading when in flower but later narrow, usually golden yellow when ripe; spikelets two- to three-flowered; glumes very unequal, thin and keeled; seed, the paleæ with kernel, outer palea with an awn rather longer than itself arising about its middle, apex notched; inner palea very thin and membranous, and in the ripe seed standing away from the outer palea; seed about $\frac{8}{16}$ in. long; rachilla with prominent hairs.

This grass seems to be of considerable value where it occurs naturally, such as on or near calcareous soils, but its produce is not great under pasturing conditions. It often flourishes on dry hay meadows, and is very responsive under these conditions to some manures. Farmyard manure alone in alternate years, or alternately with other manures, has a marked effect, as also have complete dressings of mineral manures, especially when nitrate of soda is included.

It seems to be favoured by continuous haying, and sometimes does very well under those conditions where the seed has been included in a seeds mixture for land very deficient in lime. In such a case, the soil is generally a light loam and is well treated.

LEGUMINOSÆ. CLOVER FAMILY

Very few native plants belonging to this natural order are commonly regarded as weeds, and although some others may be of relatively little agricultural importance, their appearance in a pasture is regarded with favour on account of their produce and their effect on the fertility of the soil, or occasionally for the latter reason only.

In the following pages a few botanical terms are used which should be explained.

The *tap-root* is the main root from which secondary roots arise, and it acts as the channel of communication between the root-system generally and the stem and leaves. Such a tap-root is not found in established grass plants, as a large number of adventitious roots operating independently serve the same purpose.

The *stipules* are a pair of wing-like outgrowths of the leaf-stalk. They occur quite close to the point where the leaf-stalk joins the stem or branch which bears it. They are sometimes green and leaf-like, and in other cases membranous. They vary considerably in some respects, and these variations are often of importance for the identification of clovers.

Leaves belonging to the clover family are in almost all cases more or less divided. Thus the leaf of a clover is divided into three leaflets, each of which is quite leaf-like in appearance. In other cases, the leaf is divided to a much greater extent. For example, a sainfoin leaf consists of a considerable number of leaflets, but there is always in this case a terminal leaflet which corresponds to the middle one in the clover leaf, and the others are arranged in pairs along the main axis. Such a leaf is said to be *pinnately divided.*

The *axil* of the leaf is the angle where the leaf is joined on to the stem which bears it. It is at this point that branches are given off in ordinary cases.

In the clover family the individual flowers are often very small. In such cases they are made prominent by the collection of many of them together, so that the combined effect is similar to that produced by a single but much larger flower in some other plants. In many cases they are collected into rounded or *globular heads* as in the clovers; in some other cases they are arranged along a rather elongated axis, the older flowers at the base of this collection of florets, and the younger ones higher up. That is, the stem as it grows gives off short branches, often near together, but in some cases (as generally occurs in plants of the cabbage family) at some distance apart, and on these the florets are borne. In such an arrangement, which is known as a *raceme*, the first florets produced may have withered and seeds set before florets higher up have even opened.

It is sometimes necessary to refer to the various parts of the single flower.

The *calyx* is the outer whorl of the flower. In Red Clover it is found as a more or less green tube with five distinct points, surrounding the base of the floret. In many plants, instead of forming a tube as in clovers, the calyx consists of separate segments or *sepals*. The teeth of the calyx tube in Red Clover correspond to the sepals of these other plants.

The *corolla* is the whorl next inside the calyx, and generally consists of more or less brilliantly coloured segments known as *petals*. It is this part usually that gives prominence and beauty to a flower, and it is the combined effect of a large number of these collected together that gives prominence to a clover head.

Inside the corolla there always occurs in flowers of the clover family (and usually in others) another whorl which consists of the *stamens*. These vary in number in various types of flowers, and they also differ somewhat in their arrangement. In such plants as the buttercup they are numerous, and each consists of a very slender stalk or *filament*, carrying a distinct yellow head or *anther*. In plants of the clover family there are ten such stamens, and in many of these plants the filaments or stalks of nine of them are joined together for the greater part of their length, while the tenth remains free.

In the centre of the flower the *pistil* is found, and this gives rise to the fruit and seed. In the following notes, the fruit of the clover is referred to as a *pod*, although in many cases it has no distinct similarity in appearance to a pea or bean pod.

Medicago spp.—The root-system consists of a tap-root with its branch roots; stem either erect or sometimes almost trailing, but even when near the ground, roots are not usually produced from the stem; leaf consisting of three distinct leaflets, and in appearance very similar to that of a true clover plant; margins of leaflets toothed, with a short but distinct point at the blunt, or more or less indented, apex of the leaflet; flowers very small, collected into small globular heads or into short spike-like racemes; the corolla falls away when seed has set, so that the bare more or less curved pod remains when the seed is ripe.

Medicago sativa. LUCERNE, ALFALFA, PURPLE MEDICK.—This plant is probably not native to Britain, but in some situations, where it has gained a strong footing, it appears to be truly perennial, although it rarely produces any considerable quantity of ripe seeds.

It grows to a height of about 2 ft. or even more; stem usually erect, but when growing luxuriantly, especially in a wet climate, it has a tendency to become slightly laid; in well-established and strongly growing plants the tap-root is strong and penetrates very deeply into the soil; leaflets rather narrow—about half as wide as they are long—with a rather prominently toothed margin; flowers usually bluish purple, arranged in rather loose racemes on an otherwise bare branch arising from the axils of the upper stem-leaves; the fruits are twisted pods containing two or more seeds, and coiled into two or even three complete rings; seeds kidney-shaped, rather long and somewhat flattened, yellow or yellowish brown.

In a warm climate and on deep soils rich in lime this is an exceedingly valuable plant when grown alone as a forage crop, but as a pasture plant it gives very disappointing results. Its growth during the first year is weak, and at this stage it is easily crowded out by other plants.

Medicago lupulina. TREFOIL, HOP CLOVER, BLACK MEDICK, NONSUCH.—An annual; stem weak, often trailing near the ground; leaflets rather similar to those of White Clover, but easily distinguished from those of the true clovers by the short point at the apex; flowers yellow, in small globular heads; pod one-seeded, black, hard, not covered by the remains of the corolla when ripe, usually not hairy. When ripe, the head of small black pods is very distinctive. The seed is somewhat similar to that of Lucerne, but is shorter and relatively broader, about equal in size to that of Red Clover, but more flattened, kidney-shaped, and yellow.

This plant is widely distributed in Britain, but it occurs chiefly on or near limestone and chalk soils. In its wild state it is rarely an important plant, but under certain conditions it is of considerable value when cultivated. It is best suited to short leys, especially on calcareous soils, and at fairly low altitudes where the climate is relatively dry, and under these conditions it may produce good bulk of nutritious herbage in the first year. In many districts, however, seeds sown establish but a very poor plant, or are a complete failure.

It appears that in some districts this plant is often confused with Yellow Suckling Clover (*Trifolium dubium*), and that the spontaneous appearance of the latter plant in a young pasture has led to the belief that Trefoil succeeds there. It is important, therefore, that farmers should be able to distinguish between the two plants. The chief difficulty seems to arise from the superficial resemblance of the flower-heads and the leaves. (See *Trifolium dubium*, and compare these two points particularly.)

Trifolium spp. TRUE CLOVERS.—The true clovers very closely resemble the *Medicago* spp. in most characters. They differ from them chiefly in that: (1) the midrib of the leaflet is not produced into a point at the tip; (2) the corolla does not usually fall off when seed has set; (3) the fruit-case is thinner and softer, and is not markedly curved or twisted.

Trifolium pratense. RED CLOVER.—A tufted biennial or perennial; number of flowering shoots very variable, almost glabrous to very hairy; leaf divided into three leaflets; leaflets varying considerably in shape and size but usually oval, often with a white " horse-shoe " mark on the upper surface, under surface greyish, not shiny; leaflets more or less distinctly hairy; stipules rather broad, usually membranous, prominently veined, points relatively short; flowers in a globular or ovoid head arising terminally on the main stem or a branch, usually fairly close to two leaves arising very near together on opposite sides of the stem, but sometimes on an elongated stalk, colour of flowers varies from nearly white to purplish red; seed plump (not flattened or slightly so), somewhat one-sidedly heart-shaped, varying somewhat in size and with a colour ranging from yellow through partly purple to whole purple; seed usually about $\frac{1}{12}$ in. at its greatest length.

Red Clovers have been classified by Williams [1] in three natural groups, namely:

1. The late-flowering group (single cut Red Clover type).
2. The early or medium-flowering group (Cow Grass or Broad Red type).
3. The wild or indigenous group.

Williams further states that the first two groups may usually be distinguished by the following characters:

Growth.—The early-flowering clovers have a longer growing season than the late-flowering. They start active growth earlier in the spring and yield heavier aftermaths than the late types.

Time of Blooming.—The early-flowering strains bloom about two to four weeks (according to nationality) earlier than the late-flowering.

Branching.—Late-flowering strains have a more tufted habit of growth (especially during the non-growing season) than the earlier. The late-flowering usually bear three or four times as many stems as the earlies, whilst the difference in this respect is frequently even more marked. The earlies bear only two or three side branches per stem, which are of about the same height as the main stem. Lates, on the other hand, often have as many as five or six side branches flowering at different levels.

Persistency.—On the average the lates are longer persisting.[2] Of the

[1] R. D. Williams, "Preliminary Investigations with Herbage Plants", Welsh Plant Breeding Station, U. C. W., Aberystwyth, 1922. The present section on the Red Clovers is based mainly on this account.

[2] In a footnote, he adds that "the evidence so far collected does not appear to add support to distinctions often made as to stem and leaf characters peculiar to the late and early groups respectively".

CLOVERS

1. *Alsike Clover.* 2. Red Clover. 3. Crimson Clover. 4. White Clover.

Wild Red Clover he writes: " The majority of the types flower very early, even earlier than the earliest of the early-flowering group of cultivated Red Clovers. The habit of growth is usually very prostrate. The plants are considerably smaller, the stems much shorter, the leaves smaller and not so numerous as in the case of the other groups. The stems are slender and woody."

Within each group it is shown that there is quite a marked degree of variation in respect of various characters. Thus there is quite an appreciable difference both in time of flowering and in other characteristics between the nationalities placed in the late-flowering group. These include: English Late-flowering, Montgomery, Cornish Marl, Norwegian Late, Swedish Late, and American Mammoth. The earliest flowering of these was American Mammoth, and the latest of all, Montgomery Red, these two differing by more than nine days.

In the early-flowering group are placed: English Broad Red, Chilian, Wisconsin, New Zealand, Canadian, Brittany, French, Italian, Bohemian, Czecho-Slovakian, and Danish Early. The first eight of these were the earliest and flowered within a few days of each other. The remaining three bloomed about a week later, but still some days earlier than American Mammoth—the earliest of the late group.

Stubble Grazing.—The best results have been obtained with English Broad Red, English Late-flowering, Chilian, and Italian. Most of the lates gave poor results in this connection, but it is interesting to note that English Late-flowering is a marked exception, yielding, as it did, better stubble grazing even than Chilian.

1st Harvest Year.—In the hay cut, the best yields were obtained from Swedish Late, English Late-flowering, Cornish Marl, Danish Early, Montgomery, and Dorset Marl (early). The best aftermath yields were obtained from Dorset Marl, English Broad Red, Cornish Marl, Canadian, Czecho-Slovakian, Wisconsin, and Montgomery. The highest total yield for the season from: Dorset Marl, Cornish Marl, English Broad Red, English Late-flowering, Montgomery, Swedish Late, and Danish Early.

2nd Harvest Year.—Results for only a few nationalities are given, but these show that Montgomery Red gave by far the best results with English Broad Red, Cornish Marl, Brittany, and English Late-flowering coming next. Canadian and Chilian gave poor results while Italian gave only negligible yields. It is pointed out that here the results for English Late-flowering are probably below average expectation, and that it was adversely affected by treatment given.

These results clearly show that great importance must be attached to " nationality " as well as to type as expressed by time of flowering. The persistent strains may be poor in the seeding year and in the aftermath in the first harvest year, while some persistent strains may be excellent for stubble grazing and for a single hay season. Italian seed gave quite good results in the seeding year, but has consistently given exceedingly poor results even in the first harvest year.

Red Clover is a very slow colonizer, so that for long duration leys and permanent pastures it is very important that seed of the more persistent strains should be used.

In a hay meadow, the development of Wild Red Clover is often checked by manuring, although in some cases it may be increased by the use of potash and phosphates. Under grazing conditions, the plant sometimes increases fairly rapidly by winter feeding followed by a dressing of basic slag.

A light dressing of farmyard manure in winter may be beneficial on a young clover ley, but in most cases where manures are applied at all, phosphates, or on light soils deficient in potash, phosphates with potash, give good results.

On clover-sick land it was found at Gorforth [1] that "Red Clover rot is checked by (1) grazing by sheep in autumn; (2) growing Alsike and White Clover along with Red Clover; (3) a winter dressing of quicklime".

Trifolium medium. ZIG-ZAG CLOVER.—This plant is somewhat similar in appearance to some forms of Red Clover. It differs from the latter chiefly in that it possesses long, creeping, underground stems; the flowering stems are usually less erect, and are more bent at the nodes; stipules narrower, green, with long narrow points; leaflets usually longer and narrower with the apex, especially in the upper leaves, rather acute. The flower heads are usually larger, more lax, of a brighter colour, and are carried on relatively long stalks. The calyx is usually free from hairs.

This plant, although widely distributed, is rarely found in great abundance. It sometimes occurs in considerable quantities in very old and rather poor pastures which have a tendency towards gorse-heath conditions, and also on railway and other embankments. It is sometimes known as Cowgrass, but it should be carefully noted that seed sold as that of Cowgrass is not the seed of this plant. The Zig-zag Clover is perennial, but where it occurs it is generally much neglected by stock. The amount of knowledge available concerning this plant is very limited, but in its wild condition it does not seem to be a very valuable plant. It is, however, worth encouraging for the sake of its effect on the soil.

Trifolium hybridum. ALSIKE, SWEDISH CLOVER.—This plant is a tufted, short-lived perennial; not hairy. It grows to a height of 1 to 3 ft. It is a more slender plant than Red Clover; leaflets not hairy, dull on both surfaces; stipules fairly broad with distinctly long points; flower-heads smaller than in Red Clover, of a creamy or pinkish colour, and carried on relatively long leafless stalks arising in the axils of the upper leaves. The pod usually contains two small seeds which are light to very dark

[1] Leeds University and Yorkshire Council for Agricultural Education, *Bulletin* No. 57.

green but not quite uniform colour, heart-shaped in outline but somewhat flattened, less than $\frac{1}{16}$ in. long, and nearly equally broad.

This plant is not indigenous to Britain, but its seeds have been extensively used in seeds mixtures. It usually does better than Red Clover on heavy soils, on very shallow loams, and on peaty soils, and is less liable to clover sickness. It is also considered to be more lasting than Red Clover, but it usually disappears almost entirely in about three years from sowing, except where it persists through self-seeding.

Trifolium repens. WHITE CLOVER, DUTCH CLOVER.—A perennial; usually quite free from hairs; leaf-bearing stems never erect, usually creeping and in the wild plant rooting profusely on the under surface. In the wild plant propagation by this means is very rapid on suitable ground, and in old pastures a tap-root is rarely found as the runners grow indefinitely. The stipules of the leaves cling around the stem, white; leaf-stalk short in closely grazed pastures, long in rank herbage or hay; leaflets not hairy, broader in upper half, upper surface dark green or rarely purplish, usually with a white horse-shoe mark; under surface distinctly shiny; flower-heads almost globular, rather lax, white or slightly pinkish, on bare stalks arising in the axils of the leaves, flowers becoming reflexed when old; pods two- to four-seeded; seeds br'ght yellow, about the same size and shape as those of *Trifolium hybridum*, skin smooth but not shiny.

White Clover is very widely distributed in this country. It has been found to be one of the most important plants in the best old pastures, but under poor conditions its development may be very weak or it may even be completely absent. Its increase in an old pasture under manuring has been found to be a sure sign of improvement, and the stock-carrying capacity of widely different types of poor soils has been vastly increased when, by the use of basic slag, an increased development of this plant has been induced. To such an extent has this been found, that it is now regarded as essential in order to obtain a good grazing pasture that a good development of White Clover is secured.

Where the plant is strongly indigenous, it may, without sowing, appear early in a young pasture and colonize rapidly. The essential conditions for this to occur appear to be the following.

1. The land must have been well treated before it has been ploughed up. This secures a strong population of White Clover, and in spite of fairly heavy grazing, a fair amount of seed will be produced. It is known that a high proportion of White Clover seed that is allowed to become dead ripe is " hard "—that is to say, even under the most favourable conditions, these seeds may fail to germinate for a very long time, and yet remain capable of germination. Such seeds have been kept for months under the best germinating conditions and have then germinated only when the seed coats have been lightly scratched. This seems to indicate

that some seeds may persist in the ground during a period of cultivation and may still be capable of germination.

2. In spite of good cultivation and cleaning of the ground, portions of plants may persist throughout the period of cultivation.

3. If germinable seed or portions of plants have so persisted, whether they will be able to colonize the ground rapidly depends upon treatment. If the land has been exhausted of potash and phosphates, their colonization may be expected to be very poor; if not, then provided other conditions are favourable, colonization may be expected to be rapid.

4. Rapid colonization may be very badly affected by a very heavy crop of hay in the first harvest year. This has been found to occur where sulphate of ammonia has been used to stimulate this crop.

5. With short duration leys, colonization is often found to be very slow even with excellent treatment, probably owing to the fact that in such leys natural White Clover rarely becomes abundant and relatively little seed is produced.

At present, two main types of White Clover seed are available commercially, namely, ordinary White or Dutch Clover seed and Wild White Clover seed. These two types differ in their immediate origin.

Ordinary White or Dutch Clover seed is harvested from very short duration leys. The seed is sown one year and seed from the plants obtained is harvested the following season. This or a somewhat similar method of procedure has been followed through a very great number of clover generations. The result is that plants which are producing the greatest abundance of seed under such short-ley conditions have been unconsciously selected from generation to generation, and the quality of persistency has of necessity been disregarded. Yet the plants themselves have not markedly changed in type, so that even now individual plants grown from this type of seed cannot with certainty be distinguished from wild plants. In mass, they generally appear to be more vigorous and more bulky, with larger leaves than the wild type up to the first harvest year. The seed is also somewhat larger, but not sufficiently so to make the two types distinguishable. Even what is known as the "cyanophoric test" has so far failed to provide an absolute means of distinguishing between the two types.

Wild White Clover seed, on the other hand, is harvested from very old pastures, so that in this case persistency is the chief characteristic secured. In such old pastures, the most abundant plants are those which can persist under such conditions.

The result of this difference in immediate origin is of very great agricultural importance. It has been found that on land where natural White Clover is slow to make an appearance the ordinary White or Dutch seed may give the better results in the seeding year and in the first harvest year, but that even as early as the autumn of the second year there is no greater abundance of White Clover than where, in the same field, no White Clover had been sown. Under exactly the same conditions, Wild White Clover seed has started off rather weakly, but by the autumn of the second harvest year the plants have completely colonized the ground. This same result has lasted for at least five years in some cases.

This means that for a very short duration ley the ordinary White or Dutch is perhaps the superior type, but that for a ley of three or more years' duration, the Wild White Clover seed is vastly superior.

The effect of the two types upon the crops which follow is also quite marked. In at least some cases, even when there has been only a one-year ley, the crop after the Wild White has been much better than that after the ordinary White, and this effect is still more striking after leys of longer duration, unless during that time natural White Clover has colonized the ground where the ordinary White had been sown, or the land has been so neglected where the Wild White has been sown that the plants have lost vigour and have largely disappeared.

Where it is therefore desired to form a long duration ley or a permanent pasture on land where White Clover does not come in to any great extent by the second year from sowing, the superiority of Wild White over ordinary White is unquestionable. Of late, Wild White Clover seed has been expensive, but undoubtedly for such leys a certain sum of money is far more economically used in the purchase of the smaller quantity of Wild White Clover seed than in the purchase of the larger quantity of ordinary White Clover seed. If the seeding is thin, the plants should be encouraged by the use of phosphates, and on some types of soils by the use of potash. In the case of poor old pastures basic slag and ground mineral phosphate have been found very effective in stimulating White Clover on heavy soils and on other soils not deficient in potash. Superphosphate with lime is also effective under such conditions, while superphosphate with potash may be more effective on light and dry soils in a dry climate. On well drained acid peat either basic slag or ground mineral phosphate with potash have been found very effective. It is probable that under similar soil conditions, a sparse population of White Clover would also be encouraged in young pastures by similar treatment.

" Once-grown " Wild White Clover seed might make a satisfactory substitute for the original wild seed. Here, however, great care should be taken that such seed was secured from plants derived from genuine wild seed. Cultivating for one generation only should make no serious difference in the persisting qualities of the plants obtained.

Trifolium dubium (= *T. minus*). YELLOW SUCKLING CLOVER.—A tufted annual; stem short, semi-erect in grazed pastures, long and weak in hay; stipules small, broad, green; leaf-stalks relatively short; leaflets small, broadest in upper half, middle leaflet with a fairly distinct stalk;

flower-heads small, pale yellow, of about twelve florets. The flower-heads, as they wither, first become whitish and then brown.

This, and two other species which differ but slightly from it, viz. *Trifolium procumbens* (Hop Trefoil, Hop Clover) and *Trifolium filiforme*, are often confused with Trefoil (*Medicago lupulina*, which see) on account of a certain amount of similarity. The most important distinguishing characters are that in the above three there is no point at the tip of the leaflet opposite the midrib, and the withered flowers remain on a brown head.

The seed of Yellow Suckling Clover is yellow, nearly oval in shape, but slightly more pointed at one end than at the other; skin very smooth and shiny. It is quite different therefore from that of Trefoil.

Trifolium procumbens occurs chiefly on or near chalk and limestone soils, and where Trefoil (*Medicago lupulina*) is also found growing spontaneously they are somewhat easily confused, although on fairly close examination they are found to be quite distinct.

Trifolium dubium occurs chiefly on soils which are not of a calcareous nature. It is often found in some profusion in certain seasons both in young pastures and in hay-fields, and this has often led to the confusion with Trefoil. The latter plant has, in fact, often been sown where it has no chance of succeeding, and in such cases the appearance of Yellow Suckling Clover has led to a continuance of the practice.

Yellow Suckling Clover itself can only be considered a second-rate plant. Its produce as hay, although sometimes considerable in bulk, is somewhat hard, but in pastures it is serviceable in filling up open spaces. Its appearance from seeding is usually quite unreliable, and its appearance in hay meadows seems to depend on the seasons and on the method of manuring. Alternating farmyard manure and basic slag seems to favour its appearance.

Anthyllis Vulneraria. Kidney Vetch, Lady's Fingers.—A tufted, more or less hairy perennial; stem, in pastures, almost trailing or semi-erect; in rank herbage and hay, nearly erect; first leaves simple (not divided), with a long stalk and a rather long narrow oval blade; later leaves pinnately divided—i.e. with pairs of leaflets given off on opposite sides of the main axis or stalk of the leaf and a terminal leaflet. The terminal leaflet in the lower leaves is considerably larger than the other leaves, but in the upper leaves there is relatively little difference in size. Flower-heads usually on fairly long stalks in pairs at the ends of the branches, but with a few leaf-like structures close below them; calyx inflated, hairy, whitish; flowers yellow or slightly pinkish; pod one-seeded, enclosed in the withered calyx; seed egg-shaped but slightly flattened, somewhat larger than that of Red Clover, and easily identified by its shape and by the fact that one end is usually green and the other yellow.

This plant occurs mainly on or near limestone or chalk and near the sea. It has been used with some success as a forage plant on light soils, but it has become prominent chiefly on account of the fact that its seed has been recommended as a component of seeds mixtures for poor, light soils. Under such conditions it sometimes does well in the first hay crop even on soils known to be deficient in lime, but in most cases it dies out very rapidly.

Lotus corniculatus. BIRD'S FOOT TREFOIL.—A perennial with a long tap-root; stems trailing both above and below the surface of the soil, so that the plant often occurs in distinct colonies; leaves divided into five leaflets, two very near the base and three at the tip, the latter three giving the leaf some resemblance to that of a clover; the three upper leaflets are rather thick, tapering rather gradually below but more abruptly above so that the leaflet is broadest above its middle; flowering stems fairly long, arising from the trailing stems and carrying a number of shortly stalked large yellow flowers arising nearly at the same point; pods long, containing several roundish seeds which when ripe are mottled brown in colour. When in the pod stage the flowering stem with its pods have some resemblance to a bird's foot.

This plant occurs chiefly in rather poor, dry, heathy pastures, and often occurs as almost the only plant of the clover family in open pastures at relatively high altitudes. As a pasture plant, it has not been widely studied in this country, but where it occurs naturally it seems to be of very considerable value. As it is a very slow colonizer where the ground has been thoroughly cleaned, it would appear to deserve attention in seeding down poor dry upland and other pastures. Phosphatic manures in most cases encourage its growth.

On the wetter ground *Lotus uliginosus* (Marsh Bird's Foot Trefoil), a much more erect, hairy plant, but somewhat similar in general appearance, is usually more prevalent. In closely grazed pastures this does not differ greatly from the Common Bird's Foot Trefoil, and apparently is just as well grazed, but in marshy places it is generally totally neglected.

MISCELLANEOUS PLANTS

Plants placed under this heading may belong to any natural order except the two already dealt with. The number of such plants found on pastures of various types is very large, so that here only those whose seeds are sometimes included in seeds mixtures are dealt with.

Achillea Millefolium. YARROW, MILFOIL.—This plant belongs to the natural order *Compositæ* (Daisy and Dandelion family). It is a downy perennial with strong underground stems; leaves narrow (up to about $\frac{3}{4}$ in. wide), long (a few to several inches), repeatedly and deeply divided on each side of a prominent midrib running the whole length of the leaf;

flowering stem erect, a few inches to nearly 2 ft. high, fairly deeply grooved, often whitish; stem leaves few; the greater part of the flowering stem is but little branched, but in the upper part it is much branched, the branches being more or less upright. The lower branches are so much longer than those above them that all the flower-heads appear almost at the same level. Each of the ultimate branches carries a flower-head about $\frac{1}{8}$ to $\frac{1}{4}$ in. in diameter and consisting of a few very small florets, which are quite inconspicuous in themselves, but when all the flower-heads are collected together they form a fairly prominent inflorescence, greyish or pinkish white in colour, as the individual flower-heads are closely set together.

The commercial seeds are really single-seeded fruits. They are very small (about $\frac{1}{16}$ in. long), slightly curved, flat and thin at the sides, shining, and of a silvery grey colour.

The plant is found in various situations, on dry walls, on banks, and also in pastures, especially those which are light and poor.

The real value of the plant in a pasture is in some doubt. It forms a very dense sole and thus tends to exclude other plants, including weeds; it is rarely allowed to flower in a grazed pasture, and is considerably cropped by stock. At the same time it may displace more useful plants.

In recent years the inclusion of the seed in seeds mixtures, especially for poor light soils, has been much advocated, especially for the sake of the organic matter which results from its growth and its drought-resisting character. On such land, at least, and also probably on better land in moderate quantities, it is to be regarded as a desirable plant in long duration pastures, on account of the organic matter it accumulates, its capacity for forming a dense sole, and its herbage. It is sometimes objected to on the ground that when land in which it is plentiful is ploughed up, it becomes a bad weed in the first corn crop. This has been found to be the case where the turf is not well turned over. On deep land this is easily done, and on such land it may completely disappear under cultivation, so that, if the presence of the plant is desired in the pasture which follows, it is necessary to include the seeds in the seeds mixture. It generally succeeds well from seed, and is very permanent under grazing conditions.

Carum Petroselinum. SHEEP'S PARSLEY. Natural order: *Umbelliferæ.*—The use of the seeds of this plant in seeds mixtures for light soils and sheep-walks is sometimes advocated. Where sown on such land, traces of it have been found for three or four years from sowing, but the amount of herbage produced is usually quite insignificant.

Cichorium Intybus. CHICORY, SUCCORY.—A very deep-rooted, strong-growing, and rather harsh perennial, belonging to the Daisy family. It is not naturally widely spread in Britain, but in recent years its seed has often been included in seeds mixtures especially for poor light soils.

In grazed pastures, it is generally kept very short, and its flower-heads appear very close to the ground, but when grown alone, or where it occurs in a young pasture kept for hay, it may grow to a height of 7 ft. The leaves, especially near the ground, are often divided near the base, or the margins may be strongly indented, but most commonly the margins are wavy and the leaves are long and broad, and often covered with stiff hairs. The stem leaves are smaller and usually less deeply indented, while they are produced backwards into two points almost encircling the stem. In the upper part of the plant, the leaves become very small. The stem, when it grows to a considerable height, becomes woody, and the lower leaves wither, so that the plant cannot be considered very useful in hay-fields. It is but little branched in its lower part, but is considerably branched in the upper part. The flower-heads, of a light blue colour and about $1\frac{1}{2}$ in. diameter, are set closely, two or three together, in the angle made by the leaf and the stem in the upper part of the plant, so that when in flower the plant becomes very conspicuous.

The commercial seed in this case also is really the fruit. It is greyish to dirty brown in colour, about $\frac{1}{10}$ in. long, broadening slightly from base, angular, top very blunt with a crown of short teeth.

In pastures the plant appears to be productive and is very well grazed, and under those conditions it does well from sowing for some years on a variety of soils. Even on fairly heavy land it does well for two or three years if the land be well drained. It does exceedingly well on some light soils where there is a fair depth, but dies out rather rapidly on shallow soils of a similar character. In most cases, however, traces can be found up to five years from sowing, and on light soils it is a valuable plant for grazing purposes.

Plantago lanceolata. RIBGRASS, PLANTAIN, RIBWORT. Natural order: *Plantaginaceæ.*—A non-creeping perennial with, in grazed pastures, a dense rosette of relatively long and narrow leaves closely set on the ground. These leaves are set very closely on a very short stem so that they all seem to be given off nearly at the same level. They taper gradually from the base to near the middle and again gradually to a fairly acute point. Running their entire length also they have several prominent ribs or veins. When growing in a pasture kept for hay, the leaves become nearly erect if the herbage is dense, and there also they are considerably longer and relatively narrower. From the centre of this rosette of leaves the bare flowering stem arises. This may be a few inches to well over a foot in height, and around it at the extreme top the small brown florets are crowded into a cylindrical spike, varying in length from about $\frac{1}{4}$ in. to 2 in. or even more. When in flower, the yellow anthers on their relatively long and slender stalks stand out prominently from the flowers.

In each fruit-case, two seeds are produced. Each is a bright brown in colour, glossy and very hard when ripe, rounded and smooth on the outside, and with the faces towards each other slightly hollow. The seeds are oblong in shape with well-rounded ends.

Formerly the seed of this plant was considerably used in seeds mixtures. In a pasture the chief objections to the plant are that it covers a very large area of ground in proportion to the amount of herbage it produces; that it thus lays waste ground which might be occupied by better plants; and that in some cases it tends to increase rather rapidly. On the other hand, it is palatable, and where it increases abnormally, the land in most cases requires manures to stimulate the growth of better plants. In hay meadows it is also objected to on the ground that it is difficult to harvest. When perfectly dry, it readily crumples up and is largely lost, while if it is stacked in imperfect condition it is generally considered to cause overheating. Where troublesome in a hay meadow, good manuring, and especially the application of sulphate of ammonia, will decrease it.

Poterium Sanguisorba. BURNET, SALAD BURNET. Natural order: *Rosaceæ.*—Although this plant belongs to the Rose family, it has very little similarity in general appearance to the roses themselves. It is a non-creeping perennial plant with its main root penetrating deeply into the soil. It is typically a limestone or chalk land plant, often occurring in abundance in undisturbed pastures on such soils, but it is also found naturally elsewhere in some cases. In old grazed pastures it is quite dwarfed, but when growing alone or in rank herbage it may reach a height of 18 in. or even more. The leaves are mostly produced near the ground. Each leaf is pinnately divided, so that there are numerous pairs of leaflets the whole length of a main axis with an odd leaflet at the tip. The leaflets are small, broadest below their middle and deeply toothed at the margins. The flowers occur in globular heads on leafless stems, arising either at the end of the flowering shoot or in the axils of the stem-leaves. When in flower, these heads have a greenish purple colour, owing to the colour of the calyx segments (sepals). There is no true corolla (petals) present. In the lower flowers of the head there are numerous stamens, but in the upper flowers there are no stamens. These upper flowers, however, produce fruits which remain in the withered and hardened calyx. The *commercial seed of Burnet consists of this withered and hardened calyx*, enclosing one or two single-seeded fruits. It is pale brown in colour, four-ridged lengthwise, and wrinkled or netted in between. Its length is about $\frac{1}{8}$ in.

The inclusion of the seed of this plant in seeds mixtures for permanent pastures on poor, light, or thin dry soils has been recommended to a considerable extent in recent years. With a heavy seeding there is often a good " take ", and in some cases traces may be found even on soils deficient in lime up to about five years from sowing. Its growth is in most cases, however, weak, and it does not seem to be relished by stock. On the whole, therefore, the plant seems to be in most cases unsatisfactory and of little use.

THE TEMPORARY LEY

By R. G. STAPLEDON, M.B.E., M.A.

INTRODUCTION

The total area of grassland in England and Wales, excluding hill grazing but including rotation grasses, is given in the preliminary statement of the Ministry of Agriculture for 1919 as being 16,699,440 acres, which constitutes a decrease of 1,867,541 acres since the returns of 1913. About 13·5 per cent of our grasslands (excluding hill grazings) are scheduled as being rotation grass. This figure can only be taken as an approximation, since in the case of the longer duration leys these may in some instances be returned as permanent grass and in others as rotation grass. The figure is, however, a significant one as showing the comparatively small extent to which the temporary ley enters into the scheme of agriculture in England and Wales. In proportion to the areas under permanent grass and in rotation grass it would seem, moreover, that permanent grass and temporary grass were decreased about equally as a result of the ploughing up campaign during the period of the War, both types of grassland being reduced by no more than 9 per cent. It is quite evident, however, when the country as a whole is considered, that with perhaps a few insignificant exceptions, the grassland, both permanent and temporary, that fell to the plough during the War was of an inferior character, and that the areas so broken, whether subsequently put down to grass or retained in rotation, are capable of being made altogether more productive than formerly.

Sir Thomas Middleton[1] considers it unlikely that there are 500,000 acres of grass in the country which, without the help of concentrated feeding stuffs, could fatten one bullock per acre on the average of a series of years. On the basis of this estimate it would appear that, despite the popular esteem in which our grasslands as a whole are held, not more

[1] "The National Aspects of the Case for Increasing the Supplies of Basic Slag", *The Journal of the Ministry of Agriculture*, Vol. XXVII, No. 3, June, 1920.

than about 3·5 per cent of the area under permanent grass is really of a first-class character. The contrast in productivity between the fatting pastures and the average pastures of the country is also very great. Sir Thomas Middleton estimates that the best fatting pastures in Leicestershire on the average of a number of years produce from 180 to 200 lb. of meat without the assistance of oil cakes, while many pastures on poor clay soils yield no more than 15 to 20 lb. lean meat per acre per annum; and when both the quality and quantity of meat produced is taken into account, he estimates that the best pastures have a productive capacity of about three times that of the "average" pastures, and ten or twelve times that of some of the poorest pastures. It is shown in another article [1] that the productivity of poor pastures can frequently be enormously increased by adequate manurial dressings,[2] but that improvement by this means is often uncertain, slow, and disappointing. It was shown, furthermore, that breaking and re-seeding is, under certain circumstances, the surest way of grassland improvement, the question then arising whether fields should be sown down on the basis of the temporary ley or permanently.

Comparison between the Temporary Ley and Permanent Grass.

The part that the temporary ley should be called upon to play in the improvement of grassland affords one of the most urgent agricultural problems of the day. There is unfortunately no adequate data available for a comparison of the productivity of high-grade temporary leys and first-class permanent grass on similar soils: nor is there reliable evidence for drawing a comparison between fields improved by top dressings and fields of a similar character put down and maintained as well cared for temporary leys. Statistics for the ten-year period 1903–12 show, however, that the average yields of hay from temporary and permanent grass is as 28·95 cwt. is to 23·59 cwt. These figures, of course, include the best and worst of the grasslands scheduled under both categories, but are none the less eloquent of the greater capacity for hay production of the former class. Further evidence may be deduced from the results of meadow hay manurial trials conducted in different parts of the country. The greatest yield of meadow hay at Rothamsted from any one manurial treatment averaged over ten-year periods seldom exceeds 3 tons per acre, although in individual years as much as 4 tons have been harvested from the best plots. At Cockle Park over a fourteen-year period the best yields have been in the neighbourhood of 2 tons; at Cirencester over a seven-

[1] *Permanent Grass*, by R. G. Stapledon, p. 74.

[2] Sir Thomas Middleton, referring to experiments at Cockle Park, states that over an eleven-year period an area formerly producing 20 lb. lean meat per acre per annum was rendered capable of producing about 105 lb. per acre per annum as a result of proper treatment with basic slag.

teen-year period the average yields have been decidedly less than 2 tons, with $2\frac{3}{4}$ tons the maximum. Professor Gilchrist[1] at Cockle Park has averaged 2-ton yields of ley hay over first, second, and third years. In Central Wales 3-ton crops of ley hay have been harvested in the first year and crops of nearly 2 tons in the second year. In West Aberdeenshire yields from 43 to 49 cwt. per acre per annum have been averaged over a three-year period, with first-year yields ranging from 66 to 75 cwt., second year 33 to 37 cwt., and third year 29 to 40 cwt. Thus it will be seen that well-managed leys sown with a good grass and clover mixture (reference is not here made to Lucerne or Sainfoin leys) are capable of yielding, even in their second and third years, nearly if not quite as much hay as even intensively manured meadows.

Hay harvested from well-managed leys under ordinary farm practice is usually far less weedy than meadow hay, and it is on this score that ley hay is so vastly superior to meadow hay. Meadows totally unmanured and those manured with farmyard manure frequently consist of over 20 per cent of weeds; those manured with complete artificials (including ammonium sulphate) are, however, often remarkably free from weeds, but this is not a really frequent practice.[2]

In districts where the grassland is not good, leys properly put down are on the average decidedly less weedy over a four-year period than are the more permanent grasslands, and certainly produce better crops of hay than the poor meadows. Leys badly put down and ill cared for, however, deteriorate rapidly, become full of Yorkshire Fog and weeds, and by the third, fourth, or fifth year are frequently inferior to the permanent meadows and pastures of the locality. Although exact feeding experiments have unfortunately not been conducted to compare the productivity of a series of one- to four-year leys with that of either the improved or unimproved grasslands in a particular parish, the benefit to fields so farmed is frequently sufficiently obvious to be estimated in terms of increased rental value of over 20*s.* per acre.

The Case for the Extension of the Area under Temporary Grass.

The value of the temporary ley is not, however, only to be judged by a comparison between its gross productivity with that of permanent grass. The temporary ley should make its greatest appeal to the farmer on the score of the inheritance of fertility it leaves behind it, and the scope it affords for producing keep at those times of the year when grazing is most short or when heavy grazing exerts the most harmful influence on permanent pastures.

[1] *Wild White Clover and Rotations of Crops*, 1918.

[2] For a more detailed comparison of meadow with ley hay and for references to literature cited, see R. G. Stapledon, "The Condition of Permanent Meadows", *Jour. Min. Agr.*, Vol. XXVIII, No. 3, June, 1921.

It is now an established fact that high-class leys with an abundance of White Clover in the sward give rise to fertile arable land when broken, and to both cleaner and more fertile arable land than do inferior and outworn permanent swards. There is also evidence for thinking that the risks of damage from wireworm are not nearly so great when a two- to four-year sward is broken as from a more permanent one. On poor soils, therefore, the fertility of a whole farm can be rapidly enhanced if instead of leaving one part of the holding in permanent grass and retaining only one portion under the plough, a rotation involving a three- to six-year period in grass were taken over all the fields in a well-ordered sequence.

The aim should be the dual one of producing temporary grass of high productivity and of building up fertility. It is therefore essential that the sward should be broken while still full of White Clover, and before the nitrogenous residues from the clover are dissipated in producing excess of Bent, Yorkshire Fog, and weeds. In managing a farm on the temporary ley basis the greatest skill is needed in deciding when the swards should be broken. This will vary not only from district to district but from field to field, so that no hard and fast rules can be laid down. Generally speaking, in proportion as the soil is poor so should the ley be broken when the clover is at its very best, so that the greatest benefits may be conferred upon the soil. It will be found that a courageous ploughing out of swards when at their best will so improve the fertility of the land that fields considered almost incapable of remaining in good grass will at the second or third seeding-out remain in excellent sward for the four- to six-year period or longer if necessary.

The temporary ley as a substitute for permanent grass is most applicable to friable soils and in regions of high rainfall, in regions where a tilth can be assured and where the weather conditions are such that failures of " take " due to drought have not seriously to be reckoned with.

The temporary ley may with advantage be employed on steep and more or less inaccessible fields, and on fields too heavy to be retained in regular rotation. Under these conditions the aim would be gradually to build up fertility and only to break the sward when deterioration commenced, to break and resow, first at relatively short and then at longer and longer intervals. In this connection it is necessary to emphasize the fact that under proper conditions seeds can be sown on a once-ploughed sward with every promise of success, so that, when the sward came to be broken, it would not always be necessary to put difficult or inaccessible fields through a rotation before reseeding, but the seeds would be sown under a first and only corn crop, under rape, or without any nurse crop.

A rotation taken over a whole farm, or over the greater area of a farm on the temporary ley basis, of course implies more ploughing out of sward than would the production of the same acreage of ordinary crops off a smaller area of the farm managed on a four-, five-, or six-course rotation. This, however, is probably an advantage in districts of high rainfall, for sward can be ploughed when it is too wet to put the teams on arable proper, and indeed can be broken to the best advantage during moderately wet weather. The tractor is, moreover, capable of working on sward under weather conditions which on arable would be out of the question. These are economic considerations which should be taken into account when systems of managing a farm are under review.

Farming on the temporary ley basis must of necessity be elastic, for it is impossible to foresee precisely when any particular ley should be broken. A number of crops, however, appear to succeed on a newly broken sward: rape, kale, and oats, as well as rye and wheat, have all proved successful, as have also Yellow Turnips sown quite late. As before said, a seeds mixture may also be sown on a newly broken ley sward with every promise of success. When it is intended to sow seeds the ploughing should, however, be well done, an even surface should be obtained, and the seeds put down on a clean and even tilth.

There remains the further aspect of temporary grass, namely providing keep at those periods of the year when grazing is most short, or when it is unwise to graze permanent grass heavily, that is to say, broadly considered, from about the beginning of December to the end of April. Ordinary three- to six-year leys contribute appreciably to the amount of early winter keep, for in their seeding year these should always be grazed sufficiently in the autumn and early winter to prevent the quicker growing grasses and clovers becoming winter proud, and in their second and third years will usually afford appreciable keep into the early winter; but at the best such leys cannot be regarded as making a really substantial contribution to the amount of winter grazing available. Heavy grazing during March and April is, however, as bad for the persistency of a ley intended to remain down and to continue productive for two, three, or more years as it is for permanent grass. Thus March and April grazing should be very largely catered for by short duration leys designed pre-eminently for this purpose, and which should be ploughed out to give place to other crops before the same period in a succeeding year. This and winter grazing is an important aspect of the one-year ley that is too frequently entirely overlooked. It should be realized that those perennial grasses which have the ability to throw the most keep really early in the spring, namely Tall Oat Grass and Tall Fescue, if heavily grazed at this period suffer probably more than any other grasses in respect of persistency. Consequently when used in long duration leys their greatest virtue is either not turned to advantage or is rendered nugatory after the first year; while Italian Ryegrass, the early Broad Red Clovers, and Crimson Clover—equally valuable plants for early spring grazing—are in any event only productive for a single season.

The value of short duration winter and spring leys must not be judged only by the number of sheep or cattle weeks of keep they may afford during these critical periods, but to their credit must also be placed the heavier hay crops and much increased summer and autumn keep that the permanent grass and longer duration leys will yield by virtue of having been less severely taxed during the " closed " season.

Leys sown to provide spring keep will not have established dense swards by early May, and consequently can be easily broken if so desired, and resown during May or June with a further " winter " or " spring " mixture. It is not a serious matter to put a few acres of grass out of action during the height of the grazing season, and fields so sown under a light seeding of rape, under favourable conditions, afford keep again within six to eight weeks. " Spring " fields, moreover, would come for a crop of kale, or if left on to give a measure of keep during the summer would afford an admirable preparation for winter oats and obviate many of the difficulties which count against getting this crop sown in good time.

THE ESTABLISHMENT AND MAINTENANCE OF HIGH-CLASS TEMPORARY LEYS

The establishment and maintenance of a high-class ley depends equally upon the choice of an adequate seeds mixture, the method and time of sowing, the preparation of tilth, proper manurial treatment, and attention to stocking and the taking of hay. It will be convenient to deal with each of those aspects of management separately, and since the mixture to be employed will largely turn on the general methods adopted, discussion of seeds mixtures as such will be dealt with in the closing section.

Time and Methods of Sowing.

Seeds of different species require different temperatures to germinate and establish themselves. The Ryegrasses and Red Clovers, generally speaking, will germinate satisfactorily at lower temperatures than most other species, and can thus be sown with safety earlier and later than less resistant species. Timothy, Cocksfoot, White Clover, and Alsike Clover require appreciably more favourable conditions than the Red Clovers and Ryegrasses for germination and establishment; while the Meadow Grasses, Fine-leaved Fescues, and Meadow Foxtail are incapable of strong germination and early growth under relatively cold conditions. Furthermore, most species if sown too late in the autumn, although perhaps germinating and brairding satisfactorily, cannot establish themselves to proper advantage before the advent of winter, and will never develop into robust plants. Thus, according to district, Ryegrasses and Red Clovers can generally be sown with safety from early to middle of

March till practically the end of August, and sometimes into September; while mixtures including the less adaptable seeds must be confined to a much more restricted sowing season. Except in early and mild localities, from about the middle or end of April to the middle of July represents the extreme limits of the safe sowing season—compatible with maximum germination, establishment, and subsequent vigorous growth—for all the species which are likely to be included in a general mixture, while in mixtures including grasses like Meadow Foxtail and the Meadow Grasses it would often be wise to defer sowing until towards the end of May or beginning of June.[1] In warmer and early districts general mixtures can usually be sown with safety well into August; and in these districts autumn or comparatively early spring sowing has much to recommend itself, since either practice is likely to give the seedlings the best chance of establishing themselves before summer droughts set in.

The depth at which different species should be covered and the methods of covering have recently been investigated in considerable detail by Williams,[2] and largely on the basis of his work it is possible to make the following generalizations and recommendations.

Better stands and germinations will be obtained from the grasses than from the clovers if the seed is not covered properly. It is imperative that clovers are properly covered, or the seedlings are quite unable to get an anchorage on the ground and will wither and die. Cocksfoot will stand a depth of covering of quite ½ in. and the Ryegrasses of quite 1 in., while on average soils Red Clover will establish itself well from depths of about ½ to ¾ in. Meadow Foxtail will stand covering to quite ½ in., while the Meadow Grasses should not be covered to more than about ¼ in. Although some of the grasses will establish themselves satisfactorily from surface sowing, it is highly important to cover all the seeds in order to minimize the effects of drought immediately following after conditions favourable for germination. The aim of covering operations should be to cover seeds like the clovers, Ryegrasses, and Cocksfoot to depths of about ½ in. and not to greater depths than about 1 in., and the finer grasses generally not to greater depths than about ¼ in.

Even under the most favourable conditions broadcasting entails an

[1] Owing to the drought of 1921 it was not found possible to sow two large series of seeds mixture experiments at Aberystwyth until early and late in August respectively. Although the seeds germinated and brairded well in both cases, neither Wild White Clover, Alsike Clover, nor Rough-stalked Meadow Grass established themselves in a really satisfactory manner; while in the case of the later sowing, Cocksfoot did not get properly established (despite excellent germination and brairding), with the result that the plots were disappointing. The Ryegrasses and Red Clovers, however, established themselves normally in both cases.

[2] See R. D. Williams, "Depth of Sowing Grass and Clover Seeds", *Journ. Min. of Agr.*, Vol. XXIX, Nos. 1 and 2, April and May, 1922; and "Methods of Covering Grass and Clover Seeds", *ibid.*, Vol. XXIX, No. 2, March, 1923.

enormous waste of seed, largely because not all the seeds will be properly covered. *Seeding attachments to an ordinary corn drill with careful* adjustment can be safely used for seeds standing coverings of about an inch, and are therefore admirably adapted for one-year leys, but are not suitable for sowing more complicated mixtures.

In so far as covering broadcast seed is concerned, Williams has shown that proper covering is only possible when the ground is absolutely dry at the time of harrowing and sowing, and that seeds sown under these conditions will withstand a prolonged drought with perfect safety. Excellent takes can be obtained when the surface is slightly rough, consisting largely of lumps ranging from $\frac{1}{4}$ to $\frac{3}{4}$ in. in diameter. Too fine and powdery a tilth tends to hamper proper covering, while large and coarse lumps are, of course, fatal to proper covering. On a good tilth it does not appear to make a very appreciable difference whether the land is rolled or not previous to broadcasting. The light peg harrow, or chain harrow, followed by smooth roller, can be relied upon to give good covering results, and are unlikely to bury any considerable number of seeds too deeply. Under ordinary conditions it does not appear to be a sound practice to sow a mixture in two separate portions—heavy and light. Williams has shown that when light seed (e.g. Rough-stalked Meadow Grass) is covered with a roller only, more seed is left uncovered than is covered too deeply when a chain harrow is used. For a mixture consisting of both heavy and light seed the chain harrow should always be employed in preference to the peg harrow.

"Nurse" Crop.

It is essential to sow seeds on a clean tilth, and this is particularly important in the case of those species which germinate and establish themselves slowly. Sowing under a corn crop does not give a prolonged opportunity for clearing the land, and in many districts entails too early sowing to suit all the species of a full mixture. Mixtures sown in late May or June are best sown without a covering crop or under a light seeding of rape (about 2 lb. per acre), and, when complicated mixtures for permanent grass are relied upon, this is a procedure which has much to recommend itself.

If a corn crop becomes lodged it is the finer and more expensive seeds that will suffer most. When seeds are sown under corn a stiff-strawed variety, like Record in the case of oats, should always be employed. If seeds are sown in the spring on oats or wheat sown in the autumn, it is essential to harrow the cereal "sward" thoroughly with the peg harrow before sowing the grasses and clovers.

Preparation of the Land and Formation of a Good Tilth.

This subject has been referred to already, and it is only necessary to emphasize the desirability of getting lime into the soil some little time before the seeds are sown on all soils deficient in lime. When seeds are sown with a first crop on newly broken land, certain precautions should be taken. As before said, the ploughing should be well done, the sod being turned well over and as even a surface as possible secured; it is desirable to roll the land well, and it is more than ever necessary to ensure that the seeds start well into growth. Experience suggests that it is often better to sow seeds with a first crop than with a second, to sow at once, that is to say, or at the end of a complete rotation. A second ploughing will bring the old sods to the top again and render it difficult to obtain an even surface. It has been noticed also in connection with considerable areas which came under the observation of the writer during the War, that Wild White Clover (unsown) gains on the new sward very much more quickly when poor fields have been broken and ploughed only once, than when they have been made to yield several crops before being seeded out. The effect of a single ploughing is presumably to break up the few Wild White Clover plants present on a poor old sward, each parent plant therefore giving rise to a number of plantlets but few of which are killed by a single ploughing and a few harrowings, the majority starting into vigorous growth when the field is subsequently left undisturbed.

Manurial Treatment.

In forming long duration leys it is not advisable to apply nitrogenous manures either just before or immediately after sowing the seeds. This should be borne in mind if it is desired to sow seeds in the spring on autumn-sown wheat. The Rothamsted experiments have, for instance, shown that wheat should be top dressed with nitrogenous fertilizers; this tends greatly to increase the wheat crop and proportionately to hamper the development of the seeds. Phosphatic manures such as basic slag or superphosphate on the other hand should be used liberally, and if the soil is deficient in potash a manure supplying this ingredient should also be applied.

It is not always an easy matter to decide when is the best time to add phosphatic fertilizers. On fertile fields adequately manured through the rotation, and when phosphates will have been given to the root crop, it is not desirable or necessary to apply further dressings at the time of sowing the seeds. The phosphatic residues will be sufficient to ensure a good stand of Red and Alsike Clovers for the first year's hay crop. Under these conditions it would be wisest to dress the sward after the first hay crop has been removed—with basic slag on heavy soils in the autumn, or on light soils with superphosphate the following spring.

On poor soils, or on old swards which have been broken with a view to seeding out with a first and only crop, it is generally best to apply a good dressing of basic slag at the time of sowing the seeds, and to give a further dressing about eighteen to twenty-four months before it is intended to break the ley: this procedure will do much to ensure an abundance of White Clover in the sward for the purpose of ploughing down and thus adding a capital store of fertility for the subsequent arable crops.

When heavy crops of hay are desired off temporary leys nitrogenous manures should be applied, but such dressings should always be extra to the essential applications of phosphatic fertilizers. Recent experience and experiments show that Red and Alsike Clover undoubtedly respond to nitrogenous manures, whilst Cocksfoot and Italian Ryegrass are grasses which well repay feeding. Liquid manure is an excellent dressing for hay-producing leys, and when freely applied (say about 2000 gall. = approximately 9 tons per acre) two heavy yields of hay may often be taken in the first year, and a further heavy hay crop in the second year. Sulphate of ammonia has also been successfully employed, Mr. Stratton[1] having used 1 cwt. to the acre with marked success on his leys. The present writer has seen ½ cwt. per acre applied in the spring for a first hay crop, again on the aftermath for a second hay crop, and again the following spring for a third hay crop on Cocksfoot, Ryegrass, Timothy, Red and Alsike Clover leys in Devonshire with very satisfactory results.[2] It would, however, be a doubtful policy as a general rule to manure heavily and take three heavy hay crops in two years from a ley intended to be left down for more than three years; for as before shown heavy hay crops tend to suppress the development of White Clover, and would therefore react against the formation of a lasting sward. Leys put down with the avowed intention of producing hay only may, however, by heavy dressings be maintained for four or even five years in a state of high productivity; such leys should be broken when Yorkshire Fog and weeds begin to be excessive, and should not be left to develop gradually into a grazing sward. *In so far as one-year and shorter than one-year leys are concerned*, nitrogenous manures are of very decided value, for they not only add to a hay crop, when such is desired, but they make for earlier spring keep and add to the length of the early spring grazing season and very appreciably to the gross bulk of forage available. This point has been well brought out in a recent article by Wibberley[3] on Crimson Clover, while Oldershaw[4] has shown the remarkable influence of farmyard manure on Red

[1] "My Record Seeds Hay Crop" in *Modern Farming*

[2] This is a procedure that in any event would only be legitimate when steps have been taken to safeguard the lime requirements of the soil.

[3] See T. Wibberley, "Crimson Clover", *Journ. Min. Agr.*, Vol. XXX, No. 2, May, 1923.

[4] See A. W. Oldershaw, "The Manuring of Red Clover", in *Modern Farming* for January, 1922.

Clover when either applied direct to the crop or when the clover ley has been sown on previously well-dunged land.

Stocking and Removal of Hay.

In many districts there is a tendency to stock young leys too heavily in the first autumn after the covering crop has been removed. Heavy stocking by sheep tends to injure the clovers and the young developing finer grasses. A certain amount of grazing is desirable, since it will consolidate the ground and help the young plants to establish themselves. In wet and growing summers when the clovers will have become winter-proud, fairly heavy autumnal grazing is a necessity. Young stock are perhaps better than sheep for grazing developing leys; where the latter are employed, it will have been wise to have included a little Italian Ryegrass and rapid-growing Chilian Red Clover in the mixture.

When it is desired to establish a long duration grazing ley, in which a good development of Wild White Clover is so essential, it is the safest plan to graze the fields from the commencement and not to take any hay. The grazing should, however, not be heavy during the first year, particularly from March to the middle of May.

On all leys intended to form short or long duration meadows the hay should always be cut early. It is a great mistake to allow Cocksfoot to get dead ripe before it is cut. Late cutting over a number of years always makes for deterioration due to the rapidity with which Yorkshire Fog and Soft Brome Grass gain on the ground by abundant reseeding.

THE CHOICE OF A SUITABLE SEEDS MIXTURE[1]

In addition to, or as an outcome of the various methods of management that are likely to be adopted, the following considerations should be taken into account when drawing up a mixture:

The precise purpose for which the mixture is required; the current prices of seed; the question of strain; the quality of the seeds employed; and, most important of all, the influence of competition—between not only the various species sown but equally between sown and unsown plants—on the development of the sward; the dates at which the different species and different strains of the same species come into flower. Before making suggestions as to mixtures suitable for different purposes it will be desirable briefly to deal with the above considerations.

[1] In writing this section the author has drawn largely on a recent article appearing in the *Journ. Min. of Agr.* See R. G. Stapledon, " Seeds Mixtures for Grassland ", in Vol. XXX, No. 2, May, 1923.

Importance of Strain.

It is not enough merely to choose the species to be sown; often, as for instance with White Clover, Red Clover, and Cocksfoot, the proper strain or nationality must also be selected.

With *White Clover* this is especially important. Wild White Clover is at present much more expensive than commercial White Dutch, but commercial Dutch should only be used in leys sown down for at the most two years. It is best suited for leys intended for sheep grazing only, as it will not contribute very materially to the hay crop. When using commercial White Dutch, seed from New Zealand should if possible be employed, since there is evidence to suggest that this seed gives rise to longer lived and more densely creeping plants than that from the Continent. Yet even for short duration leys Wild White is valuable, because in conjunction with Perennial Ryegrass and Rough-stalked Meadow Grass it tends rapidly to form a dense sward and to suppress weeds and Bent grasses. For longer leys and for permanent grass it is of course invaluable; it is probably the one seed of commerce capable of producing really perennial and persistent plants.

With *Red Clover* too, nationality and strain are very important. There are only two main types of Red Clover—early and late. The early are commercially known as Broad Red Clovers—sometimes also called Cowgrass or Giant Hybrid Cowgrass. The late are Late-flowering Reds or Single-cut Cowgrass, sometimes also supplied under the names of Cowgrass or Giant Hybrid Cowgrass. Unfortunately the seed of the two types cannot be distinguished. The early reds flower earlier and produce more keep early in the spring, and also tend to produce rather more in the autumn of the seeding year than the general run of the lates. They aftermath abundantly, but are not usually long persisting. The lates flower ten to fourteen days later than the earlies, have not time to produce a heavy aftermath, persist longer, and some of them, even in the first year, produce heavier hay crops than the earlies. Some, too, are extra late flowering and extra persisting, as, for instance, the typical strains grown in Montgomery and in the Wadebridge district of Cornwall. For leys of two years and upwards the lates should be mainly relied on. Unfortunately few of the foreign nationalities of Red Clover consist wholly or even mainly of late-flowering types. Home-grown seed, so far as the north and west of England are concerned, does, on the whole, better on long duration leys than foreign seed.

Of *Cocksfoot*, New Zealand seed,[1] in trials both at Cockle Park and at Aberystwyth, has proved to have certain decided advantages over Danish and American, particularly for long duration leys. French seed,

[1] There is not much New Zealand Cocksfoot on the market, but if its merit were more fully recognized by farmers, larger supplies would no doubt be forthcoming.

as was shown some time ago in Denmark and more recently in Wales, is inferior for the longer leys.

More recently trials at Aberystwyth have shown that amongst the wild forms of grasses like Cocksfoot, Perennial Ryegrass, Timothy, Tall Oat Grass, Sweet Vernal Grass, and the Meadow Grasses, strains are to be found which show very striking superiority to the plants developed from ordinary commercial seed in numerous characteristics of fundamental importance to the grazier.[1]

The Quality of the Seed in Reference to Price.

When comparing the price of different seeds the chief considerations to bear in mind are:

(*a*) the number of germinable seeds per pound;
(*b*) the suitability of the seed for the purpose required;
(*c*) the purity.

Thus at ordinary prices Timothy, by virtue of its smaller size and usually equally good germination, is generally as cheap or cheaper than the Ryegrasses. The seeds of grasses like Meadow Foxtail and Golden Oat Grass as well as being expensive usually germinate very poorly and are thus exceedingly costly. With reference to purity, what really matters is, of course, the absence of land-fouling weed seeds like Wild Carrot, Docks, Yorkshire Fog, Soft Brome, and Cranesbill; a comparatively small amount of any of these should always be enough to condemn a sample.

The presence of a certain amount of seeds of Ribgrass, Buttercups, or of species of grasses or clovers which are in themselves valuable, need seldom afford grounds for rejecting a sample. Both germination and purity must be judged in the light of strain. The farmer should not expect such high germinations from English and especially Welsh Red Clovers as from foreign, and provided the seeds of land-fouling weeds are not present in such samples he would frequently be wiser to use a lot germinating no more than 70 or 75 per cent with 2 to 3 per cent of Ribgrass, and 4 to 5 per cent of shrivelled Ryegrass seeds, than, say, a sample of Chilian Red with a germination of 99 per cent and purity of 100 per cent. A considerable amount of Ryegrass in a sample of New Zealand Cocksfoot is of very little consequence. When germination and purity are low it is generally necessary to adjust the seed rate accordingly. Wild White Clover often contains excess of Yellow Suckling Clover. This latter plant is decidedly valuable on pastures and as such does not detract greatly from the value of a sample of Wild White Clover, providing the price per pound is proportionately reduced.

[1] It is of interest to record that indigenous herbage plants have been largely studied and extensively used in connection with the improvement of herbage plants on the Continent, by Witte in Sweden, Zade in Germany, and Lindhard in Denmark.

The Significance of Competition.

The effects of competition become operative almost immediately a field has been sown to grass. There will at the outset be the competition afforded by the covering crop and by arable weeds like Charlock, Spurrey, and Sheep's Sorrel, the two latter of which are often competent almost to ruin a developing sward. As well as having to compete with weeds that will gradually be completely suppressed by grassland conditions, the sown seeds will have to contend for supremacy with numerous wild species that equally with them are proper to swards and whose spread will be favoured by sward conditions. These latter species include grasses, clovers, and miscellaneous plants, some valuable, others worthless weeds. Among these plants, moreover, are some that are likely to gain entry almost at once, and others that will not become strongly in evidence until sward conditions have become definitely established. Amongst the former are the valuable pasture plants Wild White Clover, Yellow Suckling Clover, and Rough-stalked Meadow Grass—all of which are not infrequently met with as arable weeds. Unfortunately Yorkshire Fog often also takes its place with these, especially on land that has not long been under the plough. Bent usually only " comes in " in any quantity after the lapse of some few years, except on fields full of this grass which have not been put through a complete rotation, when—especially in the absence of a good take or in competition with an ill-balanced seeds mixture sown without slag or a previous application of lime—it may rapidly and from the outset regain its previous dominance. Valuable species such as Perennial Ryegrass, Crested Dog's Tail, the Fine-leaved Fescues, Golden Oat Grass, Meadow Foxtail, and Yarrow, do not as a rule gain strong indigenous (unsown) positions till after the lapse of a moderate or considerable number of years; but by the end of a period of from six to ten years it will usually be such plants as this rather than those that owe anything to the seeds mixture that may have been employed—together with sward-forming plants like Daisies, Buttercups, Ribgrass, Hawkweeds, and the like (all, of course, unsown)—that contribute in greatest amount to the herbage.

The farmer appreciates well enough the fact that fields tend to " find their own sward ", but unfortunately at present it is almost impossible to prognosticate whether a field will find its own sward slowly or rapidly, and whether such a sward will be full of Yorkshire Fog and Bent and almost worthless or a mass of Wild White Clover, and Rough-stalked Meadow Grass—soon to be followed by Crested Dog's Tail and Perennial Ryegrass, all of extreme value.

The rapidity with which desirable species may (unsown) colonize new ground is shown by the following facts.

(*a*) On one of the experimental fields at the Welsh Plant Breeding

Station plots were sown, in May, 1922, with various herbage plants. The previous cropping had been three cereal crops in succession. At the time of sowing the field was heavily dressed with slag, and the herbage seeds were sown with no covering crop. By May, 1923, all the plots contained considerable excess of Wild White Clover and (or) of Yellow Suckling Clover, whilst plots sown only with various foreign grasses which had completely failed were a dense mass of Wild White Clover.

(*b*) On another field at the station (previous cropping, old sward, oats, rape, oats) sown with various mixtures in 1921 without a covering crop and heavily slagged, by 1923 Yellow Suckling Clover was in strong evidence on all the plots; while on those plots sown only with Red Clover and on those which had been unsown (a part of the experiment) Wild White Clover in conjunction with Rough-stalked Meadow Grass had on certain plots and in certain parts of the plots developed a dense and beautiful sward, occupying the ground between large tussocks of Bent and Yorkshire Fog.

(*c*) Stapledon and Jenkin[1] have recorded the case of a field sown with 16 lb. Perennial Ryegrass and 12 lb. of Red Clover only, which in its second harvest year consisted of a sward made up as follows: Perennial Ryegrass, 13 per cent; Yorkshire Fog and Bent together, 7 per cent; Rough- and Smooth-stalked Meadow Grasses together, 46 per cent; Soft Brome and Annual Meadow Grass together, 8 per cent; Red Clover, 1 per cent; Wild White Clover, 13 per cent; and miscellaneous plants, 12 per cent.

The above facts are eloquent of the contribution which may on occasion be made to a sward by valuable species, although not included in a seeds mixture, and show that competition with such species may begin at the earliest stages of the development of a ley.

There is also the question of competition between the intentionally sown species and plants developed from weed seeds introduced with the mixture employed. When leys are used for hay only and sown chiefly with large amounts of the Ryegrasses, the tendency is to introduce not inconsiderable quantities of Yorkshire Fog and Soft Brome, seeds which are seldom entirely absent from Ryegrass samples, and when this is followed year after year by late hay cutting, the seeds of these species are freely shed and rapidly gain on the sward, Yorkshire Fog being responsible for the ruin of numerous leys on non-calcareous soils in regions of high rainfall, and Soft Brome Grass being similarly responsible on calcareous and other soils in regions of lower rainfall.

The figures hereunder based on analyses made by the writer[2] show

[1] See R. G. Stapledon and T. J. Jenkin, "Pasture Problems: Indigenous Plants in relation to Habitat and Sown Species", *Journ. Agr. Sci.*, Vol. VIII, No. 1, 1916.

[2] "On Laying Down Land to Grass at High Elevations", *Agricultural Students' Gazette*, December, 1914.

the sequence of events on fields at high elevation in Wales sown with not less than 20 lb. of Ryegrasses (per acre)—Red and Alsike Clovers only:

Plants contributing to the Sward.	Percentage Contribution of the Several Species to Successive Hay Crops.				
	First.	Second.	Third.	Fourth.	Fifth.
Perennial Ryegrass ..	64·8	52·0	3·0	1·0	Trace
Yorkshire Fog	5·2	11·0	78·0	45·4	27·0
Agrostis (Bent)	—	—	3·0	12·0	15·0
Sweet Vernal	0·8	11·0	2·0	4·0	7·0
Other Grasses	1·4	3·0	4·0	5·0	—
Clovers (chiefly Red and Alsike)	22·6	11·0	5·0	6·0 (much Yellow Suckling)	6·0
Miscellaneous plants, chiefly Cat's Ear and Ribgrass	1·2	12·0	5·0	26·0 (large amounts of Yellow Rattle and Ox Eye Daisy)	

With reference to competition between the sown species it is to be noted that some species make very rapid growth during the seeding year; others start slowly, and, during the first autumn after sowing, produce practically no keep. The quick-growers naturally tend to crowd out the slow, especially when the slow are " top " species, requiring light to grow properly. Italian Ryegrass, unless sown in very small amount, crowds out other plants badly; Late-flowering Red Clover under certain conditions will hamper the development of Alsike. Italian Ryegrass is sometimes included in long duration mixtures to keep down weeds (work which should be done by Wild White Clover), but it will quite effectively suppress Meadow Fescue, Meadow Foxtail, and some other grasses, and considerably interfere with Cocksfoot and Timothy. Perennial Ryegrass if sown too thickly (20 lb. or in some cases less) will interfere with Timothy and Cocksfoot (especially when these are sown thinly), while if sown in less amount (14 to 16 lb.) it, none the less will hamper Meadow Fescue and Meadow Foxtail.[1]

Thus we should include in a mixture only such species as agree well together. For hay, species and strains must be chosen which will flower about the same time; this is impossible if numerous species are included. With Late-flowering Red Clover we should choose a late strain of Cocksfoot (this is a point in favour of many of the New Zealand and indigenous strains). With Timothy predominating, one of the latest late-flowering

[1] Generally speaking both the Ryegrasses germinate considerably better than all other grasses, except perhaps Timothy. This better germination must be taken into account, as well as the rate of seeding, when considering their tendency to hamper other plants.

Red Clovers, such as an approved Montgomery Red, is to be preferred.

Meadow Foxtail is not a satisfactory hay grass, because it flowers so much earlier than other bulky grasses suitable for hay production.

It will be apparent from the foregoing review that a suitable mixture for any particular purpose is not likely to be one consisting of a great number of species, for the number of species that will suit the requirements of a particular field, the conditions superimposed by date of sowing, and the needs of the farmer, cannot be expected to be many. It is furthermore a waste of seed to include comparatively small amounts of a great number of species in a mixture, for it is a mistake to suppose that a few plants scattered over a field have justified the inclusion of the seed which produced them. It is not in fact worth sowing any species unless it can be made to contribute in really appreciable amount to the sward.

Seeds mixtures fall into the following main classes: those intended for but a year or less than a year's duration; those intended for two years; and those intended for three years and upwards, including the formation of permanent swards. Each class should also be considered according as it is intended to provide grazing only or hay only or hay and grazing.

Grazing Mixtures of not more than One Year's Duration.

Autumn and Winter Bite.—In districts where stubbles are not ploughed until March or even April, winter grazing can be provided by sowing a suitable mixture with the corn crop. From 8 to 15 lb. per acre of Italian Ryegrass makes an excellent seeding for this purpose, and provides a considerable amount of winter keep. Italian Ryegrass and Early Broad Red Clover can be sown for the same purpose, but such a mixture would be more likely to interfere with the corn harvest, and if employed as a regular practice would in many districts add to the dangers of clover sickness.[1]

Early Spring Bite.—Italian Ryegrass sown alone can be made to contribute very appreciably to March and April grazing. To get the best and earliest grazing it should, however, be sown not later than about the middle of June and be lightly grazed early in the autumn. For this purpose it would be an advantage to sow an early and productive strain of Broad Red Clover also, say:

	Pounds per Acre.
Italian Ryegrass	14
Broad Red Clover (an approved early and productive strain)	6

[1] For further particulars relative to the advantages of providing for stubble grazing in wet and late districts see " Seed Mixtures for Grassland ", loc. cit., and " Preliminary Investigations with Herbage Plants ", loc. cit.

The following mixture, although expensive, would cater admirably for March and more particularly for April grazing:

	Pounds per Acre.
Italian Ryegrass	4
Tall Fescue	6
Tall Oat Grass	6
Broad Red Clover	4

April grazing can also be catered for by relying largely on Crimson Clover, say:

	Pounds per Acre.
Italian Ryegrass	14
Crimson Clover	10–12

In late districts this mixture should probably be sown in July or August; in earlier districts and where the corn is harvested in good time it might be sown after corn, when with the assistance of proper manures it should according to Wibberley,[1] provide ample keep by the middle of April.

The above mixtures, with the exception of the Crimson Clover one, could, of course, be sown with a corn crop in the ordinary way, but are probably best arranged for as part of the general sequence of temporary grass.

Hay only or Hay and Grazing Mixtures for One Year.

There are two main questions: (1) whether stubble and winter grazing are wanted as well as a hay crop; and (2) whether (*a*) one or two hay crops, or (*b*) a hay crop and abundant aftermath grazing, or (*c*) one heavy hay crop, without much stubble grazing or aftermath, be required.

Italian Ryegrass sown with clover alone does not as a rule give so heavy a single hay crop as Perennial Ryegrass with clover, but Italian gives a more leafy hay and a more abundant aftermath, and does not lodge nearly so readily as Perennial. Where stubble grazing is also wanted Italian should be either solely or mainly sown. If Italian and Perennial are mixed, the Italian will predominate over the Perennial unless only a small amount of the former is sown. Mixing certainly helps to prevent lodging, to afford winter keep, and to increase the aftermath, but there is the disadvantage that Perennial flowers earlier than Italian.

Late-flowering Red Clover will generally give a heavier one-hay crop than the Early Reds, but does not contribute so freely to a second hay crop, and is not likely to give so much stubble or early-spring grazing.

Alsike frequently succeeds better than the Red Clovers in cold and wet situations, and at high elevations. It is not often necessary to employ other grasses than the Ryegrasses for one-year leys, but Timothy is useful

[1] See Wibberley, loc. cit.

(and not too expensive) on wet situations and drained peats. Timothy flowers much later than the Ryegrasses and so is better sown alone than in mixture with them. Tall Oat Grass may give a very heavy first hay crop, but is expensive, and where the mixture is chiefly Ryegrass there is no particular advantage in adding it.

The following standard mixtures are given as examples of those designed to meet particular needs:

1.—Chiefly for a very heavy single hay crop.

	Pounds per Acre.
Perennial Ryegrass	14
Late-flowering Red Clover	4–6
Alsike Clover	1–2

2.—Catering as much or more for stubble grazing and aftermath as for hay.

Italian Ryegrass	14
Broad Red Clover	4–6
Alsike Clover	1–2

3.—Compromising between all needs, and being content to have the various species coming into flower over too long a range of time.

Italian Ryegrass	6
Perennial Ryegrass	10
Late-flowering Red Clover	2–3
Broad Red Clover	2–3
Alsike Clover	1

4.—For conditions unfavourable to the Ryegrasses but particularly favourable to Timothy.

Either (*a*)	Timothy	12
	Alsike Clover	6
or (*b*)	Timothy	12
	Late-flowering Red Clover (extra late strain)	4–6

5.—For dry and sandy soils in regions of low rainfall.

Tall Oat Grass	7–8
Cocksfoot	7–10
Late-flowering Red Clover	4
Kidney Vetch	4

It will be noted that Alsike Clover has been included with Late-flowering Red in certain of the above mixtures; the reason for this is that Alsike will serve to ensure a take of clover in the event of a failure on the part of Late-flowering Red Clover.

Mixtures for Two Years.

What has been said about the one-year ley applies in the main to a two-year ley, with the following exceptions: (1) What counts in a two-year ley is the gross yield over the whole period; it should not therefore be expected to provide abundant stubble grazing. (2) Italian Ryegrass will not contribute much in the second year, and should therefore be greatly reduced or entirely excluded. (3) Unless aftermath is particularly wanted in the first year Broad Red Clover should be excluded, or only sparingly sown. For a two-year ley Late-flowering Red and Alsike are distinctly the proper clovers. A small amount of Wild White might be included on soils where this plant is not expected to make a rapid unsown appearance; it will add to the fertility of the soil and help to suppress weeds. This clover should not, however, be included if it is intended to take two crops of hay in the first year and one or two crops again in the second.

More money may naturally be spent on a two-year than on a one-year ley, and grasses should be used which will give as high (or higher) yields in the second as in the first harvest year.

