U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 219.

LESSONS FROM THE GRAIN-RUST EPIDEMIC OF 1904.

BY

MARK ALFRED CARLETON.

Cerealist in Charge of Cereal Investigations, Vegetable Pathological and Physiological Investigations, Bureau of Plant Industry.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF.
Washington, D. C., February 25, 1905.

SIR: I have the honor to transmit herewith the manuscript of an article entitled "Lessons from the Grain-Rust Epidemic of 1904," and recommend that it be published as a Farmers' Bulletin.

This paper was written by Mr. Mark Alfred Carleton, Cerealist of this Bureau, and was submitted by Mr. A. F. Woods, Pathologist and Physiologist, with a view to publication.

Respectfully.

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

LESSONS FROM THE GRAIN-RUST EPIDEMIC OF 1904.[a]

INTRODUCTION.

In respect to grain production, the season of 1904 was characterized by one unusual feature, particularly in the hard spring wheat region. Probably the most severe attack of rust ever known in that region, certainly the most severe in the last twenty or twenty-five years, occurred during that season. While the results appear to be most serious in the States of North Dakota, South Dakota, and Minnesota, much damage was also caused farther north in the neighboring districts in Canada and in portions of the adjacent States of Wisconsin, Iowa, Nebraska, and Kansas. The season was noted for a considerable amount of rust in almost all portions of the United States. Generally, only wheat and oats were badly affected, wheat suffering most of all. There was little or no damage to barley as a rule, but in some places rye appears to have been injured considerably.

While the farmers, grain dealers, and especially millers, have generally lamented the occurrence of such unusual havoc to the grain crops, nevertheless it is probably true that this disaster, like a number of others of national importance that might be mentioned, will be followed by such improvements in grain cultivation resulting from the lessons learned at this time as will counterbalance several times over the actual loss sustained in the deficiency of grain production this one season.

It is the purpose of this bulletin to call attention to some of the lessons that may be learned from this rust epidemic, or, rather, in some cases simply to emphasize the importance of these lessons, since farmers generally have no doubt already noted that very different results would have been obtained by them if certain different methods

[a] Many of the results forming the basis of discussion in this bulletin were obtained in cooperative experiments with the South Dakota Agricultural Experiment Station, the North Dakota Agricultural Experiment Station, and the Office of Seed and Plant Introduction of the Bureau of Plant Industry.—A. F. Woods, *Chief Pathologist and Physiologist.*

had been practiced. Good results are already seen in the unusu attention being given to the subject of seed selection by grain dealer and millers in cooperation with the farmers throughout the Northwes There is nothing more promising for better things in agriculture tha the special attention at present given by commercial men to the selec tion and improvement of seed grain.

THE NATURE OF THE RUST DOING THE DAMAGE.

It is a fact not generally known, and yet of much importance fo our actual knowledge of conditions, that there are several differen kinds of rusts that attack grains and that the existence of any one o these has no relation whatever to the occurrence of any of the other except in the mere coincidence that they all thrive and propagat much more rapidly in wet weather than in dry weather.

Each of the cereals, wheat and oats, is affected by two distinct rust One of these is found chiefly on the leaves and causes very sligh damage, if any. On wheat it is called the "orange leaf" rust and o the oat plant it is called the "crown" rust, because of the fact tha the spores at their upper portions have the form of a crown. Th other kind of rust on each of these cereals is called "black stem rust, which, in seasons of great severity, is found in much abundanc on the stems. In the season of 1904, as well as in all other season when rust has done any great amount of damage, it was this blac stem rust that caused the injury. It always appears a little later tha the leaf rust, and until it does occur no particular injury to the plan can be noticed. Many varieties of grain that ripen early, therefor often escape damage by being able to mature just before the blac stem rust appears in any considerable quantity.

A very erroneous idea of general prevalence should here be pointe out. It is not true that one of these rusts is entirely a black rust an the other entirely a red rust. Each kind has two stages—the red-ru stage, appearing first, followed by the black-rust stage. The kind c rust generally called by farmers the "red" rust, and which we nam here the orange leaf rust, has, therefore, a black stage just the sam as any other rust, but as the red or orange stage is so much mor abundant than the other and occurs on the leaf, it is called the orang leaf rust. On the other hand, the black stem rust has a red or brow ish-red stage, which, however, is much less important than the blac stage that occurs on the stem, and this kind is therefore called th black stem rust. The occurrence of the various stages of these di ferent rusts among each other on the same plants makes it difficult t distinguish them.

REASONS FOR UNUSUAL ABUNDANCE OF RUST IN 1904.

Naturally there has been some discussion of the question why there should have been such an unusual prevalence of rust in 1904, and the incorrectness of certain theories should be pointed out. In the first place, it is not true that the rust is more abundant on exhausted soils and that there is any increase in rust from year to year simply because the soils are becoming "worn out." Neither is it true in principle that the weaker plants are more rusted than others. This seems to be true in the case of some other plant diseases, but in all attacks of rust it is, on the contrary, a fact that the healthiest plants are as a rule the worst rusted, and for the very natural reason that whatever conditions are best for the plant are also favorable for the rust. It is no doubt partly for this reason that some believe that the fertility of the soil is concerned, as, of course, if the plants grow more rankly in a more fertile soil, other things being equal, they will have more rust. It is not, however, because of any particular element in the fertile soil that the rust is specially abundant, but chiefly because of the greater quantity of water and therefore softer tissue in the growing plant.

