ENTOMOLOGICAL SERIES—BULLETIN No. 1

DEPARTMENT OF AGRICULTURE

MYSORE STATE

THE RICE GRASSHOPPER

(Hieroglyphus banian, Fabr.)

BY

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ASSISTED BY

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BANGALORE:
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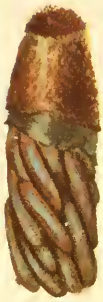
PRICE ONE RUPEE.



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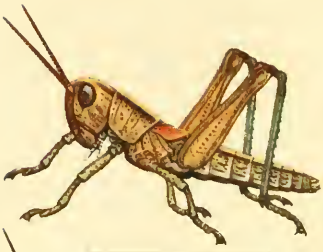

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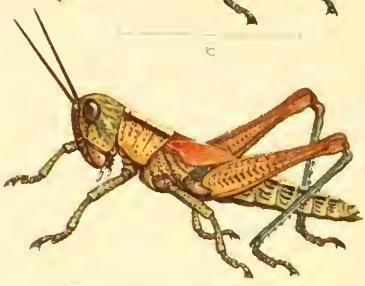

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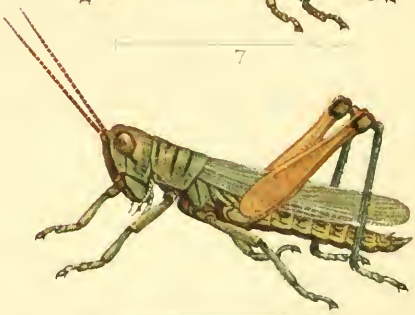

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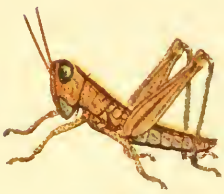

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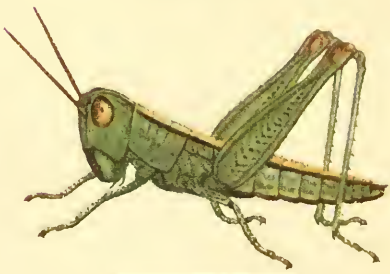

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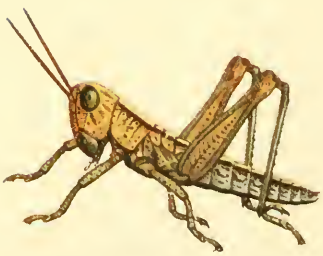

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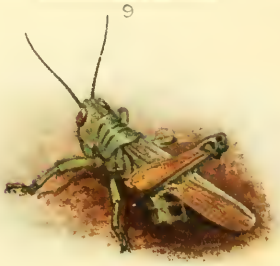

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EXPLANATION OF PLATE I.

FIG. 1.—Egg-mass of Rice Grasshopper (*Hieroglyphus banian*, Fabr.). The covering has been removed from the lower end to expose the eggs. The spongy brownish yellow plug is shown above.

FIG. 2.—Nymph of first instar.

FIG. 3.—Nymph of second instar.

FIG. 4.—Nymph of third instar.

FIG. 5.—Nymph of fourth instar.

FIG. 6.—Nymph of fifth or sixth instar.

FIG. 7.—Female nymph of seventh instar.

FIG. 8.—Adult male grasshopper.

FIG. 9.—Nymph of fourth instar showing green color variation.

FIG. 10.—Adult female grasshopper laying eggs.

The hair-lines show the real lengths of the insects painted, the figures being enlarged. Fig. 9 was evidently painted from a nymph which was ready to assume the next higher stage of development, as it is particularly large for a nymph of the fourth instar.

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FOREWORD.

This bulletin is the first of a series dealing with the insect pests of Mysore. While the insect which forms its subject is one that has been long known as a serious pest in India, no accurate and complete account of its life-history has, as yet, been published.

The present bulletin embodies results of observations and experiments which have extended over about three years. While I am to be held responsible for the facts and conclusions that are given in the following pages, the carrying out of experiments and observations in the field has largely devolved upon my Assistant Mr. K. Kunhi Kannan, under my direction.

The coloured plate has been prepared from paintings made by M. Ranganayakalu, Artist of the Department, while the photographs and the drawings from which the other plates and most of the text-figures have been prepared were made by me.

For the great care taken in the printing of text and plates I wish to thank Mr. C. H. Yates, Superintendent of the Government Press.

Leslie C. Coleman.

Bangalore,
June, 1911.

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THE RICE GRASSHOPPER.

(*Hieroglyphus banian, Fabr.*)

THE Rice Grasshopper is an insect by no means new to science. It was first described by Fabricius,[1] as long ago as 1798, under the name of *Gryllus Banian*, with habitat given simply as East India. The description of Fabricius is incomplete and, in some respects, inaccurate, so that the insect was redescribed by Serville[2] in 1839 as *Acridium furcifer*, with a note that this name is possibly synonymous with the *Gryllus Banian* of Fabricius: he, however, adds: "Sa description est tellement concise, qu'il est difficile de prononcer, il ne parle ni des ailes ni des antennes; ne désigne pas la taille et dit que les jambes postérieures sont verdâtres." Serville's description, based upon three specimens from Bombay, is very complete and leaves no doubt whatever that he was dealing with the Rice Grasshopper. He gives a figure of the posterior end of the male and of an anal cercus.

The genus *Hieroglyphus* was established by Krauss[3] in 1877. Stal,[4] in his "Systema Acrideodeorum," lists the Rice Grasshopper as *H. furcifer*, Serv., and Brunner de Wattenwyl[5] does the same in his "Revision du Syteme des Orthoptères." Kirby[6], however, in his "Catalogue of Orthoptera," recognises the priority of the name given by Fabricius and lists the form as *Hieroglyphus banian*, Fabr.

This, as far as I am aware, comprises the systematic literature dealing with the insect, with the exception of a paper by de Haan,[7] which I have not had the opportunity of consulting.

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[1] Fabricius, Entomologica Systematica, Suppl. p. 194, 1798.
[2] Serville, Hist. Nat. des Orthoptères, p. 677, pl. 14, fig. 12, 1839.
[3] Krauss, Sitz. Akad. Wiss. Math-nat. Classe XXVI (1) p. 41, 1877.
[4] Stal, Systema Acrideodeorum, Bihang Svensk. Akad. Handl. V (4) pp. 48 and 93 1878.
[5] Brunner de Wattenwyl, Revision des Orthoptères, p. 154, 1893.
[6] Kirby, Synonymic Catalogue of Orthoptera, Vol. III, p. 396, 1910.
[7] De Haan, Temminck Verhandl. Orth. p. 155, n. 10, 1842.

Besides *H. banian*, two other species of this genus are met with in India, but these other two (*H. concolor*, Walk. and *H. citrinolimbatus*, Brunn.) appear to be restricted to the northern part of the country and both differ from *H. banian* in having no spine on the anal cercus.

The Rice Grasshopper has a very wide and general distribution throughout India and has formed the subject of a number of notes. The first note on it as a serious pest of cultivated crops appeared in Indian Museum Notes, Volume I, page 203, 1889-91, where it is recorded as having been present at Raipur, C. P., in 1886 and 1889, attacking paddy and millet in Kathiawar in 1889 and in Guzerat. Each succeeding volume of Indian Museum Notes[1] has one or more references to this insect as a pest on sugar-cane, paddy, jowari, bajri, etc., from almost all parts of India, from Madras Presidency north to Bengal and west to Kathiawar.

An interesting account of observations, made by cultivators and landholders on this pest, appears in Indian Museum Notes, Volume V, page 20, 1903. The report, compiled by the Revenue Department of Kerowlee State, among a number of inaccuracies, notes quite correctly the growth and moulting of the young insect and the weak powers of flight of the adult. Lefroy,[2] in his "Important Insects Injurious to Indian Agriculture," gives, as distribution, Bengal, United Provinces, Central Provinces, Mysore, Hyderabad, Bombay, Madras Presidency and Burma, and, as food plants, grasses, rice, cane and small millets. Lefroy also gives short notes on this pest in his "Indian Insect Pests"[3] and his "Indian Insect Life,"[4] while he also refers to it in his memoir on the Bombay Locust.[5] In all four of these publications, he figures the insect; in "Indian Insect Life," he gives a not very satisfactory coloured plate showing egg-mass, and young and adult grasshoppers.

Shortly after the organisation of this office in 1908, reports of damage done by the Rice Grasshopper were

[1] Indian Museum Notes, Vol. I, p. 203, Vol. II, p. 30, Vol. III, p. 29, Vol. IV, p. 29, Vol. V, pp. 20 and 49, 1889-1903.

[2] Lefroy, Important Insects Injurious to Indian Agriculture, Mem. Department of Agriculture in India, Entomological Series, Vol. I, No. 2, p. 120, figures 3 and 4.

[3] Lefroy, Indian Insect Pests, p. 120.

[4] Lefroy, Indian Insect Life, p. 87, Pl. VII and Fig. 27, 1909.

[5] Lefroy, The Bombay Locust, Mem. Department of Agriculture in India, Entomological series, Vol. I, No. 1, p. 53.

received from Anavatti, Sorab Taluk, Shimoga District. In 1909, the infected area was inspected thoroughly by the junior author who reported as follows :—

"The infested part is a broad stretch of land occupying an area of twelve square miles, of which about 3,400 acres are in Mysore and the rest, separated by the Varada River, in Dharwar District, Bombay Presidency. Save for small patches of grazing lands or of sugar-cane here and there, the whole area is under paddy cultivation."

The raiyats reported that the pest had made its appearance in Mysore in a single village (Kubatur) two years previously and had spread from there over the 3,400 acres mentioned. Apparently it had spread from Dharwar into Mysore.

In 1910, in addition to the area already mentioned above, the following areas were reported as affected :—

Shikarpur Taluk—villages in the neighbourhood of Siralkoppa.

Tarikere Taluk—villages near Lakvalli.

Yedatore Taluk—villages near Yedatore.

All of these areas were inspected. On the area near Siralkoppa, grasshoppers were present in considerable numbers and were doing some damage. In the other localities, the damage was comparatively slight, though the raiyats on infested lands in Yedatore Taluk estimated a loss of ten per cent of the crop.

In addition to the above, stray specimens of this pest have been obtained near Talaguppe, Sagar Taluk, and in the suburbs of Mysore City. Careful search and enquiry have been made in the western part of Kadur District and the southern part of Shimoga District without revealing it at all.

It is quite apparent from the above that the pest is widespread in Mysore, but it is equally clear that large areas of paddy lands, in all probability the majority of them, are still quite free. Moreover it does not seem, as yet, to have appeared in any of the important sugar-cane growing areas with the exception of Shikarpur Taluk. It is clear, therefore, that the fullest information with regard to this pest and with regard to methods of combating it is necessary, not only in those districts where it has already appeared, but also in all parts of the State where wet cultivation is carried on to any considerable extent, so

that, should the pest appear in any of these localities in the future, prompt measures may be taken to keep it under control.

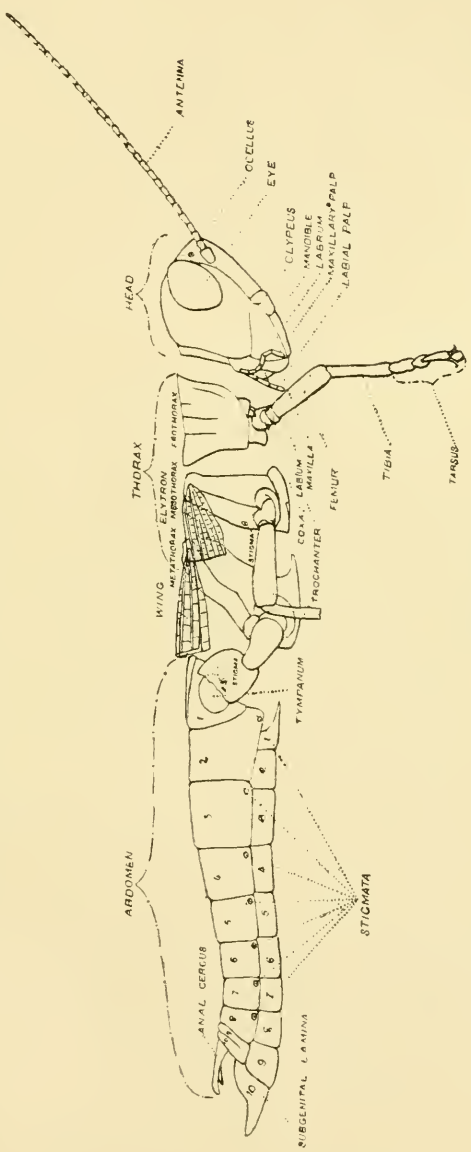
As already noted, a number of different crops have been reported as being attacked by the Rice Grasshopper, but, as far as Mysore is concerned, it seems to have confined itself entirely to paddy and sugar-cane, in addition to grass. This is explained by the fact that, in the areas from which it has, up to the present, been reported, these are the only two crops grown. The damage done to paddy is twofold. It feeds upon the leaves and also cuts through the upper part of the stalk; as soon as the ears have appeared, it does an amount of damage quite incommensurate with the amount of food it actually consumes, in that it eats through the paddy stalks and so causes the ears themselves to fall. In a badly attacked field, large numbers of these lopped ears can be found lying on the ground after the crop has been removed. It is this loss that the raiyats feel most keenly, the equally real, though less apparent, loss through eating of the leaves being much less felt by them. The paddy grains themselves are, as far as we have observed, never eaten by the grasshopper.

In the case of sugar-cane, the grasshopper confines itself to the leaves; in badly infested patches of cane, the stalks may be practically stripped of leaves, mere shreds being left here and there. It is needless to point out that such a destruction of leaves in the early or middle stages of growth is bound to have a very serious effect on the crop. Damage to sugar-cane has, as yet, been but slight and our observations on this pest have been practically confined to it as it occurs on paddy.

Before entering upon a description of the Rice Grasshopper, it may be well to explain briefly the chief external characters of grasshoppers in general. The accompanying figure (Text-fig. 1) serves to illustrate their external structure. The body of an insect is divided into three regions, head, thorax and abdomen, which, in the case of grasshoppers, can be readily made out even by a casual examination.