Thus Perennial Ryegrass *may* be either wholly or partly displaced by Cocksfoot, Timothy, or Tall Oat Grass. Whether it should be wholly *displaced, by whichever of the other three is most suited to the conditions*, is difficult to decide. In the interests of gross yield and of getting the included species to flower together, there is much to be said for excluding it, especially on other than the most fertile soils. The question of extra cost (except in the case of Timothy) often decides against leaving out Perennial Ryegrass altogether.

For Hay only or Hay and Grazing

The following mixtures afford examples of those that may be recommended. To each 2 lb. of Italian Ryegrass may be added, if it is intended to graze the leys at all heavily during the autumn and early winter of the seeding year:

1.—For soils where Perennial Ryegrass is known to hold well.

	Pounds per Acre.
Perennial Ryegrass	14
Late-flowering Red Clover	4–6
Alsike Clover	1–2
Wild White Clover[1]	$\frac{1}{4}$–$\frac{1}{2}$
or White Dutch (New Zealand)[1]	2

2.—For soils where Cocksfoot bulks very much more heavily in the second year than does Perennial Ryegrass.

Either (*a*)	Cocksfoot	10
	Timothy	4
	Late-flowering Red Clover	4–6
	Alsike Clover[2]	1–2
	Wild White Clover[2]	$\frac{1}{4}$–$\frac{1}{2}$
	or White Dutch (New Zealand)[2]	2

[1] Or excluded.

[2] If a reliable strain of Late-flowering Red (of the Montgomery type) is employed, then to save expense Alsike Clover, Wild White Clover, or New Zealand White Clover can be omitted; the Montgomery should ensure a sufficiently good clover root to plough down at the end of the second year.

		Pounds per Acre.
or (*b*)	Perennial Ryegrass	8
	Cocksfoot	8
	Timothy	4
	Late-flowering Red Clover	4–6
	Alsike Clover[1]	1–2
	Wild White Clover[1]	¼–½
	or White Dutch (New Zealand)[1]	2

3.—For soils particularly adapted to Timothy.

Timothy	10–12
Alsike Clover	5–6
White Clover[2]	¼–½
or White Dutch (New Zealand)[2]	2

Note.—Since Timothy flowers so much later than other grasses a combination with Ryegrass is not here recommended. Alsike Clover and Timothy agree well together, and the inclusion of Alsike to the total exclusion of Late-flowering Red Clover renders the mixture an exceptionally cheap one.

4.—For soils particularly adapted to Cocksfoot, and when abundant aftermath grazing is desired in both years.

	Pounds per Acre.
Cocksfoot	10–12
Late-flowering Red Clover	4–6
Broad Red Clover	2–4
Yellow Suckling Clover	4

5.—For early spring grazing and late summer grazing in the first year followed by summer grazing or a hay crop in the second year.

Perennial Ryegrass	6
Cocksfoot	6–8
Tall Oat Grass	6–8
Tall Fescue	6–8
Broad Red Clover	2
Late-flowering Red Clover	3

This mixture makes an alternative to the Tall Oat - Tall Fescue mixture suggested for a single season's spring grazing; the addition of Cocksfoot safeguards a certain amount of late summer keep. The ley if rested during the early summer of the first year should give a fair crop of hay in the second year.

It is of interest to record practical experiences with reference to the achievements of such simple mixtures as those of the type of (3) and (4) suggested above. Mr. Stratton,[3] using a slightly different combination, namely 7 lb. each of Alsike and Cocksfoot, estimates that he harvested a first hay crop averaging 3 tons per acre over an 18-acre field—a crop that

[1] See footnote 2 on p. 62. [2] Or excluded.
[3] "My Record Seeds Hay Crop" in *Modern Farming*.

would be difficult to beat from a mixture consisting of the Ryegrasses and Red Clovers only. But whereas the Cocksfoot-Alsike mixture consists of plants that are much more likely than not to bulk heavily again the second year, the Ryegrass-Red Clover mixture would be unlikely to do so. Cocksfoot and Alsike suit each other well—Cocksfoot tends to stand erect and to support the Alsike, and both plants come to maturity reasonably together.

Cocksfoot with Late-flowering Red Clover only or with the addition of Yellow Suckling Clover, although constituting a rather more expensive mixture than Cocksfoot and Alsike, tends on the average to give heavier hay crops than the Cocksfoot-Alsike mixture, and has given excellent results in Cardiganshire both in the first and second year; in some cases a third crop of hay has been taken, and in others a third-year sward has given excellent summer grazing. The inclusion of Yellow Suckling Clover has not given consistent results, but in some fields it has shown to great advantage in the second year and added very appreciably to the aftermath. Mr. Stanley Bligh, of Cilmery, Breconshire, in a district of very high rainfall, has used the cheaper combination, namely Timothy and Alsike alone, and has obtained remarkably good crops of hay in both the first and second years, the second year's crop showing a remarkably good stand of Alsike.

For Grazing Only

It is sometimes desired to sow cheap grazing mixtures for two years only; such mixtures are often very useful for sowing on an upturned poor sward the first time it is broken, with a view to rebreaking and sowing a better mixture subsequently. The following mixture should meet the case:

	Pounds per Acre.
Italian Ryegrass	4
Perennial Ryegrass	10–12
Late-flowering Red Clover (extra late strain) [1]	4–8
Ribgrass	4
White Dutch Clover (New Zealand)	2

A very similar mixture to the above would also be suitable for two years' sheep grazing on dry and poor soils in regions of low rainfall; the following is suggested:

Perennial Ryegrass	8
Cocksfoot (for preference in part New Zealand or indigenous seed)	8
Trefoil	4
Ribgrass	4
White Dutch Clover (New Zealand)	4

[1] On positions such as this there is practically no danger of clover sickness, for in all probability there will have been no Red Clovers in the field for a decade or more. Thus Red Clover can be safely sown to be followed immediately by Red Clover again.

Mixtures for Long Duration Leys and Permanent Grass.

It is when fields are put away for periods of three years and upwards that the unsown species, valuable and weeds alike, have to be taken seriously into account. It is just as important to endeavour to check the development of the undesirables and to favour the development of the desirables in the case of a three- or four-year ley as it is in the case of one intended to last for six, ten, or twenty years, for in the interests of fertility it is so essential to plough down a good clean sward full of clover when a temporary ley is broken. It is therefore necessary to sow practically similar mixtures for a three- and four-year ley as for permanent grass. In a sense, moreover, it is not at present possible to sow a permanent mixture, that is to say, to sow varieties and strains that at the end of ten years will still dominate the sward to the almost total exclusion of the natural self-established plants.[1]

In all long duration mixtures the object should be to get a good sole to the sward as soon as possible, and to crowd out weeds and Bent grasses. For providing a good " adult " sward both quickly and efficiently Wild White Clover, Rough-stalked Meadow Grass, and Perennial Ryegrass work admirably together.[2] The important question to be decided is whether Wild White Clover and Rough-stalked Meadow Grass should be sown in the mixture and if so to what amount.

It has been shown that under certain conditions these are both plants which may gain rapid (unsown) entry into a developing sward, while it is a common occurrence to find abundance of indigenous White Clover on fields that have been down no more than three or four years, although no seed of Wild White had been included in the mixtures, and the same is largely true of Rough-stalked Meadow Grass. Without resort to careful experiments and proper control plots it is therefore by no means justifiable to attribute to the seed of Wild White Clover included in a mixture the whole of a fine mat of clover that may be a striking feature of the sward, developed in a few months or a few years from the date of sowing. It is evident, therefore, that it is as important to make for conditions favourable to the formation of a dense sole as it is to sow seeds of plants that, given favourable conditions, will contribute to this sole. By both making the conditions favourable and sowing the seeds, the farmer, at the risk, it is true, of " carrying coals to Newcastle ", will almost certainly secure a good sward, and further by *sowing the seeds* he makes doubly

[1] In due time, when research methods relative to breeding hardy and persistent strains of herbage plants have become perfected, and the difficulties connected with growing and marketing pedigree strains have been generally recognized and come to be better understood, there is little doubt that this will be a perfectly easy and straightforward matter.

[2] See, for instance, " Formation of Permanent Pastures ", Univ. College of North Wales, Bangor; and R. G. Stapledon, " The Temporary Ley ", *Journ. Min. of Agr.*, Vol. XXV, No. 11, February, 1919.

certain of a rapid entry of these plants and by that much safeguards the development of a weedless herbage from the very outset. Just as the sowing of Alsike Clover (in small amount) in addition to Red Clover is to be regarded largely as an insurance in the case of one-year leys, so is the sowing of Wild White Clover and Rough-stalked Meadow Grass (on soils that suit it) to be regarded as an insurance in the case of long duration leys sown on fields where experience has shown that there is every prospect of the plants sooner or later attaining to a strong position whether sown or not. Under these favourable circumstances $\frac{1}{4}$ to $\frac{1}{2}$ lb. of Wild White Clover is generally an ample seeding. For mixtures to be sown on fields where White Clover has not been much in evidence, it may be necessary to sow as much as 1 lb. or even 2 lb. to ensure the development of the all-to-be-desired dense sward.

As to making the conditions favourable, the matter is not nearly so easy beyond attending to " lime requirement " and available supply of phosphates. Although under heavy seeding Wild White Clover can under favourable circumstances be retained in abundance for a few years on leys yielding heavy crops of hay, it is emphatically pasture conditions that favour the development of this plant to the most marked degree. Consequently if hay is taken it should be cut early. Two further factors making for the rapid development of a dense sward are a sufficiency of surface moisture and a firm and well consolidated " face ". Thus a loose furrow, a common outcome of late spring ploughing of stubbles or frequent cultivations on a loose soil, should be counteracted by heavy rolling before and after sowing a long duration mixture, while in dry districts the previous cropping and immediately preceding cultural operations should have aimed at the maximum conservation of moisture. Finally, mixtures containing Wild White Clover and Rough-stalked Meadow Grass should not be sown either too early in the spring or too near the close of the growing season.

There are two classes of long duration mixtures: (1) Those from which a first hay crop may be taken, and also, if required, later hay crops may be substituted for later grazing only; these under ordinary farm practice are as a rule sown under corn. (2) Those sown for grazing only; such mixtures are frequently sown on poor, outlying fields, from which corn will not be taken, and are sown either without a covering crop or under rape.

(1) For Hay only or for Hay and Grazing

(*a*) *Average Condition of Soil in Region of High or Reasonably High Rainfall.*—The following mixture, advocated by Professor Gilchrist,[1] has been found, over a wide range of country, equally suitable for a three-year ley or for permanent grass. It may be taken as an example of a

[1] In an address on " Seed Mixtures and the Improvement of Grassland ", delivered at the Plymouth Show (1922) of the Bath and West and Southern Counties Society.

simple mixture, although the seedings are rather heavy, and may be altered to suit various districts and conditions:

	Pounds per Acre.
Perennial Ryegrass	16
Cocksfoot (New Zealand)	10
Timothy (Scotch)	4
True Late-flowering Red Clover	4
Trefoil	1
Wild White Clover[1]	1½

In many districts Trefoil cannot be relied upon; thus, under the conditions of high rainfall and non-calcareous soils which prevail over large areas in Wales and the west of England, this species but seldom succeeds and should not be included in the mixture.

The following are suggested as suitable mixtures for such districts; to either of them not more than 2 lb. of Italian Ryegrass may be added, the Perennial Ryegrass being proportionately decreased, where sheep are kept during the winter and the fields are likely to be heavily grazed during the first autumn and winter after sowing:

(*a*) *Simplified as much as possible.*	Pounds per Acre.
Perennial Ryegrass	10
Cocksfoot (for preference in part New Zealand or indigenous seed)	8
Timothy	4
Late-flowering Red Clover (Welsh)[2]	4
Alsike Clover[3]	1–1½
Wild White Clover	½–1½

(*b*) *Rather more complex.*	
Perennial Ryegrass	6–8
Cocksfoot (for preference in part New Zealand or indigenous seed)	6–8
Timothy	4–5
Rough-stalked Meadow Grass[4]	1½
Crested Dog's Tail[4]	1½–2
Alsike Clover	1–1½
Late-flowering Red Clover (Welsh)[2]	4
Wild White Clover	½–1½
Chicory[5]	1–2

[1] In many cases the Wild White Clover might be reduced to ½ lb.

[2] A genuine strain of extra Late-flowering Red Clover should be used especially for the more permanent leys. Such a strain is grown for seed in parts of Montgomeryshire.

[3] Where Red Clover invariably takes well, Alsike can often safely be left out. At high elevations (above 600–700 ft.) Alsike often does very well and may sometimes altogether replace Late-flowering Red, but it then becomes a matter of considerable importance not to sow the seeds either too early or too late.

[4] These two grasses have both done well, especially on soils too poor to carry a permanent Ryegrass herbage. If both are sown, 1½ lb. of each would be the outside sowing If only one, then 2 lb. would not be too much.

[5] Chicory is sometimes objected to in the hay, but on many soils persists well and gives excellent spring grazing.

It will often be necessary to add to this seed-rate to compensate for poor germination.

Where Cocksfoot predominates in mixtures for leys two rules should be observed. First, the hay should be cut comparatively early, before the seed has begun to develop and ripen. Secondly, the swards should be grazed hard when Cocksfoot is making its most luxuriant growth.

Some will object to the amount of Cocksfoot in the mixtures above, but until further trials have been made it is hard to suggest anything else but Cocksfoot if hay is required on soils where Perennial Ryegrass is not productive after the second year. Golden Oat Grass, sown thickly, would probably meet the case, but unfortunately it is expensive and usually of low germinating capacity. Timothy might completely take the place of Cocksfoot in some cases, but those who object to Cocksfoot generally object to Timothy in quantity. The same may be said of Tall Fescue, which, furthermore, is expensive; while trials have shown that Meadow Fescue seldom succeeds under conditions too poor to maintain long duration Ryegrass.

(*b*) *Fertile Conditions in Regions of Moderate or Fairly High Rainfall.*—The above mixtures would usually suit these conditions also, but Meadow Fescue may now be expected to succeed. This is a grass, however, that even on the most favourable situations does not establish itself readily *in competition with other species. In consequence, when it is desired to rely largely on this grass, it should be made the predominating ingredient* in the mixture, say:

	Pounds per Acre.
Perennial Ryegrass	6
Meadow Fescue	12
Timothy	4
Rough-stalked Meadow Grass	1½
Late-flowering Red Clover	4
Alsike Clover	1½
Wild White Clover	¼–1½

(*c*) *Sandy Soils in Regions of but Moderate or Very Low Rainfall.*—This represents one of the most difficult sets of conditions to provide for, in view of the limited number of pasture plants of agricultural value that succeed under such conditions, and the difficulty in getting a good take. Not only so, but even given ideal weather and favourable circumstances culminating in a satisfactory take it is almost impossible to establish a really dense sward. The following specification includes species which have frequently succeeded under the conditions catered for. It should be possible for the farmer himself to reduce the number of species either as the result of his own experience or after a preliminary trial.

	Pounds per Acre.
Cocksfoot	8
Tall Oat Grass	8
Fine-leaved Fescue	4
Smooth-stalked Meadow Grass	2
Lucerne	4
Kidney Vetch	4
Late-flowering Red Clover	3
White Clover (New Zealand)	2–3
Burnet	4
Chicory	2–4
Ribgrass	2–4

Notes.—The Fine-leaved Fescues of commerce are very variable, and no convincing trials have been conducted to ascertain which of the numerous strains available are best suited to particular conditions; all that can be said at present is that the commercial seed sometimes does and often does not succeed in the situations under review. The same is very largely true of Smooth-stalked Meadow Grass. Lucerne is seldom a success when included in a general mixture under conditions favouring a dense sward, but frequently proves itself to be very satisfactory when included in mixtures for drier situations. Burnet affords useful grazing but is liable to become very woody, and in many cases it would be no disadvantage and would effect a saving to replace this altogether by a larger seeding of Ribgrass.

Since failure of take has to be seriously reckoned with, large sowings of Wild White Clover involve too great a risk, and since small sowings are unlikely to be efficacious it is better to rely on a heavy seeding of the much cheaper New Zealand seed. Chicory may be sown in very considerable amount if grazing rather than hay is desired.

(*d*) *Heavy Clay Soils in Regions of Moderate or Low Rainfall.*—Like the dry sands, the very heavy clays present great difficulty, and it is impossible either to take such steps or to employ such a mixture that together can always be relied upon both to ensure a take and to guarantee a dense and productive sward. The preparation of a tilth and the covering operations present perhaps the greatest difficulty, as these heavy clay soils are always very difficult to deal with and reduce to the fairly fine state of division that we like to see the soil in before proceeding to sow. It might in this case be desirable to sow the clovers and Ryegrasses with a drill, grasses like Cocksfoot, Timothy, Crested Dog's Tail, Meadow Foxtail under the peg harrow on a very dry day, and grasses like Rough-stalked Meadow Grass under the chain harrow. It is probable that in most cases a "grazing only" mixture would be most likely to give the best results; but if hay also is required a mixture based on the following specification might be tested. After preliminary trial it should be possible for individual farmers to appreciably reduce the number of species.

	Pounds per Acre.
Perennial Ryegrass	6
Tall Fescue	6
Cocksfoot	6
Timothy	4
Meadow Foxtail	0–6
Rough-stalked Meadow Grass	2
Crested Dog's Tail	2–4
Lucerne	4
Late-flowering Red Clover	3
Alsike Clover	1½
White Clover (New Zealand)	2–3

Note.—As an indigenous plant Tall Fescue is often very plentiful on the heaviest clays, and is therefore worth including in a mixture for such situations. Crested Dog's Tail, although not applicable to the dry sands, is often abundant on the heavy clays and should be largely sown. Since the germination of Meadow Foxtail is usually low, if included at all it should be sown in large amount. New Zealand White Clover has been included instead of Wild White for the same reason as for the dry sandy soils.

(*e*) *For Peat or Highly Peaty Soils.*—Timothy and Alsike Clover usually do well on peat, while under natural conditions Crested Dog's Tail often becomes very luxuriant on rather peaty soils, and Meadow Foxtail is sometimes in considerable evidence. Wild Red Clover and Wild White (usually a larger leaved and more erect form than the strains which are met with on ordinary pastures and which the commercial seed gives rise to) are not at all uncommon. The following mixture would be likely to meet the case on many peaty situations:

	Pounds per Acre.
Italian Ryegrass	2
Timothy	10
Meadow Foxtail	6
Crested Dog's Tail	3
Late-flowering Red Clover	1½
Alsike Clover	3
Wild White Clover	½–1

The *simple Alsike-Timothy-Wild White Clover mixture previously* given for two-year leys would constitute a cheap mixture, which could often be depended upon for a rather longer period on peaty soils.

In the case of all the mixtures dealt with in this article, short and long alike, the quantities given are for broadcasting—not drilling—on an average tilth as regards weeds and suitability for the seeds. Under these conditions there is bound to be a varying but always large waste of seed. A farmer who has carefully studied the question of date and methods of sowing and covering seeds might often quite safely reduce the quantities.

(2) Mixtures for Grazing Only

In a mixture designed for grazing only there is no absolute need to sow the coarser hay grasses and no risk of a hay crop hampering the Wild White Clover and finer grasses. " Grazing only " mixtures are particularly useful for out-of-the-way fields, and, as before indicated, would fit in very well with any extended scheme of improvement by breaking and resowing, and with an extension of temporary grass at the expense of permanent. These mixtures would consequently not usually be sown under corn, and it should therefore generally be possible to sow them under favourable conditions so that the seed rate could often with safety be reduced.

The essence of a grazing mixture is to ensure an immediate take of Wild White Clover so that most of the cost of the mixture should go into this seed. Ideally, 4 lb. would not be too much. At present prices this would be considered prohibitive, except perhaps by those very few but very wise farmers who, being fortunate enough to be able to, do in fact harvest their own Wild White Clover seed.

The alternative is either to reduce the seeding or to supplement the Wild White with commercial White from New Zealand. Since New Zealand White is frequently remarkably similar in growth habits to Wild White, the latter plan, although in the present state of our knowledge perhaps involving a rather risky compromise, is one deserving extended trial, and for the mixtures here suggested would probably be a safer procedure than to rely only on very small seedings of Wild White proper. The following mixtures will serve to illustrate the scope of seedings of this sort. To each mixture 2 lb. of Italian Ryegrass might be added to serve as a " nurse ", provided the sward will be grazed down during the autumn after sowing.

		Pounds per Acre.
1.	Perennial Ryegrass	10–12
	White Clover (wholly Wild White or this supplemented with New Zealand White)	4
2.	Perennial Ryegrass	10
	Rough-stalked Meadow Grass	4
	White Clover (as above)	4
3.	Perennial Ryegrass	8
	Rough-stalked Meadow Grass	3
	Crested Dog's Tail	5
	White Clover (as above)	4
4.	Perennial Ryegrass	8
	Rough-stalked Meadow Grass	2
	Crested Dog's Tail	5
	Late-flowering Red Clover (extra late strain, e.g. Montgomery)	4
	White Clover (as above)	2

Mixtures (1) and (2) above would be applicable only to highly fertile conditions, (3) and (4) to relatively poor classes of land and especially where sheep grazing was chiefly required. On land of an even poorer type, such as in the case of sowing out a poor rebroken sward for the first time, about 4 lb. of Ribgrass could advantageously be added, 4 or 6 lb. of Italian Ryegrass used instead of 2 lb., and the Rough-stalked Meadow Grass discarded.

THE NATIONAL ASPECTS OF THE TEMPORARY LEY

Before concluding this article it would seem desirable to refer in a little detail to the national aspects of farming on the temporary ley basis. It has been said that the temporary ley carried in a proper sequence over the whole farm leaves its legacy of fertility behind it. In districts where the permanent grass is poor and worn out, where bracken and scrub is gaining on the fields, and where the herbage consists chiefly of Bent and weeds, and where the ground is rough and tumpy, an even surface would be secured and fertility enhanced if the fields were broken and brought under rotation with a four- to six-year period under grass. In case of national food shortage or, for that matter, in the unlikely event of a change in the nation's policy towards agriculture it would then be an easy matter to farm such previously unproductive districts on a more intensive scale and in a manner subservient to any sudden need. The state of affairs on many farms in England still resembles that of large tracts in newer and less highly farmed countries. Corn was grown for years until fertility has become largely exhausted; the land has then been allowed to revert to more or less derelict grassland almost to the exclusion of cereal crop production generally. The remedy is in principle the same for hundreds of acres at home and for vast areas in America and elsewhere, namely, resort to mixed farming involving more intensive methods of stock raising, together with a certain amount of cereal production—a remedy which implies a greatly extended use of artificial grass and rotation farming, even if the rotation be a long one with a considerable period under a temporary ley.

It is therefore of the utmost importance not only that there should be available almost unlimited supplies of phosphatic manures, but also large supplies of high-grade herbage seeds, and that these should be procurable at a reasonable price. With the exception of the Ryegrasses (and a certain amount of Timothy grown in Scotland for seed) this country is almost entirely dependent on imported grass seeds for sowing, whilst although Red Clover and to a less extent White Clover and Alsike Clover are grown for seed in many counties, we none the less import a large proportion of our clover seeds also. There is undoubted evidence that for temporary leys home-grown Red Clover of a good strain is far superior to imported seed; whilst the value of Wild White Clover would suggest that stocks of grasses carefully selected and worked up from our indigenous plants would likewise be superior to imported seed. It is a remarkable fact that the demand for Wild White Clover has not led to more farmers growing this seed, and that the price of the commodity should still be almost prohibitive and the supplies ridiculously inadequate in comparison with the extent to which the seed *should be used*. It is no less remarkable that this country, which so justly prides itself upon its live stock, has lagged sadly behind Denmark, Sweden, and America in the matter, not only of mere grass seed production, but, what is more important, in the matter of the scientific selection and improvement of herbage plants.

Substantial advances will not, however, take place until the farming community realize more fully the value of temporary grass, and until the demand for improved strains of herbage plants becomes as great as that for improved varieties of roots and cereals and for pedigree animals.

PERMANENT GRASS

By R. G. STAPLEDON, M.B.E., M.A.

Permanent grass constitutes a very important feature of British agriculture; and notwithstanding the fact that some 1,527,000 ac. of permanent grass came under the plough during the period of the War, the most recent statistics of the Ministry of Agriculture show that about 53 per cent of the farmlands of England and Wales are still in permanent grass.[1]

Russell (41)[2] has shown the relationship that exists between the amount of cultivated land under grass and annual rainfall; this is well seen by a comparison of the two accompanying maps prepared by that author. It will be noted in a general way that permanent grass predominates in the counties where the annual rainfall is over 30 in., and that the large area in Wales with a rainfall of over 50 in. is dominated by permanent grass. Annual rainfall is, however, not the only factor influencing the ratio of permanent grass to land under rotation. Farms at high elevations tend to have large proportions of the holding under grass, and the same is true of those farms situated on stiff clays difficult to work. Thus Essex, considered as a whole, with a low average rainfall, none the less shows a comparatively high proportion of land under grass.

These comparisons refer to farm land only, and do not take into account mountain and heath land, which constitute approximately 10 per cent of the whole land area of England and Wales.

Mountain and heath lands should not, however, be regarded as of no importance, for in the aggregate they afford summer keep for large numbers of sheep, and not inconsiderable numbers of cattle and ponies, as well as providing winter keep for appreciable flocks of sheep. There can be no doubt, moreover, that very considerable areas of hill grazing in Scotland, England, and Wales alike are capable of vast improvement, and that a certain although limited proportion of this land could be advan-

[1] *Preliminary Statement of Agricultural Returns of England and Wales*, 1919.

[2] Figures in brackets refer to literature cited, a list of which appears at the end of the article (p. 134).

tageously brought under cultivation. It is necessary also to recognize down land and certain types of maritime grasslands and lowland marshes or bogs as different from permanent grassland as generally understood.

A broad distinction may be made by classifying our grassland as follows: (*a*) natural; (*b*) semi-natural, the semi-natural grasslands being divided into two classes, untended and tended; and (*c*) artificial or temporary.[1]

The natural grasslands are those which have not only never been under the plough, but which, in the main, also have never been manured, and which are not intensively grazed; are but slightly fenced and usually not grazed by stock having frequent access to tended grasslands or to land under cultivation; they are grazed, that is to say, by animals turned out for long periods at a time.

The great majority of mountain and hill pastures are to be regarded as " natural "; the same is true of many lowland or semi-lowland heaths and of a number of maritime swards. The downs are perhaps better included among the " semi-natural " untended types, since they are in much closer grazing contact with cultivated land and tended grasslands than are the more isolated hill pastures. Natural heath grasslands and maritime grasslands also pass into untended semi-natural types when more intensively fenced, and grazed by animals having repeated access to tended pastures and cultivated land. The semi-natural tended grasslands consist of the permanent pastures and meadows of enclosed farm lands, which are as a rule comparatively well fenced, more or less intensively grazed with mixed stock, manured to a greater or less extent, and subjected to appropriate surface cultivations.

It is at the outset desirable to consider in a little detail the effect of grazing animals on grassland. Emphasis is often laid on the fact that grazing animals remove essential plant foods from the soil in their milk, in the wool of sheep, and in bone formation; the need for careful manuring is enforced, and it is frequently implied that heavy stocking is of necessity an evil, and sometimes that understocking is always a virtue.

It should be more generally realized, however, that grazing, equally with the character of the soil and climatic conditions, constitutes a dominating factor in the environmental influences which make for one pasture type rather than another. Indeed, it is not too much to say that grazing is the master factor which makes it possible for the grassland and associated types of vegetation to maintain themselves at all in competition with other natural plant communities.

If grazing animals were withheld for a prolonged period from our grasslands, the great majority would gradually pass into scrub or wood-

[1] The temporary ley forms the subject of a separate article, p. 43; all suggestions as to seed mixtures suitable for different purposes and as to putting land down to grass are dealt with in it.

land or into the less productive types of moorland, heathland, or marshland. Not only is this the case, but the less productive types of grassland are in a measure unproductive *because* they only carry a small head of stock.

Any plan, therefore, that can be devised to increase the carrying capacity of a given grassland type will tend to improve that type, and to alter it in the direction of a more productive type. Manuring, therefore, acts in an important indirect as well as in a direct way, for when accompanied by intensive fencing it becomes possible to graze given areas heavily if only for comparatively short periods at a time.[1]

The natural heath pastures of hilly districts are easily altered in the direction of the semi-natural untended pastures by heavier grazing with animals having access to tended grasslands and cultivated areas. This is seen by the presence of plants like Crested Dog's Tail, White Clover, Ribgrass, Cat's Ear,[2] and the like in moderate amount—plants which are not normally associated with the natural types; thus the intensity of grazing has an undoubted determining influence on the flora and therefore on the productivity of closely related grasslands. An excellent example of the effect of grazing is shown by Brenchley and Adam (8), who give a detailed account of the fate of two pieces of land at Rothamsted which had been allowed to revert to a natural condition from cultivation, but from which *grazing animals had been wholly and continuou ly withheld for a period of over thirty-two years.* Every farmer, of course, knows that a corn stubble allowed to revert under the influence of grazing animals will, after a few years, settle down to grass—it may be good or it may be bad grass, but it will most certainly be grass.

What happened at Rothamsted, briefly stated, was as follows: on the one area where the land was not waterlogged reversion tended in the direction of an oak-hazel wood, and when the trees were grubbed up on a portion of the area, the vegetation did not assume the characteristics of normal grassland, but in 1913 as many as forty-six species of plants which were neither grasses nor clovers contributed to the vegetation, and of the grasses Tall Oat Grass (*Arrhenatherum avenaceum*) assumed a dominant position, a position to which it practically never attains on tended grasslands. The second area on a waterlogged soil had reverted rather in the direction of marsh than woodland.

The present writer studied very similar cases at Cirencester. Two small pieces of ground lapsed from cultivation in 1886; they were cut for rough hay up to about 1896, and then for fifteen years were allowed to run wild, grazing animals being practically completely withheld. In

[1] Overstocking is of course often bad for the animals and bad for the grassland; but heavy stocking is not necessarily overstocking. This question is referred to in more detail when methods of improvement are discussed.

[2] Crested Dog's Tail, *Cynosurus cristatus*; White Clover, *Trifolium repens*; Ribgrass, *Plantago lanceolata*; Cat's Ear, *Hypochœris radicata*.

both cases the areas had reverted in the direction of scrub, hawthorn bushes and wild rose were abundant, and a few oaks present. The ground flora consisted largely of a number of plants not generally associated with tended grasslands, and in both cases Tall Oat Grass was the predominant grass.

An interesting example of a field which had reverted from a corn stubble about five to six years before it was examined was also studied at Cirencester. In this case hay had been taken once or twice but the field had been left practically ungrazed. The flora was not typical of any well-marked grassland type in the district. It consisted of as many as 64 species,[1] of which 16 were grasses, 10 leguminous herbs, and 39 miscellaneous plants. Another case may be cited of a field planted in 1901 with experimental trees in lines 16 ft. apart, fenced and left ungrazed for nine years. The ground flora between the trees during that period had reverted in the direction of scrub, to an unstable type of vegetation represented by 95 species, 65 of which were miscellaneous herbs.

These examples have been quoted in order to emphasize the fact that grasslands can only be properly understood and studied if it is realized what a profound influence grazing animals have upon their genesis and upon their relationship one with another at any given time. From what has been said it will be readily appreciated that practically no types of grassland can be regarded as unchanging or unchangeable, but that grasslands can be either kept in a state of comparatively stable equilibrium or modified in a definite direction through the influence of grazing animals, and herein, of course, lies the undoubted scope that grasslands afford both for scientific study and improvement.

It will be necessary, in order properly to discuss rational methods of improvement, to deal with the various types of natural and semi-natural grassland separately, and in the case of each, first to give a brief account of its botanical characteristics, and secondly to indicate methods of improvement.

I. Natural Grasslands

Mountain and Hill Pastures.

Smith (42) estimates that about 60 per cent of Scotland consists of uncultivated land or hill pasture, whilst over 20 per cent of Wales is under mountain and heath vegetation; large areas of England, in Yorkshire, Derbyshire, in the Lake District, and in Devon and Cornwall, consist of similar types of vegetation. These grazings constitute a large

[1] It will be shown in a subsequent section that on grassland types proper, the number of contributory species seldom exceeds 50, and on many of the best types does not exceed 25.

number of well marked types of vegetation, and have formed the subject of numerous investigations.[1]

The most important types may for convenience be considered under two headings according as grasses or plants other than grasses dominate the flora.

A. TYPES DOMINATED BY GRASSES

(*a*) Mountain Fescue Pastures.

These occur on hillsides at high elevations. They give rise either to a somewhat tufted or to a relatively fine sward, and are met with on thin and rocky soils rather than on peat, although the decaying turf forms a slight humus or peaty layer. Typically the flora is a very restricted one, the flowering plants frequently being represented over large areas by no more than 10 to 15 species. Grasses dominate the sward from the point of view of herbage produced and ground covered. Sheep's Fescue is the chief grass, often representing from 40 to 56 per cent of the herbage. Bent and Heath Grass are usually appreciable contributors; these three grasses together account for from about 75 to 95 per cent of the sward. Sweet Vernal Grass and the Hair Grasses are distributed plants. The Leguminosæ are typically unrepresented in the sward. The chief miscellaneous plants are: Tormentilla and Heath Bed Straw, with Woodrushes, Sedges, and Milkwort; plants of occasional occurrence are Wild Pansy, Mouse Ear Hawkweed, and Speedwell.

At high elevations the Heath Rush sometimes dominates the flora in large gregarious patches.

Locally the sedges may become excessive, and fairly large areas are to be found where these plants have dominion over the grasses; such areas are not generally considered to afford healthy grazing. On loose soils, often at the foot of steep slopes at high elevations, Club Mosses and mosses, especially the Grey Woolly Moss, may become the predominating elements in the flora. Cases have been noted where Club Mosses contribute as much as 57 per cent of the total air-dried herbage, and where Club Mosses and mosses together contribute over 75 per cent to the bulk of the herbage.[2]

[1] The reader is referred to *Types of British Vegetation*, edited by A. Tansley (Camb. Univ. Press, 1911), and to *Vegetation of the Peak District*, by Dr. Moss (Camb. Univ. Press, 1913). Appendix III (p. 222) of this latter publication gives references to ecological literature, including the majority of primary surveys conducted in this country.

[2] For the sake of accuracy the plants mentioned in the description of the types will be given their generic and specific names in footnotes.

The plants occurring on the mountain Fescue pastures are as follows: Sheep's Fescue, *Festuca ovina*; Bent, *Agrostis vulgaris* et *A. pumila*; Heath Grass, *Triodia decumbens*; Hair Grasses, *Aira flexuosa* et *A. præcox*; Sweet Vernal Grass, *Anthoxanthum odoratum*; Tormentilla, *Potentilla erecta*; Heath Bed Straw, *Galium saxatile*; Woodrushes, *Luzula erecta* et *L. campestris*; Sedges, *Carex binervis*, *C. præcox* et *C. pilulifera*; Milkwort, Bracken is not usually met with in the mountain Fescue pastures, and when gorse occurs it is generally represented by stunted plants of *Ulex Gallii.*

These pastures are dry and healthy, and provide a measure of grazing throughout the whole year. Bent and Heath Grass are often wonderfully winter green, and it has been noted that stunted gorse bushes, the Alpine Club Moss, and the Heath Rush (*Juncus squarrosus*) are closely grazed by sheep during the winter.

(*b*) Heath Fescue Pastures.

These are, in the main, very similar to the mountain Fescue pastures, but usually give rise to a decidedly finer sward; they are, however, sometimes overrun with bracken or gorse.[1] Bracken is usually associated with relatively dry and relatively sheltered slopes, indeed it may be regarded typically as a plant of slopes, frequently occurring in luxuriance on the basal third of hillsides where the soil depth is usually not inconsiderable. Leguminous herbs are now represented by Bird's Foot Trefoil (*Lotus corniculatus*) and the Mountain Vetchling (*Lathyrus montana*), which, however, seldom contribute as much as 2 per cent to the herbage. The grasses again dominate the flora, Bent standing in a somewhat higher ratio to Fescue than on the mountain type. The flora is not nearly so restricted, and is characterized by a number of typical herbs[2] in addition to those occurring in small amount on the mountain type. It should be noted that plants like Ribgrass, Self Heal, Cat's Ear, and such grasses as Crested Dog's Tail and the Meadow grasses, freely associated with the semi-natural derivatives of heath pastures, only occur as isolated or distributed plants on the natural pastures, although sometimes more or less abundant on sheep tracks, about fences, and near roads.

The heath Fescue pastures probably afford grazing over a longer period than any other hill types, and are to be counted as amongst the most valuable. They occupy large tracks of land on the drier hillsides in mountain and hilly districts, and occur at somewhat lower elevations than the mountain Fescue pastures.

(*c*) Nardus or Mat Grass Pastures.[3]

Typical Nardus pastures are met with on relatively dry peat or on decidedly peaty or acid soils. They therefore are prone to occupy less

Polygala vulgaris; Mouse Ear Hawkweed, *Hieracium Pilosella*; Speedwell, *Veronica officinalis*; Wild Pansy, *Viola lutea* et *var. amœna.* Club Mosses: Alpine Club Moss, *Lycopodium alpinum*; Fir Club Moss, *L. selago*; Common Club Moss, *L. clavatum*; Grey Woolly Moss, *Rhacomitrium lanuginosum*.

[1] Gorse and bracken, however, in really large amount are more usually associated with heath pastures at lower elevations, and with untended semi-natural heaths.

[2] E.g. Sheep's Bit, *Jasione montana*; Wild Thyme, *Thymus serpyllum*; Heath Lousewort, *Pedicularis sylvatica*; Eyebright, *Euphrasia* spp.

[3] Mat Grass, *Nardus stricta.*

steep hillsides than the Fescue pastures, although they occur on steep slopes when influenced by acid waters from above. They cover considerable areas around the margins of types found on deeper and wetter peat. Nardus is the dominating plant, although in some areas Wavy Hair Grass is almost equally abundant; this is typically so in the Peak District. The Hair Grass, however, produces but little leafy herbage, and is not of much significance from the grazing point of view. The flora is generally a very restricted one; isolated plants typical of the Fescue pastures usually occur, whilst Heath Rush sometimes becomes a co-dominant plant, and on wetter areas the Nardus pastures merge gradually into Molinia types.

Nardus pastures occupy large tracts on the Welsh hills, are abundantly represented in the Peak District, on the Wicklow Hills, and on the Northern Pennines. Considerable areas are to be met with which are intermediate between Fescue and Nardus pastures; these are to be regarded as degenerate Fescue pastures. The degeneration would seem to be a gradual process, due in part to a slow accumulation of vegetable matter, and to the long continued withdrawal of mineral salts from the soil through grazing animals. Isolated plants of Nardus thus gain entry on the Fescue pastures. These isolated plants are grazed to a certain extent by sheep, and therefore gain on the ground but slowly; but as the Fescue pasture becomes less and less productive, so does it carry less and less sheep, such areas soon becoming hopelessly understocked, with the result that Nardus rapidly gains the mastery. The area may eventually become practically dominated by Nardus, when from the grazing point of view it will have degenerated from one of the best to the least valuable of all the mountain and hill pastures. It is to be observed that sheep will graze isolated and small Nardus plants when present in a mixed sward, but that they neglect the large and crowded plants constituting pure Nardus pastures as long as they can gain access to any other pasturage.[1]

At the best the grazing afforded by Nardus pastures is of relatively short duration. Nardus does not start into growth early in the spring, and in the autumn, winter, and early spring the bleached haulms of the grass cannot be expected to have much attraction for grazing animals.

(*d*) Molinia Pastures.

T. A. Jefferies (25), in West Yorkshire, and Smith (43), in Scotland, have observed that the distribution of the Blue Moor Grass or Flying Bent, as *Molinia cærulea* is often called, depends chiefly on an abundant supply of relatively fresh water. This would seem, in the main, to be true of the grass in the Welsh hills also, and there can be little doubt that stagnation

[1] The above sequence has been studied by the present writer in Cardiganshire. Areas have been noted where fencing bas been neglected on sheep walks that previously carried more sheep than at present. The sheep have had access to extended areas, and have largely neglected degenerating Fescue swards, which in some instances have become dense Nardus pastures.

is inimical to the development of Molinia; although it must not be supposed that acidic waters, and more or less acid conditions, are not frequently associated with Molinia pastures. It is *relative* freedom from acid, and a tolerance for excess of water not *excessively acidic* that favours Molinia; thus Nardus dominates the drier peaty soils, and Molinia both peats and peaty soils that are but moderately well drained, whilst Cotton Grass associations colonize very wet and stagnant peats.

Molinia is a very variable plant; it may grow in large tussocks. The tussocky type is found on the flushed sides of mountain rivers and should be referred to rather as "Molinia bog" than as "Molinia pasture". The "bog" areas contain a much more varied assemblage of plants than the pastures.[1]

It is also capable of a more spreading growth. Large tracts in Wales, over slaty sandstones forming a thin clay soil, with restricted subsoil drainage on slightly inclined hillsides—steep enough to allow of surface drainage, and not too steep to occasion dryness—are given over to typical Molinia pastures, which in many districts constitute a predominant pasture type. Molinia pastures of this sort are also abundant on Exmoor and on Dartmoor.

It is the hillside Molinia pastures that afford really extensive grazing areas. The flora associated with these pastures is typically a restricted one, Molinia being the dominant plant. Associated plants are: Wavy Hair Grass, Nardus, Heath Grass, Bent, Heath Bed Straw, Cross-leaved Heath (*Erica Tetralix*), and Bell Heather (*E. cinerea*), whilst on flatter ground, and therefore under more stagnant conditions, Bog Asphodel (*Narthecium ossifragum*), Devil's Bit (*Scabiosa Succisa*), and Deer Grass (*Scirpus cæspitosus*) occur; and on larger central flat zones the associations of deep and stagnant peat replace the Molinia pasture.

From the grazing point of view Molinia pastures like the foregoing types are essentially gramineous. Molinia is a completely deciduous grass and affords no herbage during the winter, but during very severe periods the "stools" are to some extent eaten by sheep. Towards the end of May, and during June, an abundance of light green foliage is produced. This is eaten readily by cattle, and if followed by sheep these pastures are of very decided value all through the summer, especially when the dry Fescue pastures may be failing under the influence of a rainless season. Taking one season with another, and given mixed grazing, comparisons between different sheep walks in Wales suggest that the Molinia pastures are surpassed in value only by Fescue pastures.[2]

[1] The following plants *inter alia* are freely associated with the Molinia bogs: Lesser Spearwort, *Ranunculus Flammula*; Sneezewort, *Achillea Ptarmica*; Ragged Robin, *Lychnis Flos-cuculi*; Marsh Bird's Foot Trefoil, *Lotus uliginosus*; Marsh Thistle, *Cnicus palustris*; Cotton Grasses, *Eriophorum* spp.; Rusbes, *Juncus* spp.

[2] Heather does not take a very prominent place on a number of the Welsh sheep walks, and where present is seldom burned on a proper rotation.

B. TYPES DOMINATED BY PLANTS OTHER THAN GRASSES

(*a*) Heather.

Heather (*Calluna vulgaris*) may become a dominant, co-dominant, or abundant plant in a variety of habitats. It is sometimes associated with bracken on Fescue pastures, clumps of Heather being intermingled with a bracken canopy of but moderate density, and with distributed gorse bushes. On more exposed and northerly slopes Heather frequently completely takes the place of bracken.

Associations of this character, or with Heather a more definitely dominant plant, are common on the moorlands of north-east Yorkshire and on the fringes of Dartmoor; they are frequently associated with scrub. On rocky slopes Bilberry (*Vaccinium Myrtillus*) is frequently a co-dominant plant.

Heather moor is developed on peat, but for the most part on such as is relatively shallow and dry; Heather moor proper occupies extensive areas at elevations above 1000 ft., and constitutes the typical " grouse moor ". It affords valuable grazing for sheep, but it does not provide early spring keep.

(*b*) Bilberry.

Bilberry, as well as being associated with Heather on heathlands, frequently becomes a dominant plant on moors. As Elgee (13) and others have pointed out, it is capable of withstanding high winds and intense cold to a marked degree, and, in the words of Tansley, " the Vaccinium ridges and Vaccinium summits are high-lying wind-swept areas, usually with rather shallow peat through which bare sandstone rock frequently protrudes ".

Bilberry is also associated with stages in the degeneration of Cotton Grass moors, due to a drying of the peat as a result of increased drainage of elevated plateaux.

These " retrogressive Bilberry moors " have been studied by Moss in the Peak District, and have been noted by the present writer to occur to a lesser extent in the Welsh hills.

From the grazier's point of view Bilberry-clad hillsides afford but a slight measure of keep, and, with the Nardus pastures, are to be regarded as the least productive types of vegetation. It must be noted, however, that the stems of the plant are eaten to a not inconsiderable extent by sheep during the winter, and consequently as a distributed or even relatively abundant constituent of more mixed types of vegetation Bilberry, as such, has a decided value.

(*c*) Cotton Grass and Deer Grass.

Cotton Grass (*Eriophorum vaginatum*) sends up flowering heads and young shoots early in March, and these are readily eaten by sheep. Thus it affords valuable early spring grazing, and during the early summer the plant continues to provide grazing.

The Deer Grass (*Scirpus cæspitosus*), although not as early as Cotton Grass, gives useful grazing in the later spring and early summer. Both plants, however, turn yellow or reddish brown in the autumn, when they become of but little value.

Cotton Grass gives rise to typical moorland vegetation on deep and stagnant peat; it is usually associated with a number of mosses and with bog plants.

The Deer Grass is frequently also an associated species, and on wet bogs often becomes a predominating plant. Both plants when growing in quantity are often inaccessible, and occur on ground that is treacherous and dangerous for sheep. Peat bogs are not, however, without value, and a certain proportion of vegetation of this type is useful on a large sheep walk, and particularly so during dry periods and in rainless seasons.

The Improvement of Mountain and Hill Grazing.

The improvement of hill pastures is, unfortunately, as Smith (42) has pointed out, very largely a matter of labour. Improvement may be considered under the following headings: (*a*) fencing and providing shelter; (*b*) breaking and re-seeding; (*c*) burning and cutting; (*d*) manuring; (*e*) drainage; (*f*) irrigation; (*g*) altered methods of stocking.

(*a*) **Fencing and Providing Shelter.**—The first essential towards improvement is to decrease the size of the enclosures in order that grazing may be adequately regulated.

Fencing should be carried out in relation to the types of vegetation, so that each type may be controlled in the most suitable manner. Given adequate fencing, much hill land might be managed on a considerably more intensive basis than at present.

The judicious planting of shelter belts would often make it possible for certain areas to be more heavily grazed, by which means mountain Fescue pastures may be altered in the direction of heath Fescue pastures, and the latter in the direction of tended pastures.

(*b*) **Breaking and Re-seeding.**—This method is applicable to considerable areas of the relatively lower land nearer the homesteads, especially in the case of heath Fescue pastures covered with bracken on deeper soils. Much of this land could be brought under rotation on the basis of arable crops and four- to six-year leys. Relatively inaccessible fields may be broken and immediately sown to grass.

Where the sward is not tufted and the soil friable, areas may be ploughed during the winter or early spring, a tilth prepared in the spring, and a seeds mixture sown under rape in May or June. Where the sward is tufted and the soil heavier it is desirable to put the land through a short rotation, or to sow Ryegrass and Clover only, and replough and sow a full mixture after this has been down for two years. If possible lime should be applied after ploughing, but some little time before the seeds are sown, and basic slag with the last stroke of the harrow before seeding.

Areas re-seeded in this manner should be grazed with mixed stock as soon as the sward is properly established.

Re-seeding may sometimes be resorted to on wet and peaty areas near the homestead, but it is usually difficult to convert these into useful permanent pastures.

(*c*) **Burning and Cutting.**—Burning on a proper rotation is an easy and excellent method of improving vast areas of hill grazing. Heather should always be burnt over at least once in about fifteen years.

The Heather should be burnt in definite areas, so that the sheep may have access to the plant in all stages of growth; this will prevent the sheep congregating on the newly burnt patches, when there would be some risk of the young seedlings being uprooted. Smith classifies Heather soils as " quick returning " and " slow returning ". Heather will usually return quickly on peat or peaty soil provided it is not stagnant; the return will be slow on hard and dry soil devoid of humus. The aim should be to have a good new Heather covering within about four years of burning. Heather generally requires to be burned when it has lost its green colour and becomes grey, when the amount of flowers produced becomes slight, and when the stems are seen to be bare near the ground and terminate in a bushy top.

Peat areas and Molinia pastures may also be improved by burning. Molinia should not be allowed to get too old before it is burned. Smith considers that an endeavour should be made to burn these lands about once in seven years. Frequent burning in suitable seasons also improves Nardus pastures, and tends to alter them in the direction of Fescue pastures. Where gorse in dense masses covers Fescue pastures it should be burned in July. Isolated small gorse bushes on Fescue pastures are of decided value, for they afford shelter during winter and a measure of keep.

Molinia pastures and peat areas are frequently cut for " bog hay "; this procedure replaces burning and tends to improve the grazing.

Large tracts of Molinia pasture are regularly cut for hay on some of the Welsh sheep walks. The hay is put up in small stacks and fed to the sheep on the mountains during the winter; this makes for increased stocking and improves the pastures considerably. It is a practice that could be much extended, especially if it were possible to introduce a suitable implement for cutting this coarse grass on rough, uneven, and somewhat boggy land.

Bracken can only be decreased by painstaking and methodical methods. Experience shows that cutting for litter in September has no very appreciable influence on the plant. Trials in North Wales (4) have proved that cutting in the middle of July, for two to three years in succession, greatly decreases bracken. More recent trials conducted in Scotland (19) have shown that spraying with 5 per cent solution of sulphuric acid in July and again in August also decreases the plant. If the bracken canopy is not dense this spray will, however, injure the sward below.

(*d*) **Manuring.**—Extensive manurial trials have not been conducted on hill grazings. Experiments in Central Wales (2), however, suggest that basic slag or ground lime or limestone and superphosphate give very appreciable results on mountain and heath Fescue pastures, whilst farmyard manure, on Nardus and Molinia pastures near a homestead, decreases these two grasses and improves the grazing considerably—the improvement is greater when the surface is broken with a toothed implement after the application of the manures. Fencing is absolutely necessary if improvement by manuring is contemplated, for it must be possible to graze the manured areas heavily without attracting sheep wholly from the unimproved portions of the walk. Degenerating Fescue pastures should be burned to decrease the Nardus, and then dressed with basic slag and subsequently grazed heavily.

Economic improvements cannot be expected from spasmodic manuring of small or isolated unfenced areas.

There is need for very extensive experiments and investigations with a view to ascertaining whether it might not be possible to utilize hill grazing on a more intensive basis.

(*e*) **Drainage.**—Improvements may be effected by draining stagnant peat areas and also by cutting drains with a view to preventing the peaty and acid waters from peat bogs flowing over Fescue pastures. The effect of draining peat is to substitute heather and grasses for Cotton and Deer Grass, and therefore makes for a rather later vegetation, but on the other hand it makes bogs less dangerous for stock.

Peat areas that have been well drained should be burned; and when near the homestead, and if enclosed, it would often be advantageous to sow a renovating mixture on the bare peat, with a dressing of basic slag, and subsequently to add farmyard manure to the sward.

(*f*) **Irrigation.**—Fresh hard water, free from peat and low oxides of iron, has a wonderful influence on Fescue pastures, and since these usually occur on slopes, it is frequently possible to divert watercourses, and by cutting a simple system of open drains to irrigate considerable areas. Areas so irrigated maintain maximum productivity over an extended period. Endeavour should always be made to irrigate degenerating Fescue pastures at the first signs of deterioration.

(*g*) **Altered Methods of Stocking.**—In Leicestershire the experienced grazier always endeavours to graze his pastures " as bare as your hand " once a year. The hill farmer should have very similar ideals, for hill pastures should be grazed more or less bare periodically, if not every year.

The coarser types of vegetation, such as Molinia, Heather, and Cotton Grass, can only be " cleaned off " by burning or cutting. Tufted Fescue pastures and Molinia pastures to some extent can be kept in check, however, if grazed periodically by ponies or cattle. Grazing with one class of animal only is bad for every type of pasture; it should be the aim of the flockmaster to arrange his scheme of grazing not only with a view to the welfare of his animals, but regard should also be paid to the needs of the pasturage. It has been said, for instance, that the aggregate keep from a Molinia pasture is greatly increased if it is grazed by cattle in the spring. Degenerate Fescue pastures and tufted Fescue pastures are improved if grazed in the autumn or early spring by cattle or ponies. In dry weather, when the peat is firm, cattle will find an abundance of keep on deep peat areas, which are improved by careful grazing with cattle for short periods at a time when the peat will hold. Peat areas near a homestead should always be divided into small enclosures in order that the animals may be repeatedly changed from place to place, the grazing on any one " field " being intermittent. It is held by many that bracken is far more abundant than formerly, and this is probably due to the fact that cattle are not kept on the hills to the extent they were. Cattle and ponies both eat bracken to some extent, and also bruise and break the young fronds in the spring. It may be said, therefore, that as far as possible sheep walks should carry ponies or cattle as well as sheep; this, of course, implies proper fencing so that the grazing can be regulated and arranged on a proper rotation; the desired end is not to be achieved by turning sheep and cattle, or sheep, cattle, and ponies together, on vast unfenced areas. Hill grazing is influenced to a marked degree by the character of husbandry on the enclosed hill farms. It should be the aim to maintain a proper sequence of productive temporary leys, and to harvest as much hay as possible. Hay or roots carried out to animals on the pasturage near the farm adds to the stock-carrying capacity of the fields so treated and improves the character of the sward.

Lowland Heaths.

These heaths, as such, do not in most cases differ fundamentally from the heaths met with on the more elevated regions. In the south and east of England, however, they are associated with pasturage of but slight value to the grazier. Many of these heaths have become practically suburbs of London, and when not built over are used as racecourses or golf links. The typical lowland heaths give rise to agricultural land of poor quality, and when reclaimed and turned to advantage they are used for specialized industries like market gardening and propagating nursery stocks of trees, shrubs, and roses.

A large proportion of these heaths are covered by heather and bracken and pass into scrub and woodland, consequently the amount of heath Fescue pasture is usually small in proportion to the more typical heathland vegetation.

Lowland heath Fescue pastures, as well as occurring in the east and south of England, are to be met with on the lowest slopes of mountain and hill districts, and as isolated pastures on relatively high land, perhaps more particularly near the sea, partially or completely surrounded by cultivated land and tended grasslands. These lowland heath Fescue pastures therefore approximate to the semi-natural, for they are usually grazed more heavily than their upland counterparts, the stock also having frequent access to cultivated land and tended grasslands.

Plants like Ribgrass, Cat's Ear, and Buttercup are therefore commonly met with on these pastures. The number of heath herbs proper is also greater on the lowland than on the upland Fescue pastures, in addition to those already mentioned such plants as Spurging Flax (*Linum catharticum*), Speedwell (*Veronica Chamædrys* et *V. serpyllifolia*), Ragwort (*Senecio Jacobœa*), Hawkbit (*Leontodon autumnalis*), Carline Thistle (*Carlina vulgaris*) being of frequent occurrence. The leguminous herbs also contribute in greater amount to the sward, often comprising over 6 per cent, and being represented by Suckling Clover (*Trifolium minus*), White Clover (*T. repens*) in small amount, and chiefly by Bird's Foot Trefoil. Tufted Vetch (*Vicia Cracca*) and Kidney Vetch (*Anthyllis vulneraria*) also occur, the latter being most common near the sea. The dominant grasses are again Sheep's Fescue and Bent; *Festuca rubra* and Smoothed-stalked Meadow Grass (*Poa pratensis*) are, however, sometimes met with. The *lowland heath Fescue pastures in regions of high rainfall have usually* a somewhat higher grazing value than the upland heaths met with in the same districts.

The typical lowland heath Fescue pastures of the south of England differ from those described above, and from the upland heath Fescue pastures, largely on account of the Hair Grasses taking a prominent place in the sward.[1] Sweet Vernal Grass is also more abundant, and the Bent Grasses usually include *Agrostis canina* as well as *A. vulgaris*. Grasses do not, however, completely dominate the sward on these pastures, and the herbage consists of a number of miscellaneous plants, many of which are annuals, consequently the flora is more varied than that of the lowland heath Fescue pastures of Wales and other regions of high

[1] *Aira caryophyllea* as well as *A. flexuosa* and *A. præcox* being frequently represented.

rainfall, and altogether more complex than that of the upland and mountain Fescue pastures.[1] The Leguminosæ are usually well represented, the number of contributing species being greater than on other heath Fescue pastures. The sward is not closely knit together, and a considerable amount of bare ground is often noticeable; from the grazing point of view the vegetation is therefore of the poorest, and the amount of keep provided for animals is very limited.

The East Anglian heaths of Breckland in the neighbourhood of Mildenhall, Thetford, and Brandon have been extensively studied by Farrow (14), and although of negligible value deserve special mention. The annual rainfall of this district is only 22·5 in., which is one of the lowest in Britain; large portions of the area consist of sandy sterile soils which have never been under cultivation. A certain amount of cultivation is carried on near the villages, rye, buckwheat, potatoes, lucerne, and lupins being the crops most successfully grown, but the land is too dry for high yields even from these crops. A large proportion of Breckland is covered with heather and bracken. Heath Fescue pastures also occur. These are characterized by a relative dominance of Sheep's Fescue and Bent (*Agrostis vulgaris*); the Leguminosæ are well represented, Suckling Clover (*Trifolium minus* et *T. procumbens*) and Hare's Foot Clover (*T. arvense*), with such plants as Kidney Vetch, Bird's Foot Trefoil, and Wild Vetches, being not uncommon. The most striking feature is, however, the extensive and varied nature of the flora, Farrow having listed 70 characteristic species and 80 less characteristic and less frequent species.[2] The vegetation forms a close short turf, but the grass plants are often wide apart and the ground is largely covered by ephemeral annual plants which finish flowering by the end of May. Fairly large areas on Breckland are colonized by dense and almost pure associations of Sand Sedge (*Carex arenaria*);[3] These areas are practically worthless from the grazing point of view; indeed this is largely true of the vegetation of Breckland as a whole, which is more or less completely overrun with rabbits.

The influence that rabbits have on the vegetation has been studied by Farrow, and affords another excellent example of grazing as a dominating factor making for the perpetuation of grassland vegetation. It appears

[1] The following plants in addition to those already mentioned are typical: (*a*) Trefoil (*Medicago lupulina*), Wild Vetches (*Vicia* spp.), Knawell (*Scleranthus annuus*), Hare's Foot Clover (*Trifolium arvense*), Sheep's Sorrel (*Rumex Acetosella*), Centaury (*Erythræa Centaurium*), Bird's Foot (*Ornithopus perpusillus*), Wood Sage (*Teucrium Scorodonia*).

[2] The following may be mentioned as typical plants: *Aira præcox*, *Festuca rubra*, *Myurus*, *Viola* spp., *Ornithopus perpusillus*, *Anthyllis Vulneraria*, *Erodium cicutarium*, *Ononis repens*, *Vicia angustifolia* et *V. lathyroides*, *Draba verna*, *Cerastium* spp., *Arenaria* spp., *Myosotis collina*.

The following species are rare in England outside Breckland: *Selene Otites*, *S. conica*, *Carex ericetorum*, *Medicago falcata*, and *Veronica verna*.

[3] This plant is characteristic of coastal sand dunes, and with *Phleum arenarium* is usually absent from inland heaths on sand.

that rabbits when fenced off from the cultivated land soon overstock the grass heath, and then resort to the heather areas for food. They attack the heather to such an extent that it is gradually killed off where it abuts on the grass heath, first in patches and finally in ever extending inward zones. The dying heather branches afford a suitable habitat for Lichen (Cladonia), which, growing luxuriantly amongst them, retains water and assists the decay of the heather; the dead branches and the associated Lichen are eventually blown away, the ground becoming colonized by grass heath. Thus much of the grass heath of Breckland is due to degenerating heather as the result of rabbit attack. Farrow epitomizes the phenomena in the following striking paragraph: " It is very interesting that on Cavesham Heath and elsewhere the rabbits very severely injure the grass heath and keep it nibbled down very closely to the surface of the soil; and yet that they enormously benefit it, since if it were not for the rabbits the grass heath would not exist at all, but would become replaced by heather. The grass heath owes its very existence to an extremely injurious influence, which nevertheless greatly benefits it because it injures its competitor slightly more."

The Improvement of Lowland Heaths.—The improvement of lowland heaths in regions of high rainfall would follow on the lines suggested for upland heaths, and would consist of bracken cutting, gorse and heather burning, and in the case of the Fescue pastures more adequate fencing and applications of basic slag.

A large proportion of the lowland heaths should, however, be brought under rotation on the basis of the four- to six-year temporary ley, or at all events broken and re-seeded down under rape with a suitable mixture.

Improvement of the English lowland heaths on dry sands in regions of low rainfall by means of top dressings and more intensive stocking is almost out of the question. The aim should rather be to reclaim such areas by bringing them under the plough, manuring heavily with farmyard manure, stable manure, or manures from deck cargoes of cattle, with such artificial manures as bone meal, and growing crops like lupins and ploughing in. There is no doubt a better sward could be produced on some of these heaths by re-seeding after a preliminary course of ploughing in lupins and other soiling plants. It is hard to say, however, whether economic results could be produced by this means on a large scale.

Maritime Swards.

A large number of types of vegetation of great interest to the botanist occur near the sea; they have been studied in detail by Oliver (39), Newman and Walworth (38), Moss (33), Priestley (40), Marsh (29), Yapp and Johns (60), and others. Two classes of maritime swards are of very decided value to the grazier, namely the close turf associated with several seaside golf links, and certain zones of vegetation on salt marshes bordering river estuaries. Although salt marshes are usually heavily grazed by sheep having frequent access to cultivated land, the periodic flooding constitutes such a dominating environmental factor that the swards, although, of course, greatly influenced by grazing, are to be regarded as natural. The sheep grazing golf links are usually turned out for long periods at a time, and consequently the herbage is not influenced very much by contact with adjoining tended grasslands, although the sheep as such must exercise a profound influence on the sward.

Salt Marshes.

Several zones occur on salt marshes; it is, however, those where grasses and the Sea Pink become dominant that frequently carry such large numbers of sheep. Sheep have been noted to congregate freely on areas almost covered with *Glyceria maritima*, but they appear to prefer the higher zones where Sea Pink (*Armeria vulgaris*) and *Festuca rubra* become the dominating elements in the sward. On these zones the Rush *Juncus Gerardi* is usually fairly abundant, and like the Sea Pink is closely grazed by sheep.[1] It is probable that these salt marsh zones are capable of carrying a heavier head of sheep per unit of area than almost any other of our natural pastures; it is interesting to observe, therefore, that the sward is completely devoid of leguminous herbs, and apart from *Festuca rubra* consists of species not usually regarded as being of the slightest economic value. When it is realized that some of these swards consist of from 60 to nearly 90 per cent of Sea Pink,[2] and carry infinitely more sheep per acre than a heather moor, and even than a good heath Fescue pasture, it will be apparent that this plant should be regarded as a valuable herbage species.[3]

It is difficult to see how the swards on the best salt marsh zones could be improved artificially, since manures would be washed away. The area available for grazing might be considerably increased by obliterating the hollows, which usually occupy over 10 per cent of the Sea Pink zones, and are practically devoid of vegetation. Improvement should also lie in the direction of endeavouring to increase the areas under Sea Pink and *Festuca rubra*, at the expense of those nearer the seaboard on the one hand, and of those areas more remote from the sea, of negligible grazing value, dominated by the Sea Rush (*Juncus maritimus*), on the other.

The Rush areas bounding many estuaries are much more extensive than the Sea Pink-Fescue zones; they would seem usually to occur on slightly higher land, but are subject to periodic flooding, and both associations flourish under what appear to be very similar conditions. The

[1] Among the associated plants are: *Lepturus filiformis*, *Glaux maritima*, *Plantago coronopus*, *Triglochin maritimum*. [2] Yapp and Johns (60).
[3] Sheep not only thrive but fatten quickly on these swards.

relationship of the two types deserves careful study and experiment, for it ought not to be difficult to convert the relatively useless Rush areas into valuable Sea Pink-Fescue zones. Observations suggest that this end might be achieved by systematically burning the rushes, and so controlling the flood waters that they would be carried off more rapidly after each periodic inundation. The value of salt marshes for grazing is much enhanced by their freedom from the liver fluke parasite. The intermediate host, the snail (*Limnea truncatula*), is usually common on the more inland marshes of extensive flats, but is absent on lands influenced by salt or brackish water.[1]

The Swards of Seaside Golf Links.

A number of interesting types of vegetation are associated with golf links; the dunes, with their masses of Bents consisting of Marram Grass (*Ammophila arenaria*), are characteristic features, as are the beautiful " dune hollows " with their varied vegetation. Nearer the sea, and liable to periodic but infrequent submergence, narrow bands of the seaside Couch Grass (*Agropyrum junceum*) are met with.

The Marram Grass and the Couch are to some extent grazed by sheep, whilst dune hollows also afford a measure of keep. It is, however, the more definitely gramineous swards, which constitute the " fairway " of the links and which cover considerable areas, that form really valuable pasturage. The herbage is usually fine and is kept closely grazed, and is often capable of carrying a large head of sheep; on the average these maritime swards are probably as productive as the heath Fescue pastures, and in some cases more so. The sward is of the grass heath type, but consists of a more varied flora than the upland Fescue pastures, and is more heterogeneous than many of the lowland heaths. Golf links pastures, of course, vary in different localities. The following brief account of the sward occurring on the Northam Burrows[2] may however be regarded as more or less typical. Unlike the heath Fescue pastures, Sheep Fescues and Agrostis do not completely dominate the sward, for a number of other valuable grasses are generally present in greater or less amounts. Dwarf forms of Crested Dog's Tail and Perennial Ryegrass are appreciable contributors, while of less valuable grasses Soft Brome (*Bromus mollis*) and the Seaside Timothy (*Phleum maritimum*) may be mentioned. The Leguminosæ contribute appreciably to the sward and are represented by White Clover, Red Clover (occasional), Bird's Foot Trefoil (usually abundant), Trefoil, and Rest Harrow (*Ononis repens*). A considerable proportion of the ground is covered by miscellaneous herbs, many of which are associated with

[1] I am indebted to Mr. C. L. Walton, who has made an exhaustive study of the incidence of liver-fluke in Cardiganshire, for this information.

[2] The home of the Royal North Devon Golf Club.

normal heath Fescue pastures, whilst others are rare on the inland swards.[1]

Depressions, which in some instances are liable to flooding by tidal waters, and in others to flooding by heavy rain, occupy a considerable proportion of these areas. These depressions tend to become dominated by Rushes and by Silver Weed (*Potentilla anserina*), and are of but slight grazing value. The maritime swards are undoubtedly capable of improvement, and are in fact to a large extent improved by the golf clubs. At Westward Ho! for instance, it is found that the sward of the fairway is improved by periodic dressings with sea sand,[2] whilst on many golf links dressings with bone-meal have been found efficacious. Improvement also results from filling up depressions, and by this means areas dominated by Silver Weed may be converted into useful sward, whilst drainage of larger areas subjected to flooding is always followed by good results. Improvements of this character are, however, but seldom undertaken with the avowed aim of adding to the stock-carrying capacity of the sward, and are usually confined to the links proper.[3]

Like the salt marshes the links are worthy of detailed study, and there is little doubt that properly conducted experiments would show means whereby the grazing might be easily and greatly improved.

II. Semi-natural Grasslands

UNTENDED GRASSLANDS

Two very distinct classes of grassland fall under this heading. The one class consists of those swards which, like the natural grasslands, have probably never been under the plough, but which are to a more marked degree influenced by the prevailing methods of husbandry, in so much as they are grazed moderately heavily by stock having repeated access to cultivated land and (or) to tended grasslands. The downs and certain types of water-logged pastures met with on enclosed farms come under this category. The other class constitutes fields that have for the most part been under cultivation twenty to sixty or even more years ago, but which have subsequently "tumbled down" to grass, have received little or no manures, but are sometimes more or less heavily stocked, and invariably by animals having access to tended grass or to cultivated lands.

[1] The following herbs are characteristic on the Northam Burrows: *Plantago Coronopus*, *P. maritima*, *Euphrasia* spp., *Galium verum*, *Thymus serpyllum*, *Spinanthes autumnalis*, *Prunella vulgaris*.

[2] That is to say the character of the sward is actually improved, apart altogether from the filling up of "divots" by the sand.

[3] It would be of great interest to conduct basic slag manurial trials, on "manuring for mutton" lines, on some of these pastures.

This latter class constitutes one of the black pages of British agriculture, for it includes some of the worst permanent grass in the country, the condition of the pastures being largely due to neglect, the result of a national policy which led to fewer homesteads, less manure, and a greatly diminished rural population. These grasslands may conveniently and with justice be referred to as " out-run leys ", for although many of them fell away to sward from a corn stubble without any seeding, the majority were probably seeded out, if only with sweepings from the hay loft or with Ryegrasses, but not with the avowed intention of being left down to grass for an indefinite period.

The Downs.

Crampton (12) and Smith and Crampton (45) have classified the downs as natural and stable types of grassland. From the strictly ecological point of view no doubt the downs should be regarded as natural; the remoter areas on the downs are, moreover, not heavily grazed, and under the classification here adopted should be regarded as natural. By far the larger proportion of the downs is, however, more or less heavily grazed by sheep having repeated access to cultivated land. Hall and Russell (21), describing the sheep farming on the South Downs, state: " as a rule the flocks travel from the downs to the fold and back every day "; this undoubtedly reacts on the flora, and tends to modify the nature of the sward, so that the present-day herbage of the downs must, in justice to the methods of husbandry adopted, be regarded as semi-natural. The downs or " wolds " (as they are spoken of in parts of England) occupy an extensive area in England; they occur for the most part on the Chalk (of the cretaceous system) and to a lesser extent on the Oolite (e.g. in Gloucestershire). Somerville (50) states that the cretaceous system covers 6,190,000 acres in England, which constitutes over 19 per cent of the total land area of that country; this is the largest contribution of any single geological formation to our soils. The cretaceous system, and therefore the wolds and downs, cover very extensive areas in Yorkshire, Lincolnshire, Sussex, Hampshire, Wiltshire, and Kent, and smaller areas in Surrey, Berkshire, Buckinghamshire, and Dorsetshire.

The vegetation of the downs is very characteristic; it gives rise to a typical springy turf, consisting of a close mat of wiry herbage easily detached from the soil. The soil depth is generally but slight, frequently not exceeding 1 in. The downs are dry and healthy, the sward frequently being remarkably uniform over very wide areas; swamps and bogs are almost entirely absent. The pasture has much in common with the various types of heath Fescue pasture previously described, *Festuca ovina* being typically but not invariably dominant. The flora is, however, very much more varied than the upper and lower heath Fescue pastures of the older siliceous rocks in regions of high rainfall, and, generally speaking, more varied than that of the dry heaths of the south of England.[1] The Leguminosæ generally contribute more to the sward on downs than on other Fescue pastures, and are frequently present to an extent of as much as 10 per cent. The number of contributing leguminous species is also considerable, including, commonly, such plants as: Horse-shoe Vetch (*Hippocrepis comosa*), Kidney Vetch (*Anthyllis Vulneraria*), Bird's Foot Trefoil, Trefoil, the Suckling Clovers (*Trifolium minus*, *T. procumbens*, and *T. filiforme*), Red Clover (*T. pratense*), and locally, but to a less extent, White Clover, as well as Rest Harrow (*Ononis spinosa*) and Purple Milk Vetch (*Astragalus danicus*). The grasses are also represented by a larger number of species than on other Fescue pastures, Golden Oat Grass (*Trisetum flavescens*) sometimes being almost sub-dominant to the Sheep's Fescue; Quaking Grass (*Briza media*) is abundant, the Upright Brome Grass (*Bromus erectus*) is locally abundant, whilst Downy Oat Grass (*Avena pubescens*) is frequent, and Cocksfoot, Tall Oat Grass, Crested Dog's Tail, and Perennial Ryegrass may contribute appreciably to the sward. Bent (*Agrostis vulgaris*) is typically much less abundant on the untended downs than on the heath Fescue pastures. Tor Grass (*Brachypodium pinnatum*) frequently colonizes large areas, practically to the complete exclusion of other species; this is a harsh grass, to all intents and purposes refused by stock.

The miscellaneous herbage is characterized by a number of rare orchids, and by a profusion of such plants as the Rock Rose (*Helianthemum vulgare*), Marjorum (*Origanum vulgare*), Dropwort (*Spiræa Filipendula*), Burnet (*Poterium sanguisorba*), and Milkwort (*Polygala vulgaris*).[2] Plants such as Ribgrass, Cat's Ear, and Dandelion are usually freely met with as distributed species, and these, with the prevalence of a number of grasses more abundantly met with on tended grasslands, as also of White Clover, suggest the influence of repeated transference of the sheep from downs to cultivated fields and vice versa.

Although the swards of the downs include a number of species also characteristic of the heath Fescue pastures, it will be noted that, as well as the flora of the downs being vastly more varied, many of the miscellaneous plants of the heath swards are rare or totally absent from the downs.[3]

The Improvement of the Downs.—The true down swards are perhaps not so amenable to improvement as are large areas under outrun leys derived from the downs. Somerville's (50) work at " Poverty

[1] Tansley, in *Types of British Vegetation*, lists 118 species as occurring on the grass-heath and 146 species as belonging to Chalk grasslands.

[2] Other typical plants are: *Gentiana amarella*, *Cnicus acaulis*, *Chlora perfoliata*, *Echium vulgare*, *Ranunculus bulbosus*, *Plantago media*, *Galium verum*, *Carex glauca*.

[3] Examples are *Potentilla erecta* (the most closely related species on the downs being *Fragaria vesca*); *Galium saxatile* (on the downs we have *G. verum*); *Carex binervis* (on the downs the chief Sedge is *C. glauca*).

Bottom", although chiefly conducted on out-run down land, clearly shows, however, that down swards respond excellently to basic slag; for if White Clover is not present in sufficient amount to react to the slag, Kidney Vetch, Bird's Foot Trefoil, or other leguminous herbs will certainly be well represented and will respond to the treatment. He has also obtained noteworthy results by sowing Wild White Clover as a "renovating mixture"; but although this succeeded on out-run down land, it does not follow that a tilth could always be obtained on the surface of an original and undisturbed down sward.

It is probable that if in a season following a dry year the turf was repeatedly harrowed with a strongly toothed implement, it would be possible to bring enough soil to the surface to afford a slight seed bed for a renovating mixture. Just as mixed grazing, with cattle and sheep rather than with sheep alone, is one of the best means of improving and getting the most out of mountain and heath pastures, so has Somerville found that mixed grazing and adequate fencing has been one of the most potent factors in increasing the stock-carrying capacity of his down land at Poverty Bottom.

The eradication of Tor Grass presents considerable difficulties. It is a perennial, tufted plant, with many underground stems, which push along about 2 in. underground and terminate in clusters of buds. These buds develop into bunchy tussocks in the following year. Other buds develop at the nodes of the underground stems and later become aerial shoots. From the under side of the nodes extensive systems of fibrous roots are produced. The roots are much branched and have a wide range both vertically and laterally. The tufts gradually increase in size, and if unchecked, tend to become united, and to crowd out the finer grasses and clovers.

The plant is spread by seed which ripens in late summer and is carried by the wind.

