SEED-HARVESTING AND OTHER ANTS IN THE TOBACCO-GROWING DISTRICTS OF NORTH QUEENSLAND.

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SUMMARY.

1. An investigation was carried out into tobacco seed-bed failures caused by an indigenous ant fauna.

2. The funnel ant, Aphaenogaster longiceps, was a serious pest because of the ramifications of the nest and the soil disturbance associated with the formicary. The chief seed-harvesting species were Monomorium rothsteini var. leda, Pheidole impressiceps, P. variabilis, and Pheidolacanthinus mjobergi. The bionomics of these and of some other species are discussed.

3. Granary contents of nests belonging to granivorous ants reflect the seed-fall at a given period, the character of the flora, and the ability of the workers to carry the seed.

4. Species which do not harvest seed preponderate in the coarse white sands and seed-harvesting species in the river silts; brown sands contain numerous nests of both types. An explanation of the species distribution, based on the reaction of individual species to the physical characteristics of the soil and on an analysis of available food materials, is suggested.

5. Losses from seed-harvesting ants may be eliminated by establishing seed-beds some distance away from the nests of the more distinctive species, by destroying nests on the site before preparing the seed-bed, or by applying sand covers immediately after sowing the seed. The river sand retained on a 16-mesh sieve, when applied to a depth of one-eighth inch, gives adequate protection.

6. Baiting is sometimes necessary to prevent damage by ants which harvest the cotyledons from seedlings. These ants collect maize meal more readily than either tobacco seed or the cotyledons of seedlings, and broadcast applications of the meal at a rate of 12 oz. per 100 square feet on and near the seed-beds give effective control. The addition of a poison to the bait is not necessary, as nest destruction is of secondary importance.

INTRODUCTION.

During recent years a considerable area of land situated in the vicinity of the townships of Mareeba and Dimbulah, which lie in the Cairns hinterland of North Queensland, has been used for the cultivation of tobacco. The producing districts are watered by the Barron and Walsh Rivers and their tributaries, but as most of these streams flow only after heavy rains the water supply, except in a few comparatively small areas, is inadequate for field

irrigation, though sufficient for the watering of tobacco seed-beds. The underlying rock throughout the area is either granite or sandstone, and the derived soils are essentially of a sandy type. Three types are recognized, viz., river silts, brown sands, and white sands.

The annual rainfall of the district ranges from 20 inches to 30 inches, the greater part falling during the three summer months of January, February and March. Transplanting takes place on non-irrigated farms from the beginning of December to the end of January, so as to take advantage of the summer rainfall. In order to provide seedlings for transplanting during this period, seed-beds are planted at fortnightly or three-weekly intervals from mid-October onwards, though where field irrigation is practised seed-beds may be established much earlier. Any considerable interference with seedling development in the seed-beds may therefore disturb the whole planting programme.

When the tobacco-growing industry was first established in the Mareeba-Dimbulah area, serious seed-bed failures occurred. In some instances the seedlings were destroyed in the cotyledon stage, but more commonly seedlings did not appear above the ground and subsequent broadcast sowings yielded no plants. An examination of these seed-bed failures showed that most could be attributed to the depredations of seed-harvesting ants. Considerable damage was also caused by other species nesting in the seed-bed site. Many seed-beds had been established over the nests of these species, and mounds thrown up by the ants frequently smothered a large proportion of the seedlings. Runways used by foraging workers of some comparatively large species crossed and recrossed some seed-beds, causing damage.

A considerable number of ant species occur in the virgin soils of these tobacco-growing districts (see Appendix 2). Species which do not harvest seed attract most attention owing to their larger size, but a close examination of nest incidence indicates that granivorous forms are very common. Ant nests are so abundant in some soils that it is difficult to find a single square yard free from nest openings.

The trees of the Mareeba and Dimbulah soils, which are relatively infertile, are of the stunted, sclerophyllous type; but during the wet summer months there is an abundant ground flora in which grasses and legumes are common. Most of these herbaceous plants are ephemerals which shed their seed in autumn and early winter, thus providing sufficient food to support a large population of seed-harvesting ants.

ANTS ASSOCIATED WITH TOBACCO SEED-BEDS.

The ants associated with tobacco seed-beds and their surroundings may be grouped into three classes, viz.—(*a*), species which are apparently innocuous; (*b*), species which disturb the surface of prepared seed-beds; and, (*c*), species which harvest either the seeds or cotyledons or both.

The more important species in the several classes are discussed hereunder. The description given in each case is intended merely to indicate the main features which the field agronomist working in the tobacco-growing districts of North Queensland may use to distinguish the various species.

Apparently Innocuous Species.

Apparently innocuous species of ants comprise forms which, though collected in or near seed-bed areas, have no harmful effect on the growth of the seedlings. They do not harvest seed or cotyledons and seldom disturb the surface of the seed-bed.

Crematogaster (Acrocoelia) fusca Mayr.

Of the several species of *Crematogaster* which are found in and about tobacco seed-beds, *C. fusca* is the largest. The workers are between 3mm. and 4mm. long and, except for the lighter coloured appendages, are shining black in colour. The meso-thorax and metanotum are minutely rugose, but elsewhere the integument is smooth. The metanotum bears two short, stout spines on the posterior dorsal edge, and fine, short hairs are scattered over the whole of the body.

Nests of this species are established in trees or logs and are generally situated beneath loose bark or in calloused tissues on the stem and branches. Several colonies have been observed on tea trees (*Melaleuca* spp.) growing in the beds of streams which are occasionally flooded. Nests on separate trees may be connected by runways on the ground.

The workers, besides garnering pieces of plant debris, dead insects and other organic materials, often carry white fragments of quartz into the nest. They occasionally fight the larger mound ant, *Iridomyrmex detectus* Sm. s.sp. *sanguinea* For., which is repelled by a poisonous fluid ejected through the tip of the heart-shaped gaster.

Crematogaster pallipes Mayr.

The workers of *C. pallipes* are between 2mm. and 2·5mm. in length and are brown in colour, with the gaster grading into a darker shade towards the posterior. The thorax and pedicel are minutely punctate and there are two sharp spines on the metanotum. The remainder of the integument is smooth, but the whole of the body is covered with long, scattered hairs.

The nests of this species occur in the ground, the brood chambers and galleries being approached through an arc-shaped passageway, which is just beneath the surface for most of its length, but which invariably breaks through the ground several times, especially under fallen leaves and twigs. The species is common in seed-bed areas of the Mareeba district. Both this insect and *C. fusca* are widely distributed throughout Australia (Tillyard, 1926).

Crematogaster pythia For.

The workers of *C. pythia* are 2·5mm. to 3mm. in length and are light brownish-yellow in colour except for the posterior abdominal segments, which are dark-brown. Fine, short hairs are scattered over the body; the thorax and pedicel are minutely punctate, and the integument of the head and gaster is smooth. The nest is similar to that of *C. pallipes.*

Paratrechina (Nylanderia) obscura Mayr.

The workers of *P. obscura* are about 3mm. long and are black in colour, though the antennae and tarsi are light-brown. The integument is smooth and shining and, except for the metanotum, carries numerous stout hairs or bristles.

The underground nests of this ant are usually entered through a single opening, which is often situated under a tussock of grass and surrounded by a characteristic mound. There is a comparatively large chamber immediately under the nest opening, and from this the galleries lead into the nest. Several nests are often linked together by runways. *P. obscura* has a fairly extensive foraging range and nests have been located in river beds which are frequently inundated during the summer. The species is widely distributed in the drier parts of the district.

Other apparently innocuous species which have been collected in seed-bed areas are *Tapinoma minutum* Mayr. var. *integrum* For., *Opisthopsis haddoni* Emery, *Opisthopsis pictus* Emery var. *lepidus* Wheeler, *Polyrachis* (*Chariomyrma*) *aurea* Mayr., and *Camponotus* (*Tanaemyrmex*) *novaehollandiae* Mayr.

Ants Disturbing the Surface of Seed-Beds.

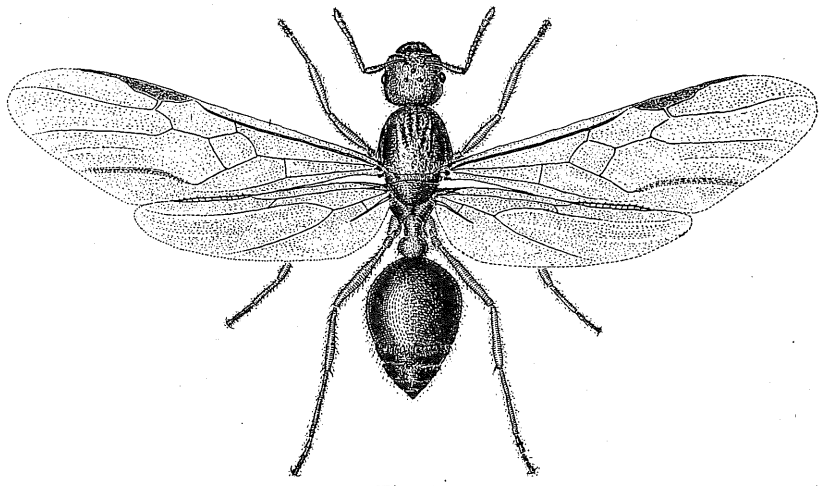
A number of ants sometimes disturb the surface of the seed-bed by throwing up mounds of earth during nest construction or by establishing runways on the site. The excavated earth smothers the seedlings, while plants on or near the runways are destroyed.