The simple reasons for the unusual abundance of rust in 1904 are (1) the fact that there was an unusual quantity of moisture just at the proper time for the rust to do the most damage to the crop and (2) the unusual delay in the ripening of the grain. The season was generally wet and besides was preceded by wet seasons. There being a considerable quantity of rust in the two previous wet seasons, it finally reached the climax of abundance in the third wet season of 1904, and especially at the critical period. This period, when the greatest amount of damage is done, is always between the date of blossoming and the date of ripening, when the head is "filling out."[a] How the rust is carried over from one season to another is not yet thoroughly understood in the case of the black stem rust, but it is possible that any unusual quantity of rust one season will make it more likely for damage to occur to a crop the following season if the disease should occur the second year at just the right time for doing the damage.

In this connection the question may be asked, Is rust increasing or decreasing from year to year? The writer does not believe that this question can be answered accurately, although it is generally supposed that as conditions throughout the country are becoming more and more complicated with respect to both animal and vegetable life there is a tendency toward the increase of all kinds of diseases. This may be true of grain rust. On the other hand, our knowledge of means of

[a] This period of "filling" of the grain was apparently delayed in 1904 in South Dakota, Nebraska, and southern North Dakota until just about the time of the occurrence of the rust in greatest abundance.

resisting or avoiding these diseases is also increasing, so that it i doubtful whether the actual damage to the crops from any particula disease is actually increasing. It has been stated that attacks of grai rust are much more common and serious now than years ago, when th land was first cultivated. On the other hand, in certain localities th worst cases of rust that the writer ever saw were only two or thre years after the settlement of the country, the rust never having bee so prevalent in those localities since that time. The prevalence of th disease is largely a question of the humidity of the atmosphere.

There is a rather common and erroneous belief among many farmer that rust is caused by the bursting of the stem or leaf of the plant by too much accumulation of "sap" within, this sap acquiring a reddis color on coming to the surface. It should be thoroughly understoo that rust is a plant, just as an oak tree or a sunflower is a plant although it propagates by means of spores instead of seeds. Thes spores are carried by the wind and grow only when they alight upon a living plant. After germinating and passing through the epidermis to the inside of the plant new spores are produced and mul tiply in such numbers that they burst the plant and emerge on th outer surface in long reddish or black lines.

PLANTING SEED DAMAGED BY RUST.

The seed from a crop injured by rust is in practically the same condition as seed that is shriveled from any other cause, such as drought or immaturity, at the time of harvesting. It is generally well known that seed that is merely shriveled from any of these other causes, unless to an extreme degree, is all right for planting. Seed that is much shriveled, however, from any cause should not be used, as it will not have the vigorous growth that it should develop after germination, not having a sufficient amount of stored-up material in the seed to give it a good start. The only important fact for the farmer to understand is that seed from rusted grain will not carry the rust into the next crop—at least so far as the grain rusts of our own country are concerned.

THE USE OF RUSTED STRAW IN STOCK FEEDING.

If straw is extremely rusted, it is of course likely to be of very little value for feeding, simply because a large part of the nutritive material has been consumed by the rust parasite. In such cases the straw becomes actually rotten and looks somewhat similar to straw that is decayed from any other cause. It is not known, however, that there is any particular poisonous action of such straw on the stock, so that while it may be a waste to feed straw badly rusted it is not likely to produce any injury. Many cases are known of feeding very large

antities of rusted straw and smutted corn and cornstalks to cattle thout any injury whatever.

In harvesting badly rusted grain, the spores flying thickly in the r sometimes cause considerable irritation in the nostrils and throats the men who are at work. This is, however, merely a mechanical ritation, occurring only when there is a great abundance of the rust. yond this, no other bad effects on animal life due to the occurrence rust are known.

VARIETIES OF CEREALS RESISTANT TO RUST.

By far the most important thing to be learned from the results of e general rust attack of 1904 is the fact, now well demonstrated, at there are a number of kinds of wheat and other grains sufficiently sistant to rust to give at least a good average yield when the disease curs in the greatest abundance. It was not until the past season at the opportunity of thoroughly demonstrating the fact of this mplete rust resistance of certain varieties was presented, and this monstration alone may yet be found to be of sufficient value to much ore than counterbalance all the losses sustained during the season. can now be seen very plainly what varieties can be depended upon withstand rust, and if such varieties are grown no considerable ss by this fungus need ever again be sustained. The many experients carried on by the Department of Agriculture and the State xperiment stations for several years have led to the belief that a umber of varieties of wheat can offer considerable resistance to rust, ut in no one locality where these experiments have been conducted as the rust ever sufficiently severe to test this question thoroughly until 904. On analyzing the results of many experiments for the season f 1904 it is found that these varieties have withstood the attacks of ust, as would have been expected, but the degree of resistance has een very much greater than would have been predicted.

RESISTANCE OF DURUM WHEATS.

The writer has for several years called attention to the fact that urum wheats resist rust very much more than the common varieties, nd that this ought to be a fact of considerable importance favorable their use. However, this quality has not been emphasized as much s it might be, for the reason that durum varieties are particularly dapted to the drier regions where rust does not often occur. It is ow seen from the results of the crop season of 1904 that rather evere rust attacks are likely even in the driest portions of the grain egion, and that in about one year out of ten this quality of rust esistance becomes of the greatest importance. The results of the eason have also emphasized two other facts, attention to which has

been called before. While the wheats of the durum group are mor resistant than common varieties, there is, however, great variation i this respect among the durum varieties themselves and also amon the common varieties. All durum varieties do not resist rust to a equal degree, and, on the other hand, a few of the common varietie are immune to a slight extent even in a bad rust season.

The extreme effect of a severe rust attack is clearly shown in th accompanying illustrations, in which are represented the seed tha was sown of the spring wheat known as Crawford's Hybrid (fig. 1) and the seed of the rusted crop (fig. 2).