Gas lime, as fresh as possible, applied any time during the year, at the rate of $2\frac{1}{2}$ cwt. per perch, has been found to kill the grass. As five months must be allowed to elapse before re-seeding, the best time to apply the lime would be in October. Isolated patches should be dug out with the spade to a depth of 3 in. In addition to burning and grubbing, grazing with cattle will also check the spreading of this grass.

Experiments conducted at Cirencester suggest that burning the grass and subsequently dressing with agricultural salt and grazing heavily with store cattle tend greatly to reduce Tor Grass and encourage the development of the finer grasses.

Wherever the grass occurs, every effort should be made to suppress it, or serious damage to pastures will ensue. In the case of large areas the best remedy is to plough up, fallow, and re-seed.[1]

[1] For further particulars as to eradication of Tor Grass see H. P. Hutchinson (24).

Re-seeding of down land would generally take place after a course of rotation husbandry, and it is somewhat doubtful if good results would follow from breaking a down sward and seeding out under rape, or in a thin corn crop, without first working through a rotation. The excellent results obtained on heath Fescue pastures in regions of high rainfall suggest however the desirability of conducting experiments on these lines on the downs also.

Water-logged Pastures.

These occupy large areas in the aggregate, being met with on isolated fields on numerous farms, especially in regions of high rainfall in the west. The great majority of the pastures here considered have not been under the plough, and are different from those large contiguous areas of poor grass met with on the retentive clays—pastures most of which have in the past been under the plough. The water-logged pasture fields generally consist of a somewhat chessboard-like vegetation, patches of fairly good sward being intermingled with areas more or less dominated by rushes and (or) sedges, or by a typical moorland or heath vegetation.

These pastures frequently have a very real grazing value, especially for store cattle, and in dry summers when the better swards become "parched", grasses like the Flying Bent, Rushes, particularly the Jointed Rush (*Juncus articulatus*), and the Cotton Grasses are then freely eaten by cattle, both Flying Bent and the Jointed Rush in some districts being held in esteem for dairy cattle.

The flora of these pastures is naturally very varied. Crested Dog's Tail, Sweet Vernal Grass, and Bent (*Agrostis alba*, vars. *stolonifera* and *coarctata*) often share dominance on the sward patches, whilst Perennial Ryegrass is frequently an appreciable contributor; characteristic heath plants, such as Heath Grass (*Triodia decumbens*), Heath Bed Straw, and Tormentilla, usually occur, while Red and White Clover and Bird's Foot Trefoil (including *Lotus uliginosus*) are generally present, with larger leguminous plants such as Gorse and Petty Whin (*Genista anglica*). A number of herbs usually associated with tended grasslands are also frequently plentiful.

The management of these pastures is not an easy matter; care must be taken not to poach the ground by overstocking in winter or in wet weather. Cutting for rough hay is frequently a sound practice; this usually encourages Meadow Foxtail, but unfortunately has a similar effect on Soft Brome or Lop Grass (*Bromus mollis*) and Yorkshire Fog (*Holcus lanatus*). If these latter grasses are abundant the hay should be cut early in order to prevent them setting ripe seed. Good results follow from burning the definitely moorland patches, and from liberal applications of slag on the sward zones. The slag reacts on the leguminous herbs and tends to suppress sedges. Maximum improvement can of course only be effected by drainage. It is beyond the scope of this article to discuss this complicated question. It may be emphasized, however, that such pastures as this can often be vastly improved by cutting a system of open shallow drains with a plough; this has the effect of carrying off excess of surface water, thus rendering the herbage earlier and the sward less liable to be injured by heavy animals. Many of these areas would be suitable subjects for mole draining, and herein probably lies the greatest hope of their radical improvement. Renovating mixtures are not likely to prove very successful, since owing to the tough nature of the turf it would be difficult to obtain a seed bed. Breaking and re-seeding might in some cases advantageously be resorted to, a summer fallow would be necessary, and a few years under crops would be essential where rushes are plentiful, as a single ploughing almost invariably increases rushes. The great advantage of breaking the sod is that it is then possible to work a good dressing of lime into the soil.[1] Although some fields of the character here described might with advantage come under rotation husbandry on the basis of the long duration temporary ley, the majority would probably pay better if as soon as possible seeded down with a permanent mixture.

Out-run Leys.

These grasslands are a part of our cultivated lands, and whether originally derived from heaths, downs, or from the heavy intractable clays, have certain characteristics in common. They always show a reversion towards the natural types; thus the swards on the clays when totally neglected become more or less covered with scrub. Heath herbs and down herbs are freely represented on those derived from heaths and downs respectively. The sward is not well knit together; bare ground is frequently excessive. Bent is usually the dominant grass, being far more abundant relative to Sheep's Fescue than on the heath Fescue pastures or on the downs. Golden Oat Grass on fields derived from downs, Cocksfoot on fields derived from heath and downs, and Perennial Ryegrass on fields derived from heaths and downs tend also to be more plentiful than on the more natural pastures, and the same is generally true of White Clover, and of herbs like *Plantago media* (on fields derived from downs) and *Hieracium Pilosella* and *Veronica officinalis* (on fields derived from heaths), whilst these out-run leys always include in their flora greater or less excess of plants like Upright Brome[2] (on fields derived from downs), Yorkshire Fog, Soft Brome, and Yellow Rattle under meadow conditions, and under both pasture and meadow conditions herbs more generally associated with the tended grasslands are common.

[1] This aspect of grassland improvement is referred to in a subsequent section.

[2] The distribution of the Upright Brome is of considerable interest; it is seldom abundant on the open downs, but is so on less well grazed banks, and particularly so on out-run meadows.

The total area of the country given over to out-run leys must be enormous; 37 per cent of the so-called cultivated land of an area of 19,896 acres surveyed in mid-Wales by the present writer consisted of out-run leys, whilst in England on the heavy clays of the Weald, Oxford Clay, Boulder Clay, and other formations, vast contiguous areas of out-run leys are to be met with, whole farms consisting of little but out-run leys. It is a remarkable fact that the great majority of grass of this character has undoubtedly been derived from land under cultivation, the old "lands" always standing as evidence of the former activity of the plough.

The methods of improvement to be adopted naturally vary for the different classes of out-run leys, but usually in proportion as the fields have been allowed to run down to grass and deteriorate, so have the fences been progressively neglected, the condition of the fences on some farms being so bad that practically the whole area of the farm amounts to but little more than a ring-fenced ranch. If it is important adequately to fence mountain heath and down areas as the first step towards improvement, it is doubly necessary to do so in the case of out-run leys, many of which have far greater potentialities than the natural pastures and downs, and therefore afford greater scope for scientific and carefully regulated grazing. Improvement of existing fences and the erection of additional fences on a well thought out plan should therefore be undertaken first and foremost on all areas of out-run grass.

One further generalization may be made with reference to these derelict grasslands before discussing in detail methods of improvement best suited to the different types. It is now generally admitted, that on land of any potential merit, a system of farming based on a rotation—even a rotation in which a well-managed four- to six-year ley takes a prominent place—will produce more stock (apart altogether from grain and potatoes) per farm than the same land even skilfully managed as a permanent grass farm. Thus, much of our out-run leys ought to be farmed on a rotation, and the grassland management of these farms should be mainly a question of the best means of establishing and maintaining good temporary leys.[1]

There are, of course, reasons why much out-run grass is never likely to come under regular rotation; some of the clays are too unworkable, fields are often too steep, besides which a certain amount of permanent grass is frequently an absolute necessity on a farm.

It has been said that the sward of out-run leys is seldom well knit together, but that useful plants are frequently present at least to some extent; the problem then consists of how to establish a sward with a good sole and how to eliminate Bent and the undesirable elements of the flora. The solution of this problem is easy if a second problem can be solved

[1] See article on *The Temporary Ley*, p. 43.

—namely how to obtain the necessary reaction of leguminous herbs to phosphatic manures. The really crucial point to decide in every case is therefore whether the desired improvement can be achieved in a reasonably short length of time by top dressings, surface cultivations and renovating mixtures, and improved methods of stocking, or whether it is necessary to break the sod and resow.

This is a question that can only be settled by a careful study of individual fields; it is, however, possible to lay down certain general principles which may be found useful.

Out-run Leys derived from Downs and Out-run Leys generally on Calcareous Soils.—It is probable that out-run grass on calcareous soils can be improved by surface treatments with more certainty than other types.

In the first place, the herbage is seldom completely overrun with Bent, there is usually a moderate amount of bare ground; leguminous herbs, often including White Clover, are always present to some extent; and certain of the more valuable grasses are constituents of the herbage; furthermore, the herbage is often short and not very tufted. In these circumstances a good harrowing with a toothed implement will generally occasion a sufficient tilth for a renovating mixture, and in some cases there will be an abundance of loose soil without any cultivation. Renovating seeds will therefore have every chance of obtaining a foothold, and phosphatic manures usually react with most certainty on fairly fine swards.

If a field has a tufted herbage, steps should be taken to graze the field as closely as possible before applying renovating seeds or top dressings, and if necessary the rough benty herbage should be cut. If a field is dominated by the Upright Brome Grass not much success could be expected from renovating seeds, unless the field was kept heavily grazed (without taking hay) for two or three years, in order, as a preliminary treatment, to reduce the grass. Renovating seeds are likely to succeed best if sown in a wet season immediately following a particularly dry one. After a dry season there will be more bare ground than usual, and it is the essence of success with renovating mixtures to get the seeds sown at the beginning of or just before a prolonged spell of wet weather. It probably does not matter when renovating seeds are sown between the middle of April and towards the end of August provided only wet weather follows, consequently, on the average, early autumn sowings are likely to be more successful than seeds sown in the spring.[1] A renovating mixture on calcareous soils should consist largely or even entirely of Wild White

[1] Wild White Clover frequently consists largely of hard seed; this, if sown in the spring or in the autumn, is unlikely to germinate until it has been subjected to the freezing and thawing of winter, when it will germinate early the following spring and probably become established before long spells of dry weather set in.

Clover. Somerville (50), in 1911, used over 3 lb. of this seed per acre; it only cost 2s. 9d. per pound in those days! Although as little as ¼ lb. of Wild White Clover per acre often produces excellent results, when included in a mixture for sowing on cultivated or rebroken land, it is very doubtful if less than 1 lb. to the acre would be of much avail for renovating purposes. The following mixture may be suggested with a view to supplementing the Wild White Clover where it is proposed to sow less than 2 to 3 lb. of the seed.

	Pounds per Acre.
Crested Dog's Tail	3
Wild White Clover	1
English grown Late-flowering Red Clover	2
	6

Somerville's experiments at Poverty Bottom have shown that renovating seeds, unless followed up by adequate dressings of phosphatic manures, are not likely to prove successful, and as before stated he has attained signal success on his out-run downs by resort to large supplementary dressings of basic slag.[1]

Opinions differ as to whether stock should be withheld from fields on which renovating seeds have been sown; it is sometimes the practice to sow in August or September and to put the field up for hay the following year, stock being kept off the field from the time of sowing until the hay has been harvested. When the seeds are sown in autumn the stocking for the following few months will in any event be light, and it is doubtful if it is necessary to completely withhold animals from the renovated areas. It is not by any means always necessary to sow renovating seeds; if White Clover and leguminous herbs are present in moderate quantity, it is probable that phosphatic manures alone will produce the necessary results.

If the old swards have become very tufted, or overrun with weeds like Yellow Rattle or Wild Carrot,[2] or if Upright Brome is the predominant grass, it would probably pay best to break the sod and after putting the land through a rotation to sow down with a permanent mixture, or, of course, to keep such a field in rotation husbandry if necessary on the basis of a long duration ley. The same procedure should be applied to those inferior swards which have resulted from out-run sainfoin leys.[3] These fields are usually overrun with Soft Brome, Yorkshire Fog, Dandelion, and Bent, which renders proper cleaning operations essential.

[1] The question of the correct dressing to apply to various classes of grassland is dealt with in the closing sections of this article.

[2] The method of eradicating weeds from existing turfs is dealt with in detail in a subsequent section.

[3] Many of these are not as old as twenty years but are conveniently considered here.

Out-run Leys derived from the English Heaths on Dry Sands and Out-run Leys in general in Dry Sandy Regions of Low Rainfall.—*This type of out-run grass is one of the most difficult to deal with.* The character of the herbage varies considerably from season to season on dry sandy soils. The sward is never well knit together; bare ground is always plentiful and weeds often contribute over 40 per cent to the herbage. Soft Brome, dry and leafless, is sometimes the predominant grass, whilst Bent and Yorkshire Fog (small and somewhat leafless plants) and the fine-leaved Fescues frequently share dominance. Tall Oat Grass (often the bulbous form) and Cocksfoot are plentiful on some fields. Clovers and leguminous herbs are not usually well represented—Suckling Clover is the commonest of these. Silver Weed (*Potentilla anserina*), Sheep's Sorrel (*Rumex Acetosella*), Cat's Ear (*Hypochœris radicata*), and Convolvulus (*Convolvulus arvensis*) are probably the commonest weeds; Ribgrass is frequently plentiful but on these poor soils is undoubtedly to be regarded as a valuable plant. It is hardly possible by any means to establish a really good sward. The absence of a continuous and sufficient supply of water near the surface, rather than a relative absence of leguminous herbs, is, as Middleton (30) has shown, the chief reason for negligible benefits from large applications of basic slag. Frequent liberal dressings of farmyard manure, supplemented with small dressings of mixed artificials, should be resorted to. Radical improvement can, however, only be expected by a gradual process of building up fertility, which should aim at creating a soil more retentive of moisture. Moderate permanent grass can therefore sometimes be established after a number of years by first ploughing in soiling crops for a season or two in succession. The next process would be to seed down to grass with a cheap sheep grazing mixture for successive two- to three-year leys, when reliance would be largely placed on Ribgrass and White Clover, and later when fertility had been built up by this means and by the abundant application of appropriate manures, and when the sward showed evidence of " holding ", the field would be sown out with a suitable permanent mixture.

Out-run Leys derived from Heaths in Regions of High Rainfall and Out-run Leys in General on the Older Siliceous and Shaley Rocks.—The turf on these fields is frequently tufted and " benty ", and often consists of a dense mat of Bent Grass; there is usually but little loose soil at the surface. It is not surprising to find, therefore, that experiments conducted in Wales with renovating mixtures have not proved successful. Basic slag by no means always gives good results, and this is probably in part due to the matted nature of the sward—consisting as it does of excess of moss and of Bent—and to the turf forming a thin layer of partly decomposed vegetable matter, which tends to prevent the spread of the clover runners, and renders incorporation of the manure with surface soil practically impossible. Added to this, leguminous herbs are frequently present in but very small amount.

If reliance is to be placed on surface treatments it is generally desirable to graze the fields with ponies during the winter, to graze with cattle and sheep in the spring, and to apply a heavy dressing of basic slag under a severe dragging with a suitably tined implement; the slag should not, however, be applied until the tufted nature of the herbage has been combated, even if this entails a year's delay. The classes of soil here under review are remarkably deficient in lime. Lime as a top dressing is by no means always successful, and applications of quicklime frequently have the effect of diminishing the yield of grass for at least a year after application. Experiments conducted in Wales and experience elsewhere, however, indicate that when suitable dressings of lime are worked into the soil under the plough, the benefit to the field when it eventually again goes down to grass is always both real and lasting.

There are probably no classes of grassland from which the results to be expected from surface treatments are so uncertain, but which can be so radically and quickly improved by a process of breaking and re-seeding.

The advantages of breaking are manifest; lime and basic slag can be incorporated into the soil, competition with Bent is checked, and Wild White Clover and other valuable seeds can be given a certain hold on the ground. These soils are usually friable and free-working; they can be ploughed during the winter or early spring and a tilth can be obtained between April and June, when the field can, if so desired, be seeded down to grass, without any necessity of working through a rotation. Interesting examples have been noted both in Wales and in Devon where such fields having been ploughed, and neither manured nor seeded, have none the less reverted to sward of a better character than before broken. The effect of ploughing is, of course, to thoroughly aerate the soil to an extent that cannot be expected of any surface treatment, totally to remove the matted turfy surface layer, and to give all the less strongly represented plants a new start in their fight against Bent.[1] A complete failure of seed take is not likely, since really dry summers are the exception. Failures are most common when oats are used as a covering crop and when the straw goes down; consequently if an expensive permanent mixture is used it is generally safest to sow under rape.[2]

It may be said in general, then, that these out-run leys should be broken, the important questions to decide being (*a*) whether the fields should then be kept in rotation on the basis of the temporary ley, or whether they should be seeded down with a view to the formation of an improved permanent pasture; and (*b*) if this latter course is decided upon, whether

[1] Somerville (47), at Cockle Park, in 1897, experimented with a German plough, which cuts a turf 12 in. wide and about 3 in. deep, stirs the soil below, and replaces the turf. The results were not satisfactory. The rainfall during the two years following the treatment was, however, low, viz. 26·3 in. and 27·8 in.

[2] See R. G. Stapledon (52).

they should be seeded out at once or put through one rotation first. The first question is dealt with in a separate article; the following considerations afford an answer to the second.

When these out-run leys have been used almost wholly as meadows they are usually overrun with Yorkshire Fog or Soft Brome rather than with Bent, whilst on many fields so treated Yellow Rattle or Ox Eye Daisy may completely dominate the herbage—grasses sometimes contributing less than 30 per cent to the exceedingly poor hay crop. Yorkshire Fog, Soft Brome, and Yellow Rattle all produce abundance of seed which is shed early; consequently if such fields are ploughed and immediately put down to grass there is a danger that these, which are exceedingly bad weeds amongst young grass, may rapidly re-dominate the sward. Such fields should always therefore be put through a rotation before being seeded down, and the same procedure should apply to fields overrun with Wild Carrot.

Certain types of out-run leys occurring near woodlands are also likely to become overrun with weeds if broken and put down to grass without preliminary cleaning operations. Bracken in particular is likely immediately to recolonize the land, and the same to a lesser extent is true of gorse.[1] Plants like Ragwort (*Senecio* spp.) and St. John's Wort (*Hypericum* spp.) are also capable of immediately recolonizing woodland fields when re-put down to grass without a preliminary rotation.

Out-run pastures which have been used as sheep grazing only are often practically covered with large gregarious patches of the creeping thistle (*Cnicus arvensis*). Fields of this character should always be put through a cleaning rotation before being re-seeded to grass.

The Out-run Leys (with a tendency to revert to scrub) of the Intractable Clays.—Two chief types of out-run leys are met with on the heavy clays: (*a*) those which are dominated by a short more or less tufted vegetation consisting in the main of herbaceous plants, and (*b*) those which in part at all events are completely dominated by larger slightly herbaceous and frequently more woody plants.

The Herbaceous Out-run Leys of Intractable Clays.—It is these grasslands which have formed the subject of the classical experiments conducted at Cockle Park and elsewhere by Somerville (46–50), Middleton (30), Gilchrist (17 and 18), and others, and they have long been regarded as the natural " home " for basic slag.[2] The character of the unimproved

[1] Heavy stocking with young cattle as soon as the sward is formed, however, serves to suppress bracken, and sheep grazing suppresses the redevelopment of gorse. Hand pulling of reappearing bracken is a task that can be cheaply and efficiently performed by children.

[2] Somerville (46), in his Presidential Address to the Agricultural Section of the British Association at Bournemouth in 1919, deals exhaustively with the improvement of grassland and with the Cockle Park experiments, and gives numerous references to the literature of the subject.

sward on typical areas that have been experimented with, is set out in tabular form hereunder.

	At Cockle Park,[1] laid down about 40 years ago.		At Cransley,[2] laid down about 40 years ago.
Bent (*Agrostis* spp.)	66·8	....	trace
Heath Grass (*Triodia decumbens*)	2·7	....	—
Crested Dog's Tail (*Cynosurus cristatus*) ..	0·1	....	18·9
Quaking Grass (*Briza media*)..	1·7	....	—
Sheep's Fescue (*Festuca ovina*)	—	....	5·8
Yorkshire Fog (*Holcus lanatus*)	1·2	....	3·0
Perennial Ryegrass (*Lolium perenne*) ..	—	....	1·0
Cocksfoot (*Dactylis glomerata*)	4·0	....	3·4
Golden Oat Grass (*Trisetum flavescens*) ..	0·7	....	2·0
Sweet Vernal Grass (*Anthoxanthum odoratum*)	1·2	....	—
Leguminous Herbs	3·7	....	22·7
Weeds	13·9	....	39·5

The two sets of figures are not strictly comparable, the figures for Cockle Park being an analysis of a sub-plot in hay and an analysis of the hay as such. An analysis of the pasture herbage on the field would have shown a somewhat higher percentage of Bent, Heath Grass, and leguminous herbs and weeds. The fields at Cockle Park and Cransley are typical of the two main types of herbaceous sward met with on retentive clays. At Cockle Park when the experiments were started the herbage consisted chiefly of Bent and Heath Grass, Crested Dog's Tail and other more valuable grasses only being distributed plants. Bird's Foot Trefoil, Trefoil, and White Clover were the chief leguminous herbs, and Sedge (*Carex glauca*) the most abundant weed. At Cransley, Crested Dog's Tail was the dominant grass, Sheep's Fescue being well represented, but Bent only present in traces. Sedge as at Cockle Park was again plentiful.

Broadly speaking, these out-run leys differ from those associated with the siliceous rocks dealt with in the last section by the presence of Golden Oat Grass and Quaking Grass, sometimes in fair amount, by Trefoil (*Medicago lupulina*) being much more abundant and universal in the sward, and by the presence of *Carex glauca* frequently in large amount. The flora is thus seen to be intermediate between that of out-run leys on calcareous soils and of similar leys on siliceous soils.

Large initial dressings of basic slag have been competent to alter completely the character of these grasslands from the stock producing point of view.

Somerville (46), discussing the results of experiments at different centres, states: "At Cockle Park, for instance, the plot, dressed once with half a ton of slag, was at the end of nine years producing three times as much mutton as the continuously unmanured ground, while at Seving-

[1] Analysis of hay, see Somerville (47). [2] Analysis of pasture, see Armstrong (1).

ton and Cransley the yield at the end of nine and eight years respectively was 70 to 80 per cent greater." Experiments and trials have shown that a high measure of fertility may be maintained over a prolonged series of years if supplementary dressings are applied at suitable intervals. This aspect of the manurial treatment of clays is dealt with subsequently; it is only necessary here to emphasize the fact that top dressings with basic slag afford the best and cheapest means of improving these pastures. Renovating mixtures are sometimes necessary on the heavy clays; Middleton (30) considers that renovating seeds should be tried when White Clover plants are few (one to a square yard) or absent. Harrowing these heavy clays with a view to obtaining an earthy matrix for the seeds is unlikely to prove of much use. In this connection Middleton states: "By repeated harrowings in wet weather a slight surface tilth was obtained on a clay soil at Cockle Park, but the results did not justify the cost." There is need for much experimental work in connection with renovating mixtures especially on intractable clays that are difficult and costly to break, and upon which the preparation of a seed bed must involve a summer fallow, the expenditure of much labour and skill, and exceptionally favourable climatic conditions. Every endeavour should be made to graze the herbage closely before seeding; to sow during wet weather; and it is not unlikely that the application of a good compost would much assist matters. The seeding should be heavier than on calcareous soils, where a tilth can be more easily obtained. If Wild White Clover alone is sown, results could hardly be expected from less than 3 lb. to 4 lb. to the acre. The following mixture is suggested with a view to supplementing Wild White Clover:

	Pounds per Acre.
Crested Dog's Tail	2
Rough-stalked Meadow Grass	$1\frac{1}{2}$
Wild White Clover	2
Trefoil	$1\frac{1}{2}$
Yellow Suckling Clover	1
	8

The Slightly Herbaceous Out-run Leys of the Intractable Clays.—These fields always present a patchwork appearance; at their worst they may be completely dominated by Dyer's Green Weed (*Genista tinctoria*). Thorn bushes are generally present to a greater or less extent. Patches of varying size occur consisting of a herbaceous sward similar to the type considered above, but even these patches are usually less gramineous and contain fewer clovers and leguminous herbs and more weeds, whilst other patches occur almost devoid of grasses and clovers, but colonized by masses of Sedges, Fleabane (*Erigeron acris*), Mint (*Mentha* spp.), Horse Tail (*Equisetum* spp.), and other weeds; whilst, apart from the various patches, weeds of one sort and another are the predominating elements in the flora. Some idea of the weed flora on such fields as this will be given when it is said that over forty species were listed on one field without attempting any critical analysis of the herbage, and that on the field in question five species of thistle were flourishing exceedingly.[1] The grasses usually include not inconsiderable amounts of Tall Oat Grass, Rough-stalked Meadow Grass, and Brome Grasses, in addition to those usually found of the more herbaceous type. The Leguminosæ, although not covering much ground, are generally represented by a number of species, Wild Vetches and allies being common, and in some districts the Zig Zag Clover (*Trifolium medium*) finds a suitable habitat.

The above heterogeneous assemblage of plants denotes hopeless understocking, which indicates that the first step in the direction of improvement must be to initiate some radical change that will make it possible to graze such fields more heavily. The Dyer's Green Weed appears to be but very little eaten by cattle, and it is difficult to eradicate; regular cutting to prevent seeding checks its spread, and it is to be supposed that repeated cutting year after year, and more than once a year, would eventually tell against the plant as it certainly does against the Sawwort (*Serratula tinctoria*), Meadow and Creeping Thistles (*Cnicus pratensis* et *arvensis*). It is sometimes said that slag decreases Dyer's Green Weed. The evidence of this being so is somewhat slender; cases where it would seem to have had the opposite effect have been noted, and increases in the amount of Meadow Thistle after slag have also been observed. Dressing with slag would, of course, improve the sward zones by developing the Leguminosæ and decreasing Sedges, and therefore, by making it possible to stock the field more heavily, would react beneficially on the whole area. Although, generally speaking, feeding cake to animals on grassland does not effect much if any improvement on the herbage, cake or hay or roots or anything that would make it possible to keep animals on these derelict fields would almost certainly produce good results.

This class of grassland, if grassland it can be called, can only be improved very slowly by surface treatments, and at very appreciable expense, involving, as it does, a considerable amount of labour; for as well as methodical cutting of the Green Weed and Thistles it is generally necessary or desirable to undertake drainage operations. Useful results frequently follow from the cutting of fairly deep open drains, and in some cases it may be found possible to mole drain fields of this character. These fields do not offer much hope of success from renovating mixtures, as there is but little chance of obtaining a surface tilth for the seeds. If substantial improve-

[1] Namely: *Cnicus palustris, C. arvensis, C. lanceolatus, C. acaulis, C. pratensis*. Other abundantly occurring plants not mentioned above are: Hard Heads (*Centaurea nigra*), Devil's Bit (*Scabiosa succisa*), and Agrimony (*Agrimonia Eupatoria*), and the Common Way Thistle or Sawwort (*Serratula tinctoria*) frequently very abundant.

ment is to be looked for within a reasonable length of time, more valuable plants must somehow be introduced, and any means that might be expected to produce results should perhaps be tried before contemplating breaking these difficult clays. A modification of the old-fashioned plan of " inoculation " might well prove efficacious.

Inoculation was practised in the seventies and eighties on heavy clays; the methods then employed are discussed by Morgan Evans (34) and James Howard (23). Inoculation was used as a method of putting a ploughed field down to grass. Briefly the plan consisted of cutting strips 2 in. by 2 in. from an excellent sward; these strips were pulled to pieces about 2 in. long and were planted all over the field to be put down to grass at distances of about 9 in. apart in every direction. By this means some excellent pastures were established on heavy soils, although at considerable cost and with a certain amount of harm to the fields from which the strips of turf were removed. It would seem probable that inoculation might produce good results much more cheaply if employed upon a pre-existing sward which it was desired to improve.

Three possible methods suggest themselves. (*a*) Plough strips across the field at about 2 to 3 yd. intervals, remove the turf and replace with turf full of White Clover taken from a good field. (*b*) Having sown a large patch, in a garden or elsewhere, of Wild White Clover—during very wet weather when the ground is soft—dibble, say, two to three plants of this Wild White Clover to every square yard of the field. (*c*) Plough and cultivate narrow strips across the field at 2- or 3-yard intervals, and when a tilth has been obtained, sow these strips with a mixture consisting largely of Wild White Clover. The seeding should be heavy, since at the best the seed bed is not likely to be very favourable. The following mixture—to sow all the strips on an acre—would probably meet the case:

	Pounds per Acre.
Perennial Ryegrass (a good indigenous strain) ..	6
Rough-stalked Meadow Grass	1½
Crested Dog's Tail	1½
Wild White Clover	2
Late-flowering Red Clover	2
	13

Experiments on these lines, followed up by heavy dressings of slag all over the field, and by increased stocking as soon as the herbage began to be improved, are urgently needed. Heroic methods are necessary on these pastures, and it must always be remembered that heavy clays can be made to carry good pastures; moreover " The Manuring for Mutton " experiments indicate that the sort of profits to be looked for, if only success can be achieved, justify a not inconsiderable expenditure of capital. A small scale trial would not be very costly.

Wrightson (59) tells us that time was when it was not an uncommon practice to subject these heavy clays to two successive summer fallows before sowing with permanent seeds; he states, moreover, that he "has seen excellent results . . . achieved on clay ground with the requisite liming and dunging". Two summer fallows would certainly be necessary in order completely to destroy the useless herbage of the character described above.

When at last a clean seed bed had been obtained it would be risky to sow the seeds under corn, and Wrightson's suggestion of sowing early in August without a nurse crop is probably a sound one. He is also strongly of the opinion that it is a mistake to take hay the following summer; this is a procedure always attended with risk, and since the seed mixture would of necessity be an expensive one, and the cultivations very costly, the wise plan would undoubtedly be to graze the field, and only to graze it lightly until the sward was fairly established.

Out-run Leys on Soils Capable of Producing High-class Tended Grasslands.—Out-run leys are for one cause or another frequently met with on soils capable of carrying excellent grass; leys may also become out-run in no more than three or four years. The former out-run leys can be more conveniently dealt with in the next section under "Tended Grasslands", and the latter are in no sense of the word permanent grass, and are therefore referred to in the article on "Temporary Ley", p. 43.

TENDED GRASSLANDS

The tended grasslands constitute the permanent pastures and meadows as generally understood. They usually occur on more or less well aerated loams and on the less stiff clays. The tended permanent pastures, like the untended, are capable of classification on a botanical basis. The types are, however, not so well defined since the husbandry practised on them is more uniform from district to district, moreover the heavy grazing and general management become almost dominating features of the environment. These pastures vary in sympathy with alterations of soil and climate rather more by virtue of qualitative and quantitative differences in the miscellaneous flora, and less important grasses and clovers, than in striking rearrangements of the more valuable grasses and clovers, although extreme types differ not inconsiderably in this respect also.

For the present purpose it will be most convenient to classify the tended permanent pastures as follows:

1. *First-class (Fatting Pastures).*—These pastures are capable at their best of fattening beasts during the summer months without the addition of feeding stuffs.

2. *Second-class (Dairy Pastures).*—These will bring beasts to a for-

ward state without additional feeding stuffs, and will carry pedigree dairy herds to good advantage.

3. *Third-class* (*General Purposes Pastures and Sheep Pastures*).—These will not fatten cattle unaided to any very great extent and will not keep the best classes of animal in full milk; in practice, however, they are accessory to the production of large quantities of beef and of milk and are extensively used for fattening sheep.

4. *Fourth-class* (*Out-run Pastures*).—These are pastures which are wholly or partially neglected, and do not therefore properly belong to the tended types, and in the main this class of grassland is very similar to the untended types which formed the topic of the preceding section. They form a link between the untended and tended, but hardly call for separate treatment. They often carry a certain number of more or less inferior dairy animals, but are chiefly used for sheep runs and for store cattle.

Permanent meadows as such will not be dealt with as separate types except in the case of water meadows, which constitute an interesting and well defined class of permanent grass.

A brief description of the botanical characteristics of the above types is given hereunder. The methods of maintaining and improving the productivity of tended pastures as a whole will form the subject of the subsequent section.

The Fatting Pastures.

These are best exemplified by the famous pastures of Leicestershire and Northamptonshire. Fatting pastures also occur in considerable amount on Romney Marsh and in the Blackmoor Vale, and to a greater or less extent in most grazing districts. Typical botanical analyses of fatting pastures are given in the table on the following page.

The figures for Leicestershire and Northamptonshire are based on analyses made on turfs by Armstrong (1) and by the present writer, for Blackmoor Vale on similar analyses by the present writer, and for Romney Marsh on analyses on the cut herbage by Hall and Russell (22). The Romney Marsh figures are therefore not strictly comparable to the others, and do not do anything like full justice to White Clover or to the weeds.

The consistent abundance of Perennial Ryegrass and White Clover is noteworthy in all cases, as is the general paucity of weeds. It is also to be noticed that neither Meadow Fescue nor Meadow Foxtail are generally conspicuous contributors to fatting pastures, but that Bent is often plentiful and Yorkshire Fog sometimes present in appreciable amounts. It is interesting to observe that Meadow Barley Grass appears to be generally associated with these pastures although usually only as a distributed plant; Golden Oat Grass, although represented on the Leicester-

THE BOTANICAL COMPOSITION OF THE HERBAGE OF FATTING PASTURES IN TERMS OF PERCENTAGE CONTRIBUTION OF THE DIFFERENT SPECIES TO THE FLORA

	Leicestershire and Northamptonshire.	Blackmoor Vale.	Romney Marsh.
Perennial Ryegrass (*Lolium perenne*) ..	27–46	14–20	32–80
Bent (*Agrostis* spp.)	4–6	5–30	2–23
Crested Dog's Tail (*Cynosurus cristatus*)	5–15	2–9	1–15
Yellow Oat Grass (*Trisetum flavescens*)	trace–2	1–3	1–8
Meadow Barley Grass (*Hordeum pratense*)	trace	trace	trace
Timothy (*Phleum pratense*)	1–3	trace–4	trace
Rough-stalked Meadow Grass (*Poa trivialis*)	2–6	7–12	1–13
Yorkshire Fog (*Holcus lanatus*)	1–9	1–5	1
Cocksfoot (*Dactylis glomerata*)	trace–3	trace–5	—
Sheep's Fescue (*Festuca ovina*, *F. rubra*)	1–8	9–17	trace
Meadow Foxtail (*Alopecurus pratensis*) ..	trace	trace	—
Sweet Vernal Grass (*Anthoxanthum odoratum*)	0–3	1–3	—
White Clover (*Trifolium repens*) ..	24–26	12–27	1–12
Yarrow (*Achillea millefolium*)	trace–1	1–2	—
Weeds	2–14	4	1–15

shire pastures, is considerably more plentiful and more generally distributed on Romney Marsh and in the Blackmoor Vale. On many of the Blackmoor Vale fields Cocksfoot was a very appreciable contributor to the herbage, and the comparatively high place taken by Crested Dog's Tail is not without significance.

White Clover is often the only appreciable representative of the Leguminosæ, and it is to be remarked that Wild Red Clover is seldom associated in any quantity with the highest grade pastures.

The number of weed species is usually comparatively few; numerous fields have been examined where the total flora (flowering plants) is represented by less than twenty-five species and sometimes by no more than twenty. It should be noted that Yarrow is almost invariably associated with fatting pastures, it was particularly in evidence on some of the Blackmoor Vale fields.

The Dairy Pastures.

These occur on a greater variety of soils than do the fatting pastures proper, and therefore vary considerably in floristic properties from district to district. When these occur on calcareous soils or soils over calcareous rocks the flora may sometimes run to somewhat over thirty species, but usually the number is not much greater than on the fatting pastures.

The chief grasses are the same as on the fatting pastures. Bent may, however, exceed 50 per cent and Crested Dog's Tail may reach to 20 per cent or over.

Meadow Foxtail, Cocksfoot, and Yorkshire Fog are often really plentiful, but this is likely to be due to occasional mowing, a practice not infrequent on these pastures. The same reason may account for a frequently greater abundance of Red Fescue. Meadow Fescue becomes an important grass in certain districts. White Clover is often very abundant, but is associated with somewhat larger amounts of plants like Wild Red Clover, Bird's Foot Trefoil, and Meadow Vetchling. Differences in the miscellaneous flora occur; the number of species represented is often slightly greater, and it would seem probable that Self-heal, Sorrel, *Leontodon* spp., and Sedges are somewhat more abundant on second-class (as here defined) than on the best fatting fields, but the same is not true of either Buttercups, Ribgrass, or the Daisy.

General Purposes and Sheep Pastures.

Of the tended grasslands this forms perhaps the most important class. It is probably more widespread than the first and second classes put together. In many districts only a comparatively few fields are even second-class, and in fatting and dairy districts a very large proportion of the fields are in reality of but third-class value. Third-class pastures (as here defined) are looked after more or less, but they would probably repay skilled management better than almost any other class of grassland. The third-class pastures vary very much amongst themselves, for they occur on all soil types and are managed in every conceivable manner. They are frequently not kept in regular pasture, but hay is often taken for runs of years together or periodically. Under one tenant they may carry practically only sheep for a number of years, and under the next be used for general purposes. The flora is of necessity therefore a varied one. Nevertheless they have certain more or less well-marked botanical features in common.

Ryegrass very seldom takes a dominant position, at best dominance is shared with Crested Dog's Tail or Bent; frequently, however, Ryegrass is but a subsidiary species. On some sheep pastures Crested Dog's Tail becomes actually the dominant grass. Bent may contribute over 50 per cent to the herbage, thus showing a tendency towards the untended outrun leys. Meadow Fescue and Meadow Foxtail are quite absent from perhaps the vast majority of these pastures. Yorkshire Fog, Rough-stalked Meadow Grass, Fine-leaved Fescues, and Cocksfoot are often abundant, the Fine-leaved Fescues not infrequently becoming co-dominant plants.

White Clover is not so consistently abundant as on first- and second-class pastures, but on certain fields it may be more abundant than on the best fatting pastures, contributions of over 30 per cent being not at all uncommon. Bird's Foot Trefoil, Suckling Clover, and other Leguminosæ are, however, more plentiful on third-class than on better pastures. Weeds are generally abundant, commonly contributing over 15 per cent to the sward and not infrequently as much as or more than 30 per cent. The number of weed species is usually considerable and the total number of species (valuable and valueless) on these pastures tends to be large, often exceeding forty and sometimes, particularly on calcareous soils, reaching to fifty. Amongst the weeds, heath herbs may be met with, thus showing a tendency towards the untended.

Before concluding this brief review of pasture types, it is interesting to note that the number of species contributing to the flora of a field affords a rough sort of guide as to quality of the sward. The flora of the really best fields generally totals to something between twenty and thirty species. On poorer fields the total may run to fifty (tended) and to over sixty (untended), or if Bent has become completely dominant (untended) the number of species may be considerably less than twenty. The same criterion applies in a broad way to the natural pastures also, for the Nardus pastures with but few contributing species and the English heaths with numerous species are of altogether less value than the heath Fescue pastures with an average number of species.

Water Meadows.

The botanical composition of irrigated water meadows varies but slightly from year to year. This is no doubt due to the absolutely constant dominating factor (irrigation) superimposed by man upon these fields. The fatting pastures are also more uniform in botanical composition from year to year than other tended types. The husbandry in their case also being unchanged over long periods of years. Thus the fatting pastures and the water meadows are remarkably stable, being in fact as unchanging as are the truly natural pastures—the stabilizing master factors are, however, the environmental influences of irrigation and stocking respectively rather than the effects of soil, climate, or altitude.

Clovers are practically absent from water meadows. A series of analyses by Fream (15 and 16) in 1888–90 showed 0·5 per cent as the maximum contribution on water meadows on the banks of the Christchurch Avon. Water meadows near Cirencester analysed by the present writer in 1911 gave 0·4 per cent of clover.

Grasses dominate these meadows, contributing from about 89 per cent (Christchurch Avon) to as much as 97 per cent (Cirencester) to the hay, the miscellaneous herbage therefore contributing from about 3 to about 10 per cent. Yorkshire Fog and Perennial Ryegrass usually share dominance, together often making up half the hay crop. Soft Brome

Grass, Rough-stalked Meadow Grass, and Timothy are often plentiful, whilst Tall Oat Grass, Golden Oat Grass, Bent, and Crested Dog's Tail are freely represented. The following grasses not usually associated to any extent with normal grasslands may sometimes together contribute about 10 per cent to the herbage: Floating Poa (*Glyceria fluitans*), Reed Poa (*G. aquatica*), Reed Grass (*Phalaris arundinacea*), Common Reed (*Phragmites communis*), and Marsh Foxtail (*Alopecuris geniculatus*).

Meadows and Pastures.

The botanical composition of the herbage of meadows differs in several respects from that of pastures. Certain grasses tend to become much more plentiful under meadow conditions; on calcareous soils this is particularly true of the Upright Brome Grass (*Bromus erectus*), which on the Cotswolds frequently contributes as much as 50 per cent to 75 per cent to the hay crop; whilst on pastures on similar soils it may be almost absent and seldom contributes more than about 10 per cent to the herbage. Of the Fine-leaved Fescues the ordinary Sheep's Fescue (*Festuca ovina*) of downs and siliceous grasslands reaches its greatest abundance on pastures, whilst Red Fescue (*Festuca rubra*) and certain varieties of Sheep's Fescue (e.g. that variety common on tended Cotswold grasslands) reach their highest figures on meadows. Of the Bents, *Agrostis vulgaris* is more essentially a pasture plant, whilst *Agrostis stolonifera* (and other varieties of *A. alba*) reach high figures on both pastures and meadows. Cocksfoot is much more plentiful on old meadows than on old pastures, and the same is true of Meadow Foxtail, and also, although to a lesser extent, of Golden Oat Grass.

Perennial Ryegrass is about equally plentiful on old pastures and on old meadows. Rough-stalked Meadow Grass probably reaches its greatest abundance on meadows; Crested Dog's Tail, although usually regarded as more essentially a pasture plant, often contributes in good amount to the hay on old meadows. Yorkshire Fog and Soft Brome Grass are considerably more plentiful on old meadows than on old pastures, but both grasses are met with in greatest amount on deteriorating leys from which hay has been taken for four to six years in succession. Amongst the Leguminosæ, Wild Red Clover, Yellow Suckling Clover, Meadow Vetchling (*Lathyrus pratensis*), and the Wild Vetches (*Vicia Cracca* and *V. hirsuta*), are decidedly more plentiful on old meadows than on old pastures, whilst as a weed Restharrow (*Ononis* spp.) is commonest on poor pastures on heavy clays. The miscellaneous plants of tended grasslands are also influenced in their distribution according as pasture or meadow conditions prevail. It will be convenient to consider these plants under three headings as follows:

(*a*) Miscellaneous plants which are usually more plentiful on old meadows than on old pastures.

(*b*) Miscellaneous plants which are usually more plentiful on old pastures than on old meadows.

(*c*) Miscellaneous plants which are usually equally plentiful on old pastures and on old meadows.[1]

(*a*) Miscellaneous Plants which are usually more Plentiful on Old Meadows than on Old Pastures.

Cuckoo Flower (*Cardamine pratensis*).—Sometimes plentiful on damp meadows, or on understocked and neglected damp pastures; generally indicates the need of drainage.

Ragged Robin (*Lychnis Flos-cuculi*). — Often plentiful on damp meadows and on poor and more or less neglected damp pastures requiring drainage.

Common Mallow (*Malva sylvestris*).—Sometimes occurs to an appreciable extent on damp meadows.

Meadow Crane's Bill (*Geranium pratense*).—In certain districts becomes a serious weed on moist meadows. Milburn relates that around hedges and where the ground has been repeatedly treaded by cattle this Crane's Bill appears to be eliminated.

Dove's Foot Crane's Bill (*Geranium molle*).—Is met with as a plentiful weed on meadows on some sandy and calcareous soils.

Greater Burnet (*Poterium officinale*).—In certain districts particularly, on damp loams, this may become a plentiful weed.

Beaked Parsley (*Anthriscus* spp.).—May become exceedingly plentiful on neglected meadows; when this is the case the hay should be cut early.

Hog Weed (*Heracleum Sphondylium*).—Although a weed of pastures as well as of meadows this plant attains to its greatest abundance on meadows and on understocked and neglected pastures. It is grazed to a certain extent by cattle, especially in dry seasons, and can be decreased by heavily grazing with sheep early in the season. Burnet Saxifrage (*Pimpinella Saxifraga*) and Pepper Saxifrage (*Silaus flavescens*) are also umbelliferous plants commonly occurring on meadows.

Ox Eye Daisy (*Chrysanthemum leucanthemum*).—This plant is most plentiful on out-run leys used as meadows, but also occurs freely on old meadows. In extreme cases it may almost dominate fields; when this is so the herbage is usually poor, and if practicable the sod should be broken and the field put through a rotation.

Knapweed (*Centaurea nigra*).—Although occurring freely on pastures

[1] It is beyond the scope of this article to give botanical descriptions of the various plants; the reader is referred to such floras as Bentham and Hooker, and Johns' *Flowers of the Garden*, and to Long's book, *Common Weeds of the Farm and Garden*. In compiling these notes on weeds the information given in Long's book and in papers by Brenchley (6, 7, 8) and Woodruffe-Peacock (58) have been freely drawn upon, and for further details the reader is referred to these works.

is most plentiful on meadows. Heavy grazing with sheep early in the spring tends to decrease it.

Rough Hawkbit (*Leontodon hispidis*).—Unlike Cat's Ear (*Hypochœris radicata*) appears to have a decided partiality for meadows, and like other mat herbs (e.g. Plantains, Dandelion, Cat's Ear, &c.) is decreased by ammonium sulphate.

Dandelion (*Taraxacum officinale*).—Plentiful as this plant often is on pastures, it undoubtedly attains to its greatest development under meadow conditions, especially when these are heavily dressed with farmyard manures. It is most abundant, however, on out-run sainfoin leys that have been down for about six to eight years.

Yellow Rattle (*Rhinanthus* spp.).—This weed, which is parasitic on the roots of grasses, is often very plentiful on old meadows and on leys older than four to five years which are continuously cut for hay. It may be reduced considerably by grazing such fields for two or three years, or by cutting the hay very early before the seed ripens. Recent trials conducted in Wales (3) show that agricultural salt ground to a fine powder and applied at the rate of 6 to 10 cwt. to the acre when the seedling plants are quite small, or better when the seeds are germinating (middle of April to early May), will completely eradicate this weed. At Cockle Park, however, the use of salt has not proved successful, and the best means of eradication has been early cutting. Dusty nitrolim (2 cwt. per acre) applied in dry weather at the end of May completely cleared the weed from plots so treated at the Harper Adams Agricultural College (20). Yellow Rattle sometimes invades arable fields, and Brenchley (6) has noted a case in Wilts, in 1911, where a barley crop was very badly attacked by it. It is interesting to note that Wild Red Clover is often very plentiful on heavy soils; on fields full of Yellow Rattle this may be due to considerably decreased competition with grasses.

Snake's-weed (*Polygonum Bistorta*).—A weed which sometimes forms large gregarious masses on meadows; it spreads somewhat rapidly and should be totally removed by digging up.

Orchids (such as *Orchis Morio*, *O. maculata*, *Habenaria bifolia*) are more plentiful on meadows than pastures, *O. maculata* being frequently abundant on poor meadows on stiff clays.

Garlic (*Allium vineale*).—This plant is objectionable because it frequently taints the milk of cows eating it. Hand pulling in June is recommended as a means of eradication.

Meadow Saffron (*Colchicum autumnale*). — This plant is highly poisonous in all its parts. It is local in distribution, but may be very plentiful on individual fields; this is markedly so in parts of Herefordshire and Breconshire. It is dangerous to graze fields in spring or autumn when the leaves or the flowers are in the herbage, but during the resting periods of the plant—summer and winter—grazing is safe. Hay containing the dried leaves must also be regarded with suspicion. The leaves should be repeatedly hand pulled in the spring.

(*b*) Miscellaneous Plants which are usually more Plentiful on Old Pastures than on Old Meadows.

Purging Flax (*Linum catharticum*).—This little plant is frequently common, not only on calcareous soils, but on thin siliceous soils also; if plentiful it is harmful, as it may cause purging.

Greenweed (*Genista tinctoria*).—*It is supposed that when eaten by* cows it makes the milk bitter, but is usually neglected by stock; on some soils it may be decreased by good dressings of lime.

Meadow Sweet (*Spiræa Ulmaria*).—Is often plentiful about flushes on old pastures; frequent cutting and drainage tend to eliminate it.

Salad Burnet (*Poterium sanguisorba*).—May occur freely on calcareous soils; in its younger stages it is eaten to some extent by stock.

Earth-nut (*Conopodium denudatum*).—Is most common on pastures on comparatively thin soils.

Creeping Thistle (*Cnicus arvensis*).—This thistle is particularly common *on pastures almost entirely grazed by sheep, and especially on those parts* of the fields where the sheep tend to congregate. It is difficult to eradicate owing to its underground runners. It may be kept in check by surface cutting twice a year, in the late spring and in the autumn—that is to say after the stems are 6 to 8 in. high and again before the seed has ripened. Farmers often hold that this weed is not spread to any extent by seed, the reason for this view probably being that much of the thistle-down carried by the wind is not attached to fully developed seeds. Ripe seed germinates freely and will readily establish itself wherever it falls on suitable bare ground, whether on pasture or arable fields. Horned stock graze thistles to a certain extent, and, as Brenchley has remarked, will frequently eat them readily directly after they have been cut, but will not do so after they have begun to wither.

Boar Thistle (*Cnicus lanceolatus*).—The rosette should be cut with a spud early in the spring or the stems cut after the flower has been produced but before the seed has developed.

Marsh Thistle (*Cnicus palustris*).—Occurs freely on spongy pastures and about the outlet of springs; should be treated in the same way as Boar Thistle.

Stemless Thistle (*Cnicus acaulis*).—Often very plentiful in calcareous pastures; should be cut with a spud.

Carline Thistle (*Carlina vulgaris*).—Is commonly met with in dry pastures near the sea and on calcareous pastures.

Soft Crepis (*Crepis virens*).—This weed is frequently common on temporary leys when used as meadows, but on permanent fields is more essentially a pasture plant.

Ragwort (*Senecio Jacobæa*).—Is probably more plentiful as a pasture than a meadow weed; it occurs in greatest amount on poor understocked pastures. It may be almost totally eliminated by heavy grazing with sheep.

Sedges (*Carex* spp.).—May dominate large areas of ground on wet pastures, but are not uncommon on dry pastures also (e.g. *C. glauca*) on calcareous soils.

Rushes (*Juncus* spp.).—Are decreased by repeated cutting, and are consequently more abundant on pastures than meadows. Rushes are grazed to a real extent by horned stock, and this applies in particular to certain species.

Mosses.—The shading of a hay crop tends to decrease moss which is most plentiful on pastures. Liberal dressings with newly manufactured superphosphate have a depressing influence on moss.

(*c*) MISCELLANEOUS PLANTS WHICH ARE USUALLY EQUALLY PLENTIFUL ON OLD PASTURES AND ON OLD MEADOWS.

Buttercups (*Ranunculus* spp.).—Upright Crowfoot (*R. acris*) occurs chiefly on wet grassland, and does not usually colonize the ground so completely as does the Creeping Buttercup (*R. repens*). This latter Buttercup is a plentiful weed on grassland on siliceous soils, being plentiful on good and poor pastures alike. The Creeping Buttercup is also a weed of arable land, and where it abounds fields should be well cleaned before being put away to grass. The Bulbous Buttercup (*R. bulbosus*) is most plentiful on calcareous soils, but occurs also on good loams.

Buttercups are not readily eaten by stock, but when the herbage is sparse they are not totally neglected; they undoubtedly, however, take the place of more valuable plants, and apart from the possibility of their tainting the milk are to be regarded as objectionable weeds.

Mouse Ear Chickweed (*Cerastium vulgatum*).—An ubiquitous weed of grasslands; being a small and harmless plant it is not of much significance.

Cut-leaved Crane's Bill (*Geranium dissectum*).—Although most plentiful on young leys (being freely introduced with Red Clover seed), is sometimes met with in appreciable amount on old grasslands.

Silver Weed (*Potentilla anserina*).—Colonizes such areas as are continually under surface water during the winter, and about gates and stationary feeding troughs and generally on ground much trodden by cattle. Sometimes introduced on grassland with road scrapings and hedge cleanings.

Lady's Mantle (*Alchemilla vulgaris*).—Common on some grasslands, but not usually troublesome.

Wild Carrot (*Daucus Carota*).—Often a very troublesome weed of grassland; it occurs alike on young leys and old pastures and meadows. It flowers late (on the aftermath); when plentiful, the mowers should be sent over the aftermath with the knives set high in order to cut the flowers.

Badly infested fields should be broken and put through a cleaning rotation and finally re-seeded. The seeds are freely introduced with Red Clover.

Yellow Bedstraw (*Galium verum*).—Plentiful on many sandy, loamy, and calcareous soils.

Daisy (*Bellis perennis*).—A generally distributed weed of grassland sometimes covering a considerable percentage of the ground. During hard winters when the grasses are making but little growth it may be heavily grazed by sheep. When present in quantity, however, it checks the development of valuable grasses and of White Clover.

Yarrow (*Achillea Millefolium*).—This plant is generally fairly plentiful on the best grasslands, and occurs also on poorer types. It is grazed by animals, and in some districts it is held that it increases milk production. In dry seasons it tends to monopolize an undue proportion of the ground.

Cat's Ear (*Hypochœris radicata*).—The seeds of this common weed of grassland usually occur in samples of Ryegrasses. The leaves are sometimes eaten to a certain extent by stock, but like other " mat herbs " it reacts against a uniform sward and is therefore a troublesome weed.

Autumnal Hawkbit (*Leontodon autumnalis*).—This weed is most plentiful on grassland requiring attention. It is, however, usually present in smaller amounts on some of the best pastures.

Fleabane (*Pulicaria dysenterica*).—This plant is locally a very troublesome weed of grassland on heavy soils in the south and west of England. It has an extensive underground root-stock, and is difficult to eradicate. It may also persist as an arable weed. Where practicable the sod should be broken and the land thoroughly cleaned.

Bindweed (*Convolvulus arvensis*).—It is interesting to note that this plant, usually regarded as an essentially arable weed, is far from uncommon even on old grassland.

Plantains (*Plantago* spp.).—Ribgrass (*P. lanceolata*) is one of the most widespread miscellaneous plants of grassland. Its leaves are eaten by both cattle and by sheep, but are troublesome in a hay crop. It has a decided value on very poor dry soils and in unusually dry seasons. On good grassland it is an undesirable weed, and on poorer types it should not be present to excess. The Hoary Plantain (*P. media*) is most plentiful on calcareous soils; its leaves are not much eaten by stock. The Broad-leaved Plantain (*P. major*), like Silver Weed, tends to colonize much trodden areas near gates and around feeding troughs.

The Speedwells (*Veronica* spp.).—The Germander Speedwell (*V. chamædrys*) and Thyme-leaved Speedwell (*V. serpyllifolia*) are often plentiful on pastures and meadows alike; on certain types of poorer grasslands the former species may become excessive.

Red Bartsia (*Bartsia Odontites*).—This plant occurs on quite good grasslands, and abundantly on more inferior types. It ripens considerable amounts of seed and persists equally well as an arable weed; it is prone to become remarkably abundant on certain fields after dry years like 1911 and 1921.

Self-heal (*Prunella vulgaris*). — One of the most widely spread weeds of grassland, often colonizing considerable areas of ground. White Clover, Crested Dog's Tail, and Rough-stalked Meadow Grass should be encouraged to compete against it, consequently heavy dressings of basic slag are efficacious.

Common Bugle (*Ajuga reptans*).—Sometimes plentiful on grassland requiring drainage.

Cowslip (*Primula veris*).—Plentiful on calcareous loams.

Docks (*Rumex* spp.).—Docks are troublesome weeds of grassland and are sometimes plentiful especially near gates. They should be repeatedly spudded out, every endeavour being made to remove the whole roots.

Sheep's Sorrel (*Rumex Acetosella*).—May occur as an abundant weed in grasslands on poor soils and on peat; it is, however, most troublesome on young leys on land deficient in lime.

Sorrel Dock (*Rumex Acetosa*).—This is the most plentiful Rumex of grassland. On old meadows, on soils deficient in lime and heavily manured with farmyard manure, it often contributes excessively to the hay crop. It is not so noticeable on pastures, but is frequently abundant. When present in large amount the land should be limed. Many meadows are so badly infected with Sorrel that it would probably be wisest to break the sod and put the field through a rotation, the more so perhaps since Sorrel usually denotes a certain measure of fertility.

Stinging Nettle (*Urtica dioica*).—This weed, freely associated with the habitations of man, sometimes colonizes patches on grassland or invades parts of fields near the hedges. It is a common hedgerow plant around some of the finest pastures in Leicestershire. Nettles can soon be destroyed by frequent cutting.

Wood Rushes (*Luzula* spp.).—*L. campestris* occurs freely on tended grasslands, it is one of the earliest plants to flower, and thus serves as a useful indication of the commencement of growth in the spring.

In addition to the miscellaneous plants dealt with under the three headings above, there are species not normally associated with pastures and meadows which are none the less of interest to the grazier. Certain poisonous plants are often met with near watercourses and in or about woods to which cattle and sheep may gain ready access, and in dry seasons, particularly when keep is scarce, these are plants which may cause the death of animals.

It is not necessary in this article to deal exhaustively with the somewhat controversial question of poisonous plants.[1] Three species, however, should be mentioned.

[1] See Long (28) for a detailed consideration of poisonous plants.

Hemlock (*Conium maculatum*).—This plant grows near streams and on hedge banks, and although not often eaten by stock is highly poisonous and should be removed from areas frequented by animals.

Water Dropwort (*Œnanthe crocata*).—This plant grows in and about streams, and is not an infrequent cause of cattle poisoning. It is of commoner occurrence in areas accessible to cattle than Hemlock, and is also more likely to be eaten. The plant should be removed and not left on the banks of watercourses that have been cleared out.

Dog's Mercury (*Mercurialis perennis*).—A common plant of woods and wood edges, sometimes spreading out into fields near woods. Cattle do not appear to graze this plant, but cases of sheep and lamb poisoning are not at all infrequent in dry seasons.

The Care of Tended Pastures.

Under this heading it will be desirable to consider in some detail—at the risk of a certain amount of reiteration—the question of the management of grasslands as a whole, and consequently much of what follows is applicable to untended and to natural grasslands as much as to the tended pastures as such.

The management of grassland would be easier to deal with if it were possible to make an accurate and detailed statement of precisely what are the factors that make for a fatting or first-rate pasture. Such a statement can, however, in the present state of our knowledge, only take a very generalized form. Chemical analyses made on soils bearing fatting and third-rate pastures respectively show in a broad way that relative abundance of phosphates is usually associated with the former class, and that a paucity of phosphates is frequently correlated with inferior grasslands. Hall and Russell (22) have also noted that fatting pasture soils tend to be characterized by the high rate at which nitrates are produced. Careful comparisons between the soils of practically adjoining fatting and non-fatting fields have not, however, in many cases been competent to reveal sufficiently good soil reasons to account for so profound a difference in productivity. Speaking generally, it would appear that fatting pastures are seldom met with where the lime content of the soil is almost negligible, but critical lime comparisons in the case of adjoining fatting and poor fields have not shown small fluctuations in lime content to be a dominating factor. The botanical comparisons already made between the different classes of grassland will have shown that the fatting pastures usually contain a high percentage of Perennial Ryegrass, and White Clover (but so often do the less superior types), while Bent may be practically as abundant on some fatting pastures as on fields of unmistakable inferiority; none the less, broadly speaking, excess of Ryegrass and of White Clover in an old pasture suggests a measure of excellence. The weed herbage is generally most abundant on the more inferior types, and even in the case of adjoining fields studied by Hall and Russell, it transpires that on the average of all their data the non-fatting fields were more weedy than the fatting ones, although striking individual exceptions were revealed by their botanical analyses. It must be noted, however, that herbage analyses made on cut samples do not do full justice to weeds, and it is more than probable that analyses made on the turf would have shown up an altogether greater relative weediness of the non-fatting fields.

Comparisons made by Stapledon (53) between nearly fatting and quite inferior adjoining fields have shown a much greater weediness of the latter, and that the aggregate weed root system of the inferior fields was very considerably in excess of that of the nearly fatting.

It is therefore probably too much to say that there is no floristic difference between practically adjoining fatting and non-fatting pastures, but the difference is often very slight, especially in so far as the grasses and clovers are concerned. There is, however, as Hall and Russell have stated, usually a decided difference in the growth-form of the chief herbage plants. On first-rate pastures the grasses are leafy and more or less succulent, providing relative excess of " root " leaves, while on poor fields the herbage is stemmy and tends to run to inflorescence; and it would seem not unreasonable to suppose the greater competition with the roots of aggressive weeds on poor fields would tend to augment this tendency.

Comparative studies on grasslands of every grade prove, moreover, that the palatability of a grass, or in other words the extent to which it is eaten by stock, varies according to the environmental conditions, including stocking and management, under which it grows. Thus Bent and Yorkshire Fog not only contribute an appreciable amount to many fatting and other high-grade pastures, but are also on these pastures decidedly leafy plants palatable to stock, and are quite likely not detrimental when present in but moderate amount. On poor soils both Bent and Yorkshire Fog, more particularly the latter, become stemmy, dry, and leafless, and are not palatable, and are to be regarded as weeds pure and simple; and further, in proportion as these grasses, and for that matter more valuable grasses also, are neglected, so do they appear to become less and less palatable.

It is important to emphasize this matter of palatability, for pasture improvement must aim, not necessarily at increasing the proportion of ground covered with so-called valuable species, but at something more, namely, either to increase the palatability of the already dominant species or to increase the proportion of ground covered by species or particular strains of species which are palatable under the actual environmental conditions which obtain on a particular field, or under the ameliorated environmental conditions that it may be possible to create. " Palatable " and " nutritive " are, of course, not the same thing, but in a pasture where the browsing animal has much to choose from, a palatable plant is obviously of more value than a nutritive one that is not also palatable, for of what avail the potential nutriment if the plant is not eaten?

Our problem would again be easier if we knew exactly what predetermining factors influence palatability, but once more only broad generalizations are at present possible. A good pasture has what the farmer calls a good sole, it gives rise to a dense sward (in contradistinction to a matted one), and a herbage consisting of little stem but much leaf, and it is always producing new and fresh growth. The herbage is kept closely grazed, that is to say, it is palatable. It would appear then that density makes for a maximum production of root leaves and therefore for palatability. White Clover and Rough-stalked Meadow Grass make for density, and although on many habitats neither would as such rank high in a scale of palatability, they are none the less valuable pasture plants, for in creating a dense sward they react on all the other contributing species, and this altogether apart from the nitrifying benefits conferred by White Clover. It must be noted that sheep grazing makes for greater density than cattle grazing, and that the swards on sheep pastures are denser than on bullock pastures. A good sole is none the less desirable on the latter pastures, and all the best fields devoted to fatting exhibit a relatively dense sward and comparatively little bare ground.

Bews (5), in connection with his work on South African grasses, has remarked that the amount of sclerenchyma (= strengthening fibrous tissue) in the leaf of a grass affords a useful measure of palatability, for, generally speaking, a grass is palatable in inverse proportion to the amount of this tissue. This is not necessarily a measure of nutritive value, for many xerophytic grasses are nutritious although highly sclerenchymatous. Bews, however, points out that xerophytic grasses are not usually very valuable for pasturage because they are slow growers, but that there are important exceptions to this rule. The relation of sclerenchyma to more succulent tissue is a matter demanding careful study in this country; especially is it desirable that comparisons should be made between different stages of growth of the same grass, and between different plants of the same species growing on different habitats and under different systems of management.

The extent to which any particular grass or plant will be eaten by stock not only depends upon its own specific palatability on a given field, but also whether it is associated with plants which are more or less palatable than itself. Thus on very dry and poor fields in the east of England sheep have been noted to prefer the broad leaves of Ribgrass to dry and stemmy Perennial Ryegrass. It is probable also that a certain species may be sought out and eaten when being complementary to certain other species, but if in conjunction with a different set of species it might be almost neglected. This would apply to miscellaneous plants as much as to grasses and clovers, and it is necessary to state in passing that very little is known as to the possible value of small amounts of, say, buttercups, daisies, dandelions, and other weeds on pastures. It should be noted as a matter of some significance that Brown (9) found that cows continuously fed indoors greatly benefited by small rations of weed, or practically weed, foods. The complementary aspect of pasture plants in relation to palatability and productivity is admittedly a difficult problem, but it is undoubtedly one that would repay detailed study. Cockayne (11), in New Zealand, has studied the question of palatability on sheep pastures, and under the conditions obtaining on many of the areas investigated it was noted that White Clover and Sweet Vernal Grass were but little eaten; Cocksfoot and Smooth-stalked Meadow Grass were freely eaten; and of miscellaneous plants which also abound on our pastures Cat's Ear was evidently palatable.

It is not possible to draw up a definite scale of palatability for our pasture grasses, since this must vary for each species according to circumstances. Observations made over a number of years on a great variety of pastures, however, suggest the following as a rough guide to average palatability arranged in descending order:

1. Perennial Ryegrass and Meadow Foxtail.
2. Cocksfoot, Meadow Fescue, and Timothy.
3. Tall Fescue, Crested Dog's Tail, and Red Fescue.
4. Rough-stalked Meadow Grass, Hard Fescue, Sweet Vernal Grass, and Yorkshire Fog.
5. Golden Oat Grass, Tall Oat Grass, Bent, and Smooth-stalked Meadow Grass.
6. Soft Brome.

The above is based on the average condition of the grasses. The first produced root leaves of Tall Oat Grass in the spring are, however, very palatable, whilst Cocksfoot and Tall Fescue would drop considerably in the scale if allowed to grow large and tufted. The palatability of Crested Dog's Tail is too often judged by the uneaten flowering heads; examination of the root leaves, however, shows it to be in most cases a palatable grass. White Clover, although undoubtedly palatable in this country, is probably considerably less so than is generally assumed, but this does not detract from its immense value, which is rather a function of its nitrogenous properties and its relationship to density.

The above outline gives some indication as to the directions in which pasture management and improvement should aim. It would seem evident that endeavour should be made to decrease weeds, to supply phosphates and lime, to favour aeration of the soil, and to prevent stagnation, to prevent the tendency to a coarse development of herbage, and to favour by all means possible the production of a dense sward and therefore to prevent the development of flowering stems.

It will be convenient to discuss the details of improvement under a number of appropriate headings. It should be insisted that many aspects of permanent improvement of grasslands should be regarded as a capital undertaking, and therefore come under an entirely different category to treatments merely designed to increase a current hay crop.

1. **Methods of Stocking and Management.**—The dominating influence of grazing animals on the grassland types of vegetation has been previously referred to. It will now be necessary to deal in more detail with the effects of management on the productivity of individual pastures and meadows. This is a subject on which there is need of extended investigation, and at present there is not a great deal of experimental evidence to draw upon. Observation and general experience, together with such data as are available,[1] would seem, however, to justify the following generalizations.

It is not sufficiently realized that the management adopted at one period has a profound influence, not only on the immediately succeeding periods, but may leave its mark on particular fields for at least the whole of a following season. Continuous heavy grazing early in the season, namely when the grasses are just commencing to " shoot " and some time before they come into " head ", that is to say—allowing for the vagaries of season and locality—during the latter part of March, through April, and into early May, will not only tend greatly to decrease the amount of keep available during the later stages of a current grazing season, but will also tend to do the pasture lasting harm. A field giving an abundance of early grass which is heavily grazed during March and April of a particular year, will be most unlikely to afford anything approaching a similar amount of keep during the same period in the following season.

Continued grazing or repeated cutting during the early stages of the growing season so seriously hampers root development that the plants recover but slowly even under favourable growing conditions, while if the heavy early grazing is followed by a dry summer untold harm may be done. It is a common experience that daisies are usually abnormally abundant on pastures in the spring following after a year of drought. This is a trouble which is much aggravated by heavy early grazing during the droughty year, and affords an excellent and striking example of the legacy of a few weeks of mismanagement, for it may take years before the grasses regain their position relative to the daisies.

It is thus evident that the greatest care should be exercised in the method of grazing adopted during March and April, and if of necessity

[1] *See, for instance, Lindhard (61), and report from Welsh Plant Breeding Station* Aberystwyth (62).

a field has been heavily grazed during those months in a particular year, it should be rested during the same period for at least two or three years.

On the other hand, when the growing season has once fairly started and the grasses are rapidly coming into head—except in years of drought—it is almost impossible to graze the pastures too heavily; the aim should then be at all costs to prevent the pasture becoming " benty ". Thus from the middle of May till early in, or the middle of, July the grazier's problem is rather to find enough stock to graze his pastures than enough grass to keep his stock. The latter part of July and early August are often difficult times for the grazier, for his pastures usually fall considerably in productivity at this stage of the growing season, and if too heavily grazed will not maintain a reasonable level during September and early October.

In order to safeguard adequate supplies of grass during this period, it is therefore generally necessary to be more lenient on certain areas during June than would otherwise be desirable. If on such areas the grass has been allowed to run to " bent ", the mowing-machine (set high) should be run over the field before the seed commences to set. It cannot be too strongly emphasized that no two factors influence density and persistency more adversely than permitting the grasses to set and ripen seed and grazing them to excess early in the spring.

With regard to late summer and autumn keep, it is probable that on fields of equal fertility considerably more abundant keep is provided by the after-grass from properly managed meadows than from fields that have been grazed—even with the greatest care—all through the earlier months of the season.

The management of meadows, therefore, should aim at an abundant supply of after-grass equally with a good crop of hay, the more so since after-grass is often largely relied upon to lengthen out the grazing season well into November. When after-grass is required for early winter grazing it is a mistake to allow it to grow too long, for it will become winter burned, diseased, and unpalatable to stock. It is a better practice to graze it fairly heavily comparatively soon after hay harvest, and to allow the third growth to run on for the later period. Management cannot effect very much to augment the keep from pastures during December, January, and February although growth is by no means at a complete standstill even then. It is probable, however, that actual grazing by animals at this period does considerably less harm than excessive grazing when growth is starting. During winter, harm follows rather from poaching the ground than from any other cause, and this is a danger that must be guarded against.

With reference to the management of meadows, having regard to hay and after-grass, it may be said that fields " put up " to hay before or not much after the new year will yield heavier, earlier, and better hay than fields put up in late March or in April, and will also yield more after-grass, while fields cut early will yield more and earlier aftermath and more and earlier keep the following spring than fields cut late.

This brief review of the effects of management shows that the length of the growing season and the productivity of grassland in general is exceedingly sensitive to agencies which the farmer has under his own control. The essence of sound management is of course control of the grazing animals and control of the pastures; thus nothing is worse for grassland than large fields or than running all the fields together, when it is impossible to control the animals, or than keeping one class of stock only, when it is impossible to control the pastures. Grazing should be managed on a well thought out rotation having regard to the peculiarities of the various fields, and in most cases it is a better plan to bring the different classes of animals on to the different fields in rotation one after the other than to adopt a system of competitive mixed grazing. On fatting pastures, especially if cake is employed, the grazing is always selective, with consequent great harm to the herbage, unless store cattle are allowed periodic access to the fields. Fields more or less exclusively grazed with sheep tend to become excessively benty, and should always be grazed by horned stock during certain periods of the year. Horses have a bad effect on the herbage of pastures, for they " stale " parts of the field and graze other parts too closely; they should, therefore, be rotated over the pastures in proper sequence and not be continually turned out on but a limited number of fields.

Cattle and sheep form the best combination for competitive mixed grazing, but whichever plan is adopted it should be borne in mind that fatting animals or high-class dairy animals do not combine well with stores, and that ponies and horses do not combine well with other stock.

An important feature of general management often neglected is the collecting of the droppings of the animals into large heaps and subsequently spreading this manure uniformly over the pasture. This is a common practice on the best fatting pastures of Leicestershire, but is one never seen in many parts of the country. Pastures which have a tendency towards excess of bent or a matted herbage should always be harrowed with a strongly tined implement instead of merely with a chain harrow. This, however, is a subject which is referred to in more detail subsequently.

2. **Substitution of Pasture for Meadow Conditions or the Reverse.**—It is generally held that permanent grass fields should be exclusively used as pastures or as meadows. This is undoubtedly a sound practice on fertile soils, provided the meadows are well manured and the hay cut reasonably early, and the pastures scientifically grazed. Long continued removal of hay without adequate manuring will, however, lead to deterioration of the best meadows. On poor soils there is much to be said against permanent meadows. Here they tend to become overrun

with Yorkshire Fog and Soft Brome—plants which ripen their seed early and thus gain progressively on the land; they are, again, frequently full of Yellow Rattle. Such fields are much improved by being used as pastures for a number of years. Poor pastures full of Bent (*Agrostis*) or overrun with thistles are often improved by being used as meadows for some little time; when this is done the aftermath should be grazed as heavily as possible.

3. **Manuring.**—The present generation has seen great changes in the practice of manuring grassland, and this is almost entirely due to the "Manuring for Mutton" and other experiments conducted at Cockle Park and elsewhere by Somerville (46–50), Middleton (30), Gilchrist (17 and 18), and others. It is now proved beyond a doubt that phosphates are of the essence of grassland improvement by the application of manures; in this country basic slag has come to be regarded as *the* improver of grassland. More recently results of first-class importance have been achieved with finely ground raw mineral phosphates. This material has been experimented with in Northumberland, North Wales, Essex, and elsewhere, and has been shown to produce results on a par with those of slag, and should undoubtedly be tried on a large scale all over the country.

The manner of action of phosphatic manures is now too well understood to demand detailed consideration. Briefly the rôle of phosphates is as follows: they encourage a great development of leguminous herbs, especially of White Clover, which by virtue of its runners is able to spread rapidly. Bird's Foot Trefoil, the Vetchlings, Wild Vetches, Wild Red Clover, and Yellow Suckling Clover also respond well to phosphatic dressings. This at once makes for an increased density of the sward, and adds to the fertility of the soil by supplying nitrogen through the intermediary of the bacteria in the leguminous nodules. The nitrogen becomes available in the soil for the benefit of the grasses, which rapidly become more productive and vigorous.

The remarkable fact is that, whereas nitrogen supplied to pastures in the form of mineral dressings or as residues from cake feeding and to a lesser extent as farmyard manure tend to make the grasses benty and favour an irregular and coarse growth (i.e. mitigate against density) which will in extreme cases cause a "matted" herbage, the induced nitrogen resulting from dressings of basic slag does not carry with it these highly undesirable effects. It must be added that another important effect of phosphatic manures, perhaps especially of basic slag, is to add to the length of the grazing season. In this connection it should be stated that in wet seasons applications of slag made as late as August have been shown to add materially to the autumn grazing.

The improvement of grassland, therefore, is largely a question of what phosphatic manure to use, and whether any preliminary treatment is necessary before the all-important phosphates are applied.

Basic slag, although having produced the most remarkable results on heavy soils, has been used to good advantage in calcareous soils and on light soils.

Superphosphate in trials at Cirencester on calcareous soils did rather better than slag, and on some soils near the sea there is reason for thinking that superphosphate gives the better results.

