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SOLENOPSIS MOLESTA SAY (HYM.): A BIOLOGICAL STUDY

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SUMMARY

1. *Solenopsis molesta* Say has destroyed thousands of acres of planted sorghum seed in southern Kansas by eating into the seed, undoubtedly for the purpose of extracting the oils.

2. The synonomy and taxonomy of the species have been greatly confused. All American citations to *Solenopsis fugax, S. debilis,* and *Myrmica molesta* refer to *Solenopsis molesta* Say.

3. The species is not only of economic importance as a field pest, but is well known in some regions as a household pest. It is widely distributed over the United States.

4. Rearing methods are difficult. In general, the life-history is much the same as other ants. The minimum length of the egg, larval, semipupal, and pupal stages was found to be 16, 21, 2, and 13 days, respectively, or a total minimum time for development of 52 days.

5. The data thus far show four general methods of procedure to control the ant in fields where damage to sorghums is being done; namely, fall plowing, early planting (before May 10), surface planting, and the use of repellents on the seed. The first three are consistent with good farming methods. As yet no satisfactory repellent has been found. Those which are of such a character as to be wholly repellent are detrimental to the germination of the seed, and vice versa.

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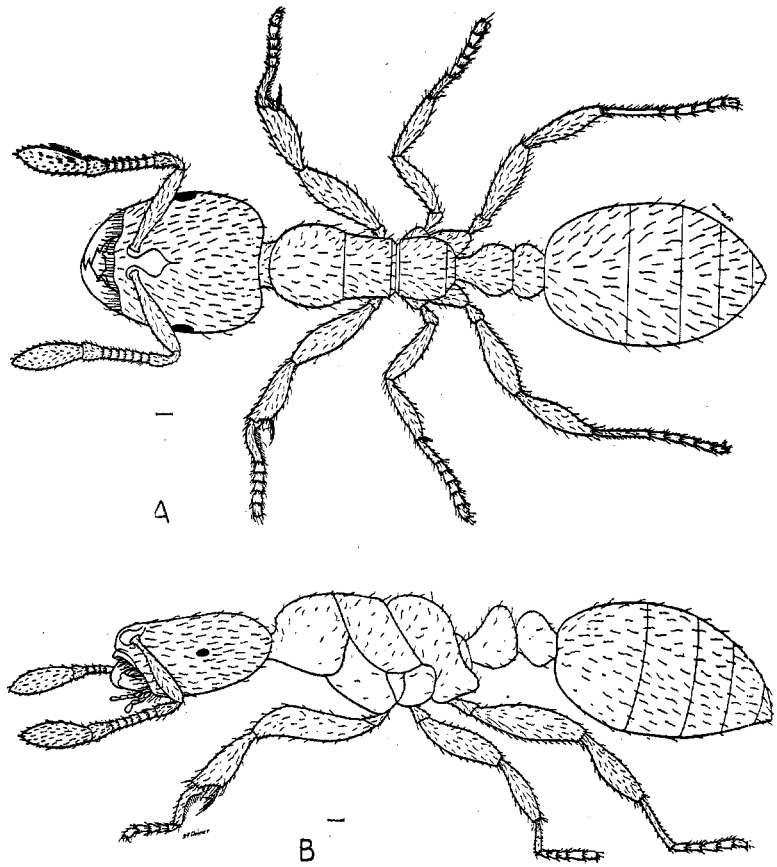

FIG. 1.—Worker of *Solenopsis molesta* Say: A, dorsal aspect; B, lateral aspect. (Both enlarged)

SOLENOPSIS MOLESTA SAY (HYM.): A BIOLOGICAL STUDY[1]

WILLIAM P. HAYES[2]

INTRODUCTION

During the past six or seven years, the tiny orange-colored ant, *Solenopsis molesta* Say, has destroyed, in eastern and south central Kansas, thousands of acres of planted seed. The principal damage has been confined to kafir, although other sorghums and corn are often subjected to the ravages of this insect. A preliminary report (McColloch and Hayes, 1916) of an investigation of the habits and control of this ant has been published.

It is the aim of the author to bring together in this bulletin the data previously reported by himself and others, to add material intentionally omitted from the preliminary report, and to present the results of more recent observations. Although the data at this time are not as complete as was originally hoped for, it is thought that the facts brought out will form a basis for further investigations, and, at the same time, put on record results already obtained.

The first report of damage by this ant was received at the office of the State Entomologist at the Kansas Agricultural Experiment Station during the spring of 1911. Soon afterward, Mr. J. W. McColloch was detailed to southern Kansas where a limited study of the ant was made under field conditions. Specimens collected at that time were sent to Dr. W. M. Wheeler, who determined them as *Solenopsis molesta* Say. Continued reports of injury during the two following seasons made it apparent that this pest was of enough economic importance to merit a more thorough study. As a result, a field

ACKNOWLEDGMENT.—The author desires to acknowledge his indebtedness to Mr. J. W. McColloch, who directed the investigations herein reported and gave valuable aid in the compilation of the bibliography; to Prof. Geo. A. Dean for permission to use experiment station data; to Dr. Paul S. Welch for reading and criticising the manuscript; and to Dr. W. M. Wheeler, Mr. Nathan Banks, and the late Mr. Geo. B. King for the determination of specimens.

[1] Contribution No. 55 from the Department of Entomology.

[2] This bulletin was presented by the author as a graduate thesis in the Kansas State Agricultural College in partial fulfillment of the requirements for the degree of master of science, May, 1918.

experiment station, fully equipped with laboratory facilities, was established in 1914 at Winfield, Kan., and the writer placed in charge. The work was carried on as a part of project No. 92 of the Kansas Agricultural Experiment Station under the immediate direction of Mr. J. W. McColloch, who, at great inconvenience to himself, often visited the Winfield laboratory and made many helpful suggestions.

Solenopsis molesta is known locally, in those parts of Kansas where its habits have attracted attention, as the "kafir ant." This name, although suited for the ant in certain sections, does not bid fair to become generally adopted. It is based on one of the many habits of the ant and would not be applicable in regions where kafir is not grown. Among the various names in common use for this species are "little yellow ant," "tiny thief ant," "tiny yellow ant," "yellow field ant," "troublesome ant," "small red house ant," and "little thief ant."

In the opinion of the writer, the last name, "little thief ant," or what is practically the same thing—"tiny thief ant"—is perhaps the most appropriate because of the ant's unique habit of stealing into the nests of other ants and making off with their brood. This habit occurs wherever the ant is found, while the attacks on kafir seed are of a more local nature. The other terms have the disadvantage of being applicable to other species, with the possible exception of the name, "little fire ant." This latter name is derived from the term, "fire ant," by which the larger and somewhat more vicious, closely allied species, *Solenopsis geminata,* Fabr., is known. Because of the possibility of confusion and the lack of any pronounced "firey" habits, this appelation seems not so appropriate as "little thief ant."

SYNONYMY AND SYSTEMATIC POSITION

ORIGINAL DESCRIPTION

Solenopsis molesta was first described as *Myrmica molesta* by Thomas Say (1836, pp. 293-294). The description, which is based on the characters of the winged female, is as follows:

M. molesta — ♀ Body pale honey yellow, immaculate; antennæ with the two ultimate joints much larger than the others, the terminal one as large again as the penultimate one; wings whitish; smaller cubital, cellule none; discoidal cellule very small, less than half as large as the first cubital; first cubital receiving the recurrent nervure near its base;

nervure of the radial cellule terminating abruptly before the tip; the two other apical nervures feebly traced toward the tip and not reaching the tip; metathorax unarmed.

Length less than three-twentieths of an inch.

POSITION IN THE ORDER HYMENOPTERA

This ant belongs to the tribe Solenopsidii of the subfamily Myrmicinæ one of the five divisions of the North American Formicidæ. The subfamily contains about 27 genera, being the largest of the Formicidæ. The distinguishing characters of the workers of the Myrmicinæ are: Ventral cloacal orifice, slit-shaped; sting, well developed; abdominal pedicle, two-jointed; frontal carinæ covering the antennal insertions; pupæ not enclosed in cocoons.

The genus *Solenopsis* as described by Westwood (1841, p. 86), is characterized as follows:

(σωλήυ canalis et σψις fascies, ob faciem canaliculatam.)

Characteres e pseudo-femina desumpti.

Caput maximum subquadratum horizontale postice emarginatum, supra linea media longitudinali in duas partes divisum antice in medio bituberculatum. Oculi parvi laterales ante medium marginis locati.

Antennæ breves gracilis prope os in foveolis duabus insertæ; 10 articulatæ articulis duobus apicalibus majoribus.

Labrum parvum inter mandibulas et supra os deflexum bilobum.

Mandibulæ magna valde curvatæ crassæ apice obliquo, edentulae.

Maxillæ et mentum minima fere membranacea, labium subductum.

Palpi maxillares et labiales biarticulati; gracillimi brevissimi, apice seta instructi.

Thorax valde angustus, prothorace mediocri; mesothorace majori.

Abdomen magnum fere circulare subdepressum segmentis basalibus duobus nodos formatibus, segmento proximo maximo.

Pedes graciles tibilis 4 posticis ecalcaratis, unguibus tarsorum simplicibus.

Donisthrope (1915, pp. 101-102) translated and enlarged the description, giving additional characters for the determination of the different castes. His description is given below:

WORKER: *Head* somewhat square, anteriorly with a distinct channel in the middle; *clypeus* armed with two teeth on the anterior margin, these teeth converging back between the base of the antennæ as carinæ; *mandibles* narrow, terminal border furnished with four teeth; *maxillary palpi* and *labial palpi* two-jointed; antennæ ten-jointed, with a distinct two-jointed club, the last joint of which is very long; *eyes* small and flat. Thorax with suture between pronotum and mesonotum obsolete; suture between mesonotum and epinotum distinct and deep; *epinotum* unarmed. *Petiole* cylindrical anteriorly, nodiform posteriorly; *post-petiole* trans-

verse, nodiform, not so high as petiole; *gaster* oval, with first segment longer than half the gaster; *sting* very large.

FEMALE: Much larger than the worker; *antenna* as in the worker, but eleven-jointed; *eyes* projecting, much larger than in the worker; *ocelli* present. *Wings: forewings* with a closed cubital cell, and one discoidal cell, radial cell open.

MALE: Smaller than the female. *Head* short; *clypeus* convex; *mandibles* narrow, armed with three teeth; *maxillary* and *labial palpi* two-jointed; *antennæ* twelve-jointed, scape short, the first joint of the *funiculus* swollen and globular. *Thorax: mesonotum* without Mayrian furrows; *epinotum* unarmed. *Wings* as in the female.