The samples which furnished this illustration came from the Soutl Dakota Experiment Station farm Brookings, S. Dak., and were take from experimental plats grown in co operation with the Department o Agriculture. The grain of a cro rusted to the extent shown in figure has reached the limit of acceptance a the elevators, and in many case throughout the Northwest grai rusted to this degree or worse wa entirely rejected by the grain buyers. The yield of grain per acre in thi case was 4 bushels. If, now, a wheat can be grown on the same quarter section of land the same season and under exactly similar conditions otherwise which will yield 20 to 2 bushels per acre, it is exceedingly important to know this fact; and this information has been obtained as the result of the cooperative experiments at the South Dakota Agricultural Experiment Station during 1904. The varieties that resisted the rust so far as to give the maximum yields mentioned were all of the durum group.

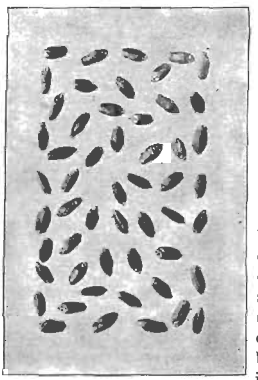

FIG. 1.—Original seed of Crawford's Hybrid spring wheat sown in the spring of 1904 in South Dakota.

A very interesting feature of the experiments as to rust resistance, which have been carried on by this Department for ten years in cooperation with State experiment stations, is that the variety Iumillo (Cereal Investigation No. 1736), which showed the most complete resistance the past season, is the same one that has been more resistant than any other in all of the experiments for the last three years or more. During the previous years the rust was not sufficiently severe to make much difference whether any of these varieties were resistant or not, but nevertheless it was still an interesting fact that this one

ariety was always marked 100 in the scale of rust resistance, while
other variety reached that grade, or, if so, at least only rarely.
ow this fact becomes much more significant and of the greatest
conomical importance after a season of extreme injury through rust.
or a while the fact was overlooked that this is a durum variety, it
eing referred to always as belonging in the common group.

In the accompanying illustration (fig. 3) is shown the grain of this
ariety for the crop of 1904 in comparison with that of three other
arieties. In the order from A to D, which is also the order of the
egree of injury from rust, the varieties represented are as follows:
. No. 1736, Iumillo; B, No. 2228, Saragolla; C, No. 1517, Ghirka
pring, and D, a pedigree Blue
tem. The yields of these varieties
er acre were, respectively: Iumillo,
$5\frac{1}{3}$ bushels; Saragolla, $12\frac{2}{3}$ bushels;
hirka Spring, $6\frac{5}{6}$ bushels, and the
edigree Blue Stem $5\frac{4}{6}$ bushels.
he first two are durum wheats and
e last two ordinary wheats.

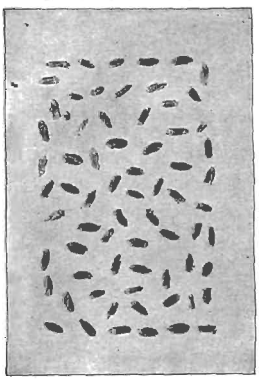

FIG. 2.—Condition of resulting crop from seed shown in figure 1 after the severe rust attack of 1904.

From all results so far obtained
roughout the country, it appears
at the variety Velvet Don stands
ext to Iumillo in rust resistance,
id therefore takes second rank in
is respect. This is shown in an
curate manner by experiments at
e subexperiment station at Edge-
y, N. Dak., carried on in coopera-
on with the North Dakota Agri-
ltural Experiment Station.

Six varieties of durum wheat and
vo common wheats grown at this
ation stand in the following order in rust resistance, the yields per
cre and weights per bushel also being given:

Velvet Don (durum) 35.2 bushels, weight 57 pounds per bushel.
Arnautka (durum) 31.3 bushels, weight 56 pounds per bushel.
Gharnovka (durum) 30.8 bushels, weight 55 pounds per bushel.
Pererodka (durum) 25 bushels, weight 50 pounds per bushel.
Kubanka (durum) 21.5 bushels, weight 48 pounds per bushel.
Nicaragua (durum) 11.2 bushels, weight 42 pounds per bushel.
Hayne's Blue Stem (common) 11.9 bushels, weight 39 pounds per bushel.
Rysting's Fife (common) 11.6 bushels, weight 42 pounds per bushel.

It is seen that at this station the variety Kubanka, which in all other
aspects appears so far to be the best durum wheat yet imported to

this country, stands rather low in rust resistance. Both the yield and weight per bushel of Nicaragua are extremely low as compared with other durum varieties. This is in accord with numerous other observations and experiments with this variety. The Nicaragua wheat has long been grown in Texas, and has reached a considerable degree of deterioration, and it is *no longer a first-class* variety of durum wheat.

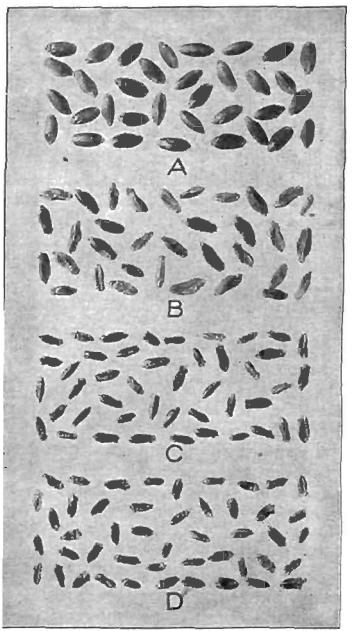

FIG. 3.—Comparison of rust resistance of four different wheats. A.—Iumillo durum, No. 1736; B.—Saragolla durum, No. 2228; C.—Ghirka Spring, No. 1517; D.—A pedigree Blue Stem.

