A study of the biology and feeding habits of an ant : the tropical greenhouse Pheidole, in connection with its control under greenhouse conditions.

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C O N T E N T S

INTRODUCTION

The work presented herewith was commenced during the end of 1936 and was suggested by inquiries received at the Massachusetts Experiment Station. Not infrequently several species of ants are reported as household pests in all temperate regions of the world, but it is especially in tropical and subtropical habitats of men's endeavors that ants dispute their rights and become a serious factor in their associations. The subject of these investigations, Pheidole anastasii, v. cellarum Forel, is a representative of a genus of neotropical and subtropical ants of which several are known to be harvesters and seed-gatherers. This small reddish brown ant was reported to be present in a local greenhouse range where three sections of about 250 feet by 60 feet, or a total of 60,000 square feet of glass, is devoted to the culture of gardenia flowers. Some time during the last ten years this species of ant apparently has been introduced in soil of balled nursery stock from the Gulf States or via other plant material received from an intermediate greenhouse.

During these years the ants have found the temperature and general conditions for development so much to their liking that their numbers and general invasion throughout the greenhouse range took on noticeable proportions.

At times and in certain places of the greenhouses, these ants would congregate in such abundance that questions were raised as to their importance in connection with the presence and distribution of mealy bugs and possible diseases, their significance as to feeding habits, and the possibility of their control or eradication.

The ensuing investigations were made in an effort to learn more about the fascinating behavior of this ant, its food habits with possible means of control, and its inter-relation to the greenhouse mealy bugs which may bear directly on the economics of flower production.

DESCRIPTION OF THE SPECIES

The species with which this study is concerned belongs to the cosmopolitan subfamily Myrmicinae, with some twenty-five genera. In the genus Pheidole the workers are strongly dimorphic, the antennae are 12-segmented, with a 3-jointed club which is longer than the remainder of the funiculus. The thorax is much constricted between the meso- and meta-thoraces; the mandibles are very broad and the frontal area is small but clearly defined. The major workers, or so-called "soldier," has the head enormously developed, it being twice as broad as the thorax.

In the female again we find broad mandibles, the apical margin acute, without teeth or with only two teeth anteriorly; the frontal groove extending as far as the occiput; thorax is broad and depressed above; metathorax bidentate; second joint of petiole transverse subtuberculate laterally; maxillary- and labial-palpi are 2-jointed.

The male has 13-segmented antennae and the first segment of the funicle is spherical. The remainder are cylindrical. Aside from being winged and very slender, this form is readily distinguished by its moniliform antennae. The marginal cell of the wing is open at the apex; the apex of the second submarginal cell is not appendiculate.

Cresson, in 1887, lists the following species:

bicarinata Mayr.
californica Mayr.
commutata Mayr.
dentata Mayr (var. *Morrisi*)
Morrisi Forel
pennsylvanica Roger
vinelandica Forel

Wheeler, in 1910, lists some forty species, exclusive of subspecies and varieties; and by 1935 well over sixty species are recorded in the literature.

Most of the twenty species recorded in this country are distributed in the southern States, although a few members, such as Ph. vinelandica, pilifera, and tysoni, have found their way into the more northern States. Pheidole pilifera Roger has been found in Massachusetts and, according to Wheeler (1916, p. 584), is common in the sandy regions of Long Island and in the southern part of Connecticut. Again mention is made of it being a harvesting ant, storing grass and other seeds in its nest chambers. The huge-headed soldiers in several species of the genus undoubtedly function as seed crushers.

Pheidole anastasii was described by Emery (1896) from material obtained in Costa Rica. The color of the soldier is given as yellow to brownish-yellow; the mandibles, anterior margin of the head, and the extremities of the abdomen are brown; frontal lamellae and antennae smoky. The posterior portion of the third abdominal segment (the gaster) and following segments are shiny; legs shiny. Length 2 2/3 to 3 mm. The worker is of the same general color; length 1 3/4 mm.

The variety cellarum was given the following description by Forel (1908). The color is red-yellowish, much deeper than the type species, but brighter than the variety Venezuelana Forel and a little deeper than variety Johnsoni Wheeler.

In general, it resembles the latter very closely, but the abdomen is duller than in either anastasii or Johnsoni.

Cellarum is described from the botanical gardens of Zürich, Kew, and Dresden, and Forel finds that the examples from Hamburg, which are introduced from Guatemala, resemble v. cellarum closer than the type material from Costa Rica.

DISTRIBUTION

Ph. anastasii, v. cellarum, as far as is known, has a limited distribution in greenhouses in the eastern part of the United States. It has been reported from Massachusetts, New York, New Jersey, Maryland, District of Columbia, Florida, and Illinois, and probably has escaped notice in several other localities, due to its small size (2 mm.) and its superficial resemblance to Monomorium pharaonis L.

M. R. Smith, in correspondence, states: "I am sure the ants were found in greenhouses in all of the States (mentioned) but Florida, and my records on this State are not detailed enough to be positive."

Since Ph. anastasii, v. cellarum under western Massachusetts conditions was found to forage outside of the greenhouses, and builds temporary nests, there appears a possibility that under Florida conditions the species may sustain itself out-of-doors for a great part of the year, if not throughout the colder months. It was found to be very sensitive to low temperatures, however, and succumbs quickly when exposed to temperatures around 32° F. The original description by Emery (1896) was based upon material collected in Jimenez, Costa Rica, whereas Forel (1908) described var. cellarum from European specimens collected in the conservatories of the Botanical Gardens of Zürich, Dresden, and Kew.

Donisthorpe (1927) in his book "British Ants" gives several hothouse localities in England from which this ant has been reported and adds the Brussels' Botanical Gardens, as reported by Bondroit (1911). Orchid houses, with often high and humid temperature conditions, are apparently favored, and Santschi (1920) records "cellarum as being very abundant in the orchid houses in the Gardens at Zurich." An earlier account is given by Viehmeyer (1906) stating that "they (the ants) eagerly attended plant lice and scale insects, and also sought the extra floral nectaries of Cattleya labiata."