Nine species of the genus *Solenopsis* are listed from North America by Wheeler (1910, p. 563); namely, *geminata, aurea, salina, krockowi, pilosula, molesta, texana, pergandei,* and *picta.* All, with the exception of *molesta* and *texana* (Tucker, 1909, p. 288), are from the southern states or California. Two varieties, S. *molesta validiuscula* Emery, and *S. molesta-castanea* Wheeler, have been recognized taxonomically. The first is a native of the "Western States" while the second is recorded from Colorado and New Mexico. Several of the species have dimorphic workers which is evidenced, in most cases, by variation in size of the workers. *S. geminata* might be cited as an example of this dimorphic tendency. In fact, *geminata* workers are highly polymorphic. Other species are not so dimorphic.

TAXONOMIC CONFUSION

Unfortunately, considerable confusion exists in the American literature with regard to this species. Originally described as *Myrmica molesta,* the species, 30 years later, was redescribed by Buckley (1866, p. 342) from specimens collected in the vicinity of Washington, D. C., as *Myrmica exigua.* This name has not, so far as the writer is able to learn, crept into the economic literature. After another period of 20 years, the same ant was again described by Mayr (1886, p. 461) as *Solenopsis debilis.* It will be noticed that Mayr was the first to place the species in the genus *Solenopsis* Westwood. Under this name the species has, much too frequently, been reported as noxious and of considerable economic importance. Previous to the time of Mayr's paper, many references to this ant were made under the name *Solenopsis fugax* Latr. This mistake is accounted for by the close

resemblance of *S. molesta* to the well known European *S. fugax.* Several workers (Forbes, Webster, et al.) referring, in earlier papers, to *S. molesta* used the term *S. fugax;* and, following the advent of Mayr's description, made similar references under the name *S. debilis.*

According to Wheeler, "Emery (1894, p. 277) was the first to insist that this *(debilis)* was merely a synonym of Say's *molesta."* Commenting further on the synonymy of the species, Wheeler in a letter says, *"Solenopsis fugax.* is a European species and does not occur in this country. It is extremely close to *Solenopsis molesta,* however. Undoubtedly, all references to *fugax* in American literature refer to *mollesta."*

Additional confusion has arisen between *S. molesta* and the little red house ant, *Monomorium pharaonis* Linn. This is due, in part, to the similarity of habits, but more to their likeness in coloration. Both species are spoken of as tiny, but only a superficial observation is needed to note the much smaller size of *S. molesta.*

Myrmica minuta Say (1836, p. 294), a meagerly described form, is thought by such an authority as Emery (1894, p. 277) to be a synonym of *molesta.*

WHEELER'S SYNONYMICAL NOTES

Wheeler, because of the inaccessibility of certain papers at the time, but which have since been seen, kindly supplied the writer with the following synonymy of the species:

Myrmica molesta Say, Boston Journ. Nat. Hist., 1, 1836, p. 293.

Myrmica exigua Buckley, Proc. Ent. Soc. Phila., 1866, p. 342.

Solenopsis debilis Mayr, Verhand. Zoöl. Bot. Ges. Wien., 1866, 36, p. 461.

Solenopsis molesta Emery, Zoöl. Jahrb. Abth. f. Syst., 8, 1894, p. 277.

Concerning Buckley's description, Wheeler (1902, p. 12) says:

> There can be no doubt, as Emery (1894, pp. 277-278) maintains, that this is the common little "thief-ant," *Solenopsis molesta* Say (= *S. debilis* Mayr). In this case again, Buckley has described the male as the female. Of late the synonymy of this species has been called in question by Forel ('01, pp. 344-345), who regards Say's description of *Myrmica molesta* as referring to *Monomorium pharaonis,* because Say mentions the occurrence of this ant in houses. Forel is quite positive

in his assertions that *Solenopsis molesta* does not have this habit, but he is certainly mistaken in this matter. Not only has Pergande found this species to be a common house ant in Washington (see Emery, 1894, p. 277), but another careful observer, Mr. C. E. Brown, of the Milwaukee Public Museum, has recently sent me numerous specimens taken in the houses in the city of Milwaukee. Should Say's specific name be discarded, which I deem inadvisable, Buckley's should be substituted. This would necessitate a change of *S. exigua,* Forel, to *S. pygmaea* as Forel suggests.

For the above reasons, the American reference to *S. exigua, S. debilis,* and *S. fugax,* as well as those of *Monomoriurm pharaonis,* applying to *S. molesta,* will be discussed in this bulletin.

DESCRIPTION OF THE WORKER.

The species, as stated before, was first described from a female and no description of the worker or male was given. As Buckley's description of the worker under the name *S. exigua* is practically worthless, the next description, that of Mayr, is perhaps the most comprehensive that is available. It is written in German and was applied to the species which he called *S. debilis.* It is as follows:

Arbeiter. Der *S. fugax* Ltr. im hohen Grade ähnlich, doch in Allgemeinen kleiner, nur 1.5-1.8 mm. lang und in der Grösse viel weniger variirend, das zweite Stielchenglied ist deutlich breiter als der Knoten des ersten Gliedes und vorne deutlich breiter als hinten, während bei *S. fugax* der zweite Knoten nicht oder kaum breiter als der erste Knoten und vorne nicht oder kaum breiter als hinten ist.

Without the European species at hand, the above description is of little value. The writer has, therefore, prepared the following description which should make the species more readily recognizable:

Worker—Length, 1.5 to 1.8 mm. *Head* subquadrate; slightly longer than wide; posterior margin somewhat emarginate at middle; outer angles rounded. *Eyes* small, flat, oval, somewhat broader behind, slightly cephalad of middle of head. *Clypeus* short, bearing a tooth at each latero-cephalic angle. *Mandibles* four-toothed, three large teeth at apex, one smaller on inner margin behind apex. *Antennæ* ten-jointed; with large two-jointed club, apical joint about twice as long as penultimate; first joint of funicle long, about equal to length of next three, joints 3 to 6 subequal in length, very gradually increasing in width toward the club; scape and funicle sparsely pubescent, club more densely so. *Vertex* with sparsely scat-

tered hair-bearing punctures, hairs erect. *Thorax* narrower than head, broadest through pronotum; constricted anteriorly, sides (from above) gradually rounded behind; suture between pronotum and mesonotum obsolete; sides of mesonotum gradually converging posteriorly to deep suture dividing mesonotum and epinotum; suture extending caudo-ventrad on each side; epinotum short, sides gradually rounded, about as long as wide when viewed from above, declivity gradually sloping, spines absent. *Petiole* two-jointed; first joint at junction of epinotum slender and narrow, widening behind center and narrowing again posteriorly, longer than second joint; second joint wider than first, broader in front than behind, somewhat wider than long when viewed in profile, first joint taller than second, anterior declivity more sloping than posterior, second joint gradually rounding. Thorax and petiole sparsely pubescent. *Gaster* small, rounded, and as long as thorax, first segment one-half length of gaster; sting large.

DESCRIPTION OF THE FEMALE

Say's description of the female has been given in a preceding paragraph. Buckley's description unfortunately applies to the male. Mayr's description (1886, pp. 460-462) is given below :

Weibchen, Länge: 4.2-4.8 mm. Rothgelb, die Oberkiefer, der Kopf, die Oberseite des Thorax, der Petiolus und die Oberseite des Hinterleibes, ausser den Rändern der Segmente, gelbbraun. Die abstehende Behaarung mässig reichlich, etwa so wie *S. fugax.* Die Oberkiefer glatt mit zerstreuten Punkten nur zunächst der Basis längsgerunzolt, der Clypeus so wie bei *S. fugax* mit zwei scharfen Längskielen, welche unten in je einen spitzigen zahn enden; die Stirn zwischen den Stirnleisten wie bei *S. fugax* dicht und fein längsgerunzolt, ebenso die hintere Hälfte des Kopfes zerstreut grob punktirt, zwischen den Stirnleisten und Augen viel feiner zerstreut punktirt wie bei *S. fugax;* die Fühler wie bei S. *fugax.* Der Throax und Hinterleib schmäler als bei *S. fugax,* Mesonotum und Scutellum feiner und meistens mehr zerstreut punktirt, das Metanotum polirt und glänzend, nur die untere Hälfte der abschüssigen Fläche and die untere Hälfte der Metathoraxseiten sehr fein runzelig gestreift. Die beiden Knoten des Petiolus oben glatt und glänzend, nur mit vereinzelten Punkten, der zweite Knoten etwas breiter als der erste, doppelt so breit als lang und vorne etwas breiter als hintern. Der Hinterleib polirt, mit zerstreuten haartragenden Punkten. Die Flügel wasserhell mit blassen Rippen und Rändmal.

Von dem weibchen von *S. fugax* besonders durch die ganz andere Färbung, sowie auch durch die geringere Grösse und etwas andere Sculptur verschienden.

DESCRIPTION OF THE MALE

Mayr's description of the male (loc. cit.) is as follows:

Mannchen, Länge: 3.5-3.6 mm. Kleiner als *S. fugax*. Glänzend, dunkelbraun, der Kopf schwarzbraun, die Mandibeln, Fühler und Beine gelb, die Hüften und Schenkel gebräunt; etwas spärlicher behaart wie *S. fugax*. Die Mandibeln schmaler als bei *S. fugax* und nur zweizähnig. Das dritte Fühlerglied ist $1^1/_3$ mal so lang als dick oder noch etwas kürzer, bei *S. fugax* ist doppelt so lang als dick. Stirn und Scheitel glatt mit zerstreuten haartragenden Punkten, nur die Mitte der Stirn jederseits der Stirnrinne fein längsgerunzelt und der Scheitel zwischen den Ocellen gerunzelt. Der ganz Thorax glatt, nur die Seiten des Metanotum sehr zart gerunzelt. Der Petiolus grösstentheils, der Hinterleib ganz glatt. Die Flügel wasserhell.

ECONOMIC IMPORTANCE

DETRIMENTAL RELATIONS

Since the time this ant was first described it has been regarded as an injurious insect. Nevertheless, it has the redeeming feature of being, at the same time, an important predaceous enemy of many other injurious insects. The literature of the species, so far as it pertains to the habits of the insect, is replete with accounts of the ant as a pest of houses and field crops. The type of injury to kafir and other sorghum seeds is much the same as described for corn (Forbes, 1894, p. 10) and, except for the preliminary report heretofore mentioned (McColloch and Hayes, 1916), has not been described in the literature.

Several short articles have appeared which discuss the habits of the ant, but by far the greater number of references consist merely of short statements recording the species as an enemy of insects and plants, or as a pest of houses. Other papers discuss enemies of the ant itself, such as birds or other ants, and some mention myrmecophila found in the nests of *S. molesta*.

Until recently it has been difficult to state whether this ant has attracted more attention as a pest of the household or as an enemy of crops and planted seed. However, since the ant has come into prominence as a pest of sorghums in Kansas, it is plainly evident that the balance swings, at least locally, in favor of the species being a field pest.