Of course, rust resistance is not necessarily *indicated by the yield* per acre, although within certain groups the yield is likely to be better in the more resistant varieties during a season of an abundance of rust. *At the North Dakota* Experiment Station durum wheats did not do as well as usual, it being a rather wet season, but they maintained well their reputation for rust resistance. Two of the varieties of Blue Stem at the same place resisted rust to some degree, one of these *being a pedigree variety*, but the resistance was small compared with that of the durum varieties.

In experiments at other points similar results were obtained, the durum wheats always resisting rust much more than the ordinary varieties, although at some points the rust was not nearly so severe as in North Dakota and South Dakota.

Among the reports received from farmers are many statements of the great damage inflicted on the ordinary varieties, while the durum wheats, whenever grown on the same farm or in the vicinity, resisted

e rust to a great degree and in some cases almost entirely escaped jury. A careful digest of numerous reports received by the Depart- ent of Agriculture from farmers in the Northwest, compared with ublished reports received elsewhere, would indicate that the loss to e wheat crop by rust amounted to as much as 50 or 60 per cent over rge areas in North Dakota, South Dakota, and Minnesota, while in l cases the loss to durum wheat through the same source seldom arbed more than 10 per cent, being usually 3 to 5 per cent, and some- mes nothing. Conservative estimates have given the decrease in the tire production of wheat in the three States mentioned at from ,000,000 to 40,000,000 bushels, or a loss in the farm value of the heat of at least $25,000,000. There is little doubt that if all wheat own in these three States during 1904 had been durum wheat this loss ould have been entirely avoided,[a] as the little damage that occurred the durum wheat would be much more than counterbalanced by the dinary increase in yield of the durum wheats over that of the com- on wheat when no rust occurs. It is not to be assumed from this atement, however, that durum wheat should be grown throughout e wheat-growing area of those States; it is only adapted to the drier ortions. The quality of drought resistance of this wheat is of even ore importance than that of rust resistance.

The following statements from farmers are given to show the actual mparison on the farm of durum wheats with other kinds in rust sistance. The yields given, as already stated, do not accurately dicate the relation of rust resistance between different varieties, but an average they will give an approximate idea of the differences:

Mr. S. Glover, owner of a large ranch at Glover, N. Dak., who ows 6,000 or more acres of wheat each year, writes that the Fife d Blue Stem varieties yielded on an average about 5 bushels per re and in a number of instances were unfit to cut because of the fect of rust. The durum wheat was also damaged somewhat, but to much less degree and yielded on an average 12 bushels per acre, rading generally No. 2. At the Glover ranch it was found that the ubanka was hurt more by rust than the Arnautka durum wheat.

Mr. Joseph Keller, at Glenullin, N. Dak., grew the Black Don rum wheat, obtaining an average yield of 14 bushels per acre by easure, which greatly exceeded the standard weight. Ordinary heat from the same farm yielded 9 bushels to the acre and was very ght in weight.

[a] At the same time it is now definitely and thoroughly demonstrated, through the perience of many millers and bakers, as well as by numerous family bakings, that e former contention that this wheat is not good for bread is entirely erroneous. ee Bul. No. 70 of the Bureau of Plant Industry, The Commercial Status of Durum heat.)

A correspondent at Arapahoe, Nebr., writes as follows:

I do not think that there is a bushel of spring wheat in this precinct excepting durum wheat. The rust struck the wheat and it blasted, but durum stood the rust all right and made about 35 bushels per acre.

Mr. David Lloyd, of Lamoure, N. Dak., reports as follows:

The crop of 1904 of the durum wheat averages 60 to 85 per cent over Fife, 50 per cent of the difference being due to rust. The probable increase in acreage of durum wheat the coming spring will be fully 50 per cent over 1904. The condition of the wheat crop in this part of the State was better than any year for over twenty years *had it not been for the black rust, said rust reducing the yield of Fife wheat about 50* to 65 per cent and the quality about 25 to 40 per cent.

An interesting feature of the reports from farmers shows that usually where the Pelissier durum wheat was grown it has been more resistant to rust than Kubanka wheat grown at the same place. Mr. C. W. Askew, of Utica, Kans., writes that the Pelissier wheat grown by him resisted rust very strongly, but that Turkey wheat, white Russian wheat, oats, and barley were completely ruined by the rust, and that the Kubanka wheat was badly affected. He adds: "I have never seen such rust as we had on small grain this year."

Mr. M. G. Blackman, of Hoxie, Kans., thrashed 350 bushels of *Kubanka wheat which yielded 15 bushels per acre. The ordinary win*ter wheat in the same locality was an entire failure. He obtained his seed from Prof. J. H. Shepard, of Brookings, S. Dak. The yield of the same wheat in 1903 was about 10 bushels per acre, the kernel being larger and of better quality than the original seed, while this year both yield and quality were still better.

Mr. M. Schievelbein, of Arapahoe, Nebr., obtained 20 bushels per acre of durum wheat, while ordinary wheat on the same farm was not considered worth harvesting because of the destruction by rust.

Mr. K. K. Lee, of Elbow Lake, Minn., reports a yield of 15 bushels to the acre of Bachir durum wheat, while ordinary wheat was a fail*ure because of black rust.*

Mr. Henry E. Schultz, of Erwin, S. Dak., after reporting on his crop of Kabla durum wheat, remarks: "The rest of my wheat, Blue Stem, averaged about 7 bushels per acre by the side of this Kabla, No. 7581, which yielded 20 bushels per acre." The inference from his report is that the difference in yield was caused chiefly by rust.