It is felt that a common name, for the use of greenhousemen and the entomologist working in the field, would be very desirous. In recent correspondence (February 24, 1939), Dr. M. R. Smith writes that cellarum has been intercepted by quarantine inspectors of the Bureau of Entomology and Plant Quarantine, Washington, D. C., from a plant shipment originating in Guatemala, and further expresses the belief that this ant may very well have been distributed in both Europe and the United States by means of tropical plant importations, probably orchids, from the Central American countries. In the latter part of the last century, orchid collections in botanical gardens, as well as on private estates, were in high esteem, and it seems appropriate and justified to propose the name TROPICAL GREENHOUSE PHEIDOLE.

REVIEW OF THE LITERATURE

In attempting a review of the literature of any group of insects, one must select from the ever-increasing amount of publications, trying to narrow down to the essential previous information bearing directly upon the subject of the investigation.

When looking up references made to the ants, we find that this form was already known in early history and that it had the attention of philosophers and the early chronicles of ancient times. In fact, the ant, with its clear demarcation of head, thorax, and abdomen, was soon regarded as the typical insect, and it is possible that the name "insect," as such, was derived from the Greek word "cut-in" and that the Latin name, "insectum" was originally applied to the ants in particular. The literature published during the last seventy years represents a stupendous array of work done in the taxonomic, biological, and experimental fields of investigation. Wheeler (1910) alone lists by estimation over a thousand authors, many of whom published extensively on the subject. Some of the more prolific Myrmecologists could be enumerated, as André with 30 papers; Donisthorpe with 20 papers; Emery with well over 130 titles (doubling the number by the time of his death in 1925); Escherich, 20; Fielde, 25; Forel close to 170; Janet with some 50; Mayr, 50; Wasmann, 160; and Wheeler with 75 titles.

Since the early years of this century, numerous other publications have occurred and during the last twenty years some 70 species, subspecies, and varieties of the genus *Pheidole* alone have been named, described, and discussed. Emery (1896) described the species under consideration, from Costa Rica, as occurring in the neotropic regions, and named it *Pheidole* *anastasii* (See "Description of Species."). Forel (1908) described the color variation *cellarum* from European material, and as compared to specimens introduced from Guatemala.

Although *Ph*. *anastasii* normally is an inhabitant of tropical and subtropical regions of the New World, by means of the roads of commerce and transportation, ever more suitable breeding grounds are being invaded and held by these persistent colonizers. The shipments of nursery stock from one locality to another, and the exchange and trading of greenhouse plants, have given the species an opportunity to establish itself far outside its natural life zone, in America as well as in other parts of the world, which they reached in ships.

"In Zürich," Forel (1926) states, "where I once described Brachymyrmex heeri, this ant was afterwards destroyed and replaced by Pheidole anastasii, v. cellarum." Further on he notes "it is now invading countless warm conservatories in all countries." Thus he points to cosmopolitanism of the more adaptable forms, due to international trade. This is well illustrated by the introduction and spread of the Argentine ant (Iridomyrmex humilis). Although this species had been described by G. Mayr in 1868 from workers collected near Buenos Ayres, Argentine, it was not until 1904 that the "New Orleans ant" or more significantly referred to as "the ant," was first reported in literature.

Newell (1908) gives an account of its history and probable introduction and was able, upon testimony of local observers, to establish the probable point of entry of this species in the South. A New Orleans newspaper editor, and for years a student of entomology, had observed the Argentine ant as early as 1891, when it was still comparatively rare, in one of the public parks, some five miles from the river, but already quite common in one section at the water front. It was in this area that the incoming coffee ships from Brazil docked to unload their cargoes. In the same account, Newell reports that "the dissemination of this ant from New Orleans to towns along the principal railroad lines within 200 miles of the city has not been particularly rapid, but has been very complete." Aided by modern means of transportation, however, the spread has been very rapid as well. In 1913, Newell and Barber (U.S.D.A. Bull. 122) gave its distribution as throughout the southern States, and California at that time had two established nuclei of infestation, - one in the southern part in the vicinity of Los Angeles, and the other in the San Francisco Bay region. It was first observed by J. Chester Bradley in Berkeley during 1907. Notes of warning were sounded by Prof. C. W. Woodworth during 1908 and 1910 in brief circular publications, but the Argentine ant had found new suitable breeding grounds and had come to stay.

Wheeler (1910, p. 154) reports I. humilis from Cape Colony, South Africa, Portugal, and according to Stoll (1898) "has been imported into Madeira where it has supplanted Pheidole megacephala, a previously introduced species, which was the house ant in the days of Heer in 1852." Also in the Cape Colony it has overwhelmed a good part of the native ant fauna, and has been reported from Hamburg, the center of

France, from the islands of Sicily and Guernsey, Belfast, Edinburgh, and Manchester.

I. humilis Mayr, though neotropical in habitat and indigenous to the northern regions of Argentina and to Brazil, appears to thrive, or at least maintain itself, at lower temperature ranges, than *Pheidole anastasii*, and some Old World tropical ant-importations, such as *Monomorium pharaonis*, *Solenopsis rufa*, *Pheidole megacephala*, and others. The latter all require considerable warmth, and have succeeded in gaining a foothold in dwellings where they can avoid competition of our native ants. *M. pharaonis*, our very small house- or sugar-ant, occurs often aboard ships and in seaboard towns, and does not usually nest out-of-doors except in the southern portions of the United States. Newell and Barber (p. 18) present a table of mean temperatures of territory occupied by the Argentine ant. The winter mean minimum temperature for Alabama, Mississippi, Louisiana, and California varies from 38° to 46° F., whereas the absolute minimum temperatures recorded are from -6° to -1° F. in Alabama and Mississippi; from 1° to 7° F. in Louisiana; and from 18° to 29° F. in California. As will be discussed in one of the following sections, this is much below the temperature range congenial to *Ph. anastasii*, v. *cellarum*, and for that reason it does not seem likely that this species would ever gain a similar wide distribution as the Argentine ant has, except that under the mild and temperate climatical conditions of the sonoral regions in California, a survival, if introduced, would perhaps not be impossible. Some tropical introductions (Wheeler, 1910), such as _P_. _flavens_ and _Camponotus_ _floridanus_, manage to live for considerable periods of time in northern hothouses, and _Ph_. _anastasii_, v. _cellarum_ seems to have been successful in several instances, as is known from recent reports on its distribution.

As regards the feeding habits and possible subsequent economic importance of _Ph_. _anastasii_, v. _cellarum_ the literature lacks very extensive information. Several members of this genus are known as harvester ants, storing and feeding upon small grains and grass seeds. In the more primitive subfamilies Ponerinae and Dorylinae, we still find exclusively carnivorous forms either, as in the latter case, roving and trekking through ever-changing new hunting grounds, or living, as the former does, in small sized colonies.

