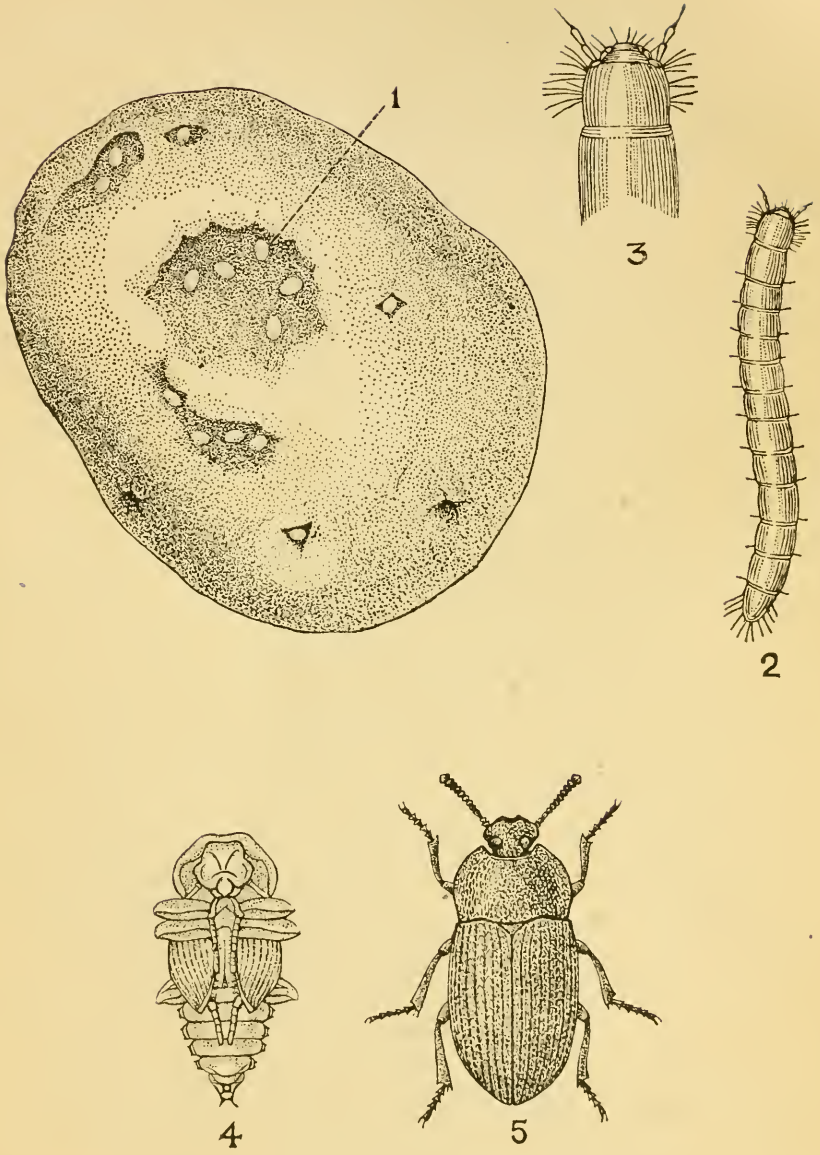
Dept of Agriculture Mysore State
Bull. No 5 1918
- Ground Beetles attacking crops
in Mysore

Frontispiece.



GONOCEPHALUM HOFMANNSEGGI

FIG. 1.—Potato Tuber showing excavations made by the beetle with eggs laid in them

FIG. 2.—Full grown larva of beetle.

FIG. 3.—Head of full grown larva enlarged.

FIG. 4.—Pupa.

FIG. 5.—Adult beetle.

ENTOMOLOGICAL SERIES—BULLETIN No. 5

DEPARTMENT OF AGRICULTURE

MYSORE STATE

GROUND BEETLES ATTACKING CROPS IN MYSORE

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BANGALORE:
PRINTED AT THE GOVERNMENT PRESS
1918

FOREWORD.

THE study of Ground Beetles in Mysore was commenced by us over eight years ago and a good deal of information was collected with regard to their life history and the damage they cause. Other and more urgent work has during the past few years, occupied our attention so that the publication of our results has been delayed till now. It is very unlikely that these insects will ever become anything more than minor pests but the publication of a short account of them will not be without interest from a practical as well as a scientific point of view.

LESLIE C. COLEMAN,
Director of Agriculture.

July, 1918.

GROUND BEETLES ATTACKING CROPS IN MYSORE.