Mr. N. L. Carpenter, of Barton, N. Dak., grew Kubanka wheat in 1904 with a yield of 26 bushels per acre, ordinary wheat in the same locality yielding about 13 bushels per acre, the difference being due chiefly to rust.

HARD WINTER WHEATS.

In a season of severe attack no kinds of wheat will withstand the ravages of rust except the durum varieties and einkorn and certain varieties of the spelts and emmers. During ordinary seasons, however, even

when the rust may be in considerable abundance, the hard-grained Russian winter wheats are found to be considerably more resistant to rust than the ordinary varieties, and the increase in yield of these varieties over others in the hard winter wheat region is often, no doubt, to a large degree due to the difference in resistance to rust.

In the experiments carried on by this Department at Halstead and McPherson, Kans., in cooperation with the Kansas Agricultural Experiment Station for three successive years, it has been shown conclusively that the hardiest and hardest-grained Russian winter wheats resist rust considerably more than other varieties. There is also a tendency among these hardy winter wheats to ripen just a little earlier than most other varieties, which is also a point in their favor in respect to rust attacks. Even among the Russian winter wheats the variety Kharkof and the recently imported Crimean variety seem a little more resistant than the common Turkey wheat generally grown in Kansas, which originally came from the Crimea. There is especially a considerable difference in rust resistance between Russian varieties of hard winter wheats and the Hungarian varieties, the difference being in favor of the former.

EMMER AND EINKORN.

For several years the writer has called attention in publications and otherwise to the rust resistance of emmer and einkorn, the latter being a kind of grain resembling emmer, but having much smaller heads and only a single grain in each spikelet. Recently it has been determined that only certain varieties of emmer are particularly resistant, there being other varieties that are rather susceptible to rust. To the farmers, therefore, who are growing emmer it is suggested that they keep close watch of the crop in the field and of the different varieties of this grain that are handled in the markets, use seed of those varieties which resist rust best, and select from their own fields the most rust-resistant plants for seed. It will probably be found that the rust-resistant varieties are also the most drought resistant.

Among the varieties of emmer grown in cooperation with the South Dakota Experiment Station during 1904 it was found that three kinds showed great differences in rust resistance, one of the three being much damaged by rust. The variety worst affected (Cereal Investigation No. 1522) gave a yield of 2⅝ bushels per acre, while the most resistant variety (Cereal Investigation No. 1526) yielded 38¼ bushels per acre. The former variety was graded 0 as its per cent of resistance to black stem rust, while the latter variety, so far as any examination could disclose, showed 100 per cent of resistance.

Einkorn appears to be completely rustproof with respect to the ordinary orange leaf rust, and resists almost entirely the black stem rust. In no instance known to the writer has there been any particular damage

to einkorn from rust in the very worst rust seasons during all the time that this grain has been under trial in this country. It is also very drought resistant and completely winter hardy for all latitudes, at least as far as the northern boundary of Nebraska. It is of slow growth, but ought to furnish a considerable amount of winter pasturage and still produce a good yield of grain at harvest time.

RUST-RESISTANT OATS.

There has not yet been found the degree of rust resistance in oat varieties that exists in certain wheat varieties. It is true, however, that in ordinary seasons certain kinds of oats in some localities are not affected by rust when other varieties are considerably damaged. What are known as rustproof oats, under the names of Texas Rustproof, Texas Red, Georgia Rustproof, etc., are generally supposed to be the only kinds that can be grown at all in the extreme South with any promise of success, because of the great abundance of rust which often nearly or entirely destroys ordinary varieties. Of course these so-called rustproof oats are not actually rustproof; there is always a considerable amount of rust on the plants, but in the extreme South they certainly resist rust to a considerable degree. It is a little peculiar that these same oats when planted in middle latitudes or in the North will resist the rust but little, if any, better than the ordinary varieties adapted to such places, and they appear in some cases to be even more affected than other varieties. There is no doubt, however, that the rustproof oats, when not affected by the winter, are the safest for general purposes in the South. On the other hand, it is an important fact that these oats, though often sown in late autumn or early winter, are not winter oats, and therefore are often winter-killed even in the far South. There is therefore a demand in the South for a true winter variety that is at the same time able to withstand the rust as well as or better than the rustproof oats.

EARLY VARIETIES OF GRAIN THAT ESCAPE RUST.

A number of varieties of grain good in other respects will often be free of rust, not because they are resistant, but because they ripen so early as to escape the disease at its worst period. Some varieties are so very early in ripening that even though their yield is not as good as that of others and their quality not so good, they become very important in certain localities, simply because of their ability to escape rust and the attacks of other fungous as well as insect pests. By this means they are able to produce a very good average yield, although their yield in any one favorable season may be less by a large per cent than that of other kinds.

EARLY OATS.

As already stated, oats do not resist rust to as considerable a degree as do a number of durum wheats, and therefore a very early variety of oats has special value. At the present time two of the most valuable varieties in the United States, probably the most valuable in this respect, are the Sixty Day and Early Burt oats, the former having been introduced in recent years from southwestern Russia by the Department of Agriculture. The advantage that the Sixty Day variety has over others in the matter of earliness has been particularly shown during the last season in the Northwest in the entire freedom from rust that has been its characteristic almost everywhere that it has been grown whenever seeded in good time. In many instances where other oats met with entire destruction through rust the Sixty Day oat was harvested in bright condition, with but very little, if any, damage from rust. In such seasons, therefore, it is not a question whether the Sixty Day oat and others of its class are good yielders, but whether such varieties are not the only ones that will yield *anything*. The Sixty Day variety also seems to stand up well. It is of short growth, and, not having a very heavy panicle, does not usually lodge. It does not have a plump grain, and is not so good in quality as the Swedish Select and some other kinds, but it makes up for these deficiencies in the certainty of producing a crop in unfavorable seasons.