In the other subfamilies, the ants have acquired a more varied and omnivorous task, feeding upon crippled or newly emerged insects as well as upon the sweet excretions of aphids and coccids or the nectaries of plants. Plant materials in the form of seeds, roots, and fleshy fruits of various kinds are also accepted, whereas only one tropical tribe, the Attii, lives exclusively on vegetable matter in maintaining fungus gardens from which the food is procured. Except for the labt mentioned and some of the more specialized seed-harvesting species, most ants readily adapt themselves to new foods.

Among the true harvesting ants, two species of Pogonomyrmex are found in the southwestern States. In the desert regions where insect food is scarce during many months of the year, the storage of seeds of herbaceous plants affords a lasting source of nutritious food, though insect food is not disregarded, especially during the period that brood is being raised. Wray (1938) found an estimated two quarts of seeds tightly stored in the granary chambers of P. badius in North Carolina during November, and gives an illustration of the arrangement of the nest. The seeds included those of ragweed, crabgrass, sedge, pokeweed, red clover, evening primrose, and vetch. Sykes (1835) was the first to describe the seed-storing habit of ants and observed Pheidole providens at Poona, India, storing grass seeds. After confirmation by Jerdon (1854), all final doubt was removed when Moggridge (1873) published his studies of the granaries found in the nests of Messor barbarus and structor, "the very species that had been observed by the ancients."

He further notes "that not only *Ph. pallidula* but also *Ph. megacephala*, an Old World species which now overruns the warm portions of both hemispheres, is a harvesting ant."

In spite of the fact that many members of the genus *Pheidole* have been found to exhibit seed harvesting habits or appear to be exclusive seed gatherers, as has been noted previously, some may revert back to the ancient carnivorous diet, either partially, or temporarily when larvae are being raised, or may adopt a more diversified diet.

During recent years investigations have appeared, of ants in their relations to insects of economic importance in agriculture. It is of interest to mention here some instances where *Pheidole* spp. are of direct assistance to man in his warfare against insect pests, or, on the contrary, become an upsetting factor in man's control programs. In some notes on the rice borer (*Chilo simplex*), Zwaluwenburg (1923) lists among the beneficial insects attacking this pest *Ph. megacephala*. This same species figures in the protection and distribution of *Pseudococcus brevipes* Ckl. in pineapple plantations. Carter (1932) ascribes this "big-headed ant" as being the principal factor in the movement of the mealy bugs from their wild hosts and old pineapple fields to new plantations. Although this mealy bug persists while the cuttings are drying preparatory to planting, most of these populations will disappear, the author found, due to predators or to the failure of the ants to become established quickly enough.

Again, another species, Ph. vinelandica, is reported attending Pseudococcus dentatus on Ambrosia sp. in Mississippi (Lobdell, 1930).

A good word is done for an unidentified species of Pheidole by Jarvis (1931) in Queensland, Australia, where among the suggested means of controlling the moth borer of cane, this ant is listed next in importance to two parasites, a Tachinid fly and Apanteles nonagriae.

Among the economic insect pests of certain coffee plantations, the predatory Pheidole punctulata may determine the seriousness of the infestation. Le Pelley (1932) states that the common coffee mealy bug, Pseudococcus lilacinus, is a most important pest on Coffea arabica in East Africa, but that its status depends chiefly upon the species of ant attending it. He found that where Ph. punctulata exists, the mealy bug frequently takes on proportions of a major pest. If, on the other hand, the attending ants are either Acantholepis or Crematogaster, the mealy bug only occasionally becomes important, or but a minor pest.

In the highlands of Kenya Colony, the mealy bug Pseudococcus citri also occurs on Coffea robusta, Rhus, and Citrus, and has a root-infesting strain on C. arabica (James, 1933). Among other ant visitors, this Coccid is also attended by *Ph. punctulata*.

From the foregoing accounts it appears that among the members of the genus *Pheidole* some species are instrumental in making control measures against mealy bugs inefficient whereas in other instances the predaceous behavior of the ants helps to destroy noxious insects.

In their studies of the citrus mealy bug and its association with ants in the eastern Province of the Union of South Africa, Smit and Bishop (1934) find that serious damage results from the wax (honey dew) and formation of sooty mold on the local citrus fruits. Various sprays and cyanide fumigation proved unsatisfactory, or did not effect control. *Cryptolaemus montrouzeiri* was ineffective due to the activities of ants and final recommendations are given in the use of the Argentine ant poison (U.S.D.A. formula) and in banding the trees. As a result of the ant control a great improvement in the quality of navel oranges was obtained.

From the coastal plain of Palestine, Klein (1936) makes similar observations in regard to the main pests in citrus groves, and mentions the attendance of mealy bugs by *Crematogaster jehovae* For.

An early account by King (1897) relates his observations of small numbers of aphids and coccids in ant nests in Massachusetts. As the nests become frozen the ants pass the winter in a torpid and inactive state without the necessity of food. He is of the opinion that "the only purpose of the ants for collecting these insects in the autumn is to supply them with food during the fall and spring months when other food is not obtainable." The "herds" were found in food storage chambers and were not observed to feed upon any of the roots entering the ant's nest, but "seem to be in as good condition in Spring as in the Fall of the year."

A more recent investigation concerning the relation of ants to aphids is contributed by Herzig (1937), who gives a detailed account of his studies with Lasius niger, L. brunneus, L. fuliginosus, and Iridomyrmex humilis to Aphis sambuci, A. fabae, A. pomi, and Macrosiphum rosea. The work was conducted in the field and partly in artificial nests. From his ecological studies the author finds that the ants frequently transport aphids in summertime, but only downward into their nest and upon closer examination finds them all dead and evidently intended for food. He further observes that young aphids are not distributed in Spring, but that the ants seek out the new colonies from winter eggs. As to the claims that ants guard their aphid colonies, Herzig disagrees in that the ants "do not intentionally protect aphids but merely reach to swift moving bodies and regard any attack as directed against themselves." As further proof of this response he notes "that sluggish Coccinellid larvae and adults are seldom disturbed." In the final analysis, it is found that injury is evident particularly in a reduction of yield if the attending ants (by means of the aphids) drain off the necessary plant juices close to the blossoms and incidentally drive away pollinating insects. In this manner Lasius niger may be of much importance in vegetable gardens.