Aphaenogaster (Nystalomyrma) longiceps For.—**The Funnel Ant.** (Plate 1.)

The funnel ant is probably the most conspicuous ant pest of tobacco seed-beds in North Queensland. The workers are between 5mm. and 6mm. in length and are uniformly chestnut-brown in colour. The body is clothed with hairs, which are sparsely distributed over the smooth integument, and there are two metanotal spines.

Funnel ants sometimes nest in areas which are otherwise suitable for the production of seedlings. Colonies may cover several square chains and possess several openings to each square yard of surface. Each of the more or less vertical openings of the nest is surrounded by a crater of loose earth about six inches in diameter: hence the common name of funnel ant. The opening varies a great deal in size, but is usually about one-half inch across. The openings may be so numerous that the loose earth of the craters covers most of the intervening ground. The funnels lead to the brood chambers and galleries underground. When seed-beds are constructed in badly-infested areas, the effect on the seedlings is serious. The small plants are buried under the freshly excavated material, and sometimes very poor stands may be attributed solely to the nesting operations of the funnel ant. The activity of the workers is not greatly affected by temperature, though foraging operations are most

pronounced in the late afternoon. Funnel ants have not been observed harvesting seed. In the tropical red loams of the adjacent Atherton Tableland they may attend aphids (*Geoica* sp.) on the roots of grasses. This ant is widespread in North Queensland and is common in both the Mareeba and the Dimbulah districts.



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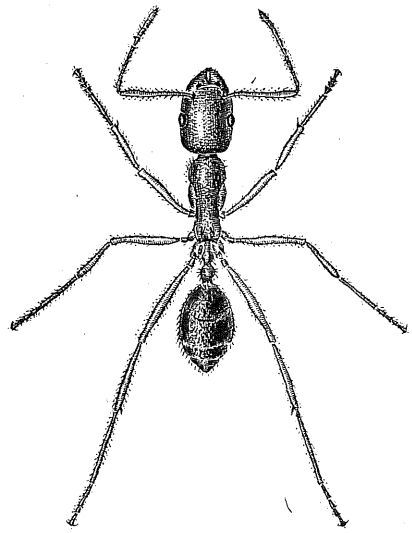


Fig. 2.

Plate 1.

Aphaenogaster (*Nystalomyrma*) *longiceps* Sm.—Fig. 1. Winged female × 4; fig. 2. Worker × 7.

[*Drawings by William Manley.*

Iridomyrmex detectus Sm., s.sp. ***sanguinea*** For.—**The Mound Ant.**

The mound ant is one of the larger seed-bed species and is perhaps the best known insect in Australia (Tillyard, 1926). The workers are about 6mm. long, with red-coloured head and thorax. The gaster and legs, except for the tarsi, are plum-coloured. Both legs and antennae are long and slender. There are a few scattered hairs on the integument of the head, thorax and abdomen. The winged females are comparatively large—12mm. in length—and their colour pattern differs little from that of the workers. The mesothorax is, however, plum-coloured and not red as in the worker.

The formicaries of this species are characteristically bare of vegetation and are decidedly mound-like, though the mound may not be more than one foot high. The mound is pierced by several openings about 6mm. to 8mm. in diameter, which lead to the extensive underground galleries of the nest. There are always a number of well-defined pathways, varying in width from three inches to six inches, leading away from the mound. These may be traced for several chains from the nest, and they frequently connect adjacent mounds.

Mound ants are continually at war with the numerous mound-erecting termites and they frequently inhabit termitaria from which the original occupants have been ousted. Sometimes a termitarium is occupied simultaneously by a colony of termites and by mound ants, the termites having preserved part of the colony intact by constructing walls to prevent further ingress by the predatory species.

The workers are extremely rapacious and attack any dead or disabled animal in the vicinity of the mound. Other insects are attacked. Mound ants are also partial to sweet substances and frequently invade houses or camps.

Should tobacco seed-beds cut across a previously-used runway, the ants may re-establish the track after the seed has been sown. Shade conditions under the seed-bed covers may also attract the workers and runways frequently deviate from an old track to pass along the seed-bed. Seedlings on these runways are inevitably destroyed and the losses occasionally reach serious proportions. The mound ant is present in all tobacco-growing regions of the State.

Iridomyrmex rufoniger Lowne.
Iridomyrmex rufoniger Lowne s.sp. ***pallidus*** For.

As *I. rufoniger* and its sub-species *pallidus* are closely related and as their habits are very similar, they can conveniently be discussed together. Differences in the colour of the integument of *I. rufoniger* and the sub-species are very striking, for while *I. rufoniger* is dull-brown to black in colour, its subspecies is uniformly light chestnut-brown. The workers are 3·5mm. in length, and have long, slender legs and antennae; the coxae are large and robust. The integument of the whole insect is smooth and possesses a uniform covering of very fine, short hairs.

In the underground nests there are numerous more or less closely-spaced chambers at a depth of one or two feet. Access to the nest is provided by one or more entrance holes, each of which is about 5mm. across and surrounded

by a symmetrical crater-shaped earth mound. Formicaries of *I. rufoniger* usually contain a greater number of individuals than do those of the sub-species *pallidus*. The latter is generally the less active, though both are very quick in their movements compared with other ants. The workers appear at dawn in summer but are almost inactive during the hotter hours of the day. In the late afternoon the insect is again actively foraging for food.

The earth crater surrounding the entrance holes may be formed in tobacco seed-beds during the reconstruction of an old nest after seed-bed preparations have been completed. When these craters occur in seed-beds, some seedlings are destroyed. The losses may be due either to the inhibition of germination by the crater-mound or to the smothering of seedlings after the plants have appeared above the ground. *I. rufoniger* is more troublesome than its sub-species, but losses are never considerable.

Both insects are widely distributed throughout the tobacco-growing districts of North Queensland and probably occur on most tobacco farms.

Seed-Harvesting Ants.

The discussion of seed-harvesting ants is complicated by the multiplicity of species involved. Four genera—*Pheidole, Pheidolacanthinus, Monomorium,* and *Meranoplus*—contain injurious species. The importance of individual species frequently varies from farm to farm, but some are represented in the ant fauna of almost all seed-beds.

Relatively large seed-harvesting species, such as *Monomorium rothsteini* var. *leda,* have a considerable foraging range but the nests are usually far apart. Consequently, seed-beds are often established in potentially dangerous areas without any seedling losses ensuing, germination having been completed before the seed has been discovered by the workers. If, however, the seed-beds are established close to, or over, nests of this species, losses are certain to occur unless special precautions are taken to protect the seed.

Though the depredations of the larger seed-harvesting species may sometimes be avoided by the chance disposition of the seed-beds, there is little prospect of ever escaping the attentions of the smaller ants whose nests crowd river silt soils. Practically any seed-bed site selected on these soils will contain nests of the smaller seed-harvesting species and some of the seed at least will be taken by foraging workers before germination. If sowing rates are heavy, the unharvested residue on the seed-beds may be sufficient to give a satisfactory strike of plants. Ants, however, remove the seed indiscriminately and, where they have been active, parts of the seed-bed carry few, if any, seedlings.

If the presence of ant nests on seed-bed sites has not been noticed during the preparation of the seed-beds, it soon becomes apparent when the workers renew the nest openings destroyed during cultivation. Within a day or two from sowing the tobacco seed, crater-like mounds, the size of which depends on the species of ant, appear in the seed-beds and the workers resume

foraging operations. Seed in the immediate vicinity of the nest opening first attracts attention and the workers show little inclination to search further afield for provender. It is thus not surprising that successive sowings on seed-beds, where ants are active, are invariably failures unless special precautions are taken to cope with the pest.

The seed-harvesting species of economic importance generally confine their attention to tobacco seed and, although a number may nip off fragments from the cotyledons, all, except *Pheidolacanthinus mjobergi,* can for all practical purposes be treated as essentially seed-harvesting forms. The partiality of *P. mjobergi* for cotyledons as well as for the ungerminated seed sometimes necessitates the adoption of special control measures.

Of the species to be discussed, two—*Monomorium rothsteini* var. *leda* and *Pheidolacanthinus mjobergi*—are relatively large in size and inhabit nests with very large populations. Both may be very destructive. In each case, however, the recorded losses are sporadic and it is doubtful whether their importance to the industry equals that of *Pheidole impressiceps* Mayr. and *P. variabilis* Mayr., whose nests occur in nearly all seed-beds.