In the cooperative experiments at the South Dakota Experiment Station, already referred to, the varieties of oats in most cases were badly rusted. A portion of the report from that station on rust of oats is as follows:

> The spores of the red stage were so plentiful that at times the ground was colored red. About the time the black rust appeared the straw crinkled so badly that it was necessary to cut green, so little can be told by quantitative results in the case of oats. In the fields shown in Photo. G the Sixty Day oat, at the right hand, stood up well and was free of rust, giving a yield of 84.5 bushels per acre testing 35 pounds per bushel. The Swedish Select field, at the left, made a much larger growth of straw, which lodged and rusted, and only thrashed out 51.7 bushels per acre with a test of 23 pounds per bushel, but for reasons given above they were cut while quite green. In the series of plats shown in Photo. H, where the Sixty Day oat is the first plat and the Swedish Select the sixth, the yields were 69 and 70 bushels per acre, respectively.

As the Swedish Select will commonly yield much more than the Sixty Day oat and nearly always greatly outweighs it, it is evident that the difference in weight per bushel in the first of these instances and the average difference in yield in favor of the Sixty Day oat is due simply to the fact that the latter variety ripened sufficiently early to escape the rust.

In all plat experiments of the Department of Agriculture the Sixty Day and Early Burt varieties have maintained the quality of escaping

rust and other diseases by early maturity. The difference in time maturing between these and the average of other varieties runs from week to ten days, or occasionally even two weeks. This, of course, giv time for great changes to occur in the abundance and rate of increa of rust and other parasites, as well as for great changes in the weathe By the same means the Sixty Day variety often escapes the drougl that begins about harvest time in many localities. The Kherson oa another very early variety—in fact, similar in many respects to th Sixty Day oat—now grown to a considerable extent in Nebraska, an also introduced from Russia, is becoming important; but being appar ently more adapted to the drier districts where rust seldom occurs, it ability to escape the rust is not of so much advantage.

JAPANESE AND CHINESE WHEATS.

In most respects Japanese wheats, which all belong to the common group, are not particularly good. They are inferior in milling quality to the varieties generally grown in this country, although really better than the white, starchy wheats of the Pacific coast. A number of Japanese wheats, however, have the important quality of great earliness, and for this reason alone are of value for certain portions of the country, particularly where there is much rust. Several of these, as well as some Chinese sorts, have been under experiment by the Department of Agriculture for a number of years, and a few kinds have given some striking results in the matter of earliness. The varieties Yemide and Onigara are particularly early, and, if sown in good time, will nearly always escape any bad attack of rust. They are, however, very inferior in the quality of their grain and are not adapted for use in the Northern States or the States of the Great Plains. On the other hand, the Pootung, an early Chinese variety, appears to have a very high proteid content, although its quality for bread making has not yet been determined.

The statements just made apply also to some early varieties of barley, although the investigation of different varieties obtained from many quarters has not yet gone so far as in the case of wheat and oats. It is known already that there are a few varieties of importance from the standpoint of earliness.

THE IMPORTANCE OF GROWING HARD WINTER WHEATS.

It has now been determined by actual trials that it is possible by the use of the hardiest varieties to grow winter wheat all over Nebraska and Iowa, in the greater part of South Dakota, and even in portions of Wisconsin, Minnesota, and North Dakota. In previous publications of the Department of Agriculture attention has been called several times to the fact that winter wheat, when it can survive the winter, will always produce a much better crop on the same farm than spring

wheat. At the same time, if the proper varieties are used the quality of the grain will be just as good on an average as the hard spring wheats. It has been stated with particular emphasis that winter wheat, by having a stronger root growth and starting out more vigorously in the spring and ripening much earlier, is able to escape to a great extent the disastrous effect of a rust epidemic, as well as the attacks of other fungi and of insects. It will often also escape the effects of drought, which usually sets in about harvest time or a little earlier.

The ability of winter wheat to escape rust has been shown very clearly the past season. In many instances this wheat has remained almost as free from rust as the durum varieties, but because of its earliness, while the durum wheats resisted the rust. Winter wheat, if ripening at the same time as spring wheat, would probably be as much affected by rust as the latter, although it would always have the general advantage of being a more vigorous plant, with stronger roots. In the season of 1904, in nearly all cases where winter wheats were grown in the spring-wheat States they were much less rusted than the spring varieties, although badly rusted in districts farther south. In the experimental plats at the South Dakota Experiment Station the winter varieties matured early enough to escape any damage, although the ordinary spring wheats, as already stated, suffered very severely last season.

It has been mentioned that the hardiest winter wheats resist rust a little more than other winter varieties, but it is also found that the earlier these varieties are the better, as of course in that case they have the advantage both of resistance and earliness in avoiding the rust. As these hardy and hard-grained winter wheats have such an advantage in respect to rust, besides being superior in other ways, there is probably nothing of more importance than the further extension of their range northward in the spring-wheat region. In this connection one of the most interesting facts now shown is that winter wheat can be grown at least as far north as Lisbon, N. Dak. This gives confidence to the prediction that the results of further experiments will show that the range can be extended to the Canadian boundary.