Towards the upper part of the head, are to be found a pair of slender antennæ or feelers and a pair of large eyes placed laterally. Below are the mouth parts, which

consist in the first place of an upper lip or labrum and a pair of powerful jaws or mandibles, which work laterally instead of up and down as is the case with our jaws. Behind the jaws, comes a pair of more slender accessory jaws or maxillæ to each of which is attached a small feeler or palp. The lower or posterior part of the mouth is bounded by a lower lip or labium, to which are also attached feeler-like structures.



TEXT-FIG. 1.

Outline of male of Rice Grasshopper to show the chief external features. Only the bases of the elytron and wing are shown. Middle and hind-legs have also been cut short.

The thorax, or middle part of the body, may be considered as the motor portion of the insect. To it are attached above two pairs of wings. In a state of rest these wings are laid back over the posterior part of the body or abdomen ; the posterior and more delicate pair are neatly folded beneath the leathery anterior pair, which are commonly called wing-covers (elytra). When in use, the wings are extended at right

angles to the body (see Plate II, Figs. 1 and 2). To the lower portion of the thorax, are attached the three pairs of jointed legs which are to be found in all insects. In the case of grasshoppers, the first two pairs of legs are comparatively slight, while the posterior pair are greatly enlarged and very strong. It is by means of this posterior pair that the insect is able to jump or hop so efficiently.

The abdomen, which consists of a series of distinct segments or rings, possesses few features that it is necessary to note. The posterior end, however, bears certain structures which allow us readily to distinguish whether the particular individual which we are examining is male or female. In the case of the male, we find a single more or less scoop-like plate, in the hollow of which are to be found the organs of copulation. In the female, we find instead an upper and a lower pair of horny valves or diggers (ovipositors) which are capable of being spread apart and drawn together. These form the apparatus by means of which the female is able to dig the hole in the ground in which she deposits her eggs. In both male and female, we find above, at the posterior end, a pair of short horn-like processes which may be called the posterior feelers (anal cerci). Along each side of the body, on both abdomen and thorax, is a series of small openings or breathing-pores (stigmata) through which the animal breathes.

It must be further noted that, in the case of grasshoppers, the male is usually smaller and slenderer than the female and this is the case also with the insect under study (see Plate II, Figs. 1 and 2).

The Rice Grasshopper may be quite easily recognised if the accompanying coloured figures (Plate I) are consulted. As will be seen there, the adult insect is green or yellowish green in color. The prothorax is marked above and laterally with four somewhat irregular transverse brown or black lines. The lower surface of the insect is brownish black while the middle division (tibia) of the posterior leg is blue. These features should be sufficient to make the insect readily recognizable.

GENERAL LIFE HISTORY.

Like most insects and all grasshoppers, the Rice Grasshopper hatches out from an egg. The eggs are laid

in masses in the ground during the months October to December, in Mysore State. They remain in the ground till the following June or July when they hatch, giving rise to very small hoppers not more than one-fourth inch in length. These commence feeding on the grass growing on the bunds. They grow quite rapidly and moult or cast their skins at intervals of from ten to fifteen days, so that, by the middle of September or first of October, full-grown insects begin to be noticed and by the middle of November the majority of the hoppers are full grown. Egg-laying takes place again during the months October to December and by the first of January most of the hoppers are dead, only a few stragglers being left. From this it will be seen that one-half the year or the dry season is passed in the egg stage, while, during the other half, the grasshopper is busy destroying vegetation.

The egg-laying.—As stated already, the egg-laying takes place from October to December. In the case of an individual female, it usually commences within about two weeks after she has become full grown.

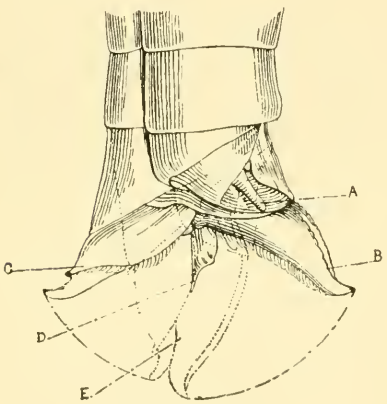
The egg-laying is done, almost without exception, in the grassy bunds surrounding paddy fields or in the corner mounds. It is the greatest exception to find egg-laying in the fields themselves, only one such case having been observed. This fact is of considerable importance for, were the eggs laid in the fields, it is moderately certain that they would fail to hatch, from the fact that, at the time when hatching normally takes place, the fields are usually flooded with water. It is a well-known fact that, among grasshoppers in general, considerable care is exercised by the females in selecting the places best suited for laying eggs, and the Rice Grasshopper is no exception in this respect.

The method of oviposition in grasshoppers, although very frequently observed, has been rarely if ever exactly described. The most exact account is that given by Riley[1] for the Rocky Mountain Locust—*Melanoplus* (*Caloptenus*) *spretus*. Riley ascertained the mode of oviposition "by repeatedly extricating and studying specimens in every possible stage of oviposition." He considered that he was thereby able to "ascertain the exact method

[1] Rep. Ins. Missouri IX, 1877, p. 86. Cited in 1st Annl. Rep. of the U. S. Entomological Commission, 1877, p. 223.

by which the egg-mass is formed." It is, however, quite conceivable that, by this method of study, he was not able to obtain an exact picture of what took place beneath the surface of the ground. In any case, there is no doubt that, in the case of the Rice Grasshopper, oviposition does not take place exactly as described by Riley for the Rocky Mountain Locust.

In order to get as accurate information on the mode of oviposition as possible, the following method was adopted. Females, ready to lay eggs, were placed in a glass dish, in which a thin layer of earth (one-quarter to one-half inch), close to the wall of the dish, was separated off by means of stiff cardboard. Only this thin layer was exposed above, all the rest of the soil being covered by cardboard. The result was that the grasshoppers were forced to dig their holes and lay their eggs in the thin layer of soil close to the glass. In many cases, the whole course of the digging, the preparation of the hole for the reception of the eggs and the laying of the eggs themselves could be observed through the glass side of the dish and even photographs of the process could be taken (see Plate II, Fig. 4). Round breeding jars were used for some of these observations, but the best results were obtained by using a rectangular glass trough such as that employed by analytical chemists.

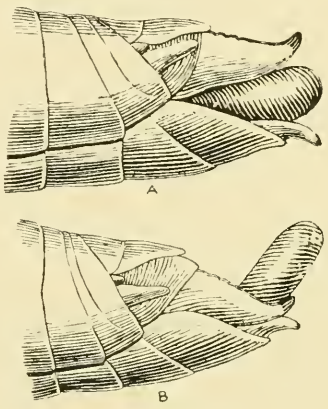


TEXT-FIG. 2.

Posterior end of female of Rice Grasshopper to show action in digging hole previous to egg-laying. The dotted outline shows the ovipositors closed, the rest of the figure shows them separated to shove the soil outward. A. Anal cercus. B. Dorsal ovipositors. C. Ventral ovipositors. D. Furcula vulvalis. E. Ovipositors closed.

The time required for the actual excavation will, of course, vary with the hardness of the soil. In our observations, the excavation took about thirty minutes. It was accomplished, as already described by Riley, by means of the four horny valve-like ovipositors situated at the posterior end of the body. The accompanying Text-fig. 2 indicates how these valves work. They are shoved into

the soil in a closed position and then separated as shown in the figure. Thus the soil is shoved outward and the cavity made. As these valves work only in one plane, it is clear that they could make an approximately round hole, only if they could be rotated so as to press in all directions, and this is what actually takes place. The whole posterior end of the body is capable of twisting laterally through 180°, so that the posterior pair of valves come to lie anteriorly and *vice versâ*. As soon as the proper depth has been reached, the grasshopper proceeds to enlarge the lower portion of the hole and make the walls smooth and firm for the reception of the egg-mass. This is done with great care by means of pressure from the extended valves, as much as twenty minutes' time being occupied in this way.



TEXT-FIG. 3.

Posterior end of female of Rice Grasshopper to show manner of exit of egg. A. First stage, in which egg appears between dorsal and ventral pairs of ovipositors. B. Second stage, in which dorsal ovipositors have moved down and grasped the egg between them.

When the egg-chamber has been properly formed, the egg-laying itself begins. It is signalled by a convulsive movement of the valves and the posterior part of the body, and the appearance between the valves of a clear fluid much resembling white of egg in consistency which, as it is expelled, is quickly worked up into a white froth by the movement of the valves. When a small amount of this frothy material has been deposited on the bottom of the chamber, the convulsive movements of the valves stop, the posterior pair of valves separate from the anterior pair and the tip of the egg appears in the space between them, just extending beyond the tips of the valves themselves (see Text-fig. 3A). The posterior pair of valves are then quickly brought forward around the end of the egg and approximated to the anterior. At this stage, the egg lies clasped between the two posterior valves in the position figured by Riley in the above-cited work (see also Text-fig. 3B). It is then forced out into the frothy matter at the bottom of the egg-

chamber. Following the extrusion of the first egg, comes another period of convulsive movement on the part of the valves with the extrusion of more frothy material and these two processes (egg-laying and formation and deposition of frothy cement material) alternate until the oviposition is completed.

The above description differs from the account given by Riley, and it is interesting to quote his description for comparison. He states: "The process has never been accurately described by other writers and the general impression is that eggs are extruded from between the distended hooks or valves. If we could manage to watch a female from the time the bottom of her hole is moistened by the sebific fluid, we should see the valves all brought together, when an egg would pass down the oviduct along the ventral side and, guided by a little finger-like style, pass in between the horny valves (which are admirably constructed not only for drilling but also for holding and conducting the egg to its appropriate place) and issue at their tips amid the mucus fluid already spoken of."

It appears highly probable that Riley overlooked the first stage in the deposition of the egg, where the valves are separated as described above, and this can be readily understood, on the one hand, from the fact that this stage is of very short duration and, on the other hand, from the fact that Riley's observations were made on grasshoppers removed from their holes during oviposition. As a matter of fact, the eggs are at first partially extruded between the two pairs of valves, so the earlier observations of Burmeister and others are only partially incorrect.

The eggs are arranged with a certain degree of order in the egg-mass, although the arrangement is by no means perfectly regular. The accompanying figures (Plate I, Fig. 1 and Plate II, Fig. 5) show its character. These bear some resemblance to the figures given by Riley for *Melanoplus spretus*, the arrangement being, however, not so regular as that indicated in his figures which are, doubtless, diagrammatic. When we come to consider the orientation of the mass, however, we find conditions exactly opposite to those figured by Riley. According to his figures, the first eggs are deposited towards the anterior side of the burrow, the succeeding ones being placed

posterior to and above the first ones. In the case of the Rice Grasshopper, just the opposite of this takes place. The first eggs deposited are placed towards the back of the egg-chamber, subsequent ones being shoved in anterior to and above them (see Plate II, Fig. 4).

When we consider the fact that the egg is pushed out between the upper pair of valves, which have a posterior position when the grasshopper is in the act of laying eggs, it is very difficult for us to conceive how the first eggs laid could be pressed against the anterior side of the burrow, as indicated in Riley's figures. Careful observations made on the Rice Grasshopper, while in the act of depositing eggs in the burrow, have shown conclusively that only the upper or posterior pair of valves have to do with the arrangement of the eggs. We are, therefore, constrained to doubt whether Riley's figures represent the actual facts of egg-laying in the case of *Melanoplus spretus*, while it is quite certain that they do not represent conditions with the Rice Grasshopper.

Another point of difference worthy of note, is the direction of the burrow or hole. Riley figures it for the Rocky Mountain Locust as curving obliquely forward, while in the Rice Grasshopper, in all of the many cases observed by us, the hole was practically straight and slanted obliquely backwards. As pointed out above, the arrangement of the eggs in the mass is the opposite of that figured by Riley, the eggs slanting backward and upward instead of forward and upward.

The deposition of the eggs occupied, in the cases observed, about thirty minutes. We have, therefore, for the whole process the following periods :—

Digging hole	... ...	30 minutes
Forming egg-chamber	...	15—20 minutes
Depositing eggs	... ...	30 minutes
Total one hour and 15—20 minutes		

At times, the grasshopper remains in the hole for a considerable period after the egg-laying is finished. At other times, it leaves almost immediately. On the whole, the above figures agree fairly well with observations made in the field as to the length of time required for oviposition.

As is well known, female grasshoppers possess two ovaries and it is an interesting point to ascertain whether, during the act of oviposition, the eggs come alternately from right and left ovary, or whether one ovary is emptied first followed by the other. As far as we are aware, no observations have been made on this point among grasshoppers, but Wheeler, in his studies on oviposition in the cockroach *Phyllodromia*, has shown that there the eggs come alternately from the two ovaries. In the case of the Rice Grasshopper, the opposite of this seems to occur. A female, killed during the act of oviposition after seven eggs had been laid, and dissected, showed that all the eggs had come from the left ovary, the right ovary being still quite full. It seems probable, therefore, that in the case of the Rice Grasshopper, one ovary is emptied of mature eggs before any pass down from the other.

The number of eggs in an egg-mass varies very greatly, and this is probably associated with the fact that the female *Hieroglyphus* lays more than one mass. Although no observations have been made on this point, it seems likely that the first one or two egg-masses laid contain more than those deposited later. The following record of observations gives an approximate idea of the number of masses laid per individual and the number of eggs per mass.

1. Nine females in breeding cage with males. Copulation first observed 14th October, 1910. First egg-mass found 29th October, 1910. By 17th January, 1911, all grasshoppers were dead. On 30th January, 1911, soil was examined, and thirty-four egg-masses were found. This, with an egg-mass previously removed, gives a total of thirty-five egg-masses laid by nine females, or almost four egg-masses per individual.

The lengths of these egg-masses were as follows:—

9—9 ½ mm.[1]	...	...	3	egg-masses
10—10½ ,,	...	...	5	,,
11½ ,,	...	...	3	,,
12 ,,	...	...	14	,,
13 ,,	...	...	2	,,
14 ,,	...	...	2	,,
15 ,,	...	...	5	,,
	Total	...	34	

Number of eggs per mass was as follows:—

53, 45, 44 (2), 43, 42, 41, 36, 35 (3), 34, 32, 31, 30, 28 (3), 26

[1] One inch = 25 mm.