SEVERAL species of ground beetles of the genus Gonocephalum (Opatrum) have been recorded from various parts of the world as more or less injurious to crops. O. sabulosum[1] has been found to attack vines, in France, and tobacco and maize, in parts of Russia. In Rhodesia and Nyasaland, G. simplex[2] is looked upon as a pest of tobacco. Lindeman has described in some detail G. intermedium[3] (Fisch) which he reports as doing serious damage to tobacco and seed-corn, while Miss Ormerod in her 'Injurious Insects in South Africa', p. 19, gives O. micans[4] as an injurious species. Koningsberger[5] reported O. depressum as probably doing damage to roots of various plants in Java as long ago as 1898. Later he substantiated this and noted that besides the damage done by the larvæ on tobacco in nurseries, the adults, at times, injure tobacco in the field by gnawing the stems at or below the surface of the ground[6]. Since then it has been recorded and

[1]O. sabulosum, L.—
Review of Applied Entomology—Series A.
Vol. I, pp. 336, 358, 485.
Vol. II, pp. 608, 50, 51, 172, 718.
Vol. III, p. 203.
Vol. IV, p. 103.

[2]G. simplex.—
Vol. I, p. 289.
Vol. II, pp. 277, 706.

[3]G. intermedium, Fisch.—
Bull. de la Soc. Imp. des Naturalistes de Moscou No. 1 1888, p. 10

[4]O. micans.—
Injurious insects in South-Africa—p. 19. Miss Ormerod.

[5] & [6]. Koningsberger—.
Med. uit'sLands Plantentuin XXII, 1898—p. 40.
Do do LXIV, 1903—p. 43.
Do do XLIV, 1901.
Med. uitgaande van het Departement van Landbouw No. 6, 1908, p. 81.
Koningsberger—Zickten van Rijst, Tabak. Thei en andere cultuvrgervassen, die door Insecten worden veroorzatekt, Med. uit'sLands Plantentuin, LXIV, 1903, p. 43.

studied by Keuchenius[1] as a serious pest of coffee seedlings in Java.

In India species of the genus have seldom been looked upon as pests. According to a reference in the Indian Museum Notes Vol. II, the larvæ of O. depressum are said to have attacked seedlings of linseed and wheat. Lefroy in his 'Insect Life' gives a short account of the structure and appearance of the larva of O. depressum but notes that they are extremly difficult to find. He states 'Opatrum (Gonocephalum) is in some places found literally in millions but the larvæ never. Larvæ have been obtained first in captivity and then in the field only after prolonged searching'[2]. He further records having reared the larvæ of O. depressum but gives no account of it. With regard to the feeding habits of this form he states that "O. depressum, like most of its family, is wholly a feeder on dead or decaying vegetable tissue and the beetles have been found even to eat planks laid on the soil"[3]. Fletcher does not list O. depressum among his 'Some South Indian Insects' but gives a brief account of G. hofmannseggi[4]. He notes the damage done by the latter species of beetles to potato and grape vines, etc., but is inclined to regard them as probably beneficial as scavengers of dead vegetable matter.

The record of this genus in other parts of the world is against the verdict given above with regard to its status as a pest in India. With the increasing knowledge of its habits Indian Entomologists are coming to adopt a more correct attitude. At the second Entomological Conference held at Pusa in 1917 several references to injury by G. depressum were made among them to roots of Cajanus indicus and gram, to seedlings and stems of potato, to leaves of Cabbage and cauliflower at Dacca, to sweet potato in Moulmein. Similar injury by O. elongatum was also reported but the status of these species as pests remained undefined largely, because as acknowledged by Fletcher 'these are insects we really know very little about'.[5]

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[1]Keuchenius.—
Opatrum depressum, F. Med. van het Besoekisch Proefstation.
[2]Lefroy.—
Insect Life, p. 336.
[3]Lefroy—
Insect Life, page 338.
[4]Fletcher.—
Some South Indian Insects, page 299.
[5]Report of the Proceedings of the Second Entomological Meeting, page, 50.

In Mysore both G. hofmannseggi and G. depressum occur but so far injury has been reported only by the former. This species has been several times reported as damaging potato and ragi (Eleusine coracana) in the field. In the case of the potato, damage may be done by either the adult beetle or the larva although the former seems to produce the more serious effects. The chief damage results from the beetles gnawing into the stem just below the surface of the ground, much as has been described by Koningsberger for tobacco. At times regular tunnels into the stem may be made with the result that the plant is either seriously weakened or killed altogether. In addition to the damage to the stem, tubers may also be attacked, in which case usually broad shallow excavations are made in the surface. These while not greatly injuring the potatoes seriously detract from their saleability. This type of damage seems to be comparatively rare in the field although larvæ and adult beetles have been kept for months in the insectary feeding on nothing but potato tubers.

In the case of ragi it appears that the larvæ are exclusively or almost exclusively to blame for the damage done. The damage here again results from the gnawing through of the plants at or just beneath the surface of the soil, the appearance reminding one considerably of the work of cut-worms or surface-caterpillars except that the cut plants are not pulled into the ground. Only seedlings in the first two or three weeks of growth are subject to attack; as soon as they reach a height of about three or four inches they seem to be quite immune. Up to the present serious damage has been reported from three localities in Mysore. At each place several acres of young ragi were destroyed so that resowing became necessary. As the cause of the damage cannot be seen on a casual examination it appears quite possible that the damage caused by this insect is fairly widespread but that it has been ascribed to some other cause or has even been overlooked altogether.