Mr. C. A. Waterman, of Hay Springs, Nebr., who grew Kharkof winter wheat, the hardiest of the introduced Russian varieties, states that, as a rule, wheat rusted very badly in his section in 1904, but that Kharkof rusted very little. His principal field of Kharkof, however, gave a small yield, because of a very severe hailstorm. This variety seemed to stand the dry weather much better than the ordinary spring wheat. The spring wheat in the locality averaged 10 bushels per acre, while the Kharkof gave indications of producing more than 20 bushels per acre before the fall of hail.

The most interesting trial of winter wheat in the spring-wheat region has been made by Mr. T. N. Oium, of Lisbon, N. Dak. Mr. Oium

has grown the Kharkof winter wheat very successfully for two seasons, obtaining in 1904, 375 bushels, with a yield of 21 bushels per acre. This yield was much better than that of the common spring wheat of the locality, although not nearly so good as the durum wheat, which latter yielded 35 bushels per acre. A particularly interesting fact in connection with this test is that the success in safely wintering the wheat was apparently due to the method of seeding it directly into ordinary wheat stubble without plowing the ground, which gave the opportunity of much protection to the wheat from the snow that was caught and held by the old stubble. This is a method that may be strongly recommended for a time until the wheat becomes sufficiently acclimated to be sown and treated in the ordinary way. It is probable that a harrowing or even a light disking might be given to the stubble ground, which would increase the chances for a good yield and at the same time not interfere materially with the protection offered by the stubble. The quality of the grain obtained by Mr. Olum in 1904 was excellent, and would easily grade No. 2, and possibly No. 1. The weight test was 59 pounds per bushel. A portion of the seed was sown on ordinary plowed land and some in short millet stubble, in both cases with the result that these seedings were entirely winterkilled about the middle of March.

A number of other reports have been received, showing complete success with winter wheat at other points in South Dakota, Iowa, and southern Minnesota. The accompanying picture (fig. 4) is as good an illustration as could well be produced of the differences in injury from rust in winter wheat and spring wheat near Sioux Falls, in southeastern South Dakota.

The winter wheat used, the Kharkof variety from the original seed received from central Russia, is represented on the right of the picture. The spring wheat represented on the left is the common Blue Stem, having a velvet chaff. In both cases the straw, the heads, and the grain are shown. The difference in the quantity of rust on the stems can easily be seen, as well as also the more important difference economically in the character of the grain, it being very much shriveled in the case of the spring wheat. The two wheats had every condition the same, with the simple exception that one was sown in the autumn and the other in the spring.

SEED SELECTION WITH REFERENCE TO RUST RESISTANCE.

Constant and thorough selection of seed is always one of the most important things on the farm, but the results of the past season have greatly emphasized this importance. One of the most interesting facts brought out in the experiments in cooperation with the State experiment stations, as well as shown by observation in many fields on the farms, is the great variation in the effects of the rust on differ-

ent plants in the same field. This was often true even on different plants of the same variety, but of course in many other cases the difference was due to the mixing of varieties in the same field.

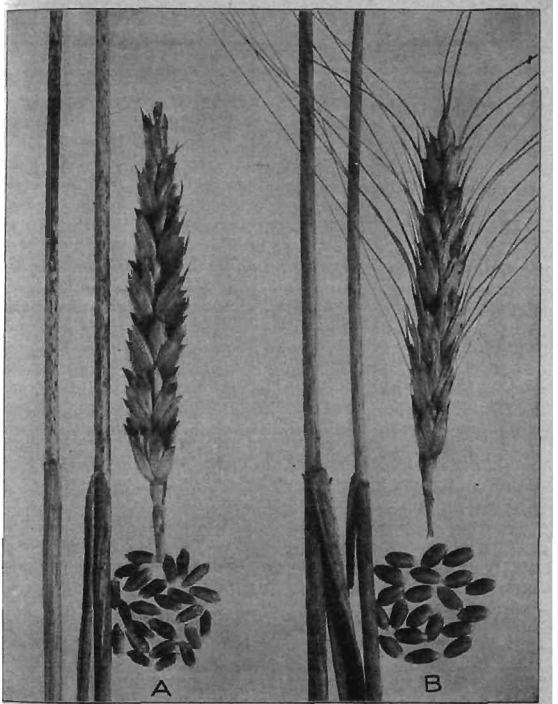

FIG. 4.—Comparative rustiness of spring and winter wheats in southeastern South Dakota in the season of 1904. A—Blue Stem spring wheat; grain much injured by rust. B.—Kharkof winter wheat; grain not injured.

Nearly all of the varieties of durum wheat recently imported from Russia and Algeria were handled in their native localities in so primitive and careless a manner that the seed when obtained here was in every case badly mixed, and much trouble has been caused to the

Department of Agriculture and to the experiment stations and others concerned to develop pure seed from these varieties. The fact of the mixture of the seed has been strikingly shown, as already stated, in the great variation in the effects of rust on different plants in the same field. In some instances certain plants have shown almost 100 per cent of rust resistance, while others, supposed to be of the same variety, were almost worthless because of the rust. There have been other equally interesting examples of mixtures of the common spring wheat with the durum wheat on many of the farms in the Northwest, it being perfectly easy always in going through a field to select the rusted plants from their habit of standing up straight and having a light head, with little or nothing within the chaff, while the durum wheat heads would hang over heavily and be full of fairly sound grains.

As a result of these conditions the farmers of the Northwest have an excellent opportunity this year of ridding themselves of mixtures of other grain in their crops because of the lightness of the rusted seed, and they will certainly not be alive to their own interests if they do not take advantage of it. In most instances the seed of the ordinary spring wheat, mixed with the durum wheat, is so very light that a good fanning will throw it all out, and the farmer therefore can readily obtain fairly pure durum wheat seed. It will be almost inexcusable, therefore, if next season in any of the fields of the Northwest there should be seen any considerable quantity of common spring wheat in the durum wheat, and at the same time the farmers who have clean fields will receive quite a premium in price for their wheat.