In the following discussion, the several seed-harvesting species are treated in the order of their generic affinities.

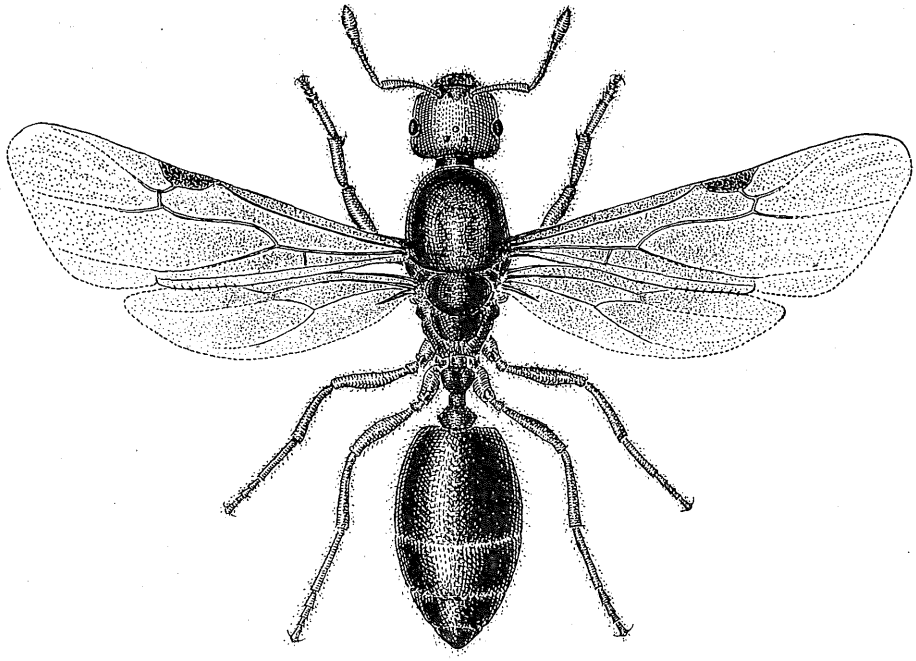
Monomorium (Monomorium) rothsteini For. var. ***leda*** For. (Plate 2.)

One of the larger seed-harvesting ants frequenting tobacco seed-beds is *Monomorium rothsteini* var. *leda;* its thickly-populated runways leading to the nests are a striking feature of many tobacco soils. The workers are very active and may forage a considerable distance from the nest: losses are frequently due to the inhabitants of nests situated more than one chain from the seed-beds.

The workers are 4mm. to 4·5mm. in length. The head, thorax and pedicel are reddish-brown in colour but the gaster and the scales of the pedicel segments are dark-brown or almost black, the intensity of these colours depending largely on the age of the individual. The whole of the thorax, other than the dorsum of the prothorax, is finely reticulate, and the posterior receding slope of the metanotum carries a number of transverse ridges. The femora are much darker than the other segments of the legs and thorax.

Alate forms are large—8mm. to 10mm. in length—and have been recovered from nests examined during the summer months. In the male, the head, thorax and pedicel are jet black while the gaster and appendages are reddish-brown. In the female, the head is reddish, the thorax smooth glossy black, and the whole of the abdomen fuscous.

The external appearance of the nest varies a great deal. At times, extruded debris may be deposited some distance from the external opening and when such heaps are levelled during the natural process of weathering the nest site becomes somewhat raised and may cover an area of more than one square yard. Occasionally the mound is restricted to the nest opening.



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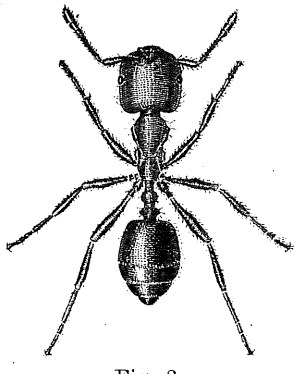

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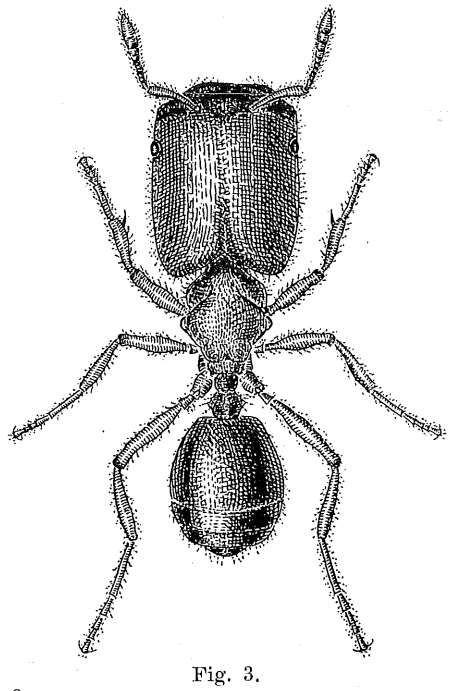


Fig. 3.

Plate 2.

Monomorium (*Monomorium*) *rothsteini* For. var. *leda* For.—Fig. 1. Winged female × 10; fig. 2. Worker × 10; fig. 3. Soldier × 10.

[*Drawings by William Manley.*

ERRATUM.

A soldier ant belonging to the genus *Pheidole* was inadvertently included in Plate 2 of the paper "Seed-harvesting and other ants in the tobacco-growing districts of North Queensland" which appeared in Volume 1, Number 3 of the Journal. Ants in the genus *Monomorium* do not possess a soldier caste.

Differences in the thoracic colour of workers from separate nests are also apparent, though there are no parallel structural distinctions of any importance. All forms have been identified as *M. rothsteini* var. *leda*.

The species has been collected in the Mareeba and Dimbulah districts and is particularly common on river silts and brown sands. Occasionally nests have been noticed in creek or river beds which are subject to frequent inundation during the summer months. The nest openings are often surrounded by bare patches on which the growth of vegetation is inhibited by the frequent deposition of excavated soil and scattered debris from the nest. One or more runways lead from the nest opening to the main foraging areas. Close to the nest each runway is devoid of vegetation and can be traced for some distance to a point at which the workers scatter in search of suitable provender. Grass seeds are apparently an important element in the dietary, being carried into the nest with the glumes intact. These glumes are removed from the caryopsis in one piece and are subsequently carried from the granaries to dumps one foot or more from the nest opening, whence they are ultimately scattered by rain and wind. Several heaps of refuse from the granaries frequently occur in the vicinity of a single nest.

The many exits from an old-established nest are linked by sub-surface tunnels which are themselves joined to the brood chambers and granaries situated at greater depths. Galleries branch from the main vertical tunnel to a depth of about 18 inches and lead to a series of roomy chambers. Deep vertical tunnels comparable to those in nests of *P. mjobergi* and *P. impressiceps* have not been observed.

During the nuptial flight period, winged forms are escorted from the nest by the workers in the early morning. Several leave each day over a considerable period and, pending emergence, both males and females congregate in the superficial parts of the burrow system. The workers are very active during the nuptial flight and cluster round the nest openings with their mandibles in constant motion. Many grip the appendages of the migrants, apparently forcing them on a path which they show little inclination to follow. Several functional queens may be found in the one nest.

Though most runways converge on a single nest, which is thus the focal point of worker movements, paired nests linked by a prominent path have occasionally been observed. In one instance two nests, complete with brood chambers and granaries, were joined by a runway along which the workers streamed in only the one direction. On dissection of the nests it was found that all the immature forms were in the nest to which the insects were moving and which was situated on the fringe of recently-ploughed land.

As with many other seed-harvesting species, foraging activities during the hotter hours of the day are slight. Normally, ant movements commence sluggishly at dawn and more and more workers pour out from the nests as temperature rises. Most of the workers take refuge within the nest from extreme

heat, but when foraging over considerable distances a few stragglers do not return to the nest, and shelter under any available debris. Activities are resumed in the afternoon when the temperature is falling but cease at nightfall, when all the workers return to the nest.

Some idea of the damage effected by this species can be gathered from estimates of the seed brought to a nest by foraging workers. One-minute counts at various times of the day showed that from 600 to 5,000 seeds passed into one nest opening each hour, the variation being a reflection of harvesting activities at any particular time. Any seeds collected are usually brought direct to the nest from the foraging area. Occasionally, however, workers have been observed accumulating seed in temporary dumps during the morning, the small heaps being removed to the central nest during the afternoon. This habit is apparent only when workers are foraging far from the nest and involves the collection of seed at focal points reasonably close to runways. The phenomenon may partly explain the relative scarcity of workers on the runways during the morning; for, once the ants have entered a foraging area, they may remain to heap the seed at suitable places from which it can later be removed to the nest.

The destructive habits of this species are directly attributable to the extraordinarily large number of ants in a single nest, for these can harvest an enormous number of seeds in a very short time.

Monomorium (Parholcomyrmex) gracillimum Smith.