FIELD PEST

When first reported, Say (1836, pp. 293-294) stated that the species attacked garden seed, whether the seed was planted of not he fails to mention. The next reference, by Fitch (1856, pp. 129-130), reports the ant so numerous in the fields as to threaten to cut off every blade of corn by gnawing the tender leaves "for the purpose of drinking the sweet juice which flows from the wounds." Forbes (1884, p. 45) found this insect, which he called *S. fugax,* in great numbers in sorghum and broom-corn fields, where he noted they were paying no attention to the superabundant plant lice. They were also observed (Forbes, 1884, pp. 61; 112-113) gnawing out the fleshy fruit of strawberries and hollowing out planted seed corn. As *S. debilis* Forbes later (1894, pp. 8-10; 66; 69) noted further injury to corn, both in the ground and in ears of standing corn which had been previously injured by crickets and grasshoppers. Workers were several times noted in attendance on the corn root-louse, *Aphis maidi-radicis* Forbes, and a minor aphid of the corn plant, *Geoica squamosa* Hart. Hunt (1886, p. 58) lists both *S. fugax* and *S. molesta* as enemies of corn.

Webster (1890, pp. 257-258) observed this ant attending a species of *Dactylopius* on red clover. Workers were seen carrying away the substance of seed corn after it had been planted. He also described them (1893, p. 158) as injuring blackberries, concerning which he says "their attacks upon ripe fruit is exceedingly annoying, as their diminutive size prevents their being readily discovered." Felt (1915, pp. 68-69) found the species injuring corn at Salt Point, N. Y. In this instance, recently planted corn seemed to be "growing smaller" and it was found that the ant was eating the interior out of the kernels as described by Forbes. The development of the plants was arrested and they appeared to become smaller.

As a field pest in Kansas, the chief damage consists largely of the destruction of seeds of kafir, cane, milo, feterita, and corn (maize) soon after they are planted. Injury to the sorghums is much the same as that described by other workers in the case of corn, concerning which Forbes (1894, p. 9)

[1] It is interesting to note here that, as stated by Wheeler, Emery (1894, p. 277) was the first to insist that *S. debilis* was merely a synonym of Say's *Myrmica molesta*, yet here we have an instance of a writer using the name *Solenopsis molesta* the same years *debilis* was described. Apparently Hunt had recognized the position of the species, or someone (unknown to the author) had previously so defined it.

writes, "a kernel may be found wholly or partly hollowed out, the mealy interior being not devoured, but scattered about in the earth, while the cuticle or outer shell of the seed remains but little disturbed."

During the past few years, thousands of acres of sorghum crops have had to be replanted from one to six times because of the ravages of this ant and in a number of cases it has been impossible to get a good stand. With seed at $3 per bushel, as it was during the season of 1914, this means a considerable monetary loss as well as time and labor spent in replanting. A few of the following records from field notes and correspondence will serve to show more vividly the amount of damage done by this pest.

May 7, '12, Milton Clegg, Neodesha, reported that ants destroyed 40 acres of cane and kafir.

May 12, '13, A. T. Sharp, Council Grove, reported ants injuring listed kafir.

June 18, '13, E. W. Dales, Eureka, had 100 acres in cane and kafir, but because of the ants only 25% germinated.

Feb. 10, '13, Chas. C. Crane, Longton, writes that on account of the ants most of the farmers in his neighborhood were compelled to replant several times last year, and some did not, even then, get a stand.

June 27, '12, B. P. Cunningham, Augusta, stated that farmers replanted five times in ant infested fields in his vicinity.

April 23, '14, W. Russell, Winfield, replanted 80 acres infested with ants three times last year and was finally left with about a twenty acre stand.

Feb. — '15, Frank Lister, Olpe, says he had 20 acres of kafir destroyed by ants last year.

Jan. — '16, Henry Hanson, Rosalia, states that the ant is very bad. Last year he replanted seven times without obtaining a stand.

HOUSE PEST

This phase of the insect's depredations has not attracted much attention in Kansas. Several reports of yellow ants as pests in houses in this state have, upon investigation, proved to be the larger ant, *Monomorium pharaonis*. There are but two records in the files of the Experiment Station of *S. molesta* as a household pest. One is from Kansas City, Mo., and the other a record of the ant being abundant in a clothes closet in Manhattan.

However, there are numerous accounts of the species infesting houses in other localities. Say (loc. cit.) records the ants as being found in houses in great numbers where they eat

vegetable food, olive oil, and grease. Fitch (1856, p. 129) calls it the most abundant and annoying ant in the State of New York, where it is common in dwellings, being attracted by sweet-meats, preserves and other sweetish substances. As a pest of insect collections, he says: "I have experienced some difficulty in preserving my collection of insects from this depredator, some box or drawer not perfectly tight being invaded by them ere I am aware of it, almost every season. But by crushing every individual which does not escape into some crevice, and permitting their dead bodies to remain where they are slain, their comrades take warning and cease to frequent the spot. The vapor of camphor also repels them." Packard (1880, p. 185) states that *Myrmica molesta* is found in houses all over the world. Evidently, he confused the species with other house ants, for *S. molesta* is a native North American ant and is not so widely distributed as Packard would lead us to believe. Webster (1890, pp. 257-258) found the ants burrowing into cured hams and ripe apples. Later (1893, p. 158) he states: "Several times this insect has made itself exceedingly disagreeable in my own house, by its presence in the pantry, and while in Washington some years since, the artist of the Division of Pomology, Department of Agriculture, complained to me of the trouble he experienced from a closely allied species, *S. debilis,* Mayr, eating the paints with which he was coloring the wax models of fruit." Wheeler in different articles (1905, pp. 377-378; 1910, p. 427) mentions the species as a pest of houses and disproves Forel's (1901, pp. 344-345) assertion that *S. molesta* does not occur in houses. Barber (1912, p. 181), in a paper on the avocado weevil, discussing seeds of the avocado infested with weevil, says: "Unfortunately the seed lay for a time on his desk subject to the attack, of the ant pest *(Solenopsis debilis)* from which the Bureau of Entomology suffers. . . ." Tanquary (1912, p. 138) reports that the ant is sometimes found in houses. Herrick (1914, p. 178) states "The tiny thief-ant *(Solenopsis molesta)* is a native ant that occasionally leaves its natural haunts and builds its nest in houses, where the occupants become pests in kitchens and pantries."

BENEFICIAL RELATIONS

This ant has varied habits. As a beneficial predaceous insect it receives perhaps as much prominence as it does as a pest. The beneficial aspect is manifested by the activities of the ant in attacking many of our other pernicious pests. A glance at the accompanying list of species which *S. molesta* attacks will serve to show the ant's usefulness. The list will be discussed in a later paragraph. The names in the list without references are from original observations.

Insect species known to be attacked by *S. molesta* are as follows:

Grape curculio, *Craponius inæqualis* (Brooks, 1906, p. 241)
Walnut curculio, *Conotrachelus juglandis* (Brooks, 1910, p. 182).
Cotton boll weevil, *Anthonornus grandis* (Pierce, 1912, p. 41).
Chinch bug (eggs), *Blissus leucopterus* (Headlee and McColloch, 1913, p. 309).
Codling moth, *Carpocapsa pomenella* (Brooks and Blakeslee, 1915, p. 46).
Maize billbug, *Sphenophorus maidis.*
Corn stalk borer, *Papaipema nitella.*
Corn earworm, *Chloridea obsoleta.*
Hessian fly, *Mayetiola destructor.*
Grasshopper (eggs), *Acrididæ* (different species).
Ladybird beetle, *Megilla maculata.*
White-marked tussock moth, *Hemerocampa leucostigma.*
Scarabæidæ, *Ligyrus relictus.*
Larger ants:
Other colonies of *S. molesta.*

The amount of damage which this species inflicts on crops and its noxious character in kitchens is somewhat compensated for by predaceous habits. Unfortunately, the ant does not appear to be of material value as an enemy of any of the species mentioned in the list for in most, if not all, cases the report of *molesta* as an enemy of various insects comes from isolated and, perhaps, chance observations. In the opinion of the writer, many of these cases arise when the ants find an injured or helpless victim that is incapable of defense, or it is even possible that they attack their victim after it has died. These reasons, combined with records of the ant feeding on fats, grease, and cured hams, might lead to the conclusion that many of the accounts of *molesta* as a predaceous enemy are only instances of the ant's scavenger habits.

DISTRIBUTION

GEOGRAPHICAL

KANSAS

The accompanying map of Kansas (fig. 2) shows by the

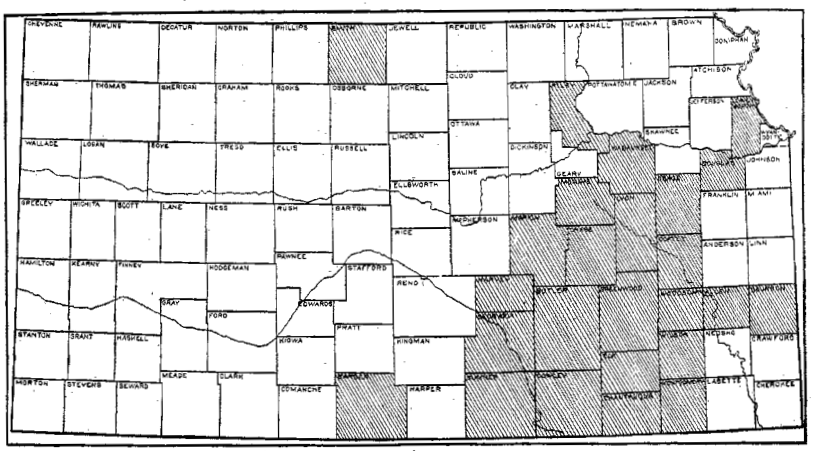

FIG 2.—Map showing known distribution of *Solenopsis molesta* in Kansas

shaded area, the counties from which the ant had been reported previous to the present study, or in which it has since been found. It will be noted that the distribution is confined chiefly to the southeastern part of the state. The unshaded area and a few of the shaded counties have not reported damage to crops by this pest. The writer feels confident, because of the wide distribution of *molesta,* that the ant would be found in every county of the state were a survey to be made.

NORTH AMERICA

Apparently there is no reason for supposing that *molesta* is anything but a species native to this country. The following citations of its occurrence show its wide distribution:

Mexico—Wheeler (1901, p. 533).
Boston—Tanquary (1913, p. 418).
Charity Islands (Lake Huron)—Gaige (1914, p. 3).
Washington (state)—Mann (1911, p. 102).
California—Mann (1911, p. 29).
Louisiana—Rosenfeld (1911, p. 406).
Oklahoma—Pierce et al. (1912, p. 41).
Ottawa, Canada—Guignard (1886, p. 70).

The accompanying map (fig. 3) shows the known distribution of the ant in North America.