The following record of an experiment will indicate clearly the possibilities of damage by this insect on ragi seedling.

18–1–10—20 larvæ collected in potato plot in Laboratory compound, were transferred to pot containing, ragi seedlings about ten days old.

21–1–10—8 seedlings cut.

23–1–10—About 100 seedlings cut.

25–1–10—About 100 more seedlings cut.
26–1–10—About 50 seedlings cut.
27–1–10—About 70 seedlings cut.
28–1–10—About 50 seedlings cut.
30–1–10—About 10 seedlings cut.

Total seedlings cut about 400 by 20 larvæ within 10 days.

On 6th February 1910 a search was made for the larvæ in the pot with the following results :—

4 larvæ at depth of one inch.
4 larvæ and one pupa found at depth of 1½ inch.
4 larvæ found at depth of 2 inches.
2 larvæ found at depth of 3 inches.

Total 14 larvæ and one pupa – 5 larvæ missing, probably eaten by the other larvæ. This cannibalism is not at all rare in the case of G. hofmannseggi. Almost invariably where larvæ in considerable numbers are kept together in captivity some of them are killed and eaten by the others.

A second experiment of the same kind showed a smaller amount of destructiveness, 20 larvæ in a pot with ragi seedlings (seven days old at the beginning of the experiment) cutting only fifty-five plants in 10 days. Here again an examination of the soil at the end of two weeks revealed 13 larvæ and 2 pupæ, the others in all probability having been destroyed by their fellows.

With regard to the difficulty of finding the larval stages, which Lefroy mentions, it is not stated at what time of the year they were looked for. As will become clear from the life history to be presently described the larvæ cannot be found in all seasons of the year but only during the hot weather when the beetles breed. Wherever the beetles are found during this season, a careful search in the upper two or three inches of soil will almost certainly reveal the presence of the larvæ sometimes in far greater numbers than the adults. In other seasons, especially the rainy season and the cold weather, usually the beetles alone are found and it was perhaps during this season that Lefroy looked for the larvæ.

Gonocephalum hofmannseggi.

Description of adult beetle.

Both the species G. hofmannseggi and G. depressum are so much alike that it would be difficult to distinguish

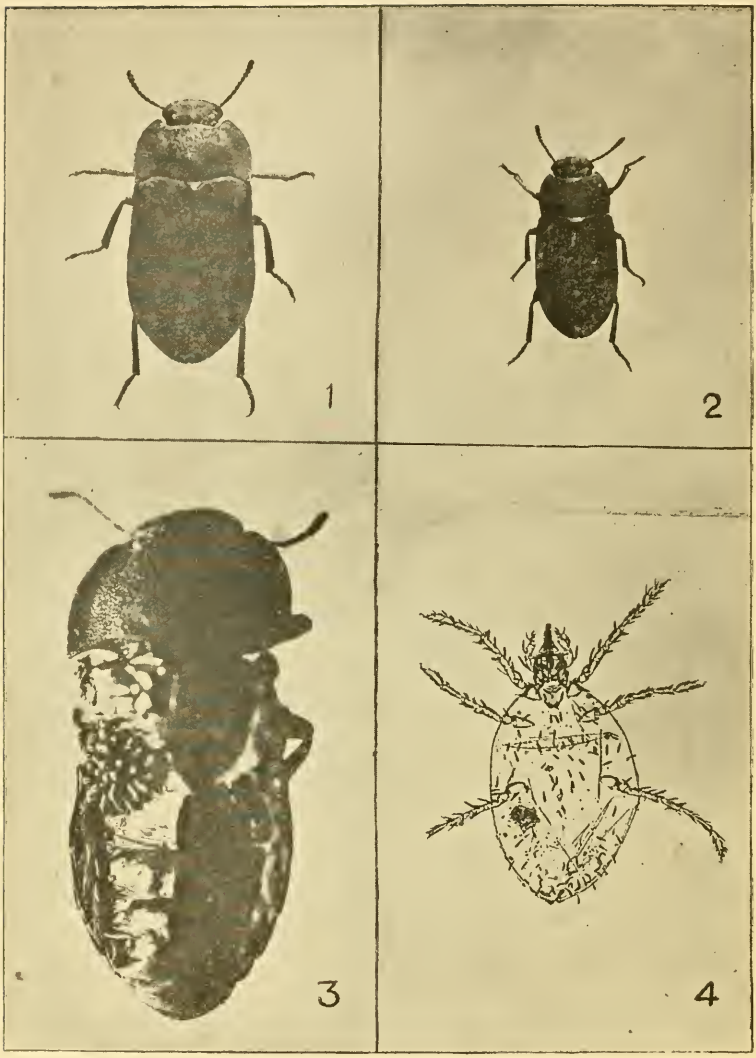


FIG. 1.—Gonocephalum depressum.