Though *M. gracillimum* is not a dominant species in tobacco-growing districts, nests of this ant have been found in and near seed-beds, from which the workers have been observed removing seed. It is rather a distinctive species though the worker is only 2·5mm. to 3mm. in length. The anterior segments are fuscous, but parts of the head may be almost black. Parts of the gaster may also be black. The metanotum has a pronounced lateral flange on each side towards the rear edge and some ridging is apparent between the two flanges. The whole of the anterior segments may possess reticulate ornamentation, and the body is more or less hairy. Males have been taken from the nest prior to the nuptial flight; they are 7mm. in length and jet black in colour, except for the distal appendages of the limbs.

The nest has a simple opening which leads directly to a sub-surface chamber and thence to brood chambers at a greater depth. As many as seven queens have been collected in a single nest. During flight periods, alate forms are escorted to the nest opening by the workers. Emergence usually occurs in the early morning and continues for some weeks, the winged insects remaining in the reception chambers just below the surface between successive flights.

Little is known of the economic importance of this species. Workers freely collect tobacco seed both in the laboratory and in the field but the incidence of the nests is so low that the actual losses attributable to the species are not extensive.

Monomorium (Lampromyrmex) ilia For. var. ***lamingtonensis*** For.

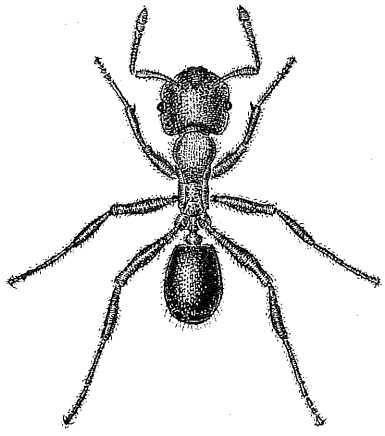
The minute species, *M. ilia* var. *lamingtonensis* has been collected in tropical red earths at Atherton and in silt deposits along the banks of creeks in savannah woodlands at Tumoulin on the upper Tableland—*i.e.*, outside the more important tobacco-growing districts. In the latter area, the workers harvested tobacco seed and carried it to nests situated in the beds. The nest openings are small, with a slight symmetrical mound, and a number may occur in the one seed-bed, possibly as independent openings to the one nest.

Workers only have been collected. They are small—1.5mm. to 2mm. in length—and are fulvous in colour. When resting they are difficult to detect, for their outlines are more or less masked by the pale background of the soil. In general appearance, they resemble the workers of *Pheidole variabilis*, but can be distinguished from them by the absence of surface sculpturing and thoracic spines.

Pheidole impressiceps Mayr. (Plate 3.)

Probably the best-known seed-harvesting ant in tobacco-growing districts is *P. impressiceps*; its nests are very common in soils of the river silt type. Only workers are normally seen above ground foraging for seed.

The workers are comparatively small, varying in length from 1·5mm. to 3mm., though individuals from any one nest are almost identical in dimensions. The head, thorax and pedicel are reddish-brown in colour, but the gaster is almost black. In old specimens the head may be darker than the thorax. The



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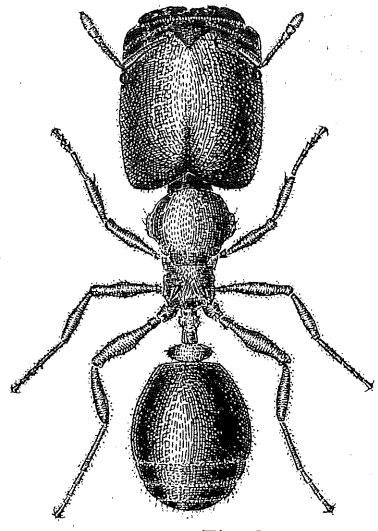

Fig. 2.

Plate 3.

Pheidole impressiceps Mayr.—Fig. 1. Worker × 14; fig. 2. Soldier × 14.

[*Drawings by William Manley.*

soldiers are much larger—4mm. to 4·5mm. in length. In both forms all parts of the body, other than the gaster, may be ornamented with reticulate sculpturing, the intensity of which varies from segment to segment.

The external openings of the nest are of two types, which can be distinguished by the mounds characteristic of each. In one type the nest opening is about 5mm. in diameter and is surrounded by a symmetrical crater-like mound: the nests to which it leads contain workers of relatively small size. The other type of opening is bounded by an asymmetrical crater, grass seed glumes being conspicuously displayed on the tapering margin. The workers inhabiting nests underlying this type of mound are relatively large. In the field the type of worker can always be determined by the conformation of the mound. However, no morphological differences other than size can be detected and both forms are grouped as the one species, *P. impressiceps*.

Each nest is entered through a number of external openings, which may be separated by distances of three or four feet, though frequently they are much closer. Immediately beneath each opening is a reception chamber in which seed may be dumped by foraging workers. While some workers use these chambers, others carry the seed directly to granaries at a greater depth. Nest openings and reception chambers are linked together at a depth of one or two inches by underground tunnels, which in turn connect with vertical passages leading to the nest proper. The approach to the heart of the nest never lies immediately beneath the external openings and cannot be interfered with through accidents which may temporarily close an exit. There may be more than one series of brood chambers and granaries, and each of these series is approached by an independent path from the sub-surface tunnel connecting the exits. Brood chambers and granaries are commonly found in lateral galleries which branch from the main vertical tunnel at depths of from one to three feet. The regal apartments may, however, be situated at much greater depths. In one nest, the underground tunnels, brood chambers and galleries were successively exposed in the soil profile and the approach to the regal chamber traced to a depth of four feet. Even at this depth, the nest had not been completely explored, but the data give some idea of the ramifications in nests of this species. Normally, soldiers are found associated with brood chambers and granaries, their protective and other activities being confined to these essential parts of the nest.

During the spring months it is not uncommon to encounter winged forms in the reception chambers near the surface. They are attended by both soldiers and workers, all forms showing considerable activity during the nuptial flight. Numbers of both males and females leave each day.

The species is essentially granivorous and harvests the seeds of numerous grasses and other herbaceous plants in the vicinity of the nest. The glumes and associated debris are subsequently discharged from the nest and accumulate at the edge of the mound fringing the external opening. The kernel of grass seeds is neatly detached from the glumes by mandibular incisions at its point of attachment, but the several glumes still cohere and can be removed from the nest in one

piece. Grass seed residues are common at nest openings in tobacco seed-beds and indicate that grass seeds had been accumulated in the granaries before the superficial parts of the nest were destroyed during the construction of the beds.

The activity of the workers is apparently influenced by temperature: foraging is confined to the morning and late afternoon during fine weather, the workers showing a rhythmical activity similar to that exhibited by *M. rothsteini* var. *leda*.

Tobacco seed is readily collected if available. Usually one or more nests occur in, or close to, any seed-bed and losses will probably take place if protective measures are not adopted. Frequently mounds at the nest opening are clustered with seedlings which result from the germination of seed dropped by foraging workers or rejected at the nest. Similar groups of seedlings have been located in the reception chambers beneath the nest opening.

Pheidole variabilis Mayr. (Plate 4.)

A common seed-harvesting ant which is widely distributed in North Queensland is *P. variabilis*. It has, therefore, been an important factor in seed-bed losses reported from tobacco-growing districts. The worker is comparatively small, being only 1·5mm to 2mm. in length. The head, thorax and pedicel are heavily chitinized, and the surface is ornamented with a reticulate pattern, the intensity of which is greatest on the prothorax. The gaster is fulvous and

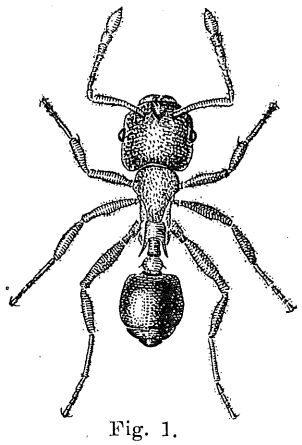

Fig. 1.

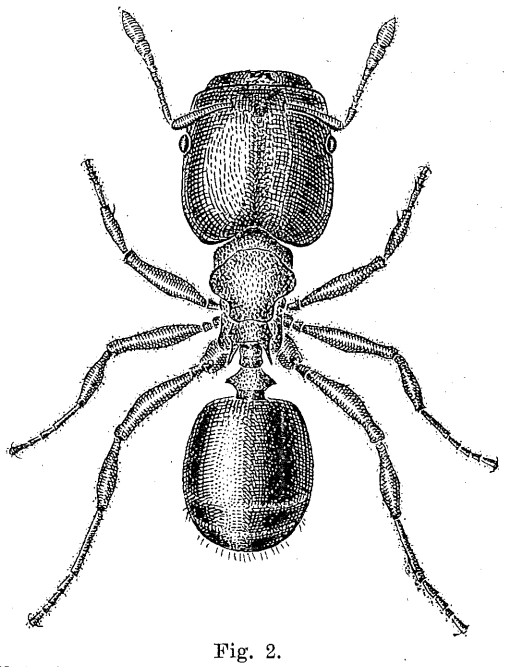

Fig. 2.