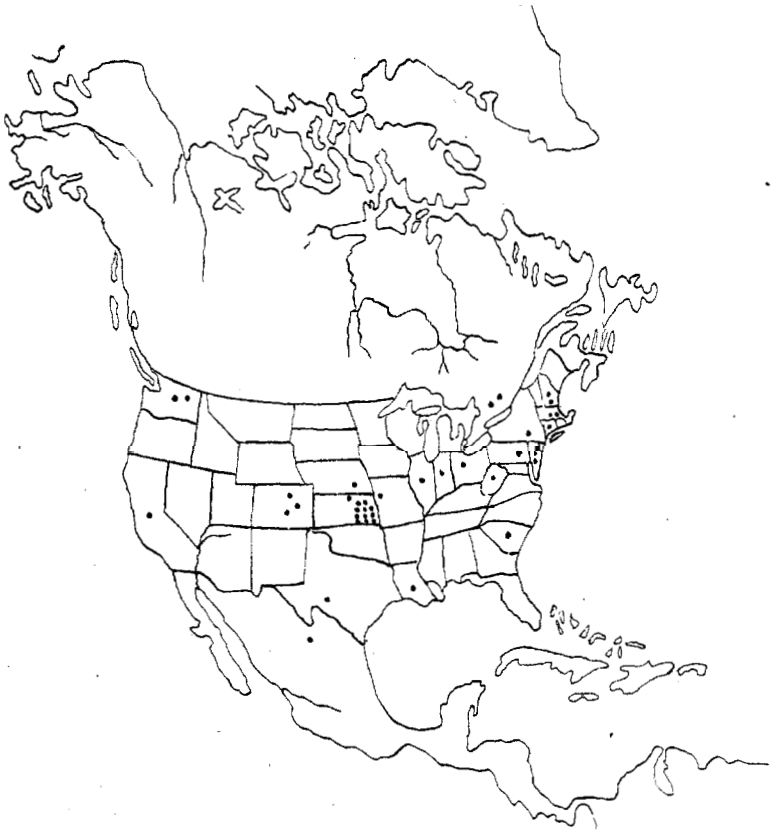

FIG. 3.—Map showing the known distribution of *Solenopsis molesta* in North America

EUROPE

So far as known this ant is not a native of Europe, and, if introduced, has not been recorded in American literature, However, *Soleopsis fugax* is so closely related to it that if they both occurred in the same region they would, in all probability, be mistaken for each other.

MEANS OF DISPERSAL

NATURAL

As with other ants, the rate of dispersal under natural conditions is very slow. Newell and Barber (1913, p. 19) estimate the spread of the Argentine ant to be a few hundred

yards each year. At this rate it can be seen that the rate of distribution of *S. molesta* in America is slow. To have been an introduced species it must have been introduced long before the settlement of America. Most writers regard it as a native ant. The fact that the species occurs from coast to coast indicates one of two things, either the ant has been introduced on both shores or has spread from one to the other many years ago. The latter necessitates the traversal of vast mountain chains, a procedure which takes time and indicates the early presence of the ant in North America. Apparently, then, dispersal by natural means has been a much more important factor in the past than it is now. Wheeler (1910, p. 221) states that *S. molesta* will nest in ships. This then might be an intermediate step between natural and artificial dispersion.

ARTIFICIAL

The artificial dissemination of this ant is perhaps not as important a factor as in the dispersion of other injurious insects. Transportation by man is rare. Likewise, if transported, the conditions encountered at the end of a journey seldom favor increase in colonies, and, from the writer's experience in handling the species, it seems the rare thing for a few workers to establish colonies, or even survive long after being removed from their natural haunts.

Many workers and fertilized queens were released in an old house at Winfield, Kan., and during that summer or the following one it was impossible to find evidence of the establishment of any colonies in the house. This, and other instances, tends to show that the re-formation of colonies is likely to be rare.

REARING METHODS

DESCRIPTION OF CAGES

Considerable difficulty was encountered in finding a satisfactory method of rearing this ant under artificial conditions that would permit of daily examination. Because of the minute size of the workers and various other factors, such cages as the Lubbock, Janet, and Fielde proved unsatisfactory. Finally, a modified type of the Janet cage was constructed, which, although not entirely satisfactory, proved useful. This cage is made by moulding a block of plaster of Paris in an ordinary dinner plate or saucer, having the upper surface level

with the top of the dish. On one side a small cavity serves as a water chamber, which can vary in size according to the size of the cage. Opposite this, an oblong chamber about one-eighth of an inch deep, two to three inches wide, and four to five inches long, is hollowed out and the half opposite the water reservoir is painted black and covered with a small square of glass. This provides a covered and an uncovered chamber. The former is then covered with a small square of black cloth, making a very satisfactory dark chamber which can easily be uncovered to permit examination. The uncovered area is used for a food chamber, and readily permits of the removal of dead or decayer food. To prevent the escape of the ants, the food chamber is completely surrounded by a barrier of vaseline, which must extend up and over the adjacent edge of the glass covering the dark chamber. An extra safeguard is had by placing a thin layer of vaseline around the dark chamber before the glass top is put on. This not only fills up any crevices through which the ants could escape, but also prevents the glass cover from slipping out of place. By making the dark room near the edge of the dish, individuals in the nest can easily be examined on the stage of a binocular.

This cage is not altogether satisfactory as the ants will sometimes burrow through the plaster of Paris into the bottom of the dish. Before ants become accustomed to the vaseline many are caught in it, especially the winged forms when they venture out of the dark chamber. In time, the ants learn to avoid the vaseline. Larger ants, such as *Cremastogaster lineolata* Say and *Iridomyrmex pruinosus* Roger, were kept successfully in these cages.

FEEDING METHODS

As stated previously, in the cage used, the uncovered area of the food chamber readily allowed the removal of old food. It likewise permitted the feeding of the colonies whenever it was necessary. Food can be given the ant at any time and removed at will. As the ants are apparently omnivorous feeders, it was thought advisable to keep a "well-balanced ration" available for them at all times. Small lumps of sugar and kafir or corn seeds were kept in the cages continuously, and, because of the ants' carnivorous habits, small bits of fresh meat or freshly killed insects were also kept available. The seeds and meat were quickly destroyed in hot weather by

fungi and necessarily had to be removed frequently and replaced with fresh pieces.

It has been stated (Wheeler, 1905, p. 377) that *S. molesta* is thought not to feed on sugar, but in these cages they were often seen eating it and frequently carried small bits into the dark chamber. As previously mentioned, Fitch (1856, p. 129) says the ant is frequently attracted to sweetmeats and other saccharine substances. The author's observations confirm his statement.

Despite the fact that the ant is a pest of planted seed in the fields, it refused to feed on corn or kafir seed in artificial snests. It was thought that perhaps, before being attacked in the field, the seed needed soaking, an operation which they naturally receive from soil moisture. Accordingly, well-soaked and even germinated seeds were placed at the disposal of the ants, but remained untouched.

MOISTURE SUPPLY

The proper supply of moisture in the artificial cages is one of the most important points in the successful rearing of this ant for the purpose of making life-history observations. The Lubbock cage was found impractical because of the inability to regulate the proper humidity in a hot and dry region, such as is found in Kansas during the summer. When the soil was dampened in these cages, it would, in some cases, dry out too quickly, and in others keep the chamber too wet. It should be stated that this difficulty was due in part to the thinness of the cages. It was necessary in order to observe this small ant to so construct the cage that the distance between the upper and lower surfaces was such that the ant could not completely bury itself in the enclosed layer of soil. Difficulty was also experienced in keeping the ants in these cages. The moisture supply in this and other types of cages always induced the growth of fungi in the nests, which rapidly killed off the colonies in spite of the efforts of the workers to ward it off with their supposedly antiseptic secretions.

When the modified Janet cage was used, the regulation of the moisture supply in the artificial formicaries was, to a great extent, accomplished by the depressions in the plaster of Paris which were used as reservoirs. By filling these once a day, except, perhaps, on exceptionally hot days when two

fillings were necessary, or on rainy and damp days when the rate of evaporation was low and filling was not required at all, the moisture content of the cage was satisfactorily regulated.

In the natural formicaries, moisture regulation likewise plays an important part in the affairs of the colony. Early in spring when the soil is soaked with water, colonies are most easily located. The brood and the workers are to be found in pasture lands on the under surfaces of rocks. As the ground becomes drier the colonies move down into the ground, and, by the time dry weather or droughts arrive, the ants have moved so deeply into the soil that it is almost impossible to locate the nests. Continued search, by overturning stones and digging, in fields that contained ants abundantly during the wetter months nearly always failed to be productive of good collecting results.

LIGHT CONTROL

S. molesta workers have vestigal eyes and are naturally of strong hypogaeic habits. As a result, they are negatively phototropic. Provision, therefore, had to be made in the artificial nests for a darkened chamber for the ants and brood. This was accomplished by covering the brood chamber with a dark piece of cloth. The colony was thus able to seek either the light or dark chambers at will. The brood is always kept in the dark, but the workers often come out into the illuminated chambers. This is also the case in the natural nests. Workers are sometimes, but not frequently, found walking on the surface of the soil. This occurs generally when the soil is shaded by trees or clouds.

DIFFICULTIES

When the cage difficulty was eliminated, other serious problems presented themselves. As yet no single individual has been followed through all stages of its life cycle. The immature forms cannot be kept under observation when piled upon each other in large colonies. When small colonies are started, the cannibalistic instinct of the ants becomes noticeable and before a series of eggs will hatch, or a group of larvae become full grown, they may be eaten by their supposed caretakers.

LIFE-HISTORY

S. molesta, like other ants, passes through four stages of development before reaching maturity, viz., egg, larva, pupa and imago. In this respect, they resemble other insects having a complete metamorphosis. Interpolated between the larva and the pupa proper, is the semipupa and between the pupa and adultis the immature adult stage known as the callow.

The habits of the ant are, in general, like other ants and will be more fully treated under the heading "Ecological Relations." The workers carry on the work of the colony; the queen, after fertilization, having only to produce the eggs. The nests consist of a number of irregular chambers in the soil connected by minute passageways. These are constructed and cared for by the workers. Likewise, the eggs, which are laid by the queen, are attended by the workers. The eggs adhere in packets, which enables the workers to transport them in large numbers. When hatched, the larvæ are fed and tended by the workers through this period and the pupal stage to maturity.

DESCRIPTION OF CASTES

Unlike other species of *Solenopsis,* this species does not exhibit any marked polymorphism among the workers. Soldiers are not present and the worker caste consists of individuals much smaller than the males or females. Wheeler (1903, pp. 146-147) expresses the relation in size between the workers and females as 1 to 20. Although this difference in size seems large, compared to some other members of the tribe *Solenopsidii,* the ratio, 1 to 20 is small. Regarding this comparison, he states:

> The males and especially the females of the smaller species of *Solenopsis,* . , , are of very large size compared with the workers. The same is also true of *Pheidologeton* and the polymorphic species of *Solenopsis* when the sexual forms are compared with the most diminutive caste of workers. The relative dimensions of the queens differ, however, considerably in the different genera. Thus in our common North American *Solenopsis molesta* the workers measure 1.5 mm. in length, the females 4.5-5 mm.; while in *Carabara vidua* the worker is hardly larger than that of, *S. molesta* (1.5-2 mm.) whereas the female is of gigantic dimensions (23 mm.). The dimensions of *Erebomyra Longii* lie between these extremes, though much nearer to those of *S. molesta.* The worker is 1.5-2.25 mm. long, the female 8-8.5 mm. If we cube the dimensions in these three species and make due allowance for the fact that the body

of the female ant is in each case proportionally much thicker than that of the worker, we have the following roughly approximate ratios between the volumes of the workers and females:

Solenopsis molesta, 1:20.
Erebomyrma Longii, 1:150.
Carebara vidua, 1:2000.