FIG. 2.—Gonocephalum hofmannseggi.

FIG. 3.—Adult of G. hofmannseggi with the elytra and the wings removed to show cluster of acarid parasites attached to the body below.

FIG. 4.—An earlier stage probably of the acarid shown in Fig. 3.

them except for the difference in size. Fabricius gives the colour of Opatrum (Gonocephalum) as grey but this is hardly correct so far as the two species are concerned. Both of them are dull black but the colour is usually obscured by a thin layer of soil particles entangled among the covering of minute curved spines on the body especially the abdomen. The insects are flat almost twice as long as they are broad. The head has a convex margin continuously with a deep indentation in the middle. The thorax is slightly elevated and has a more or less flat margin at the sides. The wing-covers are long and fit in closely (Frontispiece Fig. 5 and Plate I, Figs. 1 and 2).

The mouth parts are almost completely concealed below. They are adapted for feeding on vegetable matter the mandibles being blunt and stout. Both the palpi are well developed. Those of the maxillæ have terminal segments very broad. The head is drawn into the pro-thorax and remains so except when the beetles are feeding. The legs are not well developed and are all of the same size. The tarsal joints in the last pair, however, number only four whereas in the rest there are five each. There are no external differences between the sexes.

Life History.

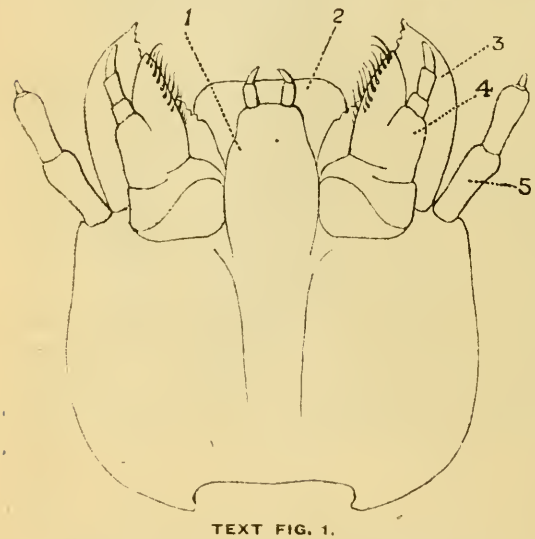
The eggs of G. hofmannseggi are laid loose in the soil or in excavations made in the plant attacked. Frontispiece Fig. 1 shows eggs laid in hollows excavated in a potato tuber. They are white in colour, elliptical in shape and are about ·5 mm. in length. When laid fresh, they appear to be slightly moistened by a secretion so that some of them become covered by particles of earth.

The larva.—The eggs usually hatch in two or three days. Occasionally it may take a week. The young larva is white in colour and about 2 mm. in length. The mouth parts are well developed. The antennæ have three segments, the second one being the largest. The third is reduced to a flagellum. There are no eyes. The legs are well developed and end in conical claws. There are nine distinct abdominal segments, the last of these segments having on the dorsal side a flattened surface which projects backwards as a triangular process. This organ is apparently intended to facilitate rapid retreats when the larva is threatened by enemies. The anus which is also situated in the last segment is in the

form of a pit with raised edges and is overlapped by two small lobes.

Moulting.—The number of moults may vary from 8 to 16. These as well as the intervals between them vary very considerably as will appear from Tables I and II. At the time of moulting, the larva becomes very tense and increases in size. In one larva kept under observation a bubble of gas was seen to pass forwards and backwards along the alimentary canal much as in a spirit level. The passage outside of this was detected by means of a drop of water placed at the anus. The gas in the alimentary canal would help to swell the larva and rupture the old skin. The split takes place, as usual, along the upper side of the thoracic region. The larva remains more or less arched during the process and it retains its hold on the soil not so much by the legs as by the anterior and posterior ends which are pressed against the soil as the body is gradually drawn out from the old skin.

The differences between the young and full grown larvæ are very slight. As the larvæ grow their colour changes from white to shining cream colour and then to dull brown. The skin also becomes thicker. In the older larvæ the mouth parts are very strong and hard and the maxillæ have an array of strong bristles which probably help in divesting the larval food of much of the encumbering earth particles. (Text Fig. 1.) The third segment of the antenna which was like a flagellum becomes a stump. The full grown larva (Frontispiece Figs. 2 & 3) is about 20 mm. or 10 times the size it had when it hatched. Save for these differences, the structural similarity between the young and the old larvæ is extremely close. Larvæ appear



TEXT FIG. 1.
Mouth parts of the larva of G. hofmannseggi.
1. Lower lip. 2. Upper lip. 3. Mandible. 4. Maxilla. 5. Antenna.

to require a certain amount of moisture for pupation. Of the same lot of larvæ collected and divided between two water-tight compartments in the same pot one watered and the other not, those in the watered portion pupated sooner and in larger numbers. This experiment was repeated several times with the same result. The age of the larvæ in each case was unknown and the larvæ grown in the insectary were too few for purposes of the experiment but the fact that in every experiment the larger number pupated in the watered portion may be taken to indicate that sufficient quantity of moisture is an essential condition of pupation.