Plate 4.

Pheidole variabilis Mayr.—Fig. 1. Worker × 20; fig. 2. Soldier × 20.

[*Drawings by William Manley.*

lacks ornamentation. The metanotum carries a pair of backwardly-projecting spines. The soldier is much larger than the worker, being 3·5 mm. in length. Apart from the typically large, square head it resembles the worker, the thoracic ornamentation being again distinct. Both worker and soldier have sparsely-placed hairs on all parts of the body.

The external opening to the nest is small and is surrounded by a symmetrical mound of fine soil particles removed during construction and maintenance. Groups of quartz grains are occasionally found in some galleries. A number of openings may lead to the same nest and communicate with each other by sub-surface tunnels about two or three inches beneath the surface. The main body of the nest is frequently one or two feet below ground level and may be built round an old root buried in the soil. The vertical approach to the nest communicates with the sub-surface tunnels and not directly with the external opening. At the centre of the nest, brood chambers and granaries are in close association and consist of lateral galleries with one or two square inches of floor space branching from the vertical tunnel. Brood chambers and granaries are often arranged in series at different depths and, being very similar, could serve either purpose equally well. Reception chambers may occur just below the external opening and are frequently used as subsidiary granaries. Seed may be lodged in them during harvesting operations.

Soldiers are numerous in the vicinity of the brood chambers and galleries. Unlike the soldiers of some other seed-harvesting species, they frequently take an active part in aggressive movements outside the nest. In one conflict between *P. variabilis* and *P. impressiceps,* stimulated by attracting workers from nests of both species to some tobacco seed, workers of *P. variabilis* clung to the appendages of the larger *P. impressiceps* while soldiers decapitated first one captive, then another, by mandibular incisions just behind the head.

During the spring and summer months, winged forms which have reached maturity congregate in the superficial parts of the nest. Towards late afternoon the workers and soldiers, sponsoring the migration, escort the winged forms to the open. Flights take place on successive nights for some weeks; the males far outnumber the females.

Nests of *P. variabilis* may contain immense numbers of workers. They are relatively slow-moving insects whose foraging range is limited, and runways can seldom be traced more than one or two yards from the nest opening. The importance of the species is therefore due less to seed-bed invasion from distant nests than to the activity of workers from nests in and near the planted area. The numerical incidence of nests on soils of the river silt type is normally such that few beds escape the attention of foraging workers.

The small size of the workers doubtless has some influence on the choice of seeds suitable for their communal food requirements. Granaries are usually stocked with minute weed seeds drawn from the native flora; the larger grass seeds furnish a relatively small proportion of the provender. The size of the

seeds of the commoner grasses would raise transport problems beyond the ingenuity of the workers, and it is not surprising, therefore, that discarded glumes seldom appear at the mound round the nest opening.

Pheidole anthracina For.

The species, *P. anthracina,* is recorded from the Mareeba district. Its workers are small—1·5mm. in length—and are somewhat dark in colour; in some specimens the head and gaster are almost black. Reticulate sculpturing is present on the head, thorax and pedicel, but the gaster is quite smooth. The metanotum carries a pair of prominent spines. This species is partial to tobacco seed.

Pheidolacanthinus mjobergi For. (Plate 5.)

An ant with rather a curious distribution in the tobacco-growing areas is *P. mjobergi.* Its nests are quite common at Biboohra and Bilwon and serious losses have been attributed to the insect in these localities. Elsewhere in the Mareeba district the species is of little importance to the tobacco-grower, though occasional nests have been located on both brown sands and river silts.

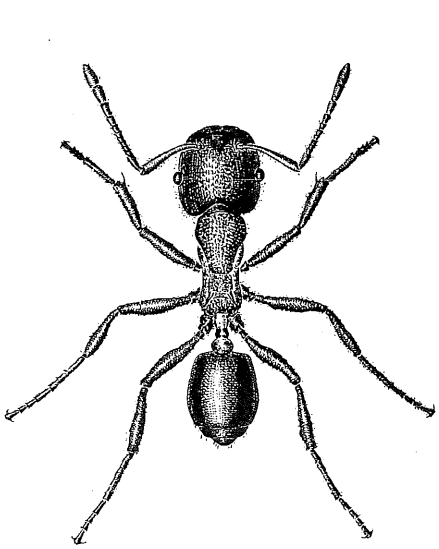

Fig. 1.

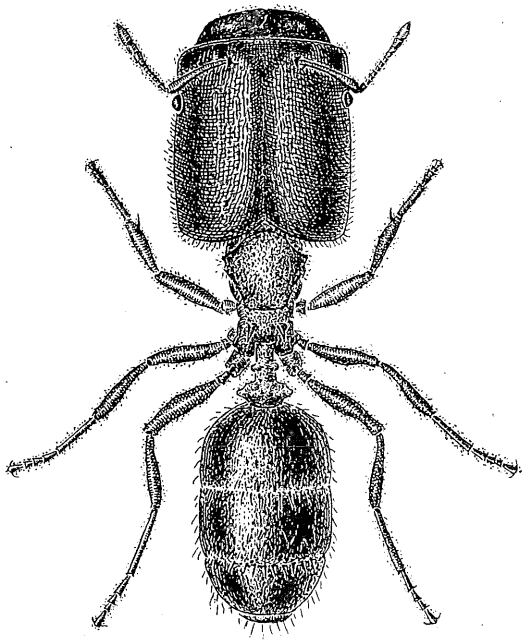

Fig. 2.

Plate 5.

Pheidolacanthinus mjobergi For. Fig. 1. Worker × 14; fig. 2. Soldier × 10.

[*Drawings by William Manley.*

The workers are 3mm. in length and uniformly dark-brown in colour. The head, thorax, and pedicel are heavily chitinized and the surface carries a reticulate sculpturing which is absent from the gaster. On the dorsum of the

head and thorax linear striations run parallel to the length of the body; on the metanotum two lateral ridges terminate in upwardly projecting spines. The body is covered with scattered hairs.

Normally the external openings of the nest are connected by sub-surface tunnels. Beneath each opening is a reception chamber in which garnered seed may be placed. From the sub-surface tunnels vertical paths lead to brood chambers and granaries in the centre of the nest. These may be placed in series along the vertical tunnels at depths of from one foot to three feet. The main vertical tunnel has been traced to a depth of six feet.

Being relatively large, the workers can forage a considerable distance; and, as large numbers are frequently associated with the one nest, seed-beds established nearby are very soon discovered and seed on them harvested. Unlike most harvesting ants found in tobacco seed-beds, the workers of *P. mjobergi* may also remove the cotyledons from the young plant, and thus destroy seed-beds in which the initial germination is satisfactory. Some other species may occasionally detach the cotyledons from seedlings, but only *P. mjobergi* causes serious injury of this nature.

Meranoplus sp.

Though most species of *Meranoplus* are seed-harvesting forms, they are comparatively large insects and normally pay little or no attention to tobacco seed. However, the smallest species occurring in tobacco-growing districts does roam over seed-beds and may take seed which is suitably exposed. It is apparently unnamed.

The worker is about 2mm. long; the head and thorax are shield-shaped, with fringing flanges which stretch beyond the sides of the body; and the dorsal surface is covered with a thick mass of hairs. Unlike the head and thorax, which have a superficial reticulate pattern, the gaster is smooth and is covered with hairs on all sides. The thoracic shield is serrated at the lateral edges. Both head and thorax are almost black in dorsal aspect, while the abdomen is a reddish-yellow which contrasts strongly with the anterior part of the body.

The nests are usually simple and are entered by one or more external openings quite close together which lead to shallow underground chambers. This ant is not an active species and is of secondary importance in the seed-harvesting ant fauna.

Other Seed-harvesting Ants.

A number of species which belong to seed-harvesting genera are, as yet, of no economic importance in the tobacco-growing districts. The commonest of these is *Monomorium* (*Lampromyrmex*) *laeve* Mayr. var. *nigrior* For., a small, glossy-black ant. *Tetramorium guineense* Fab., a fuscous ant whose workers are 2mm. to 2·5mm. in length, is occasionally found nesting in seed-beds. *Pheidole longiceps* Mayr., a minute fuscous ant, is recorded from nests in the Mareeba district. Three species in the genus *Meranoplus*—*M. mars* For. s.sp. *ajax* For.,

M. fenestratus Sm. var. *christmasensis* For., and *M. hirsutus* Mayr. var. *minor* For.—are commonly encountered. They are all much larger than the unnamed species discussed earlier, and they forage chiefly among plants which yield comparatively large seed.

THE CONTENTS OF GRANARIES.

In dissecting the nests of seed-harvesting ants established on various soil types, marked differences in the granary contents were apparent. The contents to some extent reflect the variety of the flora in the vicinity of the nest and the species of plants shedding seed for some weeks prior to the examination. Thus, the seed located in any one nest depends on (*a*), the time of the year, because seasonal conditions influence both the setting and shedding of the seed; (*b*), the character of the flora, which will determine the variety of seeds taken into the nest; and (*c*), the ability of the workers to collect the several types of seed available.