These are rather extraordinary dimensions for queens as compared with workers, especially when we reflect that they represent the sterile and fertile extremes of the same sex.

THE WORKER

The worker caste (fig. 1) (undeveloped female) constitutes the greater number and most important individuals of the colonies. The workers are among the smallest of the known ants, being from 1.5 to 1.8 mm. long and pale yellow in color. 'The caste itself does not include polymorphic forms as in some other species of the genus. Although slight differences of size are to be noted, they are, apparently, within the limits of variation and should hardly be classed as distinctly polymorphic forms, such as are found in cases where colonies contain both soldiers and workers of more varying dimensions.

The workers are the most active and perhaps the most interesting members of the colony. Upon them falls the responsibility of rearing the brood as well as the building and care of the nest. There seems to be no marked division of labor, that is, some are not occupied with the care of the nest, while others nurse the brood, forage, or guard the nest. It is this caste that makes itself noxious both in houses and in fields, due, in part, to their remarkable foraging proclivities. Aided by their hypogæic, or underground, habits, the ants are able to forage far and wide with a great degree of safety, They are thus able to travel to planted fields, pantries, or kitchens, and even to nests of other ants where they make away with their booty. Upon the workers rests the care of the immature forms of the colony. As the need arises they transport all the stages from place to place, nurse them, feed them, and even protect them.

THE FEMALE

ALATED, OR VIRGIN FEMALE

Except for the possession of wings, the virgin female (fig. 4) differs but little from the fertile queen. Upon emergence from the pupal stage, the long, narrow, and somewhat opaque wings are expanded. These she retains until mating, and until that time carries on no important function in the colony.

In outdoor natural formicaries, virgin females were found as early in the season as July 20, while in artificial nests the

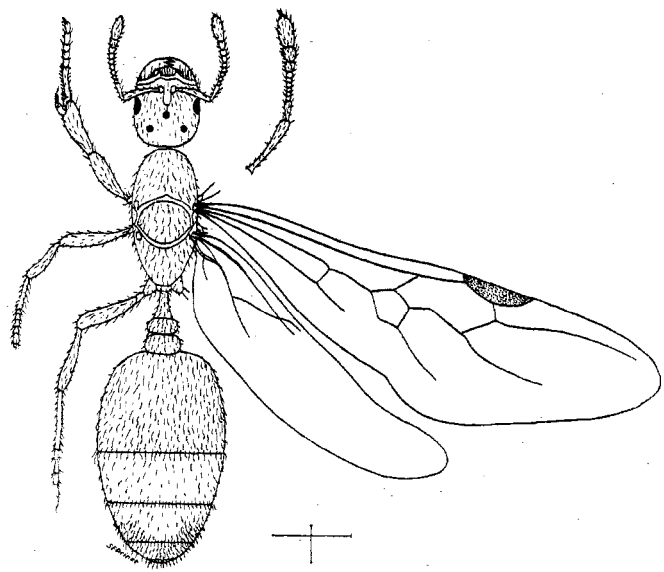

FIG. 4.—Winged queen (unfertilized female) of *Solenopsis molesta*. (Enlarged)

earliest date of maturity was July 22. Although no mating flight has been observed by the writer, indications point to July or August as the time when the emergence of the winged forms occurs. From the time of the appearance of the pupae of the males and females, it is likely that they issue during the latter part of July or early part of August. McColloch found a winged female on the windshield of an automobile at Manhattan, Kan., July 22 at 6 p. m. This is the only record of a possible flight in this state. It is not likely that any large flight has occurred in Kansas during the last few years. In 1916, the possible flight had not occurred by September 9, as males and females were very abundant in colonies on that date.

Wheeler (1905, p. 377) states that the males and females make their appearance in late August. Buckley (1866, p. 342) reports catching winged females under the name *S. exigua,* in Washington, D. C., in July, while Tanquary (1913, p. 418) observed a large flight of *S. molesta* at Boston, Mass., September 5, and possibly a continuation of the same flight on September 8. Judd (1901, p. 32) found three chipping sparrows in August eating winged forms of *S. molesta* which occurred in a field "by millions."

DEALATED, OR FERTILE FEMALE

After fertilization, the winged queen loses her wings and takes up her duties of founding a colony. In rearing cages fertile queens isolated from established colonies were frequently observed to begin the establishment of a new colony unaided by workers. They begin by laying a few eggs and caring for them until maturity. These new adults are workers and they in turn aid the increase of the new colony. This is perhaps the same method used by recently fertilized females to establish a colony for the first time. As members of different colonies are decidedly antagonistic to each other, it is fair to assume that, unless by mere chance a freshly fertilized queen takes up with members of her own colony, she will start out alone to build up her new home. Fertile queens were often observed carrying their own eggs or larvæ when workers were not around to aid. This habit is of decided advantage in the formation of new colonies.

It is an unusual thing to find a queen in out-door nests, and the number of queens in a colony, when found, vary from one to many. In a single instance 26 fertile, or at least wingless queens were taken in a colony containing a large number of workers and immature forms. One of these queens was accidentally decapitated when excavating the nest. She was alive and quite active the next day, but died the following day. Evidently, they can withstand considerable injury.

The life of a queen under artificial conditions is very short. None were able to live for an entire summer, or even be carried over winter. With other species of ants, the queens are noted for their longevity and in their natural habitats *S. molesta* queens are, perhaps, longer lived than they were in confinement. Queens were found early in May in outdoor nests, indicating that they will live over an entire winter at least.

THE MALE

The sole function of the males is the process of fertilization, otherwise they are of no obvious use in the colony. After the mating flight they soon die. The males (fig. 5) are easily dis-

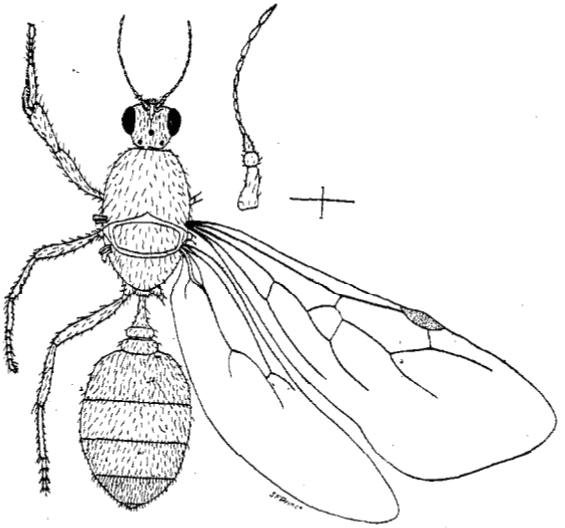

FIG 5.—Winged male of *Solenopsis molesta*.
(Enlarged)

tinguished from the females by their darker color and somewhat smaller size. The earliest date on which a male has matured in cages under the writer's observation was July 24, in a colony where a female had matured two days earlier.

THE EGG

DESCRIPTION OF THE EGG

The eggs (fig. 6) are pearly white with a bright lustre

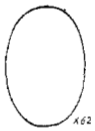

FIG. 6.—The egg of *Solenopsis molesta*.
(Enlarged)

which changes just before hatching to a clear semi-translucent color. They are elliptical in shape and about 0.25 mm. long. The eggs are covered with a viscid substance which enables

them to adhere in packets and be easily transported by workers, or to become attached to the surfaces where deposited.

PERIOD OF INCUBATION

Eggs are laid by the fertilized queens and cared for by the workers. Queens, as before mentioned, when unattended by workers, will care for and carry packets of eggs from place to place in the nests. Unless eggs are attended by either workers or a queen, they will not hatch. It was a simple matter to get eggs deposited on the sides of vials or other receptacles, but impossible to get them to hatch.

Fertilized queens collected in the fields and placed in artificial nests cease egg-laying almost entirely, and the few eggs that are occasionally laid are soon greedily eaten by the workers. This condition, coupled with the fact that large numbers of eggs in a nest are hard to keep under observation, makes it difficult to determine the length of the incubation period. A method by which the period was determined will be described later. The length of the period was found to vary from 16 to 28 days, depending on temperature and moisture conditions. Daily egg-laying records of eight queens were kept for a period of 16 days by removing from the nest eggs laid during each day. The average number of eggs laid for the period was 103.3. The greatest number from one individual was 387 and the smallest was 27. One queen deposited 105 eggs in a single day. This queen was taken in a large colony, May 10. Her egg-laying record from May 11 to June 11, is as follows:

Date	Number of eggs laid	Date	Number of eggs laid
May 11	52	May 27	14
May 12	94	May 28	5
May 13	105	May 29	0
May 14	36	May 30	1
May 15	3	May 31	0
May 16	0	June 1	0
May 17	0	June 2	0
May 18	9	June 3	2
May 19	10	June 4	20
May 20	13	June 5	5
May 21	0	June 6	0
May 22 }	16	June 7	1
May 23 }		June 8	4
May 24	0	June 9	1
May 25	13	June 10	9
May 26	36	June 11	0

The rapid decrease in egg production is undoubtedly the result of the queen's being placed in an artificial nest.

THE LARVA

DESCRIPTION OF THE LARVA

The larvæ (fig. 7) of this species resemble superficially the larvæ of any of the other Myrmicine ants except, perhaps, in size. They are white in color and covered with double-hooked hairs which enable them to cohere in packets and so be carried by the workers. The posterior end is large and tapers toward the anterior end, which is considerably curved. This curvature becomes less pronounced as the larva grows older, but is never entirely obliterated. When first hatched the young larvæ are scarcely larger than the eggs from whence they came.

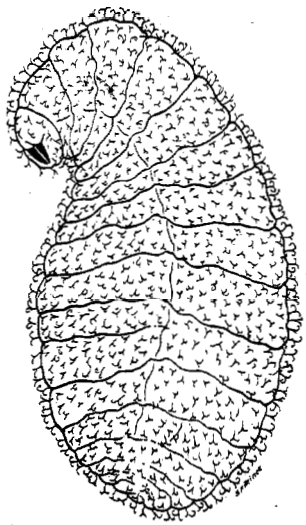

FIG. 7.—The worker larva of *Solenopsis molesta*. (Enlarged)

LENGTH OF LARVAL STAGE

The length of the larval stage is highly variable, depending on weather conditions to a marked degree. During midsummer, larvæ were reared to the semipupal stage in 21 days. In another instance, a single larva was under observation from October 10 to May 12 when it transformed to the semipupal stage.

METHOD OF FEEDING

Larvæ are fed regurgitated food by the workers. Workers, in artificial nests, were often seen to place small bits of crushed kafir seeds and torn parts of their larvae and pupae on the

bodies of the young near the mouthparts where the larvae were seen to bite them.