From the various accounts cited on the preceding pages, and many others could be added, it becomes evident that not only a great amount of field observation is necessary to determine the behavior of certain species of ants in their relationships to the sources of their food supply, but also that the study under controlled laboratory conditions is of great importance and a valuable additional means to learn more fully the intricate ways of ant life.

Many types of artificial formicaries or ant cages have been employed since the days of Swammerdam's (1737) first serious studies of ants, and who used a simple moat of water constructed from a five-inch, slightly concave strip of wax. The earth, ants, and nest contents to be studied were placed in the center of this water barrier preventing the ants from escaping. Wheeler (1910, pp. 548-556) gives an adequate review and diagrams of the development of the diverse types of ants nests made from glass and plaster of Paris. After

Huber (1810), Lubbock (1882), and Wasmann (1899), who all used soil as a nesting medium, Janet's ants nest (1893) was molded in a block of plaster of Paris and considerably different* from the existing types. A small compartment designed as a water reservoir allows the porous plaster block to absorb sufficient moisture to furnish the ants with suitable conditions to live in and rear their brood. With some modifications, the Janet plaster block (fig. 3) was used in the present studies of Pheidole anastasii, and will be discussed more fully in a later section. Light and very compact glass nests were first contrived by Miss Fielde (1900) and are especially suited for collecting small colonies in the field and for close observations and experimentation in the laboratory. A more detailed description of the construction was published by her in 1904.

Newåll (1909) found that the Janet cage did not fill the requirements in his life history studies of the Argentine ant, and modified the Lubbock nest, consisting of two glass panes, separated by means of leather strips. In spacing the glass exactly 1.75 mm. apart it was found that the workers' activities in chambers and galleries could not be hidden and that the much larger queen would have ample room to move about in a natural fashion. The space between the glass was filled with fine soil so as to afford the ants a normal nesting medium. To avoid escape, each colony was placed on wooden stands in running water, which, after trying several deterrents, was found to be the only efficient means.

Another observation nest that may be used to advantage is composed of a cylindrical jar containing a glass cylinder of smaller diameter, depending upon the size of the ant to be studied (Barth, 1909). The narrow space between the two cylinders is filled with moist earth, presenting an extensive natural building area in which the activities of the ants in their galleries and chambers aan be followed readily. The central well is used to moisten the nest periodically, food can be introduced here, and an electric light can be lowered for better observation.

In the Handbuch der biologischen Arbeitsmethoden, Kutter (1928) reviews the various types of observations nests in use and gives detailed instructions for the pouring of gypsum blocks. He suggests staining the plaster with ochre or umber, as Janet originally did, to better be able to determine the moisture of the nest. A few applications of a ten percent alcoholic salicylic acid solution are recommended to prevent fungous growths. Finally references are given to publications by Santschi, Emery, and Forel, describing the construction of small or temporary nests from sliced porous bricks, from pressed peat blocks and gypsum, for use in microscopic observations and studies on small ants.

Enough is said to indicate the great variety of nest construction and the final selection by the student of ant life depends upon the ingenuity of the worker and the special problem at hand. It should, however, be borne in mind that ample provisions should be made for an adequate supply of moisture and fresh air, but not an overabundance of food, the latter of which soon spoils in the humid atmosphere, causing putrifaction and fungous growths to the impediment of the colony.

BIOLOGICAL INVESTIGATIONS

Survey of Local Greenhouses

The presence of *Pheidole anastasii*, v. *cellarum* in disturbing numbers was first reported from the greenhouse range of Butler and Ullman, Inc., wholesale growers of gardenias and roses, in Hadley, Massachusetts. Upon preliminary investigation during the early winter months, but a few specimens were encountered along the retaining bench boards. Closer inspection, however, disclosed a preference of the small red worker ants for the ends of the benches and along the central crosswalk where the main steam pipes entered the houses to furnish heat through smaller laterals. In an effort to determine ant populations and locate nests, if possible, honey was placed at certain distances, but although some ants were attracted to this bait, several were observed foraging on small centipedes, isopods, and other dead animal matter. Bacon fat proved more attractive, but not quite as suitable and lasting as peanut butter. The vegetable oil of the latter was very much liked and preferred to other foodstuffs tested, whereas the dry remaining substance would finally be carried off. The penetrating odor of peanut butter is readily perceived by the ants, and the material usually is found within ten minutes. Making use of this fact, all subsequent surveys were made with this cheap and readily available ingredient.

Two-inch square pieces of waxed paper were placed at distances of twelve linear feet along the sides of the beds throughout the greenhouse section to be surveyed. Approximately one hour after the entire section was thus baited, an estimate was made and the abundance was recorded according to a predetermined six-point scale (fig. 1), using a rating as follows:

o - no ants present

ø - single specimens (used optionally)

/ - few; 6 - 15 ants

X - many; 50 - 80

⊗ - abundant; 100 - 200 and trail formation

• - very numerous; 500 or over; heavy trails

In connection with the seasonal abundance and control investigations, to be discussed later, periodical surveys were made throughout the year. Upon inquiry it was learned also that the original and older greenhouse range of the same Corporation in Northampton, Massachusetts, harbored ants and it soon developed that the same species was present. In fact, it appears likely that the ant was first introduced in the older establishment by means of potted plants or balled nursery stock received from other greenhouse concerns or nurseries in the southern States.

A limited survey was conducted to determine further to what extent the ant existed locally. The Montgomery Company, also situated in Hadley, Massachusetts, and well-known wholesale growers of roses, has one house devoted to gardenias. Upon inspection, no trace of *Pheidole* was found, although these houses are not over 300 yards distant from those of Butler and Ullman. It may be remarked that this greenhouse range, primarily designed for the production of roses, is kept at a comparatively low winter temperature and did not appear especially suitable to the requirements of the ant.

A number of greenhouses visited in the vicinity of Springfield, Massachusetts, were not infested. William Schlatter & Son, Inc., florists of that city, however, had received a shipment of *Sansevieria* sp. (known as "snake plants") on September 20, 1938, from Apopka, Florida, and on the two benches where these plants had been placed, *Ph. anastasii*, v. *cellarum* was abundant, though restricted in area. This illustrates very convincingly the manner of distribution of this species to greenhouses outside of its normal range, and incidentally brings out the difficulties and importance of quarantine measures which demand an ever increasing amount of biological study and a profound evaluation of acquired facts.