Some seeds are shed without any protective covering but others are enclosed in glumes, bracts or comparable structures. All seeds stored for any length of time in the nest lack protective appendages and are kept in heaps on the granary floors. Usually seeds from different species of host plants are stored in separate granaries or in separate heaps in the same granary. The manner in which the insect deposits glumes and other debris outside the nest is sometimes characteristic of the species. Thus of three important species which harvest grass seeds, *M. rothsteini* var. *leda* deposits the debris in small heaps one foot or more from the nest opening, *P. mjobergi* distributes the refuse evenly round the exit, while *P. impressiceps* places it at one side of an asymmetrical mound.

Foraging ants frequently collect seed from a single plant species growing in the vicinity of the nest. If a worker finds a readily accessible seed supply the news rapidly spreads through the colony and, in a short time, foraging activities which were previously scattered are concentrated at the one spot. Such discoveries usually comprise heavy seed deposits from plants of the same species and collaborating workers fill one granary before proceeding to the next. This habit is illustrated by the behaviour of the ants when tobacco seed was laid out in heaps over the foraging area, for the workers soon found it and avidly collected the seed to the exclusion of less accessible material. Subsequent dissection of the nests showed that the granaries were each filled with several heaps in which tobacco seed was by far the most important constituent. Seed types which are numerically of minor importance in any particular granary are doubtless brought to the nest by workers foraging apart from the majority of the nest population.

Granaries of *M. rothsteini* var. *leda*, *P. impressiceps* and *P. mjobergi* were repeatedly examined and a variety of seeds collected from each. The correlation of these seeds with the parent plant is difficult, for the seeds of the

native flora are not well known. The typical flora was sampled, however, during the summer and winter months and any seeds obtained systematically compared with those recovered from ant nests.

Two grasses, *Brachiaria piligera* and *Eleusine indica* together with the two weeds, *Portulaca oleracea* and *Desmodium Muelleri*, have been taken from the nests of the three seed-harvesting species, *M. rothsteini* var. *leda*, *P. impressiceps* and *P. mjobergi*. Six other plants are known to furnish seeds suited to the needs of *M. rothsteini* var. *leda* and *P. impressiceps*, viz., *Setaria Brownii*, *Chloris virgata*, *Eragrostis elongata*, *Crotalaria trifoliastrum*, *Cassia mimosoides* and *Ageratum conyzoides*. Other seeds taken from the nests of one or other of these two ants belong to the following plants:—*Digitaria gibbosa*, *Vigna luteola*, *Setaria glauca*, *Rottboellia formosa*, *Spermacoce sp.*, *Ipomaea eriocarpa*, *Pimelea cornucopiae* and *Phyllanthus minutiflorus*.

These seeds show a considerable variation in size and illustrate the range of seed types which can be collected by some of the more important seed-harvesting ants. Thus *M. rothsteini* var. *leda* may collect both the minute seed (·7mm. in length) of *Eragrostis diandra*, and the seeds of *Vigna luteola*, which are 3mm. long and nearly 2mm. in diameter. Similar contrasts are apparent in other species, but it seems quite clear that while the minute seeds may be collected by all seed-harvesting ants some large seeds are beyond the power of small ants to handle. Size is not, however, the only determining factor, because the shape of a seed may largely determine its suitability or otherwise for any particular species of ant. Thus a moderate-sized, round seed may be more difficult to carry to the nest than a larger, angular one.

The herbaceous plants collected in the tobacco-growing districts are listed in Appendix 1, together with records of the occurrence of their seeds in the granaries of three important ant species.

THE DISTRIBUTION OF ANT SPECIES.

Ant nests in tobacco-growing districts were sampled to determine the distribution and importance of individual species, and it soon became apparent that the composition of the ant population varied a great deal.

For purposes of comparison, the ant fauna was examined in the Dimbulah district in three selected types of soil—white sands, brown sands, and river silts. In the white sands, the dominant species were *Iridomyrmex detectus* s.sp. *sanguinea*, *I. rufoniger* s.sp. *pallidus* and *Paratrechina* (*Nylanderia*) *obscura*. Granivorous species were absent. The dominant species are all comparatively large insects, capable of foraging a considerable distance from the nest. In the brown sands, which are particularly suitable for tobacco-growing, these large species were present, together with a number of seed-harvesting ants. The latter included species in the genus *Meranoplus*, but only occasional formicaries of small seed-harvesting ants of the genera *Pheidole* and *Monomorium* had been established. Several species in the genus *Crematogaster* were also common.

In the river silts, seed-harvesting species in the genera *Pheidole, Monomorium* and *Meranoplus* comprised the greater part of the ant fauna, *P. impressiceps* and *P. variabilis* being represented by innumerable nests.

This distribution of species can scarcely be a matter of chance and some possible explanations warrant discussion. Most formicaries are built in the ground and may penetrate to considerable depths. During nest construction and maintenance, the workers carry small particles of soil from below ground to mounds at the nest opening. These workers vary in size from species to species and the minute workers of *P. variabilis,* for example, cannot carry soil particles which are within the compass of larger forms, such as *I. rufoniger.* It is reasonable to suppose, therefore, that the smaller species will be unable to establish nests in soils containing a large proportion of coarse soil particles. The nesting habits of the larger species are not limited in this way and soil texture would have less influence on their distribution.

When dissecting nests and underground tunnels connecting adjacent nests, differences in the texture of the soil were very apparent. The ramifications of formicaries in river silts were traced with comparative ease. In other soils, the collapse of a profile exposed during dissection frequently obscured the tunnel path and prevented the satisfactory study of the nest, though the main thoroughfares could often be rediscovered by noting the point at which the workers cleared a path for themselves. The dissection of nests in the white sands was particularly difficult.

Such variations in the stability of a soil profile suggest that formicaries constructed in a river silt are more durable than those in the other types of soil. As soil texture must largely determine nest stability the binding properties of the soil may be of importance. These properties will vary with the clay content, the amount of humus, and the proportion of fine soil particles. In tobacco-growing soils the clay content is very low and may be disregarded in this connexion. Humus may influence the water-holding capacity of river silts, but in the other soil types there is little humus present. The proportions of fine and coarse particles do, however, vary a great deal in the three soil types and may determine the suitability or otherwise of any soil for the needs of individual ant species.

Samples of the three soil types gave the following mechanical analyses:—

Soil Fraction.	White Sand.	Brown Sand.	River Silt.
	%	%	%
Coarse fragments (2·0—·2 mm.)	85·1	75·8	33·9
Fine sand (·2—·04 mm)	10·6	14·3	41·2
Finer particles (·04—·002 mm.)	2·63	6·64	20·0
Clay (below ·002 mm.)	1·07	1·56	0·8
Organic matter and combined water	0·9	1·1	2·3

The river silt has a much greater proportion of fine soil particles than either of the other soil types, and the brown sand holds an intermediate position between the river silt and the white sand. The ant distribution can thus be correlated with the mechanical texture of the soil, which has an important influence on nest stability and the ability of the workers to carry out tunnel excavation. On this view it may be presumed that, while all soils permit the initiation of formicaries, the successful exploitation of the nest site may be controlled by the mechanical texture of the soil. Ants with large workers may thus establish nests in coarse soils quite unsuitable for the smaller seed-harvesting species whose workers would be unable to handle large soil particles. The latter types would thus tend to congregate in river silts where burrow excavation is a relatively simple matter and nest stability better assured.

The species distribution problem can be approached from another angle. Large ants can find an abundance of food, no matter where the nest is situated, for they are able to forage over considerable distances. Granivorous species, many of which forage only in the immediate vicinity of the nest, depend entirely on seed shed by the surrounding flora. Should these seeds be limited in quantity or unsuited to the needs of a particular species, the restricted food supply would be an effective check on the increase and spread of the insect. It is thus quite conceivable that limited food supplies may keep the seed-harvesting ant fauna at a numerically low level even when the soil type is suitable for nest construction.

Marked differences in the vegetation growing on the three types of soil under discussion are not uncommon, river silts carrying a particularly rich flora comprising an abundance of species. Hence, even though many of the seed-harvesting ants may be able to establish nests in the brown sands as well as in the river silts, the ant population in the latter would be stabilized at a much higher level, for the abundance of plants producing small seeds would maintain a greater number of formicaries.

It seems, therefore, that while the texture of a soil may determine its suitability for nest establishment by the seed-harvesting species, the density of the insect population will be determined by the vegetative cover. Suitable soils with a relatively luxuriant flora would thus carry a greater ant population than similar soils with a stunted and sparsely distributed flora.

THE CONTROL OF ANTS IN TOBACCO SEED-BEDS.