Larvae were frequently observed, while lying on their back, to straighten out their curved body. These movements are repeated at short intervals and the mandibles open at each up-movement and close on the down-movement. These moving larvae were generally fed at once, or soon after making these apparent supplications.

THE SEXIPUPA

As the larva becomes full grown, a large undigested meconium is voided from the alimentary tract. Workers were seen at times aiding the larva to get rid of this mass by tugging at it while it was being cast off. This change marks the end of larval development and the beginning of the semipupal stage. Large larvæ have often been encountered in nests of this species, which were, undoubtedly, either larvae of males or queens. None were ever reared to maturity in artificial nests. Except for their much greater size, they resemble the worker larvae, and upon reaching their final stages of growth undergo similar changes to the semipupal stage. In this stage, they are not greatly unlike the larvæ except for the absence of the black mass in the abdomen. The semipupal stage was found in midsummer to vary from 2 to 11 days.

THE PUPÆ

THE WORKER PUPA

The comparative size of the worker, the queen and the male pupae is shown in figure 8. When this stage is reached in their development, the sex of the individuals can easily be distinguished by their size.

The worker pupae (fig. 9) are about 1.5 to 1.8 mm. long. When freshly transformed from the larval stage, they are pearly white in color, but as development proceeds, they darken through a creamy white to a pale yellow, and later to a darker yellow which is much the same as the color of the adult worker. The length of the worker pupal stage was found to be from 13 to 27 days. The same period for the males and queens has not been determined.

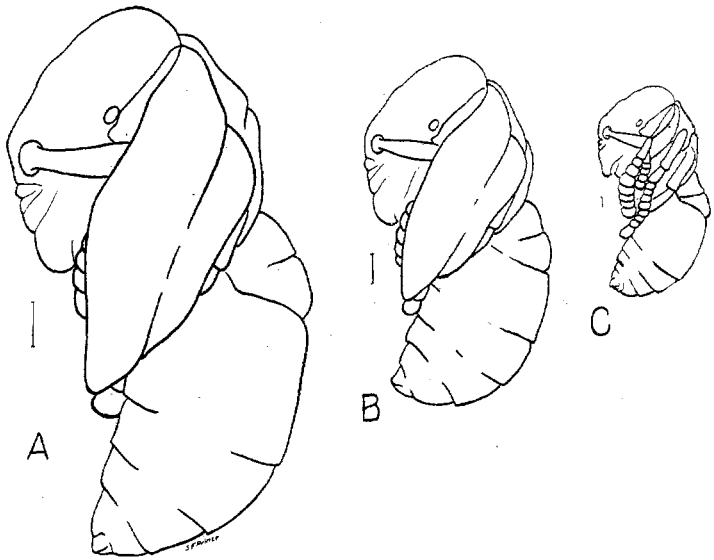

FIG. 8.—Pupæ showing comparative sizes: A, the queen; B, the male; C, the worker. (All enlarged)

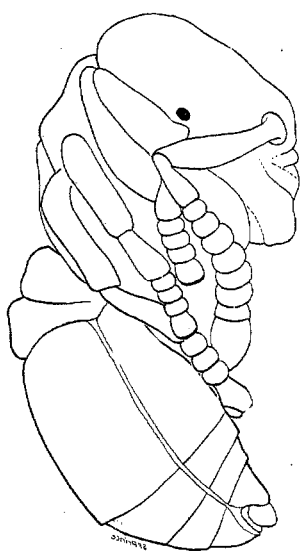

FIG. 9.—Worker pupa of *Solenopsis molesta*. (Enlarged)

THE FEMALE PUPA

The female pupæ are larger than the worker pups, measuring about 4.5 mm. long. They are also considerably larger than the pupæ of the males. At first, the queens are pearly white, but as development proceeds, they color much the same as the workers. When ready to transform to adults, the queens molt, being greatly assisted in the process by the workers of the colony.

THE MALE PUPA

The pupæ of the males are intermediate in size between the worker and queen pupæ, being 3.5 to 3.6 mm. long. From a whitish color similar to that of the other pupæ, this sex develops to a much darker color, being nearly black. By their size and this black color, they are easily distinguished from the others. Some time previous to their last transformation, the males, as well as the females, develop rather prominent wingpads. Pupæ of the males and queens are not found in the colonies until early in July. They frequently occur in fairly large numbers and are well cared for by the workers.

THE CALLOW STAGE

The newly hatched ant, before it has attained its full adult coloration, is called a callow. Except for this lack of color, the callow is almost the same in appearance as the adult workers. At first it is helpless and clumsy and must be cared for by attendant workers, which often carry it about when the need for transportation arises. Callows are even fed by the workers. As they become older and stronger they gradually darken to the adult color and are more and more neglected by the workers until at last they become entirely independent. The coloration, which is due to the deposition of chitin and perhaps some pigment, will take place in two days; that is, in less than two days one cannot distinguish the younger from the older individuals.

TIME REQUIRED FOR DEVELOPMENT

METHOD OF COMPUTATION

It is difficult to determine in artificial colonies the exact length of the different immature stages. Eggs and young are generally piled in large numbers and therefore hard to observe as single individuals. Moreover, the workers are cannibalistic

and eat many of the eggs, larvæ, and pupæ. The methods used by Newell and Barber (1913, p. 39) were employed to work out the length of the various stages. For example, in the egg stage it was assumed that the time from the laying of the first egg to the hatching of the first larva was the length of the egg stage. Other observations were made by placing a small number of individuals, either eggs, larvæ, or pupae, in a nest with a small number of workers. By careful observation and maintenance of large numbers of such colonies, it was often possible to watch a few of the individuals through at least one stage of their growth.

APPROXIMATE TIME OF DEVELOPMENT

The minimum length of the egg stage was found by the method just described to be 16 days; the larval stage 21 days; the semipupal stage 2 days; and the pupal stage 13 days. Assuming the total of these figures as a probable minimum time required for development of workers, we have 52 days as the least time in which they will mature. The maximum time for development, due to the fact that larvæ, will live over the winter, is subject to much variation. The longest time for eggs to hatch was found to be 28 days. As mentioned above, larvae will develop in 21 days. This is in midsummer. Others will live through the winter. A single larva was under observation from October 10 to May 12, when it transformed to the pupal stage. The maximum length of the semipupal stage was found to be 11 days, and that of the pupal period proper was 27 days.

ECOLOGICAL RELATIONS

HABITAT PREFERENCE

LOCATION OF COL0NIES

Adjustment to certain limited habits seems not to be the rule with the species concerned, at least, not in the localities of Kansas where the ant has been studied. Their wide and varied distribution in such diverse habitats as houses, pastures, meadows, prairies, or plowed fields seems to indicate no especially desired abode. The nature of the soil seems not to be of extreme importance, as colonies are found in heavy clay soils, light sandy soils, or many intermediate gradient types. The colonies are found in almost all situations of this region,

including variations in altitude from river bottom-lands to the highest surrounding uplands. The colonies are more easily located in pastures under stones, but this does not imply that they are more abundant in such places than in fields where they are not so easily located. Very rarely the species constructs nests in the open with small crater openings.

The location of the colonies is determined by the fertilized queen soon after fecundation, except in rare instances when a colony is forced to move because of unfavorable environmental factors. Evidently, the females select their permanent abode by the trial and error system, moving about from place to place until a situation is found where favorable conditions exist.

DESCRIPTION OF FORMICARIES

In plowed fields or other open situations the interior of the colonies is not so easily examined as under stones in prairies or meadows. This is due, in part, to the more compact soil which permits of a more careful investigation of the tunnels and chambers of the nest. Even then, because of the minuteness of these burrows, they are difficult to trace out to their destination. In general, the nest consists of random burrows through the soil, scarcely more than 1 millimeter in diameter, which frequently enlarge to form chambers from 10 to 15 millimeters in diameter. In these large chambers, the brood is reared. Often the one or more openings of a colony under a stone will be greatly enlarged at the surface of the soil to form brood chambers where the young can be taken, when the soil becomes saturated from rains, to receive the warmth of the sun through the protecting stone. The following field note describing a colony may be regarded as a typical example of a colons:

A large colony of ants was taken under a stone 18 by 12 by 6 inches in a pasture near the State School, Winfield, Kan. At the opening of the nest, there were two entrances; one was nearly round and the other was oblong oval. Several hundred workers were gathered near a large pile of larvæ grouped in the round entrance. About 200 workers were on the under surface of the stone when it was turned over. One-half inch below the round entrance about 100 larvæ were taken. Tunnels could not be traced from here, but at a depth of 1⅛ inches a tunnel was found that went south for 4 inches at the end of which were about 300 larvæ. These larvæ were in a chamber about one-half of an inch in diameter. Directly below this room at a depth of 2½ inches from the surface, a tunnel went north for 3 inches and ended in a chamber con-

taining about 200 larvæ. Down 3 inches, a tunnel was followed in an easterly direction for 1½ inches where it divided, one branch going directly east while the other went downward and in the same easterly direction for 2 inches. At the end of each were large chambers containing piles of larvæ. Workers and larvæ were scattered throughout the tunnels. No evidence of food being stored was found. No queen was found.

This colony was taken in early spring and contained no eggs or pupæ. Otherwise, the colonies examined later in the season do not differ much in their general aspects.

RELATION OF NESTS TO OTHER ANT COLONIES

It is not impossible, as supposed in the case of *Solenopsis fugax,* that isolated nests of *S. molesta* may be connected with nests of other ants by long underground galleries. It is perhaps by this hypogæic mode of travel that the workers are able to find and devastate fields of planted sorghum seed.

This species is often found under stones with colonies of other ants. The two colonies are connected by small galleries forming what are called compound nests. These small tunnels ramify through the workings of the larger ants. The minuteness of the galleries prevents the larger species from molesting the small invaders who, with comparative safety, forage at will.

Wheeler (1901, p. 533) reports *S. molesta* living in lestobiotic relationship with the following ants: *Pachycondyla harpax* Fabr., *Odontomachus clarue* Roger, *Camponotus maculatus* subsp. *sansabeanus* Buckley (?), *Camponotus fumidus* par. *festinatus* Buckley, *Formica Lasius, Stenamma,* and *Myrmica.* Forbes (1908, pp. 38, 41-42.) records it living in harmony with *Lasius niger-americanus* Emery, and King (1896, p. 169) with *L. niger* Linn. Other ants with which it has been found are: *Ponera coarctata* Latr. subsp. *pennsylvanica* Buckley (King 1896, p. 169), *Camponotus americanus* Mayr (King, 1895, p. 221), *Lasius interjectus* Neyr. (King 1895, p. 222), *L. claviger* Rog. (King, 1895, p. 222), *Prenolepis parvula* Mayr (King, 1896, p. 170), *P. imparis* Say (Mann, 1911, p. 30), *Myrmica lobicornis* Myl. (King, 1856, p. 170), *Tapinoma sessile* Say (Mann, 1911, p. 30), *Pheidole californica* Mayr (Mann, 1911, p. 30), *Camponotus maccooki* Forel (Mann, 1911, p. 30), *C. maculatus vicinus* Mayr (Mann, 1911, p. 30), *Formica fusca* Linn. (King, 1896, p. 169), *F. fusca* var. *sub-*

sericea Say (King, 1896, p. 169), *Aphœnogaster fulva* Rog. (King, 1896, p. 170), *Formica pallisle-fulva* subsp. *nitidiventris* Em. (King, 1896, p. 169), *F. cinerea* Mayr (Wheeler, 1902, p. 952) and the termite, *Termes flavipes* (King, 1895, p. 220).