Pupation.—When the larva is full grown, it enters the soil and prepares usually a small chamber out of earth mixed with a sticky secretion. After remaining in the chamber for two days it moults and then turns into a pupa which is as naked and white as that of any borer beetle. (Frontispiece Fig. 4.) Larvæ have pupated in the insectary on the surface of the soil without constructing a chamber, but the extremely soft skin of the pupa and the fact that G. depressum always pupates in a mud chamber may be taken to indicate that pupation on the surface of the soil is exceptional.

The adult beetle emerges in less than a week and is at first pure white, but turns brown in a couple of days and dull black in another day. On account of the presence of the minute spines already described, the body gets soon covered over by fine particles of earth, so that the normal colour gets very soon obscured. The beetles are nocturnal in habit. They pass the day time in situations which are screened from the sun such as below bushy growths, round the roots of plants, and in crevices in walls. As soon as it gets dark, they emerge from their hiding places and begin to move about in search of food, returning to the shelters in the morning. In very cloudy or wet weather they may venture out of these even in day time. They are provided with glands in the neighbourhood of the anus which secrete a liquid of dark brown colour. When disturbed, this is exuded and spreads over the terminal segments of the abdomen. The secretion has the odour of nitric acid and probably acts as a violent repellant. Ants kept along with beetles stimulated to exude the secretion, in a test tube made frantic efforts to escape and several died.

Enemies.—Mason and Lefroy have noticed the adults of G. depressum in the crops of the birds, Upupa indica, Centropus sinensis, Frankolimus vulgaris, Sypheotis bengalensis and Sarcogrammus indicus. And possibly G. hofmannseggi is similarly devoured. The other enemies noted are a species of an acarid and two hymenopterous parasites. The acarids were found crowded on the soft skin of the abdomen beneath the wings (Plate I, Fig. 3). They are blood-red in colour and much like those found on a common species of harvestmen found in situations similar to those where the beetles are found. They may be found attached singly to the legs of the beetles also. Plate I, Fig. 4, shows a young acarid, probably an earlier stage of the adults shown in Fig. 3. Of the two hymenopterous enemies found up to the present one is a small wasp scarcely half an inch in length which was noticed carrying a larva to its nest. The other is a large ichneumon (Text Fig. 2) which parasitises the larva. Several larvæ collected

TEXT FIG. 2.

Ichneumon Parasite of G. hofmannseggi with pupal case on the left.

in the field and reared had the development aborted by the parasite. Instead of pupating in the normal way, the larva after a moult assumes the shape of a blister beetle larva in its coarctate stage. The legs are shrivelled into shapeless stumps and the mouth parts are seen only in bare outlines. Out of this, the parasite soon emerges cutting a neat round hole (Text Fig. 2). The enemies described are not sufficiently numerous to act as efficient checks.

The following tables summarise the records of rearings in the insectary. The difficulties attending the work have been considerable. The eggs were placed separately in shallow dishes with a small amount of soil. The larvæ on hatching were placed with small pieces of

potato. Each day the soil was thoroughly searched for cast larval skins and at the same time the larvæ were examined. Even so the number of moults has not been determined for all, as the larvæ have apparently the habit of eating thier cast skins. Only the records of those that successfully completed their life history are given. They form but a small proportion of those with which the rearing commenced.

The Insectary Records.—In the Insectary beetles were got to lay eggs from December to June and again in August. Eggs were laid as early as a month after emergence. Larvæ were reared successfully both during the first and second halves of the year with this difference that those reared during January to June took only half the time that the second lot grown during the monsoon and cold weather took.

In the field.—Larvæ are usually observed only during January to May or June. As soon as the early rains are received the larvæ pupate and emerge as beetles and reproduction does not commence until December or January following. Beetles caught in the field and dissected did not show developed eggs until October. During this long interval between emergence and reproduction, of nearly six to seven months, the beetles are sluggish and inactive. It is during this period that the beetles sometimes seek the shelter of human habitations or as Lefroy observed crowd in thousands on plants to escape the wet in the soil. When the weather warms up beetles become active and breeding commences. This may happen as early as December. At this time adults may occasionally be caught at light. The possibility of a second brood has to be admitted. The shortest period taken to complete the life history being two months and eleven days there may be two broods within the first six months of the year. But considering the large number of grown up larvae which are found inactive during the hot weather, as it were waiting for the rains to pupate, it seems unlikely that under ordinary conditions of normal weather there is more than one generation during the year.