Field Observations

Nesting Habits.

The ants are very sensitive to moisture and temperature variations and even under controlled conditions as prevailing in a well-managed commercial greenhouse, preferences in nesting sites are in evidence. The individual greenhouse sections of the range under consideration are built in an east-west direction. A central crosswalk running south to north not only connects the separate houses, but contains the overhead steam mains, from which the smaller lateral lines furnish heat under the benches to the east and to the west on either side, a distance of 250 feet. Furthermore, a tunnel constructed under the crosswalk contains a complex of return steam pipes and provides for the flow of condensation water. It can readily be seen that under these conditions, an appreciable and constant temperature variation should exist. The ants have responded to this greenhouse situation as more favorable to their requirements, and we find the greatest concentration of ants on both sides of the crosswalk, and this is still noticeable some fifteen to twenty feet distant from the heat source. Other factors influencing the distribution of the ants will be discussed later, under the heading of "ecological relationships."

The nests of Pheidole anastasii, v. cellarum are not, or only little, in evidence, and consist of subterranean excavations, inconspicuous chambers and runways, and have no definite mound or entrance. The workers follow along temporary trails, if an abundant food supply has been located, but are more apt to be hunting independently. Following temporary runways the ants may disappear in small crevices in the soil, spaces at the bases of stakes or plant stems, or follow the vertical boards of the greenhouse benches for some distance. These quasi-entrances may continue as galleries or superficial runways and are very indistinct and difficult to follow. If the nest has been located some distance from where it had been expected, it merely consists of a series of irregular chambers, large and small, connected by broad galleries and containing clumps of brood in various stages of development. Among the assemblage of ants, numerous pale-colored callows may be found and a dozen or more dealated queens, depending upon the size of the colony.

The species as a whole is of a timid nature. Upon the slightest disturbance the workers will abandon the most delectable bit of food and flee over the surface of the ground. The very much larger soldiers with enormous square heads and ferocious jaws will lead the general exodus and do not seem inclined to fight. It has been experienced only once that a soldier inflicted a just noticeable bite in the tender skin at the base between two fingers. The queens are even more timid and, in addition, strongly photophobic or negatively phototropic. Upon opening a nesting site, frequently no queens are detected, although they are 5 mm. long and very active runners. When nests are dug up and the queens are exposed, their strongest response is to hide from view. The workers will at once start gathering their brood, while the soldiers mingle, excitedly and with apparent little purpose, in the general confusion. The queens, on the other hand, quickly seek cover and remain tightly under the smallest bit of soil. Only twice has a dealated queen been observed to appear voluntarily above ground, in both cases apparently attracted to food, although actual feeding was not observed.

The nests are not in restricted units, but rather are formed by a series of galleries and chambers, connected by irregular runways and more or less extending throughout a suitable area. Nests may be found at almost any place within the soil of the wooden greenhouse benches, under or within the root-sod or along the bench boards. It appears that any somewhat sheltered place around 70° F. is acceptable as a temporary or more permanent nesting site. The dense root masses protect the brood from sudden inundations, and a great preference is shown, also, in the joints and cracks of the wood work and the decaying surface of the floor boards. It is here that a constant high humidity prevails and the rotten wood surface seems to be especially selected for the young, somewhat transparent, larvae. The older larvae, whiter in appearance, and the pupae are frequently found in higher levels of the nest. After watering the soil, the building of small mounds, one to two inches in height, frequently occurs. This mound-building response has not been explained fully, but seems, in part, to be a reaction to an excess of water and perhaps a subsequent cooling of the soil. In confined colonies under observation it was found that, after watering, a two-inch high heap of soil was piled up against the glass side of the container. A little over an inch under the original soil level an aggregation of brood was found, and it is believed that these mounds are comparable to the "wet-weather sheds" of the Argentine ant, as mentioned by Newell and Barber (1913, p. 30). The formation of such mounds may be explained by the fact that renewed excavation is necessary after the nest structure has suffered by the inflowing water, whereas at the same time, the drier location may be better suited temporarily for the storage of some of the brood. It is interesting to note here that such soil deposits are often, but not always, placed against a solid object. The latter may be a metal stake, the side board of the bench, or the stem of a plant. Complication in interpretation enters where occasional mealy bugs are at the base of such plants, and this point must be discussed more fully under the section dealing with the relationship to mealy bugs.

Foraging Habits.

The manner in which the ants find and gather their food shall be discussed here only briefly and as bearing on their general behavior in their greenhouse association. Having well-developed compound eyes the ants hunt independently and are not primarily restricted to well established trails, leading from the nesting site. Lone workers are found moving about on the surface of the greenhouse benches, forming trails only if a large supply of food has been located or when following some part in the construction of the greenhouse. Individuals have been observed to carry collembolans and occasionally a first instar mealy bug. After the gardenia plants have been syringed, a number of small insects become disabled or succumb to the pelting force or chilling of the water, and it is at such times that the ants find an abundance of food. Dead sowbugs, millepeds, flies, dung beetles, or cockroaches attract hundreds of workers, and it is on these occasions that the large-headed major workers or so-called soldiers appear. Their functions seem principally concerned with the breaking up of large prey, for which they are eminently well adapted. Antennae, wings, and legs are first detached, which, in the case of enemies or only slightly injured insects, is of direct value in subduing them as quickly as possible. The soldiers do not take part in the carrying of the food, but participate mainly in the work of making the food supply accessible. After the insect has been dismembered and the integument has been torn, the workers are able to imbibe the liquid body contents. It is to a large extent the liquid substances which are preferred, although some dry food particles are taken to the nest. Wings, antennae, and legs, and even inert materials without any possible food value have been observed to be carried into the colony. It is difficult to give an explanation of such behavior. On occasions single ants were found to bring in green seeds of certain weeds, from which a liquid possibly may be secured. The habit of gathering seeds, though not uncommon in many species, is fundamentally a generic characteristic of Pheidole.