In this investigation, *S. molesta* was taken in colonies of *Iridomyrmex pruinosus* var. *analis* Ern. Andre, *Cremastogaster lineolata* var. *punctullata* Emery, *Ponera inexorata* Wheeler, *Pheidole* sp., and the termite, *Leucoterms lucifugus* Rossi.

RELATION TO THE PHYSICAL ENVIRONMENT

MOISTURE

Being subject to extremes of floods and droughts, the ants of a colony must necessarily be able to adjust themselves to these wide variations. Some species of ants move their entire colonies to different situations. For example, the Argentine ant (*Iridomyrmex humilis* Mayr) moves its brood and constructs special wet-weather nests for the rainy season. In so far as it was ascertained, *S. molesta* does not move its colonies. In wet weather, the immature stages are brought near the surface to enable them to dry out quickly, while in dry seasons, it is next to impossible to find their colonies even in soil where they were known to be abundant. During the dry periods of the summers of 1914 and 1915, it was the rare thing to find even solitary workers in the localities of southern Kansas visited by the writer. This was true during the summers of 1916 and 1917 at Manhattan. As soon as the rains start, the ants come to the surface and are again easily located. The water-holding power of different soils varies and it is upon this factor that the rates of drying of the nests depend to some degree. In artificial nests it was noted that the colonies could withstand a saturated atmosphere much better than a dry one, in which case the individuals would generally perish.

TEMPERATURE

No experiments were conducted on the relation of the ants to temperature but it was observed that in cold weather the workers were more often found clustered on the lower surface of stones to get the heat which the stones absorb from the rays of the sun. In winter, the colonies burrow beneath the frost line and are seldom seen after cold weather arrives.

During 1914, numerous temperature observations were made under stones in situations where *S. molesta* was found. The

graphs (fig. 10) show curves of the temperatures during a normal day in the shade and under two stones, one and three inches thick, respectively. In June with a maximum temperature of the air of 93.5 degrees F., a temperature of 142 degrees F. was recorded under a stone one inch thick, and under a stone three inches thick a maximum of 125 degrees F. was noted. These extreme temperatures are those that the ant must undergo if the colony is to be kept directly beneath the stone.

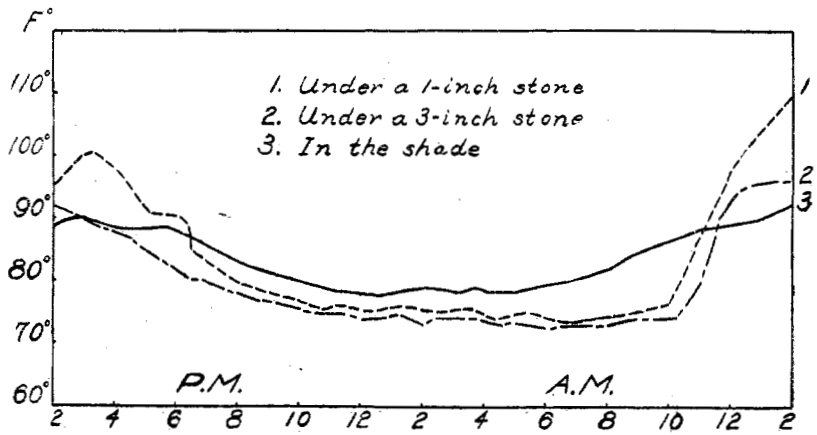

FIG. 10.—Graphs showing temperatures during a normal day in *Solenopsis molesta* habitats

LIGHT

As previously mentioned, the species is decidedly negatively phototropic in habits, due, to a great extent, to its small vestigal eyes. Like its European congenitor *S. fugax,* the workers of this species, without doubt, do much of their foraging in long underground galleries where they do not have to come out in direct light. Often individual workers are found on the surface of the soil, but, in most cases, it was seen that the individuals were in the shade of some tree or other object, or else the day was cloudy.

An exception to the above is to be had in the case of the winged males and females, which at the time of the mating flight reverse their normally negatively phototropic condition and become positively phototropic, flying out to the light. After fertilization, the female loses her wings and again shows a decided aversion to light. Wheeler (1910, p. 515) says "It is

evident that these reactions are highly adaptive and depend on important physiological changes in the wing musculature and reproductive organs."

RELATION TO THE VEGETATIONAL ENVIRONMENT

SEEDS AS FOOD

The ravages of this versatile little ant on the planted seed of sorghums are much the same as in the damaged fields of corn. Forbes (1894, p. 10) describes the injury to corn as follows:

> In the corn field these ants were usually collected about the kernels in the earth, and frequently more or less hidden in little cavities excavated in the softened grain. May 19, 1887, they were very abundant in a field of corn in sod in Champaign county, eating out the planted kernels. In autumn the same species has been detected by us indulging a similar appetite but in a way to do no harm. September 11 to 21, 1893, it was found feeding on and within the kernels of corn at the tips of ears, which had evidently been injured previously by crickets and grasshoppers. The solid substance of the grains is not actually eaten by these ants—a fact which I demonstrated by dissection of the ants—but it is simply gnawed away, doubtless for the sake of the sweetish and oily fluids of the softened kernels. If plants start from seed thus injured, they are shorter than others adjacent, and have a stunted, weak appearance.

Wheeler (1910, p. 268) states that *S. germinata* is the only species of the tribe *Solenopsidii* that is granivorous. However,

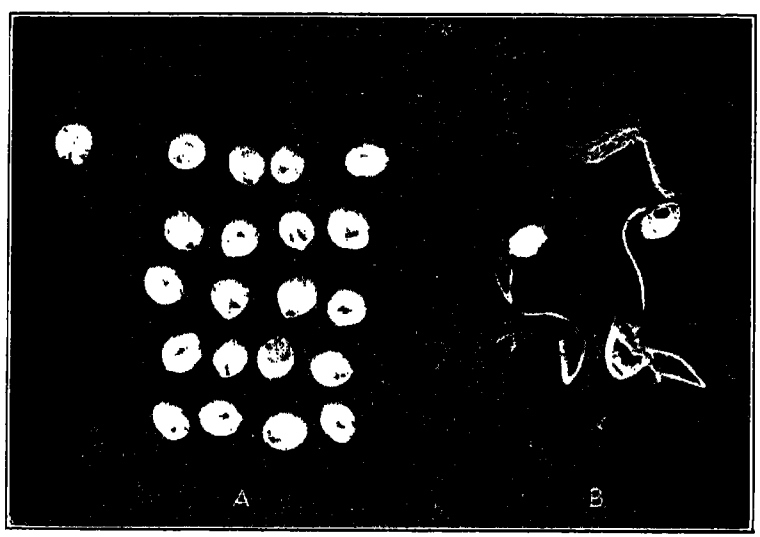

FIG. 11.—Kafir seeds injured by workers of *Solenopsis molesta:* A, seed before germination; B, germinated seed

on a following page (p. 427). quoting Forbes, he mentions X. *molesta* as eating the kernels of maize and again (p. 269) he states that *Solenopsis rufa* stores seed in its nest. Say (loc. cit.) first reported the species as an enemy of garden seed. The writer has found the species feeding on planted seed of the following sorghums: Kafir (fig. 11), cane, milo, and feterita. Workers often gather in the fall under corn piled on the ground where they gnaw on broken kernels.

STORAGE OF SEEDS FORWINTER

As this species is decidedly a granivorous species, it would not be surprising to find that they store quantities of seed for food during the winter. However, in an examination of perhaps a thousand colonies, only one instance that might indicate such a condition was found. This single nest was examined in the autumn of 1917. The colony, under a stone, contained a fertile queen and a fairly large number of workers and immature forms. About two inches below the surface of the soil, a small cavity in the earth, about one-half of an inch in diameter, was full of small seeds of various plants. No direct gallery connecting this chamber with the tunnels of the ant could be found and it is only an assumption that the ants had stored the seeds here for food. *S. rufa,* an imported species, is known to store seeds in its nest.

PLANTS AS FOOD FOR MYRMECOPHILA

The chief relation that this species bears to its growing-plant environment, is the fact that the plants offer sustenance to the many species of insects which the ant attends. In this connection the workers are recorded attending a species of *Dactylopius* on red clover (Webster, 1890, pp. 257-258), *Geoica squamosa,* an aphid on corn (Forbes, 1894, p. 99), and *Aphis maidi-radicis,* an aphis found on horse-weed *(Erigeron canadensis)* (Vickery, 1910, p. 116). The author has found the ants attending two scale insects, *Antonina nortoni* Parrott and *A. bouteloucæ* Parrott on the roots of grasses found in pastures. They also attend an undetermined aphid that is common on foxtail *(Setaria* sp.) and crab grass *(Panicum* sp.). These insects, in general, obtain their nutriment by sucking the juices of the plants. They convert much of them into honey-dew which is exuded on the plants or given up directly to the

attendant ants. Wheeler (1910, p. 340) says of this conversion:

> The aphids pierce the integument of the plant with their slender, pointed mouthparts and imbibe the juices which consist of water containing in solution cane sugar, invert sugar, dextrin and a small amount of albuminous substance. In the alimentary tract of the insects much of the cane sugar is split up to form invert sugar, and a relatively small amount of all the substances is assimilated, so the excrement is not only abundant but contains more invert sugar and less cane sugar than the juices of the plant. This excrement is voided in colorless drops, and when it falls on the leaves of the plants and dries in the air is known as honey-dew.

Rosenfeld (1911, p. 406) cites *S. molesta* living in Spanish moss thus having plants entering into the life of the ants as a material for abode. Clumps of bunch grass have also been found offering shelter to the workers.

FUNGI AS ENEMIES

No entomophagous fungus has been determined as an enemy of this species and it is doubtful if these insect-killing fungi play an important role in the life economy of the species. It is thought that the secretions of the workers in the nests tend to keep the brood free from fungi. However, in artificial nests, the common molds appear so frequently that rearing is often impossible. The necessary conditions of moisture and temperature in rearing colonies in such nests are ideal for fungous growth and apparently the workers of a colony cannot keep down the growth, for the fungus soon exterminates a colony when once started in a nest.