The interpretation of the records.—The striking feature of the records tabulated below is the wide range in the duration of larval life. The duration of corresponding instars also varies enormously. The third instar ranges from four to twenty-seven days while the eighth from seven to twelve days. These variations are in regard to

TABLE I.

Records of Moults of larvæ of G. hofmannseggi reared in soil kept more or less moist.

Serial No.	Date				1st Moult			2nd Moult			3rd Moult			4th Moult		
	Egg laid	Egg hatched	Days	Length in M. M.	Date	Days	Length in M. M.	Date	Days	Length in M. M.	Date	Days	Length in M. M.	Date	Days	Length in M. M.
1	21 2 10	25 2 10	4	2	27 2 10	2	3	19 3 10	20	5·5	26 3 10	7	7	4 4 10	6	8
2	21 2 10	25 2 10	4	2	5 3 10	8	...	1 4 10	27	6·5	7 4 10	6	8	17 4 10	10	10
3	19 3 10	24 3 10	5	2	26 3 10	2	3	30 3 10	4	4·5	2 4 10	3	6	10 4 10	8	7·5
4	19 3 10	24 3 10	5	2	26 3 10	2	3	30 3 10	4	4·5	2 4 10	3	6	10 4 10	8	7·8
5	19 3 10	24 3 10	5	2	26 3 10	2	3	30 3 10	4	4·5	3 4 10	4	6	11 4 10	8	8·5
6	22 2 10	24 2 10	...	...	.....	...	...	.....	...	...	.....	...	...	4 4 10	...	...
7	24 2 10	3 3 10	...	...	.....	...	...	.....	...	...	.....	...	...	4 4 10	...	8

Serial No.	5th Moult			6th Moult			7th Moult			8th Moult			Pupated		Emerged		Period of life history
	Date	Days	Length in M. M.	Date	Days	Length in M. M.	Date	Days	Length in M. M.	Date	Days	Length in M. M.	Date	Days	Date	Days	
1	17 4 10	13	10	26 4 10	9	12	2 5 10	7	14	.....	...	...	.....	...	5 7 10	...	134 days.
2	28 4 10	11	11	9 5 10	11	12	21 5 10	12	14	.....	...	...	Missed	...	.....	...	...
3	21 4 10	11	8	7 5 10	16	10	14 5 10	7	12	5 6 10	22	14	.....	...	14 7 10	...	117 days.
4	.....	...	...	4 5 10	...	11	15 5 10	11	12	24 5 10	9	14	19 7 10	56	28 7 10	9	131 days.
5	... ...	...	...	28 4 10	...	...	7 5 10	9	14	.....	...	...	22 5 10	15	29 5 10	7	71 days.
6	24 3 10	30	10	7 4 10	15	12	16 4 10	9	14	.....	...	...	1 5 10	...	7 5 10	...	74 days.
7	14 4 10	10	12	20 4 10	6	14	1 5 10	11	15	.....	...	...	21 5 10	...	26 5 10	...	91 days.

TABLE II.

Record of moults of the larvæ of G. Hofmannseggi reared in dry soil.

No.	Date of Hatching	1st Moult	2nd Moult	3rd Moult	4th Moult	5th Moult	6th Moult	7th Moult	8th Moult
26c	14 8 11	16 8 11	28 8 11	6 9 11	17 9 11	15 10 11	4 11 11	17 11 11	13 12 11
25	12 8 11	15 8 11	.....	10 9 11	.....	26 10 11	10 11 11	27 11 11	30 12 11
26a	14 8 11	16 8 11	24 8 11	.....	29 9 11	11 10 11	25 10 11	11 11 11	4 12 11
27	20 8 11	21 8 11	.....	.....	.....	16 11 11	10 12 11	17 1 12	7 2 12
29	24 8 11	27 8 11	.....	15 9 11	2 10 11	19 10 11	6 11 11	26 11 11	31 12 11
30	27 8 11	.....	17 9 11	13 10 11	23 10 11	8 11 11	29 12 11	29 1 12	14 3 12
31	28 8 11	31 8 11	.....	8 10 11	27 10 11	15 11 11	8 12 11	13 1 12	6 2 12
24a	8 8 11	11 8 11	22 8 11	6 9 11	.....	2 10 11	15 10 11	27 11 11	4 1 12