With mealy bugs (Pseudococcus citri) generally distributed throughout the greenhouses, the small workers have an ever abundant supply of honey-dew at their disposal. Distinct trails can be followed up the stems of the gardenia plants where the ants visit small colonies of mealy bugs. The half-grown specimens are apparently preferred and after stroking the sides in the well-known manner, a clear drop of liquid is voided. The attending ant may either imbibe the excreted drop directly, or share the food with a near worker. Soon after preliminary feeding tests were commenced, however, it was found that sweet substances, such as honey and sugar solutions, were only slightly attractive, and that animal matter, fats, and vegetable oils were greatly preferred, and it is felt that the coccidicolous habit of Ph. anastasii, v. cellarum is but weakly developed, or that this need is constantly satisfied from the ready supply of honey-dew. It appears that the supply of honey-dew can be looked upon as an accessory source of food which, at some future date, may be correlated with the prevailing climatic conditions or the state of development of the ant colony. Wheeler (1910, p. 341) points out an interesting fact in this connection, as he states that the most primitive subfamilies, viz., Dorylinae and Ponerinae, "are highly carnivorous, never attend these insects (aphids), and care not for their excretions." At the other end of the range of development it is found that the highest subfamilies, Dolichoderinae and Camponotinae, represent a most perfectly developed habit of tending aphids and coccids. With the intermediate Myrmicinae, belonging to which is the genus Pheidole, we encounter both catagories of feeding habits: first, the carnivorous, granivorous and fungus-eating genera; and second, those with many aphidicolous species; sweet-loving ants. On the strength of this general trend it would seem probable that the genus Pheidole, originally derived from strictly carnivorous ancestry, has in some instances been specialized into the granivorous and fungus-eating species, and on the other hand, is adapting itself to the often plentiful available supply of sweet insect excretions. Throughout the present investigations the opinion has been strengthened that Ph. anastasii, v. cellarum is, by preference, carnivorous in its feeding habits.

In connection with the foraging habits and the rapid means by which other workers are attracted to a desirable morsel of food, it may be mentioned that a well-developed stridulatory organ was found to be present. The pedicel is very mobile and is articulated anteriorly to the epinotum and posteriorly to the first gastric segment, being morphologically the fourth abdominal one. The base of the first gastric segment is somewhat dome-shaped and provided with a mid-dorsal "file," consisting of rather fine transverse chitinous ridges. The post-petiole overlaps this anterior portion hood-like and scrapes the file with the articulation of the gaster. By this means vibrations may be transmitted which are perceptible by neighboring ants and serve as a general alarm. When food is discovered, it has been observed that the first ants frequently circle around in a most agitated manner before feeding, and although some may return to the nest, the large numbers of ants responding can only be explained by the transmission of vibrations through the soil. In a few instances a characteristic upward jerk of the gaster during feeding has been observed suggesting that vibrations are emitted at such times, which may be perceived through the chordotonal organs of nearby ants.

Life History Notes.

The greenhouse conditions for the culture of tropical and subtropical plants is favorable to the sustenance of thriving colonies of Ph. anastasii, v. cellarum, yet it must be remembered that the environment is an adopted one. For that reason the expressions of the species' biological functions may have been altered from the endemic seasonable rhythm in certain aspects. To illustrate, it is probable that climatic factors such as periods of greater intensive heat and seasonal periods of tropical rains are quite unlike the artificially controlled temperature and humidity condition of our greenhouses in the temperate regions of the continent. Accordingly, the life history observations in the newly acquired habitat may diverge considerably from the true behavior of the species.

During the latter part of February winged males were found within a nest, while a number of large queen pupae were observed, readily discernible by the size and by the wing pads. As is frequently the case, the male form of this species appears somewhat in advance of the emergence of the female. In the second week in March alate females (queens) as well as males were encountered, but in another locality of the same greenhouse on March 22, and after the benches and ground had been thoroughly watered, great numbers of males had congregated under a board, and yet female pupae were only present. The activities and agitation of an abundance of workers pointed toward a possible forthcoming swarming, as is the case with many of our native species of ants. However, no such swarming has been observed as yet.

Under laboratory conditions, such as could be followed in artificial formicaries, female pupae were again produced during the latter part of July, and by the middle of August several dozens of queens and as many winged males were walking about throughout the nest. It was at that time that mating was noticed to occur within the nest, indicating that fertilization may take place without a nuptial flight. Winged queens have not been found above ground, and adelphogamy may be normal for the species, not excluding the possibility that males could be exchanged with neighboring colonies. On the following days young queens were found to have shed their wings, suggesting the fact that fertilization had taken place. The absence of a marriage flight among Iridomyrmex humilis, or rather its uncertain occurrence, has been reported by Newell and Barber (1913, p. 19), who witnessed such flight once during the five years of study in Louisiana. On the other hand, the winged males of our greenhouse ant are less timid and occasionally appear above ground. Again an inconsistency in a strictly limited seasonal occurrence of the sexual forms presents itself with the fact that males were taken on November 11 and December 3. It is difficult to draw definite conclusions until established colonies have been kept under close observation for at least a year and much additional information is available.

Brood appears to be present practically all the year round and is found from two to four inches below the surface of the soil. It is sometimes located in the root sod of the plants and often the young larvae are situated in cracks and on the surface of the moist and decaying bench boards. If the humidity conditions become unfavorable, the ants do not hesitate to remove their brood, and large colonies have been known to change location overnight. The pupae and nearly developed larvae seem to require a low percentage of humidity; in observation nests in which the soil became too wet this large brood was at such times left above ground for several days. In a flower pot containing a thriving colony, a canopy of fine soil was constructed and found to contain masses of large brood. In strictly aphidicolous species of ants, these shelters are interpreted as being for the safe keeping and protection of the food supply. But since this feeding habit occurs principally in the higher subfamilies of the Formicidae, it may be considered a more recent development from the older and generalized habit of excavating, building mounds, and of superficial brood chambers as the one mentioned above.

The small brood has a "glassy" appearance, due to the transparent integument of the young larvae. In most ants the larvae are covered with hairs, tubercles, and bristles of various kinds and arrangement, and may serve as a protection from cannibalism among each other. On the larvae of Pheidole bifurcated setae function as barbs or small anchors and aid in the forming of small packets and thus enable the workers to transport greater numbers of their brood at once. On the dorsal surface, five rows of long S-shaped hairs, ending in a double hook, function as anchors to retain the larvae in place and in clusters. The coiled flexible condition of the structures serve further as an added protection, as "shock absorbers," when moved about.