When seed-harvesting ants first interfered with routine seed-bed practices, numerous insecticides of possible value were applied by growers in and near the beds with the object of alleviating the trouble. Several fluid baits, mostly of the syrup type with an added arsenical poison, were used but gave inconsistent results. As a number of species, each with its own specific reactions to any single bait, were usually implicated in the losses, the merits of baiting methods

of control could scarcely be accurately assessed in the field and no fluid bait suitable for general application has been discovered. Contact sprays applied to the beds after sowing the seed also gave negligible results.

These various attempts of growers to combat seed-harvesting ants were, however, useful in a preliminary survey of the position, for they narrowed down the field of investigations. Seed-bed management, quite apart from controlling pests and diseases, is an intricate matter and it was therefore necessary to elaborate modifications in seed-bed technique which could be conveniently adopted by the growers on the assumption that ants are always a potential danger.

Selection of Seed-bed Sites.

When a creek or river runs through a property, seed-beds are usually established on soils of the river silt type situated above flood level. These soils are more fertile and better suited for seedling growth than any of the others available; but, as they are normally thickly populated with ant nests, losses through seed-bed disturbances or seed removal are very common. These losses cannot altogether be eliminated by the careful selection of seed-bed sites, but some important species can be excluded, if a preliminary survey of the ant fauna is carried out, for seed-beds can then be established at a safe distance from the more obvious formicaries.

For example, the funnel ant, *A. longiceps,* is a common species whose formicaries may cover a considerable area. The workers of this species are well known and nests can readily be detected in virgin ground; hence when seed-bed sites are being chosen, areas frequented by the pest can usually be avoided. If seed-beds, through lack of better areas, must be prepared on soils in which the funnel ant is active, a determined effort should be made to destroy the nests by fumigation with carbon bi-sulphide. The method has been described (Summerville, 1929) in a paper dealing with the control of the mound ant. Such drastic treatment should not normally be necessary, for suitable areas free from the nests of this ant are generally available.

Two of the larger seed-harvesting ants, *M. rothsteini* var. *leda* and *P. mjobergi,* can also be avoided in the same way. Unlike the smaller seed-harvesting species, their nests are relatively far apart in all soils. The workers do, of course, forage over considerable distances, but seed-beds situated more than two chains from the nest lie outside the normal range of their activities. Nests of *M. rothsteini* var. *leda* are fairly common and special attention should be paid to the incidence of this pest in any preliminary survey.

Modification of Seed-bed Management.

The careful selection of seed-bed sites remote from the distinctive nests of *A. longiceps, M. rothsteini* var. *leda* and *P. mjobergi* is only a partial solution of the problem. Quite a number of important species, such as *P. impressiceps* and *P. variabilis,* nest in profusion in river silt soils and possibly no site could be chosen which would not cover some nests or lie within the foraging range of

their workers. Special measures must therefore be elaborated for these species, which, on account of their wide distribution, probably cause greater losses than the larger ants already discussed.

In normal seed-bed practices as observed in North Queensland for some years after establishment of the tobacco-growing industry the soil was cultivated, burned over, manured and then worked into a fine tilth preparatory to the sowing of the seed. Just prior to sowing, the surface of the bed was compressed by means of a flat board and the seed, after dilution with a given quantity of wood ashes, was broadcast over the surface. The seed-bed was then watered at frequent intervals and the surface kept moist, at least until germination was completed. In the meantime, the beds were sheltered from the sun by storm covers. Seed sown on such compacted beds readily attracted the attention of seed-harvesting ants. When the attacks were heavy, only seed buried beneath the surface of the ground escaped the attention of the ants and any seedlings appearing in the seed-bed could invariably be traced to such seed.

The obvious inference was that a protective cover of soil applied to the beds after sowing the seed would, to some extent, overcome the difficulty by concealing seed from the ants. In the experimental work, sand was substituted for soil to minimize any risk of introducing disease organisms or weed seeds to seed-beds already more or less completely sterilized by burning. An abundance of clean sand is available in the rivers and creeks which cross and recross most of the tobacco-growing districts of North Queensland.

In the preliminary experiments, two seed-beds on each of four farms situated at various centres were top-dressed to a depth of one-eighth inch with sand taken direct from a river bed, the scheduled quantity required for the area being estimated previously and broadcast by hand after the seed had been sown. On those farms where the ants were observed to be active, a very irregular stand of seedlings was obtained on untreated beds, while on sanded beds germination and subsequent plant establishment were satisfactory. Variations in the depth of the cover are unavoidable when the sand is broadcast by hand, but these minor differences in no way affected the value of the treatment. Curiously enough, on the seventh day after treatment, seedlings appeared uniformly above ground in the covered beds, the period being slightly less than the usual eight day pre-germination period.

These preliminary trials indicated the usefulness of the sand cover technique, but some additional points still required investigation. The one-eighth inch cover already used was purely an arbitrary selection and the efficiency of greater and lesser depths needed checking. Again, sand taken from a river bed includes particles of all dimensions, which may individually have quite different properties when used in a sand cover.

In a further series of experiments, the sand was separated into two grades and each was used independently in cover thicknesses ranging from one-twelfth to one-half inch. When the covers did not exceed one-quarter inch,

seedlings appeared above ground within the scheduled eight day period and gave an even stand of plants. Covers of greater depths were less satisfactory, the seed germinating slowly and irregularly. The failure of beds with such excessive covers was due, not to the activity of seed-harvesting ants, but to the suppression of plant growth by the heavy top-dressing of sand.

The relative merits of two grades of sand were studied by comparing covers of similar depths on adjacent seed-beds. The river sand was first sieved into two grades, fine sand being that portion containing particles 1·5 mm. or less in diameter, and coarse sand, that portion with particles not less than 1.5 mm. and not more than 2 mm. in diameter. Judged by the appearance of the seedlings on the several treated beds, the texture of the sand was of little importance in covers less than one-quarter inch in depth. Thicker covers of either fine or coarse sand hindered germination. Covers of fine sand one-half inch in depth almost inhibited seedling development, while a similar covering of coarse sand permitted the growth of only an irregular and scanty crop of plants.

It is thus clear that sand covers adequately protect tobacco seed from harvesting ants. These insects rarely penetrate into the soil in their search for food but confine their attention to seed exposed on the surface. For ordinary purposes, the coarse sand retained by a 16-mesh sieve can be applied to the beds, provided the cover does not exceed one-quarter inch. With overhead watering, fine sand tends to pack and may inhibit the growth of the plants. Normally there is no need to use covers greater than one-eighth inch in depth. Thus, in practice, the sand is taken from the river bed, sieved, and that portion retained by a 16-mesh sieve broadcast by hand. Accepting one-eighth inch top-dressings as a convenient standard, 1½ kerosene tins (a kerosene tin has a capacity of four imperial gallons) of sand are required for each 100 square feet of seed-bed.

When the sand covering technique was first proposed, some doubts were expressed as to its cultural applicability, for it appeared to clash with the normal practice of sowing the seed on the surface of compacted soil. Both farmers' experience and the experimental work already outlined show that sand covers used in the prescribed manner have no detrimental effect on seedling development and allow sufficient latitude for ordinary farm practice. Indeed, sand covers have cultural advantages of some moment. As a mulch, they tend to conserve moisture in the soil and to minimize any disturbance to the surface of the seed-beds by storms or indiscriminate watering shortly after germination. Rapid and even germination are also characteristics of seed-beds which have been top-dressed with sand. It appears, therefore, that the practice of sowing seed on the surface of compacted soil had evolved from the need for uniform germination rather than from the inability of seedlings to emerge through a covering layer of soil.

The sand cover method of protecting seed-beds from the ravages of seed-harvesting ants is now in general use in North Queensland, the seed being sown on the compacted soil before the cover is applied.

In some instances, growers, finding sand not readily procurable, have used ordinary soil in its stead, but this alternative is undesirable. The risk of introducing weed seeds and disease organisms to sterilized seed-beds is much greater when soil is used in place of sand and some soils have the further disadvantage that caking of the surface may occur when they are used for covering tobacco seeds. If soil covers must be used, the required quantity of soil should be pre-treated by burning before application to the beds. Even with sand covers, the indiscriminate collection of sand may introduce weed seeds, in particular those of couch grass, *Cynodon dactylon*, and crow's foot, *Eleusine indica*, to the seed-beds. Well washed sand from the submerged or frequently inundated parts of the creek or river bed is thus best suited for cover purposes.

The Use of Dry Baits.

Although the collection and removal of tobacco seeds from the seed-beds can be prevented by adopting the measures already outlined, *P. mjobergi* and other less important species which harvest cotyledons remain a potential danger. Normally the foraging areas associated with nests of *P. mjobergi* can be avoided when choosing seed-bed sites, but control measures may be necessary should the beds be established before the presence of the pest is thoroughly appreciated. On unsanded beds the workers may collect the cotyledons as soon as germination takes place. When sand covers are in use, however, some time may elapse after germination before the foraging workers locate the seedlings. This interval may be sufficient to minimize the losses in dangerously situated beds but such indirect protection is not always adequate. Supplementary control measures for cotyledon-harvesting species may therefore be necessary.