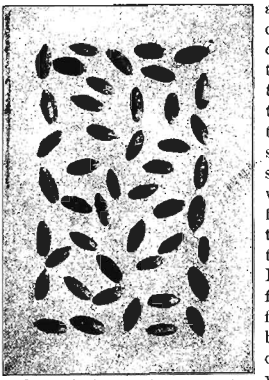

Fig. 5.—Sample of durum wheat grown at Berlin, N. Dak., in the season of 1901.

In the accompanying illustrations the very poor shriveled grains (fig. 6) shown were separated from a sample of durum wheat received from a farm in North Dakota. The seed of the durum wheat is shown in figure 5.

In this instance the rusted, shriveled seed, which was ordinary Fife wheat, made up from 6 to 10 per cent of the crop, a mixture that should never be allowed on any farm. It will be seen that the seed is so light that a large part at least, if not all, could be readily blown out with a fanning mill. The illustrations show the striking difference in the effects of the rust on the common wheat and on the durum

wheat grown in the same fields and under exactly the same conditions. At the same time, the farmers may learn the lesson from this experience of the importance of selecting sound, healthy plants from all fields in all cases. Even where they have no mixture of other varieties there will always be great variation among the plants.

The great advantage of making constant use of a regular seed plat is well shown by the season's experience. The method of making use of this plat will be described briefly. The seed plat is simply a small space of 1 acre or more (depending upon the acreage of grain that the farmer grows), in which only seed grain is grown, none of it being sold in the markets, but all being used for sowing the general crop of the next year. To start the seed plat go through the large field just before harvesting and select all the best individual plants that can be quickly obtained, keeping in mind good stooling, large heads, and vigorous, healthy plants without rust or smut. Continue selecting until a sufficient number of bundles of the plants are obtained which, when thrashed, will give seed enough for sowing an acre of ground, or more if the farmer wishes a larger plat than an acre. This can be thrashed out simply by a flail or by tramping or beating inside of a bag; or, if the seed selection should become a regular custom, which it ought to be, the farmer may be justified in buying a small 1 or 2 horsepower thrasher that can be run by a gasoline engine, at a cost of about $200 for both the thrasher and the engine, which will readily thrash any small-sized bundles, as small even as a mere handful.

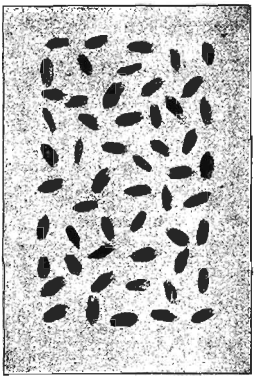

FIG. 6.—Sample of ordinary spring wheat mixed in the same field from which the sample shown in figure 5 was taken.

The seed from these bundles is used for seeding the seed plat, which should be set apart separate from any of the fields and kept thoroughly protected, even fenced in if necessary. Just before harvesting this seed plat, the very best plants should be selected from the plat in the manner described, and the seed of these plants should be used for sowing this seed plat the next autumn or spring, and all the remainder of the seed from the seed plat will then be used for seeding the general crop. Continue the same method from year to year, always obtaining the best seed from the seed plat for seeding itself and using the remainder of the seed harvested from this plat for seeding the general crop. In

this way no seed is ever taken from the general crop, and yet it is produced on the same farm, is constantly improved, and is better than seed imported.

DRAINAGE AND CLEAN CULTIVATION.

Probably in all cases where it is supposed that differences in the composition of the soil have some relation to the occurrence of rust, the real cause for variation in this respect is the relative quantity of water in the soil. A poor soil will nearly always be somewhat elevated and a rich soil low lying, as naturally the richer material of the soil will be washed to lower elevations. At the same time and for the same reason there will be more water in lower, fertile soils than in the poorer soils. The more succulent and watery the plant becomes from the great quantity of water in the soil the more rapidly the rust will grow in the plant, and this is, therefore, the reason why more rust occurs in the fertile, lower lying soils. It is evident that in grain grown on water-logged soils there will be much more rust than elsewhere, and that thorough drainage will tend to lessen the amount of rust.

On plants grown in heavily manured ground it is not directly the amount of nitrogenous material thus furnished to the plant that is the cause of more rust, but the fact that such plants are also thus enabled to absorb more moisture and always are more rank in growth and have softer straw. It will also follow that plenty of sunlight will have the effect of dissipating moisture, and therefore to some extent will prevent the spread of the rust. Thorough and clean cultivation of the soil, exterminating all weeds and drilling the wheat instead of broadcasting, will admit much more sunlight, and should always be practiced for other reasons as well.

INFECTION FROM RUSTED GRASSES.

It has been proved by previous experiments of the Department of Agriculture that the black stem rust of oats is the same as that which occurs on the wild meadow oat grass and sometimes on orchard grass. It probably occurs also on two or three other wild grasses. The black stem rust of wheat is known to occur on several of the wild-wheat grasses, or quack grasses, and on certain wild-rye grasses. It is known, further, that the rusts from wild-wheat and wild-rye grasses will readily infect wheat. It is therefore of considerable importance to the farmer to know whether these grasses on his farm are usually rusted; and if so, to try to avoid sowing the grain crops near them. It is probable that further experiments will determine what other grasses, if any, harbor these rusts, so that all the grasses that should be kept away from the grain fields may soon be definitely known, and through such knowledge the farmer may be enabled very largely to eliminate the chances for the occurrence of rust in his fields.

O