Cannibalism is of common occurrence among ants and the brood may be looked upon as an emergency food supply in case of extreme shortage. In starved colonies it is the brood that is first attacked to serve in feeding the colony. The callows are next to be sacrificed, but there is doubt as to whether the workers or soldiers are the ones to be doomed first. Soldiers have been observed to pinch ferociously the pedicel of the much smaller workers, yet remains of the large head capsules of soldiers have been found in dwindling colonies. However, the queen is left unharmed, as the last "pièce de resistance" for a possible survival of the race.

Seasonal Abundance and Behavior.

As has been stated previously, this species of *Pheidole* has migrated passively and confused in the avenues of commerce from Central and South America to the more rigorous regions of the northern hemisphere, where it found suitable greenhouses. In these it has been able to continue its life cycles and even prosper, providing that these artificial habitats were designed to grow or display tropical or sub-tropical plants. To a certain degree the seasonal influences have thus been eliminated. The winter may bring outside temperatures far below the freezing point, but the greenhouse area is maintained in a condition suitable enough to make survival possible.

At the greenhouse establishment where these studies were made, an air temperature of less than 60° F. seldom is reached, and then only for short periods of time; whereas the soil temperature fluctuates between 68° and 72° F. These may be considered the minimum winter conditions. The ants respond to these factors, in that the area of infestation is much reduced during the winter months. A heavier concentration of ants can be found not only along the crosswalk where the steam pipes enter the house and at the east end of the house where a return ditch of the steam heating system causes an accumulation of heat locally, but also the south sides of the houses and at the corresponding exposure of the benches a greater number of ants can always be found. The north side of the houses is never heavily infested, and also the northern exposures of the individual benches is frequented to a lesser extent. Thus we find during the winter months a concentration of ants at the warmest locations of the greenhouse area, and, in addition, a much retarded activity of the foraging ants on dull overcast days. As soon as the sun gains strength and the clear days are lengthening, young males and females are produced in March and April. Expansion of the colonies takes place without much outward signs. On the last day of April, ants were found to have moved outside the greenhouse, where seasonal nests were located in luxuriantly growing grass on the south side of the house and against the concrete wall. Not until May or early in June does the general increase become noticeable, reaching its peak during the latter part of August. Even then, however, the extreme north side of the greenhouse appears less favorable and also the approximate center of the greenhouse section has a comparatively light population. During the following months the population curve (fig. 2) recedes gradually in November, to reach a minimum area of density in the months of December, January, and February.

In summarizing the abundance of the ants under greenhouse conditions, we find a very definite response to the seasonal changes outside their immediate environment, and possibly in divergence with their original climatic conditions. Furthermore, we find these responses are mainly temperature reactions, and that the production of sexual forms has not proven to coincide with seasonal changes and appear erratic or incompletely understood.

Dispersal.

Little can be added to the foregoing discussions and observations as to the means of dispersal of the species. Nuptial flights have not been observed; in fact, winged queens have never been found above ground. All queens are extremely photophobic and only the winged males occasionally appear in the open light. Whether this is entirely voluntary is not certain. The workers have been seen carrying winged males, and in one instance males were being pulled, by the antennae, from one observation nest to another. This may have been in an attempted move of the whole colony. In a similar way, and on the occasion of entering a new observation nest, ants have been noticed to coax and pull their queen by antennae and legs towards and into the entrance hole. It is probable that the strong and overcrowded colonies expand and take in new territory by a gradual means of dispersion, moving part or all of the colony only over short distances. Such movements have been observed to occur overnight, and it is possible that under cover of the darkness the queens may travel over the surface of the ground.

Laboratory Procedure

Artificial Nests.

Considerable time has been devoted to the construction of a suitable observation nest for the purpose of being able to make detailed biological observations and, as was hoped, to be used in certain phases of the feeding experiments. Some of these various types of formicaries with their modifications will be described here, and their merits and shortcomings discussed.

Under the heading "Review of the Literature" (pp. 18-21) mention was made of the many types of artificial nests employed by various investigators. Practically all are modifications or combinations of two fundamental types: 1, Lubbock's glass construction, containing small amounts of earth; and 2, Janet's plaster of Paris nest blocks in which no soil or nesting materials are included. In the former a natural medium is present in which the ants can build their galleries and chambers, and if the space allowed between the glass panes is properly adjusted for the species of ants under observation, there is little opportunity for concealing their activities. The Janet plaster of Paris nests consist of castings of shallow chambers connected by narrow passages and provided with a water container to maintain the porous material damp. The degree of humidity decreases with the distance from the source of the water, thus giving the ants a choice of conditions.

The first plans made for a small and light formicary followed the general principles of an observation nest designed by Doctor Wheeler (1910), a modification of which had been used successfully at Ohio State University. The arrangement of brood chamber, feeding compartment, and water trough was made in an oblong frame 9 inches long by 3 1/4 inches wide (fig. 4). This shape was decided upon so as to make the examination of all areas of the nest possible on the stage of a binocular microscope. The brood chamber (A), the floor of which was painted white, was furnished with glass tubing of 4 mm. and 7 mm. diameter. In these the ants prefer to pack their brood, and they may also serve to remove small quantities for closer examination. The chamber was darkened with black paper. In the food chamber (B), three short glass tubes were inserted, so as to be able to offer different liquid materials, whereas solids could be placed on a metal plate. In one corner this chamber was connected with the water container (C) by means of a glass tube covered with a small amount of plaster of Paris, on either side of the partition. The transpiring moisture was found to be not quite sufficient in volume to penetrate throughout the nesting chamber, and within a week the brood would be removed close to or upon the damp plaster of the food chamber, if extra moisture were not supplied in the brood chamber or if soil was not added. In the latter instance, the purpose of the observation nest was defeated, as visibility of the ants' activities was much hampered. The humidity requirements of this tropical ant are high and the supply and distribution in the wooden structure proved inadequate for any length of time and for normal activities. The glass panes, fitted in the wooden molding, were fastened with paraffin, but the slightest irregularity in the construction gave the minute workers an opportunity to burrow through the wax and escape. For a larger species of ant, with lower humidity requirements, this type of nest may have been practicable, but under these conditions it was deemed necessary to look for other materials capable of supplying a higher degree of humidity.