On certain siliceous soils superphosphate and lime have given somewhat better results than basic slag, but in view of the higher cost of this combination not economically better results. On fields where the Meadow or Mountain Vetchlings are common and White Clover or Bird's Foot Trefoil are almost absent, superphosphate would appear to be more certain of success than slag—the Vetchlings reacting peculiarly readily to applications of this manure. Speaking generally, basic slag or the mineral phosphates are most likely to produce the required results, but the farmer should always experiment for himself as to the rival merits of slag, superphosphate, with and without lime, and mineral phosphates before embarking upon an extensive " phosphate " campaign. When phosphatic manures do not react, this is due to some limiting factor that if possible must be counteracted. The chief limiting factors met with in common practice are:

(*a*) Scarcity of potash in the soil.
(*b*) Physiological dryness of the soil.
(*c*) A matted herbage and tough organic turf.
(*d*) A water-logged condition of the soil.
(*e*) Total lack of leguminous herbs.
(*f*) Excessive weediness.

(*a*) *Scarcity of Potash.*—Under pasture conditions potash is not removed to any serious extent from the soil, and the majority of soils in this country are not deficient in potash. The need of potash is, however, often apparent on peaty soils, on sands, and on certain alluvial soils over river gravel. Where potash is needed farmyard manure is often an effective means of supplying this ingredient, and although favouring a somewhat coarse growth of the grasses, may none the less do considerable good provided the field is stocked in such a manner as to keep down " bentyness " and coarse growth.

(*b*) and (*c*) *Physiological Dryness and a Matted Herbage.*—On very dry sands phosphatic manures are often disappointing, and on these farmyard manure may assist in making the turf more retentive of moisture and therefore, despite its coarsening influence on the grasses, on the balance will do considerably more good than harm—the more so in as much as potash will also be supplied.

When the herbage has become very matted, the tendency is for the underlying soil to be dry and for the spread of leguminous herbs to be hampered by bent. This type of sod is common on sour soils, and when this occurs the condition of things can be improved by fairly heavy dressings of lime, followed up by heavy harrowing with a tined implement and grazing with ponies. Treatment of this sort should precede applications of phosphatic manures.

(*d*) *A Water-logged Condition of the Soil.*—Although basic slag in particular is capable of producing good results on more or less waterlogged soils, the benefits will be much enhanced and the grazing season considerably lengthened if drainage operations—mole draining, cleaning and cutting mains, and so forth—can be undertaken.

(*e*) *Total Lack of Leguminous Herbs.*—This condition may under favourable circumstances be rectified by resort to renovating mixtures, or even by dibbling in plants of Wild White Clover from a nursery bed.

(*f*) *Excessive Weediness.*—When a sward is full of daisies, buttercups, hawkweeds, and other mat herbs, basic slag may prove incapable of producing very immediate results. It sometimes tends actually to increase daisies, and under these circumstances it may be advisable to resort to a mixture of ammonium sulphate and superphosphate (every endeavour must, however, be made to keep down coarse herbage by skilful grazing).

Manurial trials conducted at Cirencester (26) have shown that ammonium sulphate, either alone or when included in a mixed dressing, has proved competent to decrease mat herbs by as much as 10 per cent, and it is a matter of common knowledge that the " lawn sand " used for destroying these weeds on lawns consists largely of ammonium sulphate.

From what has been said above it would appear that nitrogenous manures are usually not beneficial on pastures, and that they should be used with caution, and only when they are required to rectify a limiting factor preventing the free action of phosphatic manures.

Cake feeding on pastures has also been proved frequently to have a bad influence on the herbage, and is not, generally speaking, an economic means of utilizing these concentrated foods. Actual losses have been recorded by cake feeding to sheep, and in the case of fatting beasts the results obtained are probably but seldom economical. The results of a number of experiments (35) on feeding concentrated foods to dairy cows on pasture are conclusive, and show that if these foods are required at all they are only necessary from mid-July onwards, and even then the benefits gained are very modest, and that any improvement in the pasture was decidedly problematical.

Occasion may nevertheless arise when for one reason or another cake feeding on pasture is justified or absolutely necessary. The ill effect on the sward can be more or less completely rectified by following the dairy or fatting beasts with store cattle, and by taking the trouble to spread the dung evenly over the field at the end of the feeding season. Cake-fed sheep alone will soon lead to pasture deterioration; but on very poor fields it must be remembered the case is different, for cake will enable animals to be kept on an otherwise starving field and therefore do good.

4. **Lime as a Top Dressing.**—Lime as a top dressing on pastures is frequently disappointing, and quicklime may actually decrease productivity for at least eighteen months after its application. Small dressings of the "bagged" limes are, however, competent to occasion considerable improvements in many districts, but this is perhaps principally the case on meadows receiving frequent heavy dressings of farmyard manure. It will be shown in a subsequent section that remarkable and lasting effects of lime are, however, to be obtained in the swards on soils deficient in lime when this ingredient has been introduced during the rotation preceding seeding out.

This fact seems to suggest that before lime can react to the benefit of the herbage it must be brought into intimate contact with the soil; thus more immediate and more certain results can be obtained from lime if its application is accompanied by severe dragging with a heavy and strongly tined implement, and there is no doubt that this heavy dragging should become a regular routine of management of all matted swards.[1]

Lime compost is to be regarded as a useful top dressing for pastures; in this case the lime is applied in intimate contact with soil and rapidly benefits the more shallow-rooted plants. When making compost the greatest care must be exercised in the soil used, as there is considerable risk of introducing such undesirable plants as Silver Weed when road scrapings, cleanings from ditches, and similar earthy matter is employed.

5. **Manuring for Hay.**[2]—When a crop of hay is carted off the field almost as much plant food is removed from the soil as in the case of a corn crop; hence the need for continuous and liberal manuring if the meadow is to be kept fully productive.

The manuring should aim at encouraging the stronger-growing grasses and clovers so that bulky hay crops may be secured, and at the same time should not be such as to make for ultimate deterioration of the sward.

The application of nitrogenous manures only, however successful it may be at first, will, if continued for some years in succession, result eventually in deterioration of the meadow; this is sometimes also true of the continued use of superphosphate. These influences are most noteworthy on soils deficient in lime.

Medium grassland under meadow hay should, if possible, get about 10 tons of dung per acre applied in autumn or winter at fairly frequent

[1] Mr. Johnstone Wallace, County Organizer for Devon, has informed the writer that he has obtained good results in Yorkshire by substituting tines with a fine cutting edge for the ordinary dragging tines on a cultivator; he states that with the special tines there is no difficulty in pulling the implement through the sward.

[2] This section is largely based on the paragraphs appearing in Miscellaneous Publication No. 24, of the Ministry of Agriculture, on the Improvement of Grassland.

intervals, according to the supply available. Dung in amounts similar to this has produced heavy crops on light sandy land at Garforth and on moderate loam at Cockle Park. Dung, with artificials in alternate years, has proved profitable on both light and heavy soils in practically all experiments carried out on this plan. In the generality of cases this is probably a cheaper procedure than dung every year, and has the important advantage of not making for such weedy hay. The artificials used in alternate years may be sulphate of ammonia only (1 cwt. per acre) or sulphate of ammonia (1 cwt. per acre) and superphosphate (2 cwt. per acre) on light soils. Equivalent results will be obtained by using about 1½ cwt. of nitrate of soda, nitrate of lime, or nitrolim instead of 1 cwt. of sulphate of ammonia. Dung applied every fourth year with artificials in the intervening years has also well repaid the cost of treatment on gravel, loam, and clay soils. The artificials used in the intervening years may be 2½ cwt. of superphosphate or 4 cwt. of basic slag per acre applied in the autumn, and 1 cwt. of sulphate of ammonia or 1¼ cwt. of nitrate of soda per acre applied in spring; in many cases the slag or superphosphate need only be used every second year. These quantities may be reduced if the aftermath is grazed by stock which are receiving cake. Potash manures when available should also be applied in intervening years on light soils which are likely to need potash, but when dung is applied once in four years potash will usually be unnecessary.

The value of liquid manure for meadow hay has been brought out by experiments in Ireland, both in wet and dry seasons. The quantity used has been 16 tons per acre both alone and in combination with artificials. It would be best to apply the dressing at different times during the late autumn and winter months, going over each part of the area two or three times.

When dung is not available high hay yields may be obtained by resort to complete dressings of artificials, such as 2 to 5 cwt. of either superphosphate or basic slag, 2 to 3 cwt. of kainit or an equivalent amount of sulphate or muriate of potash, and about 1 to 1½ cwt. of nitrate of soda or sulphate of ammonia.

As regards incomplete dressings of artificials, it is interesting to note that mixtures of nitrogen and phosphates have given very satisfactory results in nearly every experiment in which they were tried. Turnbull (57), in an article on the use of manures on grassland, lays emphasis on the economy of small doses of artificials, especially in the case of the nitrogenous manures, but in the case of superphosphate the profit from 5 cwt. compared to 3 cwt. has in many instances proved to be almost negligible.

Experiments conducted at Cockle Park (17) indicate that when reliance is placed on artificials the quality of the hay is not as good as when dung is used, but on the other hand it must be noted that continued applications of dung undoubtedly make for weedy hay, such plants as Sorrel, Dandelion, Yorkshire Fog, and Soft Brome becoming very excessive. This tendency may however be countered by alternating dung with basic slag; at Cockle Park, Gilchrist states the most satisfactory results as to both quantity and quality have been obtained by applying 6 cwt. per acre high-grade basic slag every third year and also 12 tons of dung per acre every third year.

Fields have been noted in Devon where dung is used every second or third year, and about 4 to 6 cwt. bagged lime applied at four-year intervals. The hay crops have been remarkably good, and were noteworthy for the very large amounts of Wild Red Clover they contained.

When reliance is placed upon artificials it is not easy to choose between ammonium sulphate and sodium nitrate; in favour of the former is its effect in decreasing mat herbs, but as previously stated it should not be continually used on soils deficient in lime. The effect of both manures on individual grasses depends not only upon the soil but also upon the relative abundance of the various species prior to treatment.

A broad generalization is often made to the effect that sodium nitrate has maximum effect on the larger grasses and ammonium sulphate on the smaller. This is, however, only partially true; thus, in the case of Cocksfoot, at some centres "nitrate" and at others "sulphate" has had the greater influence. Yorkshire Fog at Rothamsted has been much decreased by sulphate, but at other centres it has been increased by the same dressing. Sulphate usually decreases Bent (*Agrostis*), but this is not invariably the case.[1]

The time at which hay is cut has considerable influence on the nutritive value of the crop. Growth does not much continue after the grasses come into flower, and if the plants are allowed to remain uncut long enough to ripen seed, the stems become fibrous and the nutritive value of the hay diminishes, and, moreover, much of the elaborated foodstuffs contained in the seeds is largely lost in the process of harvesting, and in all the movements the hay will be subjected to before it finally reaches the manger. From the point of view of the meadow, grasses that have been allowed to mature ripe seed year after year will not remain long-lived perennials, and they will not aftermath well after cutting.

Late cutting, as previously indicated, favours the development of Yorkshire Fog, Soft Brome, and Yellow Rattle.

6. **Improvement by Breaking the Turf and Re-seeding.**—The advantages of this method have been discussed previously in relation to inferior types of grassland. It may be here emphasized that on fields deficient in lime, where a matted herbage and dense sod has accumulated, it is of great advantage to be able to work a good dressing of lime into

[1] For further particulars as to the influence of manures on individual species see Stapledon (55).

the soil, which can only be done really efficiently if the sod is broken. The effect of lime under these circumstances is often remarkable; an example will serve to illustrate the point.[1]

On a particular farm in Cardiganshire two apparently similar fields at an altitude of about 700 to 800 ft. were broken eighteen years ago. The fields, previous to being ploughed, were covered with gorse and fern, and consisted of a rough mountain herbage.

They were put through the following rotation: (1) mixed corn, (2) mixed corn, (3) rape folded on the land, (4) mixed corn and " seeds ", and both received in the rotation abundant dressings of farmyard manure, basic slag, and superphosphate. One field received about 2 tons to the acre of lime, and the other no lime; neither field has received any subsequent top dressing.

The portion receiving no lime soon reverted to gorse and a poor mountain herbage, and after six years was again broken and put through the same rotation, again manured, but without an application of lime. Six years later the portion receiving no lime had again reverted to gorse and poor mountain herbage, consisting only of Heath Grass, Bent, and Sheep's Fescue, with 29 per cent of moss and no clovers. The limed portion, although broken eighteen years ago (and receiving no subsequent top dressing) is still quite free of gorse. The herbage contains 22 per cent of White Clover (although not included in the original seeds mixture) and 18 per cent of Smooth-stalked Meadow Grass and Red Fescue (*Festuca rubra*) together, although neither of these valuable bottom grasses was included in the mixture.

Another advantage gained by breaking the sod is that it is possible to introduce a seeds mixture with every promise of a good take. On fields where leguminous herbs are absent this is often the best means of safeguarding the ultimate presence of White Clover. From ¼ to ½ lb. of Wild White Clover is usually a sufficient seeding in a mixture on a new tilth. At the present exorbitant price of this seed the large sowings necessary for renovating mixtures to have a reasonable chance of success on closely knitted turfs are too expensive in view of the risk of failure.

On suitable situations there can be little doubt that breaking during the winter or in the spring and sowing in May or June on the upturned sod is a safer and quicker means of improving many types of very inferior grassland than surface treatments and top dressings.

It is wiser to defer seeding out till June and to use rape as a nurse than to sow in April or early May under a corn crop. There is always a risk that the upturned soil may contain numerous buried weed seeds, especially of Charlock,[2] which would smother the young seeds. By sowing later it is possible to kill the seedlings of these and other weeds and to allow a sufficient interval between applications of lime and seeding. It

[1] See Stapledon (52). [2] See Brenchley (7).

is moreover essential that seeds sown on an upturned turf should grow away rapidly without any check, and so be able in their turn to smother the Bent and other perennial plants before these are able to force their way up from the buried turf.

The method of seeding out on a freshly broken turf with rape has proved so successful on free-working soils under conditions of high rainfall, that it should be experimented with even on less friable soils and where the rainfall is less considerable, particularly in cases where rapid improvements cannot be achieved by surface treatments.

7. **Seeds Mixtures and Methods of Sowing.**—The establishment of a permanent pasture or meadow by sowing down to grass presents precisely the same problems as putting down a temporary ley.

The considerations which influence the choice of a mixture and the methods of seeding down are dealt with fully in the article on " The Temporary Ley ", p. 43, consequently this aspect of the management of permanent grass does not call for further discussion in the present article.

REFERENCES TO LITERATURE

1. ARMSTRONG, S. F. " The Botanical and Chemical Composition of Pastures and Meadows ", *Journ. Agr. Sci.*, Vol. II, No. 3, 1907.
2. ABERYSTWYTH. " The Improvement of Upland Pastures ", *University College of Wales Buls.*
3. ABERYSTWYTH. " The Eradication of Yellow Rattle ", *University College of Wales Buls.*
4. BANGOR. " Eradication of Bracken ", *University College of N. Wales Buls.*
5. BEWS, J. W. *The Grasses and Grasslands of South Africa* (Pietermaritzburg, 1918).
6. BRENCHLEY, WINIFRED E. " West Country Grasslands ", *Journ. Bath and West Agr. Soc.*, Ser. 5, Vol. XI, 1916–7.
7. BRENCHLEY, WINIFRED E. " Buried Weed Seeds ", *Journ. Agr. Sci.*, Vol. IX, No. 1, Aug., 1918.
8. BRENCHLEY, WINIFRED E., and ADAM, HELEN. " Recolonization of Cultivated Land allowed to revert to Natural Conditions ", *Journ. Ecology*, Vol. III, No. 4, Dec., 1915.
9. BROWN, JAS. C. " Farming on the Soiling System ", *Journ. Board of Agric.*, Vol. XXVI, No. 4, July, 1919.
10. CAMBRIDGE. *Guide to Experiments* (University Dept. of Agric., 1907).
11. COCKAYNE, L. " The Relative Palatability for Sheep of the Various Pasture Grasses ", *New Zealand Journ. Agric.*, Vol. XVIII, No. 6.
12. CRAMPTON, C. B. " The Geological Relations of Stable and Migratory Plant Formations ", *Scot. Bot. Review*, Jan., April, July, 1912
13. ELGEE, FRANK. *The Moorlands of North-eastern Yorkshire* (London, 1912).
14. FARROW, E. P. " On the Ecology of the Vegetation of Breckland ", *Journ. Ecology*, Vols. III, No. 4, IV, No. 2, V, No. 1, and VI, No. 2.
15. FREAM, W. " The Herbage of Water Meadows ", *Journ. Linn. Soc. Bot.*, Vol. XXIV, 1888.

16. FREAM, W. " The Constitution of the Hay of Water Meadows ", *Journ. Bath and West Agr. Soc.*, Ser. 3, Vol. XXI, 1889–90.
17. GILCHRIST, DOUGLAS A. " The Best Methods of Laying Down and Improving Grassland ", *Journ. Farmers' Club.*
18. GILCHRIST, DOUGLAS A. " Guide to Experiments ", *County of Northumberland Annual Bulls.*
19. GORDON, G. P. " Bracken: Life History and Eradication ", *Trans. High. and Agric. Soc. of Scot.*, Ser. 5, Vol. XXVIII.
20. HARPER ADAMS. *Agricultural College Joint Report*, 1914.
21. HALL, A. D., and RUSSELL, E. J. *Agriculture and Soils of Kent, Surrey, and Sussex* (London, 1911).
22. HALL, A. D., and RUSSELL, E. J. " On the Causes of High Nutritive Value and Fertility of the Fatting Pastures of Romney Marsh and other Marshes in S.E. of England ", *Journ. Agri. Sci.*, Vol. IV, June, 1912.
23. HOWARD, JAMES. " Laying Down Land to Grass ", *Journ. Roy. Agri. Soc. Eng.*, Ser. 2, Vol. XVI, 1880.
24. HUTCHINSON, H. P. " Tor-grass or False Brome and its Eradication from Down Pastures ", *Journ. Board of Agric.*, Vol. XIX, No. 8, Nov., 1912.
25. JEFFÈRIES, T. A. " Ecology of the Purple Heath Grass ", *Journ. Ecology*, Vol. III, No. 2, 1915.
26. KINCH, E., TURNER, D., and STAPLEDON, R. G. " Manuring Experiments ", *Agric. Students' Gaz.*, Dec., 1912.
27. LONG, HAROLD C. *Common Weeds of the Farm and Garden* (London, 1910).
28. LONG, HAROLD C. *Plants Poisonous to Live Stock* (Cambridge, 1917).
29. MARSH, A. S. " The Maritime Ecology of Holme-next-the-sea, Norfolk ", *Journ. Ecology*, Vol. III, No. 2, 1915.
30. MIDDLETON, T. H. " The Improvement of Poor Pastures ", *Journ. Agric. Sci.*, Vol. I, No. 1, Jan., 1905.
31 MIDDLETON, T. H. " The Formation of Permanent Pastures ", *Journ. Board of Agric.*, Vol. XII.
32. MOSS, C. E. *Vegetation of the Peak District* (Cambridge, 1913).
33. MOSS, C. E. " Geographical Distribution of Vegetation in Somerset, Bath and Bridgwater District ", *Journ. Roy. Geogr. Soc.* (London, 1907).
34. EVANS, MORGAN. " Notes on Inoculation of Grassland as practised at Kimbolton ", *Journ. Roy. Agr. Soc., Eng.*, Ser. 2, Vol. XII, 1876.
35. MINISTRY OF AGRICULTURE. " The Feeding of Concentrated Food to Dairy Cows on Pasture ", *Journ. Board Agr.*, Vol. XXV, No. 1, April, 1918.
36. MINISTRY OF AGRICULTURE. " The Improvement of Grassland ", *Miscellaneous Publications*, No. 24.
37. MINISTRY OF AGRICULTURE. " Rape Pastures ", *Food Production Dept. Bul.*, Ser. C., No. 2.
38. NEWMAN, Q. F., and WALWORTH, G. " A Preliminary Note on the Ecology of part of the South Lincolnshire Coast ", *Journ. Ecology*, Vol. VII, Nos. 3 and 4, Nov., 1919.
39. OLIVER, F. W. " Some Remarks on Blakeney Point, Norfolk ", *Journ. Ecology*, Vol. I, No. 1, March, 1913.
40. PRIESTLEY, J. H. " The Pelophilous Formation of the Left Bank of the Severn Estuary ", *Proc. Bristol Nat. Soc.*, Ser. 4, No. 3, 1911.

41. RUSSELL, E. J. "The Possibilities of Increased Crop Production", in *Life and its Maintenance* (London, 1919).
42. SMITH, W. G. "The Improvement of Hill Pasture", *Scot. Journ. of Agric.*, Vol. 1, No. 3, July, 1918.
43. SMITH, W. G. "The Distribution of *Nardus stricta* in relation to Peat", *Journ. Ecology*, Vol. VI, No. 1, March, 1918.
44. SMITH, W. G. "The British Ecological Society President's Address", *Journ. Ecology*, Vol. VII, Nos. 1 and 2, May, 1919.
45. SMITH, W. G., and CRAMPTON, C. B. "Grassland in Britain", *Journ. Agr. Sci.*, Vol. VI, No. 1, Jan., 1914.
46. SOMERVILLE, W. British Association, Section M. (Agriculture): President's Address at Bournemouth, 1919.
47. SOMERVILLE, W. *Five Years' Work at the Northumberland County Farm* (Newcastle-on-Tyne, 1902).
48. SOMERVILLE, W. "On the Botanical Composition of the Herbage of Permanent Grassland", *Journ. Board Agr.*, Vol. II, No. 2, Sept., 1900.
49. SOMERVILLE, W. "Influence on the Production of Mutton of Manures applied to Pasture", *ibid.*, Supplement, Jan., 1911.
50. SOMERVILLE, W. "Poverty Bottom: An Experiment in Increased Food Production", *ibid.*, Vol. XXIV, No. 11, Feb., 1918.
51. STAPLEDON, R. G. "On the Flora of certain Cotswold Pastures", *Royal Agr. Col. Sci. Bul.*, No. 1, 1909.
52. STAPLEDON, R. G. "Rape and Rape Pastures", *Journ. Agr. Dept. Aberystwyth*, Vol. VIII, and "The Uses of Rape Pastures" in *Modern Farming* for Jan., 1922.
53. STAPLEDON, R. G. "Botanical Considerations affecting the Care of Grassland", *Journ. Board of Agr.*, Vol. XX, Nos. 5 and 6, Aug. and Sept., 1913.
54. STAPLEDON, R. G. "Grassland and Ploughland", *ibid.*, Supplement No. 17, May, 1917.
55. STAPLEDON, R. G. "Pasture Problems", *Journ. Agr. Sci.*, Vol. V, No. 2, March, 1913, and Vol. VI, No. 4, Nov., 1914.
56. STAPLEDON, R. G., and JENKIN, T. J. "Pasture Problems", *ibid.*, Vol. VIII, No. 1, Sept., 1916.
57. TURNBULL, GERVAISE. "Increased Production of Grass", *Journ. Board of Agr.*, Vol. XXVI, No. 6, Sept., 1919.
58. WOODRUFFE-PEACOCK, E. A. "Pasture and Meadow Analyses", *Rural Studies Series*, No. 9, 1907.
59. WRIGHTSON, JOHN. *The Principles of Agricultural Practice* (London, 1893).
60. YAPP, R. H., and JOHNS, D. "The Salt Marshes of the Dovey Estuary", *Journ. Ecology*, Vol. V, No. 2, 1917.
61. LINDHARD, E. "Om Vaeksten af Hundegraes og Draphavre", *Statens Forsgsvirksomhed i Plantekultur*, Beretning 69.
62. WELSH PLANT BREEDING STATION. "Preliminary Investigations with Herbage Plants", *Bull.*, Series H, No. 1.

GRASSLAND IN SCOTLAND

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Before modern rotations came into vogue, most of the arable land in Scotland known as the " outfield " was cropped with grain as long as the soil would produce a crop. It was then allowed to take care of itself, and as no grass seeds were sown, it became filled up with inferior grasses and weeds. This was the first pasture. After a few years, when it was considered that the land would grow grain again, it was ploughed up and cropped as before. It is interesting to note that up to fifteen to twenty years ago a modification of this system was practised in the Outer Hebrides, where about 95 per cent of the arable land was cropped every year, potatoes being grown every third, fourth, or fifth year, and grain (oats or bere) the other years.

The first step in advance was when the seeds of grasses growing in the meadows were collected and sown. This practice was followed, in turn, by the sowing of mixtures of Perennial Ryegrass and clovers.

Another alteration made was that part of the land was allowed to lie fallow, that is without a crop, in order that it might be thoroughly cleaned during the dry summer months. After turnips were introduced it was found that they could be grown on the fallow land without interfering with the cleaning process. This was the beginning of the rotations now in vogue, the earliest and simplest being:

4-course—Grain, grass, grain, roots.
5-course—Grain, grass, grass, grain, roots.

As time went on, however, great difficulty was experienced in many districts in growing good, sound turnips, owing to their being attacked by finger-and-toe, but it was found that by leaving the land down to grass for a longer period the turnips were greatly improved, and nowadays much of the arable land in Scotland that used to be worked on a five-course rotation is worked on the six-course, and in some cases on the seven-course.

The following rotations are common:

6-course—Grain, grass, grass, grain, grain, roots; or
Grain, grass, grass, grass, grain, roots.
7-course—Grain, 4 grass, grain, roots; or
Grain, 3 grass, 2 grain, roots.

Generally speaking, the short rotations are practised on the good deep soils in the drier climates along the east coast of Berwick, the Lothians, Fife, Forfar, and Kincardine, where potatoes often partly take the place of turnips. In these short rotations a very large proportion of the grass is usually made into hay. The longest rotations are practised chiefly in the dairying districts in the southern counties, and in the latest, chiefly inland, districts. Usually in these long rotations about one-third or one-half of the first year's grass is made into hay, while the remainder, and also the older grasses, are pastured.

The agricultural returns of the Board of Agriculture for Scotland show that in 1922 fully 60 per cent of the total acreage was under grass.

	Acres.	Acres.
Cultivated Crops		1,827,133
Ryegrass and other Rotation Grasses (for Hay)	431,356	
Clovers (not for Hay)	1,078,540	1,509,896
Total arable land		3,337,029
Permanent Grass (for Hay)	147,006	
Permanent Grass (not for Hay)	1,241,505	1,388,511
Total acreage under all crops		4,725,540

Before discussing the characteristics of the different grasses and clovers, it will be well to state briefly the objects in view when selecting the kinds of seeds to sow in grass mixtures. These may be stated briefly as follows:

1. *First Year.* To get either:
   (*a*) A good hay crop and aftermath; or
   (*b*) Grass to cut early for soiling purposes; or
   (*c*) Pasture very early in spring for ewes and lambs; or
   (*d*) Good pasture during the grazing season.
2. *Second and Subsequent Years.* To get either:
   (*a*) Good pasture for as long a period of the year as possible, which will be eaten readily by the stock and have good fattening properties; or
   (*b*) In a few cases, a good hay crop.
3. To keep out inferior plants.
4. To improve the fertility of the soil.

Due consideration should be given to each object or combination of objects as may be required according to the rotation, and in discussing the different grasses and clovers we must keep in mind their individual value for each of the above purposes.

It will also be well to remember that there are other factors besides the kinds of seed used in the mixture that affect the result. Some forget this, and may give all the credit of a good result to the seeds mixture, or, on the other hand, when a poor result is got, blame the grass seeds mixture, whereas, no matter what mixture may, under the circumstances, have been sown, the results would have been poor. Some of the factors, such as the kind of soil and weather conditions, are outwith the power of the farmer to control. There are others, however, which are entirely within his control, such as the thorough cultivation, manuring, and cleaning of the soil and the sowing of the seed, and which will have a marked influence on the result.

Effects of Kind of Soil.

The best all-round results are usually got from good deep loams in good heart that are not liable to suffer from either excessive rains or excessive drought. Clay soils will often produce heavier hay crops, but the pasture is, in many cases, not so satisfactory. On light sandy soils both the hay and the pasture are inferior, while peaty soils may produce quite heavy hay crops of inferior quality, and usually form poor pasture of low feeding value.

Effect of Weather Conditions.

Possibly the factor that most largely affects the grass crop is the rainfall during the summer months. Grass cannot flourish on dry soils, and as soon as the soil becomes dry the grass ceases to grow. The freshest and greenest grass is found on the west coast and in such countries as Ireland, where the rainfall and the temperature are high. Even the lighter soils will produce fair crops if they do not get dry.

There is a saying that " May makes the hay ". While this may be true as regards England, it is only partly true as regards the most of Scotland. A field may look quite well during May, but if there is not sufficient rain and heat during June, the crop will become comparatively worse and the amount of Red Clover will likely be small. On the other hand, if there is a sufficient supply of rain and a sufficiently high temperature in the first part of June, a good crop of hay with plenty of Red Clover will likely result. While the farmer cannot control the rainfall, nor prevent the loss of moisture in the soil, he may make the loss less rapid by careful grazing. If the stock are not put on the pasture until the grass is fairly well up, and if the grass is not eaten too bare, the surface will be kept better covered and so prevent excessive evaporation. On the other hand, if the field is eaten bare the plants are unable to make food for themselves, and both plants and animals suffer.

Although moisture is so necessary to the success of the grass crop, it does not follow that land should not be drained. Undrained land, unless it is very dry and open, tends to get into a sour condition, and in many cases becomes waterlogged under the ploughed part, and air is kept out. It will usually be found that the grasses and other plants found growing on such soils are inferior. The absence of air is specially harmful to clovers, as the nodule-forming organisms cannot flourish without it. The best grasses and clovers can only thrive where there is both moisture and air, and this can only be got where the soil is properly drained.

Nurse Crop.

The grass seeds are usually sown as part of a seeds mixture along with a grain crop—oats, barley, or wheat—and in many cases where the grain crop grows luxuriantly, and especially if it lodges, the grass is very adversely affected. Oats, owing to their greater tillering power, their more leafy growth and spreading panicle ear, have usually a more adverse influence than either barley or wheat. The newer varieties of oats, however, which do not tiller so much and have not such a leafy growth, and are not so liable to lodge as the older varieties, are, as a rule, not so injurious. On several occasions we have noticed that where part of a field had been seeded with an old variety and part with a new variety of oats, the difference in the hay crop in the following year was very marked. After the new variety, the Red Clover was both plentiful and luxuriant, whereas after the old variety it was neither so abundant nor so strong. On all good land and on peaty soils, a dwarf early variety of grain should invariably be sown if the grass and clover is to get a chance. Late sown grain lodges much more readily than when early sown, and is thus more liable to rot out the grass.

Nitrogenous manures applied to the grain crop encourage the growth of straw, and this in turn also has an adverse influence on the grass. To give it as good a chance as possible the grain should not be sown too thickly, and it should be cut as soon as possible so as to remove competition. Rape is sometimes sown with mixtures for permanent pasture. It should not be sown too thickly, about 4 lb. of seed per acre being quite sufficient.

Cultivation.

The grass seeds are usually sown after the grain crop is sown and harrowed. The length of time between the sowings varies greatly from farm to farm. Some sow almost immediately, others wait for a few days, while a few do not sow until the grain crop is well up. The time of sowing the grain and the kind of soil are the two factors that require to be considered in determining the most suitable time.

There are also considerable differences in the methods adopted when sowing. Some sow the seeds directly on the harrowed surface, and either finish by rolling or give another harrowing before rolling. Others either roll, or roll and again harrow before sowing the seeds, harrow them in, and finish by rolling. Some use ordinary harrows, some lighter grass-seed harrows, and others chain harrows.

Four factors require to be considered in determining what method to adopt, viz. tilth, soil moisture, consolidation of the soil, and the time of sowing the seeds. These may be affected to a considerable extent by the kind of soil, the time and depth of ploughing, and the amount of rainfall between the time of ploughing and sowing the seeds.

The seeds should be as near the surface as possible, so long as they get sufficient moisture to germinate. The closer the seeds are surrounded by the soil particles the better is their chance of getting sufficient moisture. It has been found that, on the average, the largest number of Red Clover seeds and seeds of similar size grow where there is a covering of about ½ in. of soil, while about half the seeds will grow with a covering of about 1½ in. of soil. If the surface is dry, however, it will be well to have them deeper than on a damp soil.

When the grain crop is sown early in spring it may be well to wait a short time, or, especially on clay soils, to wait until the grain is well rooted, before sowing the seeds. If this method is adopted, the soil should be well harrowed with a good heavy harrow before the seeds are sown, after which it should be again harrowed and get a light rolling to level the soil. The same procedure should be followed if the seeds are sown after autumn-sown wheat. Care should be taken not to roll this class of soil if it is at all damp, otherwise, if a dry spell comes, a crust may form on the surface through which the young seedlings may be unable to pierce.

If the grain crop is later in being sown on clay soil, and it is necessary to sow the grass seeds shortly afterwards, it will be well to roll before sowing them, in order to break the clods which are usually common on this class of soil. This will prevent the seeds being buried too deeply. They should be sown on the rolled surface, lightly harrowed in, and rolled. It would be advisable, however, to give soils that are apt to become cloddy a good dressing (25 to 30 cwt.) of lime at least a year, and if possible two years, beforehand. This would help to get them into a more friable condition, especially if they were ploughed early, when they would get the benefit of the winter's frost. Such soils are usually far too late in being ploughed.

With regard to light sandy soils, the time of sowing the seeds depends mainly on the conditions as regards moisture. In a wet season there will be little difficulty in getting seed to grow, but if the soil is dry when the grain is sown it will be of very little use sowing the grass seeds if the weather is also dry and has the appearance of remaining so. The sowing should therefore be delayed until there is sufficient moisture for the seeds to germinate. The grain seed is, of course, much deeper, and may get sufficient moisture for germination.

There will be more chance of getting an opportunity to sow the seeds in proper condition if the soil is ploughed early. By so doing, it would soak in more of the winter's rain and would be more consolidated, and the moisture would therefore more readily come up from below.

In this case it is best to sow the seeds on the harrowed surface and roll them in. If it is impossible to get light soil ploughed early, and if it is only done a short time before the grain is sown, it should be ploughed shallow. If ploughed deeply, and especially if there is dry weather, it is apt to lose too much moisture. It should be rolled before the grass seeds are sown in order to consolidate it, and to assist the looser newly ploughed part to renew the connection with the soil underneath. After being rolled it should be lightly harrowed and the seeds sown, again lightly harrowed or chain harrowed and rolled. If too heavy a harrow is used there is a danger of the seeds being buried too deeply. Paradoxical as it may seem, there is a danger of this class of soil having too fine a tilth, in which case Yarr may come up so thickly as to endanger the lives of the young clovers.

On peaty soils, where the usually heavy grain crop is apt to choke out the grass and especially the Red Clover, the seed should be sown as soon as possible after the grain, in order that the latter should not get the advantage at the start. This also applies to all soils capable of growing heavy grain crops. As peaty soils are always very loose, they should be heavily rolled before the grass seeds are sown. These should be sown on the rolled surface and be lightly harrowed or chain harrowed and again rolled.

On ordinary medium soils there is, as a rule, little difficulty in getting a good braird. If the ploughing has been done some little time previously and if the tilth is good, it is sufficient to sow the seeds on the harrowed surface soon after the grain is sown, give a light harrowing, and roll. On the other hand, if the ploughing has been recently done, or if the tilth is not good, the land should be rolled first and the seeds sown, lightly harrowed, and rolled.

Manuring.

Regarding the manuring, dung is usually applied to the root crop, although on some clay soils it is applied after the root crop has been removed, with excellent results so far as the grass is concerned. Two distinct methods are followed in applying artificial manures. One is to apply sufficient phosphates and potash, for the grass, to the preceding turnip and grain crops and get them well worked into the soil, and the other is to apply less to the previous crops and give a top dressing to the grass. With old pastures, which are nearly always deficient in phosphates and potash, the latter method must, of course, be followed, and in many cases wonderful results have been got. Such dressings, however, only influence the surface-growing plants.

A very interesting result in the hay crop on a comparatively light soil was got recently from different treatments applied to the turnip crop two years previously. No manure was used on the grain crop (except on one plot) or on the hay. The same seeds mixture was used in each case. The treatments and weights of hay were as follows:

Plot.	Manures applied to Turnips.	Hay, Cwt. per acre.
1	8 tons dung	38
2	12 tons dung	47
3	8 tons dung, 1½ cwt. bone meal	42
4	12 tons dung, 3 cwt. bone meal	52
5	12 tons dung, ½ cwt. sulphate of ammonia, 2 cwt. superphosphate, 3 cwt. steamed bone flour, and 1 cwt. potash salt ..	58
6	12 tons dung, 1 cwt. sulphate of ammonia, 3 cwt. superphosphate, 4 cwt. steamed bone flour, and 2 cwt. potash salt; and to the oat crop, ½ cwt. sulphate of ammonia, 2 cwt. superphosphate, and ½ cwt. muriate of potash	63

In plots 1 and 3 there was hardly any Red Clover at all. In plots 2 and 4 there was a fair quantity, while in plots 5 and 6 there was a large quantity.

Undoubtedly many of the poor hay crops, deficient in Red Clover, are due to the land not being in good heart and not being sufficiently well treated.

On ordinary medium soil the following mixtures may be used with every prospect of success.

For turnips: 12 to 15 tons dung, ½ cwt. sulphate of ammonia, 2 cwt. superphosphate, 1½ cwt. steamed bone flour, and 1 cwt. potash salt.

For grain crop: ½ to ¾ cwt. sulphate of ammonia, 1½ cwt. superphosphate, 2 cwt. steamed bone flour, and 1 cwt. potash salt.

If considered necessary, a small quantity—not more than ¾ cwt.—sulphate of ammonia may be applied to the hay crop.

Where such mixtures have been used it has been found that further application of insoluble phosphates and potash to either the hay or pasture have had no beneficial effect, evidently due to the fact that there was a sufficient supply of these ingredients in the soil.

Quality of Seed Used.

Unfortunately in many cases, farmers in Scotland do not pay that attention to the quality of the seed used that it deserves, although during the last decade there has undoubtedly been an improvement in this respect. Possibly the chief reason for this indifference is that very few farmers know either the different grass and clover seeds and their impurities or the plants that grow from them. A very common practice in many districts is to buy seeds for so many acres, no particulars being given to the seedsman as to the seeds to be supplied. To many the price is the only consideration—if they are cheap enough they are good enough. At one time many used, or even bought, the sweepings of hay lofts, and possibly wondered why they did not get such good crops as their neighbours.

There has been a great improvement in the quality of seed sold during the last twenty years or so, due largely to the wholesale dealers erecting elaborate machinery for cleaning the different kinds. Frequently a special machine has been erected to take out one particular weed seed. Nowadays, with the information which has to be given under the Seeds Act, there should be no difficulty in securing seeds of good quality as regards purity and germination.

Perennial Ryegrass (*Lolium perenne*).—Perennial Ryegrass was the first grass to be cultivated, and for a long time was the only one sown. As evidence of the very high estimate in which Perennial Ryegrass was held in the past, many leases contained a clause requiring the tenant to sow not less than 2 bus. of Perennial Ryegrass per acre. There were several reasons for its popularity. These were:

1. It seeds freely and the seed was consequently cheap. Also in many cases the seed was home saved and so did not require to be directly paid for.
2. Other grasses were much dearer and were often of very inferior quality.
3. It was reliahle and grew readily on most soils, and it was rarely an absolute failure. Even if it was very thin in a pasture it closed up owing to its good tillering powers.
4. It had a good appearance in the early part of its life—that is immediately after harvest—and also in the first spring, and it produced a good crop the first year, and, as much of the land was only a short period under grass, it gave quite a good result.

In the eighties of last century there was a great controversy regarding the value of Perennial Ryegrass. Some condemned it entirely, while others stated that it was the best grass and the only one that need be sown. The truth is likely between these two extremes.

Perennial Ryegrass, being comparatively shallow rooted, is best suited to a cool climate, and good, well-drained moist soils, but does not do at all well in hot dry summers or on poor dry soils. It responds readily to good treatment.

The seed germinates rapidly, and at harvest time has a better appearance than any other grass except Italian Ryegrass. One can always tell where it has been sown in large amount, as the herbage in early winter is very thick and close. In such cases if the weather is good it grows considerably, and during winter the plants compete against each other so severely that many of the blades wither. On the other hand, where used in smaller amount the plants have plenty of room to develop and there is no loss due to competition.

In spring, where a large seeding is used, the "sole" is usually thick and gives the appearance of a good crop. In many cases, however, it does not come up to expectations, whereas where a smaller amount is sown, although it does not look so well at first, it ultimately gives quite as good and thick a crop as the heavier seeding.

Perennial Ryegrass is often regarded as our hardiest grass. As a matter of fact it is one of the most tender. If a spell of cold weather comes, and especially if there are frosts, after the plants have begun to grow in late spring, the young shoots are very easily injured and become reddish brown in colour; growth ceases for a time and the plants go into ear prematurely. On the other hand, grasses like Cocksfoot and Timothy are not harmed by frost but remain fresh and green.

Many experiments have been carried out with grass seeds mixtures containing different amounts of Perennial Ryegrass. So far as the hay crop is concerned, these have shown that there is usually very little difference in yield per acre from large and small seedings of Perennial Ryegrass, as the following average result of an experiment carried out at a large number of farms will serve to show.

Ingredients of Mixtures.	Seed Sown per Acre.		Yield per Acre from the different Ingredients of Mixtures.	
	A	B	A	B
	lb.	lb.	cwt.	cwt
Perennial Ryegrass ..	43·7	20·4	32·0	26·3
Cocksfoot	—	3·9	—	1·1
Timothy	—	1·7	—	2·9
Clovers	7·2	7·2	11·3	12·9
Weeds	—	—	2·4	3·9
			45·7	47·1

In this trial, samples of the hay from each plot were taken and the different grasses, &c., separated out and weighed and the proportion of each calculated. Then from the proportion and the total weight per acre the weight per acre of each ingredient was calculated.

The following points were brought out in the trial:

1. While on some farms the hay crop on A was heavier than on B and on others B heavier than A, in no case was the difference very great, and on the average plot B, where the smaller amount of Perennial Ryegrass was sown, produced rather the heavier hay crop.

2. Compared with the amount of seed sown the proportion of Perennial Ryegrass in B was much larger than in A. The reason for this was that in B the plants tillered more and the stalks were bigger and heavier.

3. There were fewer weeds in the hay where the thicker seeding was used.

The stalks become somewhat weak as they ripen, and tend to become laid, which makes Perennial Ryegrass more difficult to reap, but when made into hay, if the weather is at all favourable, it dries fairly rapidly, as there is a large proportion of these stalks and comparatively few blades. It does not show at all prominently in the aftermath. Later on, however, it begins to grow, and during winter it is usually fresh and green. In the late spring and during the second summer it is not nearly so prominent, especially if there is a long spell of dry weather. With a thick seeding the plants appear to be half starved, whereas on the same soil and with the same treatment the Perennial Ryegrass plants are stronger where less seed is sown. During July and August it usually becomes very bare and brown unless there has been much rain.

On many of the poorer soils Pluff Grass or Yorkshire Fog (*Holcus*) and Bent Grass (*Agrostis*) are indigenous, and take the place of the Perennial Ryegrass as the latter begins to lose ground. Therefore, where a large amount of Perennial Ryegrass has been sown, the pasture during the third year often consists mainly of these inferior grasses, which cattle will only eat if they can get nothing else. Where, however, a small amount of Perennial Ryegrass along with other grasses is sown, very little Yorkshire Fog is seen. Where Wild White Clover is used and where White Clover comes naturally, there is certainly a great improvement, but on such soils the season of growth of the White Clover is a comparatively short one and the total amount of food in the season is small.

Judging Perennial Ryegrass, then, from the standard we set up we find that its ability to produce a good hay crop or good pasture the first season is the chief point in its favour. It fails in providing good aftermath after hay, although it grows later, and may produce a good bite for sheep during winter, while in the second and third years it provides good pasture for a lengthened period only under the best conditions. Except during the first season, it is unable to keep out weeds, while in improving the fertility of the soil it is inferior to many of the other grasses, as after three years the plants are so very small and therefore the amount of organic matter to be ploughed in is very meagre.

For one year's hay and two years' pasture we conclude, as a result of experiments, that in the majority of cases about ½ bus. of Perennial Ryegrass is quite sufficient to use along with other grasses and clovers. This amount will ensure a good hay crop, and there will not be excessive competition against the other slower growing ingredients of the mixture.

There are several cases, however, in which it may be advisable to use more. These are:

(*a*) In fields where Red Clover usually does not grow. In this case, especially on poorer soils, more of the quick-growing grasses like Perennial Ryegrass are necessary to take the place that the Red Clover would normally occupy and to ensure that there may be a sufficiently thick crop the first year.

(*b*) Where food is wanted for sheep during the first winter and spring. Many flockmasters require grass early for their lambs, and a larger amount of Perennial Ryegrass in the mixture will ensure this. It should be noted that in all probability a smaller total crop will result, especially if the season is dry, but the smaller crop at this particular time of the year, when it is often so necessary for the well-being of the lambs, may be much more valuable than a larger crop later on.

(*c*) If the tilth is poor more seeds will be required, as a smaller number will germinate. It should be noted in this respect that a larger porportion of Perennial Ryegrass than of the other grass seeds will grow where the tilth is bad.

(*d*) Where the germination is low, proportionately more seed must be sown.

In many districts it is the custom to save a sufficient amount of seed of Perennial Ryegrass for use the following year. This is not a practice to be recommended, as where the seeds are allowed to ripen the pasture next season is usually very poor. Also, most of the home-grown seed contains a considerable proportion of weed seeds, and as this is usually sown without being properly cleaned, it means weedy pasture. Where Perennial Ryegrass is seeded, it would be well to treat it as a cereal and plough up the land after the seed is saved. During the last year or two we have examined a very large number of samples of farmers' home-grown Ryegrass, and there were very few that did not contain a large and varied assortment of weed seeds. Recently several of the local seed dealers have installed machinery for cleaning Ryegrass, and many farmers send their seed to them to be cleaned.

Much of the Ryegrass seed that the farmers in Scotland buy is seeded in Ayrshire. Farmers in that county have for long laid themselves out to grow Ryegrass seed, and it is usually very much cleaner than the seed grown in other counties. Some seed also comes from England and the north of Ireland.

There is a considerable variation in the longevity of different plants even in the same sample of Perennial Ryegrass seed. If a sample is sown sufficiently thin to make observation easy, it will be found that there are great differences in the proportion of leaf to stalk in different plants. Some form practically no leaves but a large number of stalks. This type would be most useful as hay. These, after seeding, usually die. At the other extreme we have plants that produce a large proportion of blades and comparatively few stalks. These would be particularly valuable plants for pastures. Between these extremes will be found all intermediate types. Now, when seeding, the proportion of the first-mentioned type will tend to increase and that of the latter to decrease, so that practically all our stocks of Perennial Ryegrass contain the largest proportion of the short-lived plants. Attempts are being made at the present time to separate these types by selection, and already some seedsmen have on the market selected leafy Perennial Ryegrass. It must be obvious that such seed will be dearer. Some of the leafy strains, however, appear to be more susceptible to rust, and care must be taken to select rust-proof strains.

Italian Ryegrass (*Lolium italicum*) —Of all grasses, Italian Ryegrass has the quickest growth. After harvest and in early spring, fields where it has been sown are very conspicuous, due to its tufty habit of growth and the graceful appearance of its spreading leaf blades. This early character makes it a very valuable grass for those farmers who require very early spring grazing or cutting grass.

When Italian Ryegrass was first introduced great expectations were held forth regarding it, but, unfortunately, these were not wholly realized. The reason for this was that in the early trials the Italian Ryegrass was usually sown on good land and was well treated, and under such conditions it did well. But many who subsequently used it in the early days did so on inferior land and without any particular treatment, and under these circumstances it did not give so satisfactory results. This led to a disparagement of its merits.

Italian Ryegrass is particularly suited for good soils, but it may do quite well on medium soils if well and suitably treated. On dry sandy or moorish soils, and all soils in poor heart, it should *not* be used.

In duration it is essentially a biennial plant, although a few plants may last for several years if they are not allowed to form seeds. If made into hay, most of the plants die during the next winter. If, however, the hay is rather late in being cut some seeds may be formed, and when these are shed young plants of Italian Ryegrass may spring up. If cut before the seeds are fully ripe, there will be a good aftermath and a fair appearance in the pasture in the spring of the following season, but the majority of the plants disappear during summer.

In an experiment where 5 lb. per acre of Italian Ryegrass was used in the seeds mixture, and where hay was made every year, the following amounts were found on the average when botanical analyses of the hay were made.

1st year	.. ..	5·4 cwt. per acre.
2nd ,,	.. ..	0·4 ,, ,,
3rd ,,	.. ..	0·1 ,, ,,

These figures give a very good idea of its occurrence during the different years.

In the first year its spreading habit of growth tends to keep down weeds, but in subsequent years, as it dies out, weeds take its place; and where a large proportion of Italian Ryegrass has been sown the pasture may become very foul.

Italian Ryegrass is largely used, usually along with Red Clover, for hay, especially along the east coast where short rotations are in vogue, and it is generally regarded as superior for this purpose. The reason for this opinion is that it is tall and has a bulky appearance. As it is also early, and as heavy dressings of manures are often applied, a good crop of hay may be secured early in the season. Although it produces bulky hay crops under suitable conditions, it does not weigh so well as one would expect from its appearance. Of all the grasses it weighs least for its bulk. An examination of the stalk will show why this is so. When cut across it is seen that it is very thin, whereas in most other grasses the stem is much thicker. The stalks, however, are quite strong, and are not so easily laid as those of Perennial Ryegrass, and for this reason it is preferred in some districts.

Although large quantities (7 to 10 lb.) of Red Clover are often used along with Italian Ryegrass, a comparatively small amount of the clover is found in the hay. This is due to the overshadowing effect of the Italian Ryegrass. For this reason, when used as part of a seeds mixture, the weight of hay is less than where no Italian Ryegrass is used. Examples of this will be given when dealing more particularly with Red Clover. It has also an adverse influence on the slow-growing grasses, with the result that when it dies out the latter may not be able to fill up the vacant spaces sufficiently, and thus weeds gain entrance.

One of the reasons why Italian Ryegrass is so much favoured in the districts where it is grown is that the horse-owners who buy it prefer it alone, and say the horses stand up better without Red Clover. It is interesting to note in this respect that, in the districts round London, Red Clover is grown without any grasses mixed with it at all, as the horse-owners there consider that their horses do much better on the Red Clover alone!

Although it is usually considered to be a good hay plant, Italian

Ryegrass, except under special circumstances, is possibly more valuable for short-period pastures. Where it is present the pasture is earlier in spring, and when young and succulent is extremely well liked by stock. On the other hand, if it is allowed to go into ear, the stalks become hard, and it is neglected. When well eaten down it has not the same adverse influence on Red Clover.

Probably the best return from Italian Ryegrass can be obtained by sowing it alone or as the predominant ingredient in the mixture. If well supplied with moisture and nitrogen, as on sewage and irrigation farms, it will produce a large amount of grass, which should be cut green if the most is to be made of it. Two or three cuts can thus be obtained in a season. On many farms the liquid manure is used with great success for the same purpose.

In the early potato-growing districts of Ayrshire, Italian Ryegrass is largely used as a catch crop. As soon as possible after the potatoes are lifted, 1½ to 2 bus. are sown and harrowed in. It soon germinates, and by late autumn there is a considerable growth. It may either be eaten down by sheep and what is left ploughed down, or the whole crop may be ploughed in. In several cases potatoes have been grown on the same field for many years in succession, and the organic matter content has been kept up by dressings of dung or seaweed and the growth of Italian Ryegrass or Rape as a catch crop. Italian Ryegrass is also sometimes used to sow patches in fields that have been rotted out by a heavy grain crop. Where this is done care should be taken that the seed is well raked in, otherwise only a small proportion will germinate.

The seed of Italian Ryegrass comes mainly from the north of Ireland, England, and France. So long as the samples are pure and the germination high it does not apparently matter from which source it is obtained. Much of the French seed is imported in the uncleaned state, and as such, often contains a quantity of weed seeds and immature seeds incapable of germinating.

Cocksfoot (*Dactylis glomerata*).—During the last twenty years no grass has increased more in popularity and use than Cocksfoot. At the beginning of the century very few farmers included it in their seeds mixture, and those who did, used it only to a very limited extent. No one need wonder at its popularity, however, as it is suited for practically all soils.

So far as the hay crop in the first season is concerned, it is of comparatively little importance, there being only a small amount of it present —usually not more than 1 to 3 cwt. per acre. A very large proportion of this, however, is leaf blades, which are of higher feeding value than stalks and have the further advantage of making the hay greener. The amount present will depend to a great extent on the quantity of seed sown and on the amount of quick-growing plants sown along with it.

Perennial Ryegrass, in particular, if used in large quantity, has a considerable adverse influence on Cocksfoot and decreases the amount in the hay, as will be seen from the following results of an experiment, where three plots were sown with the same amount of Cocksfoot, Timothy and Clover, viz.:

Plot.	Mixture, common to each.	Perennial Ryegrass added.	Yield of Cocksfoot per Acre.
1	6 lb. Cocksfoot.	19 lb.	0·9 cwt.
	3 " Timothy.		
2	3 " Red Clover.	13 "	1·4 "
	1 " White Clover.		
3	1 " Alsike Clover.	7 "	2·0 "

Cocksfoot grows very rapidly after being cut, and the aftermath is greatly increased in value when it is present. In one experiment where plots were seeded with mixtures, one with and another without Cocksfoot, the aftermath from the former was valued at a considerably higher rate than that of the latter.

When a field is pastured in its first year, the Cocksfoot is not very prominent at the beginning of the season but gradually increases, and before the end of the season it adds very appreciably to the amount of food. During the second and subsequent years it is, in the majority of cases, the most prominent grass in the pasture. Pastures which contain it in quantity are ready for grazing three to four weeks earlier in spring than pastures where Perennial Ryegrass is the predominating ingredient, and continue growing during practically the whole summer. Of all grasses it grows quickest after being eaten down. During dry summers, in particular, it is very valuable, as it withstands drought better than others.

As with Perennial Ryegrass, there are considerable variations in the individual plants of Cocksfoot. We have noted three quite distinct types, one in which the shoots are very few and the plants assume a " V " shape, and another a " U " shape. Both these go into ear very readily, and are consequently not so valuable for pasture. In a third type, roundish in form, a large number of fresh leaves are formed; it is very slow in forming ears, and consequently is most suitable for pasture.

An objection often taken to Cocksfoot is that, being a strong-growing grass, it forms large tufts and goes into ear readily, and is consequently apt to be neglected by stock. That it does so is true under two different conditions, first, where too small a quantity of the seeds of Cocksfoot is sown, and second, where too large a proportion of short-lived plants is sown along with it. In the former case, the Cocksfoot plants have too much space, there not being a sufficient number to occupy the land,

and they grow much larger, while in the latter case the short-lived plants diminish the number of Cocksfoot plants and then die out, leaving space for the Cocksfoot plants to grow tufty. It should be noted that the Cocksfoot plants go into ear much more readily where they have room to grow than where they are closer.

Many farmers hold the opinion that Cocksfoot is not present at all during the first season. The reason, of course, is that those farmers have been using only 2 or 3 lb. of Cocksfoot along with a large quantity, possibly a bushel or over, of Perennial Ryegrass, and the result is that the Cocksfoot was smothered out.

Another serious disadvantage of the irrational use of Cocksfoot in the above ways is that when it gets tufty it prevents the growth of White Clover and decreases the quantity of this valuable plant in the pasture. There is often competition between Cocksfoot and White Clover, and sometimes the one and sometimes the other gets the upper hand. When a field is well and evenly grazed, especially at the beginning of the season, the White Clover is usually able to spread and a fine mixed pasture is obtained. Cocksfoot is often considered to be coarse and is condemned because of this. It is this tendency to coarseness, however, that is one of its most valuable characteristics, as coarseness means quantity, and furthermore, the coarseness can be removed without reducing the quantity by the use of thicker seedings and also by the addition of bottom plants, especially White Clover.

Experiments have shown that on medium soils with a good tilth when about 8 lb. of good average seed of Cocksfoot are sown as part of a seeds mixture, along with not more than 12 to 14 lb. of Perennial Ryegrass, the Cocksfoot plants are much smaller, and neither tend to form tufts nor go so readily into ear, thus making a more even pasture and giving the White Clover a better chance to flourish.

Cocksfoot, when properly managed, is well liked by all kinds of stock, especially sheep, but if they are kept too long on the pasture they will eat out many of the plants and will keep the remainder so bare that the fields may appear to have very few Cocksfoot plants. If the sheep are taken off for a period, however, the plants will very soon make their appearance again. It would be well not to over-graze with sheep, but alternate these with cattle and horses.

Cocksfoot is of very little value for winter grazing, as it becomes very withered and grey in appearance. It is a very useful grass for helping to keep out weeds. Fields that used to fill up with the inferior Yorkshire Fog (*Holcus lanatus*) when Ryegrass was the only grass used are almost now entirely devoid of it when better balanced mixtures including the longer lived Cocksfoot are used. As it is a very deep-rooted plant, it is specially valuable when ploughed up for increasing the amount of organic matter in the soil. Care must be taken in ploughing that it is well turned over, otherwise some of it may grow in the grain crop.

Timothy (*Phleum pratense*).—Timothy is a grass that grows well on all good deep soils where there is a plentiful supply of moisture. It is specially suited for those of a clay or peaty nature. On dry soils, and especially in a dry season, the yield of Timothy is small. On such soils it forms a thickening at the base, and it is often thus mistaken for Knot Grass or Pearlwort (*Avena elatior*, var. *bulbosum*).

Timothy is, on the whole, better suited for hay than pasture. Even in the first year there may be a considerable amount in the hay, but the amount will not only depend on the kind of soil but also to some extent on the amount of seed sown.

The following amounts were obtained in experiments on three different soils where 3 to 4 lb. of seed were sown as part of the seeds mixture.

	Per Acre.	
Kind of Soil.	Total Hay Crop.	Of which Timothy.
1. Sandy loam	42·5 cwt.	2·5 cwt.
2. Clay	63·6 „	8·2 „
3. Peaty	54·2 „	17·4 „

As in the case of Cocksfoot, the amount of Timothy in the hay will depend largely on the quantity of Perennial Ryegrass sown along with it. In the experiment described at p. 151, the amounts of Timothy present in the three plots, where 3 lb. of seed were sown in each, were as follows:

With 19 lb. Perennial Ryegrass	3·1 cwt.
„ 13 „ „ „	4·6 „
„ 7 „ „ „	6·2 „

As it is later than most other grasses, it is cut in a greener state and consequently the hay is greener. Of all grasses, Timothy weighs most for its bulk. A cross-section of the stem will show that is nearly solid. It responds readily to good treatment, and a largely increased weight is got from an application of a nitrogenous manure or liquid manure or dung.

The hay is considered to be of superior quality, and it always commands a high price in the cities, where it is in demand for feeding horses. It should not be too closely cut, as this is found to have an injurious effect on the plants. In the same way, if the aftermath is grazed too soon or too close, Timothy may be injured.

Timothy produces a fair amount of aftermath, especially if cut early. In this respect it is intermediate between Perennial Ryegrass and Cocksfoot.

Even on soils not particularly suited to Timothy it is advisable to use some, as it evidently has a very valuable influence on Cocksfoot. The Cocksfoot is improved with the association of Timothy, and the

In the second and subsequent seasons, although it is not such an early grass for pasture in the spring as Cocksfoot, still it is very useful for this purpose.

In some districts it is largely grown and cut for hay every year, and this practice might be considerably increased in many clay districts where it is difficult to get good crops of any kind. For this purpose 12 to 15 lb. of Timothy and 7 to 8 lb. of either Perennial or Italian Ryegrass, and sometimes a few pounds of Red or Alsike Clover are sown.

The length of time a meadow will last depends largely on how it is treated. If well managed it may easily last ten or more years, whereas if it is allowed to grow naturally it will become weedy much more quickly, and will last only four or five years. On many well-managed Timothy meadows it is the custom to apply a dressing of dung every second year, and a complete artificial manure such as 1 cwt. sulphate of ammonia, 2 cwt. superphosphate, and 1 cwt. potash salts in the intervening years.

Wild White Clover has also been found in some cases to be beneficial, not so much on account of the amount present in the hay, as on the good effect it has on the vigour of the Timothy. In many cases when hayed every year, there is little chance of the White Clover surviving, but Timothy, being very much opener, has not the same over-shadowing effect as other grasses.

Meadow Fescue (*Festuca pratensis*).—At one time those farmers who sowed other grasses in addition to Perennial Ryegrass included a small quantity (1, 2, or 3 lb.) of Meadow Fescue in their seeds mixtures. When their pastures were examined it was found that there were very few plants of this grass present, either in the first or subsequent years. As Meadow Fescue is known to be a good grass, especially for pasture on good soils, experiments were carried out to endeavour to find out why it was so rarely seen, and if it could be got to grow better. In these experiments, in one plot, A, Meadow Fescue was sown along with clovers, on another, B, Meadow Fescue was sown along with Ryegrasses and clovers, and in a third, C, Meadow Fescue was sown along with Ryegrasses, Cocksfoot, Timothy, and clovers. In B and C the quantity of Meadow Fescue, both in the hay and pasture, was small, while in A there was a large quantity.

These experiments, therefore, clearly showed that Meadow Fescue was not able to compete against quick-growing grasses like Perennial Ryegrass. It is very slow in growth at first, and the Perennial Ryegrass never allows it to get a start. When sown alone it forms good pasture on the better soils after it is established, but as it requires nearly a year to get established it is obviously not an economic proposition to use it for temporary pasture. On poor dry soils, even when sown alone, it is not a success.

For permanent pasture, however, on good rich soils with sufficient moisture, if it is sown with only a small quantity of Perennial Ryegrass, it may be a very useful grass after it gets established. It is especially valuable after Cocksfoot and Timothy have become less prominent.

Tall Fescue (*Festuca elatior*).—Tall Fescue is altogether a bigger, rougher, and more robust plant than Meadow Fescue, although in general appearance it is somewhat similar. It grows naturally on dampish situations, yet it can flourish on much drier soils than Meadow Fescue. In fact, for pasture purposes it is more suitable for such dry situations, as, when it does grow, it is really too luxuriant on the moister soils.

At the present time the seeds are too dear for its inclusion in temporary pastures, and even on permanent pastures it is doubtful if it would repay the cost. If seed could be obtained cheaper, however, it might be useful to use a proportion in mixtures on medium soils. It withstands competition with Perennial Ryegrass better than the Meadow Fescue.

Rough-stalked Meadow Grass (*Poa trivialis*).—Rough-stalked Meadow Grass grows naturally in all damp situations. It is very common in ditches, and patches of it are easily recognized by its conspicuously light green colour. Under moist conditions it is perennial, and has above-ground creeping stems, so that it is readily able to fill up the vacant spaces in a pasture. It is almost useless on dry soils, however, except perhaps during winter or in wet seasons. It is freshest and greenest from late autumn to spring, while in summer if there is a dry spell the plants assume a sickly reddish brown appearance, and if no rain comes may gradually wither away.

As it is liked by stock, and as the seeds germinate very readily, giving no difficulty in getting plants, it may be advisable, on suitable soils, to sow a small quantity (up to 1 lb.) even for temporary pastures (three to four years). In some cases there may even be an appreciable quantity in the hay. Owing to its spreading habit of growth it is very useful in helping to keep out weeds.

Smooth-stalked Meadow Grass (*Poa pratensis*).—Smooth-stalked Meadow Grass grows naturally on many dry sandy places. It is a perennial grass with underground creeping stems. These make it unsuitable for temporary pastures owing to the labour that would be necessary to clean the land. It is chiefly suited for permanent pasture on light soils. In America it is very largely grown in the best feeding districts, where it is known as Kentucky Bluegrass.

Being very slow in germinating, and largely owing no doubt to the other grasses and clovers growing more rapidly, great difficulty is often experienced in getting it established. After it is established, however, it comes fairly early in spring, and its underground stems enable it to withstand drought to a considerable extent, and to continue fresh and green when other grasses suffer.

Meadow Foxtail (*Alopecurus pratensis*).—Meadow Foxtail grows naturally in many damp situations, such as waste places and ditches. It flourishes under the same conditions as Timothy and Meadow Fescue, and is therefore suited for clay and all moist good soils, and in such soils it is perennial.

It is one of the earliest grasses to mature in spring, and the seeds are usually ripe before other grasses have formed ears. This peculiarity makes it unsuitable for mixing with other grasses for hay.

It is well liked by stock, and it is therefore chiefly useful for permanent pastures on good damp soils.

As the seeds shake readily it must be cut very early, and the result is that most samples are light, and therefore germination is usually poor.

Crested Dogstail (*Cynosurus cristatus*).—Crested Dogstail is a dwarf grass that grows naturally along roadsides, on sandy land near the sea and on hills, and on moist shallow soils. It is a perennial grass, and often forms a large part of permanent pastures. Although only a small quantity of seed may be sown, the number of plants in a pasture rapidly increases owing to the fact that stock rarely eat the stalks, so that abundant seed is formed, and when it is shed it germinates readily. In this way, in a few years it is apt to crush out other grasses and clovers and even weeds, and may thus take entire possession. Where there is abundant Crested Dogstail in a pasture very few plants of Yorkshire Fog will be found. The seeds are able to retain their vitality in the soil for several years, so that once it has been used in temporary pastures it may be depended on to grow during the next rotation although seeds have not been again sown.

Crested Dogstail is of little use for hay, as very few stalks are formed the first year. Where they do form, they are apt to become very hard and woody.

It is of comparatively little use for pasture during summer. In some experiments the plot where it was included as part of the seeds mixture was neglected by stock, the dividing line between it and other plots being very marked. It is of a somewhat tufty habit of growth, and the dark green blades, which are always fresh looking during winter, are very conspicuous. It is especially useful for winter pasture on third-class sheep land, and in such cases it should always be included in the mixture.

Tall Oatgrass (*Avena elatior*).—Tall Oatgrass is our tallest growing grass, and may rise to a height of 4 ft. or more. It is specially suited for light soils, and is largely grown in France, where it is known as French Rye or Ryegrass. It is essentially a hay plant, and when used as part of a seeds mixture will usually increase the yield, but as the seeds are rather dear, the increase will, as a rule, only pay for the seeds used. When present in the hay it makes it open, and consequently easier to cure.

In pasture the long spare stalks are quite conspicuous, but as it does not tiller much it does not add appreciably to the amount of food. It has been found that in pasture cattle do not care for it. Where plots have been sown with it they were neglected, whereas the pasture alongside without it was closely cropped. The leaves are hairy, which may be the reason why it is not readily eaten.

Red Clover (*Trifolium pratense*).—This is perhaps the most valuable of the forage plants grown in this country at the present time, looking to its value as a food and its effect on soil fertility. Although it can be grown successfully on almost all classes of soil, yet it often happens that it is deficient in hay and pasture, the extreme soils—sand, clay, and peat—being chief in this respect. Red Clover seems to be more easily affected by adverse conditions than most plants. It is more often either a complete failure or a complete success than just a fair crop.

Under the conditions of soil and climate prevailing in Scotland, none of the cultivated Red Clovers are perennial, although some are longer lived than others. What usually happens is that in the first year there is a large, or a fairly large, quantity in the hay or pasture. In the second year there may be a few plants in the pasture, especially at the beginning of the season. In the third year the plants are more rare, although we may find a few in the fields. It must always be remembered that its longevity will depend on circumstances. Some plants produced from a sample will live longer than other plants produced from the same sample. Again, if seeds from a certain sample are sown in two different fields, it may be that some plants will live longer in one field than in the other.

While there are undoubtedly many variations in size, shape, and colour of leaves, hairiness, earliness, &c., all plants of Red Clover may be classified under three distinct types, namely, Broad-leaved, Late-flowering, and Wild. The Late-flowering is also called Single-cut Cow-grass, and in America it is known as Mammoth Red Clover.

The chief differences between these types are: first, although there is a considerable variety of shape, even in the same plant, on the whole the leaves of the Broad-leaved Red Clover are, as its name implies, broader than those of the Late-flowering, which are comparatively long and narrow; while those of the Wild are usually still narrower. Second, during winter and in early spring the plants of the Late-flowering and Wild types appear to be closer to the surface of the soil, and altogether have a more prostrate habit of growth than the Broad-leaved. Third, the Late-flowering, as its name implies, is about 10 to 14 days later in flowering than either the Broad-leaved or the Wild, and before it flowers the plants have a very characteristically fresh green appearance.

Many trials have been carried out at different centres to find the relative merits of the Broad-leaved and Late-flowering, while, as it is only within the last two or three years that there has been any quantity of seed of the Wild type on the market, only a few trials have been made with it. In one of these trials with Broad-leaved and Late-flowering the same seeds mixture was sown, except that in one plot Broad-leaved Red was used and in another Late-flowering.

When the hay was weighed it was found that the plot where Late-flowering was included had produced the heavier hay crop, and this result was due to the larger amount of clover present, as will be seen from the following figures:

Clover Sown.	Yield per Acre.		
	Grass.	Clover.	Total.
Broad-leaved	18·3 cwt.	26·8 cwt.	45·1 cwt.
Late-flowering	16·2 ,,	35·9 ,,	52·1 ,,

It will also be noted that there was less grass present where the Late-flowering was used. This is an important point, and has a bearing on the amount of Late-flowering that should be sown. As a result of this and other trials, it is concluded that in the majority of cases 1 to 1½ lb. per acre of Late-flowering along with 2 lb. of the Broad-leaved is sufficient.

The Broad-leaved produces a large quantity of aftermath, but generally the Late-flowering produces comparatively little unless it is cut very early. For this reason it gets the name Single-cut Cowgrass. In most cases more plants of the Late-flowering type are present in second and third years' pastures than of the Broad-leaved type.

The few trials that have been carried out with the Wild Red show that it is apparently of very little use for hay production, there being only a few weakly plants present. In the second and third years, however, a larger number of plants are found, but these do not seem to be eaten with relish by the cattle. It is quite possible there was too much sown, and further trials will have to be made before definite conclusions can be drawn regarding it. It should be noted that there is much more variation in the plants from a sample of Wild Red seed than there is from samples of the other two types. Some of the plants of Wild Red have very hard bare stalks, while others are more leafy. If a selection were made of the leafy plants a strain could be raised which would likely prove more useful.

Some Red Clover seed is very often offered on the market under the name of Cowgrass. This term is very misleading, as it is applied either to the Late-flowering type or to any good-looking "bold" sample of the Broad-leaved type. If it were applied to the former only there would be no confusion, as we should know what we had, but when it is applied indiscriminately to all good-looking samples it necessarily leads to great confusion. Many farmers and local dealers are of opinion that Cowgrass is Perennial Red Clover, and pay a higher price for it. This is not the case; it is not more perennial than another sample labelled Red Clover. Altogether, Cowgrass is an unfortunate term, and it would be better not to use it at all, but to use the terms Broad-leaved and Late-flowering.

A fairly large proportion of the seed of Red Clover sown in Scotland is grown in England. Unfortunately, in many seasons great difficulty is experienced in saving it in good condition, with the result that many samples contain brown and shrivelled seeds which are of low germination. Seeds are also imported, principally from Chile and France, while Canada, Italy, and some other countries also send small amounts. The quantity imported from any particular country varies considerably from year to year.

The question naturally arises, are those foreign-grown seeds as good as English-grown seeds? Many trials have been made with seeds from these countries, and in considering the results four points must be kept in mind.

1. The weather conditions during winter vary very much in different years and in different parts of the country, so that if a trial is carried out during a mild winter or in the milder districts most of the clover plants may survive, and quite a good crop may follow, whereas in a severe winter or in a cold district many plants in some samples may die, and a poor crop result.

2. There may be considerable differences in samples from the same country. This would be especially the case in large countries, where there is a wide range of temperature, rainfall, and altitude. For example, samples from an upland district in the north of France may be quite different from samples from the south of France.

3. Samples may be sold as English Red Clover which had grown in another country, or which contain only a proportion of English seeds.

4. Another point of considerable importance regarding English seed is its original source. In many cases the English grower, after he has secured a vigorous strain, sows it year after year. In other cases, however, especially after a bad hay season, he may sow Chilian, French, or other foreign seed. The produce is undoubtedly English seed, but, although it is very difficult to get reliable information regarding the point, there is reason to believe that such seed is inferior to the acclimatized seed. Unless one is absolutely sure of the strain, it is always well, as a precautionary measure, when selecting Red Clover to buy three or four different lots of English and mix them.

The general result of experiments indicates that in the northerly part of Scotland, Red Clover seed from England or Wales, or from the colder northerly countries such as Sweden, &c., are more reliable than those from southern, warmer climates. In many districts in the south of Scotland, however, where the climate is much better than in the north, seeds from some of the warmer countries or districts, such as Chile and Wisconsin, have been found to do well. The American Mammoth although quite hardy does not appear to be so vigorous as English or Welsh Late-flowering.

The following average result was got from an experiment carried out at a number of farms in the north of Scotland where the different Broad-leaved clovers were added in turn to the following seeds mixture:

12·2 lb. Perennial Ryegrass.	1·7 lb. Timothy.
4·4 „ Italian Ryegrass.	1·2 „ White Clover.
5·9 „ Cocksfoot.	1 „ Alsike Clover.

The quantities of Red Clover sown represent the same number of pure and germinating seeds per acre.

	Grass. Cwt.	Clover. Cwt.	Total Weight. Cwt.
3·9 lb. English	18·3	26·8	45·1
3·1 „ Canadian	19·8	14·4	34·2
4·6 „ Chilian	20·9	13·4	34·3
3·7 „ French	21·1	11·4	32·5
3·7 „ German	20·0	12·3	32·3

The value of the English seed in this case was even more marked than the figures would indicate, as the clover present in all the foreign plots *included large quantities of Alsike.*

Red Clover is useful both for hay and pasture. Although it does not weigh well for its bulk, its presence or absence usually makes a considerable difference to the total weight of hay produced per acre, especially on the poorer classes of soil. On better soils, and especially if an application of a nitrogenous manure has been made, the grasses tiller more and so help to make up, to some extent, the lack of Red Clover. It improves the feeding value of both the hay and pasture, and, like all legumes, it is able to take nitrogen from the air, thus leaving the soil *richer in this ingredient than it found it.*

One of the chief reasons why in many cases Red Clover is deficient in the hay crop is the adverse influence of a heavy grain crop or of grasses. While all grasses have some influence, the quick-growing Ryegrasses have the most. As showing the influence of Perennial Ryegrass on the clover, in one series of experiments, where 1½ bus. of Perennial Ryegrass was used, there were on the average 19·4 cwt. of clover per acre in the hay, whereas where only ½ bus. along with Cocksfoot and Timothy was used, there were 24·3 cwt. of clover, the same quantity of Red Clover seed having been sown in each case.

In many districts, even although as much as 8 to 10 lb. of clover seed are sown, complaints have been made of the difficulty of getting Red Clover to grow. In those districts Italian Ryegrass is used in large quantities, and undoubtedly this is the chief reason why the clover is deficient. Many experiments have been carried out with Italian Ryegrass, and in practically every case where it was used the amount of clover in the hay was reduced.

In an experiment where the same amounts of Cocksfoot, Timothy, and clovers were used, one plot had also included 20·4 lb. of Perennial Ryegrass, while in another plot 14·6 lb. of Perennial Ryegrass and 4·2 lb. of Italian Ryegrass were used. These weights represent the same number of pure germinating seeds. The substitution of even this small amount of Italian Ryegrass for Perennial Ryegrass reduced the clover in the hay from 15·2 cwt. to 11·8 cwt. per acre.