(2), 25, 22 (2), 20 (2), 19, 18 (2), 17 (2), 9, 7. In addition, one was simply froth, no eggs being present at all, and one mass was missed. Average number of eggs per mass 29.

2. Seven females with males transferred to cage, 15th October, 1910. On 20th October, 1910, first egg-laying observed ; last egg-laying observed 13th December, 1910. Last female died 25th January, 1911. Examination of soil on 31st January, 1911, revealed twenty-one egg-masses or three per individual female. The measurements varied between 8 mm. and 18½ mm., the majority lying between 13 and 15½ mm. The number of eggs per mass was as follows :—

59 (2), 54 (4), 52 (2), 50 (2), 48, 47 (3), 45 (2), 44, 43, 36

Two masses were broken and so could not be counted.

Average number of eggs per mass 49.

In this case, the average is very much greater, as is also the total number of eggs laid per individual. In the first case, we have about 103 eggs per individual, while, in the second case, there were about 150 laid per individual and this notwithstanding the fact that there was a decidedly higher number of masses per individual in the first case than in the second.

The egg-masses are very firm and tough. This is so much so that it is very difficult to dissect out the eggs from them. In the above, the egg-masses were first boiled in solution of caustic potash before the eggs were dissected out.

The eggs themselves are elongate elliptical, of a yellowish colour and measure on the average 5¼ mm. by 1¼ mm. in the case of alcohol specimens. They are so arranged in the mass that the head of the developing insect lies at the upper end. Thus when the young grasshopper emerges from the egg, it is in the position best suited to facilitate its escape to the surface of the soil. At the lower end of the egg, is the small opening in the shell or outer covering, the so-called micropyle, through which the male cell enters to fertilise the egg.

Hatching of the eggs.—The hatching of the eggs of the Rice Grasshopper commences shortly after the beginning of the south-west monsoon, or, in other words, about the middle of June, and continues for about a month and a-half. There may be considerable variation, however, as to the time of commencement of hatching, and this is no doubt connected with the rains. Thus, in 1909, young grasshoppers in considerable numbers were found in some villages in the neighbourhood of Anavatti on the 15th

June. In 1910, the first emergence was observed at Anavatti itself on the 8th July, while, in a neighbouring village, they had begun hatching about ten days previously. In 1909, rain fell early in May, so that ploughing operations began on the 8th of that month. In 1910, there was practically no rain in May and in June rain fell in appreciable quantities first on the 22nd, while ploughing operations did not begin till the 7th July. While emergence is, for the most part, completed within thirty or forty days, there may be a few decidedly belated cases. Thus, we have a record of one egg-mass which hatched as late as the 24th August.

The actual process of hatching is that usual among grasshoppers. In the egg-mass as normally situated, the eggs are placed, as already stated, so that the head of the embryo grasshopper is pointed upwards. By means of a peculiar convulsive movement, accompanied by a swelling out of the body just behind the head, the shell is ruptured and the young hopper, enclosed in a delicate membrane (the amnion), makes its way out of the shell. From here to the surface of the soil, the young hopper makes its way normally by a series of worm-like movements. The legs, which like the rest of the body are enclosed by the amnion, are usually not at all used. Occasionally, however, the young hopper extricates itself from the amnion before reaching the surface (see Plate II, Fig. 3). The original hole made by the female at the time of egg-laying has, in most cases, been quite obliterated but the young hoppers are quite able to force their way up through the one or two inches of earth lying between the egg-mass and the surface.

As soon as the young hopper reaches the surface of the soil, it proceeds to divest itself of its membranous covering. This is split open just at the back of the head and, by a series of contractive and expansive movements, is worked gradually back over the body till it is finally kicked or thrust off as a small whitish crumpled mass by the hind legs. A mass of these small white pellets is to be seen about the exit hole of each hatched egg-mass and a count of them enables us to estimate, with a fair degree of accuracy, the number of eggs that have hatched from the mass. As already pointed out by Riley and others, one of the chief functions of this membranous covering seems to

be to protect the delicate young hopper while it is forcing its way up through the soil. The newly-hatched grasshopper is almost pure white in colour. The colour, however, gradually changes so that within a few hours it has become dark yellowish brown.

Development of the grasshopper.—All insects during their growth go through various stages or instars. This is made necessary from the fact that the outer covering of the body becomes very hard and inelastic. In this condition, it does not allow the insect to increase in size to any very marked extent. In order to allow for a comparatively free increase in size, it is necessary that a fresh, soft and elastic covering or skin should be formed beneath the old one and that the old one should be shed. This fresh covering, in its turn, becomes, in time, hard and inelastic and has later to be replaced by another one formed underneath it.

In the case of grasshoppers, this process of moulting takes place at intervals during the whole period of growth up to the time when the insect becomes full-grown. The growing period is thus divided into a series of stages or instars which are marked off from each other by the various moults. The first stage or instar, therefore, extends from the time the young grasshopper hatches to the time when the hardened outer covering is shed for the first time.

The newly-hatched Rice Grasshopper resembles, in general appearance, the full-grown insect. We find jaws, eyes and legs present very like those of the adult insect. There is, however, as yet no sign of wings. The colour and markings on the body are also very different from those of the full-grown insect, while the antennæ are also distinctly simpler in structure.

FIRST INSTAR. (PLATE 1, FIG. 2.)

The accompanying figure gives an accurate representation of the insect during this first instar after it has assumed its permanent colour. The following are the chief points to be noted :—

Length of body on hatching	...	5—6 mm.
Length of antennæ	...	2 ,,
Number of segments or divisions in antennæ	...	13

The 8th segment shows signs of division.

The antenna is slightly club-shaped (clavate), the distal six

segments being dark brown, the proximal seven being paler in colour Sensory pits on the distal six segments are very numerous, much more so than on the rest of the antenna (see Plate III, Fig. 1*a*).

Colour.—The ground colour of the body is yellowish but the body is so covered with reddish-brown spots and patches as to have a general yellowish-brown appearance. On the middle of the back is a bright greenish-yellow band about $\frac{1}{2}$ mm. broad, extending from the head to the posterior end of the body. On each side of this, is a dark brown longitudinal band of about the same extent and half the width. These two bands serve to mark off the yellow band very distinctly from the rest of the body. The legs are pale yellow with numerous reddish spots. The main division of the hind leg (femur) has a reddish longitudinal streak on its outer surface.

The ventral surface of the body is dark brown in colour. The whole surface of body and legs is clothed with rather fine short hairs, those on the legs being somewhat longer.

SECOND INSTAR. (PLATE I, FIG. 3.)

Length on day of moulting ... ... 8—8$\frac{1}{2}$ mm.
Length of antennæ ... ... 2·5 „

Number of segments in antennæ 13, but segments 3, 7 and 8 show distinct signs of division, so that 16 segments are visible. In some cases segment 6 also shows signs of division (see Plate III, Fig. 2*a*).

Colour.—Much as in previous instar, in general, however, paler.

THIRD INSTAR. (PLATE I, FIG. 4.)

Length on day of moulting ... ... 11—12 mm.
Length of antennæ ... ... 4— 4·5 „
Number of segments in antennæ ... 19—20

Segments 4-7 of the previous instar have divided to form two. In some cases, however, the division in segment 5 is faint or absent, in which case only 19 segments are to be made out (see Plate III, Fig. 3*a*).

Colour.—In general as in previous instar, but in a very few cases observed the ground colour was markedly tinged with green.

FOURTH INSTAR. (PLATE I, FIG. 5.)

Length of body ... ... 14— 15 mm.
Length of antennæ ... ... 5·5- 6 „
Number of segments in antennæ ... 21— 22

Colour.—In this instar, the variation in colour between different individuals becomes quite marked, so much so that a casual observer would think that he was dealing with different species.

While already in the third instar some few specimens show signs of a change to a greenish ground colour, this becomes quite pronounced in the fourth instar. In fact, the insects become almost uniformly green, the brown patches on the head and prothorax practically disappearing. The red spots on face and legs are, however, for the most part retained. The legs are distinctly pale green (see Plate I, Fig. 9).

A second colour variety is distinctly darker than the normal. The two dorso-lateral bands bounding the median dorsal yellow one become almost jet black, while the face assumes a similar colour. The antennæ are also much darker than normal. The normal colour type remains much as in the previous instar.

We have, however, besides these three distinct colour types, gradations. Both green and dark varieties are usually much fewer in number than the normal yellowish-brown forms. It must be noted here that all these different varieties can be found among young grasshoppers which have hatched from a single egg-mass, so that there is no possibility of our having here distinct but closely-related species.

An important point in development has, up to the present, not been noted and that is the formation of the wings, which become quite distinct in this instar. An examination of Plate 1, Fig. 4 shows them in the form of distinct out-growths (so called wing-buds) from the two posterior divisions of the thorax (meso- and metathorax) above the points of origin of the middle and hind legs. These wing-buds begin to appear in the third instar but are hardly distinct in that stage (see Plate III, Figs. 3 and 4)

FIFTH INSTAR. (PLATE I, FIG. 6.)

Length of body ...	...	... 15—16·5 mm.
Length of antennæ	...	... 7— 8 ,,
Number of segments in antennæ		... 24—25

Colour.—The colour variations noted under the previous instar continue here and, in fact, persist up to the last moult, when the insects assume the adult form and with it the fairly uniform colour of the adult Rice Grasshopper.

The most interesting feature connected with this instar is the appearance of two distinct stages in the formation of the wing-buds. This may be illustrated by giving the record from a single rearing jar, In this particular jar, there were, on the 25th August, fifteen young grasshoppers (nymphs), all of which had moulted for the fourth time, and hence were in the fifth instar, between the 22nd and 25th August. Eight of these—six females and two males—had wing-buds very similar to those already described for the fourth instar (see Plate III, Fig. 5). The remaining seven—all males—showed the wing-buds in a more advanced stage of development. The buds were folded upward on the meso- and metathorax so that they almost touched the opposite pair dorsally (see Plate IV, Fig. 1).

This interesting observation was later made on a large number of developing Rice Grasshoppers and it was found that, regularly in this instar, the nymphs split up into two divisions, (1) those with wing-buds still growing downward and (2) those in which the wing-buds have been folded upward. It was found, further, that these two divisions almost, but not quite, exactly coincide with the divisions into female and male hoppers. In no case has a female of the fifth instar been observed with upturned wing-buds. On the other hand, while the great majority of the males of this instar have their wing-buds folded upward, a few (two out of nine in the record given above) are to be

found in the same stage as the females with their wing-buds still extending downward.

This is a fact of some importance and, as far as I am aware, has never previously been noticed among grasshoppers. With it is connected the fact that the males of the Rice Grasshopper almost invariably undergo one less moult, and therefore pass through one less stage in development, than do the females, and this, in turn, accounts for the interesting fact that, on the whole, the males assume the adult form decidedly earlier in the season than the females do.

SIXTH INSTAR. (PLATE I, FIG. 7.)

Length of body	...	...	17·5—19 mm.
Length of antennæ	...	...	8— 9 ,,
Number of segments in antennæ		...	25— 26

Colour.—Colour variations as in the previous instar.

Males of this instar show, with very few exceptions, a marked development of the wing-buds (see Plate IV, Fig. 3) which have grown backward to cover over the first and part of the second segment or division of the abdomen (length of forewing 6·5 mm.). In the case of all males of the sixth instar which have reached this stage of development, this is the final instar. With the following moult the adult form is reached.

Females of the sixth instar have, as already noted, all the general appearance of the males of the previous instar except, of course, that they are larger and their antennæ are longer and contain more segments. The wing-buds are folded upward for the first time (see Plate IV, Fig. 2).

SEVENTH INSTAR.

In this stage are to be found, for the most part, females. In rare cases, males are to be found which also pass through this stage.

Length of body	...	...	27·5—30 mm.
Length of antennæ	...	...	11·5 ,,
Number of segments in antennæ		...	27—28

The wing-buds resemble in appearance those of the male in the sixth instar but, of course, are longer corresponding with the greater size of the individual (length of anterior wing 8 mm., see Plate IV, Fig. 4).

It is interesting to compare the length of females of this instar with that of adult males of the same age and reared in the same jar. These latter had a length of 26—27 mm. or almost the same as that of the females. It seems fairly clear, therefore, that, in the case of this species, the almost uniformly greater length of the females is to be accounted for by the fact that they undergo a longer period of growth and development represented very definitely by an additional instar.

In connection with measurements of length in developing and adult grasshoppers of this as well as other species, it must be pointed out that the length is subject to considerable variation and the above figures must be taken as applying only to the grasshoppers actually under

observation here. It is impossible to state definitely, from the length of a young Rice Grasshopper, the instar to which it belongs. On the other hand, the length of the antennæ and the number of segments they contain are much more constant and, by means of these two factors, combined with an examination of the development of wing-buds and external sex organs, it is a comparatively simple matter to place the developing hopper in its proper instar, a matter of considerable importance in deciding, in any particular case, the time at which the insect can best be combated.

The above account of the developmental stages has been made somewhat full from the fact that they have never been fully described before and also from the fact that the imperfect accounts we have are inaccurate. Lefroy,[1] in his "Indian Insect Pests," gives the following short statement of the development :— "They (the young grasshoppers or nymphs) are at first dark-coloured with a green dorsal stripe but later become green. . . . They undergo the usual five moults and become full-grown in 8–10 weeks." From this, one is led to expect to find half-grown hoppers invariably green, whereas, in our experience, only comparatively few are green during development, the majority not assuming this color till they become adult. The statement with regard to the number of moults is also incorrect. All the individuals, numbering over a hundred, of which we have kept a record, underwent at least six moults, while the females invariably and the males occasionally underwent an extra moult, making seven moults in all. While our investigations have been made in Southern India, it is still hardly likely that there should be such a difference in the life-history of the insect in different parts of India as would appear from these two accounts.