RELATION TO THE ANIMAL ENVIRONMENT

COMPOSITION OF THE COLONY

As mentioned hitherto, the ant colony consists of various members of the same species. In the colonies of *Solenopsis molesta* are found, in the adult form, winged and wingless females or queens, winged males, and workers or infertile females. It must not be understood that all these forms are found in the same colony or do they all appear at the same time. The workers are not divided into castes of workers and soldiers as in some species. The eggs which are laid by the queen are not distinguishable into groups of worker, queen or male eggs. Older larvæ can be divided into larvæ

that will produce workers, or larvae that will produce either males or queens. When the pupal stage is reached, the pupae are likewise separable. These colonies are in most cases started from single females and the size of the colony depends to a marked degree on the availability of food, the age of the colony and the fertility of the queen-mother. Some colonies are found with but few individuals while others contain thousands. Table I shows the composition of a number of nests that have been examined.

TABLE I.—COMPOSITION OF ANT NESTS

Date collected	Number of workers	Number of pupæ	Number of semipupæ	Number of larvæ	Number of eggs	Number of fertile queens	Number of inquilines (mealy bugs)
April 16	149			31			20
April 16	481			28			7
April 19	1349			1902			
May 1	64		6	216			
May 10	535	324	456	662	1182	1	
May 29	(a)	(a)	(a)	(a)	(a)	9	
July 20 (b)	216	34		74	12		
July 28 (c)	336	247		78		1	1
Aug. 10	348	10		1			
Sept. 2	1436	2012	355	64	28		
Sept. 3	101	197		62			
Sept. 29	312	485		48			

(a) Not counted.
(b) One, winged queen found.
(c) Four, winged queens; two, winged males; and seventy-three larvæ and pupæ of sex forms found.

CARE OF THE YOUNG

Among some species, the care of the brood is placed upon certain workers which have this service as their sole duty, and because of the nature of their work are called "nurses." In the colonies of *S. molesta* under observation, it was impossible to find any workers with nursing as their only occupation. The work was seemingly done by any or all of the workers present in the nest. It was no uncommon thing to see a worker, returning from a foraging expedition with food in her mandibles, drop her burden and care for a helpless larva or pupa. The care of the brood consists mostly of cleansing, feeding, and protecting. The protection afforded consists chiefly of transporting the immature individuals from places unsuited or dangerous to them. Workers also care for the adults, especially the callows, in much the same manner. They feed the larvae mostly with regurgitated food, but it is a common sight to see the workers feed them with small bits of seed or torn parts of dead insects. However, when hunger threatens, the workers will fail to keep their trust and straightforth devour some or all of their own young.

ASSOCIATES

This phase of the colonial life is perhaps one of the most interesting and characteristic of the species. The unique habit of preying on the brood of other ants gives the species the name "little thief ants." The different species upon which *S. molesta* are known to prey are practically all of those with which the ant has been found associated and listed in the preceding paragraph on "The Relation of Nests to Other Ant Colonies." Other associates are those which live in the nests of *S. molesta* and still others are the ant's enemies. Among those that live in the nests are two *myrmecophiles* reported by Schwarz (1890, p. 241; 1890, pp. 244 and 247), a species of *Lithocharis,* and a species of *Myrmecochara.* Other insects that have been reported found in the nests are *Atheta exilissima* Casey (Wickham, 1894, p. 80). *Rhyssemus sonatus* Lec. (Wickham, 1892, p. 322) (possibly accidental), *Isobrachium Myrmecophilum* Ash. (Mann, 1911 p. 29). *Aleocharini* g. et sp. (King, 1897, p. 102), and *Auxopœdeutes sodalis* Brues (Brues, 1903, p. 127). *Dactylopius* sp., a mealy bug, was found repeatedly in the nests of *S. molesta* in Kansas, this being the only true inquiline observed. When so found, there are gen-

erally a number of grass roots in the soil near the nests where the mealy bugs can get their nourishment. Workers will pick up these guests as they do with their own young and carry them to places of safety when danger threatens,

Other types of associates are those upon which the antsare in attendance, such as aphids and scale insects; while still another group includes those upon which the ant preys. The latter have been listed elsewhere in this paper. An interesting phase of the colonial life of this species is found in the attitude of members of one colony toward those from a widely separated nest. It was found that the ants from one colony would not tolerate members from the other colony, immediately attacking and killing the intruders.

ENEMIES

The known enemies of *S. molesta* are few and of widely different kinds. Spiders often trap the workers in their webs. Two other ants, *Cremastogaster lineolata* Say and soldier ants of *Pheidole pilifera* Roger, were observed killing workers. The common horned toads *(Phrymoma cornuturm* Harlan), upon examination of their stomach contents, were found to have eaten numbers of *S. molesta* workers. In the stomach of a skunk *(Eumeces* sp.), one *S. molesta* worker was found. A small mite *(Hypaspis* sp.), which is probably ectoparasitic, was repeatedly taken on workers, queens, and eggs. West (1910, pp. 14-22) found *S. debilis* in the stomachs of two moles. No endoparasites are known.

The following birds are known enemies of *S. molesta:* English sparrows, bank swallows, barn swallows, chipping sparrows (Judd, 1902, pp. 33-34), flicker (Beal, 1911, p. 56) and the kingbird (Beal, p. 16, and Judd, loc. cit.).

HABITS AND RESPONSES

CANNIBALISM

The cannibalistic habit is not a rarity in artificial nests of this ant, but to what extent it occurs in natural formicaries has not been determined. In the artificial colonies, it was frequently noticed that the eggs, larvæ, and pupæ gradually disappeared and several times workers were observed carrying about, or eating small bits of dead pupæ or larvæ. Perhaps this habit is only resorted to when food becomes scarce. It is to be expected that ants which prey on the brood of other species would eat their own young when necessity demanded.

SIGHT

It is plainly evident that the small workers with only vestiges of eyes do not seek their food by the sense of sight. Although no experiments were made to show the ant's aversion to light, it was often noted that the workers as well as the males and queens sought to shield themselves from light whenever exposed to it. Especially when the stones covering colonies were overturned, were the workers seen to seize the brood and carry it to the interior of the nests. On cloudy days or in the shade of some object, the workers were sometimes seen on the surface of the soil. If circumstances were such that they were compelled to leave the shade they would soon find a crack in the soil or some object, under which they could hide.

The number of facets of the eyes is possibly an indicator of the ant's ability to see. *S. fugax* has been shown to have the following number of facets—worker 6 to 9; female 200; and male 400. It is not unlikely that these, or approximately these, same numbers will be found in *S. molesta.*

HEARING

Ordinary noises have no effect on workers in artificial nests and it is doubtful if the auditory organs of the ant have reached any special degree of development.

SMELL

This is perhaps one of the most important senses of the ant. Due to poorly developed eyes and auditory organs, it is commonly known that ants recognize each other by their nest odor, and it is also by this method that they are able to forage at long distances from their nests. As to their trail-forming habits, only a single colony has been observed by the writer to form a trail. On August 25, 1916, a large number of workers were seen carrying small bits from a graham cracker to a hole in the soil about eight inches from the cracker. They were going and coming in a single trail, following each other and side-stepping to allow each other to pass. On the following day, a second trail was found at a second cracker a few feet from the first. These workers were evidently from the same colony. This trail was about 12 inches long. In these trails, as other investigators have shown, the workers are guided almost entirely by the sense of smell.

METHODS OF CONTROL

Earlier investigations brought out the fact that the workers ceased to damage the plants soon after the seed germinated. It was therefore evident that measures of control should be of such a kind as to save the seed between the time of planting and germination. This could be done, in part, by hastening germination. A general study was made by Mr. J. W. McColloch in 1912 of the agricultural methods practiced in planting sorghums, with especial attention to the methods of seedbed preparation and the manner and time of planting. From the data thus collected the four methods which follow were suggested for the protection of the seed. These are fall plowing, early planting, surface planting and treatment of the seed with repellents.

FALL PLOWING

Plowing in the fall, or even listing, aids in preventing ant injury by getting the soil in better condition for the seeds to germinate. Breaking the soil enables the ground to accumulate more moisture and makes it easier to prepare a good seedbed in the spring. This practice breaks up, before winter, any nests of *S. molesta* that are in the field. All measures which tend to increase the rate of germination reduce the amount of ant injury.

EARLY PLANTING

During the past few years it has been noted that all reports of damage were coming from late-planted fields while the early-planted fields showed scarcely any injury. Field studies, together with the general experiences of sorghum growers, have brought out the facts that the early-planted seed is rarely if ever injured, especially if it was surface planted. This is because of the fact that the seed germinates in the soil before the ants are very active in the spring. McColloch found that in 1911 and 1912, all the fields, where injury was reported, were planted after May 20, and in many cases as late as June 1. The regular time for planting kafir in southern Kansas has been established by the Kansas Agricultural Experiment Station and United States Department of Agriculture as about ten days after corn planting time, or about May 10. It is customary in the southern part of the

state to delay planting kafir, thus producing ideal conditions for injury by the ant.

SURFACE PLANTING

Surface planting was first brought to Mr. McColloch's attention on a farm at Hackney, Kan., in 1911. At this place, 25 acres had been planted to kafir, of which 10 acres had been surface planted and the remainder listed. This field was examined June 7 and almost a perfect stand was found on the surface-planted part of the field. The listed area had been planted three times and showed less than 50 percent of a stand. The only explanation for the difference in the stands was probably the two methods of planting. Further investigations have shown that each year very little injury occurred on surface-planted fields, especially when the planting is made at or near the optimum time for planting kafir.

Surface planting has several advantages over listing, and experience has shown that in places where the soil does not blow, it is preferable to listing. Sorghums need warm soil and will lie in cold soil many days before germinating, thus giving the ants a longer chance to work on the seed. Surface planting provides a warm seedbed and thus hastens germination. Planted seeds in lister furrows are often drowned out by water from rains standing in the furrows.

EXPERIMENTS WITH REPELLENTS

Among the measures that were early suggested for the control of the ant was the treating of the seed with some repellent that would keep the ants away until after the seed had germinated. In 1912, Mr. McColloch conducted a number of experiments in the vicinity of Derby, Kan., to determine the value of various repellents against the ant. In one experiment, 10 plots of kafir were planted in a badly infested field, using kerosene, turpentine, "Black Leaf 40," oil of lemon, camphor, refined carbolic acid, crude carbolic acid, and two brands of commercial chicken dip composed largely of crude carbolic acid and creosote. These plots were later inspected and the results indicated that crude carbolic acid or any stock dip composed largely of crude carbolic acid and creosote would practically protect the seed. A number of farmers who had followed this experiment immediately treated their seed with the

repellents and in every case obtained an excellent stand. The result of this work was so promising that the following year these substances were recommended generally and many hundreds of acres were planted with seeds treated with them. Many of the fields were later visited and in every case an excellent stand was found. The lowest germination reported by any farmer was 75 percent.

A continuation of the experiments in 1914 showed results strikingly at variance with those of the previous years. In many tests few seeds would germinate when dipped in crude carbolic acid and in other tests the treated seed germinated as well as the checks. These tests were made both in the field and in the laboratory. The latter consisted of four groups of experiments as follows: Blotting paper tests, soil germination tests with no ants present, soil tests in a greenhouse with no ants present, and soil tests with ants present. Several thousand of these tests have been carried on and a more detailed account of them will be given in a later publication.

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