In another experiment carried out on a clay soil, five different mixtures were sown along with the grain crop. All mixtures contained 6 lb. Cocksfoot, 3 lb. Timothy, 3 lb. Red Clover, and 3 lb. Alsike Clover per acre, and the following amounts of Ryegrasses:

	(1)	(2)	(3)	(4)	(5)
			Pounds per Acre.		
Perennial Ryegrass	20	15	10	5	0
Italian Ryegrass	0	5	10	15	20

In the following February moss litter dung at the rate of 15 tons per acre was applied to part of each plot. After cutting, samples of the hay of each plot were taken, the grasses and clovers separated out and weighed, and the percentage of each calculated. From these the weights in hundredweights per acre of grasses and clovers were estimated. These were as follows:

	(1)	(2)	(3)	(4)	(5)
(a) With dung—	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Grasses	37·0	38·5	37·4	37·1	37·5
Clovers	22·6	18·9	12·5	9·8	6·6
	59·6	57·4	49·9	46·9	44·1
(b) Without dung—					
Grasses	17·9	19·4	24·4	21·2	27·0
Clovers	25·7	20·9	15·0	12·4	10·5
	43·6	40·3	39·4	33·6	37·5

This shows very markedly the adverse influence of the Italian Ryegrass on the clovers, the more Italian seed sown and the more its growth was encouraged, the smaller was the quantity of clover in the hay. In (*b*) plot 1, where no Italian was sown and where no dung was applied, there was about 60 per cent of clover (25·7 cwt.) in the hay, whereas in (*a*) plot 5, where 20 lb. of Italian Ryegrass were sown and where dung was applied, there was only about 15 per cent of clover (6·6 cwt.) in the hay.

Anything that tends unduly to stimulate the grasses will intensify the influence they have on the clover, and in this connection the excessive use of nitrogen for the hay crop is the most common.

Though clovers are able to make use of nitrogen from the air, it is undoubtedly true that an application of a nitrogenous manure in moderation has a beneficial effect on the growth of Red Clover. Where used in excess, however, and especially without phosphates and potash, it encourages the grasses so much that they exert an adverse influence on the clover and reduce both the amount and proportion in the hay.

Liquid manure, although it contains large quantities of potash, contains also a considerable amount of nitrogen, and its effect on the clover is often similar to a nitrogenous manure. If used in moderation it has usually no bad effect on the clovers. In an experiment where about 2000 gall. per acre of weak liquid manure were used, the hay crop was increased by 6 cwt. per acre, and there was no diminution in the amount of the clover. Where, however, large quantities of liquid manure are used, and especially where there is a large proportion of Italian Ryegrass in the mixture, and on soils suited to the luxuriant growth of this grass, Red Clover is very adversely affected.

When dung is used as a top dressing for hay on light and comparatively poor soils, which are often deficient in potash, and where luxuriant growth is rarely seen, it will encourage both the grass and Red Clover, and altogether a much better crop will be got. This, in all probability, is partly due to the potash which the dung supplies. Where it is used on good land, however, and especially where Italian Ryegrass forms a fairly large proportion of the seeds mixture, it will have much the same effect as a nitrogenous manure under the same circumstances, as in the experiment described on p. 161.

On many light soils the lack of potash is the chief reason why Red Clover is always deficient, or unhealthy looking when it is present. Often clayey or peaty soils are also deficient in lime, and no doubt the lack of this is, in many cases, the reason why Red Clover does not grow. Where it is deficient it would be well to apply a good dressing of lime (20 to 30 cwt. per acre) some time before the seeds are sown, so that it may get thoroughly mixed with the soil.

White Clover (*Trifolium repens*).—White Clover is essentially a pasture plant, being of very little use for hay.

It has a creeping habit of growth and sends out roots at the joints, so that when once established it soon covers the ground, and is extremely useful for filling up spaces and so helping to keep out weeds and prevent evaporation. In addition to the adventitious roots it has a tap-root, which enables it to withstand drought to a considerable extent.

It will grow on almost any soil, except those that are wet or are deficient in lime, phosphates, and potash. All the best pastures contain White

Clover, and its absence usually indicates that the grazing is of inferior feeding quality. On many light, poor soils White Clover grows naturally, while on good soils the strong growth of the grasses often prevents it getting a start. Frequently clays on which White Clover was deficient have been considerably improved by an application of 5 to 10 cwt. per acre of basic slag.

There are two kinds of White Clover on the market, viz. ordinary or Dutch White Clover and Wild White Clover. The former has been in use for a long time, but from the experience that we now have of experiments where plots with ordinary White, Wild White, and no White Clover were sown, it is questionable whether the ordinary White was present to any great extent in third year's grass in fields where it had been sown. Undoubtedly in many cases the White Clover present in the pasture was natural White Clover, and was not the produce of sown seeds at all.

Although Wild White Clover had been used in the south of Scotland and in England several years previously, it has only been employed in the north of Scotland to any extent since about 1910, when several farmers commenced to grow it. It was several years, however, before its great value as a pasture plant was realized.

In 1913, when the fields which had been sown in 1910 were in third year's grass, and where in many cases the farmers had forgotten all about the Wild White Clover, their attention was drawn to the luxuriance of both the grasses and clover in the parts where it had been sown. This result was most marked where ordinary White Clover had been sown alongside it. Many farmers who gave it a trial at that time now use it constantly in their mixtures.

If a field is pastured and not hayed the first year, the Wild White may occasionally make its appearance that year, but generally in the following year. On the other hand, if hay is made the first year it will usually be the third season before it is at all prominent, although in some cases it may be present in the second, especially if the hay crop has been light, or has been cut early. If the grass is, therefore, to be laid down for two years only, Wild White Clover may be used with every prospect of success where it is pastured both years, while if a crop of hay is taken the first year it will generally be better not to use it, but to use ordinary White, which grows more luxuriously the first and second years.

In some cases where a large quantity of Perennial Ryegrass is used in the seeds mixture the Wild White Clover takes almost entire possession, as it also sometimes does when White Clover grows naturally. This, of course, is not wanted. What we desire is to get a good herbage consisting of a mixture of grass and clover. Therefore, both on soils where White Clover grows naturally and also on fields where Wild White is sown, a better result will be got if a considerable proportion of the seeds mixture consists of strong-growing, long-lived grasses, as they are better able to compete against this clover. Conversely, on soils where these grasses grow luxuriantly, there would be more chance of getting a good result if Wild White Clover were included in the mixture, as it is evidently better able to compete against these grasses than ordinary White Clover.

About 1910, when the Wild White Clover was first used to any extent in the north, it was only slightly higher in price than ordinary White Clover, but now it is considerably dearer, and many are in doubt as to whether it will pay to use it at the high price. When first tried, about 1 lb. per acre of seed was sown, and on clay soils, which are usually cloddy, or on soils where it does not grow naturally or where it has not been used previously, this amount may still be necessary; but it has now been found that on average soils in good tilth ½ lb. per acre is usually quite sufficient, especially if it has been used in the previous rotation. Though the cost is high, all who have seen the results acknowledge that the pasture is increased in value by much more than the amount expended. In addition the succeeding grain crop is usually improved. In several cases during the past few years the grain and straw on plots with and without Wild White Clover have been weighed, and there have been increases of from 8 to 16 bus. per acre of grain and 8 to 10 cwt. of straw. Wild White Clover is probably the cheapest source of nitrogen that the farmer has at his command.

Seeing that White Clover grows naturally and so luxuriantly on some soils, evidently from self-sown seeds, another question often asked is: "If once sown in a field, will Wild White Clover re-seed itself in the same way?" In the cases noted above, the plots where seeds of Wild White were sown in 1910, and which showed luxuriant growth in the third year's grass in 1913, were in third year's grass again in 1919. These were examined, and in some instances no trace of the Wild White Clover could be seen. Occasionally, however, where Wild White Clover had not been sown in the seeds mixture in 1916, the plot seeded with it in 1910 could still be seen quite distinctly. The White Clover plants were thicker than in the surrounding area, thus making the whole plot much darker in colour. Evidently, therefore, under certain conditions this clover is able to re-seed itself.

The seeds of the ordinary White Clover are got from England, New Zealand, America, &c., but the seed of the Wild White is saved from old permanent pastures in England, chiefly in the Weald districts of Kent and Suffolk. The area is limited, however, and the supply is considerably less than the demand, hence the high price. In order to augment the supply some seed growers save seeds from temporary leys seeded with Wild White Clover, and the question is asked: "Will the White Clover seeds saved from these young pastures have the same valuable characteristics as seed saved from the original permanent pastures?" No one can say definitely, but trials are being carried out to elucidate this matter. The examples stated above, however, where the White Clover showed distinctly in the second rotation in 1919, indicate that seeds so saved from young pastures might be as valuable as those saved from permanent pastures for a time at any rate.

If the individual plants from the same sample of Wild White Clover are examined it will be seen that there are great differences among them. Now, as in the case of grasses, some of these plants are shorter lived than others. These will naturally seed earlier and more freely, so that the "once-grown" seed would contain a smaller proportion of the essentially perennial plants. If seed were again sown from the once-grown and again saved it will likely contain a larger proportion of the shorter lived strains.

During the last year or two several lots of White Clover seed, chiefly from the Continent (Morso, &c.) and New Zealand, have been put on the market, but they have not been tried sufficiently long to enable a true opinion to be formed of their value. So far as outward appearance goes, they are, however, more like ordinary White than Wild White, but they seem to recover better after being eaten down.

Another and quite different type of White Clover that has been introduced during the last year or two is that known as Giant, Mammoth White, or Ladino. It is a much larger plant altogether than ordinary or Wild White, but has the same creeping habit. Unfortunately, however, it does not appear to be sufficiently hardy to enable it to withstand our severe winter.

Alsike Clover (*Trifolium hybridum*).—Although Alsike is not as valuable for hay as Red Clover, nor so valuable for pasture as White Clover, still it is a very useful plant. Its chief use is to act as a reserve plant if Red Clover fails. Its value in this respect will be best appreciated by an examination of the results of an experiment in which different samples of Red Clover were used in the seeds mixture, and in which 1 lb. per acre of Alsike was used in each plot.

Plot.	Weight per Acre.			
	Red Clover.	Alsike Clover.	Grasses and Weeds.	Total Hay Crop.
	Cwt.	Cwt.	Cwt.	Cwt.
A	65·3	1·8	7·9	75·0
B	46·3	6·6	9·1	62·0
C	22·3	12·8	21·4	56·5
D	13·3	19·5	16·2	49·0
E	6·0	24·0	18·5	48·5

Here it will be seen that the larger the quantity of Red Clover in the hay the smaller was the quantity of Alsike (and grass), but as the Red Clover decreased the quantity of Alsike increased.

It is a more slender plant than Red Clover and usually branches more, hence it is not so rough in the hay. In addition, it keeps green and succulent longer. It produces a medium amount of aftermath. Alsike usually lasts longer than Red Clover, and is not so readily thrown out by frost. A good many plants are present in the pasture. Although it is more particularly suited for dampish, good soils, still it will grow on lighter soils if there is a sufficient rainfall. It is somewhat bitter in taste, and when present in large amount is not well eaten by stock.

Trefoil (*Medicago lupulina*).—In some cases Trefoil or Yellow Clover, which is a biennial plant with a prostrate spreading stem, is sown in seeds mixtures. In trials which have been carried out, however, and where 1 to 2 lb. of seed per acre were included in the seeds mixture, the quantity in the hay or pasture was so very small that there is apparently no advantage in sowing it.

It is often mistaken for Yellow Suckling Clover, which grows naturally on many light soils. Both plants have small, yellow flower heads, and are very like each other. In many cases farmers sow Trefoil and are under the impression that it comes all right, but the fact is that they mistake Yellow Suckling Clover for the Trefoil.

Factors to Consider in making up the Seeds Mixture.

Having examined the characteristics of the grasses and clovers generally used for seeds mixtures, we can now proceed to consider the factors that require to be kept in mind when making up mixtures for pastures.

1. *The plants selected should be adapted for the particular soil.*—Most of the plants suitable for pastures will grow on ordinary medium soils, but some of them suit the extremes—clay and peat—better than others, and as there is usually more difficulty in getting a good " catch " on such soils, care should be taken that those selected are adapted for such extreme soils. These are set forth in the following table.

Clay Soils.	*Sandy Soils.*	*Peaty Soils.*
Meadow Fescue.	Smooth-stalked Meadow Grass.	Timothy
Tall Fescue.	Sheep's Fescue.	Rough-stalked Meadow Grass.
Timothy.	Crested Dogstail.	Meadow Foxtail.
Rough-stalked Meadow Grass.	Tall Oatgrass.	
Meadow Foxtail.	Trefoil.	
Italian Ryegrass.	Kidney Vetch.	

2. *Plants selected should be adapted for the time they are to occupy the land.*—Although the different grasses and clovers may be divided into two classes according to their longevity, viz. long-lived and short-lived,

there is no strict dividing line between them, but the following lists indicate how they behave under average conditions.

Short-lived.	Long-lived.	
Red Clover.	White Clover.	Timothy.
Trefoil.	Perennial Ryegrass.	Meadow Foxtail.
Alsike Clover.	Cocksfoot.	Crested Dogstail.
Italian Ryegrass.	Fescues.	Meadow Grasses.
	Tall Oatgrass.	

The short-lived plants grow very rapidly at first, and in the first season produce their maximum crop. After this they either die out altogether or become so small that they are of comparatively little value. The long-lived plants, on the other hand, grow much slower at first, but gradually improve and generally remain good for several seasons. If the conditions do not suit them, however, they may last for a much shorter time, and when present are small, and might even be included in the first class. Thus, Timothy, if used on poor soil, will not last much longer than one year.

The proportion of these two classes to use will depend on the length of time the grass is to lie. If for only one year, we would use generally only short-lived plants, while if for longer periods we would include a proportion of the short-lived plants to ensure a good crop the first year, and a proportion of the long-lived plants to take the place of the short-lived plants as they die out. If too large a proportion of the short-lived plants is used, while a good result would be got the first year, it would be at the expense of the long-lived plants, since many of these would most likely be overshadowed, with the result that weeds, especially Yorkshire Fog, would gain an entrance as the short-lived plants died out. On the other hand, if too large a proportion of long-lived plants were used there would likely be a comparatively poor crop the first year, and this would also tend to allow weeds to enter, although during the following years it would improve materially.

3. *Different habits of growth of plants.*—We may divide plants into two classes according to their habits of growth, viz. top and bottom plants. The chief plants in each group are:

Top Plants.	Bottom Plants.
Red Clover.	White Clover.
Alsike Clover.	Trefoil.
Cocksfoot.	Kidney Vetch.
Timothy.	Meadow Grasses.
Italian Ryegrass.	Crested Dogstail.
Meadow Fescue.	Sheep's Fescue.
Tall Fescue.	Perennial Ryegrass.
Meadow Foxtail.	
Tall Oatgrass.	

The top plants usually have big, broad, spreading leaf blades and deep roots, and tend to grow in tufts. This class usually supplies the most food for stock, but if too large a proportion is used the pasture is open. The bottom plants, on the other hand, have smaller, narrower leaf blades and shallower roots, and have often a creeping habit of growth, and thus help to fill up the open spaces between the top plants.

Both classes should be properly represented in mixtures, as we then have a better chance of filling both soil space and air space more completely.

4. *Different plants are at their best at different times of the year.*—It is very important to have pasture for as long a period in the year as possible. This can only be got by a proper selection of plants. Perennial Ryegrass during its first year is early in spring, while in summer it produces very little, whether it has been hayed or pastured, but it recovers and provides a green bite in autumn and early winter. In the second and subsequent years it is much later in spring, and usually becomes very bare and brown in the late summer. Italian Ryegrass is the earliest grass of all in the first season, and, where it persists, in the second. Cocksfoot, after it is established, comes very early in the second and third years, and continues good all summer, but is of little use during winter. Timothy, after it is established, is not so early in spring as Cocksfoot, and it is not so good in late summer, but recovers later on, especially if there is rain. Crested Dogstail and Rough-stalked Meadow Grass are best during the moist autumn and winter months, when they are quite green. During the dry summer weather, however, they are very much poorer. Red Clover is good in spring and early summer, while the White Clover is best about early midsummer.

5. *No ingredient should be sown in excess.*—Many examples of the adverse influence which one plant may have on another have already been given, e.g. Italian Ryegrass on Red Clover; Perennial Ryegrass on Cocksfoot, Timothy and Meadow Fescue; Red Clover on Alsike, &c. It will suffice to say that much of the success of the hay or pasture will depend on the care taken in considering how much of each individual grass and clover should be used in the mixture so that there may be no undue competition.

6. *The plants must be readily eaten by stock.*—All the best grasses and clovers are readily eaten by all kinds of stock if the pasture has been properly managed. The palatability of any plant depends largely, however, on its condition. When fresh and succulent it may be eaten greedily, but when it becomes older and more woody it may be neglected. Such grasses as Yorkshire Fog and Brome Grass may produce quite heavy crops, but are unsuitable, as cattle won't eat them unless they can get nothing else, while Bent Grass, which also grows readily, especially on light soils, is of very little feeding value. Kidney Vetch, although it is quite

readily eaten by sheep, is avoided by cattle, while Wild White Clover may cause scouring if present in too large an amount without a proportionate quantity of grasses. Also, Red Clover if in too large a proportion is not relished by cattle.

In a trial where a plot was seeded with a large quantity of Perennial Ryegrass and clovers there was practically no grass but a large amount of Red Clover in the aftermath. It was found that the cattle ate very little and made no increase in live weight on the Red Clover alone, but after the grass began to grow, and there was a mixture of grass and clover, they ate more and made an increase in live weight.

7. *Feeding quality.*—A factor of the first importance is the feeding value of the different grasses and clovers, but, unfortunately, our information regarding this is very limited. Investigations carried out in England showed that the feeding value of the same grasses varied greatly on different fields even where the soils were similar. It is known that clovers are, in general, of high feeding quality, but the examples given above show that even they, if present in too large a proportion, may be of comparatively little use. A difficulty with regard to finding out the relative feeding value is that different grasses are at different stages at a particular time, and, if a comparison is made, one grass may be fresh and succulent and another old and woody.

Undoubtedly the more an animal eats the more is its chance of increasing in live weight. It is very important that there should be a sufficient amount of food that the animals will consume readily. No matter how nutritious a grass may be, if it is present in insufficient amount the animals cannot increase in live weight, and where pastures are very bare they have to spend too much time in nibbling the short blades. When grass is allowed to be eaten bare it will be found that a much smaller total amount of food will be produced than if it is only moderately grazed. In some trials carried out nearly twenty years ago, it was shown that when cut close down frequently, grasses produced much less during the season than where they were allowed to be full grown before being cut. This indicates that pastures should not be overstocked, especially in the beginning of the season.

It has been found that both cattle and sheep make the greatest live weight increases on pasture during or round the month of June, when there is usually plenty of grass. After this period the increases are very much less. This may be due, partly at any rate, to the amount of albuminoids in the pasture. Analyses of pasture grasses in England showed that there was a gradual decrease in albuminoids as the summer advanced, but in all probability the quantity of herbage is of much greater importance than the mere chemical composition of the different constituents, that is, provided it is green and succulent and does not contain too large a proportion of the more worthless grasses. In some cases on old pastures an application of phosphatic or potassic manures has improved the feeding quality, but again this may have been partly due to the increased quantity.

In an experiment carried out several years ago in Banffshire, a field was divided into two parts. One, A, was sown with 1½ bus. Perennial Ryegrass and clovers, while the other, B, was seeded with ½ bus. Perennial Ryegrass, 8 lb. Cocksfoot, 4 lb. Timothy, and the same clovers, Wild White being included in both. There was little difference in the crop of hay produced the first year, but in the second year, when in pasture, the part B was much earlier in spring and was able to keep 7 animals for the season on 5 ac., whereas part A kept only 5 animals. This increased capacity was entirely due to the inclusion of Cocksfoot and Timothy in B.

8. *The plants must die readily when ploughed down.*—It is very important when ploughing lea to turn the sod well over, otherwise some of the plants will grow. Where the ploughing has not been well done, the ears of Perennial Ryegrass, Cocksfoot, and Timothy may be quite readily seen growing among the grain. The latter two grasses are possibly more difficult to cover up, especially if they have been sown in small amount, when they are apt to grow stronger and in tufts. In a proper mixture there is usually no difficulty in ploughing them down. Smooth-stalked Meadow Grass and several other grasses have underground creeping stems, and even though useful, are difficult to eradicate, and so should only be used for permanent pasture.

Making up the Seeds Mixture.—Different methods have at different times been advocated for the scientific making up of grass seed mixtures, but, unfortunately, none of them are perfect, as there are several unknown factors that affect the amount of seed required.

The following methods have been used:

1. Number of pounds of each kind of seed required per acre.
2. Stebler's method.
3. Number of seeds per acre.

1. *Number of Pounds Method.*—This is the method adopted by mos seedsmen and farmers in making up their seeds mixtures, and as the resul of experience there is no doubt but that in most cases it comes as nea the proper proportions as one could reasonably expect. The chie drawbacks are that no notice is taken either of the size of the seed o the power of germination, both of which may vary greatly in differen samples.

Thus, one sample of, say, Perennial Ryegrass may have 210,000 seed in 1 lb. and the germination may be 84 per cent, whereas in anothe sample there may be 230,000 seeds in 1 lb. and the germination may b 98 per cent. If 14 lb. of seed per acre are sown, the following calculatio will show that from one sample 2,499,000 good seeds are sown and from the other 3,059,000.

$$(1) \qquad \frac{14 \times 210{,}000 \times 84}{100} = 2{,}499{,}000.$$

$$(2) \qquad \frac{14 \times 230{,}000 \times 98}{100} = 3{,}059{,}000.$$

If the first sample is sufficient then the second must be too thick, and both seed and money are wasted.

2. *Stebler's Method.*—After experiment, Stebler fixed the number of pounds of pure and germinating seed of each kind of grass and clover required to cover an acre when each was grown separately. From this the weights of average commercial seed required are calculated—purity and germination being known. These are shown in the first column.

	Required per Acre. Lb.	Plus 50% Lb.
Perennial Ryegrass	38·5	57·75
Italian Ryegrass	32·4	48·6
Cocksfoot	18·5	27·75
Timothy	14·0	21·0
Rough-stalked Meadow Grass	8·4	12·6
Meadow Fescue	37·0	56·5
Crested Dogstail	37·0	56·5
Red Clover	15·8	23·7
White Clover	7·5	11·25
Alsike Clover	9·0	13·5

As the roots and leaves of the different ingredients do not occupy the same places—some have deep, some shallow roots, and some tall, some dwarf leaves—an allowance is made for interlacing. The more complex the mixture the greater is the allowance. In ordinary mixtures 50 per cent is recommended by Stebler (see second column).

Stebler's method of making up a mixture may be stated shortly as follows:

(*a*) Select the plants suitable for the soil and purpose.
(*b*) Fix the percentage of ground to be covered by each ingredient.
(*c*) Fix the allowance over a pure sowing.
(*d*) Calculate the weight of seed of each from the table.

The table on p. 172 is an example of how to make up a mixture by this method.

The chief objection to this method is, that at no time is there any connection between the proportion of the seeds sown and of the plants, either in the hay or in the pasture. With the same seeding in no two fields would the proportion of the plants be the same. Also, it does not

	Percentage of ground to be covered by each.	Pounds of pure and germinating seed required for a pure sowing + 50 per cent.	Percentage of pure and germinating seed.	Pounds of commercial seed required.
Perennial Ryegrass ..	20	11·55	90	12·8
Cocksfoot	25	6·94	85	8·2
Timothy	15	3·15	95	3·3
Red Clover	15	3·55	95	3·6
White Clover ..	15	1·68	90	1·9
Alsike Clover ..	10	1·35	90	1·5

take into account the influence that one plant may have on another. Thus, according to the table, 37 lb. of Meadow Fescue are sufficient to cover an acre, but if we sow, say, 20 per cent or 7·4 lb. in a mixture including, say, 20 per cent of Perennial Ryegrass, it will likely be found that 40 per cent to 50 per cent of the ground is covered with Perennial Ryegrass and less than 1 per cent with Meadow Fescue.

3. *Number of Seeds Method.*—The basis of this method is in determining the number of seeds per acre that are to be sown—usually from 10 to 15 millions according to circumstances. The following factors require to be considered in estimating the total number required:

(*a*) Whether for hay or pasture. When for hay, fewer seeds are necessary than for pasture, as in the former we wish to encourage the formation of ears, and this is done by giving a comparatively thin seeding. In the latter case we wish to encourage the growth of leaf-blades.

(*b*) The size of the seeds of the different ingredients. If the seeds are small it will usually be found that a comparatively larger total number will be necessary, as owing to their smallness fewer in proportion will germinate than of larger seeds. Thus, a greater number of Timothy or Rough-stalked Meadow Grass seeds would require to be sown than of Perennial Ryegrass or Cocksfoot to get the same number of plants.

(*c*) The tilth of the soil. Whenever a soil is cloddy more seeds of all kinds are required, as many are placed under conditions not suitable for germination.

The method is carried out as follows:

(*a*) Determine the kinds of seeds required.
(*b*) Determine total number of pure germinating seeds to be sown.
(*c*) Determine percentage of each.
(*d*) Find number of seeds in 1 lb. of each kind.
(*e*) Calculate pounds of pure and germinating seeds required thus:

$$\frac{\text{total number of seeds} \times \text{percentage}}{\text{number in 1 lb.} \times 100}.$$

(*f*) Test seeds for purity and germination and calculate real quality thus:

$$\frac{\text{percentage purity} \times \text{percentage germination}}{100} = \text{real quality.}$$

(*g*) Calculate pounds required of sample thus:

$$\frac{\text{pounds of pure and germinating seeds} \times 100}{\text{real quality}}.$$

(*h*) Formulæ (*e*) and (*g*) may be combined as follows:

$$\frac{\text{total number of seeds} \times \text{percentage}}{\text{number in 1 lb.} \times \text{real quality}}.$$

The following will serve to illustrate the method.

Example showing method of making up grass seed mixture at the rate of 12 millions pure and germinating seeds per acre:

Ingredients of Mixture.	Per-centage.	No. of Seeds in 1 lb.	Pounds of pure and germinating seeds required.	Real Quality of Sample.	Pounds required of Sample.
Perennial Ryegrass ..	25	230,000	13	90	14·4
Cocksfoot	30	450,000	8	85	8·5
Timothy	25	1,000,000	3	93	3·2
Red Clover	7	247,000	3·4	90	3·8
White Clover ..	7	700,000	1·2	90	1·3
Alsike Clover ..	6	700,000	1·1	90	1·2

To take the Perennial Ryegrass as an example, we find by calculating according to the formula that 14·4 lb. of this particular sample are necessary, thus:

$$\frac{12{,}000{,}000 \times 25}{230{,}000 \times 90} = 14{\cdot}4 \text{ lb.}$$

Although in practice it is unlikely that many will follow this method, the principles underlying it should always be kept in mind. Also, the mixtures used in the previous years should always form the basis of the mixture, and it should be altered if necessary according to how it was considered suitable or otherwise, and allowance must always be made for any difference in the conditions of the soil.

Elliot's Mixtures.

An account of the pastures of Scotland would be incomplete without reference being made to the work of the late Mr. Elliot of Clifton Park, Roxburghshire.

In 1887, Mr. Elliot took over the farm of Clifton-on-Bowmont, which was at that time in a very poor and impoverished condition. This farm is situated at the foot of the Cheviot Hills, and the arable part is from 400 to 700 feet above sea-level. The soil, which is mostly shallow, is of a stony nature, and liable to suffer from drought. The seeds mixture formerly used consisted largely of Ryegrass and clover, with the result that the pastures were bad, and the soil, instead of improving, had grown gradually worse.

Mr. Elliot at once set about considering how matters could be improved, and he decided to sow a large proportion of deep-rooted and drought-resisting plants. A great improvement was soon effected, and he altered the mixtures as his experience showed this necessary.

A full account of his work in this connection will be found in a book [1] which Mr. Elliot issued, and which has passed through several editions. The book contains many valuable hints, and is well worth studying.

The following mixture is typical of what Mr. Elliot sowed:

	Lb.
Cocksfoot	10
Tall Oatgrass	3
Golden Oatgrass	½
Tall Fescue	4
Meadow Fescue	5
Hard Fescue	1
Rough-stalked Meadow Grass	½
Smooth-stalked Meadow Grass	1
Italian Ryegrass	3
Kidney Vetch	2½
Chicory	3
Burnet	8
Sheep's Parsley	1
Yarrow	½
Late-flowering Red Clover	2
White Clover	2
Alsike Clover	1
	48

Trials with this mixture were carried out at several centres. As the result of these, and of several visits to Clifton, the following conclusions were arrived at.

[1] *The Clifton Park System of Farming*, by R. H. Elliot.

The mixture produced a heavy hay crop, and its success for this purpose was undoubtedly due to the great growth of the Late-flowering Red Clover, there being a much smaller proportion of grasses than is common in good hay.

Of the grasses, Italian Ryegrass was present in largest amount, as much as all the others put together. Tall Oatgrass was second in quantity and Cocksfoot third, while there were only small quantities of the other grasses present.

The success of the pastures was mainly due to Cocksfoot, with the help of Tall Fescue and Rough-stalked Meadow Grass, the other grasses being scarce and small.

Burnet was not a success, either in the hay or pasture, the plants being both few and small.

There was a small quantity of Kidney Vetch in the hay at some of the centres, but it did not appear as if its omission under average conditions would be a serious loss, especially as very few plants survived until the following year. Probably the only case where it might be profitably grown is on light sandy soil where it is difficult to get Red Clover to strike. Cattle do not seem to care much for Kidney Vetch, but sheep eat it more readily.

Chicory was present in larger amount than the other "special" plants, and—although not of much value in hay, as, being succulent, it dries up very readily—appeared to be a useful plant for pastures, being eaten quite readily by stock. Although it lasts for three or four years, the leaves get smaller and smaller every year and the tap-root larger.

It was claimed for Burnet, Chicory, and Kidney Vetch that their deep tap-roots are able to penetrate and break up hard "pan". This, however, was found not to be the case. The roots went down into the subsoil where it was soft, but wherever it was hard they turned and went along it.

The general conclusion regarding "Elliot's Mixtures" is that they give quite good results, but many of the ingredients could be omitted without harm.

It is impossible to give the best mixtures for every class of soil, but the following, which have been found to answer in experiments, are given as examples. It would be well to again state, however, that success will not depend entirely on the seeds mixture. Unless the other factors and conditions mentioned previously are carefully attended to, no seeds mixture, however carefully made up, can give good results. It is assumed that seeds of good quality are used.

For One Year's Hay—Medium Soils

15 lb. Perennial Ryegrass.	3 lb. Red Clover
6 lb. Timothy.	2 lb. Alsike Clover.

Two Years' Pasture—Medium Soils

13 lb. Perennial Ryegrass.	2 lb. Broad-leaved Red Clover.
5 lb. Italian Ryegrass.	½ lb. Wild White Clover.
6 lb. Cocksfoot.	½ lb. Ordinary White Clover.
3 lb. Timothy.	1 lb. Alsike Clover.
1½ lb. Late-flowering Red Clover.	

One Year's Hay and Two Years' Pasture

	Medium Soils.	Clay Soils.	Very light Soils.	Very peaty Soils.
	Lb.	Lb.	Lb.	Lb.
Perennial Ryegrass	13	13	13	10
Cocksfoot	8	6	12	6
Timothy	4	5	2	8
Rough-stalked Meadow Grass	—	1	—	2
Crested Dogstail	—	—	1	—
Hard Fescue	—	—	1	—
Late-flowering Red Clover	1½	1	2	—
Broad-leaved Red Clover	2	2	2	—
Kidney Vetch	—	—	1	—
Alsike Clover	1	1	—	2
Wild White Clover	½–1	½–1	½–1	½–1

Permanent Pastures

	Good loamy *Soils.*	Clay *Soils.*	Light *Soils.*
	Lb.	Lb.	Lb.
Perennial Ryegrass	6	8	6
Cocksfoot	7	8	12
Timothy	3	4	2
Meadow Fescue	5	4	—
Tall Fescue	—	4	3
Meadow Foxtail	4	5	—
Rough-stalked Meadow Grass	1	1½	—
Smooth-stalked Meadow Grass ..	1	—	2
Crested Dogstail	—	—	2
Hard Fescue	—	—	2
Broad-leaved Red Clover	1	1	1
Late-flowering Red Clover	½	½	½
Wild White Clover	¾	1	½
Alsike Clover	1	1½	1
Kidney Vetch	—	—	2
Chicory	—	1	2
Yarrow	—	—	½

With the improved mixtures and methods now in use, in the 6- or

7-course rotation the pasture at the end of three years is usually in excellent condition when it is ploughed up, and could easily last for a few years longer. With the condition prevailing regarding prices and labour, several farmers are considering the advisability of leaving the land longer in pasture before ploughing it up and then taking more crops before sowing it out again, and thus lengthening the rotation to eight or ten years. There would still be about half the farm in grass.

There are several advantages of such lengthened rotations, and the first is, that the expenses would be less as (*a*) fewer seeds would be required to be bought, as there would be a smaller area to sow out every year, and (*b*) less artificial manure would be necessary, as the amount of organic matter in the soil would increase and consequently also the fertility of the soil. Then secondly, the returns would be greater, as larger grain crops would be got from the improved condition of the soil. Although there would be a smaller area under turnips, in all probability the total weight would be quite as great and the bulbs would be sounder, as there is less chance of their being affected with finger-and-toe.

Of course, considerable trouble would be experienced in many cases in making such changes in the rotation, but we are confident that the benefits accruing would more than compensate for this.

THE HAY CROP

By W. STRANG, B.Sc.(Agric.), N.D.A., N.D.D.

The term " hay " is applied to the feeding material obtained when the unripe stems and leaves of certain plants have been preserved by the process of drying for use as fodder for live stock. The object of making hay is simply to preserve food grown in the summer in order to have a supply with which to feed stock during the months of the year when there is very little or no vegetable growth. The methods adopted vary considerably according to the climate of the country or locality in which the hay is grown, and also according to the species of plants or the mixture of plants from which the hay is made. The plants most commonly grown for this purpose are the grasses and clovers, but many others are now made use of to augment the supplies.

When the green plants are cut for haymaking they may contain from 70 to 75 per cent of water. Before they can be preserved in the form of hay this water content must be reduced to within the region of 15 to 20 per cent. The natural agencies of sun and wind are relied on to perform the drying process, and as these are very unreliable the quality of the hay made in different seasons and at different times in the same season varies to a great extent. The whole process is an endeavour to prevent the action of the several factors which promote the decomposition of any cut vegetation in the absence of special precautions. Besides rendering conditions unfavourable to fungal and bacterial growth, the nutritive value and ultimate palatability must be kept in view. If the material be subjected to repeated wetting and drying, a large proportion of the soluble carbohydrates and other substances is lost and so the fodder is robbed of its most valuable constituents; and further, should the hay be stacked before sufficiently dry, heating may occur or mould growths intervene which will render the food highly unpalatable.

Experiments have now been conducted in drying hay by artificial means. The green material is carted straight from the mowing machine to the stack, and a current of air is driven at intervals through the stack by an electric fan. By this means the temperature of the stack is prevented from rising above a certain height at which bacterial action would then proceed. Quite good quality hay has been made by this method, but as it is still in the experimental stages the advantages or drawbacks of the method have not been fully tested.

THE HAY CROP IN SCOTLAND AND NORTHERN COUNTIES OF ENGLAND

In these areas the hay crop is mainly obtained from Ryegrass and clover mixtures, Timothy meadows, and temporary and permanent pastures.

Ryegrass and clover mixtures are more or less confined to land that is regularly under arable crops. Where the mixture is for one year, Italian Ryegrass with Red Clover and Alsike will form the predominant ingredients; for two years the Italian will be largely replaced by Perennial Ryegrass. The mixture will vary from 1 to 1½ bus. Ryegrass with from 6 to 10 lb. of the clovers, according to the nature of the soil. On soils where clovers grow well the amount of clover seed can be increased and the Ryegrass reduced, and vice versa. It is generally found that on the heavier and wetter soils Alsike does better than Red Clover. In such cases the Red Clover should be partly replaced by Alsike.

The young seeds are usually grown under a nurse crop. That may be any of the cereals, but preferably oats or barley. If the land is clean, as it should be after a root crop, a better plant of young seeds is more likely to be obtained. The Ryegrass and clover seeds are mixed together and sown from a seed barrow about a week after the grain crop has been sown. They are then lightly harrowed and rolled in. The best results are obtained when there is a good tilth. When the ground is rough the seeds, especially the clovers, are apt to be buried too deeply. The young seeds are often grazed in the autumn after the grain crop has been harvested. Where this is done such a large crop of hay the next summer cannot be expected. If grazed too closely, especially with sheep, the clover plant is apt to be killed out entirely.

Unless on the very richest soils it will generally be found that it pays to manure this crop. It is always advisable to use a complete manure. A mixture of 2 cwt. superphosphate, 2 cwt. kainit, and 1 cwt. nitrate of soda is a suitable dressing for most soils. The nitrate of soda may be replaced by its equivalent of sulphate of ammonia according to which is the cheaper per unit. The superphosphate and kainit should be applied in January or February and the nitrogenous manure sometime in April. In some cases a nitrogenous manure alone is applied. From this an increased yield of crop is generally obtained, but the full benefit from the nitrogen is not thereby realized, and moreover there is a certain exhaustion of the soil which will make itself apparent in subsequent crops. When kainit or other potash manure is applied it encourages the growth of the clovers, and the nitrogen in the soil is further increased by the bacteria in the nodules on the clover roots fixing the nitrogen of the atmosphere and storing it. It is a common experience in practice that after a strong plant of clover good crops can generally be grown.

In the spring of the year the young seeds should be rolled. This is doubly important after a very severe winter. The frost acting on the surface soil is apt to loosen it, and unless pressed down by rolling, the drying winds in the spring absorb the moisture round the roots and the crop suffers accordingly. The yield of hay from a Ryegrass and clover mixture may vary from 30 cwt. to 3 tons per acre according to the fertility of the soil and kind of season.

Timothy Meadows.

On some soils and in some districts Timothy can be grown more successfully than in others. The plant seems to thrive best on the stiff clays. On some of the lighter and more fertile soils it cannot be grown with any degree of success. Once a good plant is established it sometimes does well on blackish loams, also on peaty soils, but on the latter it does not stand so long, being soon crowded out by Agrostis and other weed grasses which seem to thrive well on that class of soil.

In seeding down a Timothy meadow only Italian Ryegrass and Timothy should be included in the mixture—about ½ bus. of Italian and 20 lb. of Timothy. It should be sown with a nurse crop in the same way as a clover mixture, but in this case a fine tilth and a clean seed-bed is doubly important. The Timothy seed is small, and if buried too deeply the young shoots will not be able to reach the surface of the soil before the food material stored in the seed becomes exhausted. In some cases the seeds are sown down with a nurse crop of rape, the rape being fed off with sheep in the autumn. This is a good plan on those soils such as peats, where a grain crop is apt to become lodged and smother out the young plants. Seeding down with Timothy alone is sometimes tried, but it takes fully a year to become established, and there is a danger that the plant may be smothered out by weeds in the interval. When seeded down along with Italian Ryegrass very little Timothy will be seen in the crop of hay the first year; in the second year there will be a fairly strong plant; by the third year the plant will be fully established, and on suitable soils the crop should consist of practically nothing but Timothy.

Where conditions are favourable and the meadow has received proper treatment, the Timothy plant may last from 10 to 20 years or even longer. There is always a tendency, however, for the Timothy plant to become gradually weaker and die out and for weed grasses, such as Yorkshire Fog and Common Bent, to take its place.

In manuring Timothy meadows chief attention should be paid to the application of nitrogenous manures. The Timothy plant is a gross feeder as far as nitrogen is concerned. Up to 2 and 3 cwt. of nitrate of soda, or its equivalent of sulphate of ammonia, per acre has been applied to Timothy meadows without producing any harmful effect on the plant and with profitable results. Where possible, a dressing of 10 to 15 tons of farmyard manure should be applied every alternate year, but in situations where a plentiful supply of town refuse can be obtained, it has been proved that a good dressing of this material is even better than dung. The town refuse does not seem to encourage the growth of the weed grasses so much, with the result that the meadow remains cleaner and the Timothy has a better chance to survive. In any case a good top dressing of nitrogenous manure should never be omitted if the best results are desired. Besides manuring, the meadows should be harrowed every year. Repeated harrowing has a very beneficial effect. It helps to tear out the weed grasses, aerates the surface soil, and encourages the growth of the Timothy plant. The Parmiter type of harrow is the best for this purpose, but where a set of that type is not available the ordinary zigzag harrows may be used. Like many other plants Timothy seems to thrive best on land on which it has never been grown as a hay crop before. Many farmers have had the unfortunate experience of finding that after having ploughed up a Timothy meadow that had run out, a good plant of Timothy could not be again obtained unless the land was rested for a period by growing other crops.

The Timothy plant grows very well under irrigation. When it was first introduced into this country as a hay crop many irrigated meadows were laid down. Some of these were cut for long periods and yielded big crops of hay. Many of them have now run out and have not been re-seeded down. This is not due to any failure of the system to grow the crop, but is mainly due to the introduction of so much modern haymaking machinery. The presence of so many small ditches and gutters, which are necessary for the proper irrigation of the meadows, makes it very awkward for the working of these machines. Frequent breakages and delays at haymaking are very annoying, and it comes to be a question of either scrapping the irrigation or the machinery and it is the former that invariably goes.

The yield of hay from good Timothy meadows is sometimes very high. It may be anything from 2 to 5 tons per acre. When it is a big crop and strongly grown it appears coarse, but if well made it is sweet and well liked by stock. It is when the meadow begins to run out and there is a large proportion of the softer grasses in the hay that the quality is not so good.

Harvesting the Hay Crop.

In these northern areas the harvesting of the hay crop begins about the end of June, and may continue until the end of August or longer if the season is tedious. The Ryegrass and clover mixtures are ready to cut first. The proper time to cut is when the grasses are at the " flowering " stage. Then the stamens are seen to protrude from the spikelets, and when the ear is shaken the pollen floats about in the air like a fine powder. It is advisable to be guided more by the condition of the Ryegrasses than the clovers, as the former will lose more by being too ripe than the latter will lose by not being ripe enough. It will always be found that Alsike flowers later than Red Clover, and it is only when cutting has been delayed on account of the weather that much of the Alsike will be seen in flower before cutting. It is always wisest to err on the side of being too early rather than being too late. As soon as a plant flowers, much of the nutrient material in the stems and leaves begins to be drawn to the ear, and be stored up in the body of the seed. The stems at the same time become more lignified and are consequently less palatable and less digestible.

The cutting of the crop is done by mowing machine. These machines have been in use for over fifty years, and during that time they have been improved till now they can be relied on to do excellent work with the minimum of trouble. If the crop is not heavy, cutting may be done right round the field, but if the crop is at all laid it may be necessary to cut in one direction only. This means that the machine has to travel back over the mown ground without cutting. In this case more time is required for the operation, but it is seldom that the loss of time is grudged, as it is generally an indication that the crop is good and will more than repay for the extra time spent. After cutting, the ultimate quality of the final product depends largely on the weather.

Where there is a large proportion of clover in the crop the process of drying takes longer. When the Ryegrasses are long and strong the hay lies more loosely on the ground and dries much more quickly. If the weather is dull it may be necessary to leave the hay in the swath for several days untouched. So long as the hay remains green in the swath wet does not damage it much for several days; if however it gets partially dried and then soaked with rain it very quickly spoils. It requires wide experience and good judgment to know exactly what to do in a hay-field in unsettled weather. The swaths should be turned whenever there appears to be a likelihood of getting the hay dry enough to put into the cock or " cole ". Unless both operations can be done in the same day it may be better to leave the swaths untouched, as the hay deteriorates more rapidly if it gets wet again after having been disturbed. The turning on most farms is now done by a swath-turner. This machine turns two swaths at once, and does quite as good work as was done at one time by hand with a small hay-rake. Where the crop is very heavy the machine may even be superior to the hand.

During unsettled weather it is a safe policy not to cut down any more hay than can be conveniently tackled by the staff of workers available on the farm. The best drying part of the day is often the afternoon and evening, and frequently hay that has been turned earlier in the day is ready for cocking at that time. No such chances should be lost, and farmers and their employees should not regulate their hours of work by the clock, but by the amount of crop that is to save and by the condition it is in. As soon as the hay is in the cock it is partially saved. It is most important that these cocks are made properly. The hay is raked by a horse-rake into rows at convenient widths according to the heaviness of the crop. Horse-rakes are generally made of the correct width to gather together two swaths at a time. When the direction of raking is parallel to the swaths it is speedier and easier done, and the hay from each swath will lie more or less separate in the rows, making it much more convenient for cocking. In making the cock the hay should not be rolled or pushed into a heap, but lifted in tidy pitches and laid one layer on the top of the other. The centre of the cock should be kept well raised so that the layers on the surface slope outward and downward. This will throw off the rain should the weather break. It is surprising the amount of rain a well made cock will throw off, and how soon a badly made one will get wet through and through. Hay raked into rows should never be left overnight without being cocked. In that position any rain that may fall runs right into it, and it will never dry properly until it is shaken out into thin layers again.

In good weather the hay in the cocks should be dry enough to be gathered into the field ricks in one or two days. If it is necessary to leave them longer than this it may be desirable to turn them over an hour or so before taking them up, in order to dry the bottom layer. This bottom layer always tends to absorb a certain amount of moisture from the soil, the amount depending on the dampness of the soil at the time the cock is made. The field ricks are built to contain from 9 to 14 cwt. of hay. In some districts and on some farms it is a common practice to put " bossoms " in the centre of each rick. A bossom is constructed simply of three batons of wood bolted together at one end. When set on end and the batons spread it forms a tripod. This is set up in the position where the rick is to be built and the hay is built round and over it. Care must be observed when starting the rick that none of the legs of the bossom is displaced, as if one of the legs should by any chance be shifted out of position it is impossible to build round it a rick that will stand erect. When this practice is followed, the hay may be put into the rick rather sooner than when no tripod is used. Moreover, this support keeps up the centre of the rick, which maintains a better shape, and consequently there is less likelihood of the rain penetrating for any distance into the hay.

In choosing the sites for the ricks the main point is to place them where there will be the shortest distance to haul the hay to them. They are thus generally dotted all over the field. The gathering and hauling of the hay to the rick is done by small one-horse collectors. These little implements are of the most simple construction, and in the hands of an active man and a tractable horse they are one of the greatest labour-saving devices on the farm. In building the ricks the aim should be to have them a uniform width at the bottom, well rounded off at the top, and not too high. They should be well raked down and the hay should be well pulled out round the bottom. Attention to this minimizes the amount of waste should it be necessary to leave the ricks out for a considerable length of time. The ricks are tied down with two ropes of coir yarn crossing directly over the top at right angles. When the hay has reached this stage it is considered safe, and subsequent wet weather will not affect its feeding value to any appreciable extent. One precaution which is often neglected, but which may save much trouble later, is to go round the ricks again in about a week's time and tighten the ropes. It is surprising how slack they become as the ricks settle down, and if tightened they may prevent the tops of the ricks being blown over should there be strong wind.

In the case of Timothy and pasture hay the process of handling at the various stages is exactly the same. Timothy hay, however, is easier to dry. Good clean Timothy hay, free from other grasses, in good hay-making weather, can sometimes be ricked on the day following cutting. In such cases it may not be necessary to cock it at all, but collect it directly from the raked rows into the rick. Pasture hay, on the other hand, requires careful drying. It may be necessary to turn it frequently. In this case it is more difficult to build ricks that will throw off the rain, on account of the hay being shorter and softer.

The time that must elapse before the hay can be taken from the field ricks into the large rick or Dutch barn depends on the weather. It varies from three to six weeks or even longer. On some farms where a large quantity has to be handled, this work may commence before all the crop has been secured. In others there may be an interval of a week or a fortnight between the time of finishing the ricking and commencing to cart. The work of carting and building in the large rick or Dutch barn is not quite so dependent on the weather. So long as it is not actually raining there is no need to stop. Rick lifters or trolleys are used for this purpose, of which two types are in common use.

One type consists of a low trolley on wheels, with a flat top, fitted with a set of rollers on front. The body of the trolley is made to tip up, so that the hinder part can be backed in under the outer edge of the rick. A pair of stout ropes which are fixed to the front rollers are placed round the rick and fixed together by means of a clasp at a point on the other side of the rick directly in line with the centre of the trolley. The ropes should be kept on the ground, well under the edge of the rick unless at the point where the clasp joins them. The rollers are then revolved and the ropes are gradually wound round them. As the ropes are thus pulled in, the rick is drawn on to the top of the rick-lifter. As soon as it has been drawn far enough forward, the body of the rick-lifter can be tipped up into position again. It is then only necessary to tie down the rick to keep it steady and start off with the load to the place where it is wanted. For operating the rollers there are several devices. One is to operate them by means of two levers, one fixed at each end of the rollers. Another is an arrangement of two pinion wheels at one end of the rollers which are operated by means of a handle. The quickest and best method, however, is the one where the rollers are operated by the aid of a horse. A wheel is fixed to one end of the rollers. Round this wheel a rope is wound. The end of the rope is attached to the horse. The horse is led out in a straight line, pulling the rope. This revolves the wheel and operates the rollers. The rope is rewound on the wheel, which, being detachable, can be taken off and used for the next rick. An extra horse must be kept in the field for this purpose, but it saves the men much hard manual labour and is speedier. The whole operation of loading a rick can be performed in the space of about five minutes.

The other type of rick-lifter is constructed in the shape of a very large tripod. Each leg of the tripod stands on a small wheel, and the whole appliance can be drawn on these wheels from rick to rick. The tripod is fixed so that it stands directly over the rick to be lifted. From the apex of the tripod there hangs a set of pulley blocks, to the lower end of which are attached four ropes. The lower ends of these ropes are fixed at equal distances round the rick to four stout iron spears that are driven under the bottom of the rick. The pulley blocks are then operated by a rope which runs on a pulley wheel at the lower end of one of the legs of the tripod. This rope is pulled by a horse, and the rick is lifted bodily until it is high enough to allow a hay wagon to be backed in under it. The hay wagon is then backed into position and the rick gradually lowered down on to it. After being tied down it is ready to be hauled away. The rick-lifter is then dragged to the next rick and the operation repeated.

Each of the two types of rick-lifter has its advantages and disadvantages. With the trolley type it is necessary to have several. To keep one or two gangs going, if the hay has to be hauled a long distance, requires a considerable number. With the other type one rick-lifter will keep two gangs going, and the ordinary farm wagons and carts can be used for the hauling. The trolley type has the advantage that it is very easy to unload. It is simply a matter of taking off the ropes, tipping up the body, and sliding off the rick.

A fairly large proportion of hay is now stored in Dutch barns, or haysheds as they are more commonly called in Scotland. A large hayshed is a great asset to a set of farm buildings. Neither when it is being filled nor when it is being emptied is there any need to cover up the hay with a waterproof sheet on leaving it as in the case of a rick. No thatching requires to be done, and the building can be performed by a more or less inexperienced hand without incurring the risk of the hay being damaged through faulty work. A hayshed should always be erected as near as possible to the point where the hay has to be consumed, so that it can be carried to the stock without any further carting. It is also better if the side and end exposed to the prevailing winds are lined with corrugated iron or wood down to the ground, as this prevents rain blowing on to the top of the hay when a division is only partly full. No building on the farm will give a better return for the outlay of capital expended on it than a large and commodious hayshed.

Most modern haysheds are constructed so that a horse-fork can be used. Where much hay has to be handled a horse-fork is now looked upon as absolutely essential. An iron rail is fixed under the ridge of the roof along the whole length of the shed. On this rail a small carrier runs. The fork, which is in the form of a four-pronged clasp, is connected by a rope which runs over the carriage and down to a pulley fixed to the bottom of one of the upright standards. The rick of hay is tipped down close to the division that is being filled. The fork is fixed on to the hay. A horse draws the rope which lifts the loaded fork up to the carriage, which then runs along until it is over the adjoining division. The fork is then unloaded by a man on the ground pulling a rope attached to the fork, which releases a catch. The empty fork is then lowered to the ground and the operation repeated until all the rick has been lifted up. The hands working on the division should see that the hay is properly levelled and well trodden down. After the hay has settled down, which will be in about the course of a week, it is advisable to fill up the top of each division. If an open space is left the rain is apt to blow in during the winter, and may damage a layer of hay at the top of each division.

Where the farm is not equipped with a hayshed, the hay has to be built into large ricks.

Should the hay be intended for the feeding of stock, the ricks should be situated as near to where it is required as is conveniently possible. If it is proposed to sell the hay it is not necessary that the ricks should be near the farm buildings, but it is desirable that they should be close to a hard road. A large proportion of the hay that is now sold is delivered to the consumer in bales. If the ricks are not close to a hard road it is difficult to get the baling machine and engine to them, and besides, the hauling of the hay over soft ground is a trying job for the horses.

The situation should also be level. The bedding for the rick should be made of some material that will keep the hay well off the ground. Logs of wood or a thick layer of brushwood with a good covering of straw on the top makes a satisfactory bedding and prevents moisture from drawing upwards from the ground and damaging the bottom portion of the hay.

Ricks are usually built in circular form, and are made in various sizes, containing from 6 to 12 tons. As in the hayshed, a horse-fork is used. In this case it is worked on a pole or crane with a jib arrangement for throwing the loaded fork over the centre of the rick. Otherwise the fork operates in the same manner as in the hayshed.

The building should be carefully performed, the sides projecting a little from the perpendicular to throw off the water from the top, and the top should be curved off with a uniform slope all round. It is also very important to have the centre of the rick well raised during the process of building, so that the outer layers of hay are inclined downward towards the outer surface to throw off the rain.

Shortly after being built, ricks should be well thatched to prevent damage from the elements. Nothing is a surer indication of bad farming than ricks standing unthatched for long periods—the tops growing green, and good material being ruined after all the labour and anxiety of getting it to that stage. After thatching, the whole process of haymaking has been completed, and the hay remains in the rick until it is required for consumption or sale.

At no part in the whole process is it desirable that heating should take place to any appreciable extent. In dealing later with haymaking in the more southern areas it will be stated that a certain amount of heating may be desirable, but in these northern areas heating is more likely to have a deleterious effect. Moulds are likely to intervene, which render the hay unpalatable and in some cases even dangerous to the health of stock. Heating is an indication that the hay has not been sufficiently dried, and it should be the aim of the farmer to wait until all danger of this is over. Only experience can teach when that stage has been reached, and it is in such points as these that the thoroughly practical farmer is likely to score.

Hay grown for Seed.

The growing of hay for seed is more or less confined to certain districts in the county of Ayrshire, where Perennial Ryegrass and to a much less extent Timothy are grown for this purpose. For the Perennial Ryegrass the seeding may be pure, though more frequently the clovers are also included in the mixture. The crop is allowed to ripen and is harvested in much the same way as a grain crop, though it is seldom that a self-binder is used. When dry the sheaves are built into small " rickles " in the field, from which they are carted direct to the threshing machine.

The seed, which averages about $5\frac{1}{2}$ cwt. per acre, is sold, while the threshed hay is looked upon more or less as the by-product. The feeding value of threshed hay is very much inferior to that of the crop that has been cut when green. Its value is about the same as that of good oat straw, though when sold it generally realizes considerably more in the market.

The growing of Ryegrass for seed has a bad effect on the subsequent pastures where they are intended for permanent or temporary leys. In the first instance the seeding is entirely wrong for this purpose, and it is hopeless to look for good pastures and a return from seed off the same field at the same time.

The harvesting of Timothy for seed is not so common, but where there is a good plant this can be done quite successfully. The threshed Timothy hay is of rather better quality than the threshed Ryegrass hay. The harvesting of the crop in this way does not injure the plant to any appreciable extent. It is not, however, wise to use the same meadow continuously year after year for this purpose, as it is liable to impoverish the soil and the plant will suffer accordingly.

Marketing of Hay.

At one time it was the usual custom for large quantities of hay to be sold and delivered out of the small ricks in the fields. The purchasers built the hay into large ricks or sheds in the towns, where it was ready for use when required. This practice has now very largely died out, and only the hay required for immediate use is delivered to buyers directly out of the field ricks. When delivered at this time it is built on the hay wagons in its loose condition. In order to ascertain the weight the load is drawn to a weighbridge.

After the hay has been placed in the large ricks or Dutch barns, a certain amount of it is still delivered in a loose condition when sold, but there is a growing tendency to have it baled before delivery. The baling is done by a special machine which compresses the hay into oblong blocks round which wire bands are tied. These machines can generally be hired to do the work. They are driven by an ordinary traction engine in the same way as a threshing machine. The bales are usually made in sizes to weigh from 1 to $1\frac{1}{2}$ cwt. each.

When hay is baled in this way it is much easier to handle. If transported by rail very much greater weights can be loaded on the trucks, and it is carried at a cheaper rate. Where it is necessary to haul it long distances by road, motor-lorries are now often used, and for these baling must be done. In the large towns the regulation of the traffic at busy centres is becoming such a difficult problem, that it is not unlikely that the cartage of large bulky loads of loose hay and straw through the streets may yet be stopped. Baling of hay will then become practically universal.

THE HAY CROP IN THE MIDLAND AND SOUTHERN COUNTIES OF ENGLAND AND IN WALES

In these areas there is a greater number of crops from which hay is commonly made than in the north. Besides Ryegrass and clover mixtures, and temporary and permanent pastures which are largely utilized for this purpose in the south as well as the north, crops of pure clover, Sainfoin, and Lucerne are grown for hay on suitable soils. Mixtures of vetches and peas with the various grain crops are also drawn upon, while crops like Trifolium or Crimson Clover and Trefoil, when not required for folding, can be made into quite good hay.

Permanent Grass Meadows.

A very large proportion of the hay made in these areas is made from permanent grass meadows. In many of the districts where dairying is the principal branch of farming, meadow hay is practically the only source of fodder for the dairy stock. These meadows vary to a very great extent as to the quality and quantity of the herbage they produce. They range from being simply a massed collection of weeds and inferior grasses, like Yorkshire Fog and Agrostis, to a fine rich sward of Wild White Clover with a mixture of Perennial Ryegrass and Meadow Grasses. In probably no other branch of farming is there more need for improvement than in the management of meadow land. Experiments have proved beyond a doubt that by judicious manuring the productivity of grassland can be greatly increased and a greater profit returned thereby. (See article on " Permanent Grass ".)

Temporary Pastures.

Unless in some of the wetter districts, temporary pastures have never been relied on to the same extent as they have in the northern areas. This is probably due to the fact that the effect of drought is more pronounced on the temporary than on the old permanent pastures. It is also due to the fact that in these areas, when a temporary pasture is ploughed up, the ravages of wireworm are more severe on the subsequent grain crops than is the case in the colder districts in the north. Provided these pastures have been properly seeded down, the quality of hay obtained is generally good though the yield may not be heavy.

Ryegrass and Clover Mixtures.

These are grown in much the same way as in the northern areas. Since, however, the clover plant can be better relied on to succeed, the mixture is generally somewhat modified. The amount of Ryegrass is reduced and the amount of clover increased according to the suitability of the land to the clover plant. In some districts, especially on farms where sheep are folded, a small quantity of Trefoil or, as it is sometimes called, Hop Clover, is included in the mixture. This plant does not give a big yield, but it is much liked by the sheep and yields a bottom feed for them when grazed. The season being much earlier in these areas, it is a common practice to cut a second crop of hay from Ryegrass and clover mixtures when the aftermath is not required for the feeding of stock. Good second crops are sometimes obtained, especially in an early and moist season. The quality of the hay is not quite so good as from the first cut, but if the weather is favourable it forms a very valuable addition to the supply of winter fodder.

Clover Crop.

This is a very common crop in some districts. On the wheat lands the clover crop is looked upon as a valuable preparation for wheat. A satisfactory crop of wheat can never be relied on when preceded by a Ryegrass and clover mixture, but after a crop of pure clover good results can generally be expected. Where clover hay is grown Broad Red Clover is sown alone. There are various strains that are reputed to succeed better than others in different districts, to which they are more or less indigenous. Some farmers have sown the same strain from seed grown on their own farm for a long number of years. By following this principle they maintain that the plant is acclimatized to their farm and that they obtain better crops on account of this fact. The clover plant, however, is subject to what is known as clover-sickness. But Alsike is not so subject to the disease, and on land that is badly infected this clover may be substituted for the red variety in seeds mixtures. (See article on " Diseases of Clover ", Vol. III.)

The clover crop is generally seeded down under a nurse crop in the same way as a grass mixture. It is a more common practice, however, to drill the seed. By this method the seeds are covered to a more uniform depth, and as the seed is small this is a decided advantage in its favour. The quantity of seed should not be less than 14 lb. per acre, but in some districts a much larger amount than this is sown. The young plants should be well rolled down in the autumn or early spring and should not be grazed. Grazing young clovers with sheep is especially harmful, as they eat closely into the crown of the plant and are very apt to destroy it. In the manuring of clover it is unnecessary to apply a nitrogenous manure, as the clover plant is able to obtain an adequate supply from the soil atmosphere through the nodules on its roots. The clover plant, however, responds readily to potash, and on land which is inclined to be lacking in this ingredient it is advisable to apply a dressing up to 4 cwt. per acre of kainit in the autumn to the young plants.

The yield of hay from a crop of clover should average about 2 tons per acre. A good second cut of at least 1 ton per acre is often obtained in addition.

Large areas of the clover crop are harvested for seed. It is almost invariably the second crop that is left for this purpose. Seeding is only attempted where there is a good plant of clover. In some cases the first crop is grazed lightly by sheep instead of being cut for hay. Then the crop is left to ripen, which it does generally by September. It is cut with a mowing machine and is not difficult to dry provided the weather is favourable. Careful handling is necessary so that the seed is not lost by too much shaking.[1]

Sainfoin, Lucerne, and Trifolium.

These crops are largely drawn upon as sources of hay and fall naturally for consideration in this place, but their importance is such that special articles are devoted to them, and to these the reader is now referred (p. 209).

Trefoil or Hop.

This is occasionally grown alone as a hay crop. Sown in the same way as clover it can be grown on land that has become clover-sick, but does not yield such a large crop. It is not advisable to sow it alone for this purpose unless there is little likelihood of any of the other crops succeeding.

When making clovers and allied crops into hay great care has to be observed to prevent the leaves being knocked off, as these are the most valuable part of the plant for feeding purposes. If the hay is exposed too long in the swath in sunny weather and then tossed about by the hay-making machinery, the leaves are apt to be lost. The best way to secure the hay is to cock it before it is too brittle, and thus let the process of drying continue slowly.

Vetches and Grain Mixtures.

On farms where there is a large proportion of arable land, these mixtures are often grown for the purpose of making the crop into hay. Winter vetches are generally used for this purpose. The variety of grain that may be sown with them is more or less a matter of choice. Rye is sometimes recommended, but as the rye is much earlier than the vetches the straw is apt to be too tough and fibrous before the vetches are ready for cutting. The object in sowing grain with the vetches is to carry the vetch plants. The vetch is a very recumbent plant, and when grown alone the stems lie on the ground. In this position they are difficult to handle, and if a period of wet weather sets in before the crop is cut, the vetch haulm may become partly rotted. Wheat, which has the stoutest straw of all the grain crops, fulfils the purpose of holding up the vetch plants

[1] For further information, see article on "Seed Production and Seed Testing", Vol. III.

the best; it is however rather hard for fodder. Winter oat straw though not quite so stout makes better hay, and taking both factors into consideration is probably the best grain to use. A good mixture is 1½ bus. winter vetches and 1½ bus. winter oats per acre. The grey variety of winter oats will produce the larger bulk of fodder of finer quality, but as it is more likely to lodge, the black variety, which has a stouter straw, should be grown.

This crop can be grown anywhere in the rotation, but the most common practice is to grow it as a catch crop. Immediately the stubbles are cleared the land is ploughed and the seed drilled. The best results are obtained when it is sown about the end of September, but if the winter is not too severe it will do quite well up to the end of November. It is not advisable to manure the crop. It can generally be relied on to produce a good yield unless on the very poorest of soils, and it is a great disadvantage to have the crop too heavy as it is almost sure to become lodged and be spoiled in that way.

It should be ready to cut for hay about the end of May. Whenever the first vetch pods begin to form, and milky material begins to appear in the oat grains, cutting should commence. The hay is made in the same way as clover hay, and here also care should be observed in handling so that the leaves are not knocked off the vetch stalks and the most valuable part lost. This is a favourite mixture for the making of silage, and where a silo is available it should be dealt with in this way for preference. A good crop should yield up to 3 tons of hay per acre, and the hay is of high feeding value when well secured.

As soon as the crop is cleared the land can be ploughed and turnips or swedes sown, or if desired the land can be fallowed in preparation for another winter grain crop. The vetches enrich the soil in nitrogen, and when included in the rotation this crop allows ample opportunity for the subsequent cleaning of the land by roots or fallow in the same season as that in which it is grown.

Peas and Oats.

In order to increase the supply of hay on farms where there is difficulty in growing enough for the stock kept, a mixture of peas and oats is frequently sown. It can be sown to replace a part of the grain in the rotation without interfering with the general plan of cropping. The mixture should be sown early in spring in the proportion of 1 bus. peas to 2 bus. oats at the rate of 4 bus. per acre. Either Maple or Dun peas can be used, but for the oats it is best to select one of the varieties that produce a large bulk of straw. Varieties like Potato or Sandy tiller better and produce a larger bulk of finer straw than some of the heavier grain-producing varieties. The seed should be drilled, and at the time of sowing a dressing of 2 to 3 cwt. superphosphate and 2 cwt. kainit per acre should be applied and harrowed in. It is not necessary to apply a nitrogenous manure as the pea plant has the power of fixing the nitrogen of the soil atmosphere. A sufficient supply is obtained in that way.

If the crop has been sown in February or March it should be ready for cutting sometime in July. As soon as the pea pods have been formed and before the peas appear in the pods the crop should be cut. At this stage the oats should be in ear, but in the grain there should only be a milky juice. If allowed to become riper than this the feeding value of the resultant hay will not be so high. The haulm of the peas and the straw of the oats become hard and lignified, and the valuable feeding material gradually concentrates in the pea and oat grain.

The crop is secured in the same way as other hay crops. However, it requires considerable drying, and in no case should heating be allowed to develop. The feeding value of the hay when properly made is very high. A good crop should yield at least 3 tons per acre, and where the land is fertile considerably larger yields than this may be obtained.

Water Meadows.

Irrigation is not practised extensively, but in a few isolated localities exceptionally good water meadows are to be found. Where there is a good supply of water it is run over the meadows during the winter. The ditches and sluices require constant attention to see that the water is evenly distributed. About the middle of February the water is shut off, and as soon as the meadows are dry enough they are folded over with sheep. This sheep feed is very valuable at this time, especially where there are early lambs. As soon as the folding is finished the water is turned on again, and by the end of June a large crop of hay will be ready to cut. It is necessary to turn off the water as soon as the grass has grown a certain length or there will be danger of the crop being washed down. These meadows can always be relied on to produce good crops of hay even after having been eaten closely down in the spring. They are considered a valuable asset to a farm, and where they are let separately they can generally command high rents.

Harvesting the Hay Crop.

It is sometimes assumed that the harvesting of the hay crop in these southern areas is a much more simple process than in the northern districts, but this is not always so. As in all areas the process depends entirely on the weather conditions, and while the drying agencies of sun and wind may be more effective when the weather is fine, it is not uncommon to have long spells of wet weather at hay-time, when large quantities of hay may be badly damaged.

Haymaking begins about a month earlier than in Scotland. *Trifolium* is generally the first crop that is ready for cutting, which may be in the last week in May. Early in June the clover, and Ryegrass and clover mixtures are ready; when these have been disposed of the meadows are cut. The general practice is to leave the hay a sufficient length of time on the ground to have it dry enough to cart directly into the large ricks or stacks. By this means the intermediate process of leaving it in small ricks in the field to dry further is dispensed with.

After the cutting, which is done in the ordinary way with a mowing machine, the hay is left for several days to dry. It is then turned, and if cocking is considered unnecessary it is left for another day at least. Unless the weather is very settled it is advisable to put the hay into cocks. This entails a little extra labour but better hay is made. In the case of clovers and allied plants the leaves are not so likely to be lost if this is done. When left in the swath under a blazing sun the leaves get shrivelled, and when the hay is raked together they crumple up into small pieces which are left on the ground. If the hay is put into cocks it is specially important that these should be well made. In wet weather hay is just as well in the swath as in badly made cocks, but in well made cocks it is partly secured.

The raking of the swaths into rows is done by a side rake. This machine has an action something similar to a horse road-sweeping machine. It consists of four rows of rakes which revolve on a shaft, and being set at an angle to the direction in which the machine is drawn sweeps the hay into one continuous row. Being made the proper width to take two swaths, the machine, by working alternately in opposite directions, can throw four swaths into one row. Where the hay is being carted directly from the rows these machines have a great advantage over the ordinary horse rake. As soon as raking is commenced there are rows the full length of the field and loading of the wagons can be started forthwith. With the horse rake a considerable time must elapse before the rows of hay are a convenient length to be picked up without much turning backwards and forwards with the wagons.

If the hay is considered dry enough to be placed in the large rick directly out of the rows, the farmer has the choice of several methods of collecting it together. The oldest method and one which is still practised a good deal is to load the hay on wagons by fork. Where there is a sufficient staff two men can be delegated to one wagon to pitch the hay up and two to build. The rows should be a convenient width to allow the wagon to be led along between two, and one man works at each side. When the hay is long and sticks well together rapid progress can be made in this way, but when the hay is short it is a slow and tedious process. Where this method is employed it is advisable to cock the hay. The labour in making the cocks is largely saved when the time comes to cart it, as it is so much easier to load the wagons from the cocks than from the rows.

Another method employed at this stage is to load the hay on the wagons by means of a hay-loader. This machine is constructed on somewhat the same principle as a hay elevator. It is coupled on behind, the top projecting well over on to the wagon, and as this is moved along it pulls the hay-loader behind it. The wheels of the hay-loader work the elevator, which picks up the hay from the row and deposits it on the wagon. The wagon and the loader must be led along so that they stride over the row of hay. This machine enables the farmer to economize in manual labour where extra men are difficult to secure at hay-time. It requires two men to build the hay on the wagon, and they require to be smart, active men at that. The building has to be done while the wagon is in motion, thus besides moving the hay they have to balance themselves so that when the wagon lurches they are not thrown off. Frames are made to run along the sides of the wagons, which, if used, makes the building of the hay somewhat easier. It is not advisable to have the hay in the rows too thick. The machine works easier and the men on the wagon can handle the material better when it is delivered up at a moderate rate. Where the hay is short the machine is at its best. It picks it up more quickly and much cleaner than could possibly be done by hand. Wind is most troublesome, and if very strong it makes it almost impossible to work the machine at all. The hay gets blown over the side of the wagon before it can be caught by the builders, so in these circumstances it is as well to let the machine remain idle and resort to hand pitching.

For economy in labour the hay-sweep is perhaps the most useful implement at this stage. The use of this is only suitable when it is convenient to build the rick in the field. On the large arable sheep farms, where the hay is usually consumed on the field or near the field where it is grown, the hay-sweep is almost universally used. It consists primarily of a series of long poles or teeth arranged in a row parallel to each other. These are attached at one end to a framework on which is an arrangement for lowering or raising them as desired. Two horses are yoked, one to each end of the frame, and as they move forward the poles or teeth run along the ground and gather up the hay, which collects on the top of them. As soon as a full load is gathered it is drawn to the rick and unloaded by simply backing the machine from under the hay. By the use of two sweeps a gang of men can be kept fully employed at the rick. It is better if it can be arranged to build the rick right in the middle of the field as this reduces the distance over which the hay has to be hauled. If necessary these sweeps will gather the hay straight out of the swaths without having it first raked into rows. A cleaner job is, however, made when it has been previously raked. The ground must be level for the sweeps to do good work, and where many loose stones are lying on the surface there is always a danger that some of these may be gathered up with the hay and give trouble later on if part of the hay is chaffed. On the smaller farms where the fields are not so large the small one-horse collectors may be used, but unless the distance that the hay has to be hauled is very short they are not very suitable.

At this stage in the making of hay the farmer must use most careful judgment. If he errs in gathering the hay into the rick before it is properly dried the quality of the hay will suffer. In some cases heating may develop to such an extent that spontaneous combustion takes place and the rick " fires ". More hay is spoiled by ricking too soon in good hay-making weather than when it is duller. In the middle of the day, when the swaths have been exposed to a blazing sun, the hay takes on a very birsled appearance, and to the uninitiated it may seem to be perfectly dry. But as soon as the sun sets or when the hay is placed in a rick it quickly changes, and may then appear to be almost as green and soft as it was when cut. Under these conditions care is necessary, and more especially if the hay was cut before it was quite at the flowering stage. The strong sun dries the outer surface of the leaves and stalks, giving them this dry appearance, while the inner cells still retain their sap. This appears on the surface as soon as the hay is removed from the sun-light. Thus a certain amount of time is always necessary however forcing the weather may be, and when one is apt to be too anxious to get the hay into the rick it is well to remember that it is better to risk leaving it out for another day than to spoil it by putting it in the rick too soon.

Unless on the smaller farms, an elevator is generally used to lift the hay on to the rick. This is a very expensive machine, but is such a labour-saving device that few farmers would care to be without it. It consists principally of a long wide trough along which a series of prongs are carried on chains. The trough is carried on a framework on wheels, and it is constructed so that it can be doubled up for transport. There is an arrangement whereby the trough can be gradually elevated at one end as the rick gets higher. At first the end of the trough projects over the rick and drops the hay into the centre, but as the rick rises and the trough is elevated it does not throw the hay quite so far over. Sometimes he elevator is driven by means of a horse gear, which is arranged so that the horse walks in a circle at the side of the machine. However, since small petrol- or paraffin-engines can be so cheaply procured these are often fitted to the elevator and replace the horse. The cost of fuel is small, and an engine gives a much more regular motion than a horse.

The hay is pitched into the lower end of the trough, which usually stands 4 or 5 ft. above the ground. When unloading from a wagon one man can keep the elevator well supplied, but when sweeps are used two and sometimes three men are required as the hay is all at the ground level.

It is the usual custom to make the hay ricks rectangular in shape. The size may be varied according to the amount of hay they are desired to contain. Within limits the larger the ricks the less labour per ton will be required for building and thatching. A convenient size contains from 25 to 30 tons. The bottom for a rick of this size would be 12 yd. long and 6 yd. wide. In laying this down, brushwood or logs should be used with a good layer of straw on top. These preserve the lower layers of hay by preventing the moisture from the ground rising up into them.

In building the rick the sides and ends should incline slightly outwards from the perpendicular in order to throw the water from the roof clear of the body of the rick. The centre should always be kept well raised during the process of building, and the roof should be firmly built with a uniform slope.

Hay made in this way always develops a certain amount of heat, and as the rick settles down the roof may go out of shape. Before thatching, the shank of the rick should be raked and the roof squared up by adding more hay to it if necessary. Careful thatching finishes the process.

Dutch barns are less frequent in these southern areas than they are in the north, though they are not uncommon in the western districts where the rainfall is high. They are of decided advantage where feeding or dairying is practised, but on the large sheep farms they are unnecessary since the hay is consumed in the fields. However, the remarks already made concerning the filling of these sheds apply equally to those cases in the south where they do exist.