No.	Date of 9th Moult	10th Moult	11th Moult	12th Moult	13th Moult	Pupation	Emergence	Period from hatching of larva to emergence of beetle
26c	21 1 12	8 2 12	29 2 12	20 3 12	6 4 12	4 5 12	10 5 12	270 days.
25	31 1 12	17 2 12	6 3 12	21 3 12	7 4 12	25 5 12	31 5 12	293 days.
26a	14 1 12	8 2 12	1 3 12	18 3 12	13 4 12	18 5 12	24 5 12	284 days.
27	23 2 12	10 3 12	26 3 12	13 5 12	18 6 12	6 8 12	10 8 12	355 days.
29	6 2 12	14 3 12	2 4 12	21 4 12	8 5 12	19 8 12	.....	
30	1 4 12	18 4 12	10 5 12	.....	.....	27 6 12	3 7 12	311 days.
31	21 2 12	12 3 12	7 4 12	21 4 12	8 5 12	15 5 12	.....	
24a	8 2 12	28 2 12	7 4 12	28 4 12	.....	31 5 12	9 6 12	306 days.

larvæ kept in soil supplied regularly with a certain amount of moisture. In all these the number of moults was not more than eight. In the second table the records are of larvæ which were not supplied with moisture at all or were supplied with it only after the eighth moult. The larval stage in these was enormously lengthened and the number of moults increased from eight to thirteen. The differences in the length of larval life are brought about in the following table:—

First series	Second series
2 months and 11 days	9 months and 9 days
2 ,, 15 ,,	9 ,, 14 ,,
3 ,, 4 ,,	9 ,, 23 ,,
3 ,, 27 ,,	9 ,, 26 ,,
4 ,, 11 ,,	10 ,, 6 ,,
4 ,, 14 ,,	10 ,, 11 ,,
	11 ,, 25 ,,

In some dishes to which moisture was not added at all, the larvæ moulted as many as sixteen times. On the other hand others precisely similarly situated pupated in the eleventh instar. Of the four that were supplied with moisture in the fourteenth instar one died, the second pupated six days, the third a fortnight, the fourth a month after water was added but all the three before another moult.

The variations in the size of the larvæ are equally puzzling. The following are the measurements of larvæ grown in soil supplied with different degrees of moisture:—

Date	Number of larvae supplied daily with					
	5 C. C. of water	Average size	3 C.C. of water	Average size	2 C.C. of water	Average size
14th April 1910.	15	2 mm.	15	2 mm.	15	2 mm.
2nd May do	7	4·5	11	5	13	7
7th May do	5	5·2	11	5·1	12	7·3
14th May do	4	6·3	11	5·8	11	9
22nd May do	4	7·7	10	6·0	11	9
28th May do	4	8·5	9	6·7	10	11·0
13th June do	4	10·2	9	8·0	9	11·0
24th May do	4	13·0	7	8·3	7	12·0

The table does not disclose the range of individual variation which is enormous. Larvæ hatched on the

same date and grown in the same conditions were found to vary in size from eight to fourteen mm. in the course of one month and twenty-four days. Under more moist conditions the variation was not more than three m. m. With such variability it is unsafe to draw any conclusion from so small a number of rearings. The inference seems however permissible that in the earlier stages of growth an excess of moisture retards considerably the growth of the larvæ if it is not actually injurious to its life.

Compared with the larval stage the egg and pupal stages are remarkably short and hardly subject to any variation. Whatever the length of larval life the pupal stage does not take more than a week and this must be of great advantage to the species seeing that pupation takes place after the rains have commenced, and that the mud chamber is not sufficient protection for the naked pupa inside. So too with the eggs which are laid loose in the soil never deeper than one inch which is thus practically unprotected against enemies.

The extreme variability of the larvæ with regard to the period of growth is probably an adjustment to the conditions in which they have to live and thrive. It has already been seen that beetles may lay eggs as early as August, in the necessarily artificial conditions of the laboratory. In the field they may lay eggs any time during the first five months of the year as beetles caught on different dates throughout the period commenced egg laying soon after they were caught. The larvæ from all these layings cannot pupate until the rains after summer. As has already been seen a certain amount of moisture is required for the larvæ to pupate. Furthermore, beetles emerging too early will have considerable difficulty to find in the hot weather the decaying vegetable matter on which mostly they feed. The pupation at or about the time of the first rains appears therefore to be an adjustment to the conditions which enables the beetles to find the food they require in abundance. It is therefore natural to conclude that at whatever time the eggs are laid whether in December or late in May the larvæ hatching out of them must grow sufficiently rapidly to enable them to pupate before the soil is too wet for pupation and emergence.

While the conclusions drawn above are not to be accepted as anything else than the interpretation of Insectary results, they appear to be justified both from observations in Mysore and from observations made in Java

by Keuchenius in regard to G. depressum which has habits almost identical with those of G. hofmannseggi and has the same life history. In Java the rainfall has a distribution over the year almost the reverse of that in Mysore. The rainy months commence from November and end in May the driest months being from June to October. With this reversal of conditions the life history of G. depressum has also changed, for in Java this species lays its eggs in June and the first pupa is not observed in the field until November, when the wet weather commences. The period of inactivity is from December to June instead from June to December as in Mysore.