In the above account of the development of the Rice Grasshopper, no reference was made to the length of time occupied by each instar. As a matter of fact, there is a certain amount of variation in this respect, some individuals growing more rapidly than others. It may be roughly stated, however, that each instar occupies from ten to fifteen days. The accompanying table contains a record of rearings carried out in the insectary in Bangalore, and indicates the number of moults undergone and the length of time which expired between each two moults. It should again be noted that moults and instars do not

[1] Loc. cit., page 120.

coincide, but that the first moult follows the first and precedes the second instar. In fact it is, as it were, the boundary mark between the two stages. One rearing record chosen from a large number kept during the summer and autumn of 1910 is given on the next page.

This record may be considered as fairly typical and representative. It will be noticed that, in this case, the males of the fifth instar, without exception, had their wing-buds turned upward and that all the males completed their development at the end of the sixth instar, and this is the general rule. All the females, on the other hand, had one more instar and one more moult in their development. The length of time occupied by each instar can be calculated, with a fair degree of accuracy, if we suppose that the individual moulting first at the end of one instar also moulted first at the end of the following instar and, conversely, that the individual moulting last at the end of one instar also moulted last at the end of the following instar. If we go on this supposition, we get the following results :—

Instar	Duration in days
1st	... 8—9
2nd	... 9—11
3rd	... 11—13
4th	... 10—11
5th	... 10—16
6th ♀	... 13—15
6th ♂	... 15—18
7th ♀	... 11—16

Total length of developmental period for males 66–78 days, for females 77–82 days.

This is, of course, only an approximation ; one or two individuals may have taken less time than that noted while, in some cases, they have probably taken a day or so more. On comparing these figures with those of our other rearing records, we find them fairly representative. The duration of the first instar is here rather shorter than usual. In other cases, it has lasted from eleven to sixteen days. With regard to the total length of the developmental period, the following records, in addition to the above, may be of interest:—

1 *a*. Record of 14 males:—
Hatched, 15-6-10. First assumed adult form, 29-8-10.
Last assumed adult form, 21-9-10.
Length of developmental period 75–98 days.

TABLE OF REARINGS OF RICE GRASSHOPPER.

Hatched		1st Moult			2nd Moult[1]			3rd Moult[2]			4th Moult			5th Moult[3]						6th Moult						7th Moult[4]		
Date	No.	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal	Date	No.	To-tal
														♀[5]			♂[6]			♀			♂			♀		
12 7 10	28	20 7 10	6		29 7 10	7		9 8 10	5		19 8 10	4		29 8 10	3		1 9 10	2		11 9 10	3		16 9 10	1		27 9 10	1	
		21 7 10	22	28	30 7 10	13		10 8 10	1		20 8 10	2		31 8 10	2		3 9 10	2		13 9 10	2		18 9 10	2		28 9 10	2	
					31 7 10	4		11 8 10	11		21 8 10	3		1 9 10	1		4 9 10	4		14 9 10	1		20 9 10	1		1 10 10	2	
					1 8 10	2	26	12 8 10	2		22 8 10	6		6 9 10	1	7	5 9 10	1		21 9 10	1	7	22 9 10	4		2 10 10	1	6
								13 8 10	1		23 8 10	3					6 9 10	1					23 9 10	1				
								14 8 10	1	21	24 8 10	2					7 9 10	1					25 9 10	1				
											25 8 10	1	21				10 9 10	1	12				26 9 10	1				
																							28 9 10	1	12			

[1] Two have died without moulting.
[2] Five escaped before moulting.
[3] Previous to separation into males and females on 29th August 1910, two had died leaving only 19 (7 ♀ + 12 ♂).
[4] One moult not recorded.
[5] ♀ = Female.
[6] ♂ = Male.

1 *b*. Record of 9 females :—
Hatched, 15-6-10. First assumed adult form, 10-9-10.
Last assumed adult form, 28-9-10.
Length of developmental period 87–105 days.

2 *a*. Record of 6 males :—
Hatched, 25-6-10. First assumed adult form, 2-9-10.
Last assumed adult form, 26-9-10.
Length of developmental period 69–93 days.

2 *b*. Record of 3 females :—
Hatched, 25-6-10. First assumed adult form, 13-9-10.
Last assumed adult form, 27-9-10.
Length of developmental period 80–94 days.

3 *a*. Record of 4 males :—
Hatched, 18-7-10. First assumed adult form, 3-10-10.
Last assumed adult form, 12-10-10.
Length of developmental period 77–86 days.

3 *b*. Record of 4 females :—
Hatched, 18-7-10. First assumed adult form, 14-10-10.
Last assumed adult form, 23-10-10.
Length of developmental period 88–97 days.

It is possible that the results above recorded slightly exceed the normal as it frequently happens, in rearing insects in captivity, that they do not develop so rapidly as in the open. However, this does not seem to apply, to any great extent, in the case of the Rice Grasshopper. Careful observations made in the field, as well as measurements of captured and reared specimens, indicate that the development in captivity is normal and that development in the open takes place as slowly as in captivity.

In this connection, a series of observations, made in the field at the beginning of October, may be recorded as illustrating the shorter developmental period in males. Four sweeps with a bag were made along grassy bunds in different places and, in each case, the total catch was examined with the following results : —

First sweep—	18 adults	=	11 ♂
			7 ♀
Total catch 34 =	16 nymphs	=	5 ♂
			11 ♀
Second sweep—	20 adults	=	13 ♂
			7 ♀
Total catch 26 =	6 nymphs	=	all ♀
Third sweep—	49 adults	=	31 ♂
			18 ♀
Total catch 71 =	22 nymphs	=	4 ♂
			18 ♀

Fourth sweep—

Total of catch 177 = { 76 adults = { 68 ♂ / 8 ♀ ; 101 nymphs = { 29 ♂ / 72 ♀

Summary for the four sweeps.

Adults—123 ♂ + 40 ♀ = 163 ... Percentage, Males 75·4
,, Females 24·6

Nymphs—38 ♂ + 107 ♀ = 145 .. Percentage, Males 26·2
,, Females 74·8

The nymphs belonged, in the great majority of cases, to the last instar. A few were in the second to the last instar but no specimens belonging to earlier stages were found.

The above figures furnish a fairly accurate picture of the state of development at the beginning of October. In November, practically no immature specimens were to be found in the field.

In summing up the results of experiment and observations, we find that the males require from two to three months for their development while the females need two and a-half to three and a-half months, or approximately half a month longer.

Still another feature which has not been noted in the description of the instars is the development of the posterior part of the abdomen and the external sexual organs. While the general appearance of male and female nymphs is practically the same up to the fifth instar, when, as described, the males suddenly show a higher development of the wing-buds, the sexes can be distinguished from the day of hatching by means of an examination of the posterior end of the abdomen.

Plate IV, Figs. 1–21 show in outline the gradual stages in the development of the posterior end of the body. Figs. 1–11 show the various stages in the female, while Figs. 12–21 show the same stages in the male.

An examination of the figures illustrating the development of the ovipositors shows that the upper pair arises as a pair of outgrowths from the ventral region of the ninth abdominal segment, while the lower pair arises similarly from the eighth abdominal segment. In the first instar, the upper pair have the shape of two approximately equilateral triangles with their bases touching and attached

to the posterior border of the ninth abdominal segment, while the lower pair are two minute protuberances resting on the posterior border of the eighth segment (see Figs. 1 and 2).

In the second instar (Figs. 3 and 4) the lower pair has greatly enlarged and taken on a triangular form, while the upper pair shows only a comparatively slight growth.

In the third instar (Figs. 5 and 6), the lower ovipositors have grown backward so as to cover a large part of the ventral portion of the ninth segment. In the upper pair, a very interesting change has taken place. From the inner edges of the two, a pair of lobes have been partially separated. The division is not, however, yet complete as the dividing line or furrow does not yet reach the posterior border of the ninth segment. An examination of the previous instar shows no sign of this division.

In the fourth to seventh instars, we find a gradual growth backward of the two pairs of ovipositors till their ends come to lie at the posterior end of the body (see Figs. 7-11). At the same time, there is a gradual separation of the interior lobes from the upper pair. These lobes come to lie beneath and between the upper pair of ovipositors and to form a forked structure (the furcula supravulvalis) lying just above the female genital opening.

The development of the ovipositors in this form, as described, is probably representative for the whole group of short-horned grasshoppers (Acridiidæ). It also appears to bear a general similarity to the development of the much more conspicuous ovipositors found in the group of long-horned grasshoppers (Locustidæ).[1]

In the sixth instar appears another structure which also functions in the act of egg-laying—the so-called egg-guide. This is a minute, pointed, awl-shaped structure which grows out from the posterior border of the eighth abdominal segment between the lower pair of ovipositors and which aids in directing the egg between the upper pair of ovipositors. The appearance of the ovipositors in the adult and their method of working has already been explained and illustrated.

In the case of the male grasshopper, the development of the external structures at the posterior end of the body

[1] In this connection *vide* Dewitz, Über Bau und Entwicklung des Stachels und der Legescheide einiger Hymenopteren und der grünen Heuschrecke, Zeitschr f. wiss Zool. XXVI, 1874, pp. 74—200.

is much more simple and consists simply in the gradual growth backward of the ventral portion of the tenth abdominal segment. This can be readily followed in Plate IV, Figs. 12–21 and hardly requires any comment. As already noted, this ventral portion has, in the adult, the appearance of a somewhat pointed scoop with the hollow portion directed upward. In this hollow lies the organ of copulation (the penis) covered over, in a state of rest, by a membrane, which stretches from one edge of the scoop to the other. At the time of copulation, this membrane is pushed back and the penis is protruded above it (see Plate IV, Fig. 21). The penis is provided with a series of quite complicated and hard hooks and ridges, by means of which it becomes attached to the posterior end of the female.

The general appearance of the adult Rice Grasshopper has already been described and pictured, and it has already been noted that the adults, both male and female, possess wings, in general very similar to those of other common species. Lefroy has recorded the presence of a micropterous form, differing from the normal form in that the wings are very short and stunted. He also figures it and it appears quite certain from his figures that the form belongs to the same species. Among all the hundreds of specimens examined by us, we have never yet seen any indication of wing reduction and we are led to believe that, in Mysore, this must be of extremely rare occurrence, if it occurs at all. We have, however, reared another species of grasshopper quite distinct from *H. banian*, and clearly belonging to a different genus, in which the wings appear always to be very short in the adult. This species occurs fairly commonly in association with the Rice Grasshopper in wet grass lands at Anavatti, but even in its nymphal stages there is hardly a possibility of confusing it with the Rice Grasshopper.

Notwithstanding the fact that the wings of the Rice Grasshopper are normally quite well developed, Lefroy[1] states that it does not fly. He says "as the insect never flies, wings are apparently useless." This statement is quite incorrect, as far, at least, as Mysore specimens are concerned. In fact, the adult insects fly regularly when disturbed. They do not, however, appear to be able to

[1] Indian Insect Pests, p. 120.

fly far. Observations made in the field show that they rarely fly more than twenty or thirty feet at a time, but this is quite sufficient to make an attempt to catch them in the winged state very difficult.

That this ability to fly is confined to those of the species found in Mysore, is, of course, out of the question. It has been observed before, as is indicated in the report from the Revenue Department, Kerowlee State, already cited[1] where the following occurs:—"Those who [*sic*] have wings cannot fly more than forty or fifty feet at a time."

While the Rice Grasshopper is quite well provided with auditory organs of the type common to this group of insects, there is, as far as we are aware, no record of their making sounds. The ability to produce sounds is apparently restricted to the males and appears to be exercised only during the mating period. There are no special organs for sound production, the sound produced being of a simple and feeble character. It is produced as follows:—The distal end of the hind tibia is armed, on either side, with two stout black spine-like processes, which are especially prominent on the inner side. The adult male grasshopper, in a position of rest on a grass or paddy stem, commonly has the hind legs drawn upwards, with the tibia quite close to the femur and near to the wing-covers. By a convulsive, kicking movement, these spines are scraped over the rough and veined outer surface of the wing-covers, thereby producing a low rasping sound. There are no localised thickenings on the wing-covers, the ordinary nervure thickenings providing the unevenness necessary for the production of the sound.

NATURAL ENEMIES OF THE RICE GRASSHOPPER.

For a pest so widespread as is the Rice Grasshopper, the natural enemies appear to be few and unimportant. During observations in the field extending at intervals over two growing seasons, a careful search has been made for enemies, without revealing any of prime importance.

In the egg stage, only one form has been discovered which may possibly be an enemy. This is a blister beetle,

[1] Indian Museum Notes, Vol. V, p. 2.

the coarctate stage (resting larval stage) of which was found in fairly large numbers during ploughing operations in June 1910. Although attempts to rear adult beetles from these larvæ failed, it is very probable that they belong to a species of Mylabris (or closely related genus) adults of which were found later on grass and were caught in the bags along with the hoppers. As the active larvæ were not found, it is not certain that they feed upon the eggs of the Rice Grasshopper. We know, however, that grasshopper eggs form the regular food of the larvæ of some species of blister beetles. As far as we are aware, no species of blister beetles have ever been reared in India, but we have succeeded in rearing larvæ of the common *Mylabris pustulata* up to the third instar by feeding them upon the eggs of grasshoppers, and are, therefore, the more ready to presume that the larvæ found in the ground infested by the eggs of the Rice Grasshopper had been using these eggs as food.[1]

Some few egg-masses exposed during ploughing were found in which fungus growth had made its appearance, however apparently too late to produce any serious effect.

During the developmental stages, no insect enemies were observed. Among the higher animals, three were discovered feeding upon the grasshoppers. These were a small frog (*Rana leptodactyla*, Boulenger), a skink (*Mabuia beddomi*, Boulenger) and a lizard (*Sitana ponticeriana*, Cuv.). None of these, however, was present in any considerable numbers. Fish, in the pools lying close to the paddy fields, fed eagerly upon the hoppers when the latter were driven on to the water. However, they can hardly be considered as a check upon the spread of the pest.