The question of "heating" is of particular importance where hay is stored in this manner, since such large quantities are involved. If there is the least suspicion that the hay is getting too hot an iron rod should be used to test it. This should be long enough to reach well into the centre of the bulk. It is then pushed into the part that is believed to be heating most and allowed to remain in until it is raised to the same heat as the hay. When withdrawn, the temperature of the iron is judged by holding the heated part on the hand. So long as the rod is not too hot to hold in the hand there is no immediate danger of firing. Some rods are made so that a thermometer can be inserted in a cavity at the end that is pushed into the centre of hay. The actual temperature can then be read. This gives a much better guide to the inexperienced than the "rule-of-thumb" method of testing the heat by holding the iron on the hand. As soon as the temperature exceeds 140° F. action should be taken at once to endeavour to save the hay from firing.

Overheated ricks may be treated in several ways. Air-holes may be bored in them by an instrument like an auger. This should be done at the place where the greatest heat has been developed. If, however, a sudden rush of air enters these holes combustion may develop straight away. Another plan is to cut out a narrow section through the centre of the rick with a hay knife. This is hot work, but if done in time may save the rick. When there appears to be great risk of firing the safest plan is to turn the rick. This is done by placing the elevator alongside the rick and turning it over and rebuilding it on another site. All this means extra labour, the quality of the hay is generally very much impaired, and, taking everything into consideration, the loss is very considerable. Any farmer who has once experienced the anxiety of watching one of his large ricks of hay developing a daily rise of temperature, not knowing how much farther it may still rise, and having eventually to turn it or lose it altogether, is less likely to make the mistake of carting it too soon in succeeding seasons.

In a few isolated cases hay is built into small ricks in the field in the same way as it is done in the north. During unsettled weather this system has certainly a decided advantage over the other. It is unnecessary to leave the hay so long lying in the swath, larger areas can be saved in a given time, and the quality of the hay made is quite as good. In the western and south-western districts where the rainfall is greater, the extension of this method should certainly be recommended. Especially now that the machinery for handling hay in this way has been developed to such an extent, the extra labour involved is practically negligible. On small farms where there is not a sufficient number of employees to make up a full gang to keep a large rick and an elevator going by this method, very much better use can be made of good haymaking weather while it lasts.

Marketing of Hay.

A very large proportion of the hay that is marketed is still transported in the form of trusses. These trusses are simply blocks of hay cut out of the rick and tied firmly with bands to keep them from falling to pieces. These blocks are usually rectangular in shape, 3 ft. long, 2 ft. wide, and vary in depth according to the firmness of the rick. The bands are sometimes made of twisted hay, but for machine-pressed trusses cord is used. Trusses are made to weigh ½ cwt., and an experienced worker can judge to within a few pounds when cutting out the trusses. Baling machines are also used, but trussed hay is preferred especially when the hay is of very fine quality. The bales, weighing up to 1 cwt. and 1½ cwt., are held together by light wires. These are more convenient than trusses for transport, as they occupy less space for their weight and are more convenient for storage where accommodation is limited. Large quantities of hay in the rick are sold by farmers to the hay merchants, who do all the work of tying and carting. The content of the rick is estimated by measurement. The weight per cubic foot varies according to the extent the rick has settled down. From 1½ to 2 cwt. per cubic yard is a fair average.

Variations in the Quality and Feeding Value of Hay.—The value of the ultimate product, as may be assumed from the foregoing remarks, varies to a very great extent. The principal factors which influence the quality are:

(1) *The varieties of plants or mixture from which the hay is made.*—As a general rule the clovers and allied leguminous plants produce a hay which is richer in albuminoids than is obtained from the grasses. The hay from the grasses, however, is rather richer in carbohydrates, and consequently their feeding value as shown by their total starch values is more or less equal. In the case of meadow hay from permanent pastures there is great variation, according to the composition of the herbage. Where this is largely composed of the poorer grasses the hay will be naturally of poor quality. On meadows that have been manured with basic slag there is generally a great improvement in the quality, partly on account of the more abundant growth of clovers and partly because of the great influence of the manuring in encouraging the better grasses.

(2) *The age at which the plants are cut.*—The maximum amount of feeding value can generally be obtained from any of the plants when they are cut just after they have reached the flowering stage. If mown before this the hay will have a higher feeding value, but this will not compensate for the loss in bulk. Should cutting be delayed, a larger bulk of crop will be obtained, hut this increase will not balance the loss in feeding value. As soon as the plants flower the stems become more lignified and the increase in yield largely consists of indigestible material. In the case of meadow hay it is impossible to have all the various plants flowering at the same time, thus when it is estimated that the greater proportion of the plants is at this stage the hay should be cut.

(3) *The nature of the soil.*—There can be no doubt that the nature of the soil has an important influence on the quality of the hay. Though there may be little difference in the chemical analysis of the same variety of plant when grown on different soils, experience points to the fact that the feeding value may vary. As a general rule the more fertile soils produce better feeding plants. Where there is excessive growth due to moisture the quality of the hay will not be so good. Very light land does not produce hay of such high quality as do the medium and heavier soils.

(4) *The climatic conditions during the period of growth.*—In very moist mild weather the plants grow too luxuriantly. The stems become too rank and coarse, and consequently there is a large proportion of stems to leaves. Moreover, if the crop becomes too heavy it is very likely to lodge, and the parts lying close on the ground undergo a certain amount of decay. On the other hand, if the weather is excessively dry the plants are stunted. This is more pronounced on soils that are naturally deficient in moisture. Under these circumstances the plants become more lignified, they develop smaller leaves, and the quality of the hay suffers accordingly.

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The best hay is produced in normal seasons when there is a fair amount of sunshine but not excessive growth.

(5) *The application of manures.*—Well-balanced manures have a tendency to improve the quality. Except in the case of Timothy meadows too heavy nitrogenous dressings are apt to produce rankness. The improvement from basic slag is mainly due to alteration in the botanical composition of the herbage. Where vetches and oats are grown for hay, manuring is not to be recommended as the crop may become lodged.

(6) *The condition of the weather during the process of making.*—This is the greatest factor in determining the final quality of the hay. If the weather is good the feeding value falls very little in the making, and the hay produced is almost equivalent in total value to the original green material. When there is much rain during this process the value may be reduced to about half. Intermittent drying and wetting washes the soluble proteins and carbohydrates out of the material, and these are the most valuable nutrient portion. If the conditions are so bad that sufficient drying cannot be accomplished, moulds will develop in the ricks and further depreciate the feeding value, besides making it much less palatable and perhaps positively injurious to the health of the stock.

(7) *The changes which occur in the rick.*—These depend entirely on the process of making before it reaches this stage. In the northern areas heating is not desired. Where this takes place to any extent it is frequently associated with the production of moulds. The only change which should occur when the haymaking has been properly managed is a fall in weight due to loss of moisture. The feeding value in the spring is thus slightly higher than it is in the autumn. In the southern areas heating to a slight extent is considered desirable. This " sweating ", as it is called, produces a sweet aroma in the hay, and causes the ricks to settle down firmer and in so doing prevents excessive drying should the hay be left in the rick over a long period before being consumed. Whenever heating takes place it is an indication of a loss of energy, which is practically coincident with a loss of feeding value. Excessive heating should be avoided if possible. When it develops to the extent of carbonizing the hay the loss of total feeding value is very great. When heating has ceased the hay alters very little. If left for several years it gradually loses its flavour, becomes very dry, and is not readily eaten by stock.

Utilization of the Hay Crop.

In the feeding of farm stock during the winter months no crop grown on the farm plays a more important part than hay. With the exception of the pig, all farm animals require a certain amount of bulk in their rations. Hay provides this bulk, and at the same time supplies a large amount of nutrient material in a digestible and well-balanced form. On farms where there is a large proportion of arable land, straw may be used for the same purpose, but as the feeding value of straw is not so high it is necessary to supplement it with a greater amount of concentrated foods, which add very materially to the expense of feeding.

Feeding of Hay to Horses.—For horses in hard work hay may be considered as an almost essential part of their ration. The amount fed may be varied from 10 to 20 lb. per day according to the amounts and kinds of other foods supplied. All kinds of hay may be fed, but clovers and clover and Ryegrass mixtures are preferred. Lucerne hay where it can be grown is also very useful. In town stables it is customary to feed a large proportion or all of the ration in the form of chaff. In this way there is less waste, for when fed long the hay is apt to be drawn out of the rack and trodden under foot. Where chaffing is done on a large scale the chaff should be passed over a sifting machine to remove the dust. This has been proved to reduce the cases of colic among the horses in some of the large town studs where chaff is mainly used.

In no case should hay that has developed moulds be fed to horses, as it is very liable to cause digestive troubles. New hay should also be fed very sparingly for the same reason. For hunters and race-horses well preserved hay which has been at least a year in the rick is preferred. On some farms it is customary to feed the work-horses during the short winter days on straw in order to leave a greater supply of hay for the other stock, or for sale. Before this is done a careful comparison of the relative feeding value of the two should be made, as in some seasons the selling value of hay and straw bears very little relation to the difference in their feeding value.

Feeding of Hay to Cattle.—Unless on farms where there is very little or no arable land, hay is only fed to cattle as part of their fodder ration. Straw is generally used to supplement the hay in proportion to the amount of hay available. For dairy cows hay is very valuable, and where there is an abundant supply it may be fed up to 20 lb. per day, but a more usual ration is 12 lb. of hay and 8 lb. of straw. In some districts, especially in the north, all the fodder is fed to the cows long; in others it is the common practice to feed a large proportion or all of it in the form of chaff. The chaff is mixed with the pulped roots and some of the meals and fed in that way. Chaffing to a certain extent prevents waste, but it is questionable if the saving in this respect compensates for the extra labour involved.

Where only a small proportion of the fodder ration consists of hay, foods richer in protein must be used and in greater amount in order to make up for the deficiency of protein in the straw. When hay has been very much damaged by bad weather during the process of making, it may be reduced to about the same feeding value as straw, and in constructing the rations this should be taken into consideration. When it is of such inferior quality it is a good plan to chaff it and sprinkle it over with treacle dissolved in water. This does not improve its feeding value in any way, but by treating it thus it is rendered more palatable and the cattle will be induced to eat more of it.

For fattening cattle hay is a very useful food, but the quantity fed to such stock is regulated entirely by the amount available for the purpose. Straw is in most cases fed *ad lib.* and a small allowance of hay. The greater the amount of hay fed the less expense there will be for concentrated foods. For calves and young stock up to one year old, hay is absolutely essential. Calves will begin to pick a little hay in a few weeks, and when sixteen weeks old will eat several pounds per day. Some of the best clover mixture should always be reserved for them. It should be fresh and green so that it will tempt them to eat. As they grow older the amount fed should gradually be increased, and at one year they will require from 8 to 10 lb. per day. Young stock fed on good hay do not become "pot-bellied", they develop plenty of bone and muscle, and there is no danger of them becoming stunted in growth.

Feeding Hay to Sheep.—When sheep are being fed on roots an allowance of hay is almost essential. Roots contain a very high percentage of water, and the sheep require to consume a very large quantity in order to get sufficient dry matter for their needs. The addition of 1 lb. of hay per head per day to their ration supplies both bulk and dry matter, and they will do better on a much smaller amount of roots. In districts where the breeding flocks are folded on roots before lambing, an allowance of hay is always given. This maintains the ewes in good condition and reduces the percentage of losses at lambing. The hay fed to sheep should be good. Clover and clover mixtures are the best unless on farms where good Sainfoin can be grown. When hay of inferior quality is fed a large amount of it is wasted. The sheep pull it out of the cribs and tread it into the mud. When good hay is fed care should be observed that they are given no more than they will clear up each day, and that none of it is trodden under foot. For hill flocks hay is only required when the ground is deeply covered with snow. The hay is generally made from a pasture field near the hill, and the supply is only drawn upon when extreme conditions arise. In long severe winters the store may run out, and then it is necessary to purchase hay and sometimes haul it long distances. Flockmasters maintain that even though such purchased hay is seemingly often of better quality than that grown on the farm, the flocks do not appear to do so well on it. This is probably due to the fact that the home-grown hay is somewhat similar in composition to the pasture of the hills.

Hay is such a suitable form in which to preserve fodder for winter use, it is also such a suitable and valuable food for stock, that it is very unlikely that the hay crop will ever occupy a less important place in farming practice than it does at present. It is possible that the available supply may yet be further increased by the improvement of existing plants and the introduction of new ones. Haymaking machinery may be still further improved in the direction of labour-saving devices. The drying by artificial air-currents may yet get beyond the experimental stage and render the process less dependent on climatic conditions. Meanwhile, though the crop cannot be considered one of the most difficult farm crops to grow, it is certainly still the most difficult of all crops to secure without damage.

CHEMICAL COMPOSITION OF PASTURE PLANTS AND HAY

By Professor T. B. WOOD, C.B.E., M.A., F.R.S.

This is an extremely important subject, but has received nothing like the attention which it deserves. The following remarks will, it is feared, serve rather to emphasize the need of further investigation than to provide a source of readily available practical information.

The cultivated land of the United Kingdom extends to about 47 million acres, of which about 27 million acres are under permanent grass. In addition to this about $6\frac{3}{4}$ million acres are occupied by rotation grasses and clovers, making a total of $33\frac{3}{4}$ million acres under grass, which is over 70 per cent of the total cultivated area. It is estimated that the total produce of this enormous acreage under grass is approximately 50 million tons measured as hay, or about three times the weight of the total produce of corn, straw, roots, &c., grown on the remaining 20 million acres of cultivated land measured, or rather weighed, at the same moisture content as hay. Grass and hay, therefore, account for about three-quarters of the total produce of the land of the United Kingdom.

Our knowledge of the chemistry of grass is confined to a number of scattered observations from which it is almost hopeless to generalize usefully. Many workers have specialized in branches of the subject, such as the botanical characteristics of natural grassland, the improvement of poor grassland by basic slag, and so on, but no one has tackled the subject as a whole. Perhaps it is too big: grassland varies so widely, from the magnificent fattening pastures of the Midlands, which readily let at several pounds per acre, to poor grassland which would be dear at half a crown an acre.

The herbage of ordinary grassland usually contains something like thirty species of plants, many of which are common to both the best and the worst pastures, though the predominant species are different. Recognizing that pastures are so variable, the difficulty of making definite statements as to the chemical composition of their produce is at once apparent. From the scattered investigations which have been carried out, certain general conclusions can, however, be drawn.

A poor pasture or meadow contains a greater variety of species, including grasses, clovers, and weeds, than a good pasture or meadow, and under natural undisturbed conditions the relative proportions of the various species remain fairly constant, fluctuating, however, to a considerable extent according to the season. The application of any kind of manurial or other treatment is usually to the advantage of a few of the species, which, with this handicap in their favour, crowd out the other species. If such treatment is repeated continuously, the favoured ones will increase very greatly at the expense of others, which may be entirely crowded out. A herbage will result which gives a greater amount of produce per acre, containing, however, a smaller number of species.

Since all species have their own particular chemical composition, a change of this kind will result in a change in the chemical composition of the herbage. Good treatment will, for instance, cause good grasses and clovers to crowd out bad grasses and weeds, and the chemical composition of the herbage will be improved. Good grassland produces a herbage containing relatively few species, among which certain ones, e.g. Perennial Ryegrass and White Clover, predominate. Such grassland is further characterized by producing a herbage which grows more " blades " per square inch than poorer land. Its sward is characteristically dense, and it also frequently contains rather more nitrogen and phosphates than the herbage of poorer land.

On such dense growth an animal will be able to fill itself with comparatively little walking in search of food, and since walking or any other muscular effort uses up food which would otherwise produce increased live weight, such pastures are more valuable for the production of beef or mutton than the actual weight of their produce or its chemical composition would indicate.

New growth on a pasture always contains more protein, more soluble carbohydrates, and less fibre than older vegetation, and is consequently higher in food value. Indeed fresh-grown grass is a highly nutritious food containing abundant protein, compared with hay or older grass. These results have been derived from analyses of repeated cuttings, the weighing of which showed that whilst repeated cutting of the same area gave produce of good food value and high digestibility, the total weight of produce was considerably smaller than that yielded by a single cutting when the herbage was mature.

Assuming, as seems justified, that repeated cutting fairly imitates grazing, and single cutting when mature represents haymaking, it appears that land yields to grazing a comparatively small amount of highly nutritive and digestible fodder, to haymaking a larger amount of coarser indigestible fodder. Grassland under well managed grazing will yield to the animals it supports a better balanced and more nutritious ration though comparatively less in absolute quantity than it would produce if it were allowed to run to matured hay. Again, by good management grassland, unaided by concentrated feeding stuffs, may yield to grazing animals a well balanced ration when the same land would provide herbage deficient in protein and of low digestibility if stock were not given access to it until the herbage became long and mature.

For similar reasons hay is richer in proteins and more digestible if cut early, e.g. when the majority of the species are coming into flower, than if the cutting is delayed until seeds have been formed. Further, hay should be mown early because in haymaking seeds are invariably lost, and their loss robs the hay of much material which has been removed from the leaves and stems by the process of translocation.

As grass grows in the spring and early summer, the total amount of dry matter in the herbage increases, at first rapidly, then more slowly, until at the time when most of the species are in flower the total dry matter reaches its limit. If the crop is allowed to stand beyond this date, some of the dry matter is translocated to the seeds and is probably lost in harvesting. The result is less dry matter actually saved as hay, and that of lower nutritive value, for it is the more digestible material which is translocated from stems and leaves to seeds.

In the course of haymaking there are at least three further sources of loss which should be avoided as far as possible. Of the various constituents of hay, the leaves are more nutritious and digestible than the stems. Unfortunately the leaves are also more brittle and therefore more subject to destruction by excessive handling.

Some of the more valuable constituents of hay are soluble in water and therefore liable to loss by wet weather at harvest-time. Excessive exposure to the sun bleaches hay and is said to reduce its content of vitamines. By care in haymaking it is possible to minimize these losses, but they can never be entirely avoided in practice. Hay, therefore, never possesses exactly the same chemical composition as would be calculated by eliminating the requisite amount of water from the herbage from which the hay was made.

Figures for the percentage composition of several species of grasses and clovers are given in *Feeds and Feeding* by Henry and Morrison, in *The Scientific Feeding of Animals* by Kellner, translated by Goodwin, and in Sutton's *Permanent and Temporary Pastures*, analyses by J. A. Voelcker. The two former works also give coefficients of digestibility for several species, and based upon these, estimates of the percentage content of digestible nutrients. Most of the analyses and digestibility determinations were carried out on German or American produce, in view of which, and remembering the many causes of variation in such materials, it is evident that no good purpose would be served by tabulating such figures for application to home-grown fodders.

From consideration of these figures it appears, however, that the average composition of fresh green grasses and clovers at flowering time, stated in round numbers, is approximately as follows:

PERCENTAGE COMPOSITION OF FRESH GREEN GRASSES AT FLOWERING TIME, IN ROUND NUMBERS

	Grasses.	Clovers.
Crude protein	3·0	5·0
Crude fat	1·0	1·0
Carbohydrates	13·0	10·0
Fibre	9·0	7·0
Ash	2·5	2·0
Total dry matter	28·5	25·0
Water	71·5	75·0
	100·0	100·0

The average percentage digestibility of such materials, from Kellner's and Henry and Morrison's figures, appears to be about the same for both grasses and clovers, namely:

Crude protein	70
Crude fat	60
Carbohydrates	75
Fibre	60

Combining these figures, and still retaining round numbers, it appears that the average percentage of the various digestible nutrients in fresh green grasses and clovers is:

DIGESTIBLE NUTRIENTS PER CENT IN FRESH GRASSES AND CLOVERS

	Grasses.	Clovers.
Crude protein	2·0	3·0
Crude fat	0·6	0·6
Carbohydrates	10·0	7·5
Fibre	5·0	4·0

In the present state of our knowledge these figures may be applied to calculate the amount of digestible nutrients in any ordinary grasses or clovers with as much probability of exactitude as would be obtained by using either German or American figures for the individual species.

Hay.

As in the case of green produce, there are a good many scattered analyses of hay, but the causes of variation in composition are so numerous, and the variations they produce so great, that there is no point in giving a list of detailed analyses of individual species. The date of cutting, for instance, causes greater variations in the chemical composition and digestibility of hay made from one individual species than the difference between that species and another species. These analyses too are mostly American or German.

There is, however, a very notable difference in composition between hay made from grasses and from leguminous plants. Average figures are given in the following table:

PERCENTAGE COMPOSITION OF HAY MADE FROM GRASSES AND LEGUMINOUS PLANTS

	Grasses.	Leguminous Plants.
Protein	10	15
Fat	3	3
Carbohydrates	38	33
Fibre	28	26
Ash	7	7
Water	14	16
	100	100

DIGESTIBLE NUTRIENTS PER CENT IN HAY MADE FROM GRASSES AND LEGUMINOUS PLANTS

	Grasses.	Leguminous Plants.
Protein	5	10
Fat	1	1·5
Carbohydrates	22	23
Fibre	15	12

Average samples of meadow hay will approximate closely in percentage composition and in content of digestible nutrients to the figures given above for hay made from grasses. This is because the percentage of leguminous plants in average samples of meadow hay is too small to cause an appreciable departure from the composition of grasses. In the case of hay made from meadows manured with basic slag or from meadows whose herbage for any other reason contains over an average percentage of *Leguminosæ*, the percentages of total and digestible protein will be appreciably higher.

SAINFOIN

By W. J. MALDEN, A.S.I.

AND

A. F. R. NISBET, M.A., B.Sc., N.D.A., N.D.D.

About the middle of the seventeenth century Sainfoin was introduced to this country from the Continent, where previously it had been cultivated as a fodder crop for several centuries. It came first under the name of " Fingergrass "; Sainfoin, the name now used, is the French *Saint-foin*, meaning " holy hay ".

Botanical.

Sainfoin (*Onobrychis sativa*) is a perennial, belonging to the natural order *Leguminosæ*. The plant when young forms a rosette of leaves close to the ground. The foliage leaves of the seedling are at first small and undivided, with long stalks; later the leaves are trifoliate; and as the plant develops still further all the leaves are compoundly pinnate, with ten or twelve opposite leaflets and a terminal leaflet.


Sainfoin

The inflorescence forms a close raceme rising from the axil of a leaf. The flowers are a rosy pink in colour with darker veins; and these in July make a field of Sainfoin in bloom a most pleasing sight.

The fruit appears almost semicircular, and has its pericarp covered with an irregular network of raised lines with spiny projections. It is indehiscent, and contains one brown bean-shaped seed.

The primary root is fairly thick and penetrates deeply into the subsoil where this is dry and open, and Sainfoin is thus able to withstand drought fairly well; where, however, hard "pans" are present in the soil the roots often fail to penetrate these and incline to turn along the top of them.

Varieties.

Two varieties are cultivated, Common Sainfoin and Giant Sainfoin (*Onobrychis sativa*, var. *bifera*). The former is more lasting than the latter, and may be useful in leys up to seven years; it is also later in flowering. Giant strains seem to have been much later in reaching this country than Common Sainfoin, as it was not till 1834 that *Sainfoin à deux coupes* (two-cut Sainfoin) was introduced; and still later—in the fifties—a Giant variety was brought across, known as French double-cut Sainfoin. The different uses of Giant and Common will be noted later.

Soils.

Sainfoin appears to take most naturally to the light chalky soils where there is good depth. The strong tap-root renders it almost independent of surface moisture, which is an advantage on these soils. It is not, however, confined to chalk lands, and where the climate is dry and fairly warm it may be successfully grown on loams and clays, but in every case the drainage must be good, as stagnant water soon ruins the crop.

One reason why it is not found more commonly in other than the calcareous districts may be the difficulty in fitting into a more or less fixed rotation a crop which comes to its best only about the third year and then holds the land for seven or more years. But as evidence that it is capable of wider application than it generally receives, it may be recalled that exceptional crops were grown on the cold clays of North Beds, Northhants, and Huntingdonshire over a number of years towards the end of last century. These heavy lands fell out of corn-growing in the worst days of the depression, and would have become derelict or, at the best, tumble-down pastures, but for the growth of Sainfoin. In spite of this case, it cannot be maintained that all heavy clays are suited for this crop.

On account of the strong tap-root already mentioned, Sainfoin has been found useful on some rather shallow soils in opening up the deeper layers and so exercising a beneficial effect on succeeding crops.

Place in Rotation.

Sainfoin is generally sown with a grain crop, usually barley, and follows roots. After the ley is broken up, roots may be grown to enable thorough cleaning, for when it has been down a number of years the land becomes foul; indeed it is often the presence of weeds which necessitates the breaking of the ley. Thus it is advisable to follow with a fallow crop rather than grain immediately. However, in the districts where Sainfoin is mostly grown, a certain latitude in the arrangement of rotations is adopted.

Seeding.

A fine seed bed is necessary, and as this is generally prepared for the barley in any case, no special precautions need be taken. Sainfoin, however, is sometimes sown on clear land without a cover crop, and in such cases the usual tillages must be given to produce the fine tilth required.

The seed may be either sown broadcast or drilled. 4 bus. (100 to 110 lb.) of unmilled seed (i.e. in the husk) or about 56 lb. of milled seed per acre is an average seeding. Less than this will suffice if drilled, and if the land be in good condition as regards fineness and moisture to aid germination.

After the barley is in, the Sainfoin seed should be drilled at right angles to it, and then lightly harrowed and rolled or simply rolled as is considered necessary. Too deep burying of the seed should be avoided, ½ to 1 in. being sufficient. The rows should be not less than 10 in. apart, so that if necessary, hoeing may be done at a later time to keep down weeds. Where Common Sainfoin intended for several years' ley is sown broadcast, a seeding of Trefoil or Ryegrass is sometimes given at the same time. These help to give bulk in the first hay crop, and they smother weeds till the Sainfoin is strong enough to accomplish this itself.

Whether drilling or broadcasting should be practised will depend on a number of factors which the grower must weigh up for himself. But where seed is to be sown on clear land the balance will almost surely be in favour of drilling; for if the land cannot be cleaned, in the absence of a nurse crop weeds will intervene and greatly lessen the value of the Sainfoin, and the time it can be left down will be reduced. The usual time for sowing is from the middle of April to the middle of May, though a backward season may necessitate this being deferred to the end of May or beginning of June.

In regard to the purchase of seed, it is desirable, where possible, to get a guarantee from the seller, not only of purity and germination, but of variety. This is necessary on account of the similarity of the seeds of the Giant and Common varieties; but because of this similarity seedsmen are very unwilling to sell Sainfoin without fully protecting themselves against any legal action arising through a confusion of the varieties.

In a good sample of seed the pods should be fairly bright and of a reddish brown or dark straw colour. If milled seed is purchased it should be plump and of light brown colour outside and faintly greenish inside. Seed which appears black or wrinkled has been badly harvested or is old, and in either case should be avoided, as only fresh seed gives a satisfactory germination.

The commonest impurities are the seeds of Burnet (*Poterium poly-*

gamum) and Brome Grasses (*Bromus* spp.). These, however, are easily detected, especially in the milled seed, and samples containing them should be rejected.

Manuring.

Sainfoin in common with many other leguminous crops benefits greatly from dressings of farmyard manure, and medium dressings when required should be applied during the winter months. The manure should be spread uniformly and broken well down, never being left in large lumps.

This crop also responds well to dressings of phosphates and potash, and also to lime when there is not a great amount present in the soil. Where the rainfall is not too low, basic slag may be used with advantage, 6 cwt. per acre of a medium grade being applied along with 1 to 1½ cwt. of muriate of potash or potash salts equivalent thereto. In the drier districts the slag does not answer quite so well, and it is therefore better in these areas to use superphosphate on all soils with sufficient lime in them.

It is important to keep up a good balance of lime in the soil, for, as previously pointed out, this crop does best on calcareous soils. Lime when required can be applied either as burned lime or as ground limestone. If the latter form is used it should always be finely ground to ensure fairly rapid action.

Treatment and Use.

Sainfoin is grown either for hay or for grazing, or it may be taken as a soiling crop. In these cases a pure seeding is generally given, but sometimes—in the south and west of England—we find it as a constituent of mixtures for temporary leys or permanent pasture.

The Giant variety, on account of its size and vigour and from the fact that it can only be relied upon for about two years, is most suited for hay-making and must thus be considered in the nature of a rotation crop. It will give two or more heavy cuts of hay in the year, the mowing being done just as the plant comes into bloom. If, however, seed is required only one cut can be taken.

Common Sainfoin does not come to full growth till about the third year, and only gives one crop of hay per annum, but where the land is not Sainfoin "sick" it can be maintained for seven or more years. Where seed is to be taken, it is usual to wait till just before breaking the ley, as the process of seeding is exhaustive and the plants have not the same vigour afterwards.

Common Sainfoin is very suitable for grazing, especially by sheep, but while the seeds are young they should be stocked very lightly if at all. A slight treading by sheep may be of advantage on light puffy soils in giving the roots a firmer hold, but care must be taken that the crowns are uninjured. It is for this reason that cattle should never be put on Sainfoin in the first year. The year after sowing, the Sainfoin should be mown, after which the crop may be mown or grazed. This practice may be followed out in the succeeding years, as the crowns will then be strong and the roots big and vigorous. One advantage, apart from feeding, in taking a ley of Sainfoin is that the land is rested from Red Clover, and so clover-sickness is less likely to occur.

Hay.

Sainfoin hay is of very high feeding value, and is especially favoured by shepherds on the chalk down lands where they are often more anxious for an abundant supply of it than for a full root crop. It is a safe winter food and sheep thrive well on it. Horsemen and stockmen generally also highly appreciate it.

For haymaking the accepted time of cutting is when the plants are in full bloom. If earlier than this much weight is lost in drying; and if later the plants are weakened and new growth is slow to commence. After cutting with the scythe or mower it has been common in some districts to leave the swath until it was baked very dry by the sun, then to turn it and shortly afterwards stack it. In favourable circumstances this answers reasonably well, but the over-drying of one portion and the under-drying of another is not conducive to the making of the best quality of hay. There are the added disadvantages that should the swath require to be left on the ground some time on account of rain, new growths rise up through it, it becomes fusty from contact with the soil, and there is a considerable loss of leafage in handling. The more recent method of turning with the swath turner (and rakes) gets the hay into good condition and ready for carrying much sooner.

Probably the best quality with the smallest loss is obtained by making the hay in the cock. In this method the swath, when sufficiently dry, is broken with the hand-fork and placed in small heaps through which the air can pass freely. As these dry they are lifted in turn to form larger heaps and so on, the "flaky" condition of the hay being all the while disturbed as little as possible. In this way colour is well preserved, very little leaf is lost, and a high quality of product results.

The average yield of hay is between 20 and 30 cwt. per acre, and the Sainfoin therefore, though very valuable, is not so productive as Lucerne.

As has been mentioned, it is not customary to take seed from crops in their first vigour, but from those soon to be broken up, so that the loss of vitality is unimportant. If, however, it is determined to thresh from a comparatively young crop, it should be left untouched in the autumn following, when it will regain its strength.

The period of cutting has to be judged by the ripeness, which is indicated by the change in colour and the tendency of the seed to fall off.

The end of July is the usual time. The seeds at the bottom of the heads ripen first, and as they are the best, cutting is done when they are mature. Before deciding to cut it is advisable to test by hand the ease with which the seeds will thresh out. It is a saving of seed to reap on a dull day or in early morning while the dew is still on the plants. Great care must be exercised in handling the cut crop to avoid loss of seed. The swaths should be raked cautiously back out of the way of the horses. When sufficiently dry they are broken and piled, as previously explained, till ready for carting.

Carts or wagons should have seed-proof bottoms, or have a sheet stretched in them to catch falling seed. Moreover, only narrow loads should be carried, so that shaken seed may all be retained in the cart. Sheets should also be placed where unloading takes place, and round the base of the stack, and when the stack is completed the sides should be beaten with a rake to knock out all loose seed, which can then be collected. The high price of Sainfoin seed warrants these somewhat elaborate precautions.

A good yield of seed in the husk is from 25 to 30 bus. per acre.

LUCERNE

By H. M. M^cCREATH, B.Sc.(Agric.), N.D.A.(Hons.), N.D.D.

Description.

Lucerne (*Medicago sativa*, L.) is a leguminous plant belonging to the same family as beans, peas, and clover. It is characterized by a distinct tap-root which in suitable soil extends to a considerable depth, and which has few to many branch roots. Close to the surface of the ground the plant has a semi-woody base known as the crown, from which arise the erect stems. These commonly reach a height of 2 ft., and are not usually more than $\frac{1}{8}$ in. in diameter. The leaves are arranged alternately on the stem, and like clover are in threes. The plant has racemes of purplish flowers in loose bunches. The seed is produced in pods which are twisted spirally, each pod containing several small kidney-shaped seeds.

Origin of Names.—The origin of the name, Lucerne, is not quite clear. Some authors suppose that it came from Lucerne, one of the Swiss cantons, while others state that it is a corruption of the old Catalan name *userdas*, from which comes the common name *laouzerdo* used in the south of France.

In America it is almost universally known as *Alfalfa*, which is of Arabic origin and means " the best fodder ".

History indicates that Lucerne grew wild in Persia, and, being a favourite food for horses and cattle employed in early wars, it was carried to Greece with the moving armies. From there it was taken to Italy and Spain, and the Spaniards took it to South America and Mexico.

Acreage.

Lucerne is one of the most important forage plants in the southern counties of England, and the areas devoted to its growth have shown considerable increase during the last few years. The following table from the Ministry's Agricultural Statistics, 1922, shows the counties in which it is most widely grown:

County.	Acreage, 1922.	Acreage, 1921.
Bedfordshire	784	694
Berkshire	1,308	1,258
Bucks	1,203	1,069
Cambridge	1,525	1,554
Essex	11,891	11,145
Gloucestershire	498	397
Hampshire	693	487
Hertfordshire	2,434	2,175
Huntingdonshire	710	619
Kent	9,528	8,968
Lincolnshire	1,619	1,381
Norfolk	4,227	4,056
Northamptonshire	1,017	893
Oxfordshire	1,395	1,417
Somerset	611	441
Suffolk	5,547	5,272
Surrey	576	597
Sussex	820	723
Warwickshire	533	457
Wilts	434	351
Worcestershire	671	689
Yorkshire.	494	487

The total areas devoted to Lucerne in England and Wales were 50,630 and 47,174 acres for the years 1922 and 1921 respectively.

	Acreage, 1922.	Acreage, 1921.
England	50,466	46,965
Wales	164	209
Scotland	9	5

Varieties.

The leading commercial varieties of common Lucerne are: Chinese, Turkestan, Provence, and Grimm (a hardy variety grown in north-west Canada).

Soil and Climate.

The distribution of Lucerne indicates that it is not a crop which will succeed on all soils and in all climates. It prefers a soil containing a considerable percentage of lime, but good crops are grown on clays and loams where the climate is dry and warm. The tap-root descends to a great depth and the plant is thus enabled to resist severe droughts. On soils in need of drainage it will not succeed, and both surface and under-drainage are necessary if the Lucerne is to thrive. Deep loams with open porous subsoils are undoubtedly the best. The presence of hard pans is fatal to the growth of Lucerne.

Preparation of the Seed-bed.

It is absolutely essential before attempting to sow Lucerne to have the land clean and in good heart. The subsoil must be well drained, and if there is the slightest danger of a shortage of lime, this must be made up before sowing. There is always a great risk of weeds coming up on land laid down to Lucerne and smothering out the young plants before they are thoroughly established. Consequently it is advisable to sow after a fallow crop, such as roots or potatoes.

Seed and Method of Sowing.

The productivity of Lucerne depends to a great extent on its source, and experience in England has proved that seed produced in Provence, France, and at home is the best. Seed is also grown in Canada and China, but in this country it is very little used. It is essential that the seed be free from Dodder, and the following statistics obtained from the National Seed Testing Station are of interest in showing the quality with the impurities in seed put on the market:

Season.		Average Percentage Purity for Season.
1917–8		97·99
1918–9		97·70
1919–20		97·00
1920–1		97·92
1921–2		98·02
1922–3	English,	97·7 (43 samples)
	Provence,	98·5 (32 ,,)
	South American,	98·8 (7 ,,)
	South African,	98·3 (2 ,,)
	Italian,	96·7 (1 ,,)

Common Impurities.

English.	*Provencal.*	*S. American.*	*S. African.*	*Italian.*
Ribgrass. Red Clover. Melilot. Fat Hen.	Ribgrass. Red Clover. Melilot.	Melilot. Dock. Sedge. Ribgrass.	Dock. Fat Hen.	Wild Carrot. Ribgrass. Red Clover.

The seed may be sown with a nurse crop or alone. Opinions differ on the relative merits of these two methods. The nurse crop should be an open-growing one such as wheat or barley, and when this is the method adopted the seed should be sown in April or May. This will come into yield the following year. When sown alone in April on clean land it can be cut the following autumn.

Varying according to the condition of the land and the tilth, from 20 to 30 lb. of seed per acre are broadcasted, or if drilled from 15 to 25 lb. per acre are sufficient. Generally the drills are placed from 8 to 10 in. apart. The seed is broadcasted when the ground is perfectly clean and a good tilth has been obtained. The plants very soon cover over the ground and the growth of weeds is checked. Drilling, on the other hand, allows of the spaces between the rows being cleaned by horse-hoeing in after years, and for this reason it is more universally practised.

The difficulty of keeping the crop clean has led to the practice of sowing suitable grasses along with the Lucerne, but the grasses included must not be of a creeping habit of growth. Thus along with about 25 lb. Lucerne, 3 lb. Italian Ryegrass, 5 lb. Cocksfoot or Timothy, or 7 lb. Meadow Fescue can be included.

As a constituent of mixtures of grasses and clovers for grazing, 2 lb. Lucerne per acre may be included.

Manuring.

Lucerne requires chiefly phosphatic and potassic manures, varying according to the soil. Thus on a clay soil no potash will be necessary, and a dressing of 2 or 3 cwt. superphosphate per acre or its equivalent in basic slag will be sufficient. On light soils, however, the addition of $\frac{3}{4}$ cwt. sulphate or muriate of potash may prove beneficial. Farmyard manure should be thoroughly rotted to destroy weed seeds, and it is best applied to the previous fallow crop as a preparation for bringing the surface soil into good heart before sowing the Lucerne. It is not generally used afterwards.

Emphasis has already been laid on the importance of the lime content of the soil. If this is not naturally rich, 10 to 20 cwt. ground lime should be applied before sowing the seed, or 2 to 3 tons per acre may be used for a preparing crop.

Where Lucerne has not been previously grown, there is a risk that the proper nitrogen-collecting organism is not present or sufficiently active, so that the inoculation of the seed previous to sowing with an artificial culture of the Lucerne organisms has been advocated. These cultures are prepared in America, where it is claimed they have been used with considerable success. A surer way, however, of getting a good plant of Lucerne on fresh ground is by scattering over it soil from a successful Lucerne field. When as much as 2 cwt. per acre are necessary the application becomes expensive, and recently a small quantity of soil has been mixed with the seed and drilled at the same time with very successful results. Provided the soil does not become acid the bacteria multiply and further inoculation is unnecessary.

Cutting and Using the Crop.

Unless the plants reach the flowering stage during the autumn of their first year they should not be cut. Cutting at this stage checks root development and weakens the plants, so that they are unable to compete against weeds.

Once established, Lucerne will give at least 2 tons of hay per summer, and cutting should commence just before the flowers open, as if left longer the plants become more fibrous. Early cutting has also the effect of inducing a better aftermath and a more leafy growth. The making of Lucerne hay is a process which requires careful attention. It must not be allowed to lie long in the swath or the leaves will get scorched. When it is only partially dried it should be put up in cocks and allowed to cure gradually. In all the operations care must be exercised to prevent the leaves being broken off. These are the most nutritious parts of the whole plant, and careless handling of the crop results in their being broken off and lost. It is on this account that Lucerne hay should receive the minimum amount of handling.

When Lucerne is stacked before it is properly cured, fermentation takes place, resulting in a brown product which is not of as high feeding value as the green hay.

The yield of hay per acre in England varies from 2 to 3 tons.

When used as green fodder Lucerne is cut before it reaches the flowering stage. It will yield from 10 to 15 tons forage, which must be given sparingly to cattle and sheep at first as it is apt to cause " hoven ".

In the counties in the south of England where Lucerne is chiefly grown, grass from the middle of June onwards is rarely too plentiful for dairy cows, and the freshly cut Lucerne takes a very important place in their rations. For horses, it is fed green or as hay, and during hot summer weather green Lucerne is exceedingly valuable for them. In this condition it contains 24 per cent dry matter, 4½ per cent protein; so that where it can be successfully grown it keeps down the bill for purchased foods.

For pigs, Lucerne keeps the animals in good health during hot weather. It is specially good for sows that are suckling their youngsters, and is a great milk producer.

Lucerne should never be grazed the first year, and only lightly the second. A good " take " of the plant can very easily be ruined by overgrazing. Never at any time should the plants be grazed so closely that the crown is injured.

Once established, Lucerne will stand for a number of years, and it is only broken up when weeds get so bad that they threaten the progress of the crop.

CRIMSON CLOVER

By H. M. McCREATH, B.Sc.(Agric.), N.D.A.(Hons.), N.D.D.

Crimson Clover or Trifolium (*Trifolium incarnatum*, L.) is an annual erect-growing clover introduced into cultivation in England from the south of Europe. It has elongated flower-heads of rich crimson flowers and attains a height of from 1 to 2 ft. It is chiefly grown as a catch crop, being sown on stubble land after winter cereals, and it is essential that the corn should be harvested early to ensure that the Trifolium gets a satisfactory start.

Varieties.

There are three varieties of Trifolium—early, medium, late; and also a white-flowering variety. Sown all at the same time, they are ready for consumption at different periods in the following April and May, but the same result may be obtained by sowing any one of the varieties at short intervals of about a week to a fortnight.

Preparation of the Land.

The essentials for success are suitable soil, early sowing, a firm seed-bed, and heavy rolling. The crop is best grown on loamy soils, and it will not do on white, chalky land. It is, however, cultivated in chalk districts, but it is always sown on the lower gravelly areas and never on the higher fields.

When sown on stubble land, the cultivation generally consists in harrowing the stubble once or twice, broadcasting the seed, harrowing well again, and finally rolling firmly. Any elaborate cultivation which loosens the soil too much is not to be advocated.

After a vetch stubble, a silage crop, or soiling crop the same procedure is generally adopted, but the land ought to be fairly clean, otherwise the Trifolium, which takes some time to establish itself, might be smothered out by weeds. In order to avoid this a little White Mustard, 6 to 10 lb., along with the Crimson Clover will tend to check the weeds until the clover is established.

While many farmers still plough the stubble with a shallow furrow and clean it before sowing Trifolium, that increases the difficulty of obtaining a successful growth, and generally it will be found that the crop fails.

Seed.

Practically all the seed sown in England is grown at home. In the district between Dunmow and Bury most of the English Trifolium seed is produced. When put on the market its average purity is between 96 and 97 per cent, the impurities occurring in greatest frequency being Cranesbill, Campion, Trefoil, Red Clover, Madder, and Ribgrass. The seeds are almost perfectly oval, and are larger than any of the commoner clovers. New seed is a rich reddish yellow colour, but old samples are of a darker tint and duller.

Seeding.—The usual amount of seed sown per acre is from 20 to 24 lb., but many advocate a lower rate of seeding. If the crop succeeds well on a large area, it is so thick that it rots at the bottom before it can be consumed, and it is also difficult to make into hay. In an advanced stage the flowers of Crimson Clover are very hairy, and if fed to sheep cause the formation of hair-balls. At that stage the feeding of Crimson Clover to young lambs is highly dangerous. The hay made from over-ripe Trifolium is also the cause of " hair-balling " in horses.

Italian Ryegrass is very often mixed with Trifolium to provide a crop suitable for folding off with sheep or pigs. Sown in the autumn after the previous crop has been removed, 12 lb. Crimson Clover with 14 lb. Ryegrass is a mixture which has given very good results. Such a crop will be ready for consumption in the following May and June, and if carefully grazed then, it may be folded again about September before being broken up for wheat.

The practice of folding off Crimson Clover is to hurdle sheep on very small areas of the crop. This results in the Trifolium being so eaten and trodden on that it gives little second growth. When a second growth does follow such close folding, pigs are the only animals which will eat it down. A much better plan of eating the crop is not to keep the sheep too long on the one small area, and as these areas are finished it is wise to give the sheep as much scope as possible. By this means the land is not unduly trampled and soured.

Manuring.

Trifolium is sown at a time of the year when the farmer has very little or no supply of artificial manures on hand, and consequently it is generally not adequately manured or receives nothing at all. It is true that, being a leguminous crop, it will collect nitrogen from the atmosphere, but that power should not be overestimated and manuring wholly neglected. Rather should that characteristic be encouraged to exert its fullest effect.

Hence the necessity for liberal manuring, which not only results in an earlier and better yield, but maintains the benefit in the following crop.

It is very often assumed that nitrogenous manures of any description are not necessary for a leguminous crop. Here with Trifolium such manures have a very marked effect whereby the crop remains succulent for a much longer period—a highly desirable thing with any crop which has to be folded off.

3 cwt. superphosphate, 3 cwt. kainit, and ½ to ¾ cwt. sulphate of ammonia per acre is a suitable dressing for Crimson Clover. This should be applied at the time of sowing the seed. The crop may further be assisted by a light dressing of nitrate of soda or sulphate of ammonia in the early spring. Shepherds who have tended sheep on Trifolium do not favour this practice, holding that it is the cause of scour in ewes and lambs; but even although this belief may have some foundation in that the crop is made too succulent, that defect can be guarded against by judicious folding, as any very succulent green crop in the spring will, if given in excess, have the same effect. It is wise then to remember that corrective foods such as hay, crushed oats, or cotton-cake, can be given. The sheep, also, should always go on to a new portion of the crop when it is dry, and never until frost has lifted from it.

Utilization.

Being ready for folding early in the spring, Crimson Clover is specially valuable for the production of early fat lambs and for pushing on ram lambs intended for sale in the autumn. It is to a great extent due to the value of this crop that ram lambs of the Hampshire, Dorset Down, and South Devon breeds have attained such large sizes when the sales in the autumn are held.

Trifolium Hay.

Those who have ever made Trifolium into hay will understand the many difficulties which have to be faced. First, cutting is most difficult, which operation should be performed before the flowering period has reached an advanced stage, as the florets are then very hairy. The plants at this stage greatly deteriorate in value, becoming woody and tough, and cannot be given to young stock. Thus, when Crimson Clover is grown for seed, the straw after threshing is only fit for litter purposes.

Fine weather is absolutely essential for the making of Trifolium hay, as it very soon becomes mildewed when subjected to the slightest dampness. When made, sueh hay is best utilized along with other hay (meadow or clover) to avoid the risk of injuring stock, and by taking this precaution it need cause no harm to matured cattle.

VETCHES OR TARES

By A. W. OLDERSHAW, M.B.E., B.Sc.

Vetches, known in some districts as tares, are grown to a considerable extent in Britain as a forage crop and to a lesser extent for seed purposes. Statistics for the year 1922 show that the area under this crop in England and Wales was 136,179 ac., whilst in Scotland there were 354 ac. grown for seed in addition to a considerable portion of 9564 ac. under fodder crops (vetches, beans, peas, mashlum, &c.). The extension of the modern soiling system and the increasing use of ensilage tend to make the cultivation of vetches more widespread in that they are very often included in seeds mixtures for these purposes.

Largely of the nature of a catch crop, they are chiefly grown in the southern, eastern, and midland counties of England, where they are widely used for folding with sheep, but they also play an important part in providing green cut fodder for horses, cattle, and pigs, especially in times of drought, and in furnishing bulky nutritious material for the silo. Of late years they have found favour with enterprising farmers in the northern and western districts of England and in the Lowlands of Scotland for mixing with rape, oats, rye, or barley to provide forage crops for dairy cows.

Botanical Characters.

The vetch belongs to the natural order *Leguminosæ* and is technically named *Vicia sativa*. It is an annual plant with trailing, branched stems and compound, pinnately divided leaves. Each of the old leaves usually consists of six or seven pairs of leaflets carried laterally on a main midrib which terminates in two or three tendrils. The stipules, attached to the base of the leaf-petioles, are very small and have a characteristic dark spot in the centre of each.

Flowers, of the usual papilionaceous nature, are carried on short stalks in the axils of the leaves and are purplish in colour. The fruits are legumes containing from four to eight oval seeds.

Varieties.

There are two varieties in cultivation, viz. autumn and spring. These differ chiefly in respect of hardiness and habits of growth. The autumn or winter variety is much more hardy than the spring, which is not capable of withstanding the effects of severe frost, but the winter vetch is a slower grower and scarcely so bulky. In the midland, eastern, and southern districts of England, autumn-sown vetches usually give the best results, whereas in Scotland, the north of England, and Ireland the spring variety is probably on the whole more reliable.

Suitable Soils.

Vetches suit a wide variety of soils, doing well under both heavy and light conditions, but they always do best on a good loam in good heart. On less suitable soils, very good crops can be grown when well treated. Like other leguminous crops, soils with a good lime content are best, but, in this respect, they are less particular than such crops as sainfoin and clovers.

Place in Rotation.

There is no fixed place in any scheme of cropping for the taking of a crop of vetches. As a rule they follow a cereal crop, when they are sown in the autumn. Then, after folding in the spring, they are succeeded by late-sown turnips, cabbage, or maize. Spring-sown vetches usually follow a winter crop such as late-sown turnips and are followed by wheat. In some cases on ordinary arable land, and in practically all cases when grown in mixture with other crops for ensilage purposes on heavy soils, they take the place of the root crop. Their dense growth of foliage acts as a smother to weeds, thereby effectively cleaning the land.

Cultivations and Seeding.

When grown in the pure state the land is usually ploughed, harrowed, and the seed drilled in at the rate of 3 bus. per acre. If sown broadcast it is better to sow on the plough seam before harrowing. In this way the seed will be covered much better, and the rate of seeding should be increased to 4 bus. Winter vetches are occasionally drilled direct on to unploughed stubble in autumn, after a moderate fall of rain has made the surface friable. If sufficient mould can be found to cover them well this method may prove successful. It is usually only necessary to employ a light spring cultivator followed by a disc harrow. Some growers, who save the seed, say that they can obtain more seed in this way as the crop produces less haulm and more seed. The method has the disadvantage that rubbish on the stubbles is not turned in. Under favourable conditions vetches may also be used in this way to fill up a thin clover plant.

The time of sowing is widely extended through the existence of the two main varieties. Autumn vetches may be sown any time after the end of September, and spring ones from February to April, if grown for seed, whilst if intended for forage they may be sown as late as the end of June. When grown for forage purposes it is customary to sow small areas at short intervals so that a succession of green material will be available for folding. The autumn variety may be sown in the spring, but continued adoption of that practice leads to feebleness of the plant.

The rates of seeding already indicated apply to those cases where a pure crop is grown. This, however, is exceptional. Autumn vetches are usually sown along with other seeds, and spring vetches are very frequently treated in the same way. Even when grown for seed they are mixed with other crops. When grown alone they usually lie down flat on the ground, and, in addition to being difficult to cut, quite a considerable portion of the lower part of the stems become rotten, thereby making inferior food. It is therefore an advantage to have the vetches held up from the ground even when the crop is to be folded, and this is made possible by introducing erect-growing plants to which the tendrils of the vetch leaves may cling. For this purpose rye, oats, barley, wheat, beans, or rape all suit well.

When it is desired to fold the vetches early in the year on heavy or poor light soils, particularly if exposed, rye is the most adaptable cereal to mix with them. For later use winter oats, winter barley, or wheat suit quite well for sowing in the late autumn. Rye is also suitable for sowing with spring vetches for early use, but oats suit better if the utilization of the crop is to be postponed, for rye is apt to get too forward before the vetches are fit for use. If spring vetches be sown in mixture after the middle of April, it is advisable to refrain from using oats as they seldom succeed. In this case barley suits very well, as does also rye. When sowing is delayed till late in May or June, rape suits admirably. Indeed a rape-vetch mixture makes a very suitable crop for either folding or cutting. Beans may be used with success along with vetches if sown before the middle of April, but it is an advantage for the former to be ploughed in a week or two before sowing the latter. All of the above can be sown with success either separately or together with vetches.

Suitable mixtures containing vetches are as follows:

(*a*) 2 bus. vetches and 1 bus. of oats per acre;

(*b*) 1½ bus. vetches, ½ bus. beans, 1 bus. of oats;

(*c*) 2 bus. vetches, 1 bus. rye (for light land);

(*d*) 2½ bus. barley, 1½ bus. vetches;

(*e*) 2 bus. oats, 1 bus. barley, ½ bus. vetches, ½ bus. beans, ½ bus. peas;

(*f*) 100 lb. vetches, 5 lb. rape.

Mixtures (*a*), (*b*), and (*c*) are very suitable for sowing when the crop is intended for silage, and of late years have given good results in the east of England.

After seeding, the cultivations are completed by a light rolling in spring. It is not necessary to weed the crop owing to the smothering nature of the vetches. In fact somewhat foul land may very well be sown with vetches and subsequently cleaned by a bastard fallow after the green vetches have been removed.

Manuring.

Being a leguminous crop, vetches are independent of a supply of nitrogenous manures since the bacteria in the nodules of their roots utilize the nitrogen of the soil air and in turn supply the needs of the plant for nitrates. However, they must be supplied with suitable dressings of phosphate and potash. On heavy and peaty soils or those deficient in lime, basic slag 30 per cent, applied at the rate of 5 cwt. per acre, gives the best results in conjunction with a dressing of 1 cwt. of potash salts or 2 cwt. of kainit. On lighter types it is better to replace the basic slag by an equivalent amount of superphosphate and increase the kainit to 3 cwt. A nitrogenous manure should be added when vetches are sown in a mixture with cereals. In this case ¾ cwt. nitrate of soda or ½ cwt. sulphate of ammonia is ample.

Farmyard manure is occasionally supplied as a manurial dressing, but unless the crop is taking the place of roots it is better to reserve it for the root crop. Even in this case the dung should be supplemented by a dressing of 3 or 4 cwt. of basic slag, but the potassic and nitrogenous manures may be omitted.

Folding.

Autumn-sown vetches come in for folding from the end of May onwards according to the nature of the crops with which they are mixed, the date of sowing, and the season. Spring-sown vetches are later, those sown in March being ready by July, whilst the June breaks are not usually fit for use much before September or even October. When it is desired to make use of vetches for folding, care is to be taken to sow successive breaks at suitable dates, for the various sowings to give a continuous supply at their most nutritious stage. This is when the plants begin to flower. However, in the early part of the season the demands of the sheep for green food make their utilization necessary after mangels, kale, Crimson Clover, rye, &c., have been used up, and before they have reached the ideal state for consumption.

When sheep are folded on vetches, the concentrated food given should be such as to balance the ration properly. Consequently the additional feed should be one high in carbohydrates, e.g. maize meal or rice meal, since vetches are rich in proteid matter. In this respect vetches make very good food for ewes in milk and for lambs.

Harvesting.

Vetches are harvested with the object of using them as a soiling crop, converting them into hay or silage, or obtaining seed. With any of these ends in view it is extremely difficult to cut and handle a pure crop, and consequently one or other of the mixtures previously referred to is usually adopted.

When used for soiling purposes, vetches may be cut whenever required, but it is advisable that this be neither too early nor too late. In the former case there is an overabundance of succulence, and in the latter the stems are very woody and unpalatable. They are most useful for this purpose in the flowering stage. But by cutting earlier and leaving a stubble of several inches, the vetches and cereal crop with which they are mixed will renew their growth and may be cut for hay or silage later on.

Vetch hay is a good material if well harvested, but the difficulty is that, owing to the succulent nature of the crop, a lengthy spell of fine weather is necessary. Thus when intended for haymaking the proportion of vetches in the mixture should be reduced. The best time for cutting is when the seeds in the lower pods are just beginning to form. If cut too soon the vetches wilt very rapidly and very little is left of them. Further, care should be taken to cut them in the dry state, for if they are covered with dew excessive difficulty ensues later in drying them.

There is usually much trouble involved in cutting the crop, especially if there be a large proportion of vetches present, as the work needs to be carried out with the scythe. It is better to include a smaller amount of vetches in the mixture so that it may be cut with a mower. In this case it is sometimes necessary to have workers separating the cut crop from the uncut. Inconvenience is often experienced too with the vetches lying in front of the blades, but this can be largely overcome through the use of the grain-lifting appliances used for laid corn.

After cutting, the vetch mixture should be turned over several times with a swath turner to ensure thorough drying. Then it should be put in cocks which are well topped, so that rain will be easily cast off. In broken weather it is advisable to put it into Scots ricks of about 8 to 10 cwt. When dry it can be stacked with safety, but should there be doubt as to its liability to excessive heating, the addition of salt at the rate of 1 lb. to 1 ton hay is a useful practice.

In wet seasons the open nature of the crop permits rain to go straight through the cocks and the hay is much damaged. It is probably for this reason that the practice of making vetches into silage has extended. When to be used for this purpose it is best cut at the same stage as for hay, and after being allowed to dry slightly, the crop is carted direct to the steading, cut, and blown into the silo, where it is preserved for winter use (see " Ensilage ", Vol. IV).

Saving of the crop for seed purposes demands rather different treatment. When grown alone the harvesting is very difficult. The crop may be mown with the scythe or grass-mower, or it may be pulled with pea-hooks. In each case it is tied into sheaves and put up in stooks to dry, after which it is stacked for future threshing. When grown in a mixture the crop usually stands up sufficiently well to enable it to be cut with some form of machinery—either the side-delivery reaper or the binder. After drying in stooks in the field, it is stacked in the same way as ordinary cereal crops.

The separation of the vetch seed from the other constituents of the grain mixture is often a matter of difficulty. Vetches can be separated from beans with comparative ease, but if oats and vetches are grown together, it is usually necessary to utilize the seed-cleaning machinery of an up-to-date seedsman or co-operative society. The oats and vetches or rye and vetches are put through an adjustable rotary screen, when most of the cereal is taken out. Then the vetches are put through a special machine in which the grain gradually acquires velocity around a spiral. At the bottom of the spiral separation takes place, the heavier and better vetches going to the outside of the spiral whilst the oats and lighter vetches go to the centre.

When vetches are grown alone the produce of seed per acre varies on an average from 20 to 28 bus. per acre, the bushel weight being approximately 64 lb. The return from a mixed crop naturally varies with the proportion sown.

Utilization.

Vetches and mixtures containing vetches are used in various ways for feeding purposes. In the green state they are used for folding and soiling purposes. The former is widely practised on the Downs, where the vetches provide an excellent proteid-rich succulent food for sheep, whilst the trampling and manure of the sheep, aided by the nitrogenous residues of the vetch roots, maintain the land in a sufficiently high state of fertility for the growth of cereal crops. Pigs kept on the open-air system, too, are often folded with much success on mixtures of rape and vetches or kale and vetches. In common with other soiling crops, vetch mixtures are becoming increasingly important as food for dairy cows. Cows kept indoors all the time are fed up to 56 lb. per day along with concentrated food, whilst those on restricted areas of pasture greatly benefit by from 20 to 30 lb. per day.

Whether used for folding or soiling, the vetches should be consumed before the seeds are fully formed, as the stems become very hard and woody and therefore lose their digestibility.

In the preserved state vetch mixtures are used as hay or silage. Vetch hay is superior in feeding value to Ryegrass and clover or meadow hay. A mixture of oats and vetch hay contains on an average about 6 or 7 per cent digestible proteids and 35 per cent carbohydrates. It is excellent fodder for feeding in conjunction with cabbages, as it not only provides more protein than ordinary hay but also serves as a corrective to the laxative nature of the cabbages.

Silage mixtures containing vetches are widely used. The average composition of oat and vetch silage is as follows: 1¼ per cent digestible protein, ½ per cent oil, 13 per cent carbohydrates, 12 per cent starch value. It thus contains about five times as much protein as swedes, and possesses almost double the starch value. It makes an excellent food, in conjunction with suitable concentrates, for either fattening cattle or dairy cows, and can be fed up to 40 lb. per day.

SEED PRODUCTION AND SEED TESTING

By R. G. STAPLEDON, M.B.E., M.A.

Plant breeding, seed production, and seed testing are three closely related and essential aspects of crop production with which even the successful farmer is often not intimately acquainted, and are matters which in this country to a marked degree he has been content to leave in the hands of others. In a sense this is not to be wondered at; in some respects it is well that it should be so, in others it is much to be deplored. Seed production in many of its bearings is but a continuation of plant breeding, is a highly technical, not to say highly scientific, undertaking, and therefore from many points of view is best left in the hands of specialists, particularly in so far as the growing of stock seed is concerned. On the other hand, this leaving of the matter entirely with the specialists is responsible for a considerable amount of ignorance in respect of the essentials underlying successful seed production, and has been responsible for a great deal of negligence with reference to the production of seed of those crops—cereals, sainfoin, and the clovers, for instance—which many farmers harvest in the ordinary course of events, hardly realizing the tremendous responsibility they are taking on themselves, and gloriously oblivious to the immense significance of purity of strain and contamination with seed-borne diseases.

In regard to roots and vegetables which are and should be essentially the matter of the specialist, the lack of interest displayed by the average farmer in the profoundly interesting technicalities of this very real aspect of farming has been partly responsible for the undue localization of the seed industry as generally understood. There can be no doubt that the enterprising farmer willing to master the practical operations of seed production could often, with great advantage to himself and to the country, successfully grow remunerative seed crops outside the confines of, say, Essex, Lincolnshire, or Bedfordshire. Attempts made in this direction by persons unacquainted with the numerous precautions to be taken can, however, only lead to disappointment, and will tend to the production of unreliable supplies of seed and may be responsible for untold harm. It is desirable from all points of view that the production of seed of the readily cross-fertilizing crops should not be confined to limited areas, for in proportion as really sterling varieties become greater and greater in number, so it is necessary to isolate these one from another with ever increasing care, which becomes almost impossible if the only areas deemed to be available become over congested.

SEED PRODUCTION

Seed of the various crops is not only produced in a great variety of ways, but also gets into the hands of the farmer through innumerable channels. Before discussing the details of seed culture, it will be desirable briefly to indicate in a broad way the methods underlying the production of seed of the chief crops. Practically all the seed sown in this country owes its origin to one of the following general methods of procedure.

The Growing of a Crop by Special Methods for the Explicit Purpose of Seed Production.

This is the method always applied to the production of stock seed, and usually also in respect of seed for distribution in the case of proprietary and named varieties. Some crops so grown will have practically no market value should the seed crop as such be a failure. This is pre-eminently so with roots like mangels, swedes, and turnips, vegetables like onions, parsnips, lettuce, spinach, and numerous others; thus the utmost skill must of necessity be exercised in the production of such seed, and the demand needs to be cleverly anticipated. It is largely on this account that the growing of root and vegetable seeds has become a specialized industry.

Crops like peas and beans, field and vegetable alike, will have a certain value even if satisfactory seed samples are not forthcoming, while the haulms will often also have a value of their own. In the case of pedigree varieties carefully grown for seed, however, the prices obtainable for the crop in the ordinary markets afford but a poor compensation for the trouble and expense involved, so that the growing of named varieties of peas and beans is, equally with roots and the general run of vegetables, very largely the concern of the professional seed grower only. Thus it follows that all these commodities are essentially proprietary articles sold under endless descriptions and bearing a bewildering number of attractive names.

The cereals, relative to the expense incurred in growing specially for seed, will often demand a better comparative price, having regard to grain and straw, in the ordinary market than roots and vegetables; thus wheat, oat, and barley seed production, even in the case of proprietary varieties distributed by the original producer, hardly involves the same risk.

It is usual in the case of most of the better known proprietary varieties for the large seed houses to grow their own stock seed. The stock seed is "grown on" under contract by farmers specializing in this business, usually under the general supervision of the experts of firms responsible for the distribution of the seed. The final cleaning and dressing is also performed by the distributors, this being a highly specialized aspect of the seedsman's business demanding expensive machinery, well trained technical supervision, and skilled labour.

In this country it can hardly, with truth, be said that the grasses and clovers are grown to any extent specially for seed, and if so grown the same care and attention is not given to the undertaking as to roots, vegetables, and named varieties of cereals. A possible exception is the production, to a very limited extent, of "once grown" Wild White Clover seed. In Denmark and Sweden, however, it is now a common practice to grow pedigree strains of Ryegrasses, Cocksfoot, Timothy, Meadow Fescue, and to a smaller extent Red Clover, by special methods with the sole aim of seed production. In this case the "straw" has a value as feed, and if by weather conditions the seed crop is foredoomed to failure hay can always be taken instead.

The Growing of a Crop by Ordinary Methods with Seed Production the Chief or an Alternative Aim in View.

This method may often be adopted by some of the larger market gardening farmers who produce a considerable proportion of their own vegetable seeds.

Certain portions of crops like parsnips, onions, lettuce, spinach, &c., may, under suitable conditions, be set aside for the necessary modifications in cultural methods demanded by seed production. Field peas, beans, and vetches are all crops which are largely taken for seed or at least sold for seed as an afterthought, so to speak—many farmers producing their own seed in this way and disposing of their surplus to local merchants and to their neighbours.

The great bulk of the oats, wheat, and barley sown by farmers is of course saved from their own routine crops, and enormous quantities of seed grain annually pass from farmer to farmer without coming into the hands of the merchant. In districts famous for the production of seed grain, apart from seed being grown under contract, in ordinary seasons the farmer will look to dispose of a considerable proportion of his crop to merchants at seed prices.

It is perhaps largely owing to the vagaries of our climate that such grasses and clovers and other herbage plants as are harvested for seed in this country are taken on the haphazard principle of appropriating a ley to seed production only if and when the weather conditions and the markets appear likely to justify such a procedure. This method obviously has much to recommend it to individuals, but has been largely responsible for the slow progress that has been made relative to the production and distribution of improved strains of herbage plants not only in this but in numerous other countries. Thus in the United States of America it has been found exceedingly difficult to maintain stocks of improved strains of Timothy because, when hay is fetching high prices, farmers prefer to market the crop in this more easily handled form rather than as seed. This method also carries with it numerous other drawbacks which will be discussed when dealing in detail with grass and clover seed production.

The Harvesting of Seed in the case of Herbage Plants from Grasslands not originally Designated for Seed Production, or from Waste Places.

In England Wild White Clover is harvested in large quantities off permanent grassland, while in Ireland, Crested Dog's Tail is taken in a similar manner. Cocksfoot in New Zealand is largely harvested from what are now permanent grazing lands, and in the United States of America the Kentucky Blue Grass (*Poa pratensis*) is taken from what are tantamount to permanent pastures and from temporary leys. Sweet Vernal and other grasses are harvested on the Continent in considerable quantities from poor grasslands and waste places, while Meadow Foxtail is largely harvested in Finland off meadow land.

Obtaining Seed by Cleaning it from that of other Species.

The seed of quite a number of herbage plants is obtained by screening it from the bulk of more valuable species. Thus Ribgrass is a by-product of Red Clover, Yellow Suckling Clover a by-product of the Ryegrasses and of Wild White Clover; Wild Red Clover and Bird's Foot Trefoil are also by-products of Wild White Clover.

Precautions to be taken Relative to the Production of High-grade Seed.

The aim of the seed grower should be first and foremost to produce stocks which are absolutely pure as to variety or strain, and every possible precaution should be taken to ensure this; it is hardly less important to prevent the seed grown becoming contaminated with seed-borne diseases which may largely ruin subsequent crops.

Every endeavour should be made to grow clean crops that can be harvested free from weed seeds. For the rest, attention must be given to producing and harvesting heavy yields of seed capable of good germination and robust growth. This entails doing everything possible to eliminate the ravages of diseases and pests adversely affecting seed production, and the employment of cultural methods and applications of manurial dressings designed to favour seed development to the maximum. It will be necessary to deal in some little detail with the numerous factors to be taken into account.

Purity of Variety and Strain.

A great number of precautions have to be taken in this connection, and they may be conveniently considered under the following headings.

Purity of Stock Sown.—In the case of named varieties grown under contract or by the producer, great care will have been taken that the stock seed to be grown on will be of a purity beyond reproach. In the case of cereals grown with seed purposes only partly in view, this is a precaution frequently sadly neglected. Thus, for example, the farmer accustomed to sell well-known varieties of oats like Record or Victory, or of wheat like Yeoman, should frequently obtain new stock seed from the producers or from sources which are absolutely reliable. Or he should produce his own stock seed every year on small areas which should be kept under close observation, all departures from type being "rogued" out during the growing season.

It is, however, in respect of the grasses and clovers and other herbage plants that so little attention is prone to be given to the question of stock seed, and it is in this connection that current methods need to be so rigorously overhauled.

It is well known that certain districts are more or less famous for particular strains of herbage plants. Long-lived strains of Sainfoin are grown in Hampshire, Gloucestershire, and in parts of Glamorganshire, for example, while local long-persisting strains of Red Clover emanate from Montgomeryshire and over the Shropshire border and from the Wadebridge district of Cornwall. Excellent strains of various types of Red Clover are produced in the Vale of Clwyd, in Dorsetshire, and in numerous of the eastern counties. It is, however, an exceedingly difficult matter to obtain seed of any particular strain in anything approaching a pure state—and this is due not only to difficulties inherent in clover seed production to be discussed hereafter, but even to a greater extent to the fact that growers are not themselves able to recognize either the essential botanical characteristics or economic value of the strains for which they or their districts are or should be famous.

It is a common practice even for a man who has had a good strain on his farm for a generation or more to mix with his stock seed after lean years either seed obtained in the district, or what is far more disastrous to purity of strain, seed purchased from a merchant, which may have been grown not only in another district, but in a foreign country; while men starting clover and grass seed production in a particular district are not likely to have taken precautions to have acquired a strain of outstanding merit, since more likely than not the leys would not have been sown down with seed production chiefly in view.

"Volunteer" Plants of other Varieties of the same Crop.—The extent to which seeds are capable of lying dormant in the soil for shorter or longer periods has been beautifully illustrated by the work of Dr. Brenchley on buried weed seeds. Seeds of crops are, of course, to some extent capable of producing plants from one year to another, and even after the most careful cultivation are liable to produce volunteers by this means. This may become a very real danger when different varieties of the same crop are grown two or more years in succession in the same field. This is a source of contamination that is sometimes operative when, for instance, oats follow oats in the rotation, and is likely frequently to occur on congested seed farms unless a very well planned rotation is practised. It is thus a generally accepted fact that varieties of *Brassica* should never follow each other on the same piece of ground. This is a precaution not usually taken with mangels, but Nilsson has recently alluded to a case which seems to prove that beet seed under certain circumstances is able to retain its power of germination in the soil for a period of seven years.[1]

Contamination of the Seed after Harvest with that of other Varieties.—All thrashing operations entail a certain risk of mixing the seed of different varieties or strains, and it is impossible to take too much trouble with reference to cleaning machinery after dealing with each lot of seed. The greatest risk of serious mixing occurs with travelling thrashers going from one farm to another for the purpose of dealing with cereals and Red Clover. It should be a regular practice to discard the first seed coming through the machine.

The Dangers of Cross-fertilization.—In nature, plants are either wholly self-pollinated, are capable of producing seed to some extent if self-pollinated but of producing far more seed if cross-pollinated, or are to all intents and purposes self-sterile and will only produce seed if cross-pollinated. It invariably happens in the case of plants which must necessarily be cross-pollinated, or that are easily capable of cross-pollination, that all the varieties of one species (= one crop or closely related crops) will readily cross-pollinate amongst themselves and frequently also with weeds representing the same species.

When the profusion with which pollen is produced in nature is realized, and the distances to which it may be carried by the wind or by insects is fully appreciated, it will be apparent that in the case of all crops bearing

[1] See note by N. Hjalmar Nilsson in *Sveriges Utsädesförenings Tidskrift*, Vol. 32, p. 250, 1922.

"open" flowers this is at once the greatest and most difficult danger *to be guarded against in the production of the seed of definite varieties or* strains.

The ill effect of cross-pollination will not be apparent at harvest-time or when the seed is cleaned and dressed, but will only show itself when the seed has been sown and the plants commence to develop, that is to say, after the seed has left the growers' and the merchants' hands and has reached the farmer, who will have purchased it as representing a definite variety or strain.

There is little danger of cross-pollination in the case of wheat, oats, barley, peas, and beans, although in very dry seasons the various varieties of wheat may intercross to a limited extent as may those of oats, an extent to which the plant breeder must guard against but which for all practical purposes the seed producer can safely ignore, as he does in the accepted practice with peas and beans. Lettuce and tomato are highly self-fertile. Some growers take no particular precaution to separate tomato varieties although these may be crossing to an extent of about 5 per cent, and it appears to be often taken for granted that it is safe to grow lettuce varieties in close proximity as the amount of crossing will apparently be but slight. The cereals rye and maize and nearly all the ordinary herbage grasses, with the apparent exception of Western Ryegrass (= Slender Wheat Grass), fairly extensively used as a forage grass in Canada, are freely cross-pollinated and will only produce small amounts of seed if selfed. The same is true of many herbage clovers and their allies, Red Clover being amongst those plants which will produce but a negligible amount of seed, if any at all, when selfed. Thus the production on a large scale of pedigree varieties or strains of these plants necessitates careful isolation from other strains, and in many instances from hedgerow plants also.

It is, however, in respect of roots and vegetables like mangels, the beets, carrots, swedes, turnips, cabbage, cauliflower, all the other *Brassica*, onions, radishes, spinach, and numerous others, of which there are such endless trade varieties on the market and which also, although in many cases self-fertile, cross-pollinate very freely, that the greatest precautions have to be taken to prevent contamination by this subtle means. The plant breeder and he who is concerned with the early building up of stocks of new varieties regulates pollination and protects his plants from stray pollen by resort to coverings of suitable fabric. This is a procedure which cannot, however, be applied to the considerable areas necessary for the production of seed for distribution.

Darwin has given interesting details of the distances to which pollen can be carried, and it is generally considered by seed growers that it is desirable in many instances to separate crops of different varieties of the same species like the Brassica by at least half a mile, and it is by no means certain that even this is a sufficient distance. The dangers from wind-borne pollen can to some extent be reduced by sowing on the lee side of some natural shelter to the prevailing wind, but there are numerous cases on record which show that this only affords partial or additional protection. In general, however, it is not necessary to distance as generously in hilly and wooded districts as in flat open localities. Red Clover and other crops worked by bees can be partially protected by sowing considerable blocks for seed production, since bees tend to confine themselves to a congenial hunting ground. Considerable protection can often be afforded to both wind and insect pollinated crops when varieties are grown which come into flower at decidedly different periods, for these differences can usually be accentuated by time of sowing or planting, and in the case of herbage plants by grazing.

The seed grower is unfortunately affected not only by his own practices but by those of his neighbours. Thus in seed-farming districts the crops to be grown with safety by any individual should be decided upon in co-operation with all the persons engaged in the business within the danger zone. There will still remain the risk of stray pollen reaching the pedigree cultures from, say, patches of cabbage, kale, or other Brassica having been allowed to run to flower in some private or cottage garden, for the pollen so produced may be sufficient to contaminate a considerable area devoted to the production of a special variety of a Brassica; while wild carrot, often a very abundant weed on clover leys and on grassland generally, may pollinate and ruin an area devoted to cultivated varieties. The wild parsnip and wild radish may also act in a similar manner on the cultivated varieties allied to each.

The damage done in this way is the more serious because it may not have been suspected, and the seed may have been distributed under the impression that every risk had been successfully guarded against.