Harvesting ants gather any conveniently sized food particles occurring within their foraging range and this habit suggested the recommendation of a dry, poisoned bait for the control of the seed-harvesting Nyerere ant in tobacco seed-beds in Nyasaland (Smee, 1929). This bait is composed of finely-ground maize cobs to which Paris green has been added and is described as a satisfactory control measure when the area attacked is extensive. An attempt was made to elaborate a somewhat similar bait for the control of ant species which harvest tobacco seedling cotyledons in North Queensland, but a finely-ground maize meal was substituted for the ground maize cobs as a carrier for the poison.

The attractiveness of the bait was tested observationally in the field. Both *P. mjobergi* and other species harvested a wide range of maize meal-Paris green mixtures from the 10:1 strength to the undiluted meal. When tobacco seed was strewn among baits placed in the vicinity of the nest, both poisoned and unpoisoned meals were collected in preference to the seed, although the latter was ultimately taken into the nest. This preference may be due to the ease with which angular meal particles can be collected by the workers.

Occasionally some of the bait particles were rejected from the nest, although the quantity discarded was always small compared with the total amount harvested. Subsequent dissection of the nests revealed granaries packed

with either poisoned or unpoisoned meal. Rapid destruction of the nest did not occur and would, in fact, only be expected if the food reserves were depleted and the bait was consumed within a short time of its being received into the nest.

Preliminary trials indicated that a dry bait composed of maize meal and Paris green in the proportions 50:1 gave excellent protection to seed-beds, the conclusion being assessed on the seedling survival in susceptible seed-beds. At that time, information concerning the nesting and harvesting habits of the several ant species was limited and maize meal-Paris green baits compounded to the 50:1 formula were tentatively considered suitable for the control of *P. mjobergi*. Shortly after the preliminary trials had been completed, a severe attack by this species on seed-beds at Bilwon took place. The grower attempted to counter the invasion by sowing at four times the scheduled rate, but only a few seedlings appeared above the ground and many of these were destroyed within three weeks of germination. Both newly-sown and recently-germinated seed-beds were subsequently treated with a 50:1 maize meal-Paris green dry bait broadcast at the rate of 12 oz. per 100 square feet of bed. In this way the attention of the ants was effectively diverted from both tobacco seed and seedlings and, by the systematic use of the bait, the farmer was able to grow an abundance of plants both for his own use and for sale.

As *P. mjobergi* and other species addicted to harvesting cotyledons are irregularly distributed, losses comparable to those just cited have not since been recorded. The workers of this species readily harvest unpoisoned maize meal in preference to both tobacco seed and the cotyledons. Hence, as the diversion of the ants from the plants, rather than the destruction of the nest itself, is the primary aim of control measures, there seems no essential reason for adding Paris green to the maize meal. For ordinary purposes, broadcast applications of maize meal in and around the beds, together with a further distribution of the bait in the vicinity of the ant nests if these can be located, should meet growers' requirements. The rate of application should be retained at the level found effective for the poisoned bait, viz., 12 oz. per 100 square feet of seed-bed. Protection may be necessary for about three weeks after germination; by that time the plants are large enough to escape attack. In acute cases, bait applications may be necessary every three or four days but, ordinarily, one, or at most two, treatments will be adequate.

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APPENDIX 1.

Herbaceous Plants collected in Tobacco-Growing Districts.

	Seeds found in granaries of		
	M. rothsteini	*P. impressiceps*	*P. mjobergi* var. *leda*
BORAGINACEAE—			
Heliotropium tenuifolium R.Br.			
COMPOSITAE—			
Ageratum conyzoides L.	+	+	
CONVOLVULACEAE—			
Evolvus alsinoides L.			
Ipomaea eriocarpa R.Br.	+		
CYPERACEAE—			
Cyperus sp.			
Fimbristylis sp.			
EUPHORBIACEAE—			
Euphorbia pilulifera L.			
Phyllanthus minutiflorus F. Muell. ..		+	
GRAMINEAE—			
Aristida sp.			
Brachiaria foliosa (R.Br.) Hughes			
Brachiaria piligera Hughes	+	+	+
Chloris pumilio R.Br.			
Chloris virgata Sw.	+	+	
Dactyloctenium aegyptium (L.) Richt.			
Digitaria adscendens (H.B.K.) Henr.			
Digitaria gibbosa (R.Br.) Hughes ..		+	
Echinochloa colona (L.) Link			
Ectrosia leporina R.Br.			
Eleusine indica (L.) Gaertn.	+	+	+
Eragrostis australiensis Domin			
Eragrostis cilianensis (All.) Link			
Eragrostis elongata (Willd.) Jacq. ..	+	+	
Eragrostis japonica (Thunb.) Trin.			
Eragrostis sp.			
Panicum effusum R.Br.			
Panicum maximum Jacq.			
Perotis rara R.Br.			
Rottboellia formosa R.Br.		+	

APPENDIX 1—continued.

Herbaceous Plants collected in Tobacco-Growing Districts—continued.

	Seeds found in granaries of *M. rothsteini*	*P. impressiceps* var. *leda*	*P. mjobergi*
GRAMINEAE—continued.			
Setaria Brownii Herrm.	+	+	
Setaria glauca (L.) Beauv.		+	
Sporobolus capensis Kunth.			
Thaumastochloa pubescens (Domin) C. E. Hubbard			
LEGUMINOSEAE—			
Aeschynomene americana L.			
Atylosia scarabaeoides L.			
Cassia absus L.			
Cassia concinna Benth.			
Cassia mimosoides L.	+	+	
Crotalaria crispata			
Crotalaria linifolia L.f.			
Crotalaria trifoliastrum Willd.	+	+	
Desmodium biarticulatum (DC.) F. Muell.			
Desmodium Muelleri Benth.	+	+	+
Indigofera enneaphylla L.			
Indigofera viscosa Lam.			
Rhynchosia minima DC.			
Vigna lanceolata Benth.			
Vigna luteola (Jacq.) Benth.	+		
Zornia diphylla Pers.			
LOGANIACEAE—			
Mitrasacme longiflora F. Muell. ex Benth.			
MALVACEAE—			
Sida rhombifolia L.			
PORTULACACEAE—			
Portulaca oleracea L.	+	+	+
PRIMULACEAE—			
Anagallis pumila Sw.			
RUBIACEAE—			
Richardsonia brasiliensis Hayne			
Spermacoce sp.		+	
SCROPHULARIACEAE—			
Herpestis floribunda R.Br.			
STERCULIACEAE—			
Melhania oblongifolia F. Muell.			
THYMELAEACEAE—			
Pimelea cornucopiae Vahl.		+	
TILIACEAE—			
Corchorus acutangulus Lam.			

APPENDIX 2.

Named Ants from Mareeba and Dimbulah.

Sub-Family *PONERINAE*—

Odontomachus ruficeps Sm.

Ponera convexiuscula For.

Sub-Family *MYRMICINAE*—

Aphaenogaster (*Nystalomyrma*) *longiceps* For.

Crematogaster (*Acrocoelia*) *fusca* Mayr.

Crematogaster pallipes Mayr.

Crematogaster pythia For.

Meranoplus fenestratus Sm. var. *christmasensis* For.

Meranoplus hirsutus Mayr. var. *minor* For.

Meranoplus mars For.

Meranoplus mars For. s.sp. *ajax* For.

Monomorium (*Parholcomyrmex*) *gracillimum* Sm.

Monomorium (*Lampromyrmex*) *ilia* For. var. *lamingtonensis* For.

Monomorium (*Lampromyrmex*) *laeve* Mayr.

Monomorium (*Lampromyrmex*) *laeve* Mayr. var. *nigrior* For.

Monomorium (*Monomorium*) *rothsteini* For. var. *leda* For.

Pheidolacanthinus mjobergi For.

Pheidole anthracina For.

Pheidole athertonensis For.

Pheidole impressiceps Mayr.

Pheidole longiceps Mayr.

Pheidole proxima Mayr.

Pheidole variabilis Mayr.

Tetramorium guineense Fab.

Sub-Family *DOLICHODERINAE*—

Iridomyrmex detectus Sm. s.sp. *sanguinea* For.

Iridomyrmex gracilis Lowne.

Iridomyrmex punctatissimus Emery.

Iridomyrmex rufoniger Lowne.

Iridomyrmex rufoniger Lowne s.sp. *pallidus* For.

Iridomyrmex stewarti For.

Tapinoma minutum Mayr. var. *integrum* For.

Sub-Family *FORMICINAE*—

Camponotus (*Tanaemyrmex*) *novaehollandiae* Mayr.

Melophorus formicoides For.

Opisthopsis haddoni Emery.

Opisthopsis pictus Emery var. *lepidus* Wheeler.

Paratrechina (*Nylanderia*) *obscura* Mayr.

Polyrachis (*Chariomyrma*) *aurea* Mayr.