Of parasites living on or in the grasshoppers during the nymphal and adult stages, only two can be mentioned. One of these is a small reddish mite found occasionally on grasshoppers collected in the field. Whether these actually do any serious damage to the grasshoppers infested, may be doubted. No difference in vitality between infested and non-infested grasshoppers was perceptible

[1] Since the above was written the active larvæ of a blister beetle have been found feeding upon the eggs of the Jola or Deccan Grasshopper (*Colemania sphenarioides*, Bol).

The other parasite is an internal one, one of the so-called hairworms found, now and then, as a much-coiled whitish thread-like body, especially in the thoracic cavity of infested hoppers. This was identified as probably a species of *Gordius*. Somewhat related species have been recorded by Riley as attacking the Rocky Mountain Locust.

Birds, which are by some considered as of great service in keeping insect pests in check, seem to be of comparatively slight importance in connection with the present form. According to the raiyats' report, during a part of September, 1910, a flock of birds destroyed considerable numbers of grasshoppers, but this could not be verified nor could the species concerned be ascertained. The common Myna (*Acridotheres tristis*) was observed during the bagging operations on the bunds, but was not seen to feed on the grasshoppers. Unfortunately, specimens could not be obtained at the time, so an examination of the stomach could not be made.

The above discussion is clearly by no means complete. It seems very probable that a number of enemies of the Rice Grasshopper have not yet been observed. Still it seems clear that it is quite useless to expect much assistance from the enemies of this pest, whether insect, reptile or bird, wherever the attack is in any way severe.

THE EFFECT OF CLIMATE UPON THE GRASSHOPPERS.

Whether the exposure of eggs, on the one hand, to drought and sun or, on the other hand, to excessive moisture has any detrimental effect upon them or not, seems to depend largely upon whether the egg-masses have been broken up or have been preserved intact. Eggs removed from the egg-mass and exposed to light and air collapse very soon, especially if such exposure takes place during the dry weather. On the other hand, intact egg-masses may be exposed for months throughout the whole dry weather, apparently without in any way injuring their powers of hatching. Thus, egg-masses removed from the soil in the month of December were kept exposed to the air until the following June when they were buried in soil again.

They all hatched out normally, although some of them were very late in doing so.

Much the same thing happens when egg-masses are exposed to excessive moisture. If they are intact, they are able to withstand this for long periods. If, however, the masses are broken they become rapidly injured by moisture. In this connection, it should be noted that egg-masses, as they approach the hatching time, swell out, due to the growth of the embryos within the eggs. This may lead to a loosening of the covering of the egg-mass so that moisture may act more readily upon the eggs.

The effect of climate on the growing and adult grasshoppers is more difficult to ascertain. It seems possible, however, that very moist weather may have an injurious effect on them. There is no doubt that the pest was in general less severe in 1910 than in 1909 in the neighbourhood of Anavatti, and the raiyats account for this by the fact that the monsoon in 1910 was much more severe and prolonged than that of 1909. On the other hand, inspection revealed no dying off on the part of the grasshoppers, nor was any trace of fungus disease made out among them, something which commonly attacks insects during abnormally moist seasons. It seems very probable that the excessive moisture of the summer of 1910 affected the hatching of the eggs, rather than the development of the grasshoppers. On the whole, the Rice Grasshopper appears to be a particularly vigorous insect, upon which adverse physical conditions seem to have comparatively little effect.

EXPERIMENTS IN THE CONTROL OF THE RICE GRASSHOPPER.

Experiments in the control of the Rice Grasshopper may be directed against either the eggs, the nymphs or the adults. Of these, clearly measures for the destruction of the eggs would be the most effective, could they be satisfactorily carried out. Unfortunately, the fact that the egg-masses are buried some two inches beneath the surface of the ground, renders the task of collecting them difficult, if not impracticable. It is true, we know where

and where not to expect to find egg-masses. Grassy bunds, especially the narrower ones, and boundary demarcation mounds are favorite spots for egg-laying, while the fields themselves remain practically free. Any search made for egg-masses must, therefore, be directed to the bunds and they can usually be found in considerable numbers there. The work of digging for them in heavy sod is, however, difficult and in order to be really effective would have to be carried out thoroughly over all the infested bunds, something which it would be very difficult to persuade the raiyats to do.

Another possible means of preventing the eggs hatching suggested itself. It seemed quite possible that by means of comparatively deep ploughing with improved ploughs which would invert the soil containing the egg-masses that these masses could be buried so deep as to prevent, to a large extent, the escape of the young hoppers to the surface of the soil at the time of hatching. On the other hand, a shallow ploughing might result in the exposure of a considerable number of egg-masses.

The fact that the eggs are, for the most part, laid in bunds, which are frequently quite narrow, makes the work of ploughing difficult. A first attempt was made in December 1909, but it had to be abandoned. There was still a fair amount of moisture in the soil, but the local bullocks proved too weak to draw the somewhat heavy steel plough used. Two pairs of bullocks were tried on the plough, but they still were unable to pull it through the sod.

In June, 1910, the experiment was again tried, this time with a lighter plough capable of going from four to six inches deep and with a larger pair of bullocks from the Experimental Farm. The work proved very difficult and the plough did not average more than three inches in depth. The inversion of the sod was also imperfect and had to be completed by hand. The work was extremely slow, it requiring about twenty hours' labour to plough the bunds surrounding and separating the plots in three acres of paddy land. It must be noted, however, that some of these bunds were quite wide, being six feet or over.

It is clear that this depth of ploughing could not bring about the burial of the egg-masses. In fact, as the egg-masses are laid up to two inches in depth it should rather have tended to expose them. It was found, however, that

only about fifteen per cent of the egg-masses were exposed. The ploughing occurred about a week before emergence and so had no appreciable effect upon the hatching of the eggs. It is possible that, could ploughing be done a month or so earlier and could it be accompanied by a breaking up of the clods and an exposure of broken egg-masses, good might be done. It seems doubtful whether the work could be done sufficiently thoroughly to give results commensurate with the labour expended.

Deep ploughing to bury the egg-masses has not, as yet, been tested. However, experiments have been carried out to ascertain through how many inches of soil the freshly-hatched hoppers are able to work their way upward. The different power of different species of grasshoppers in this respect is quite remarkable. Riley[1] reports the results of experiments on the power of emergence of newly-hatched hoppers of the Rocky Mountain Locust, which show that they do not usually make their way up through more than two inches of soil, though they occasionally may do so. A still weaker power has been observed by the senior author for the Jola Grasshopper (*Colemania sphenarioides*, Bol), the record of which will be published shortly.[2]

The results obtained in experiments on the Rice Grasshopper are quite different from those already mentioned. Two series of experiments were carried out, which show quite conclusively that freshly-hatched Rice Grasshoppers are able to tunnel their way up through at least six inches of fairly well compacted soil.

In the first set of experiments, two egg-masses were buried upright, at a depth of five and six inches respectively, in two glass tubes filled with fairly compact but rather light soil. In each case, all the eggs hatched, and all the hoppers made their escape to the surface through a common somewhat tortuous tunnel, made in the soil close to the wall of the tube. Plate II, Fig. 3 is reproduced from a photograph of one of these tubes made during the emergence. Only about half the burrow is visible, the lower part curving off out of sight to the right. Two nymphs are to be made out close together in the burrow and one of these has already shed the amnion.

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[1] Riley, loc. cit., p. 356.

[2] Coleman, The Jola or Deccan Grasshopper, Mysore Agricultural Department, Entomological Series, Bulletin No. 2, 1911, already published.

In the second series of experiments, four egg-masses, removed from soil in June, 1910, were buried in light soil in four separate tubes (*a*, *b*, *c*, *d*) at depths of from three and a-half to four inches. On 24th June, 1910, hoppers had emerged from the mass in tube *a* and had worked their way to the surface through a tortuous tunnel made along the glass. In tubes *b* and *c*, hatching had begun but tunnelling to the surface had not commenced. In tube *d*, hatching had not commenced.

Tubes *b* and *d* were now inverted and sunk in sand, while tube *c* was left erect. The object of the inversion was as follows:—The masses had been placed in their natural position in the tubes so that the head ends of the eggs were directed upward. By inverting the tubes the position of the hatching grasshoppers was reversed. It might then be supposed that the hatching hoppers would in tunnelling take the natural direction, which as they were inverted would be downward, not upward. In this way it was thought that the nymphs might continue burrowing downward and so sink themselves deeper into the soil instead of getting nearer the surface. This has a practical bearing for, in the case of ploughing with an improved plough, the soil is inverted and large numbers of the egg-masses thus come to lie with their upper ends downward.

The results, however, did not agree with these theoretical considerations. It is true that the young nymphs continued burrowing downward in the two inverted tubes until they had worked through to the top of the tube. Instead of remaining there, they tunnelled back upward and continued burrowing in all directions through the upper closed end of the tube for several days. On the 30th June, or four days after hatching, twelve nymphs were found still alive in the upper closed end of tube *d*. On the following day, all the hoppers but one in this tube were dead.

The above experiments indicate two things:—Firstly, that the young hoppers are capable of living a comparatively long time in the soil after hatching; and secondly, that, during that time, they are capable of burrowing many inches in all directions. From this it will appear clear that no practical results can be anticipated from burying the egg-masses five or six inches in the soil by means

of deep ploughing, even if the burying is accompanied by an inversion of the egg-masses. Freshly-hatched nymphs with burrowing powers and with powers of endurance such as those exhibited by the Rice Grasshopper would certainly be able to make their way to the surface, even if buried at a depth greater than is at all practicable with an improved plough.

THE USE OF SPRAYS AND POISONED BAIT AGAINST THE RICE GRASSHOPPER.

The use of poison for combating grasshopper pests has been frequently tried and, at times, with very marked success. Perhaps the most signal success in this direction has been achieved against migratory grasshoppers (so-called locusts) in South Africa, where, yearly, thoroughly organised campaigns directed by a central committee save immense sums of money to the farmers. The mixture there used is one of arsenic or arsenite of soda (strong poisons) with sugar or molasses and water. The usual strength used is 1 lb. of arsenite of soda and 2 lbs. of raw sugar or molasses to 16 gallons of water. This is commonly sprayed upon the grass in front of the advancing swarms of grasshoppers and has proved most efficient. Lefroy, in his work in connection with the Bombay locust, investigated the effect of insecticides (lead arsenate, jaggory and water; sodium arsenite, jaggory and water; white arsenic with caustic soda, jaggory and water) upon that insect. He dipped fodder in the poisonous mixtures and fed it to locusts in captivity. The weaker solution of lead arsenate 1 lb., jaggory 5 lbs., and water 100 gallons, he found to kill the locusts, while they refused to touch the other and stronger mixtures. Lefroy also tried contact poisons such as kerosene emulsion, and McDougal's sheep dip sprayed on to captive locusts with apparently satisfactory results. He does not appear to have tried any of these measures to any considerable extent in the field. They were, however, tried in a practical way in the Central Provinces during the campaign against the Bombay locust and were not found satisfactory (*vide* Standen's Report in Lefroy's Memoir on the Bombay Locust, Appendix B, pages 85-86).

In most cases where poisonous sprays or baits have been used successfully against grasshoppers, it has been against the migratory forms which, at least during their migrations when they are driven from their native haunts by lack of food, are most omnivorous feeders, eating practically all vegetation in their path. It might, then, be anticipated that they would take more kindly to poisoned bait than such a comparatively dainty and specialised feeder as the Rice Grasshopper.

Notwithstanding the comparative improbability of success with poisoned baits, a few experiments were tried during the summer of 1910. No experiments were tried with kerosene emulsion or other contact poisons as it seemed clear that the expense of such a method of combating this pest would be much too great.

In most of these poisoned baits, where they are successful, the attraction to the grasshoppers lies in the sweetening substance—whether sugar, molasses or jaggory—that is used. In our experiments, therefore, we varied the strength of the jaggory more than we did that of the poison as we wished, if possible, to attract the grasshoppers to comparatively small quantities of bait. Spraying the poison over large areas of bund was, in our opinion, out of the question from a practical standpoint.

The following mixtures and solutions were prepared and experimented with both in the field and in breeding cages :—

A. 1 lb. lead arsenate, 5 lbs. of jaggory to 100 gallons of water (this is the mixture found by Lefroy to give the best results in the case of the Bombay locust).
B. 1 lb. lead arsenate, 5 lbs. jaggory to 50 gallons water.
C. 1 lb. lead arsenate, 10 lbs. jaggory to 50 gallons water.
D. 1 lb. lead arsenate, 20 lbs. jaggory to 10 gallons water.
E. ½ lb. white arsenic, 2 oz. caustic soda and 20 lbs. jaggory to 50 gallons water.
F. 1 lb. white arsenic, 4 oz. caustic soda and 20 lbs. jaggory to 50 gallons water.

1. Experiments with baits in the field.

Clumps of grass were removed with the earth, sprayed with the various solutions (six clumps to each solution), and spread along badly-infested bunds. These were left for three days and were inspected each morning and evening. In no case, however, did the hoppers show any

disposition to feed on them; in fact, they appear to have been left severely alone and no dead hoppers were to be found on the treated bunds.

2. Spraying on the bunds.

For this experiment, a badly-infested grassy bund about twenty feet wide was chosen and was divided up into equal portions each about sixteen feet long. Each alternate plot was left untreated while one plot was sprayed with each of the six solutions mentioned above. The spray did not spread well on the grass blades but it was distributed as evenly as possible, about three gallons of mixture being used for each plot. The spraying was done from two to six o'clock in the afternoon and no rain fell during that day or the following night. On the following day, a light shower fell in the evening. A careful inspection was made at the end of the second day but not a single poisoned hopper was found. On the plots sprayed with solutions A to D, the grasshoppers were present in normal numbers and the solution had had no effect on the grass. On the plots sprayed with solutions E and F, the grass was badly scorched, most of it having turned brown. These two plots were practically free from grasshoppers, but here, as in the other, a very careful search revealed not a single dead hopper. They had evidently deserted the plots for other portions of the bunds where the grass was still to their taste.

The above two experiments show fairly conclusively that poisoning baits or spraying with the above mixtures is useless in combating this pest; it seems very improbable that any other combination of poison and sweetening material would have yielded better results.