Rogueing the Crop.—Many varieties of crops are similar to some of our breeds of animals in that they are not inherently pure to type, that is to say, will give rise to a certain proportion of individuals which will possess characteristics rendering them different from and in most cases less valuable than the variety they are supposed to represent. It is with a view to eliminating plants which develop in this manner, and also to further safeguard purity of stock from plants produced from seeds in the soil or which may have been introduced at the time of sowing, that it is so essential for seed crops to be carefully rogued before harvest-time and at frequent intervals throughout the growing season.

This is an operation demanding a great deal of skill and a thorough knowledge of the peculiarities of the varieties of the several crops, and a quick eye for the detection of small differences.

In the case of certain crops like peas and beans, the process of rogueing can be followed up on the harvested seed. Skilled "pickers" are employed who will not only readily detect and discard damaged seed, but also seed showing obvious departures from the varietal characteristics in respect of colour, size, and shape, or other features readily appreciated by the trained eye.

The Influence of Disease.—Plant diseases must be considered from two points of view in relation to seed production, firstly in so far as disease may be carried in or on the seed and show itself in the subsequent crop, and secondly in so far as disease tends to decrease seed yield or to render the seed produced inferior in respect of germination and vigour.

Seed-borne Diseases.—This is a question that is receiving increased attention, and is very important in respect of seed passing from one district to another or from country to country. The dangers of infecting crops by this means can be obviated by proper disinfection of the seed in the case of many, but by no means all, of the diseases which are carried by seed. It should always be considered a most important function of the roguer to destroy plants which are affected with a disease known to be seed borne, whilst crops which are too badly attacked to permit of rogueing should be discarded—regardless of the excellence or otherwise of the seed yield as such.

It may serve a useful purpose to allude briefly to the more serious of the seed-borne diseases.

The Cereals.—In Britain, bunt of wheat and the smuts of wheat, oats, and barley are serious seed-borne diseases. Of these, the loose smuts of wheat and barley (*Ustilgo tritici* and *U. nuda*) are the most serious to the seed producer because not easily destroyed by simple treatments which may be applied to the harvested grain. Heads bearing these smuts should always come under the hand of the roguer. The scab of wheat (*Giberella saubinetii*) is also common in Britain, while the same fungus and other closely related species are amongst the most serious diseases of this sort affecting wheat and maize in the United States. Ergot is serious, particularly on rye on the Continent; it sometimes occurs in wheat in Britain, but can be removed by screening.

Peas and Beans.—These crops are liable to a number of bacterial diseases which are seed-borne. "Streak" of Sweet Peas and "stripe" of culinary peas are both common in England. "Bacterial leaf blotch" is plentiful on Dwarf Beans in England, while the "chocolate spot" of Broad and Field Beans is very common on both crops.

Anthracnose occurs fairly commonly on Dwarf Beans, but is rare on Runner Beans in this country. In the case of small or special lots seed should be saved from healthy pods only. In the case of large areas all discoloured seed should be discarded when "picking" the harvested seed.

Clovers.—There is some ground for thinking that anthracnose (*Glœosporium caulivorum*) of Red Clover may be a seed-borne disease.

Grasses.—Ergot is common on a number of grasses, and occurs not infrequently in seed, but is always screened out of high-grade samples.

The smut of Tall Oat Grass is sometimes very plentiful and should be regarded as a somewhat serious seed-borne disease.

Of insects, the grubs of which may be carried in the seed, the foxtail midge or gnat (*Oligotrophus Alopecurii*) is perhaps the most serious. Tests made at the Danish Seed Testing Station on 978 samples of Meadow Foxtail showed that hardly 5 per cent of the samples were free from the larvæ of this insect, and in some years up to 20 per cent of the seed is destroyed.[1] It is largely on account of the ravages of this pest that Meadow Foxtail usually has a very low germination. It is recommended that yearling seed of this grass be sown for seed production, for the insect will have developed and left the seed during the first year.

Onion.—Smut (*Urocystis cepulæ*) is a particularly serious seed-borne disease of this crop which is abundant in the United States, and in Britain has been recorded near Newcastle and Bangor and has possibly been introduced on imported seed.

Flax.—" Seedling blight " (*Colletotrichum linicolum*), a serious disease in Ireland, has been definitely proved to be carried in the seed.

Cabbage.—In America it is stated that " yellows " and other diseases may be carried on the seed, and seed disinfection is recommended.[2]

Celery.—" Leaf spot " (*Septoria apii*), a somewhat serious disease of this crop in Britain, has been proved to be a seed-borne disease.

Diseases Detrimental to Seed Production.—Any disease adversely affecting the healthy growth of the crop will, of course, react on seed production. Apart from insects attacking the actual seeds, there are certain general diseases in addition to those primarily discussed which are undoubtedly of particular significance in relation to seed production. Mention may be made of the following.

Cereals.—The rusts in epidemic violence cause greatly reduced gain yields. Black rust is capable of practically ruining cereal crops; fortunately, however, this is a disease of very local distribution in Britain. Yellow rust of wheat and crown rust on oats are both serious in Britain, and in certain seasons are capable of very considerable local damage to grain harvests. " Whiteheads " (*Ophiobolus graminis*) is common on wheat and barley in Britain, and is responsible for reduced grain yields.

Grasses.—The rusts, particularly the stem rust of Timothy (*Puccinia phlei-pratensis*) and yellow rust (*Puccinia glumarum*) of Cocksfoot, are common in parts of Britain, and in the case of bad attacks damage the plants sufficiently greatly to reduce seed yield.

The seeds of grasses are liable to attack by a number of insects in

[1] Rostrup Sofie; see Review in *Sveriges Utsädesförenings Tidskrift*, p. 96, 1920.
[2] See J. B. S. Norton and C. E. Leathers, " Conditions Detrimental to Seed Production," *Bull.* 216, Maryland State College of Agriculture.

addition to those, the grubs of which may be retained in the seed until sowing time.

Cocksfoot in Wales, for example, is liable to severe attack by the grubs of *Glyphipteryx fischeriella*, which greatly reduces the yield of viable seed.

Beet and Mangels.—The rust of beet and mangels is often abundant in seed-growing districts, largely because it is able to over-winter on such plants as may be left standing through the winter for seed production.

Onion.—The "Botrytis rot" is a serious disease of onions in store, and in consequence may have a very appreciable indirect influence on seed production.

Damage by Birds.—Birds have to be guarded against both at sowing- and harvest-time. Cereals should always be drilled to reduce the danger from birds, while peas should be well covered to depths of about 1¾ to 2 in. At harvest-time it is generally necessary to patrol seed crops in order to eliminate damage by birds.

Weeds in Relation to Seed Production.—Weeds as such are detrimental to seed production, since they will tend to hamper harvesting operations, to delay ripening, and hinder drying. Amongst roots and vegetables weeds like Bindweed, Black Bird Weed, and Cleavers are always to be avoided; yet the seeds of the latter two species are frequent impurities in samples of seeds, showing that sufficient care is not always taken to keep seed ground clean.

It is not sufficiently realized, however, that the best means of producing clean seed is to grow clean seed on lands free from weeds.

Seed cleaning, no matter how cleverly conducted, entails a very considerable waste of good seed, and this applies in particular to the grasses and clovers, and in no small degree to the cereals also. The necessity for elaborate cleaning operations and the practice of highly dressing samples raises the question of the relative values for crop production of large and small seed respectively—the modern tendency is all in the direction of grading up to a large seed standard. This has been particularly marked in the case of grasses and clovers,[1] and of named varieties of cereals.

It is, however, very far from proved that, in all cases, it is the largest seeds that produce the best results or the heaviest yields. The practical issues raised by the "large and small" seed problem are exceedingly involved, for purity of strain or variety may well be at stake, and under field conditions a slight adjustment of the seed rate will often be sufficient to cause either the large seed to out-yield the small or the small to out-yield the large. In the case of more or less spaced sowing, such as is adopted with beans or peas in a garden, one may usually expect the better yields from the larger seed. In the case of cereals, whereas trials conducted with large against small seed fanned from the same bulk have

[1] See Table I, facing p. 272.

generally, but by no means always, been in favour of the large, it has yet to be proved that the large seed as such will out-yield the unfanned and undressed grain either appreciably or consistently. When it is remembered that a great number of popular and valuable cereal varieties are in no sense of the word pure, and consist of an aggregate of strains having a wide range of adaptability to varied conditions, and taking into consideration the fact that it is, to say the least of it, highly probable that some of these strains will be relatively large seeded and others relatively small seeded, it will be apparent that the rejection of the small grain from a sample constitutes blind selection that is just as likely to operate against increased crop production as in favour of it.

This process applied to grasses and clovers is altogether more preposterous than in the case of cereals, for even the older varieties of oats, like Potato, represent an aggregate of but a more or less limited number of strains.

With grasses and clovers the average commercial seed passing through cleaning and dressing machinery represents an almost unlimited medley of strains, from which those strains with a marked tendency towards small seeds tend to be ruthlessly rejected by the blind selection of the machinery. It is only necessary to add that the seed of Wild White Clover, for instance, runs considerably smaller than that of White Dutch, and that the seed of commercial Cocksfoot tends to be considerably larger than the indigenous. It is therefore quite possible that modern methods of seed cleaning, as applied to grasses and clovers—an outcome of the complete lack of attention given to growing these for seed production free from weeds—has not been without its influence on the gradual selection of strains of grasses and clovers chiefly remarkable for their lack of permanency.

It is, in any event, obvious, from the above brief review and considering the seed question as a whole, that the case for the large seed is based on very slender evidence, and that the growing of seed crops of grasses and clovers without proper attention to elimination of weeds may have been responsible for greater harm than merely a large annual waste of seed.

Precautions to be taken with Reference to Cultivation, Harvesting, and Storage.—It has been shown that in the case of many crops the greatest care has to be exercised to prevent cross-pollination as between variety and variety. With all crops it is almost equally important, as far as is possible, to secure favourable conditions for the pollination of the individual plants of a particular variety amongst themselves, or by selfing, as the case may be, and for the setting and ripening of seed.

Situations liable to continual damp mists are unfavourable for seed production, thus stagnant hollows should always be avoided. In the case of insect-pollinated crops, endeavour should be made to bring the plants into flower at the most favourable period for the chief insects visiting them. This requires local knowledge and close observation. The time of flowering of a clover crop can, for instance, be regulated by previous cutting or grazing, and can generally be made to fit fairly closely with the period when bees are most active or most plentiful.

Plants to produce maximum seed crops must make normal healthy growth and not become unduly rank or leafy. A well-drained soil is a necessity and water-logged conditions must be avoided. This is particularly important in the case of more or less tender biennial crops left *in situ* during the winter after sowing. A good loam is a suitable soil for most crops; certain crops, such as Red Clover and mangels will, however, produce heavy seed yields on comparatively heavy clays. Cold and late districts are unsuited to seed production, largely because harvest will be delayed, and it will be difficult to get the seed garnered in good condition; for a similar reason regions of high rainfall, although in certain cases compatible with the production of heavy yields, will make for very precarious harvest conditions. It is largely the combination of suitable soil and climatic conditions that have made the Kelvedon district of Essex the centre of the seed-growing industry of this country.

Lodging and "shedding" are two factors to be guarded against. Lodging is favoured by excessive soil fertility and by too dense crops, and is most to be feared in the case of cereals and grasses, which should therefore not be sown too thickly. Very exposed situations favour shedding; sheltered fields should therefore be selected particularly in the case of grasses like Tall Oat Grass and Meadow Foxtail, which shed their seed very easily. Nearly all the Brassica, all the grasses, Wild White Clover, and other crops require very careful handling at harvesting, and the carts should be lined with sheeting.

The cultural operations previous to sowing or planting should aim at a complete elimination of weeds, because in the case of certain species (e.g. grasses and clovers) the crops may occupy the ground for two or more years, and in the case of most biennials the crop will have to stand on the ground over the winter; while in the case of such crops as are grown in rows, even if not occupying the ground for long, it will be impossible to continue hoeing operations after the plants have attained a certain size. It is therefore necessary to commence horse hoeing as soon as the rows are well defined, and to keep the hoe active until there is danger of injury to the plants. Fairly deep horse hoeing will retain the soil in a friable condition, and will thus hasten the growth of the plants and tend in the direction of an earlier harvest. This is a very important consideration with respect to late ripening varieties.

Seed production is favoured by adequate manuring, and it is erroneous to suppose that nitrogenous manures should not be used in fair amount. Indeed in Essex nitrogenous manures are freely employed, and large amounts of stable manure used to be brought from London. It is not, however, advisable to apply farmyard manure directly to a seed crop, and the risk of introducing weeds or even volunteer seeds should always be borne in mind when employing dung. Direct dressings should only be made with artificials; mixtures of ammonium sulphate (in small amount) and superphosphate are frequently employed to advantage. Potash has usually a beneficial effect on seed production and makes for healthy growth, and now that fertilizers supplying this essential plant food are again readily procurable, application is to be recommended, particularly on soils deficient in this substance.

If lime is lacking in the soil this defect should be made good, and on soils which tend to be heavy the ameliorating influence on texture of adequate dressings of burnt lime is of particular significance in relation to seed production.

It is of the utmost importance that seed should be properly dried before it is stored, and this equally whether the unthrashed crop or the thrashed seed is in question.

In favourable districts where the crops can always be harvested perfectly dry, harvesting and thrashing are practically continuous operations, and as a general rule it may be said that the sooner fully ripened seed is thrashed the better. When it is impossible to harvest seed in a really dry and ripe condition, which is so often the case with cereals and Red Clover in the north and west of England, the crops have, of course, to be stacked; while in the case of roots and vegetables and some of the finer grasses they have to be dried and matured under cover previous to thrashing, and they are never stacked in the ordinary sense of the word.

It often happens that seed has to be thrashed before it is really mature or dry; such is frequently the case with oats and wheat for autumn sowing. When cereals are brought straight from the field to the thrashing-machine the grain should always be spread thinly on a barn floor and frequently turned. If put in sacks or in large heaps it will be liable to heat in an incredibly short time, and may be completely ruined. Similar precautions should always be taken in the case of Red Clover and cereals after poor harvest conditions, even when the crop may have stood in stack for several months. The artificial drying of seed previous to storage is a question full of difficulty, and one to which the large seed houses pay the closest possible attention. Seed in a poor condition will not withstand as rapid drying as that in a good condition, thus much skill is needed in deciding upon the treatment that is applicable to each lot of seed as such.

There can be no doubt that very considerable amounts of clover seed and seed grain are ruined in years of poor harvest, because the farmer has not the necessary facilities or does not take the necessary precautions as to drying, either before or after thrashing, while in other cases grain is ruined by being subjected to too high a temperature in the kiln.

The method of drying hay recently successfully employed by stacking the crop over an air channel fed by a belt-driven fan[1] would seem to be one full of promise as applied to crops harvested for seed, particularly in the case of clover and grain grown in wet districts.

Seed that has been well cured will keep much longer than that subjected to unfavourable conditions. Indeed the seed of many crops when properly handled and stored will often germinate better when a year old than in the spring immediately after harvest; this is generally the case with well-cured Kentucky Blue Grass (*Poa pratensis*), and not infrequently with mangel seed.

Having regard to the uncertainty of our climate, with consequent great annual variations in seed yield (the Red Clover seed crop is often a complete failure in many districts), and to the undoubted superiority of home-grown seed in the case of a number of crops, it is very important that any surplus from one year should be carried over with safety to the next. This is a matter to which the farmer who has inherited or procured a meritorious and old-established strain of Red Clover or of Sainfoin should give very particular attention.

Brief Particulars with Reference to the Production of Seed of the Chief Crops.

Seed production in recent years to a marked degree has become almost a world-wide industry. We in this country can probably no longer claim a monopoly in respect of a single crop, while countries which but fifteen years ago were importing a large proportion of their seed supplies are now becoming more and more self-supporting and are even large exporters of the seed of certain crops of first-rate importance. Thus, for example, Denmark has to-day to be placed in the forefront of seed-producing countries, and as well as supplying her own needs takes a giant's share in contributing to the world's calls on Cocksfoot, to the production of which she devotes over 16,000 acres. She practically meets the whole of the demand for the Rough-stalked Meadow Grass, and is doing a considerable export trade in certain roots and vegetables. Great strides have been made in Denmark with reference to producing mangels, swedes, and turnips, giving high dry-weight yields per acre, whilst cauliflower seed from this source has achieved a considerable reputation. The climate of California has proved very suitable to root and vegetable seed production, and this state of America, aided in the first instance by relatively cheap Chinese labour, has rapidly attained to very considerable importance in this connection. Recently we read of successful enterprise in turnip, swede, and rape seed production in New Zealand, while the United States imports considerable quantities of rape seed from Japan.

It will be of interest, therefore, when discussing the methods applicable

[1] See recent article in *Modern Farming*.

to the several crops to deal also in the case of the more important with the chief sources from which this country, at all events, obtains the bulk of her supplies.

It is not intended in this section to give exhaustive particulars as to the methods adopted by the large seed growers, but rather to indicate the principles underlying successful seed production, which will serve to emphasize the difficulties connected with the undertaking and to show certain directions in which the grower for the ordinary market, the amateur, or the man in charge of a private garden, given sufficient care to details, may move with safety in regard to seed production.

Roots and Vegetables (other than Peas and Beans).

Three main methods, each of which is liable to modifications, are employed in the production of seed of the biennial roots and vegetables.

1. A portion of an ordinary crop may be left standing through the winter to produce seed the following year.
2. Selected fully developed plants from an ordinary or specially grown crop may be stored through the winter and planted out in the spring for seed production.
3. Seed may be sown at a special date to produce small plants or roots, which will be dealt with in an appropriate manner to produce a seed crop.

The first constitutes a rough and ready method not infrequently adopted by market gardeners growing their own seed, and despite considerable winter casualties often results in good seed yields, but is usually not accompanied by sufficiently careful selection or by adequate precautions against cross-pollination. The second method affords abundant opportunity for rigid selection and careful isolation, but involves much labour; while the third method favours very heavy seed crops and is an excellent means of growing on stock seed which has been previously subjected to rigid selection, but as such does not of itself afford the same scope for selection as the second method.

Mangels and Beet.—Mangels and beet are nearly always grown for seed by the second or third of the methods. When full-grown roots are employed thinning should be postponed longer than under ordinary field conditions, so that only robust and typical plants are left standing. Great care has to be exercised in the lifting, and only roots which are absolutely sound and of good shape are selected—the largest roots are not as a rule favoured for seed production. The foliage must be carefully trimmed off, great care being taken to leave the " crown " untouched. The roots must be carefully stored and protected from frost during winter. They are planted in the spring on land prepared very much as if for sowing, and at the same time or a little later than is customary for sowing, but always late enough to be safe from hard frosts. The roots can be planted fairly close in the rows, ample distance being left between the rows for cultivation. Planting may be performed by taking out furrows with the plough, or by digging separate holes with a spade; in either case the roots should be completely covered in order to afford protection against frost.

Mangels are often produced for seed on the " small root " plan, which is, however, the business of the expert and not to be undertaken by the amateur. Seed to produce small roots is sown usually at the end of June or early in July; the rows are thinned and the roots lifted in the autumn, carefully stored with their foliage on. Planting out must be performed rapidly and in favourable weather in the spring. In Lincolnshire mangel seed is produced by sowing seed on specially prepared plant beds early in August. " Small plants" rather than " small roots" are produced; these are usually left *in situ* on the plant beds during winter and are planted direct in the spring. The plants are set in rows about 27 in. apart, with about 8 to 12 in. between the plants in the rows. Sometimes the small plants are lifted and planted out in the late autumn; this ensures an earlier harvest but involves a considerable risk of loss of plants during the winter.[1]

When the plants begin to send up their flowering stalks it is a common practice to take a small piece off the main shoot; this prevents the plant growing too tall and encourages the development of laterals. In the case of the garden beets in particular ripening tends to be uneven. It is not easy to know when is the correct time to cut mangels or beet, since the plants may still be green towards the top when the seed is ripe. It is wisest to cut a few plants when the fruits in the inflorescence are showing a brown colour, and only to harvest if and when the seed heads are nearly black and solid. The stems are made into sheaves, which are put up to dry and usually left on the field for about a week or a little longer. In Lincolnshire the seed crop is matured in small and very narrow stacks which should always be ventilated, and the seed is not usually ready for thrashing before Christmas.

When seed is harvested from an adult crop left in the ground to over-winter, all roots which have " bolted " and all plants showing departures from type should be destroyed. The remainder should be earthed up to the crown and later covered with straw or seaweed (if available), which protecting material should be removed in April.

The yield of seed from mangels varies very greatly as between season and season, and according to the methods employed; an average yield is probably about 10 cwt. per acre, while yields of upwards of 20 cwt.

[1] See Thomas W. Lane, " Growing Turnip, Swede, and Mangold Seeds in the Holland Division of Lincolnshire and Adjoining Districts," *Journ. Min. of Agr.*, Vol. XXX, No. 4, July, 1923.

have been recorded, but under unfavourable conditions the crop may amount to but a few hundredweights.

The country is to all intents and purposes self-supporting in the matter of mangel seed, Essex, Lincolnshire, and Kent practically producing the entire crop. A few early varieties and also varieties required for re-export are, however, obtained from Denmark and elsewhere. A little seed of garden beet is grown in Essex, but probably nine-tenths of the seed sown in this country is obtained from France, with small quantities from Holland and Denmark.

Swedes, Turnips, and other Brassica.—Since practically all the Brassica intercross and cross also with the Wild Turnip or Smooth-leaved Charlock (*Brassica campestris*), and since there are such numerous varieties of swedes, turnips, cabbage, cauliflower, &c., in cultivation, the greatest possible precautions have to be taken to prevent intercrossing in respect of all these crops. Swedes are frequently grown for seed by selecting and storing selected mature roots on a similar plan to that adopted for mangels. The seed harvest is, however, much earlier, and the seed is prone to shed somewhat freely. When the pods have become yellowish brown it is usually time to cut; it is advisable to cut early in the morning while dew is still on the plants as this prevents shedding. Turnips and swedes are often sown after midsummer and towards the autumn, and left standing through the winter, when they will produce abundance of flowering stalks the following spring. This plan has been recently employed in New Zealand, the turnip being drilled at 4 lb. per acre and not subsequently cultivated, the crop being finally harvested with the binder.

In Lincolnshire turnips and swedes are grown for seed on two different plans. Turnip seed is drilled on the flat in the autumn at the rate of 2 to 3 lb. per acre. The distance between the rows varies from 18 to 23 in. Lane [1] states that on medium soils yellow turnips should be drilled not later than 14th September and white turnips by the 21st.

Swede seed on the other hand is sown on "plant" beds during the latter part of July and the first half of August. " Stocky " plants are aimed at, 1 acre of " plant bed " being about sufficient for a 7-acre crop. The plants should be put out in rows about 24 to 28 in. apart, with 6 to 12 in. between the plants. The roots should be shortened before planting, and it is desirable that the young plants should be transplanted during October and November, but in practice this operation often drags on until February, when the plants frequently do not establish themselves well.

Cabbage.—With late cabbage, and in order to give the maximum scope for rigorous selection, the safest plan is to dig up typical and healthy plants and to store these in a cellar or in carefully prepared and covered trenches during the winter, and to plant out in the spring for seed production. When the heads are solid they should be cut across the top,

[1] See Lane, loc. cit., for further particulars of the methods adopted in Lincolnshire.

as this will assist the production of flowering stalks. With early cabbage, selection can be achieved by marking the plants from which satisfactory heads have been taken; secondary heads will be developed, and from these in due season flowering stems will be produced. This plan has the disadvantage of being wasteful of ground, since a large proportion of the plants should have been discarded for seed production, and the remaining plants will have to occupy the ground for a prolonged period.

Late sowing and over-wintering of small plants is largely employed as a commercial method of seed production, and this is a satisfactory plan when absolutely reliable stock seed is assured. Cabbage ripens very unevenly, and it is desirable to harvest the seed from individual plants as they become ready.

Speaking generally, the various Brassica are more or less capable of self-pollination if not crossed; individual plants may, however, be practically incapable of self-pollination, so that the leaving of a single plant for seed will not necessarily give the desired result.

Broccoli and Cauliflower.—Very great precautions are necessary with reference to both the growing and the production of seed from the cauliflowers. These are tender plants and are generally started in frames, and it is only after the risk of night frosts is passed that they are planted in permanent quarters. Later, all plants with non-compacted heads and which only form small " button heads " must be rejected. The seed invariably ripens unevenly, and if good seed samples are desired the crop should be harvested bit by bit as the individual plants ripen.

Cross-pollination is a grave risk with cauliflowers and broccoli, and owing to the need of discarding unsuitable plants it is difficult to grow large compact masses for seed.

In the Penzance district of Cornwall growers frequently harvest their own seed, particularly in the case of the Penzance Early Broccoli which is so largely grown. Frequently a block in one corner of the field is left for seed, when no rigid selection will be undertaken, only the coarsest of the heads being removed. Sometimes a block representing the best part of the field is left for seed. It is the practice of the more careful growers to mark and retain a number of the best plants at the time of cutting the heads for market, and after clearing the crop to transplant and bring these plants together for seed production. The plants usually recover sufficiently well after transplanting and yield good seed crops. This method makes for a compact seed area and allows of careful selection.

The methods generally adopted in the Penzance area have, however, been too individualistic, with numerous small and scattered areas left for seed, in some cases with and in others without selection; and with other varieties or other Brassica all too frequently allowed to run to flower, the tendency has been for stocks to deteriorate: thus showing that unorganized seed production, with careful and careless methods equally adopted in a restricted area, does not react to the advantage of a district as a whole.

Most of the other Brassica are grown in the ordinary way and left standing for seed. Selections may be made by hand rogueing or by lifting and transplating.

The following brief statement may be made as to the chief sources of origin and yields of seed per acre in respect of the more important of these crops.

Swedes: Essex, the Fens of Lincolnshire, Kent, and Denmark.[1]

Turnips: Essex, the Fens of Lincolnshire, Kent, and Denmark.[1]

Cabbage: Essex and Lincolnshire, with a small quantity imported from Holland.[2]

Rape: Essex, Lincolnshire, and Japan.[3]

Kales: Essex and Lincolnshire.

Cauliflower: about nine-tenths from Italy, small quantities from Holland and Denmark.

Broccoli: almost entirely Essex.

Radish.—This is a crop which presents no very great difficulties in growing for seed, and when well harvested the seed retains its power of germination at a high level for three or four years. Thus in the case of market gardeners growing but one variety or say two varieties, seed could with advantage be harvested from selected areas of the different varieties in alternate years. Considerable amounts of radish seed are imported into this country from France and elsewhere.

Celery.—Celery is cross-pollinated, but there is not so large a number of varieties of this crop as is the case with so many vegetables, but Red and White Celery should not be grown for seed close to each other.

Celery is grown for seed on a large scale by planting out on the flat and allowing the plants to stand to produce seed in the second season. This plan does not, however, allow of rigid selection. The yields from celery vary within wide limits, in some years as little as 4 cwt. being an average crop, while in others as much as about 12 cwt. may be looked for.

Celery is still grown for seed to a considerable extent in Essex, but is also imported in appreciable amount from France and California.

Lettuce.—This is a crop of which the large market gardener frequently does not grow more than one variety, and from which seed may be produced by the plan recommended by Macself,[4] namely by the piecemeal transplanting of really good plants to a seed area. If care is taken the

[1] 300 to 1000 lb. per acre, turnips usually giving the higher yield.
[2] "Market" about 600 to 800 lb., and "Drumheads" about 700 lb. to over 1000 lb.
[3] Yield very similar to that of turnip.
[4] A. J. Macself, *Seed Farming in Britain*, 1919.

plants can be successfully transplanted, and after lifting will soon run to flower and seed. Lettuce seed is now largely imported from Italy, France, and California; probably hardly one-tenth of the seed sown in this country is home grown.

Spinach.—The male and female flowers are borne on different plants, thus cross-pollination is necessary, and as a rule about one-third of the stand will consist of male flowers incapable, as such, of seed production. Spinach will run to seed comparatively soon after sowing, and is capable of yielding heavy seed crops, 12 cwt. per acre being frequent, and this is sometimes considerably exceeded. Spinach when properly harvested retains its germination well, and thus different varieties (and they are not excessive in number) might also be harvested for seed by the market or ordinary gardener in alternate years.

Carrots and Parsnips.—In mild situations carrots are sometimes left in the ground to over-winter; this is, however, a practice more frequently adopted in the case of parsnips. The roots of both crops are usually lifted and stored, when both carrots and parsnips can be planted out earlier in the spring than is safe for the beets. On small areas the heads of these plants are often supported by stakes, and with parsnips in particular it is desirable to harvest the central heads earlier than the lateral ones.

Great care is necessary in the harvesting and drying of these seeds as the germination tends to be low. The thrashing of carrot seed presents difficulties, and it is said that a clover seed huller can be used for this purpose with advantage.[1] Care must be taken to eliminate wild carrot and wild parsnip from the vicinity of areas growing these crops for seed.

Parsnips are still grown to a considerable extent for seed in Essex, while carrots are grown less extensively than formerly, the vast majority of the seed employed in this country being imported from California, France, Holland, and Denmark.

Parsnips are capable of yielding 10 to 12 cwt. of seed per acre, but the crop is a decidedly uncertain one; the yield of carrots varies considerably from season to season and between variety and variety; yields of between 5 to 6 cwt. per acre are recorded as average crops in Sweden.

Onions and Leeks.—Onions are usually grown for seed from selected and winter-stored bulbs; in exceptionally sheltered positions they may be left *in situ* protected by straw or seaweed. This is, however, not a plan to be recommended, and in any event does not permit of adequate selection.

Macself[2] states that bulbs " thoroughly ripened and sun-roasted early in the autumn " may be planted on light and well-drained soil about

[1] See M. O. Malte and W. T. Macoun, " Growing Field Roots, Vegetable and Flower Seeds in Canada ", *Bull.* No. 22, Dominion of Canada Department of Agriculture.

[2] Loc. cit.

Michaelmas; the bulbs should be planted fairly deep, when they will over-winter safely and produce good seed crops the following year.

Onion seed should be sown as early as possible in the spring, and when selecting bulbs for storage and subsequent seed production, as well as rejecting all those that are not typical of the variety, only healthy and well compacted onions should be retained.

It is very important thoroughly to dry the onions before they are stored. The seed harvest tends to be rather late, so that much care has to be exercised in drying both the heads and the seed, processes which should be performed as rapidly as possible.

Onions are grown to a varying extent for seed in Bedfordshire, but we import by far the greater quantity of our requirements from California and France.

Onions do not yield such heavy seed crops as most roots and vegetables, and about 2 cwt. to the acre is considered a good crop. In the case of " growing on " the seed of leeks for distribution it is not usual to trench, but when selecting plants for stock seed it is necessary to do so.

Tomatoes.—This is a crop, although not cross-pollinating to a very considerable extent, the varieties of which are none the less prone to deteriorate unless careful selection is always adopted. Early flowering and maturing is essential for seed production, consequently the heavy nitrogenous dressings employed for market purposes are not advantageous for seed production. Seed should not be taken from rotten tomatoes, but only from well-ripened, well-shaped fruits of medium size. The seed should be extracted from the tomatoes when they are dead ripe but before they have commenced to rot.

General Considerations.

It might appear from the foregoing review that persons occupying gardens or holdings remote from the well defined seed-growing districts might with safety be encouraged to produce their own seed. It must be emphasized, however, that if an appreciable number of persons adopted this course in every district throughout the country it would soon become impossible for individuals to maintain the purity of their stocks in the case of all the readily cross-pollinating crops.

Seed production is essentially a matter for organization and co-operation. Market gardeners could often produce their own seed on an extended scale in particular districts. It would be necessary, however, for individuals to regard it as a point of honour to allow nothing to run to flower which could have the effect of pollinating plants occupying areas selected for co-operative seed production. If this plan became more general it would be possible for more careful attention to be given to the selection of varieties most suitable to particular districts, and for the production of different varieties to become largely the concern of different districts sufficiently remote from each other to prevent all risk of contamination by pollen of other varieties.

The individual is only entitled to produce his own seed in the case of crops which either do not cross-pollinate or which do so to a slight extent, or of which there are not any very great differences in the trade varieties which are available. Individualistic seed production in so far as the crops dealt with in this section are concerned may be regarded as legitimate in the case of lettuce and tomato, and by those occupying walled, sheltered, or particularly secluded gardens in the case of, say, spinach, celery, and radish, while of course the keen gardener is not on national grounds debarred from growing small quantities of seed of any crop he desires, provided he takes the necessary steps to isolate his plants by pollen- or insect-proof cages as may be necessary in each case.

Peas, Beans, and Vetches.—The culinary varieties of peas and Runner and Broad Beans are largely grown for seed in Essex, and, as before said, rogueing and picking are important features of seed production in respect of these crops. Field peas, beans, and vetches are grown for seed in a number of English counties. Peas are chiefly grown in Essex, Suffolk, Bedfordshire, and Lincolnshire, and vetches in eastern and southern counties, notably in Lincolnshire and Kent. In the case of these crops, both garden and field, since even in the seed-growing districts experience has shown that no very great precautions are necessary with reference to dangers of cross-pollination, it is perfectly legitimate for individuals up and down the country to save their own seed. In the case of standard varieties even of culinary peas and beans in good seasons, market growers and gardeners may be well advised to harvest seed from a portion of their areas devoted to these crops. In order to maintain purity of stock this plan should not be adopted for a number of years in succession unless individuals are competent and willing to do their own rogueing, but stock seed from a reliable source should be purchased at regular and frequent intervals.

Peas.—In England the majority of the culinary varieties are sown during April and May; this applies particularly to the wrinkled types, which are susceptible to frost. Hardy types, like "Telegraph", are sown in February or occasionally in November.

Ripening takes place according to variety, the pea harvest generally commencing in the middle of July. The crop is harvested when the foliage is dead and when the pods are well dried.

The yield of seed varies considerably as from season to season and as between the varieties, the average crop is about 16 to 24 bus. per acre, but this may on occasion be considerably exceeded, while the haulms will often yield upwards of 10 cwt. to the acre.

Peas are imported in considerable quantities from New Zealand, the United States of America, and Canada.

Broad Beans.—Broad Beans are not particularly sensitive to frost, and may be sown earlier than most peas. The crop should be grown on an open and airy situation. When the pods and leaves have turned black the crop is cut and placed in sheaves to dry on the field. The crop of course varies for the varieties, but is usually a heavy one, being in excess of that looked for from other vegetables or roots. Broad Beans are largely grown in Lincolnshire, Kent, and Essex, and are imported in small amount from Spain and France.

Kidney Beans.—Since this crop ripens late it is desirable to grow for seed in warm and sheltered situations. The seed should not be sown until there is no further risk from frost. It is difficult to dry the crop properly and also undesirable to remove the pods from the haulms too soon, consequently thrashing should be delayed for some little while after harvest, and if possible the haulms should be first dried off in a barn.

Seed yields of upwards of 12 cwt. per acre may be looked for. Runner Beans are largely grown in Essex, Lincolnshire, and Kent, but we probably import nearly half of our requirements from Holland; for Dwarf Beans we are almost entirely dependent on France, small quantities also being imported from New Zealand and Australia.

Vetches.—Most of the vetches grown for seed in this country are the winter variety sown in September and October. Vetches grown for seed are sown alone, but good seed samples are often separated from oats and other cereals when a portion of a field sown with such a mixture has been left for seed. With an increasing use being made of "vetch hay" mixtures, there is little doubt that farmers could with advantage produce their vetch seed to an increasing extent by this means. In some years not inconsiderable amounts of vetch or tare seed is imported to this country from the Continent, now chiefly from Holland, formerly largely from Russia.

A good average crop of winter vetch seed should run to about 1440 to 1800 lb. per acre.[1]

Cereals.—With the exception of appreciable amounts of stock seed of the more famous of the Svalöf varieties of cereals imported direct into this country from Sweden, Great Britain to all intents and purposes produces all her cereal seed for sowing.

As before said, rogueing and seed treatments are important aspects of cereal seed production, which are prone to be entirely neglected except in the case of proprietary varieties grown under the general supervision of the producers.

Generally speaking, it is the more eastern counties which produce the best samples of cereal seeds. Wheat and oats are both largely grown for seed in East Anglia, while excellent oat samples are of course har-

[1] The writer is indebted to Mr. H. Chambers of the Ministry of Agriculture for valuable information as to the source of origin of root and vegetable seeds.

vested far north, the Lothians, Moray, Aberdeen, Banff, Inverness and Ross, Forfar, Perth, Fife, and Stirling all being famous oat-producing centres in Scotland.

Oats are also grown for seed in the Isle of Man, and although in general the western counties of England and Scotland are not so favourable to the production of attractive samples, it has to be admitted that excellent seed grain is produced in Ayr and Dumfries, in Scotland, and in some of the western English counties as well as in various parts of Wales.

Grasses and Clovers.—The methods employed in Britain have been reported upon by Mercer[1] and need not be considered in detail. It will be convenient to deal with the important species separately, and to describe the precautions that should be taken with reference to seed production, having regard to the practices in vogue in other countries as well as at home.

Red Clover.—A clear distinction must be made between Broad or Early Red Clover and Late-flowering Red Clover (or Single-cut Cow-grass). The former clover is always and of necessity taken for seed during the first year after sowing, and is usually grazed during the early spring, in this country, even up to June, or is allowed to yield a hay crop to be followed by a seed crop. Late-flowering Red Clover flowers late and cannot yield both a hay crop and a seed crop, and must therefore be allowed to run straight to seed and should not be grazed long into the spring. Since some strains of Late-flowering Red Clover in particular are long persisting, seed crops may be taken in a second or even in a third or fourth year. When this is done the yield will be considerably less than that taken in a first year.

This is in many ways a sound practice, since it tends in the direction of selecting the more persistent plants from which to take seed.

In this country Late-flowering Red Clover usually comes for harvest in August or early September, while Broad Red, being a second crop, may not be ready for seed until late September, October, or even November.

Red Clover is grown for seed in numerous countries all over the world. Most of the Red Clover imported into this country is of the Broad Red type, coming chiefly from France, Central Europe, Chile, United States of America, Canada, and New Zealand. Late-flowering Red Clover represented by the "American Mammoth" is to some extent imported, while late-flowering strains are also to be obtained from Denmark and Sweden and from Canada.

In this country excellent extra late late-flowering strains are grown to a limited extent in Montgomery and over the Shropshire border, in the

[1] See S. P. Mercer, "Report on the Agricultural Seed-growing Industry in Great Britain", *Miscellaneous Publications No. 29, Ministry of Agriculture and Fisheries*, London, 1921.

Vale of Clwyd, in Denbighshire, and over the Flintshire border and in the Wadebridge district of Cornwall.

Medium and medium-late strains of Late-flowering Red Clover are grown to a slight extent in most of the counties where Red Clover is taken for seed, and perhaps to the greatest extent in some of the eastern counties, in Hampshire, and in Gloucestershire.

Broad Red Clover is grown chiefly in the eastern and southern counties, but not inconsiderable harvests are taken in Oxfordshire, Herefordshire, Shropshire, Wiltshire, Somersetshire, and in most of the districts mentioned in connection with Late-flowering Red.

In this country there can be no doubt that one of the chief causes which reacts against clover seed production is the general ignorance that pervails in regard to the essential difference between Broad Red and Late-flowering Red Clover. Thus in Montgomeryshire, for instance, it is no uncommon practice to graze a field of extra late Late-flowering Red so long into the spring that the seed crop is of necessity almost ruined, while in the west of England and in Wales the too late cutting of Broad Red Clover for hay renders the subsequent seed harvest so late that it is practically impossible to garner the seed in good condition.

The Late-flowering Red Clovers are probably best adapted for seed production in late districts, because it is in such districts that the leys are left down for several years, and since two crops in one and the same year are hardly feasible in any event, it is safest to rely on an early harvest, which can be ensured from the Late-flowering Red by withholding early spring grazing.

It would be a great advantage if different districts concentrated either on the production of the seed of Early or Late Red Clover, for this would make it much easier for farmers to procure the particular variety they require for ordinary purposes.

In some districts Red Clovers are grown alone, in others they are sown with the Ryegrasses or Timothy. If grasses are included in the mixture, *a certain amount of grass seed is likely to be harvested with the clover* and will have to be subsequently removed. More attention in this country should be given to the elimination of weeds; in Sweden this is achieved either by only taking seed from those parts of a ley which have produced the best stand and are free from weeds, or by sowing the clover specially for seed in rows about 1 ft. or 1 ft. 6 in. apart and keeping the stand clear by hoeing. This method has been tested at Aberystwyth, but further trials are necessary, for it did not appear to give as good results as in the case of some of the larger grasses.

Cutting should not take place until the seeds in the majority of the flowering heads are ripe, namely when the flower heads are brown. The ordinary mower, or side delivery mower, may be used for cutting.

The flower-heads fall off easily at this stage; the cutting must therefore be carefully done, either during slightly damp weather or early in the morning. The crop should not be carried until it is quite dry—in Sweden it is customary to hang the crop up on drying hurdles, a practice that should recommend itself to west country farmers. In Essex the crop is left in small heaps from the side delivery mower; these are carefully turned and when dry pitched direct.

Red Clover should be thrashed immediately; the seed is then more easily freed, particularly if the crop is dry and the thrashing conducted in dry weather. Early thrashing not only makes it easier to protect the seed from vermin, but gives ample time to clean the seed and for the necessary tests to be conducted. The practice of stacking till the spring is responsible for much inferior seed being hurriedly distributed without proper cleaning, particularly in Wales and the west of England, and this could be obviated if greater endeavour were made to ensure early harvests, which could be handled before the days become short and the weather unfavourable. In this country an average yield of Red Clover seed per acre may be taken as from 260 to 300 lb.; exceptionally, however, the yields may run up to 650 to 750 lb. per acre. About 356 lb. per acre appears to be an average crop in Sweden.

The soils best suited to Red Clover seed production are medium clays showing no deficiency in lime. When seed will be taken from Late-flowering Red Clover in a second year, a generous dressing of basic slag should be applied in the previous autumn.

Alsike Clover.—The majority of the Alsike Clover used in this country is imported from Canada; large quantities are also grown in the United States. This clover is also grown in Sweden and elsewhere on the Continent. Alsike is only grown for seed in a spasmodic manner in England; crops are sometimes taken in Essex, Suffolk, Herefordshire, and in other counties where Red Clover is also grown.

Alsike is very frequently grown with Timothy, which is thus a common impurity in this clover. It should be grown alone for seed production. Alsike will not yield a seed crop as well as a hay crop, but good seed yields can be obtained when the crop is grazed well into the spring.

Alsike ripens a little earlier than Red Clover. The crop should be cut when it is wet with dew; the whole flower-heads will not fall off, but the individual pods are prone to fall from the heads. The crop should be thrashed as soon as possible after carting.

The yield of seed is not usually quite as high as Red Clover; in this country the average yield may be taken as about 230 lb.; crops of abou 340 lb. have been harvested in Sweden.

White Clover.—It is probable that most of the commercial Whit or Dutch Clover sown in this country now comes from Slovakia an New Zealand, although in favourable years appreciable amounts ar harvested in Essex and other Red Clover growing counties. This clove is also harvested off the Blue Grass pastures in Wisconsin, Idaho, and Louisiana, this American seed to some extent being imported into this country.

White Clover is generally ready for harvest in July-August; the leys are most usually sheep fed into May and then shut up for seed production. The yield is very variable in this country, an average crop being about 195 to 260 lb. per acre.

White Clover will yield heavier crops in the second year relative to the first year than is the case with Late-flowering Red Clover.[1]

Wild White Clover.—Wild White Clover for use in this country is, of course, only harvested at home. The great bulk of the Wild White Clover seed of commerce is harvested from permanent pastures in a remarkably restricted area in Kent, with Ashford as the head-quarters of the industry. This clover is also harvested to a limited extent from old pastures in Gloucestershire. It is somewhat extraordinary, as Mercer has remarked, that this valuable seed is not harvested from permanent pastures over a wide range of country. White Clover is strongly indigenous in numerous counties, and grows to profusion in Herefordshire, Devonshire, Cornwall, Somerset, and locally in numerous other counties.

The growing of " once-grown " Wild White Clover is also very slow to spread, and is practically confined to restricted areas in Gloucestershire and Suffolk.

Considerable prejudice exists with reference to the once-grown article. Provided, however, that reliable stocks are used in the first instance and that commercial White Dutch is not grown in the immediate vicinity, and provided also the seed crops are not taken until the Wild White leys have been down for a few years, there is no reason to suppose that the once-grown seed should not be perfectly satisfactory. On many soils indeed Wild White Clover can be induced in profusion on a ley without ever sowing a single seed, such is the effect of generous slagging; thus when seed is sown it will be pretty certain that a large proportion of the resulting stand, often enough, owes nothing to the parent seed.

When once-grown Wild White Clover seed is produced, the usual practice is to sow about 12 lb. per acre alone (as little as 4 lb. is sometimes used), or to sow 6 to 9 lb. with Perennial Ryegrass. A simple mixture, such as Wild White, 4 lb., Perennial Ryegrass, 6 lb., Crested Dog's Tail, 6 lb., is sometimes employed with a view to developing as quickly as possible what is tantamount to a permanent sward—generous dressings with basic slag being necessary.[2]

[1] Detailed particulars of the precautions to be taken with reference to the growing and harvesting of White Clover are given by Mercer on pp. 14, 16, and 17 of his report, Miscellaneous Publications No. 29, Ministry of Agric. and Fisheries, London, 1921.

[2] Wild White Clover will readily form a dense mat if sown in drills about 1 ft. apart, and this procedure affords an opportunity of rogueing out the less desirable plants and also makes for an economy of seed, and is therefore a procedure worth trial by those producing the once-grown article.

The general operations before and during harvest are essentially the same in respect of both once-grown seed and that taken from old pastures. In the case of once-grown crops, however, there is some danger of stock pulling the plants up during the first year, consequently when seed is taken in the first year it is customary to mow early (instead of grazing) —about the middle of May.

Pastures and leys alike should be kept well rolled. In the case of pastures these are generally kept closely grazed with sheep until about the middle of May; sometimes a small crop of hay is taken in the middle of June. Harvest is in August. The crop must be cut with great care and turned with caution. The carts should be lined with sheets to prevent loss of seed.

It is probable that there is a tendency to allow Wild White Clover to become rather over-ripe before harvesting; this practice tends to favour the development of hard seed and makes for loss by shedding.

In the long run it is advisable not to take seed from old pastures more than once in three years, or certainly not more often than every other year.

The crop is usually a little heavier from once-grown than from old pasture—about 50 lb. per acre is considered a good crop; the yield may however fall as low as 20 lb., or occasionally go as high as 100 lb.

Crimson Clover.—This clover is not grown for seed in this country to the same extent as formerly, large quantities being imported from France. It is, however, grown to a not inconsiderable extent in Essex, Suffolk, and Hampshire, but is not well suited as a seed crop farther west as it suffers badly from wet, and even in the more favoured countries it is the most hazardous of clover seed crops.

Crimson Clover is generally sown immediately after corn harvest; occasionally it is sown in the corn when the crop is fairly high. This clover only gives one crop per season, so that it cannot be grazed off or hayed early in the summer. The seed harvest is therefore an early one. The early variety is fit for harvest in the middle of July, and the late strain three to four weeks afterwards. The heads shed very easily; the cutting should be conducted in the early morning while the plants are moist with dew, and the crop handled as little as possible. A good average crop wil be from 520 to 650 lb. per acre.

Trefoil.—Trefoil is grown for seed in Essex, Suffolk, Sussex, an to a less extent in some other countries; large quantities are also importe from France. On thrashing, the pods break away from the straw intac with the seeds. This produce is usually sold by the grower to the mer chant as "Trefoil in cosh". The extraction of the seed from the cos is performed by the merchant.

Kidney Vetch.—Kidney Vetch is not grown for seed to any conside able extent in this country, occasional crops only being taken in some the eastern counties. The bulk of the seed used in this country comes from France.

Sainfoin.—Both Giant and "Old English" Sainfoin are grown for seed in England, but large quantities of the seed of the former variety are imported from France. Seed from Giant Sainfoin is usually taken from a second crop, as in the case of Broad Red Clover, when the harvest will be in September and the yield about 800 lb. per acre of unmilled seed. The Old English, which is chiefly grown in Hampshire, in parts of Gloucestershire, and to a limited extent in Glamorganshire, is seeded from the first crop, seed usually being taken from leys that have been down for a number of years. Seed of this variety will be harvested in about the middle of July, and an average crop may be taken at about 400 lb. of unmilled seed.

Lucerne.—The seed of this species is chiefly grown in France, Italy, Hungary, and other south European countries. Seed production is uncertain in America; considerable quantities are, however, grown in Utah, Idaho, Kansas, Nebraska, California, and Arizona, while that of the Grimm and other hardy strains come mostly from the Dakotas, Montana, and Idaho.

In this country, as also in Denmark and Sweden, the cultivation of Lucerne seed is very precarious. The second or even the third crop is usually reserved for seed, and the methods employed are very similar to those which are applicable to Red Clover. The seed is, however, easier to thrash.

The Ryegrasses.—Ireland produces large quantities of both Italian and Perennial Ryegrasses and, as well as contributing freely to the home demand, exports extensively to other countries. Perennial and to a smaller extent Italian Ryegrass are grown in Ayrshire and Stirlingshire in Scotland. The latter variety is also grown in large quantities in the Isle of Ely. Italian Ryegrass is, however, imported in considerable amount from France, and in recent years appreciable amounts of pedigree Perennial Ryegrass have come into this country from Denmark.

The methods adopted in Ireland, Scotland, and England alike are very similar, and consist of taking seed from broadcast leys sown with Ryegrass alone or with either Italian or Perennial mixed with clovers or or with clovers and other grasses.

On the Fens in Cambridgeshire Italian Ryegrass is sown alone with a corn crop in the usual way, and in the spring cattle are fed on the ley until early May—the seed crop being ready about the second week in July.

In Stirlingshire it is usual to sow Perennial Ryegrass in a simple mixture, and to take a seed crop in the first harvest year and subsequently to graze the ley for two or three years. In recent years no attention appears to have been given to the selection of leafy or persistent strains of Perennial

Ryegrass, the so-called "Ever Green" and leafy form being hardly obtainable. Formerly "Devon Eaver" was grown for seed near Sampford Courtency, but this is a local industry that has practically disappeared.

The Ryegrasses need to be well ripened—the harvest being about middle or late July. In Denmark a self-binder is often employed, but there is risk of the binder thrashing out too much seed, and in Scotland an ordinary reaper followed by women tying is employed. I alian Ryegrass usually gives a heavier crop of seed than Perennial; about 8 cwt. of seed per acre is deemed a good crop from the latter species, but yields considerably higher than this have been reported from Sweden.

In Denmark and Sweden the Ryegrasses are grown for seed in rows which are kept cultivated and clean. This method has been tested at Aberystwyth. It appears to be more suited to seed production on good than on poor land, and from the point of view of growing clean seed crops has everything to recommend it.

Cocksfoot.—Of Cocksfoot it may be said that it has been grown for seed in England, but it cannot be claimed that we have a Cocksfoot seed-production industry in this country. This grass is particularly amenable to seed production on the Danish-Swedish row plan, for with proper cultivation and adequate manurial dressings, very large and absolutely clean crops of seed may be obtained.

With a rapidly growing demand for Cocksfoot in connection with temporary leys, it is much to be desired that more attention should be given to the home production of this seed, and there can be little doubt that large areas in Britain are admirably suited for the purpose.

Cocksfoot demands a rich soil and should be well nourished in order to produce maximum seed crops; in Sweden liquid manure has been found very efficacious. A full mineral dressing, including nitrate of soda or ammonium sulphate such as that employed for meadow hay, should be applied to the seed-producing area.

The seed should be sown in drills about 2 ft. apart, on land that has been well cleaned; horse and hand cultivation should be carried out until the plant is well established, when the grass will hold its own, and seed crops can often be taken for five or six years in succession, provided the stand is adequately manured every year.

Cocksfoot will come for harvest from the middle of July to early August according to the variety or strain, and should be cut when the stem below the panicle turns yellow.

In Denmark and Sweden the crop is cut with the self-binder. I weather conditions are favourable it is a sound practice to leave the stook standing for a period of even a few weeks on the field.

It is sometimes grown for seed by sowing with Broad Red Clove when a hay crop will be taken in the first harvest year. There will b practically no clover present in the subsequent harvest years, so that a Cocksfoot seed crop may be taken in the second and frequently again in the third and fourth harvest years.

Where grown for seed on the row plan in Denmark and Sweden it is capable of giving yields of 300 to 600 lb. per acre, about 450 lb. being a good average crop; yields over 800 lb. per acre have, however, been recorded.

Most of the Cocksfoot seed employed in this country is now imported from Denmark; considerable quantities are, however, harvested in Kentucky, Indiana, Ohio, Virginia, and Tennessee, and American seed is sometimes offered for sale in Britain. The seed of Cocksfoot harvested in France is also to some extent employed in this country.

In New Zealand before the War, Cocksfoot was harvested for seed from about 30,000 ac.; most of this seed was taken from steep hillsides on Banks Peninsula in the South Island, this seed being known as "Akaroa" Cocksfoot.[1] Seed is also taken from Cocksfoot-Ryegrass pastures, and this is known as "Plains Cocksfoot".

The Akaroa seed is hand picked and is taken from what is tantamount to permanent grass, while that taken from the plains is frequently the produce of leys that have been down for a number of years. Seed from New Zealand, and especially that from the Banks Peninsula, gives rise to more leafy plants than that from Denmark or the United States, and is particularly suited to long duration leys in this country, and it is unfortunate that the amount of seed imported into Britain appears to have diminished in recent years. An average seed crop in New Zealand appears to be about 160 lb. per acre.

Timothy.—Timothy, like Cocksfoot, is best grown for seed in spaced seed-production rows. These are usually spaced a little less than 2 ft. apart; the crop should be liberally dressed, for it should be emphasized that nitrogenous manures are necessary in order to obtain good seed yields from practically all the grasses. Considerable discrimination is necessary in deciding when to cut Timothy. This should be done when the spikelets at the top of the ear are loosening; if cut too early the seeds will be small, while if cut too late there will of course be much loss due to shedding.

From rows, yields of upwards of 700 lb. per acre have been obtained in Sweden. In Scotland, Timothy is obtained for seed from leys sown with about 20 lb. Timothy and 10 to 14 lb. of Perennial Ryegrass, and frequently supplemented with 3 lb. of Red Clover or with 2 lb. of Red Clover and 1 lb. of Alsike. The leys are left down for a considerable period, sometimes over twenty years. Seed may be taken annually after the first year, provided the ley is regularly dressed. The seed meadows

[1] See A. H. Cockayne, "The Grass and Clover Seed Industry in New Zealand", *Int. Inst. of Agr. Monthly Bulletin*, Year V, No. 11, November, 1914

are grazed in the spring; harvest takes place in August. The yield varies from about 330 to 560 lb. per acre.

The amount of Timothy produced in Ayrshire and Stirlingshire is not nearly sufficient to meet the home demand, and we import annually large quantities from Canada, this seed being extensively harvested both in the Dominion and in the United States of America.

Meadow Fescue.—Most of the Meadow Fescue seed employed in this country comes either from Denmark or the United States of America; seed crops are only taken in Britain occasionally and under exceptionl circumstances.

In Denmark the crop is grown in a manner similar to Cocksfoot in seed-production rows. A rather damp soil suits Meadow Fescue best, and this crop does not require as heavy manuring as Cocksfoot. The crop is cut with a self-binder, but considerable care is necessary as the seed sheds easily.

Seed can also be taken in the second, third, and fourth harvest years from a ley sown with Meadow Fescue and Broad Red Clover. Grown in rows, yields of about 550 lb. are obtained. In the United States, Meadow Fescue is harvested for seed in Eastern Kansas and Western Missouri.

Tall Fescue.—The seed of commerce comes to this country from Holland and Germany; in the latter country it is cultivated for seed in the neighbourhood of Geinsheim.

Tall Fescue is very suitably grown for seed in rows in a manner similar to Cocksfoot. Indigenous Tall Fescue has been grown for seed in this manner at Aberystwyth with very promising results.

Fine-leaved Fescues.—Hard and Sheep's Fescue are obtained chiefly from Germany, a variety of *Festuca duriuscula* being cultivated from seed produced near Janikow. Chewings Fescue, which is imported from New Zealand, is taken for seed from about 6000 ac. in the South Island, the average yield per acre being 400 lb.

Tall Oat Grass.—Practically all the seed of Tall Oat Grass used in this country comes from France. Heavy crops of indigenous seed have been obtained at Aberystwyth from seed-production rows. The seed sheds very easily, and sheltered fields should be selected for seed production.

Meadow Foxtail.—At the present time nearly all the commercial seed employed in this country is obtained from natural meadows in Finland. This seed was formerly produced in Denmark, but chiefly owing to the ravages of the foxtail gnat the growing of special crops for seed production has been practically discontinued.

Satisfactory crops have been harvested at Aberystwyth by growing the plant in spaced drills. It is, however, a difficult crop to handle; the straw is very soft and becomes easily lodged, moreover the seed ripens very irregularly and sheds freely. Seed can be taken for several years in succession from the same plot.

Rough-stalked Meadow Grass.—Denmark practically meets the world's demand for the seed of this grass. It is grown specially for seed production on the drained bottoms of lakes. The seed is sown broadcast under a covering crop of barley, and a seed crop is taken in the first harvest year and generally in the second harvest year also, but this species will not yield remunerative crops for more than two years. An average crop appears to be about 260 lb. per acre.[1]

Smooth-stalked Meadow Grass.—Very large quantities of this grass are harvested for seed from the Blue Grass pastures of Kentucky, Missouri, and Iowa in the United States, and it is these areas which chiefly meet the world's demand for the seed of this species.

The seed is harvested by horse-drawn strippers and piled in long wind-rows for curing. The curing is sometimes completed in large barns.

SEED TESTING

The object of testing seeds, on the one hand, is for the vendor to ascertain whether the bulks are satisfactory before the seed is distributed, and on the other for the purchaser to satisfy himself that the seeds are up to the standard specified.

Sufficient emphasis is not, however, laid on the obvious limitations of seed testing; the results of analyses reveal much that is important with reference to crop production, but it must be remembered that the process of testing does nothing to improve the seed, and the report of a test gives the farmer no information whatever as to variety or strain, and very slender information as to nationality.

The reports from official stations are usually and of necessity confined to a statement as to the quality of the seed considered merely as seed. The following are the more important of the characteristics of seed revealed by a laboratory test.

Capacity to Grow.

Germination.—The percentage germination of a seed sample indicates the number of seeds per hundred which under practically ideal conditions have the power to grow, that is to say, which are not dead. Obviously it is useless to sow dead seed, and no sample is of value unless capable of reasonable growth. There are, however, often occasions when it is necessary to employ seed of poor or even very low germination, but when this is less than 85 or 90 per cent the seed rate should be adjusted in sympathy with the growth. "Energy of germination" is sometimes

[1] The writer is indebted to Dr. Dorph Petersen of Copenhagen for information kindly given relative to Meadow Foxtail and Rough-stalked Meadow Grass.

reported, and is an additional piece of information as to capacity for growth revealed by a test.

A full test usually runs from ten to twenty-one days according to species; the " energy " figure is arrived at by counting the number of seeds which have germinated in a specified shorter period, usually in three to six days according to species.

It is frequently taken for granted that high energy of germination is of necessity an additional recommendation to a sample of seed. This is, however, only the case when comparing samples of one and the same nationality and strain.

Hard Seed.—In the case of clovers, lucerne, and related species, it is frequently found at the end of the full period of the germination test that a varying and often very considerable number of seeds have neither sprouted, swollen, nor decayed, but have remained hard and uninfluenced by the moist seed bed. These " hard " seeds are not dead and are capable eventually of germinating, but when sown will lie for long or short periods dormant in the soil. In practice it is found that hard seed sown in the spring will not usually germinate until it has been subjected to conditions of frost and thaw during the following winter. Thus much hard seed is a serious defect in Broad Red Clover sown for but one year; is of less significance in the case of Late-flowering Red Clover sown in leys for two or more years; and unless the amount is upwards of 15 or 20 per cent does not very seriously detract from the value of a sample of Wild White Clover.

Sprouted Seed.—This is a defect in samples easily detected by the seed analyst, and the presence of appreciable amounts of sprouted seed is usually reported. The presence of sprouted seed indicates unfavourable harvest conditions, and thus of itself counts against the probable usefulness of a sample.

Shrivelled or "Pinched" Grain and Brown Seed.—In official tests the amount of these present in cereal and clover samples respectively is not as such usually reported. Shrivelled or pinched grain will often germinate comparatively well, but since it indicates unfavourable conditions during the growth period of the crop producing the seed, it detracts from the value of a sample. Brown and shrivelled clover seeds do not as a rule germinate well, thus the germination result sufficiently emphasizes the condition of a sample containing excess of such seeds.

Purity.

The purity of a sample, in so far as seed testing is concerned, refers only to the presence or absence of the seeds of other species and not of other varieties or strains, and to the presence or absence of dirt and other inert matter. Thus, of course, wheat is an impurity in oats, and oats an impurity in wheat. In the case of the Brassica it is not possible to distinguish all of these one from the other, and consequently in official tests it is seldom the practice to attempt to report admixtures.

"Purity" is always reported as the percentage by weight of pure seed of the species which the sample is stated to represent. Impurity is considered under the following headings.

Other Valuable Species.—Samples may sometimes contain the seed of species of greater value than the sample itself; Alsike Clover, for instance, is a common impurity of Timothy. More usually the impurity is of less value. Thus Yellow Suckling Clover is often abundant in Wild White Clover and Ryegrass in Cocksfoot.

Weed Seeds.—In reports the weed seeds present are named. Weed seeds are conveniently divided as follows.

Injurious.—These are of two classes, either such as are the seeds of plants which are parasitic on the species which the sample represents, or on other species sown along with the particular sample, or those which are of a particularly land-fouling type.

(1) *The Seeds of Parasitic Weeds.*—The most important of these are the seeds of the Dodders. The large Clover Dodder is frequent in samples of Chilian Red Clover, while the European Dodder is met with in samples of Red, Alsike, and White Clovers, and not infrequently in samples of Timothy, which so often contain Alsike Clover as an impurity.

The following statement taken from the reports of the official seed-testing station indicates the extent to which the Clover Dodders occur in samples.

Percentage of Samples containing Dodder[1]

Red Clover.	Alsike.	White Clover.	Lucerne.
22·8	6·0	2·7	9.1

Dodder is not very abundant on clover fields in Britain, and the presence of Clover Dodder (especially the large-seeded species) in samples for use in Scotland and the north of England is not considered to be of great significance, as the conditions so far north are not favourable to the growth of this Dodder. Over the greater part of England, and especially in the south, Dodder may, however, become serious, and samples containing the seed of this parasite should never be employed.

The Flax Dodder is not infrequent in samples of Linseed, and should always be guarded against.

The seeds of Yellow Rattle, a weed which grows parasitically on the roots of grasses, is sometimes present in poorly cleaned samples of the Ryegrasses, and is rather a frequent impurity in Meadow Foxtail.

(2) *The Seeds of Land-fouling Weeds.*—Some weeds far more than

[1] The figures given above are averages obtained from those given on p. 33 of "The Fifth Annual Report of the Official Seed Tests Station for England and Wales". See *The Jour. of the Nat. Institute of Agr. Bot.*, No. 1, 1922.

others gain rapidly on the land and are difficult to eradicate if once introduced; the seeds of such weeds are most troublesome if sown with grasses and clovers, since subsequent cultivation will be impracticable. The most serious weed seeds of this sort are those of Yorkshire Fog, Soft Brome, the Docks and Sorrels, Wild Carrot, and the Crane's-bills.

The extent to which these seeds are met with in samples of grass and clover seeds is shown by the following statement taken from the reports of the official seed-testing station:

PERCENTAGE OF SAMPLES WITH 1 PER CENT OR OVER OF INJURIOUS WEED SEEDS[1]

Red Clover	4·9 [2]
Alsike Clover	7·9
White Clover [3]	39·9 [4]
Perennial Ryegrass	26·0
Italian Ryegrass	36·0 [5]
Meadow Fescue	34·0 [5]
Cocksfoot	8·5
Timothy	0·5

It should be pointed out that the above figures do not by any means represent to the full the position as to land-fouling weed seeds. In the case of Yorkshire Fog, Soft Brome, and Wild Carrot in particular, which are capable of abundant seeding on grassland and which are common impurities of the Ryegrasses (Yorkshire Fog and Soft Brome) and Red Clover (Wild Carrot)—species usually sown in large quantities—a very small amount (less than 1 per cent) included in a sample may be sufficient to introduce enough plants to produce a sufficient seed crop, progressively increasing year after year, to completely ruin a sward in a surprisingly short time. It is important, therefore, that the farmer should satisfy himself that his samples of Ryegrasses are practically free from Yorkshire Fog and Soft Brome, especially when sowing upwards of a bushel to the acre, and the same applies to Wild Carrot in Red Clover, particularly if sowings of 10 to 16 lb. per acre are contemplated.

Seeds of Docks and Cleavers are sometimes met with in samples o vegetables, while in cereals the most harmful weed seeds found in sample are those of the Rye Brome Grass (*Bromus secalinus*), Docks, Cleavers Wild Radish, and Black Bindweed. The first of these is sometimes ver abundant; it has been met with in amounts up to 5 per cent in sample

[1] The figures are average of those given for the two seasons 1920–21 and 1921–2 See " Fifth Annual Report " (loc. cit.).

[2] The most usual injurious impurities are Docks, Wild Carrot, and the Cut-leave Crane's-bill (*Geranium dissectum*). [3] Not including Wild White Clover.

[4] The most usual injurious impurities are Sheep Sorrel and the smaller Crane's-bi (*G. molle* and *G. pusillum*).

[5] The most usual injurious impurities are Soft Brome and Yorkshire Fog.

tested at Aberystwyth. Fields have been frequently noted in Wales where this Brome Grass has completely ruined crops of oats and barley, and thus precautions should always be taken to clean the seed out of cereal samples.

Other Weed Seeds.—Apart from the injurious weed seeds, samples may contain: (1) the seeds of species which, although plentifully establishing themselves, are not so markedly detrimental or in certain cases may even be valuable; and (2) the seeds of weeds that seldom take a dominant place on grasslands in this country. Amongst the former, Ribgrass and Self Heal are the most plentiful. Self Heal is a weed pure and simple on grassland, while Ribgrass in excess is to be regarded as a weed on most grasslands but has a decided value on very poor and dry soils. The seeds of a number of foreign weeds do not establish themselves under our conditions, and are therefore from the land-fouling point of view without significance.

Index Seeds.—The seeds of foreign weeds have in certain cases a very decided value, that is to say, they may afford an important clue as to the country of origin of the samples containing them.

Inert Matter.—Small stones, grit, dirt, chaff, and the like detract from a sample only in as much as the purchaser is paying for material which is useless. It is usual to include with inert matter seeds that are so badly broken that they are manifestly incapable of growth.

Other Characteristics of Seeds.

A laboratory test can give information of great value to the grower in respect of three further important attributes of seeds.

Seed-borne Diseases.—Bunt and Ear Cockle can be easily detected in wheat, and the presence of these diseases is usually reported by official stations. Close examination can reveal the presence of smuts and certain other fungus and insect diseases; and no doubt as methods of detection are perfected it will become practicable to report on the presence or absence of the great majority of seed-borne diseases.

Grain Weight.—The grain weight is usually expressed as the average weight of 1000 seeds in grammes. It is unfortunately not the practice in this country, at all events, to report the grain weight of a sample sent to an official station to be tested.

A knowledge of grain weight is in certain cases valuable as a further clue to the country of origin or even the variety or strain of the sample, and in the case of cereals in particular is of great assistance in deciding upon the seed rate. It is also useful in arriving at the average number of seeds per pound for the different grasses and clovers, and is thus essential with reference to drawing up seeds mixtures. In this connection, however, average figures are usually relied upon. It has been before stated that the modern tendency is to grade up seeds to a large size, consequently the number of seeds per pound is now generally less than that given in older works; the number of viable seeds (= seeds capable of growth) per pound, by virtue of a higher average germinating capacity is, however, usually greater than was the case twenty or thirty years ago. Although average figures give a fair guide as to the amount of seed to be sown, it must be remembered that in the case of Red Clover, for example, there is a wide discrepancy between the grain weight of different nationalities and strains, and it is often desirable to adjust the seed rate on the basis of exact determinations.

Moisture Content.—The moisture content of seeds has a considerable importance, particularly in relation to the keeping ability of a bulk. This is information that can be obtained by a special laboratory test. Moisture tests are made at a number of the Continental stations, but are not at present conducted at the official stations in this country. It is much to be desired that these tests should be undertaken, and average figures obtained over a number of years for numerous clearly defined districts.

The Interpretation of Results of Seed Tests.

The whole value of seed testing depends upon the farmer's ability to interpret accurately the results with which he is provided. It is essential to distinguish clearly between the various properties of seeds that render them valuable for crop production. On the one hand it is necessary to estimate the value of the seed as such—its purity, germination, and freedom, or the reverse, from all defects, and on the other hand to give proper weight to nationality, variety, and strain.

Real Value.

By real value is understood the amount of pure seed capable of growtl contained in a sample. Real value is readily calculated as follows:

$$\text{Real Value} = \frac{\text{Germination per cent} \times \text{Purity per cent}}{100}$$

With a knowledge of the real value and grain weight of a sample th number of viable seeds per pound can be readily calculated, and thus th price asked per pound for various samples can be compared.

Comparisons made on the real value basis entirely ignore the presenc or absence of land-fouling weeds—the presence of which in a samp even in small amount should be regarded as more detrimental than, sa a difference in real value of upwards of 10 or 15 per cent, provided th real value does not fall too low; while upwards of 1 per cent of such weec should generally, no matter how excellent the real value, be regarded a sufficient grounds for rejecting a sample.

Nationality, Variety, or Strain.

The farmer who selects his seed only on the basis of the seed-test data with which he is provided is likely in many cases to be sadly disappointed when it comes to the supreme test of crop production. This is particularly the case in respect of Red and White Clover, Sainfoin, and many of the vegetables. It is obvious that the more favourable the climatic conditions under which a crop is grown and harvested the better will be the germination of the seed, and it is equally obvious that in proportion as seed passes through the hands of well equipped seed houses, the higher will be its purity and the more complete its freedom from land-fouling weeds.

It is very generally realized that onion seed from California does not give such good crops in this country as seed harvested in Bedfordshire, and that there exists in England and Wales strains of Red Clover and Sainfoin which are vastly superior to the crops produced from imported seed, particularly for the longer duration leys; while of imported clovers some are better than others, that from Italy, for example, being particularly unsuited to our conditions.

A very striking example of the differences given by germination tests between home-grown and imported seed is afforded by the results obtained from Indian or Californian barley in comparison with British; in good seasons the British may germinate nearly as well as that from the countries mentioned, but whereas the British will usually germinate relatively slowly, the Californian and Indian will often be capable of germinating to practically 100 per cent in no more than two days, that is to say, they will have an altogether higher energy of germination.

The following statement speaks for itself in respect of home-grown and imported clovers and onion seeds.

The average germination of 145 samples of onion seeds tested at the official station during 1917–8 was 78·9 per cent. The great majority of these samples were, however, of Californian origin; the English-grown seed then tested only gave a germination of 57 per cent.

The average germination over a five-year period for English Red Clover compared with various foreign nationalities is shown by the following figures: English, 76·3 per cent; French, 90·3 per cent; Czecho-Slovak, 89·2 per cent; Chilian, 90·6 per cent; American, 90 per cent; and New Zealand, 91·7 per cent.[1]

The figures from the "energy" test are usually even more striking. Thus Stapledon in 1917 compared Chilian samples with British with the following results. The Chilian germinated 70 per cent in 20 hours, and in three days germinated within 4 per cent of the figure reached in ten days. The British germinated 53 per cent in 20 hours, and in three

[1] See "Fifth Annual Report of The Official Seed Testing Station" (loc. cit.).

days showed a germination of 11 per cent less than that in ten.[1]

It is therefore apparent that the farmer must not expect home-grown seed to attain to such high germinations as much of the foreign, and that it is entirely misleading to compare germination and even more misleading *to compare energy figures of one sample with another unless previously correctly informed as to the source of origin of the seed.*

It is, however, in the case of home-grown seed, with its tendency in the direction of poor germination, that the results of tests are so important. It is of very little significance whether a sample of Chilian Red Clover or Californian Onion germinates 90 per cent or 95 per cent, but it is of considerable moment to know that one lot of, say, genuine Welsh-grown Red Clover germinates 50 per cent and another lot 75 per cent.

From the point of view of crop production, therefore, the farmer must first satisfy himself that the samples he is considering represent the nationality, variety, or strain he requires, and then compare them with each other on the basis of freedom from weeds and real value, and he should be backed by a knowledge of the real value he can reasonably expect from the source which experience has taught him he may with safety procure the seeds that best suit his needs.

In some years he may have to be content with real values nearly as low as 50 per cent, and in others he may look for over 80 per cent. In the case of Red Clover, for example, it would not be an overstatement to say that the farmer in regions of high rainfall, sowing a long duration ley, would be better advised to procure a genuine English or Welsh Late-flowering Red Clover with a real value as low as 60 per cent, than a Chilian Red Clover with a real value of 98 per cent; while a Welsh sample with a real value of 30 per cent would be superior to an Italian sample with a real value of 100 per cent—always supposing that the home-grown samples were reasonably free from land-fouling weed seeds, and that the seed rates are adjusted in sympathy with the real values.

A Nationality Test.

It is unfortunately impossible to conduct a test other than a growth test to ascertain the variety or strain of a seed sample. Similarly, it is not possible to conduct tests with a view to establishing with certainty the country of origin of a sample. It has been seen that germination and energy may provide a valuable indication; thus after poor harvests the buyer may well be sceptical of the genuineness of a Welsh Red Clover if the germination is high,[2] and still more sceptical if the energy is high.

The appearance, grain weight, and nature of the impurities afford further guides to the nationality of a sample, so that in the case of Red Clover, at all events, it is possible with a little practice to form at least a

[1] See R. G. Stapledon, " Seed Studies ", in *Jour. Agr. Sci.*, Vol. X, Part I, Jan., 1920.
[2] In many years 90 per cent or even 85 per cent would be a decidedly high figure.

fairly accurate opinion as to whether a sample represents seed harvested in England or Wales or that imported from abroad.

The following brief notes may be helpful in this connection.

British Seed.—British samples, particularly those grown in Wales and the west of England, are prone to contain more brown seed than foreign (this is markedly so after years of bad harvest); they usually contain less yellow seed than foreign, especially than Chilian, Italian, and Canadian. British seed is usually larger and weighs more per 1000 than foreign, with the exception of Chilian. There are no impurities that may be regarded as typically British, although excess of Cut-leaved Crane's-bill (*Geranium dissectum*) is more usually associated with British than other samples. Should seeds of Lucerne, Chicory, Ox Tongue, Setaria spp., or other foreign species be present, this would afford grounds for regarding the sample as not wholly of British origin.

Chilian Seed.—This is the largest of the commercial seeds; the samples are always of a bright, bold appearance, and usually contain over 30 per cent of yellow seed. The germination is invariably high. Most samples contain at least a trace of the large Dodder (*Cuscuta racemosa*, var.), and, like most of the foreign clovers, frequently contain Lucerne.