We are now in a position to discuss the status of G. hofmannseggi as a pest in Mysore. Though the species is found practically all over Mysore, so far damage by it to crops has been reported only from three localities where the rainfall, in the quarter April to June is notoriously deficient, irregular and uncertain. It often happens that sufficient rains are received to plough and in some parts to sow as well but are not followed by further showers so that the larvæ are without the requisite amount of moisture to pupate. The tillage operations which involve the removal of the roots of weeds, etc., deprive the larvæ of their food and compel them to concentrate on the few fields which have been sown early and where the seedlings have come up. Irrigated ragi is not attacked because at the time of transplantation sufficient rains will have been received for the larvæ to pupate and in the nursery the soil is too wet to attract the larvæ which have moreover the young seedlings in fields themselves to feed on. In the case of Potato which is usually grown in the early part of the year, the attack is usually from the beetles rather than from the larvæ. The crop is in the field at a time when the beetles become active and begin to breed, and in all probability they are attracted to it and lay their eggs there. Only in one instance has damage been reported as late as August. In this locality the rain fall averages only about twenty-two inches and the rainiest months are May and October. It is probable that here there may have been a second generation. When the crops were inspected in August, full grown larvæ were found concentrated along the rows of ragi seedlings. They were near pupation. Possibly therefore with the 7·32 inches received in May, the first generation pupated and emerged and since for the three months following there

was little more than 7 inches, the beetles may have laid eggs which developed and were near pupation in August. It is difficult to explain otherwise that grown up larvæ were found as late as August, seeing that the rainfall in May was sufficiently heavy for pupation.

Remedies.—From the habits of the species already discussed it will have become obvious that remedial measures are difficult to apply. Any application of gaseous or liquid poison is out of the question as the area to be treated is too large even if the remedy should prove within the reach of the raiyat. Equally impracticable is the application of tobacco dust and similar repellants. Tobacco dust was actually tried as an experimental measure but failed to affect the larvæ at all. We have thus no alternative but to fall back upon the adult stage as the only point of attack. The beetles are usually found on the upper surface of the soil and any attractive bait will easily bring together large numbers which can be collected and destroyed without difficulty. Various baits were tried as decaying straw of paddy, ragi (Eleusine coracana) and *bharagu* (*Panicum miliaceum*) soaked long in water. Weeds with roots from the ground were also tried. While each of the above proved as good baits, the most attractive was found to be the weeds. To secure the best results, these have to be spread on the bunds an hour or so before sunset. The beetles are best collected soon after nightfall when they emerge from their hiding places and begin to feed. Where the beetles attack potato the best remedy appears to be a poison bait. Chopped grass soaked in a solution of jaggory and some form of soluble arsenic will attract the beetles which are killed in about a day after the first feed. The bait is prepared as follows—One pound of sodium arsenite is dissolved along with 8 lbs. jaggory or molasses in 10 gallons (2½ kerosine tins) of water. Chopped grass in sufficient quantity is mixed with the solution and spread over the field in the evening.

The chief obstacle in the way of carrying out the remedies suggested lies in the fact that it is impossible to tell in any one year whether the pest may appear in numbers in the next or not and since in normal years the raiyats do not suffer any serious loss, they are apt to neglect the collection of the insects. However, it should not be difficult to eradicate the pest if the collection and destruction on the lines suggested is carried out year after year for three or four years. Once this has been done, the raiyats

may feel secure that among the many consequences of erratic rainfall the damage by ground beetles will not be one.

The larger ground beetle (*G. depressum.*) (Plate I, fig. 1.) —The life history of this species is much the same as that of G. hofmannseggi. The surface of the adult is smoother. There is therefore less accumulation of mud on the surface which usually shows the normal dull black colour. The eggs and larvæ are, as is to be expected, larger but are similar in structure. The larvæ are larger by about 5 mm. and are usually marbled with black. Their habits are the same. All that has been said about the life history G. hofmannseggi applies to that of G. depressum also.

This species has seldom been noted as a pest but there is the possibility of it assuming that character when conditions are favourable.

Summary.—

(1) The two ground beetles G. hofmannseggi and G. depressum are common in Mysore.

(2) The larvæ usually attack the roots of grass and the adults feed on decaying vegetation, but both may attack a summer crop like the potato.

(3) The larvæ become pests of ragi (Eleusine coracana) in regions of deficient rainfall when the rains are delayed after sowing and the larvæ have not sufficient moisture to pupate. Crops like the potato grown in summer are also liable to attack mainly by the adults which are attracted to it.

(4) The life history usually takes a year, the larval life being confined to the hot weather. The beetles emerging after the first heavy rains remain inactive until December following when they commence to breed.

(5) A second brood is possible in years when the first heavy showers are followed by a drought of two or three months.

(6) The pest may be controlled by the collection of beetles in October by means of fresh weeds pulled out along with roots and spread along the bunds.

(7) There are three enemies, an acarid on the adult, a wasp and an ichneumon on the larva. These are not efficient checks.