3. Experiments with poisoned bait in breeding cages.

Finally, in order to ascertain if these poisons would be effective in cases where the grasshoppers were compelled to eat the poisoned bait or fast, 100 hoppers of the fourth and fifth instars were placed in each of six large field cages and were fed with grass upon which the various solutions had been sprayed. The number of deaths at the end of two days was as follows:—

Mixture used			Hoppers dead
A	...	...	... 80
B	...	...	... 58
C	...	...	... 20
D	Ants had entered and destroyed the hoppers.		
E	...	...	... 97
F	...	...	... 100

Mixtures A, E and F had been quite effective. These results indicate that the hoppers are fairly susceptible to poison when they are compelled to eat it. The results obtained in this experiment, however, when compared with those of the previous two, show that it is unsafe to apply the results from experiments on the effect of poison in breeding-cages, to work in the field. Altogether we may say that the application of arsenical poisons with a view to combating the Rice Grasshopper can, on the side of efficiency alone, not at all be recommended. This is leaving out of consideration two important facts which militate very much against the use of arsenical poisons in the field. One of these is the heavy rainfall at this time of the year which is likely to remove very much of the poison from the grass and the other is the danger of poisoning cattle which might eat the grass treated.

BAGGING OPERATIONS AGAINST THE RICE GRASSHOPPER.

Grasshopper pests have always proved decidedly difficult to combat. Their appearance over large areas makes the application of stomach and contact poisons costly and difficult. As already indicated, the destruction of egg-masses is also commonly attended by great difficulties. The result has been that mechanical contrivances for collecting these insects have been more extensively used than against any other group. Many such contrivances have been devised and a few of these have proved very efficient in the countries in which they are especially used. Among these may be mentioned the so-called hopper-dozer used almost exclusively in the United States on grass lands. It consists of a long shallow pan on runners with a sheet of cloth or tin stretched across its hinder border. In the pan is placed kerosene, or tar. As this is drawn through the grass, the grasshoppers spring up in front of it, strike against the

sheet behind, drop into the pan and are killed by the kerosene.

Such a contrivance is fairly expensive and cannot be worked satisfactorily on uneven ground or in crops that are at all high. In India, the contrivance for catching grasshoppers which has found most general acceptance is in the form of a broad bag of cheap cloth. Various different sizes have been used and much diversity exists as to the amount of framework used to support the bag. The size and pattern to be used will depend largely upon the character of the ground over which the bag is to be drawn.

In the case of the Rice Grasshopper, bagging is possible at two distinct periods of the grasshoppers' development. Firstly, it can be done shortly after the hoppers have emerged and while they are still feeding almost entirely upon the bunds; secondly, it can be done after they have gone over on to the paddy. Where sugar-cane is attacked, it is impossible to bag on the crop, at least in Mysore,[1] so in this case measures must be taken before the hoppers have migrated from the grassy bunds.

For the Rice Grasshopper, Lefroy recommends a bag or net 36 feet by 7 feet weighted at one side, having ropes at the bottom and a bamboo to hold on the top.[2] Such a bag, when open, would be at least 30 feet wide and would require a number of coolies to draw it. It could, of course, be used only on the paddy fields and would be a decidedly awkward thing to handle. Our experience indicates that the effectiveness of bagging operations depends very largely upon the rapidity with which it is done. For this reason, if for no other, a large bag is unsuitable. In the case of the Rice Grasshopper, it seems also to be unnecessary for the additional reason that bagging can be done most effectively on the grassy bunds, before the hoppers have gone over on to the paddy. These bunds are usually comparatively narrow, rarely reaching six feet, and a comparatively small and narrow bag is the most suitable.

Bagging was first attempted in November 1908, therefore at a time when the grasshoppers were all adult and were on the paddy. It was quite unsuccessful owing to the power of flight of the adults. Practically no grasshoppers were caught.

[1] Sugar-cane is usually planted from January to March and so is quite high by the time the hoppers emerge.

[2] This bag was first devised by Mr. Stewart Stockman, of the Central Provinces, *vide* Report on the Department of Agriculture, C. P., for 1901-02, p. 12.

A second trial was made in June, 1909, just after the hoppers had begun to emerge in numbers. The bags worked this time very well and about a seer (one pint) of grasshoppers was caught in each sweep over one hundred yards of bund. The attachment of a frame to the bag was found more of a hindrance than a help on the bunds, which are frequently very uneven. The jumping power of the hoppers, at this stage of their development, is very limited and it was found that the mouth of the bag could be reduced to one foot in height without diminishing the effectiveness.

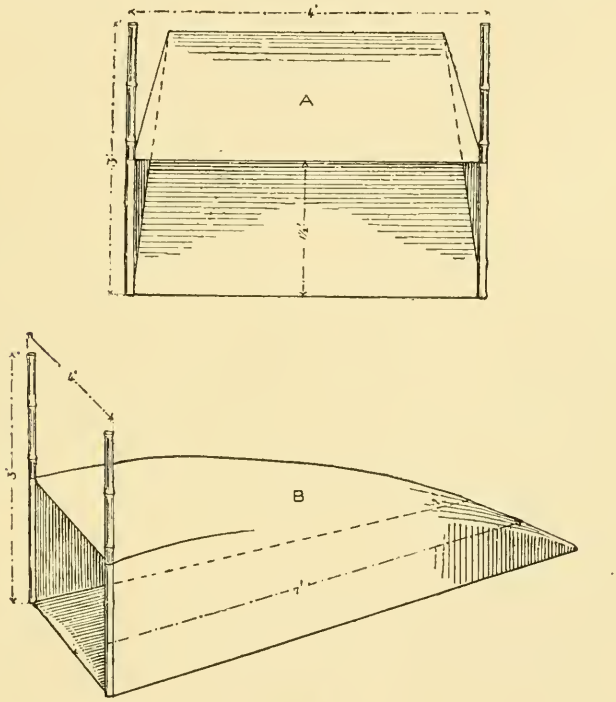
While many of the raiyats appreciated the usefulness of this method of combating the pest, the usual lack of co-operation rendered the few spasmodic attempts made by individuals abortive. In the combating of perhaps no other class of insect pest is the necessity of co-operation so pronounced as it is in the case of grasshoppers. With their great powers of movement, they are able quickly to change their feeding grounds. The result is, that if one raiyat succeeds in practically clearing his land of the hoppers, they are quite certain to invade his fields again from the surrounding areas, unless his neighbours have co-operated with him and have cleared their land at the same time. Individual effort is, thus, almost certainly doomed to failure, where co-operation might have been successful.

As it seemed hopeless to expect the raiyats to co-operate on their own initiative, it was decided, in 1910, to conduct a campaign, in several of the worst-affected villages, under the direct supervision of the Department. The help of the Amildar and other local authorities was solicited and obtained for the purpose. The whole of the paddy areas of six villages, Anavatti Nerlige, Mallapur, Vitlapur, Kubatur and Hoshalli, forming a block of about nine square miles in extent, was selected and the patels of these villages were made responsible for the supply of the men required for bagging. As full a record as possible was kept of the area covered per day and the number of hoppers collected.

The infestation in all these villages was much less severe than in 1909, probably on account of the heavy rains during the period of emergence of the hoppers. The worst infested areas were the fields of Anavatti, Kubatur

and Hoshalli; those of Nerlige were less infected, while those of Mallapur and Vitlapur were comparatively lightly attacked.

The bags used measured about seven feet in length three to four feet in breadth and one and a-half to two and a-half feet in height at the mouth (see Text-fig. 4). To each side of the mouth of the bag, was attached a light bamboo pole about three or four feet in height. The lower end of this pole was flush with the bottom edge of the



TEXT-FIG. 4.
Bag used for catching the hoppers. A. Front view. B. Side view.

bag mouth, while the upper end projected above the top of the bag and served as a convenient handle for holding the bag without undue stooping. Each bag was worked by two men, one to each pole. In dragging the bag along the bunds, care must be taken to keep the mouth taut and to keep its lower edge close to the ground. This is comparatively easy, from the fact that the lower edge of the mouth has no pole attached and so can be readily adjusted to unevennesses of the ground. It is also important,

in sweeping the bag over the ground, for the men working it to move as fast as possible. Thereby larger catches can be made and there is less danger of the escape of those grasshoppers already caught in the bag. At the end of each sweep, the grasshoppers are shaken into a corner of the bag and crushed or emptied into a tin containing water with a small quantity of kerosene on the surface.

Two patterns of bags were used. In one type the base of the bag was square (see Text-fig. 4), in the other the bag was cut away about two feet back so as to come to a point. The two types were about equally effective, the second type offering a slight advantage in that the grasshoppers were more readily shaken together in it than in the first.

Anyone, who has had experience in organising a campaign among raiyats, will appreciate the difficulties and delays that are sure to occur in a first attempt in this direction. Our experience in this regard was no exception to the general rule. The result was that operations could not be begun before the 1st of August, when the hoppers had, for the most part, reached about the third instar. The whole of the operations had thus to be conducted during the height of the monsoon, when the heavy rains and high winds made the work very difficult, while at the same time the results obtained were less satisfactory.

The extremely wet weather prevailing during the bagging operations introduced many difficulties. The bags became almost immediately saturated with water and so were heavy and did not open up readily. Moreover the hoppers sought, to a large extent, the bases of the clumps of grass for protection from the rain and were more difficult to dislodge.

While the main campaign was conducted in August, in the case of some of the villages the work was continued into September. In some cases, the hoppers had already transferred themselves to the paddy in large numbers and in these cases bagging was done in the paddy fields themselves. The following table shows the time and labour expended, amount of land covered and results obtained.

DETAILED STATEMENT OF VILLAGES BAGGED, AREA COVERED AND NUMBER OF HOPPERS CAUGHT, ETC.

Name of village	Date of bagging	No. of bags used	Area covered	Time	No. of hoppers caught	Remarks
Anavatti ...	3rd August, 1910 ...	2	...	3 p.m. to 5 p.m. ...	About 5,000	1st bagging. Total number of hoppers, 52,400.
	5th do ...	10	About 80 acres ...	2 p.m. to 6 p.m. ...	,, 10,000	
	15th do ...	5	,, 50 acres ...	1 p.m. to 5 p.m. ...	,, 14,800	
	16th do ...	4	,, 30 acres ...	1 p.m. to 5 p.m. ...	,, 9,400	
	17th do ...	4	,, 60 acres ...	2 p.m. to 5 p.m. ...	,, 8,700	
	18th do ...	4	,, 40 acres ...	2 p.m. to 5 p.m. ...	,, 4,500	
	19th do ...	1	,, 4 acres ...	2 p.m. to 5 p.m. .	,, 2,700	2nd bagging, 18,800.
	21st do ...	8	,, 25 acres ...	9-30 a.m. to 11-30 a.m.	,, 13,600	
	21st do ...	8	,, ,, ...	2-30 p.m. to 5-30 p.m.	,, 2,500	3rd bagging, 17,100.
	14th September, 1910	3	...	2 hours ...	,, 4,400	
	15th do ...	4	...	3 ,, ...	,, 3,200	The whole of the area in the kasaba was gone over, but bagging was done only where hoppers were sufficiently numerous.
	16th do ...	4 butterfly nets...	...	3 ,, ...	,, 3,100	
	19th do ...	2 do ...	...	5 ,, ...	,, 5,000	
	20th do ...	1	...	3 ,, ...	,, 1,400	

DETAILED STATEMENT OF VILLAGES BAGGED, AREA COVERED AND NUMBER OF HOPPERS CAUGHT, ETC.—*concld.*

Name of village	Date of bagging	No. of bags used	Area covered	Time	No. of hoppers caught	Remarks
Kubatur ...	7th August, 1910 ...	...	20 acres ...	8 to 12 noon ...	4,000	
	8th do ...	5	1 acre of grassy land.	12 to 5 p.m. ...	10,200	
	11th do ...	4 butterfly nets ...	do ...	12 to 4 p.m. ...	7,900	
	12th do ...	10	A strip of land 20 yards broad and 2½ miles long.	12 to 5 p.m. ...	11,400	
	14th do ...	4	1 acre of grassy land.	1-30 p.m. to 4 p.m.	8,200	Total number of hoppers, 76,900.
	15th do ...	5	do ...	1 to 5 p.m. ...	6,400	
	16th do ...	4	do ...	do ...	4,400	
	18th do ...	14	60 acres ...	12 to 5 p.m.	10,800	
	19th do ...	12	do ...	do ...	13,600	
	14th September, 1910...	5	.....	3 hours ...	2,000	
	15th do ...	4	.. ...	do ...	2,200	
	16th do ...	do ...	.....	do ...	1,400	
	18th do ...	4 butterfly nets in heavy rain.	.....	2 hours ...	1,400	2nd bagging.
	21st do ...	2 do ...	.....	3 hours ...	2,500	Total number hoppers, 14,500.
	22nd do ...	do ...	.....	do ...	2,000	
	23rd do ...	2 butterfly nets ...	.....	do ...	1,000	
	24th do ...	do ...	.....	3½ hours ...	2,000	

Neralige ...	6th August, 1910 ...	8	... ...	The whole village was gone over in two days.	8 to 12 noon ...	Not ascertained
	7th do ...	7			do ...	do
	22nd do ...	1	.. ...	5,000 square feet of paddy field.	½ an hour ...	5,000
	21st September, 1910...	1	... ...	do ...	2 hours ..	4,500
	22nd do ...	1	... ...	do ...	do ...	3 500
Hosahalli ...	14th August, 1910 ...	8	... ...	Total area covered in four days, 366 acres.	12 to 5 p.m. ...	4,200
	15th do ...	8	... ...		do ...	8,300
	16th do ...	8	... ..		do ...	5,800
	17th do ...	8	... ...		do ...	8,000
Mallapur ...	7th August, 1910 ...	8	... ...	The whole village gone over in three days.	12 to 5 p.m. ..	Not ascertained ...
	8th do ...	8	... ...		do ...	do ...
	9th do ...	8	... ...		do ...	do ...
Vitlapur ...	8th August, 1910 ...	8	... ...	The whole village gone over in two days.	12 to 5 p.m. ...	Not ascertained ...
	9th do ...	8	... ...		do ...	do ...

Total number of hoppers, 13,000.