Canadian, French, and Italian Seed.—The seed of these nationalities is small, usually with fairly high percentages of yellow seed. Dodder is not infrequent in these samples, the Chilian Dodder being sometimes found in samples purporting to be Canadian and the European Dodder in French and Italian. Seeds of Timothy and of Alsike Clover are very frequent in Canadian samples, whilst Lucerne is particularly frequent in Italian and French samples. Both these latter nationalities are characterized by the presence of Ox Tongue (*Picris echioides*), whilst Sulla (*Hedysarum* spp.) is frequent in Italian samples, and Wild Carrot (*Daucus Carota*) more plentiful in samples from France than from other sources.[1]

Central European Seed.—Seed from these sources is intermediate in size between British on the one hand and Canadian, French, and Italian on the other. Dodder is a more frequent impurity of these than of other European samples, both the large and small species being freely met with. Lucerne is perhaps even a more common impurity than in Italian samples, whilst Mayweeds in large or appreciable amount are more often met with in Red Clover from Central Europe than from other sources. Rib-grass (*Plantago lanceolata*) and Docks (*Rumex* spp.) are met with in samples of Red Clover from practically all sources.

The Average Quality of Agricultural and Vegetable Seeds.

The germination of seeds naturally varies considerably from year to

[1] For further particulars as to nationality tests on Red Clover, see " Seed Studies ", (loc. cit.)

year. It remains a fact, however, that the seeds of some species tend to give high germinations while those of other species tend to give low figures. The average germinations for the chief species are given in Tables I and II, together with average purity, the figures being those obtained at the official station at Cambridge over the five years 1917–22. The grain weights are also shown; the figures given for the grasses and clovers are based on weights from modern high-grade samples kindly obtained for the author by Mrs. Bury; the grain weights for the vegetables have been kindly provided by Mr. Saunders from data obtained at the official station at Cambridge.

TABLE II.—THE AVERAGE QUALITY OF THE CHIEF FIELD AND VEGETABLE SEEDS

The prices cannot usefully be compared, since they vary considerably for the different varieties

	Germination.[1]	Grain Weights per 1000 Seeds in Grammes.	Number of Viable Seeds per Pound.[2]
Peas, Field and Garden ..	84·8	— [4]	—
Beans, Field	96·6	— [4]	—
Beans, Broad	94·7	— [4]	—
Beans, Runner	75·8	— [4]	—
Beans, Dwarf	83·8	— [4]	—
Vetches	90·8	— [4]	—
Turnips	88·2	1·85	214,000
Swedes	84·4	2·90	131,000
Rape	86·0	4·06	95,000
Kale, Thousand Headed ..	78·3	3·10	114,000
Kale, Marrow Stem ..	—	3·96	—
Cabbage	77·5	3·40	102,000
Brussels Sprouts	*76·8*	*3·35*	*103,000*
Broccoli and Cauliflower ..	73·0	2·80	117,000
Mangel	75·0[3]	18·99	17,900
Beet, Garden	68·6[3]	14·56	21,000
Parsnip	59·0	4·09	65,000
Carrot	64·5	1·17	248,000
Onion	71·1	4·10	78,000

[1] Average figures from the Official Seed Testing Station at Cambridge over the five-year period 1917–2.

[2] Calculated on the assumption of an average purity of 99 per cent in all cases.

[3] Results for 1921–2 only, and represent percentage, weight, and number of "seed" in terms of clusters.

[4] Owing to large differences between the varieties, average figures are without significance.

The price per pound of commercial seed in 1913 compared with that in 1923 is given in the case of the grasses and clovers, the figures representing averages obtained from the same seedsmen's catalogues in the two years. The values cannot be taken as absolute, since there is always a considerable difference in the prices quoted by different merchants.

The approximate number of viable seeds per pound and the approximate cost of 1,000,000 viable seeds are also shown in the table. The former figures serve to indicate that the number of good seeds obtained in a pound varies within wide limits as between the different species.

Speaking generally, it is those seeds with the fewest viable seeds per pound that are the most expensive per commercial pound also, it is thus evident that seeds like Meadow Foxtail and Golden Oat Grass are exceedingly costly, when considered from the point of view of the price of 1,000,000 good seeds. Judged by the same standard it will be seen that Timothy, although costing more per pound than the Ryegrasses, is yet the cheapest grass or clover seed that the farmer can buy.

LEGISLATION IN RESPECT OF SEEDS

The first official station to be opened in the United Kingdom was that of the Department of Agriculture and Technical Instruction for Ireland which started operations in Dublin in 1900. In 1909 the Weeds and Agricultural Seeds (Ireland) Act was passed, and on the 1st January, 1910, seeds legislation came into force in that country. The Board of Agriculture for Scotland established an official station in Edinburgh in 1914, but this was not supported by seeds legislation. It was not until the War that an official station was started in England. The Testing of Seeds Order came into operation in January, 1918, and this rendered necessary an official station, which was established at the Food Production Department in Victoria Street at the end of 1917 in anticipation of the order. In 1920 the Testing of Seeds Order was replaced by the Seeds Act, which thus made permanent one of the most far-reaching minor reforms in the interests of good agriculture. The official station for England and Wales was moved from London in 1921, and in the autumn of that year was installed in specially built laboratories at the head-quarters of the National Institute of Agricultural Botany at Cambridge, and now annually conducts tests on upwards of 20,000 samples.

Under the terms of the Seeds Act it is arranged that regulations shall be issued from time to time; the most recent regulations are those of 1922. The chief provisions of the Act as specified in the different regulations are briefly as follows.

General.—But for a few minor exceptions certain particulars have to be supplied by the vendor to the purchaser at or before the time of sale or delivery of the seed of all species covered by the regulations. It is

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General.—But for a few minor exceptions certain particulars have to be supplied by the vendor to the purchaser at or before the time of sale or delivery of the seed of all species covered by the regulations. It is important that farmers should realize that the necessary particulars have to be given in the case of sales between farmer and farmer equally with sales between merchant and farmer, and that the Act applies to cereals as well as to grasses, clovers, and other seeds.

Cereals.—The distinctive name of the actual variety must be stated. If the germination is not less than the authorized minimum germination presented in the regulations, a statement that the germination is not less than the minimum (the figure must be stated) is sufficient. If the germination is lower the actual germination must be stated.

The authorized minimum percentage of germination in the 1922 regulations is for wheat, 90 per cent; barley, 90 per cent; oats, 85 per cent; and rye, 80 per cent.

The regulations do not at present demand any statement in respect of purity or as to the presence of seed-borne diseases.

Roots, Pulses, and Other Field Seeds.—The distinctive name of the variety has not to be stated. The actual germination has only to be stated if less than the prescribed minimum for each species.

The actual purity need not be stated unless below 97 per cent (or 90 per cent in the case of carrot seed; the seed of this species often contains rather much immature seed which is considered as impurity).

The authorized minimum percentage of germination is as follows for each species (1922 regulations): Tares or Vetches, 90 per cent; Mangel, 60 per cent of clusters; Field Beans, 90 per cent; Field Peas, Swede, Rape, and Turnip each 80 per cent; Cabbage, Kale, and Kohl Rabi each 70 per cent.

Garden Seeds.—The regulations in respect of garden seeds are similar to those applied to field seeds, except that in the case of "packets" certain modifications are made. The following minimum percentages of germination apply to garden seeds (1922 Regulations): Peas, Cabbage, Kale, and Brussels Sprouts, 70 per cent; Broad Beans, Dwarf Beans, and Turnip, 75 per cent; Runner Beans, Onion, Cauliflower, and Broccoli, 60 per cent; Carrot and Beet (of clusters), 50 per cent; Parsnip, 45 per cent.

Grasses and Clovers.—Perhaps the most important declaration to be made in the case of grasses and clovers is the country of origin or nationality of the seed. The actual germination has to be stated except in the case of the Ryegrasses, which are treated in the same way as the cereals, the authorized minimum germination being as follows: Perennial Ryegrass, 85 per cent; Italian Ryegrass, 80 per cent. In the case of clovers the percentage of hard seed has to be stated.

The actual purity must be declared except in the case of the Ryegrasses, when if not less than 98 per cent a statement to that effect is sufficient.

The total per cent by weight of injurious weed seeds has to be stated when over 2 per cent in the case of the grasses, and when over 1 per cent in the case of the clovers.

The injurious weed seeds for the purposes of the Act are as follows: Docks and Sorrels (*Rumex* spp.), Crane's-bills (*Geranium* spp.), Wild Carrot (*Daucus carota*), Yorkshire Fog (*Holcus lanatus*), and Soft Brome Grass (*Bromus mollis* et spp.).

If the percentage of Suckling Clover and of other related clovers[1] exceeds 2 per cent in Alsike, White, or Wild White Clover the exact percentage must be declared. If Burnet exceeds 5 per cent in samples of Sainfoin, the exact percentage present must similarly be declared.

The presence of Dodder has to be declared when: more than one seed is present in 1 oz. for Wild White Clover; more than one seed is present in 2 oz. for Timothy, Alsike, and White Clover; and when more than one seed is present in 4 oz. for Red Clover, Crimson Clover, Lucerne, and Flax seed.

For further details as to the regulations the reader should refer to the full text of the Seeds Act and of the Seeds Regulations, and also to the explanatory leaflet issued by the Ministry of Agriculture.[2]

It will be apparent from the above brief review that the chief aim of the Act is to provide the farmer with exact information as to the quality of his seeds; it therefore rests with the farmer himself to turn the provisions of the Act to the best advantage in respect of crop production.

There is, however, one very important prohibitory clause in the Regulations, and one which applies to the farmer equally with the seedsman, viz.: *Any person who sells or exposes for sale, or knowingly sows any seeds to which the Seeds Act, 1920, applies containing more than 5 per cent by weight of injurious weed seeds is liable to prosecution in accordance with the provisions of the Act.*

Farmers desiring to send samples to an official station to be tested should obtain from the official station at Cambridge (apply Chief Officer, Official Seed Testing Station, Huntingdon Road, Cambridge) or from the station at Edinburgh (apply Official Seed Testing Station, East Craigs, Corstorphine, Edinburgh) the publications of the stations setting out the fees, giving particulars of how to draw samples, the minimum weight of samples to be sent, and other information as to the conditions under which seeds are tested at the stations.

In addition to the three official stations mentioned in this section, the Official Seed Testing Station for Northern Ireland started operations early in 1923.

[1] *Trifolium dubium*, *T. procumbens*, *T. parviflorum*, *T. angulatum*, and *T. glomeratum*.

[2] The former may be obtained from H.M. Stationery Office, Imperial House, Kingsway, W.C., and the latter (Form No. 728/C.S.) from the Ministry of Agriculture, 10 Whitehall Place, S.W.1.

THE TECHNIQUE OF SEED TESTING

The testing of seeds is a matter demanding a considerable amount of skill and knowledge. Although the farmer in many cases can conduct simple tests for his own information, that is to say, he can ascertain whether the germination and purity is reasonably good, it is difficult for him to obtain absolutely reliable and accurate results. If a home test reveals obvious defects he should always obtain the results of an official test in cases where he wishes to take action with the vendor in respect of a particular sample. It must be remembered that a germination test made some considerable time after the receipt of a bulk of seed will not afford reliable evidence as to the condition of the seed at the date of its receipt. A purity test will, however, hold valid months after a sample has been received, and thus in the case of grasses and clovers a small and carefully taken sample should always be retained for future reference if necessary.

The accuracy of a test on seeds is in the first place determined absolutely by the accuracy with which a sample taken for testing is drawn from the bulk which it represents.

Sample Taking.

A considerably larger sample should be taken from a bulk than would be sent to an official station for testing. In the case of bulks in large heaps or bins a large number of small samples should be drawn from different parts of the bin or heap (bottom, middle, and top), and in the case oi seeds in sacks, samples should be drawn from towards the bottom, middle and top of each sack. All the samples drawn should be thoroughly mixec together and then reduced to the necessary size for sending to be tested by a process of dividing, mixing, and rejecting until sufficiently reduced Thus the whole sample would be divided into two portions, each portior should be well mixed, and then each again divided and the process agaii repeated; then of the eight little portions every other one would be dis carded.

The four portions remaining would be mixed together and then th whole process gone through again, and if necessary again and again unt the sample was twice as large as was required for a test. At the last prc cess, say, the odd divisions would constitute the sample sent for testin; and the even divisions would constitute a duplicate sample which shoul be retained.

A sample drawn from a bulk for the purpose of testing should alwa be considerably larger than the sample upon which the actual test w be made.

The amount necessary for an accurate test will vary from about 1 gm. in the case of large seeds like peas and beans, to about ½ gm. in tl case of the smaller grasses. The bulk sample should be worked down to the appropriate size by a process very similar to that described on p. 276.[1]

The Purity Test.

Having obtained a representative test sample of about the right size, the first process in testing is to conduct the purity test. This consists of dividing the test sample into two portions, one consisting only of the seed which the sample represents and the other of all impurities—dirt, badly broken seed, chaff, and weed seeds. This is most easily done by placing the sample on a glass sheet and drawing out the seed from left to right in a narrow stream, and then removing the impurity towards, say, the top and the pure seed right away towards the right of the sheet. The size of the two heaps, " pure " and " impurity ", will give a very good index of the quality of a sample. So far the farmer may easily conduct a purity test for himself; all he requires is a knife, a piece of glass, and an ability to recognize the seeds of the crop he is considering—say Wheat, Red Clover, or Cocksfoot. The next process is to identify the weed seeds and separate these into injurious and non-injurious, and to separate weed seeds from inert matter and from other valuable seeds.[2] The final process involves the use of a precision balance and the application of a little simple arithmetic.

Where official tests are concerned, and where it is absolutely necessary that tests made by different stations should give practically similar results, a number of difficulties present themselves; these are fully dealt with in the leaflet issued from the official station at Cambridge, previously referred to. The chief difficulties are those connected with broken seed, insect-attacked seed, and with tests on the grasses. In regard to broken seed and insect-attacked seed, such seed is deemed to be impure when the damage is so severe, particularly at the root or radicle end of the seed, that germination is an impossibility. These are, however, distinctions which only the trained analyst can accurately make, and need not be considered in the present article.

Purity Tests of Grasses: "Irish" and Continental Methods.

It will, however, be necessary to deal in a little detail with the methods employed in testing grass seeds. It should in the first place be explained that the germination test is of course only conducted on the pure seed;

[1] A slight modification of the method of obtaining a bulk sample is used at the Official Station, and is described in detail in *Methods of Seed Analyses*, by C. B. Saunders, issued by Nat. Inst. of Agric. Botany.

[2] With a very little practice, the farmer can identify the injurious and other chief weed seeds for himself. He should have for reference the admirable book on weed seeds, *Impurities of Agricultural Seed*, by S. T. Parkinson and G. Smith. He may refer also to the leading seed firms' catalogues, in which the chief weed seeds are generally very accurately illustrated. When unable to identify the seed, he has only to send same to the Agricultural Organizer for his county, or to the nearest Agricultural College.

thus if seed which is obviously incapable of germination, such as badly broken seed or seed obviously defective in any essential respect, is placed with the "pure" seeds, the germination will be by that much reduced.

The commercial seeds of most of the grasses resemble rather oats than wheat, that is to say, they do not consist merely of a caryopsis or a kernel, but of a kernel surrounded by a pair of scales (= pales) and sometimes surrounded by a further pair of scales (= glumes). Thus the commercial seed is more than just a seed, it is the seed plus the scales; and since the scales surround and hide the kernel, particular seeds are recognized, and those of one grass are distinguished from those of another, by the appearance and characteristics of the scales and *not of the kernel*.

It often happens that no kernel is developed within the scales, and yet from casual observation this fact would pass notice—when a structure devoid of kernel, and therefore strictly speaking having none of the attributes of a seed and incapable of germination, would none the less be considered as a seed. When kernels are not developed within the surrounding scales it is customary to speak of the kernelless structure as a "light seed".

These light seeds have been and still are responsible for a great deal of disagreement amongst official seed analysts all the world over. Should they be regarded as seeds proper and placed with the pure seed and so contribute to the germination test, with inevitable reduction of the percentage germination, or should they be taken out with the impurity?

On strictly scientific grounds it would seem that since light seeds are in fact not seeds at all they are therefore impurity, and the matter thus decides itself. In practice, it is, however, found that all gradations occur between a well developed kernel, rudimentary kernels, and scales utterly devoid of kernels. Thus the separation of light from heavy seed is far from a simple matter, and unless the methods employed are very well standardized as between different stations, the separations made at different stations on samples drawn from one and the same bulk are likely not to show sufficiently good agreement. In addition to this, the withdrawing of light seed from a sample adds greatly to the work of testing and demands a higher technical skill.

The matter has an added importance, since the real value result may be greatly influenced by the method employed. Thus, for example, in the case of, say, Perennial Ryegrass with a high percentage of light seed, since this seed is *light* it will not depress the purity—if placed with impurity—to nearly the same extent as it will depress the germination if placed with the pure seed.

Thus a test conducted on the former plan will show a very much higher real value than one carried out on the latter.

The Irish station at Dublin and a number of stations in the British

Empire adopt the method of including light seed with the pure seed, and this practice has come to be spoken of as the "Irish method"; the leading Continental stations, however, adopt the plan of including light seed with impurity, known as the "Continental method", and recently this procedure has been followed by the official station at Cambridge.

There is no doubt that particularly in the case of poor samples the Continental method "puts the best face on the sample", and since the farmer sows light and heavy seed alike and can hardly be expected to distinguish between them when handling a sample, there are reasons for thinking that the Irish method gives the farmer the truer index of the value of the sample. On the other hand, since the Continental method shows of what a bulk is inherently capable, this provides the most valueable information to the seed merchant proper, particularly with reference to imports and large-scale transactions, for he can estimate the amount of dressing necessary to produce a high-grade sample from a bulk containing a considerable amount of light seed.

As to which method, all things considered, is in the highest interest of the agricultural community is a matter that should be settled once and for all, for it is deplorable that agreement cannot be reached on so fundamental a question by all the seed-testing stations of the world.

The Germination Test.

The percentage germination is ascertained by arriving at the number of seeds per 100 capable of growth. A test is usually made by putting up five separate sets of 100 seeds each and taking the average result. In the case of large seeds like peas and beans the sets may be 25 or 50 seeds each. It is essential that seeds fairly representing the sample are taken for the sets. There must be no selection of the larger or plumper seeds. The 100 seeds should be counted by spreading the pure seed out in a stream and removing two, three, or five at a time, making ten little heaps of ten seeds each. The several sets should be collected on separate watch glasses ready for placing on the prepared "seed bed".

The 100 seeds should be well spaced out so that none touch each other on the seed bed. After two to seven days according to species, all that have sprouted should be removed and counted; counts will be made on each subsequent day until the duration of the test is completed. The total of the counts plus the seeds which will not have sprouted should add up to 100, and the total of the sprouted seeds of course gives the percentage germination for each set. The first count may be taken to represent the energy of germination.

A number of precautions have to be taken in conducting a germination test; the moisture and temperature of the seed bed and the nature of the seed bed itself are all matters demanding careful attention.

Over saturation is always to be avoided; the aim should be to keep the seed bed just sufficiently wet to prevent its drying out altogether. A slight fluctuation in the degree of moisture of the seed bed seems to help germination in some cases and to some extent probably favours the germination of hard seed.

It is now generally realized that a fluctuating temperature is the best for the germination of all seeds. The range of temperature required varies considerably for different species, and it should never be allowed to fall below or exceed the limits to which the several species are suited.

Species with small seeds germinate readily if merely placed on a sufficiently moist surface; larger seeds like peas, beans, cereals, vetches, and mangels need to be more or less surrounded by a moist medium. Filter paper or blotting-paper (the latter for home use) makes the best bed for the small seeds, while fine sand serves admirably for the larger seeds, and these are usually pressed lightly into the sufficiently moistened sand.

When counting off the germinated seeds care must be exercised only to count seeds which have developed a definite radicle or root growth. Sometimes the germination will be abnormal when the cotyledons (young leaves) may break through the seed coat first; such seeds must not be counted off unless or until they show root growth. In other cases what are known as " broken growths " occur, that is to say, during the process of germination one or both of the cotyledons or the root may break off. Seeds which behave in this manner will have been internally fractured or broken during the processes of cleaning and dressing, and this is most common in the case of Trefoil and Crimson Clover. Internally broken seeds of this sort are seldom capable of producing seedlings, and therefore they should not be counted as germinable seeds.

The question of abnormal and broken growths is a difficult one and is calculated to lead to disputes in respect of the results of tests. This question is fully dealt with in the leaflet previously referred to, and should be carefully studied by all who are actively concerned with the conduct of tests.

The experience gained at official stations over a number of years has made it possible to draw up a schedule showing the number of days which tests on the various species should be allowed to run, and the number of days given is practically the same at all stations.

Table III shows the methods adopted for the various species at the official station at Cambridge; the facts given in the table may, however, be supplemented by a few brief notes in respect of the chief crops.

Cereals.—It is essential to test wheat, oats, and barley at low temperatures, and within reason to keep the seed bed as dry as possible. It is often found that cereals do not germinate properly when tested immediately after harvest. Thus difficulties often occur with winter oats and winter wheat. The difficulty can generally be overcome in the case of wheat by drying for three days at about 40° C. before conducting the test. With oats it is generally necessary to dry for a longer period at ordinary room temperatures.

Farmers can easily conduct informing tests for their own use with cereals by placing the grain in sand in garden pots or saucers. The pots should be kept in a cool room.

Roots and Vegetables.—It will be noted from the table that mangels, parsnips, and carrots require fluctuation in the direction of rather high temperatures for the best results to be obtained.

Two methods may be employed in counting out mangels from the germination test. The commercial seeds of mangels and beet consist of fruits, each fruit being a cluster of several seeds. A good sample may therefore give about 250 or even 300 germinable seeds from 100 clusters, about 160 being a good average. The germination may be expressed by counting the seedlings when the figure should exceed the 100; this was the plan originally adopted at the official station. On the other hand, the cluster may be taken as the unit, that is to say, a cluster which produces but one seedling equally with one which gives rise to two or three is counted as having germinated, and the germination is expressed by the number of clusters per 100 which will have produced one or more seedlings. Judged by this standard 65 to 75 per cent represents a fairly good sample. This is the method now adopted at the official station.

In the case of mangel and beet, clusters which contain no seeds should not be counted into the germination test, but should have been removed with the impurity.

The seeds of swedes, turnips, and other Brassica are best germinated on moist filter papers and as a rule present no great difficulties, but like the cereals sometimes germinate poorly immediately after harvest.

The farmer can conduct useful tests for himself in the case of these seeds by placing moist blotting-paper on a saucer and, after spreading out the seeds, inverting a second saucer over the first.[1] The receptacles may be conveniently placed on the mantelpiece of a room in which a fire is maintained during the day. The blotters must be sprayed once or twice a day in order to prevent drying out.

Simple home tests are not likely to be very reliable in the case of mangels, beet, parsnips, and carrots.

Grasses.—The tests on grasses are invariably conducted on moist filter papers. Some species germinate best in the light; the Meadow Grasses are favoured by being exposed to actual sunshine.

The method usually adopted in the case of seeds requiring light is that employed at the station at Copenhagen. Tanks containing water,

[1] Ventilation can be assured by raising the second saucer from the first at one or two points by the insertion of wedges; matches answer the purpose sufficiently well.

the temperature of which can be regulated, are set out in a well lit room. The sets of seed to be germinated are placed on filter papers which in turn rest on glass strips or other convenient supports about an inch above the surface of the water. The filter paper seed beds are kept moist by other filter paper or wicks dipping into the water below. Too rapid evaporation is prevented by placing over each set a small bell jar provided with a proper ventilating opening at the top.

It has been found that in the case of Tall Oat Grass and Sweet Vernal Grass in particular, germination is assisted by carefully shelling out the kernels before conducting the germination test.

Home tests are difficult to conduct with the grasses, but the farmer can obtain useful preliminary indications in the case of the Ryegrasses, Timothy, and Meadow Fescue by employing the saucer method described above.

Clovers.—The clovers are usually tested in closed incubators running at about 22° C. The Hearson incubator is now very generally employed for seeds of this sort.

It has been found desirable to cover clover seeds with a fold of filter paper.

At the official station a double layer of moist flannel is placed on the incubator tray, and on this the sets are placed, each enclosed in folded filter paper of a rather thick texture. It is in the case of the clovers that abnormal germination and broken growths are most commonly met with, and on this account it is not desirable that the first germination count should be made until the test has been running for three days.

Home tests conducted on the saucer plan may be relied upon to give a useful indication of the character of a sample of clover seed, and such tests should always be conducted by the farmer who is in doubt as to the quality of his seed or who intends employing yearling seed which may be in his possession.

Methods Employed at the Official Station at Cambridge.

The methods employed at the official station are set out in Table III facing. The table has been reproduced from the leaflet published by the National Institute of Agricultural Botany, "Methods of Seed Analyses", C. B. Saunders.[1] The article in question gives very full particulars with reference to the technique of seed testing, and should be referred to by all students of the subject and by those who are requiring detailed information.

[1] Thanks are due to the National Institute of Agricultural Botany for permission to reproduce the table in question.

INSECT ENEMIES OF PASTURE PLANTS

By R. STEWART M'DOUGALL, M.A., D.Sc.

The insect enemies of cereals and leguminous plants have already been described (see Vol. I, p. 337), and speaking generally they, or most of them, stand as the chief enemies of pasture, clovers, vetches, lucerne, and sainfoin. On a pasture, however, it is very difficult to bring into play the remedial measures that can be attempted with some success against field crops that last only for a year or a season.

The Coleopterons or beetle enemies likely to affect pasture are wireworms and the larvæ of the chafer beetles, especially the larva of the Cockchafer, and on hill pastures the larva of the Garden Chafer (see Vol. I, p. 340). Different species of Sitones (already described, see Vol. I, p. 354) weevils attack the various clovers, vetches, and lucerne, the adults destroying the leafage and young shoots, and the larvæ being destructive at the roots.

A genus of weevils, named Apion, rich in species, contains forms harmful to clovers, lucerne, and sainfoin. These beetles are minute in size, e.g. *Apion apricans* of red and white clover measures $\frac{1}{10}$ in., and are commonly known as the pear-shaped weevils as the distinct snout projecting from the oval body suggests a pear with its stalk. While the adult weevils may do a little damage by mining stem or root, or puncturing young shoots and leaves, the chief damage is due to the larvæ or grubs. These grubs are typical weevil grubs, legless, with curled wrinkled body, and dark heads with biting jaws.

In the British species, concerning which complaints are made, the grubs live in the flower-heads and pods of clover, vetches, lucerne, and sainfoin, feeding on and in the seeds. More than one species of Apion can be found attacking the same plant.

The life cycle of the pear-shaped weevils is not a long one, so that two or more generations can take place in a growing season. Winter is passed, generally in the adult condition, in some sheltered place, the beetles appearing from their winter quarters in spring, to proceed to feeding, pairing, and egg-laying. Pupation follows in the place where the larvæ have been feeding. Attention is called to the presence of the enemy by the discoloured, prematurely faded, infested flower-heads.

LEPIDOPTEROUS ENEMIES

The Antler Moth or Grass Moth and the Common Rustic Moth have already (see Vol. I, p. 342) been described as enemies of graminaceous plants. An ally of the latter, the Rustic Shoulderknot (*Apamea* or *Hadena basilinea*) deserves mention as its caterpillar is a grass enemy as well as destructive to wheat. Professor Somerville recorded it in August, 1915, as harmful on some experimental wheat plots. The caterpillar measures up to 1 in. in length when full grown; the general colour is brown with a pale line down the middle of the back and two pale lines down each side, one high up and the other low down; the breathing pores down each side of the body are dark coloured. Here and there over the surface of the body black dots are seen from each of which a bristle springs.

The Rustic Moths belong to a family of night-flying moths, the Noctuidæ, to which the so-called surface caterpillars or cutworms belong Two more Noctuids with surface caterpillars need mention, viz. *Agrotis segetum*, the Turnip Moth, and *Agrotis exclamationis*, the Heart and Dart moth. Their caterpillars are often very harmful to root and garden vegetable crops, but they are general feeders and fodder grasses are among their food plants.

These Noctuids have a resembling life-history. The adults are found in flight in summer. The females lay their eggs in numbers on the shoots and leaves of plants, near the surface of the soil; the caterpillars live through the summer and autumn feeding on the above-ground parts of the plant and eating the plant across at the ground-level; the caterpillars feed at night and hide in the day-time in the surface layers of the soil. The very earliest of the caterpillars may complete their growth in the same autumn, but the commoner thing is for the caterpillars to pass the winter as caterpillars, either in a dormant condition or, if the weather be open and mild, continuing their feeding. Feeding is continued or renewed in the next spring, and is followed in late spring or early summer by pupation in the soil, the moths coming away in summer, i.e. the generation typically is an annual generation.

The caterpillars of *segetum* and *exclamationis* are rather like one another The *segetum* caterpillars are pale smoke-coloured or glossy grey with a faint pale, dark-edged dorsal line; the breathing pores down the sides are black and smaller than the dots or warts above and behind them under surface light grey; head grey with two dark arched lines. Th *exclamationis* caterpillars are light or dark brown with a pale line showing down the front rings; breathing pores dark, and as large or larger than the dots or warts above and behind them; under surface grey; head brown, with a dark streak down each lobe. Both caterpillars have sixteen legs.

The pupæ, found in an earthen chamber in the soil, are often turned up in digging; they are brown or yellow-brown; both pupæ end in two small diverging spines, but in the case of the pupa of the Heart and Dart moth the two small spines turn inwards at the tip.

Another Agrotis enemy of grasses is *Agrotis tritici*.

There are certain butterfly caterpillars that feed on leguminous plants, but none of them rank as serious enemies. Now and again the Clouded Yellow Butterfly (*Colias edusa*) is reported from Scotland, but more commonly from the southern parts of England. This butterfly belongs to the same family as our better known Cabbage White Butterflies. The caterpillar is dark green with a dark line down the middle of the back; the spiracular line is white or reddish with yellow spots, and along it are the red-yellow spiracles. The caterpillars feed in summer, and it may be also in autumn, on such plants as red clover, white clover, birds-foot trefoil, lucerne, sainfoin, and black medick or trefoil. The caterpillars of a rarer species, the Pale Clouded Yellow (*Colias hyale*), feed on the same plants. Caterpillars of another family of butterflies, the *Lycaenidæ*, are found typically on leguminous plants. Four or five different species are found on clover and allied plants, especially in the south of England, but none that can be described as harmful. The late Miss Ormerod[1] recorded a case of damage to stacks of clover, sainfoin, and hay due to the caterpillars of a Pyralis moth which Miss Ormerod named the Haystack Moth. Pyralis belongs to one of the families of small moths, and several Pyralis species lay their eggs in collections of rubbish, dried plant material, thatch, &c. One species introduced to the United States is a regular and troublesome enemy of stacked or stored clover, especially when such has been held over for a year or when placed on old hay. The caterpillars are only troublesome when the hay has been kept over the second year. The Pyralis species sent to Miss Ormerod breeds not only in stacks and plant-rubbish heaps but has been reared several times from the debris mixed up in the witches-brooms that are often a feature on the birch. The females are found in flight during the summer and early autumn; they lay their eggs under shelter in the stack, and the caterpillars feed on the material of the stack, at the same time spoiling the fodder with their excrement and their webs. Miss Ormerod quotes Buckler's description of the caterpillar: "Length $1\frac{1}{12}$ to $1\frac{1}{8}$ in., slender, back black bronzy green, paler along the spiracles, warts bearing hairs present". The full-fed caterpillar pupates in the stack under cover of a delicate white flattened cocoon. The cocoons are found in clusters.

[1] *Report on Injurious Insects* for 1894, p. 18.

It is more common, however, to have complaints, or at least questions, regarding the presence of mites in hay—ryegrass hay, meadow hay, clover ricks. Especially there are records in the literature of masses of mites in hayricks and in haylofts; sometimes at the base of a haycock hundreds of thousands of mites may be present, forming what look to the casual observer like little heaps of dust.

The mites may be of different species, but the common one is *Tyroglyphus longior*, a very near relative of the well-known cheese mite *Tyroglyphus siro*. *Tyroglyphus* has an interesting life-history. The females, which are eight-legged, lay their eggs over the material on which they chance to be feeding. From the egg hatches a tiny six-legged form which feeds and moults, attaining a fourth pair of legs; the adult sexual condition is reached after further moulting. A very remarkable intermediate stage may in certain conditions be passed through, viz. what is known as the hypopus stage. Instead of the adult condition being reached at once a hypopus is formed, namely a very hard-bodied form with short legs and no mouth or mouth-parts; this is a protective stage and one fitted for spreading, as the hypopus is furnished on its under surface with suctorial discs by which it can become attached to mice or passing insects and so be carried to other places. In a new and favourable environment the hypopus moults, and a normal, feeding mite stage is resumed, resulting in due course in a sexual male or female. The mites measure only from 0·28 mm. to 0·36 mm. (a millimetre is roughly $\frac{1}{25}$ in.), and so nothing of their structure can be made out with the naked eye. Under the microscope the body is seen to be elongated oval in shape with conical mouth parts, the legs end in hook and sucker, and bristles project from the body. Cattle or horses do not suffer any ailment from feeding on such mite-infested hay. If the mites are in great numbers and reach the skin, either of worker or of beast, there may be some very slight skin irritation. During the War, when numerous skin scrapings were made from horses suspected of mange (also due to a mite), examples of *Tyroglyphus longior* were found; the *Tyroglyphus* had doubtless come from the hay, fodder, or bedding.

DIPTEROUS ENEMIES

The worst of these have also been detailed elsewhere (see Vol. I). As regards the gall-midges mentioned, it may be noted in addition that one of the causes of the poor germinative capacity of Meadow Foxtail seed can be due to the previous presence of the larvæ of Diplosis in the flower-heads of the grass.

The larvæ of the Daddy Long Legs (see Vol. I) is sometimes confused with another larva found abundantly at the roots of grasses, viz. the larvæ of the Bibio flies. The Bibio flies sometimes appear in immense numbers in spring and early summer in meadows and among fruit-trees, where they often settle on the blossom. Their great numbers may cause alarm, but the adults are harmless (they lay the eggs, of course). The larvæ of three species can be found in large numbers at grass roots, viz. the Fever Fly (*Dilophus febrilis*), St. Mark's Fly (*Bibio marci*), and St. John's Fly (*Bibio johannis*).

The larvæ are found in the soil not singly but many together. At first sight a well-grown Bibio larva suggests a Leather-Jacket or Crane Fly larva, because of position in the soil, colour, and tough external covering. If the larva be cleared of soil, however, and examined with a lens very distinct differences will be seen.

In colour a Bibio larva is brown or grey-brown, and its tough skin—under a higher magnification than a hand-lens—shows a number of scales and backward-directed spines and teeth. The head is very distinct (a typical fly maggot has a very poorly developed head region) and carries two small antennæ; the head is provided with two strong gnawing mandibles. The body of the larva has twelve joints, each with rows of distinct warts or processes; specially large are the projections from the last joints. All the joints except two bear a pair of spiracles; the two spiracles of the last joint are specially prominent. The larva is legless, and when full-grown measures up to ½ in. in length. The larvæ of most of the Bibionidæ are scavengers, but the species named above are proved enemies of grasses, among other crops.

The full-fed Bibio larva pupates in the soil, in the surface layers, enclosed in an earthen chamber. The pupa is mummy-like and is distinguishable from the Daddy Long Legs or Crane Fly pupa by the absence of the marked body spines by which the Daddy pupa is enabled to raise itself above the surface. The flies lay their eggs on the soil and in decaying matter, specially making use of places covered with fresh dung; the Bibio larvæ can be introduced to fields in dung.

DISEASES OF GRASSES, LUCERNE, AND SAINFOIN

By D. G. O'BRIEN, M.A., B.Sc., B.Sc.(Agric.), N.D.A.

DISEASES OF GRASSES

A great many fungoid diseases affect cultivated grasses. Unfortunately in the past the economic aspect of these has been neglected, attention being mainly devoted to their study from a mycological point of view.

Rust on Grasses.

The Puccinia rusts are the most important of the various parasites that attack the members of the order *Gramineæ* (Grasses).

It is said that in 1916 the loss of wheat in the United States and Canada from black rust alone amounted to 280,000,000 bus.; and while this is recognized as the most serious form of rust, yet there are others scarcely less destructive to their hosts. The damage done to grasses by all forms is beyond even approximate estimation.

The fungus propagates more in damp than in dry weather, and consequently the extent of the damage is always most serious during wet seasons.

Rusts usually have three distinct stages in their development.

(*a*) In spring the spring or cluster-cup stage occurs. During this period small cup-like structures may be seen embedded in the tissues of the host, with only the rim of the cup projecting. These cups produce spring spores, technically called æcidiospores. As a rule, and simultaneously, other spores known as spermatia are formed in special flask-like structures or spermagonia, but of the importance of these little is known.

(*b*) During the summer or uredineal stage long narrow stripes appear on the host plant. Within these stripes summer spores or uredospores are formed which are set free, as they mature, by the rupture of the overlying tissues.

(*c*) Towards the end of summer the winter or teleal stage is reached, when winter spores or teleutospores are formed, often in the same sorus which produces the summer spores.

Each stage performs a particular function. The spring spores bring about a rapid spread of the disease in spring; the summer spores serve a similar purpose later; while the winter spores may be said to represent the resting stage of the fungus, although in warm climates the uredospores or summer spores are also known to live over winter and cause infection the following spring. In explanation of this it may be added that the first two forms of spores are less resistant, and shorter lived, than the third form, which can persist throughout the winter even although the conditions are very severe.

Summer spores continue to be produced throughout the winter when the host plants grow over this period; in this case the formation of teleutospores is unnecessary.

Some rusts do not, as far as is known, go through the complete life cycle, as one or even two of the stages may be omitted. However, in those forms which have the three distinct stages, the spring stage often occurs on another host, e.g. the æcidiospores of the black rust of oats are developed on the buckthorn. The black rust of wheat on the other hand develops its æcidiospores on wheat.

The different forms of rust are varied in their range of attack, some being parasitic on many hosts, and others again confined to a single host. The following are the most important forms occurring on grasses.

1. The Cereal Rusts.

Technical Name.	Principal Hosts.	Subsidiary Hosts.
a. *Puccinia graminis tritici* (Black Rust of Wheat).	Wheat.	Bromes, Meadow Foxtail.
b. *P. graminis avenæ* (Black Rust of Oats).	Oats.	Bromes, Meadow Foxtail, Ryegrasses, Fescues, Timothy, Tall Oat Grass, Sweet Vernal, Cocksfoot.
c. *P. graminis secali* (Black Rust of Rye).	Rye.	Bromes.
d. *P. glumarum* (Yellow Rust of Cereals).	Wheat, Oats, Rye.	Cocksfoot.
e. *P. coronata* (Crown Rust of Oats).	Wheat, Oats, Rye.	Timothy, Meadow Foxtail, Sweet Vernal, Cocksfoot.
f. *P. dispersa* (Brown Rust of Rye).	Rye.	Ryegrasses, Fine-leaved Fescues, Bromes.

2. The Grass Rusts.

Technical Name.	Principal Hosts.	Subsidiary Hosts.
a. P. phlei-pratensis.	Timothy	Cocksfoot, Fescues, Meadow Foxtail, Tall Oat Grass, Ryegrasses, &c.
b. P. lolii.	Ryegrasses.	Tall Oat Grass.
c. P. perplexans.	Meadow Foxtail.	
d. P. triseti.	Golden Oat Grass.	
e. P. poarum.	Meadow Grasses.	
f. P. anthoxanthi.	Sweet Vernal.	
g. P. arrhenatheri.	Tall Oat Grass	
h. P. bromina	Brome Grasses	
i. P. agrostis.	Species of Agrostis (Bents).	Meadow Foxtail, Bromes, Timothy.

It will be noticed from the above table that the cereal rusts may attack grasses, and vice versa. It seems feasible from this to assume that the cereal rusts may in most cases hibernate on grasses.

P. phlei-pratensis, which is closely related to the black rusts of the cereals, is generally recognized as the most important of the grass rusts, and is probably the most serious of the various grass diseases. It occurs mainly in the uredo stage; the æcidial stage has not been noted, while the teleal stage, though existent, is not very common. Uredospores are produced throughout the whole year, but are most numerous in May and June and again in September and October. During these periods affected plants may be seriously injured or even killed.

The yellowish brown sori in which the uredospores are formed may be found closely crowded together and on all parts of the plant—blade, sheath, stem, and even glumes.

There is reason for believing that plants vary in their susceptibility to this disease, and consequently the selection of resistant strains may prove to be the most effective method of control.

P. lolii, a species closely related to *P. coronata*, is found frequently on Ryegrasses in May, June, and July, and on the aftermath in September and October.

P. perplexans is often a serious pest on Meadow Foxtail, and is most noticeable in this country on the aftermath in September.

P. triseti, Eriks.—The uredospores of this fungus are most prevalent from April to June, and occur on Golden Oat Grass in the form of small, fairly even, pale yellow sori on the upper surfaces of the leaves. Teleutospores appear later in the season.

P. poarum, Niels., is found on most members of the Meadow Grass family in the form of small yellow uredospores scattered on the upper sides of the leaves. The disease, to which individual plants show varying susceptibility, is especially common between the months of June and September, but may in certain cases be evident all the year round. The æcidium stage occurs on Coltsfoot.

P. anthoxanthi, Fckl., gives rise to brown coloured spots, generally in July and August, on the leaves, sheaths, and stems of Sweet Vernal. Plants affected suffer severely, and may actually succumb to the disease.

P. arrhenatheri, Eriks., attacks Tall Oat Grass, producing on the upper surfaces of the leaves small round yellow spots. These are most noticeable in June.

P. graminis, Perc., does not occur very often on grasses in this country.

P. glumarum (yellow rust of oats) is probably the most serious pest affecting Cocksfoot in Britain, and is found on this plant only in the uredo stage.

The uredospores are especially prevalent in May and June, and the sori in which they are formed are found on the blades and later on the sheaths, on the stalks, and in severe cases on the glumes. As the season advances the disease wanes until about August when it is comparatively rare. In about a month after this it again assumes serious proportions, and is generally fairly common during the winter months.

Individual plants vary markedly in their resistance to this form of rust, but there seems to be no difference in susceptibility between Cocksfoot of different nationalities.

P. dispersa (brown rust of rye) is frequently associated with *P. lolii* in Ryegrasses during the same periods.

Protective Measures against Rust.—Practicable methods of dealing with the disease are at present very limited, and the work of the future must be directed more than hitherto to the evolution of strains capable of resisting rust. Grass seeds of different nationalities do not seem to offer any solution to this problem, as from these, plants of markedly varying susceptibility occur with about equal frequency. On the other hand, there is evidence to show that individual plants of the same species vary in their degree of susceptibility to practically all the rusts which have been mentioned.

It might be considered good practice to keep down ruthlessly any weeds whieh act as hosts. This has been successfully done in the case of the barberry bush. With grasses, however, this method of control is not likely to be very effective, as the affected plant has a chance of carrying infection over the winter if it has survived the attack of the previous year.

In dry districts the burning of badly rusted stubble before ploughing would in all probability lead to a reduction in the extent of the disease.

Smut on Grasses.

The characters of this disease as it affects cereals are known to most agriculturists, and have been dealt with more fully under the cereal crops. Attacks of smut on certain grasses are, however, generally overlooked, although in some cases a considerable amount of damage may be done.

There are many species of the fungus, but these are divided into two orders or families, viz. *Ustilaginaceæ* and *Tilletiaceæ*, which cause respectively " ordinary smut " and " stinking smut ". The following are the grasses most commonly attacked:

A. Ordinary Smuts.
  1. Tall Oat Grass—causative fungus, *Ustilago perennans*, Rostr.
  2. Timothy—causative fungus, *U. striæformis* (West.), Niessl.

B. Stinking Smuts.
  1. Ryegrasses—causative fungus, *Tilletia lolii.*
  2. Bromes and Soft Grass (Holcus)—causative fungus, *T. holci.*

Tall Oat Grass Smut.—This disease closely resembles smut of oats except that, as the result of an attack, the ear is not so completely destroyed. The fungus remains on its host over the winter, and, in consequence, affected plants bear smutted ears every year.

Smut of Timothy.—This form of smut attacks, in addition to Timothy, many species of Poa, the Fescues and Bromes, Bent and Cocksfoot, and is noted as occurring in Europe, America, and Australia.

On Timothy the disease chiefly affects the leaves and is very rarely found upon the other parts of the plant. It may be recognized by the presence on the leaves of long black lines containing spore masses. Such leaves generally become torn and withered, and the whole plant presents a stunted and unhealthy appearance. When the ear emerges it also becomes infected, and, as a result, is partly or wholly destroyed. Any seeds formed are contaminated with the fungus, and serve to transmit the disease in the following year. Once a plant is affected it continues to bear smutted ears annually.

Hot-water treatment, consisting of the immersion of the seed, firstly, in cold water for six hours, and, secondly, in water at a temperature of 123° F. for 15 min., has proved an effective and practicable method of controlling this disease.

Stinking Smuts.

The disease as it affects grasses is similar to " stinking smut " of wheat.

Other Diseases.

The following diseases, though not usually serious in their effects, are general on almost all cultivated grasses:

1. Powdery Mildew.
2. Ergot.
3. Phyllachora.
4. *Reed Mace Disease.*

Others that are less universal are:

Stripe Disease of Grasses.
Grass Leaf Spot or Septoria Disease.
Grey Leaf Spot.
Leaf Blotch.
Rust (Uromyces Rust).

Powdery Mildew.—The causative organism in this case is described as *Erysiphe graminis*, D.C., but it is not improbable that distinct forms of this fungus are responsible for the disease in the different species of grasses attacked. Since, however, the trouble is not of much practical importance, it will be convenient to discuss it as being caused by one and the same organism.

Early in spring a white or pink network of mycelium can be detected on the upper surfaces of the leaves and on the stems of affected plants. Peculiar bead-like strings of bud cells are produced later, which are readily dispersed and serve to spread infection to adjacent healthy leaves. During late summer the growth of the fungus becomes somewhat greyish in colour, and typical brown or black spore bags containing ascospores are formed. These ascospores do not develop until the following spring. In severe cases leaves may die as the result of an attack and bring about the premature ripening of the plant.

Owing to the limited nature of the damage done by this disease, control methods are seldom required. Spraying with a 2-per-cent solution of Bordeaux mixture will generally prove effective in checking it. Resistant strains of plants could also be procured, if necessary, as amongst the various species of grasses the range of individual susceptibility is varied.

Ergot.—Commonly occurring on rye, this disease also frequently affects the following: the Ryegrasses, Fescues, and Meadow Grasses, Timothy, Cocksfoot, Tall Oat Grass, Meadow Foxtail, and Sweet Vernal. It is probable that the forms on different hosts are distinct.

The fungus, *Claviceps purpurea* (Fr.), Tul., attacks and destroys the ovaries of affected plants when in bloom, and gives rise to the so-called " ergots ". Each ergot is composed of a hard, black, felted mass of mycelium, termed a sclerotium, and occupies the place of the grains or seeds, Though generally longer and projecting, the shape is somewhat similar to that of the normal grain.

Ergots are mainly found in grass ears in September and October, and may persist in this position or fall to the ground and remain over winter in the soil. When conditions are favourable, either in autumn or spring, they germinate and produce spores (see " Ergot of Rye ") which are capable of infecting healthy susceptible plants. Infection, however, only takes place when the latter are in flower.

As a rule no great damage is done to plants attacked by this disease, and the loss of seed is only slight, but when ergotted ears are fed to cattle serious results may follow, due to the deadly poisons, ergotin and cornutin, which are present in the ergots. The poisoning may be slow if the ears are only slightly affected. In bad cases the animals become emaciated, with dry staring coats, and develop later on, as the result of retarded circulation in the extremities, gangrenous sores on the teats and mouth; affected parts of the tail, ears, or hoofs may drop off. Pregnant animals are also liable to abort.

Samples of hay have been known to be worthless owing to attacks of ergots on their component grasses.

Preventive Measures.—Since this disease may affect a very large number of host plants it is obvious that effective control of it is a comparatively difficult matter.

Early cutting of hay before the seed has formed in the ear prevents the development of sclerotia and, consequently, the further spread of the disease. If, at the same time, susceptible grasses on the outskirts of fields, e.g. hedgerows, head rigs, &c., are cut before seeding, then this may be all that is required.

It is of interest to note that in this country only second cut hay is likely to be affected by ergot.

The destruction of sclerotia by the burning in autumn of infected grass or stubble land is a further remedy.

Seed containing ergots should on no account be used for sowing purposes, as the disease would, of a certainty, be propagated thereby.

Phyllachora graminis, Fcl.—This fungus causes the formation of long black shiny spots on the leaves of grasses, especially on Cocksfoot and certain species of Agrostis. These spots eventually show on both sides of the leaves, which, in turn, become yellow and wither prematurely.

Reed Mace Disease.—This disease, also known as " Smother Fungus " of grasses, is caused by the organism *Epichloe typhina*, Tul., and attacks a large variety of cultivated and weed grasses. Although commonest on Timothy, Cocksfoot, and Meadow Foxtail, it may also be found on the Fescues and Meadow Grasses and on Sweet Vernal.

The loss sustained is not as a rule serious, except occasionally on

Timothy, in which case the yield may be as low as one-third of the normal yield.

Symptoms.—The uppermost sheathing leaf becomes surrounded by a collar or muff-like growth, composed of interwoven hyphæ, which is at first greyish white in colour, but later changes to golden brown. Corresponding with these colours, and in the order named, two different kinds of spores are formed: (*a*) conidia, which rapidly spread the disease, and (*b*) ascospores, which are produced in spore cases and probably serve to carry the fungus over the winter.

Growth is checked and the proper development of the ear prevented, as a result of the penetration of the sheath and the filling up of the space between the sheath and the stem, by the hyphæ.

No effective remedy is known for this disease. On account of the perennial nature of the various hosts it is obviously difficult to control.

It is believed that it may be spread by seed containing the spores of the fungus.

Stripe Disease of Grasses.—A form of stripe, resembling that which affects barley, has been diagnosed on the Ryegrasses in this country, while in America a similar disease occurs on Meadow Foxtail.

The causative fungus is *Pleospora gramineum*, Diet., the conidial stage of which is known as *Helminthosporium gramineum*, Eriks.

Symptoms.—Longitudinal yellowish green spots, arranged in parallel rows on the leaves and sheaths, appear from May to July and, later on, in the winter months. Affected leaves develop a peculiar yellowish brown appearance, starting at the tip and progressing towards the base. The bottom leaves usually suffer most.

The disease in the case of barley is seed-borne, and treatment of the seed with a formalin solution in the proportions of 1 pt. of formalin to 30 gall. of water has given beneficial results. It is to be expected that grass seeds similarly treated would be freed from any lurking infection.

Grass Leaf Spot or Septoria Disease.—A species of Septoria, namely *Septoria culmifida*, Korst., attacks, among other grasses, Cocksfoot, Timothy, Meadow Foxtail, Tall Oat Grass, and the Ryegrasses and Meadow Grasses.

Symptoms.—In April and May, and again in October on the aftermath, or even throughout the winter, light brown oval-shaped spots, with broad puce-coloured borders, are formed on the leaves and stems of affected plants. These spots show numerous very small black dots or pycnidia arranged in regular rows.

The disease seldom causes much damage to the foliage unless when young seedling grass plants are attacked, but, by diminishing carbon assimilation in the leaves, it interferes with the productiveness and general health of the plant.

Nothing is known as to the best preventive measures to adopt to control the trouble.

Grey Leaf Spot.—The fungus *Scolecotrichum graminis*, Fcl., similar to, if not identical with, that which produces "grey leaf spot" on oats, attacks many grasses, including Timothy, Cocksfoot, Crested Dogstail, Tall Oat Grass, and the Meadow Grasses.

Symptoms.—A few scattered dark or purplish brown spots develop on the leaves, especially on the lower outer ones. These spots increase in size and may join up to form large affected areas with grey or white centres on which blackish dots appear in rows parallel to the leaf edges.

Plants mildly attacked are stunted in growth and produce distorted and poorly nourished ears. Badly affected leaves usually die, death commencing at the extreme tip and progressing towards the base, and as a result of the whole leaf system becoming involved the diseased plant generally succumbs.

The disease seems to be favoured by a relatively low temperature in the early spring months, and its tendency to be confined to certain areas in a field probably indicates that soil conditions exert some controlling influence on its prevalence.

Little is known as to methods of preventing this disease, but observations go to show that certain strains of grasses are more or less resistant to attack. These if necessary could be used for propagation, and employed for seeding infected areas.

Leaf Blotch.—This disease is found on Meadow Foxtail, Cocksfoot, species of Agrostis, and probably on other grasses. On the first-named it is caused by the fungus *Mastigosporium album*, Reiss., and on Cocksfoot and Agrostis by *M. album*, Reiss., var. *muticum.*

Symptoms.—Reddish brown blotches with light coloured margins appear on the leaves at all seasons of the year, but particularly in late autumn and early spring. The centre of each blotch is white in colour and gives rise to spool-shaped, colourless conidial spores. Such spores have three traversing walls and are provided with fine hair-like projections coming from their two ends.

Leaves are generally so badly affected as to cause their destruction.

It has been noted by observers that certain strains of grasses have well-marked powers of resisting this disease. The selection of such strains therefore holds out most hope as a means of control.

Uromyces Rust on Grasses.—Two species of Uromyces occur on grasses:

(*a*) *U. poæ*, Rab., on the Meadow Grasses;
(*b*) *U. dactylidis* on Cocksfoot.

Uromyces poæ, Rab., produces on the leaves and sheaths of affected plants about the month of June a very large number of tiny yellow spots which later in the season (autumn) become black. The cluster-cup stage of this fungus is harboured on several species of Ranunculus, e.g. *R. repens* (common buttercup) and *R. bulbosus*.

Uromyces dactylidis forms similar sori on the leaves and sheaths of Cocksfoot, and has also its cluster-cup stage on species of Ranunculus.

DISEASES OF SAINFOIN

This crop occupies a relatively unimportant place among the forage crops in this country, and consequently little is known about the diseases which affect it. In brief, those recorded on Sainfoin are also parasitic on Clover and Lucerne.

Rust.—A species of Uromyces—*U. Onobrychidis*—has been described as causing the formation of brown sori on the leaves and stems of affected plants. These sori, later in the season, become black. The trouble is worst in July and August, by which time the Sainfoin should be mature. The damage, however, will not usually be serious.

Mildew.—Powdery mildew is commonly found on Sainfoin. The fungus responsible is generally given as *Erysiphe polygoni*, D.C.

Wilt.—Wilt caused by *Sclerotinia sclerotiorum* affects Sainfoin in addition to Clover and Lucerne.

Ascochyta Leaf Spot.—A leaf spot disease occurs frequently on Sainfoin, and is commonly ascribed to a fungus belonging to the genus *Ascochyta*. Others, however, regard it as similar to leaf spot caused by *Ramularia onobrychidis*.

DISEASES OF LUCERNE

These have been extensively studied in America and in some European countries, but in Great Britain, owing to the relative unimportance of the crop, little research has been carried out.

Leaf Spot.—This disease, known in Europe since 1832, is in some countries the most important and widespread of the various troubles with which Lucerne has to contend.

The fungus *Pseudopiziza medicaginis* (Lib.), Sacc., causes the formation of small brown or black spots of varying shape on the leaves, which extend through the tissues until they can be observed on both surfaces. Spotting may also take place on the stems. In the centre of old spots spore-producing organs can be identified with a lens. Such spots eventually rupture, leaving wounds with ragged edges.

As a rule the lower leaves suffer most and, if badly affected, turn yellow and drop off, thus contributing to what may be a considerable loss of crop.

The disease is worst in dry seasons, and is generally much more serious on the later cuttings of Lucerne. It persists from year to year on the same plant, as mature plants are seldom, if ever, killed by an attack.

No control measures are of much value, but it is well to remember that early cutting may reduce the damage, since the disease is often not at its height at the normal time of cutting.

Cercospora Leaf Spot.—The fungus *Cercospora medicaginis*, E. and E., attacks the leaves of Lucerne, causing them to yellow and drop oft.

The circular spots formed, which are dark brown or black in colour, are noticeable on either surface and pass into the healthy leaf tissue without any clear definition.

The disease is transmitted by the seed, and disinfection of the latter is the only feasible method of control.

Yellow Leaf Blotch.—This affection, due to the fungus *Pyrenopeziza medicaginis*, Fcl., *Sporonema*, is widely distributed and frequently causes more damage to Lucerne than leaf spot.

The leaves become covered with yellow or orange spots which bear numerous orange-coloured spore cases or pycnidia. In other respects the symptoms are very similar to those of leaf spot.

The fungus hibernates on the leaves, and by this means sets up infection the following year.

As in leaf spot, early cutting of the crop is fairly effective in reducing the loss.

Blight.—This is a bacterial disease, caused by the organism *Pseudomonas medicaginis*, Sack., and described as doing much damage to Lucerne in some parts of America. It is not known whether it occurs in this country.

Most damage is done early in the season, hence the first cutting suffers to greatest extent. An affected stem develops on one side a peculiar yellowish green colour, becoming at the same time semi-transparent and weak. Later the diseased part blackens and exudes water which dries on the stem, giving to it a characteristically glassy or varnished appearance.

The bacterium gains access to the plant through frost wounds on the stem.

Crown Wart.—In this country crown wart on Lucerne was first noted in 1906, and is caused by the fungus *Urophylctis alfalfæ* (Lag.), Magn. At the present time it is very prevalent in Europe, South America, and the United States.

The disease is characterized by the presence of numerous galls or swellings, varying in size from a pea to an orange, which are formed at, or near, the base of the stem. Affected plants have either brown dead stems, or weak sickly stems with yellow leaves.

The uprooting and burning of diseased plants is the only effective method of control.

Wilt.—This affection (causative fungus, *Sclerotinia Trifoliorum*, Eriks.) is described under DISEASES OF CLOVER, p. 300.

Root Rot.—Root rot of Lucerne is generally caused by a fungus belonging to the genus *Rhizoctonia*. *R. medicaginis*, D.C., is sometimes given as its specific name, but there is reason to believe that the organism is identical with *R. violacea*, which is found on a large variety of plants.

Affected roots are covered with a fine network of the mycelium of the fungus which is usually brownish red or violet in colour. As the name indicates, rotting takes place, resulting in the yellowing and ultimate death of the foliage. The disease tends to occur in circular patches which gradually extend their area.

It is almost impossible to control root rot on account of the wide range of host plants, as well as the fact that sclerotia are formed which can remain dormant in the soil for fairly prolonged periods.

Damping Off.—The fungus *Pythium de Baryanum*, and species of *Rhizoctonia*, are causes of this disease on Lucerne seedlings. The latter is likely to be the more destructive.

Fusarium Root Rot or Wilt.—Species of *Fusarium* may bring about a wilt of the Lucerne crop.

The outer leaves turn yellow at the onset of the disease, but soon all the leaves and stems become discoloured, wilt, and die.

No specific control measures are available. It may be added, however, that *Fusarium* species are present in all soils to some extent, and, for this reason, the only method of combating such diseases would be to breed strains or varieties resistant to their attacks.

Rust on Lucerne.—*Uromyces striatus*, Schr., is the name of the responsible organism in this case. The uredospores and teleutospores of this fungus also affect some other leguminous crops, while its cluster-cup stage occurs on the Spurges (Euphorbia).

On Lucerne the symptoms are marked by the appearance on the lower sides of the leaves of typical rust sori.

Ascochyta Leaf Spot.—The fungus *Ascochyta medicaginis*, Bres., is found affecting Lucerne, where it produces characteristic spots, especially on the lower leaves. The spots are more or less circular except when they are placed at the margins of the leaflets, in which case they are V-shaped. They are light brown in colour, and bear small black dots—spore bags or pycnidia—on their surface.

The loss occasioned is, as a rule, not very great.

Another fungus, *Staganospora carpathica*, Baeu., likewise causes the formation of spots on the leaves, but the loss is even less serious than from Ascochyta leaf spot.

Mildew.—Downy or false mildew is commonly found on Lucerne. See under DISEASES OF CLOVER.

Anthracnose.—Anthracnose is fully discussed under DISEASES OF CLOVER, p. 302. In Lucerne it may be caused by two organisms, namely *Colletotrichum trifolii*, Bain., and *Glœosporium medicaginis*, E. and K. The former is the more injurious.

DISEASES OF CLOVER

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AND

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Clover-sickness.

Under the general term " clover-sickness " two distinct diseases have long been confused by agriculturists. One of these diseases is caused by a parasitic species of eelworm, *Tylenchus devastatrix*. Under the attacks of this eelworm the clover plant becomes stunted in growth, the shortened stems become swollen, and the foliage, at first pale or yellowish, turns brown and the plant dies. The female worms produce eggs which are found together with adults and larvæ in the affected tissues. The larvæ on hatching are a seventh of the size of the mature worms, but they grow rapidly at the expense of the host plant. On the decay of the clover they pass to the soil, where they can survive for some considerable time. They may even lie dried up for several months, but are revived by moisture, when they again pierce and enter the roots of a new victim.

The other disease, which kills off Red Clover so frequently if this crop is taken too often in the rotation, is caused by the parasitic fungus *Sclerotinia trifoliorum*, and may be distinguished by the name of " clover stem-rot "; this disease is described in detail below.

The theory often advanced that clover-sickness is due to a poisonous substance excreted into the soil by the roots of the clover plants, which prevents the healthy growth of subsequent clover crops for some years, is not supported by any scientific evidence.

Clover Stem-rot.

The first indication of this disease is the appearance in the autumn or early winter of a few pale, withering plants here and there among the healthy green specimens; a little later such plants are found to be brown and dead. The further extension of the disease depends entirely upon weather conditions. If the weather turns dry the disease is at once arrested, and no serious harm is done to the clover crop; if, however, the weather continues wet or "muggy", more and more plants succumb, until the clover field is seriously affected by the presence of numerous bare patches, often several yards across, where all the clover plants are brown and dead.

The fungus, *Sclerotinia trifoliorum*, which causes the disease can easily be seen. If plants which have been recently attacked are examined during a spell of wet, warm weather a white, soft "cobwebby" growth of the spawn (*mycelium*) of the fungus will be found covering the surface of the leaves. Further, this spawn will be found extending in all directions from the dying clover, over the surface of the wet soil, and attacking the neighbouring plants. Given a luxuriant growth of clover and mild, wet weather the spread of the disease in this way is very rapid.

As soon as a clover plant is killed, small masses of the spawn in a resting condition may be observed. These bodies, each of which is termed a *sclerotium*, are whitish at first, but soon turn to dark grey or black; they are somewhat variable in size and shape, and may be compared with mouse dung in general appearance. They are frequently to be found inside the hollow, dead stems, and often occur in considerable numbers on the dead parts of the plant near the crown of the root, or on the surface of the soil under the decayed plant.

Each sclerotium germinates in October or November and produces one or more minute trumpet-shaped fructifications, like a small toad-stool. Myriads of winter-spores (*ascospores*) are produced by each fructification, and these spores, expelled forcibly into the air, are carried by the wind to clover plants, which they infect immediately. The sclerotia thus act like the seeds of weeds and other plants in keeping the soil infested. As an instance of the immense numbers that may be produced, the case of some clover-sick plots at the Rothamsted Experiment Station may be mentioned here. In certain experiments Red Clover was grown continuously on the same ground for a number of years; when the crop failed owing to the attacks of the fungus *Sclerotinia trifoliorum*, a plot of 10 sq. yd. in the diseased area was closely examined. Sclerotia were found in the soil, and no less than 6 oz. by weight of these bodies were collected from the surface of the soil over these 10 sq. yd. On calculations being made, this was found to be equivalent to 181 lb., or 14,000,000 sclerotia, to the acre, which is about 2 sclerotia to each square inch of ground.

Since sclerotia are able to be produced in such profusion, and since they are capable of remaining alive in the soil for many years until another clover crop is taken, we have the explanation of why it is that this form of clover-sickness is so widespread and so persistent.

Remedial Measures.

When a field has become clover-sick, the safe remedy is to allow an interval of 8, 10, or even 12 years to intervene before another crop of

Red Clover is taken. By this means the sclerotia of the fungus in the soil are forced to die out. During this period other less susceptible leguminous crops may be grown in the affected field, such as Trefoil (*Medicago lupulina*). White or Dutch Clover (*Trifolium repens*), Sainfoin, or such crops as peas or tares. According to Mr. Arthur Amos beans may take the disease badly, although this author considers it safe to grow beans on affected soils, provided they are not taken shortly before the next clover crop. It is possible that in some cases a confusion has arisen between the fungus *Sclerotinia trifoliorum* and *S. sclerotiorum*, which is not uncommon on beans.

On soil which is naturally healthy for Red Clover, and on which the disease is not prevalent, Red Clover may safely be taken once in five or six years, especially if it is sown in a mixture with grasses and other leguminous plants. Late-flowering Red Clover or Single-cut Cowgrass is not quite so susceptible to the disease as the common Red Clover. Alsike (*Trifolium hybridum*) is also somewhat resistant, and Crimson Clover (*T. incarnatum*) appears to be completely resistant. Sainfoin is frequently attacked during the first autumn of its growth, but generally speaking it is much less susceptible than Red Clover. Lucerne often suffers destruction during the first winter of its growth, but those plants which stand the first winter are rarely attacked in the succeeding years.

It should be remembered that if Red Clover is grown on rich land abundantly supplied with organic and nitrogenous manures, there will be the danger of the production in autumn of a too luxuriant matted growth which will prove very susceptible to the disease; such manuring requires to be balanced by the addition of mineral plant-foods (lime, potash, and phosphates). Mr. Arthur Amos has pointed out that where luxuriant autumn growth is produced upon rich land, it is often advisable to feed off the clover to sheep during September and October; this practice reduces contact between the leaves of neighbouring plants, so that the disease has less chance of spreading. On poor, thin land such procedure will probably reduce the crop, but upon rich land, known to be subject to the disease, considerable benefits may result.

Anthracnose.

Hitherto it has been assumed that wilt was the only important disease affecting clovers. Recent investigations have shown that clovers are subject to other fungoid pests which in many cases cause more loss than the above. Of these anthracnose is probably the most destructive.

In America and in most European countries very considerable damage is done to Red Clover by anthracnose. There are differences of opinion as to the actual organism which causes the disease, and the position at present is that two species of *Colletotrichum* and two species of *Glœosporium* are recorded by writers on the subject as being responsible.

It is usual to describe the disease under two headings:

1. Anthracnose caused by *Colletotrichum trifolii*, Bain.
2. Anthracnose caused by *Glœosporium caulivorum*, Kirch.

So far as can be determined the second is the form of the disease prevalent in this country, and while mainly attacking Red Clover, Alsike, and White Clover, can also be artificially infected to a slight extent. In America Lucerne as well as other hosts have been noted.

Symptoms.—The disease is most evident when the clover plants are in full flower, and is characterized by the appearance of long, brown, sunken spots, with black margins on the leaf stalks, flowering stems, and petioles. The laminæ of the leaves are never found to show natural infection of their tissues although artificial infection can be satisfactorily performed.

The development of the spots causes the death of the more distant parts of the plant and considerably reduces the yield of the crop. In Europe the damage has on occasions amounted to 50 per cent of the total yield, while in America the disease is so serious that in certain localities the growing of Red Clover has been abandoned.

Attacks vary in their severity in different years, and are worst when wet conditions prevail.

No resting spores of the fungus have yet been discovered, and it would seem that infection is borne over the winter either on the leaf-stalks of previously affected plants or through the agency of contaminated seed.

From observations carried out at Aberystwyth and at the West of Scotland Agricultural College it is evident that Red Clovers of different nationalities vary in their degree of susceptibility to anthracnose. Among early-flowering Red Clovers those from Italy, Chile, and France appeared to be very susceptible. English Red closely followed. Canadian and Wisconsin were least affected, and apparently possessed a marked power of resisting the disease.

It is interesting to note that the susceptibility to anthracnose and the permanence of Red Clover are probably correlated. The least permanent Red Clover at the West of Scotland station was Italian, while Canadian Wisconsin outlived all the others. In connection with this, it might be further observed that late-flowering Red Clovers, which are generally the more permanent, are not so prone to attacks of this disease as the early-flowering Reds. Some indigenous strains of Red Clover are also remarkably resistant.

Not only is there a considerable difference in susceptibility between clovers of different nationalities, but there is an equally striking difference between plants of the same nationality.

Anthracnose, caused by *Colletotrichum trifolii*, Bain., occurs on Red

Clover and Lucerne in many parts of America, and is there a very serious disease. Similar wounds are found on the leaf-stalks and, later on, on the stems near the ground surface as well as just below the flower clusters. These lesions ultimately cause the death of the host plant.

The failure of Alfalfa (Lucerne) in some districts is attributable to attacks of this disease.

There is a similar variation in susceptibility to this form of anthracnose in the strains and nationalities of Red Clover and Lucerne.

Leaf Spot Diseases of Clovers.

A. *Leaf Spot caused by Pseudopeziza trifolii*, Fckl.—This disease principally affects the leaves of Red Clover, although other clovers may on occasion also suffer. Another species of the fungus, namely *Pseudopiziza medicaginis*, which is said to occur on the leaves of White Clover, is responsible for a similar disease on Lucerne (see "Leaf Spot of Lucerne", p. 297).

The fungus produces on the upper surfaces of the leaves many small, dark, rounded spots which later give rise to waxy discs with rugged edges. Each disc contains a large number of spore bags.

The spots may be found present on the leaves during the whole year. A bad attack may cause the affected leaves to prematurely wither and die, but as a rule little damage is done. No methods of preventing or checking an attack are yet known.

Wisconsin and Canadian clovers seem to be very susceptible to this disease.

B. *Leaf Spot caused by Mycosphærella carinthiaca*, Jaap.—This form of leaf spot was first noted in Britain in 1921 on English Broad-leaved Red Clover at the Welsh Plant Breeding Station. No information is yet available to show whether it is a widespread affection in this country.

Angular brown patches are found on the leaves, and on the resulting dead areas black spore bags are distinguishable.

This disease seldom causes much damage, and on this account control measures so far seem unnecessary.

C. *Cercospora Leaf Spot.*—A species of *Cercospora* attacks the leaves of clovers, causing the formation of spots. A similar disease also affects Lucerne (see "Cercospora Leaf Spot of Lucerne", p. 298).

D. *Leaf Spot of White Clover.*—The fungus *Sphærulina trifolii*, Rostr., is a frequent cause of this trouble on the leaves of White Clover.

On the upper surfaces of the leaves a large number of small, round, dark brown spots with reddish purple margins appear in June or July. These later become lighter in colour, and give rise to spore bags or perithecia which can be detected in the form of small black dots.

Nothing is known as to the seriousness or the methods of controlling this disease.

Sooty Leaf Spot of Clover.

Phyllachora trifolii (Pers.), Fcl., is a common cause of disease on Red Clover (*T. pratense*), and is also found to some extent on Alsike Clover (*T. hybridum*), White Clover (*T. repens*), and Crimson Clover (*T. incarnatum*).

The disease is sometimes ascribed to the fungus *Polythrincium trifolii*, Kze. This, it is held, is simply the conidial form of *Phyllachora trifolii* (Pers.), Fcl.

An attack is characterized by the appearance of spots, very similar to the sori produced by rust, on the upper and lower surfaces of the leaves. On the former they are of a pale colour, and on the latter black.

Attacks of this disease are frequently serious, but so far no preventive measures have proved of much practical value in combating them.

Black Mould.

This disease occurs on the leaves and stems of Red Clover. It is fairly widely distributed, and is caused by the fungus *Macrosporium sarcinæforme*, Cav.

Concentric spots, black in colour and circular in outline, appear on the leaves and petioles of affected plants. Usually the damage done is not serious.

The fungus has been located in clover seeds, and it is said that its presence is indicated by the seed being smaller, more wrinkled, and of a darker colour than usual. In this connection it would seem that the sowing of good seed would lead to the elimination of the disease.

Black Rot of Clovers.

Root rot, caused by *Rhizoctonia*, is sometimes serious. In the months of June and July apparently healthy plants become yellow and die. An examination of the roots of such plants reveals a felted mass of the threads of the responsible fungus. Roots affected in this manner ultimately rot.

Rust on Clover.

This is a true rust and attacks the following species of clover: Red Clover (*Trifolium pratense*), Alsike Clover (*T. hybridum*), White Clover (*T. repens*), and Crimson Clover (*T. incarnatum*).

The cause of the disease is the fungus *Uromyces trifolii*, Lev.[1] Some authorities, however, have limited this species to Red Clover, and describe other species as being responsible for rust on White, Alsike, and Crimson Clovers. The fungus does not change its host at any point, as all three

[1] Uromyces rusts are closely related to Puccinia rusts, but the teleutospores of the former have only one cell, whereas those of the latter have two.

stages—æcidial, uredineal, and teleal—may occur on the same plant. The disease varies in severity in different seasons, and tends to be worst after a mild spring. Æcidial spores appear on the under surfaces of the leaves of White Clover very early in spring or even during an open winter. It is noteworthy that these spores are not known to occur on Red Clover.

The cluster-cup stage is not usually associated with any extensive damage to affected plants, and may actually pass unnoticed. Immediately prior to this, however, an examination will reveal pale swollen regions on the leaves and petioles, these patches later developing into the so-called cluster cups.

Uredospores, which convey the disease from plant to plant, are formed during the summer, and even in winter, especially on Red Clover. They are in the form of profuse circular or elongated chestnut brown powdery sori. Very often the sori occur in abundance over the whole leaf, which ultimately, blackens, dies, and shrivels.

Teleutospores are produced later in the season in the uredospore sori or in independent sori, and germinate several weeks before the appearance of the spring or æcidial spores.

The disease as a rule does not do great damage, although in isolated cases, and especially in damp cool weather the loss may amount to 50 per cent of the total crop. The aftermath generally suffers most.

No methods of practical value are yet known for the control of this form of rust, although with regard to susceptibility it may be said that ordinary White Clover is more prone to it than Wild White Clover.

Downy Mildew.

Caused by the fungus *Peronospora trifoliorum*, de Bary., this form of mildew is common on all kinds of clovers, as well as on Lucerne and other closely related leguminous crops.

On the under sides of affected leaves pale areas can be seen. Such leaves when viewed from below are coated with a downy mould which is at first yellowish grey but later develops a purple colour.

From the fact that crops grown from American seed suffer worst, it would seem that the disease is seed borne. Seed disinfection with a weak solution of either formalin or bluestone would consequently be an effective preventive measure.

Violet Felt-rot.

This new disease has lately been described as attacking a field of Red Clover at Wye, Kent. It probably occurs elsewhere, and has been overlooked. The fungus (*Rhizoctonia violacea*) which causes the disease attacks the main root and its branches and covers them with minute, twisted, brown strands of mycelium; it then penetrates the outer layers of the roots and forms there minute resting bodies (sclerotia). The parts of the roots in contact with the sclerotia die, while the fungus gathers strength and envelops the roots further, until these become soft and rotten. When the tap-root is thus destroyed the clover plant often dies, but sometimes fresh, adventitious roots are formed and the plant recovers. Affected plants can be recognized by their being dwarfed and stunted, their outermost leaves yellow and wilted or dead, the young shoots stunted, the stipules and leaf-stalks bright red, and the leaf-blades pale green or yellowish. Frequently the surfaces of the lowermost stipules and shoots show the purple-brown felted spawn of the fungus. This brown spawn has been found growing on the dead stubble of the previous oat crop.

Where violet felt-rot occurs in a field, a long rest from a clover crop is desirable.