Total number of hoppers, 26,300.

NOTE.—The hoppers secured by the bags were so mixed up with mud and other foreign matter that they could not be separated and counted. What was done, therefore, was to measure out the whole mass in a large specimen tube, and multiply the number of tubes thus obtained with the number of hoppers actually obtained from one specimen tube full.

The area covered by the bags varied with the number of infested bunds in it, the degree of infestation and the facilities for bagging.

The results obtained in the two years 1909 and 1910 in the bagging of hoppers in different stages of growth on the bunds, as well as on the crop, indicate that its effectiveness is at its height soon after the emergence of the hoppers. Weak, and with limited powers of jumping in the first and second instars, they are then easily gathered into the bags and no more than three sweeps were necessary to clear even the worst infested bunds. The operations can then be conducted, also, under more favorable weather conditions. The only disadvantage in conducting operations so early is that a second bagging may be necessary after an interval of about ten days in order to catch the hoppers that have hatched late. In the later stages of growth, the bags can with difficulty be pressed down into the thick growth of grass and the hoppers with their additional strength are better able to evade the bags. In September, bagging on the paddy itself was found more effective than that on the bunds. The crop was not yet too high and was not so thick as the grass and so allowed more satisfactory work. Unfortunately, it was only occasionally that the paddy was found badly infested, so that this course could not be generally followed. The grasshoppers go over on to the paddy usually decidedly later (October) after the grass on the bunds has been cut. Under these circumstances, bagging on the paddy is practically useless. The crop is high and the grasshoppers are for the most part winged and can readily escape. Moreover the raiyats have a distinct objection to having their crops bagged at this time. There is a certain amount of danger of heads being broken off by the bag and, in cases where individual plants are trampled down, they do not recover. It will be noticed from the above table that, in certain cases, hand-nets were used. These are small cloth bags mounted on a hoop or a ring made of cane or stout iron wire and fastened to a bamboo handle. They were used in catching hoppers on grass growing on the borders of tanks and pools, where the water was so deep as to make the use of the bag impossible. They were also useful in places, such as survey mounds and bunds bordering hedges or streams, where bags could not be worked. They are quite effective and form a useful supplement to the bags, their disadvantage being the comparatively small area that can be covered in a given time.

Although the difficulties were many and the conditions were unfavorable, the results leave no doubt that bagging can be done effectively. The cost is comparatively small, for each raiyat will be able to look after his land with the help of his own family. As the infestation last year was comparatively light, the numbers of grasshoppers caught cannot be taken as a gauge of the effectiveness of bagging. In Anavatti village, where bagging was carried on most thoroughly, the hoppers were reduced to such small numbers that practically no damage was done to the crops, while in the other villages bagged, the losses this year were slight. We are quite satisfied that a thorough bagging on the bunds begun about the first or second week in July followed by a second one also on the bunds after an interval of ten or fifteen days, and, in badly infested areas, a third one about the beginning of August, will prove an effective check to the ravages of this pest.[1] It is, however, absolutely essential that all the raiyats in an infested village co-operate; otherwise, the efforts of those who do take up the work will in all probability fail.

SUMMARY OF RESULTS.

1. The Rice Grasshopper while found widespread over Mysore has, as yet, proved a serious pest only in a few isolated localities. However, as it is capable of doing immense damage to sugar-cane as well as to paddy when it is present in large numbers, a knowledge of its life-history and of means of combating it should be acquired by all those interested in paddy and sugar-cane cultivation.

2. The grasshoppers hatch out about the middle of June from masses of eggs laid the previous autumn.

3. The developing hoppers pass through six (males) or seven (females) stages or instars in their development. They take, in all, from two and a-half to three and a-half months for growth.

4. The full-grown grasshoppers are provided with wings and can fly short distances. They do not, however, move from one locality to another by flight as do the migratory species. Their spread is therefore likely to be comparatively slow.

5. During a considerable portion of their development,

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[1] ee Appendix.

the grasshoppers remain, for the most part, feeding on the grass bordering paddy fields. Later, in September and October, they go over in large numbers on to the paddy. This change seems, at least partially, due to the fact that the grass is cut off by the raiyats. The most apparent damage done to the paddy is in cutting through the stem so that the ears fall to the ground.

6. Eggs are laid in October—December, chiefly in the grassy bunds, very exceptionally in paddy fields themselves, in masses at a depth up to two inches. A single female is capable of laying as many as four masses and a total of over a hundred eggs.

7. Ploughing the bunds either to expose or to bury the egg-masses cannot, from our present knowledge, be recommended. It is possible that shallow ploughing of the bunds accompanied by breaking of clods about one month before emergence may prove of value but this has yet to be tested.

8. The natural enemies of the Rice Grasshopper are few and unimportant. Climatic conditions do not appear to affect the growing or adult grasshoppers appreciably. The eggs, if exposed to the direct action of drought or moisture by breaking the egg-masses, are killed.

9. The use of poisons for combating the Rice Grasshopper is ineffective and costly and cannot be recommended.

10. The most efficient method of combating these grasshoppers is by catching them in bags, as described above, on the bunds soon after they emerge and before they migrate to the paddy or sugar-cane.

During the printing of this bulletin, there has appeared an article in the *Agricultural Journal of India*, Vol. VI, part II, April 1911, page 147, by Mr. Bainbrigge Fletcher, Officiating Imperial Entomologist, dealing in a popular way with this pest as it occurs in the United Provinces. It appears that the pest in that part of India does most

damage to sugar-cane and it is with the pest as it occurs upon that crop that the author chiefly deals. His short description differs somewhat from the account given here. For instance, he notes the occurrence of six instars but makes no mention of a seventh instar in the females.

From his description, it appears that hatching, development, and egg-laying occur through about the same periods of the year as they do in Mysore.

As regards combative measures, his conclusions are decidedly different from those reached in this bulletin. This is, of course, partly due to the fact that he is dealing with the pest chiefly as it occurs on sugar-cane, while this bulletin deals with it as attacking paddy and also probably to the fact that conditions in the United Provinces are different from those in Mysore.

With regard to bagging, he states that it may be done in the early stages, but, in his opinion, it is out of the reach of the small cultivators on account of cost. Almost immediately afterwards, he suggests, as the most efficient method, the use of iron ploughs to plough up the fields and expose the egg-masses after the crop (sugar-cane) has been harvested in March. As a bag, such as that used here, can be made for little over one rupee and as an iron plough, such as could be used effectively in ploughing dry sugar-cane land, would cost, at the very least, Rs. 8 or 9, the force of his argument is lost. Where egg-laying is done in the fields, such a course as ploughing with an iron plough would, no doubt, be beneficial, but just how beneficial it would be, would, as already pointed out, depend upon how thoroughly the egg-masses could be broken up. Where, as in the paddy fields of Mysore, the eggs are laid almost exclusively in the bunds, such a course cannot be recommended. These measures, I may say, have already been discussed in the Report of the Cawnpore Agricultural Station for 1908-09, where it is stated that the cattle of the infested district are not capable of doing such work on dry land.

The author further suggests the encouragement of insect-eating birds by the erection of resting-places for them among the crops. This hardly appeals to me as a practical measure, nor do I think it would appeal to the raiyats as such. How the raiyat can, on the one hand, manage to frighten off only the grain-eating birds from

his paddy, etc., by means of the scarecrows and tins suspended from poles which he so commonly employs, at least in Mysore, and, on the other hand, can succeed in attracting only insect-eating birds by the erection of resting-places for them, seems difficult to answer. Further, a fact that is very frequently overlooked, is that many birds are decidedly promiscuous feeders, eating grain as well as insects, and any good they may do by destroying insects is likely to be counterbalanced by the damage they do to the crops.

One thing seems perfectly clear, and that is that practical measures must be worked out with special reference to the needs and conditions of each separate tract. Measures may be quite successful in one Province or State while they may be a failure in another. It is, therefore, necessary to emphasize the point that, while the general facts and conclusions of this bulletin will probably apply to the whole of India, the recommendations as to combative measures are intended to apply to conditions as they at present exist in Mysore.

APPENDIX.

THE EFFECTIVENESS OF EARLY BAGGING.

To indicate that the recommendations given above as to early bagging are well advised the following figures of this year's work may be given. These were received after the bulletin had been finally passed for the press and so could not be included under the proper heading. They are of course incomplete, containing only the results of preliminary work. All the results of bagging during the summer of 1911 will be published together at the close of the season.

I. Catches at Anavatti on 12th July 1911.

Dimensions of bunds bagged	Description of bunds	Number of sweep	Catch	Time	Remarks
				Mim.	
30 yds. × 2 ft. ...	Level ...	4	3,500	15	Practically cleared.
20 yds. × 4 ft. ...	Two survey marks and grass clumps	4	1,000	15	Some still left.
44 yds. × 3 ft. ...	Level ...	6	2,700	20	Fairly cleared.
12 yds. × 6 ft. ..	Level ...	3	700	10	Do
40 yds. × 6 ft. ...	Bund bordering pool of water.	6	7,100	30	Fairly cleared. The hoppers disturbed by the bagging had to be driven back from the water to the bund after each sweep.
	Total catch ...		15,000		

We get, then, as a result of an hour and a-half's work with one bag, a catch of 15,000 hoppers together with the clearing of extensive areas of grass land surrounding paddy fields.

II. Catches at villages near Siralkoppa on the 18th July 1911.

Dimensions of bunds	Descriptions of bunds	Number of sweeps	Catch		Remarks
35 yds. × 3 ft. ...	Level ...	4	1st	2,400	Fairly cleared in 20 minutes.
			2nd	3,600	
			3rd	600	
			4th	400	
			Total	7,000	
12 yds. × 3 ft. ...	Level ...	2	1st	400	Cleared.
			2nd	200	
30 yds. × 6 ft. ...	Sloping ...	3		9,000	Fairly cleared.
30 yds. × 3 ft. ...	All level ...	3		36,000	Caught in 40 minutes.
30 yds. × 3 ft. ...		3			
20 yds. × 4½ ft. ..		1			
60 yds. × 3 ft. ...		2			

Taking the first and the last of these records, we get a total catch of 43,000 grasshoppers in about one hour with one bag together with the practical clearing of 185 square yards of bund representing at least two acres of paddy land and probably decidedly more.

A comparison of these figures with those given above in the body of the text shows quite clearly that early bagging can be done both more rapidly and effectively than later bagging and should be insisted upon in any organised campaign against the pest as it occurs on paddy.

EXPLANATIONS OF PLATES II—V.

All drawings were made with the aid of the Abbe camera lucida

PLATE II.

FIG. 1.—Male of *Hieroglyphus banian* with wings spread.
FIG. 2.—Female of *Hieroglyphus banian* with wings spread.
FIG. 3.—Nymphs emerging from an egg-mass buried six inches deep in a glass tube.
FIG. 4.—Female of *Hieroglyphus banian* laying eggs close to side of glass dish. Beneath can be seen the egg-mass close to the glass.
FIG. 5.—Two egg-masses of *Hieroglyphus banian* with the covering removed to show the arrangement of the eggs. The posterior side of the masses is facing outward in both cases.

PLATE III.

FIG. 1.—Thorax of nymph of first instar to show meso- and metathoracic lobes.
FIG. 1a.—Antenna of nymph of first instar.
FIG. 2.—Thorax of nymph of second instar.
FIG. 2a.—Antenna of nymph of second instar.
FIG. 3.—Thorax of nymph of third instar showing first sign of development of wing-buds.
FIG. 3a.—Antenna of nymph of third instar.
FIG. 4.—Thorax of nymph of fourth instar.
FIG. 4a.—Antenna of nymph of fourth instar.
FIG. 5.—Thorax of female nymph of fifth instar.
FIG. 6.—Antenna of female nymph of fifth instar.

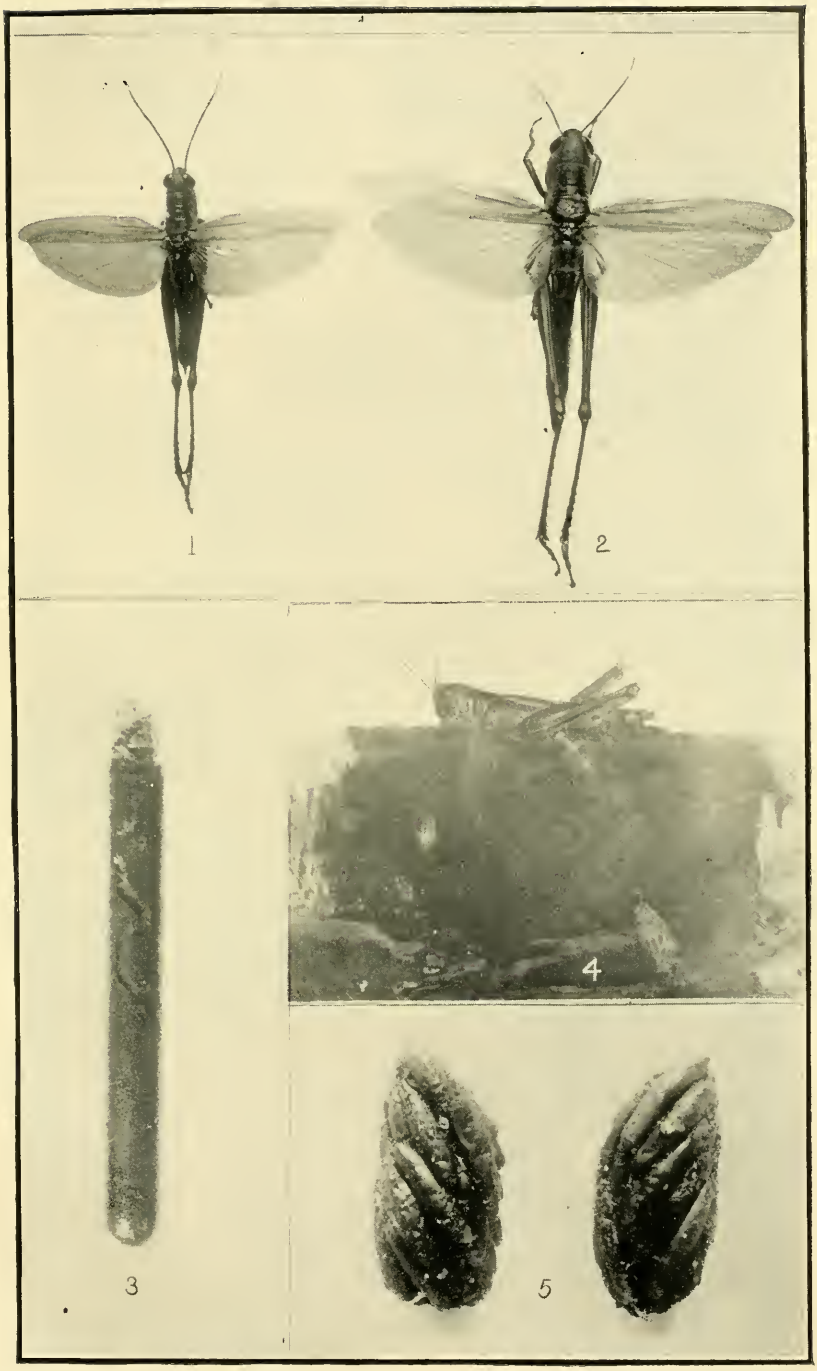
PLATE IV.

FIG. 1.—Thorax of male nymph of fifth instar to show upturned wing-buds.
FIG. 1a.—Antenna of male of fifth instar.
FIG. 2.—Thorax of female nymph of sixth instar to show upturned wing-buds.
FIG. 3.—Thorax of male nymph of sixth or last instar.
FIG. 3a.—Antenna of male nymph of sixth or last instar.
FIG. 4.—Thorax of female nymph of seventh or last instar.

PLATE V.

FIGS. 1-11.—Development of posterior end of female *Hieroglyphus banian.*
FIG. 1.—First instar from beneath.
FIG. 2.— Do side.

FIG. 3.—Second instar from beneath.
FIG. 4.— Do side.
FIG. 5.—Third instar from beneath.
FIG. 6.— Do side.
FIG. 7.—Fifth instar from beneath.
FIG. 8.— Do side.
FIG. 9.—Sixth instar from beneath
FIG. 10.— Do side.
FIG. 11.—Adult from side.
FIGS. 12-21.—Development of posterior end of male *Hieroglyphus banian*.
FIG. 12.—First instar from beneath.
FIG. 13.— Do side.
FIG. 14.—Second instar from beneath.
FIG. 15.— Do side.
FIG. 16.—Third instar from beneath.
FIG. 17.— Do side.
FIG. 18.—Fifth instar from beneath.
FIG. 19.— Do side.
FIG. 20.—Adult from above.
FIG. 21.—Adult from side with penis partially extruded.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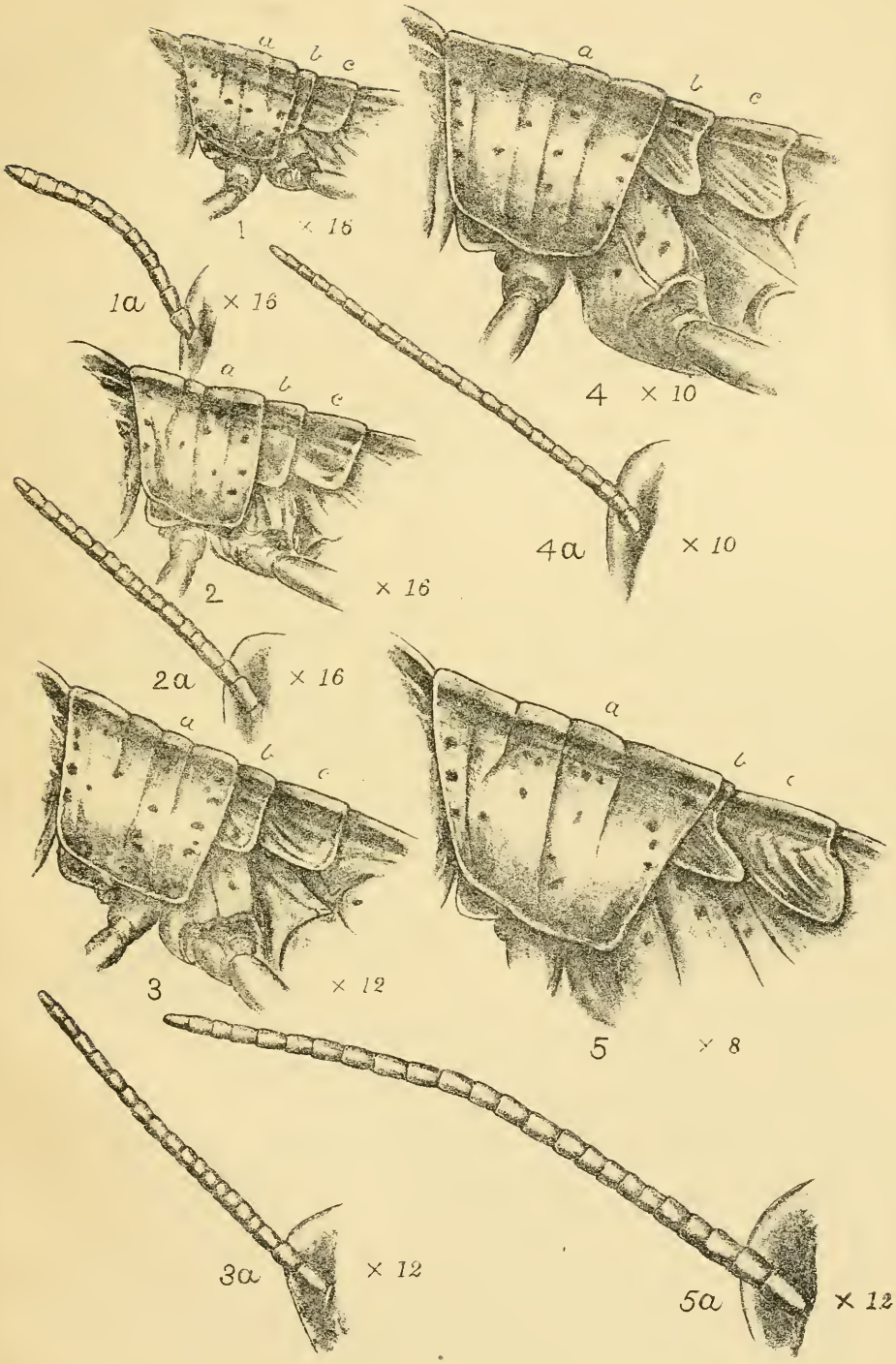
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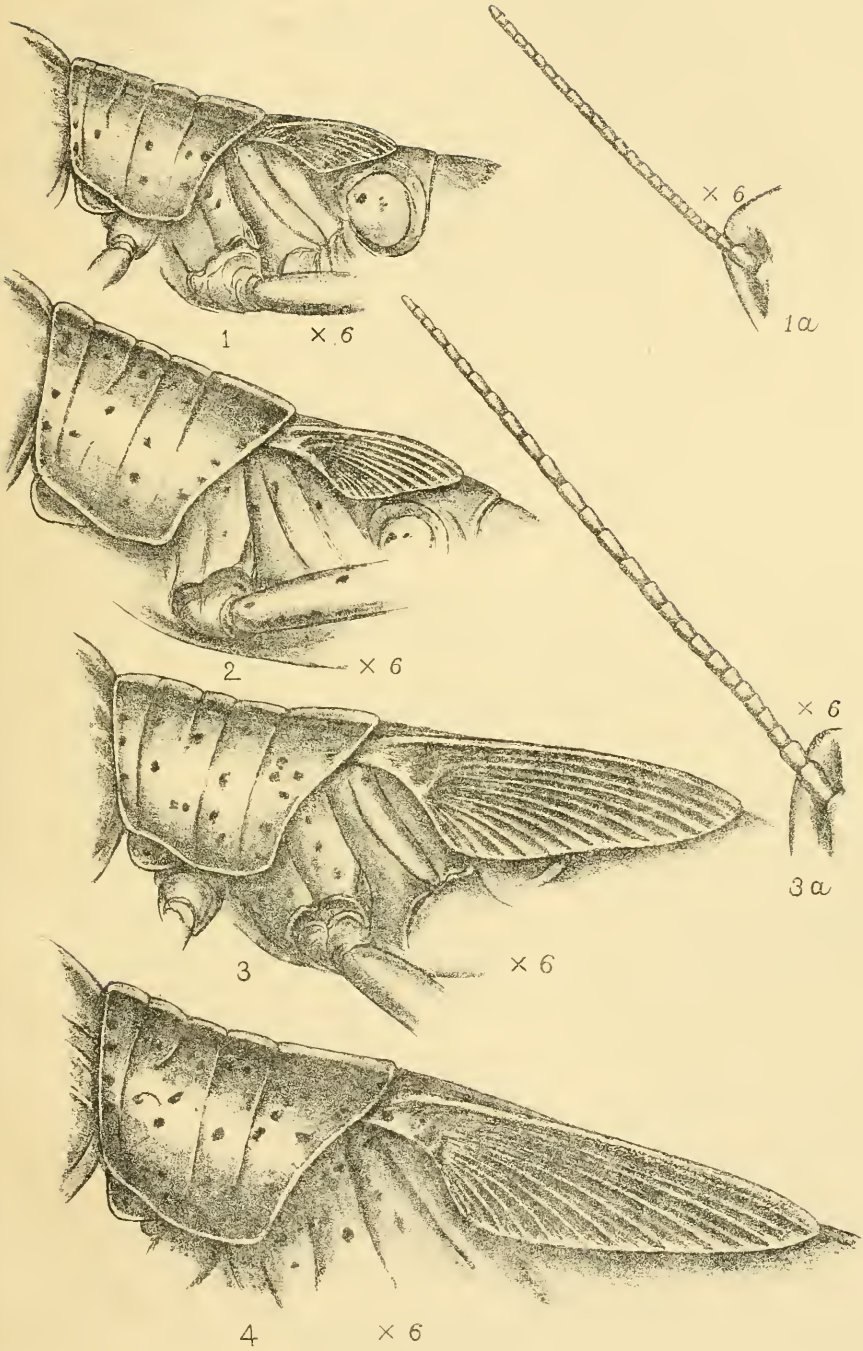
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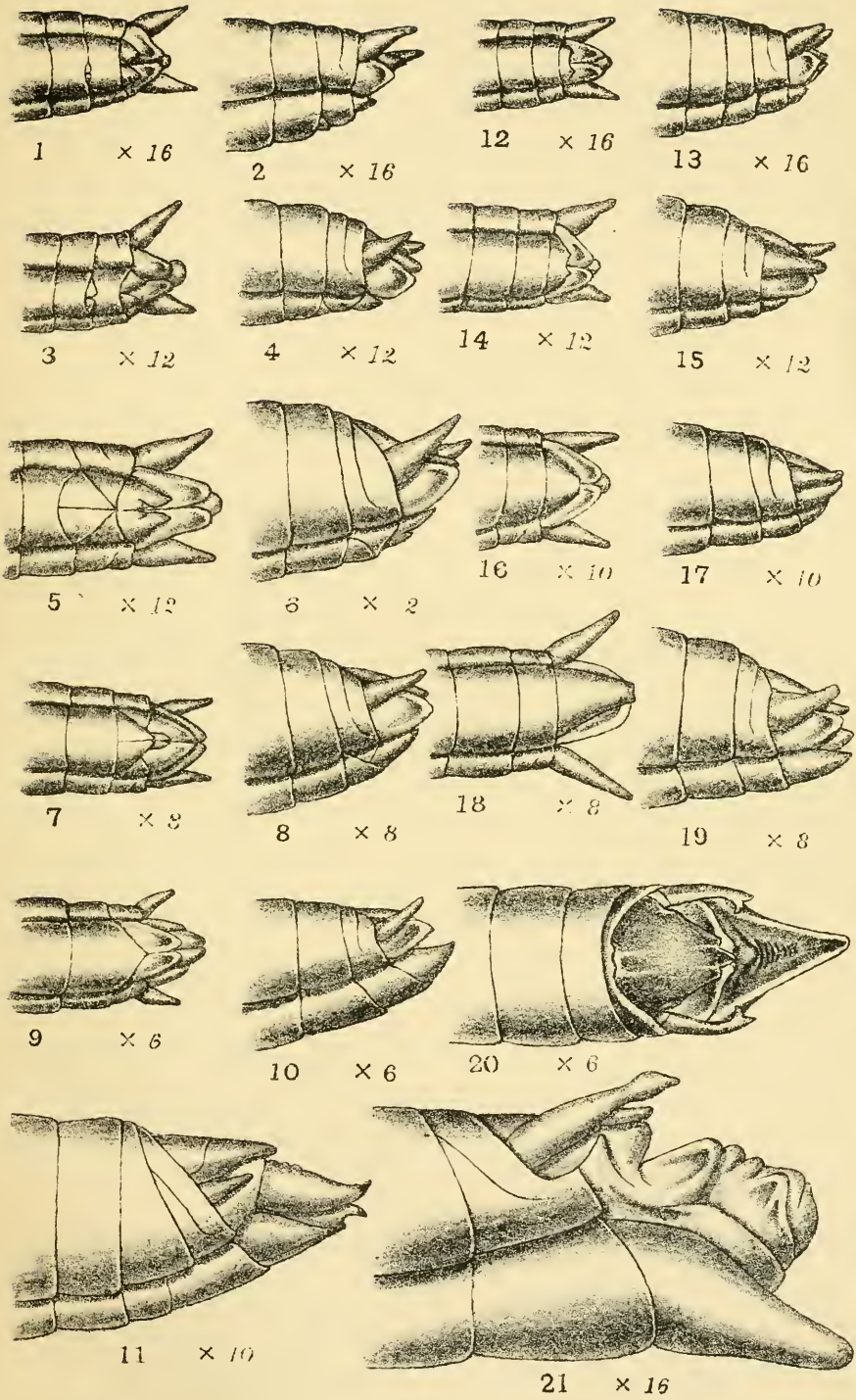
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