Following the general idea of the Janet nest block, several castings were made out of plaster of Paris, with the final result a model as illustrated in figure 3. The dimensions of the block are 7 inches long by 5 inches wide and 1 1/2 inches thick. A photographic glass plate, 4 by 5 inches, is used to cover the nesting compartments and food chamber. The larger water container on one end of the block is filled frequently, and gives a general moisture to the nest block when the plaster absorbs the water. To prevent the nest from being constantly wet on the sides and bottom, the outer surface may be coated with several layers of varnish or it may be water-proofed by dipping it in paraffin. It was also found that a glass plate fastened to the bottom with adhesive tape makes the nest easier to handle. Initially some difficulty was experienced in separating the mould from the casting. Modeling clay was first employed to make the moulds of the various chambers, but this proved time-consuming and the last models were made from a wood and press-board pattern. These should be well soaked in paraffin and before each casting greased with vaseline. The solid bottom board of the mould bears the projections which will form the depressions in the upper surface of the plaster nest block. Two L-shaped side pieces fit together to form the 5 by 7 rectangle and this is enclosed in a larger rectangular outer frame. After the plaster is set this outer solid frame is taken off and the inner L-shaped pieces are pulled away sidewise. When the block has hardened somewhat it can be lifted off the wooden base without much difficulty, providing the form has been made correctly and all parts were well greased beforehand. In gauging the plaster of Paris, care should be taken not to stir the water too vigorously, so as to prevent the suspension of air bubbles in the settling mass.

To observe the ants under more natural surroundings and to study their nesting habits in soil of various types, use was made of upright observation frames (fig. 5). These consist of an 11 by 17 frame built upon a solid base. The double glass panes can be adjusted in three grooves, - 3/4, 1/2, and 1/4 inch apart - admitting a total spacing of 1 3/4 inches. For the purpose of housing larger colonies of the tropical greenhouse Pheidole, the glass sides were placed 1/2 inch apart and the space was partly filled with various types of soil at hand.

The construction of these formicaries being of a fairly crude machine-made type, the ants would find their way out through small cracks between the woodwork and the glass, and through ill-fitting joints, foraging freely on the laboratory table. If the moisture is maintained and an adequate food supply is furnished, the ants can be kept for long periods of time. If, on the other hand, conditions became unfavorable, the colony might remove overnight to a more suitable nesting site.

Another method of keeping confined colonies on hand in the laboratory consisted of enclosing such stock material in pint milk bottles, two-thirds filled with soil, and covered with black paper. Before the soil and ants were introduced, a large test tube, from which the bottom was cut off, was placed in the center so as to better be able to moisten the soil from the bottom. Large rubber stoppers with one or two holes were used to close the bottles. The existing holes were plugged with fine copper screening, of forty mesh per inch, or glass tubing could be inserted for feeding or transfer purposes.

Aside from high humidity requirements, the ants were found to respond readily to, and prefer, high temperatures. The laboratory room of 70° F. was barely warm enough and their activities were greatly accelerated by placing the colonies in a constant temperature chamber (fig. 6) regulated at 27° to 28° C. (80° to 83° F.).

Ecological Relationships

Response to Temperature and Humidity.

Among the principal factors determining the maintenance of a species of insect are the availability of food and suitable temperature and humidity conditions. Since food for a carnivorous and active little ant, as this tropical *Pheidole*, is abundantly present in greenhouse associations of most types, this factor does not need to be considered here at present. The question of humidity is of somewhat greater concern, although also in this instance the necessity of frequently watering the plants grown under such artificial conditions gives the ants ample opportunity to choose nesting sites with the required moisture content. They readily adapt themselves to the changes of the environment and periodically shift their brood to locations of optimum conditions (see under Nesting Habits, pp. 25 - 28).

The greenhouse temperature is maintained by steam under pressure and distributed throughout the houses by means of two pipes under each bench and a series of six suspended along the sides of the houses. The regulation of the house temperature is accomplished by manipulation of a certain number of ordinary steam valves located at the central cross-walk, and depending upon the outside weather conditions and temperature. Under the present day heating systems the houses are operated mainly according to the existing air temperature and a considerable fluctuation may be found in the soil temperature. After the heat enters the house, it follows the benches at right angles from the main and at the end of either greenhouse section, the steam and condensation water flow back through a return pipe under the ends of the benches. To provide further for the necessary ventilation to either cool or dry the atmosphere, a series of double ventilators are situated in the very peak of the roof. In an effort to maintain a certain temperature range, the greenhouse operator must open two, four, six, or more pipes under the benches. If a strong cold wind comes from the north, extra pipes need be turned on at that side. As soon as a bright sun breaks through, even in midwinter, steam has to be reduced and ventilators have to be opened. Yet, as a result of constant observation and manipulation, the grower is able to maintain a night and day temperature varying from 60° to 70° F., or but a little higher for a few hours after midday. Weekly charts of recording thermometers show a surprising uniformity of air temperatures.

However, soil temperatures may be at great variance with those of the atmosphere. Although not strictly hypogaeic in character, the ant and its brood are much influenced by the prevailing soil temperatures and thus we find a very definite response, not only to local soil temperature variations but also to the seasonal changes.

Whereas the air temperature on a clear winter day (November) may show a rapid decrease, as follows:

76° F. at 2:00 P.M.

75° F. at 3:00 P.M.

71° F. at 4:00 P.M.

67° F. at 4:30 P.M.

63° F. at 5:00 P.M.

the moist and absorbent soil retains its heat for longer periods of time and shows a much slower oscillation of temperature. To determine the actual fluctuations of the ants' habitat, several stations were established throughout one greenhouse section and readings were recorded periodically. During the middle of November, two-hourly readings of the soil and air temperatures were made initially (6 - 8 - 10 P.M. - 12 - 2 - 4 - 6 A.M.) but after finding only slight variations and slow changes, the records were taken at 9 P.M. and at 12 - 3 - 6 A.M. The daily temperatures were computed from mean averages obtained from hourly recordings between 9 A.M. and 5 P.M. Making use of the greenhouse routine practices and some established thermometers, the air and soil temperatures, at night as well as during the day, were taken over a period of six days. The locations of the five stations (see fig. 7) were in the center, north, and south sides of the house, and at the far ends, west and east, of the benches. The soil thermometers were placed three inches in the bench soil and the air thermometers were situated at approximately ten inches above the bench. All thermometers were located at the north side of the benches, shaded by the plants, so as to prevent exposure to direct sunlight. In the following tabulations, tenths of a degree have been given in full figures; and also the mean temperatures have been corrected to the closest figure to a tenth of a degree.

Table I

Daily Average Temperatures in °F.

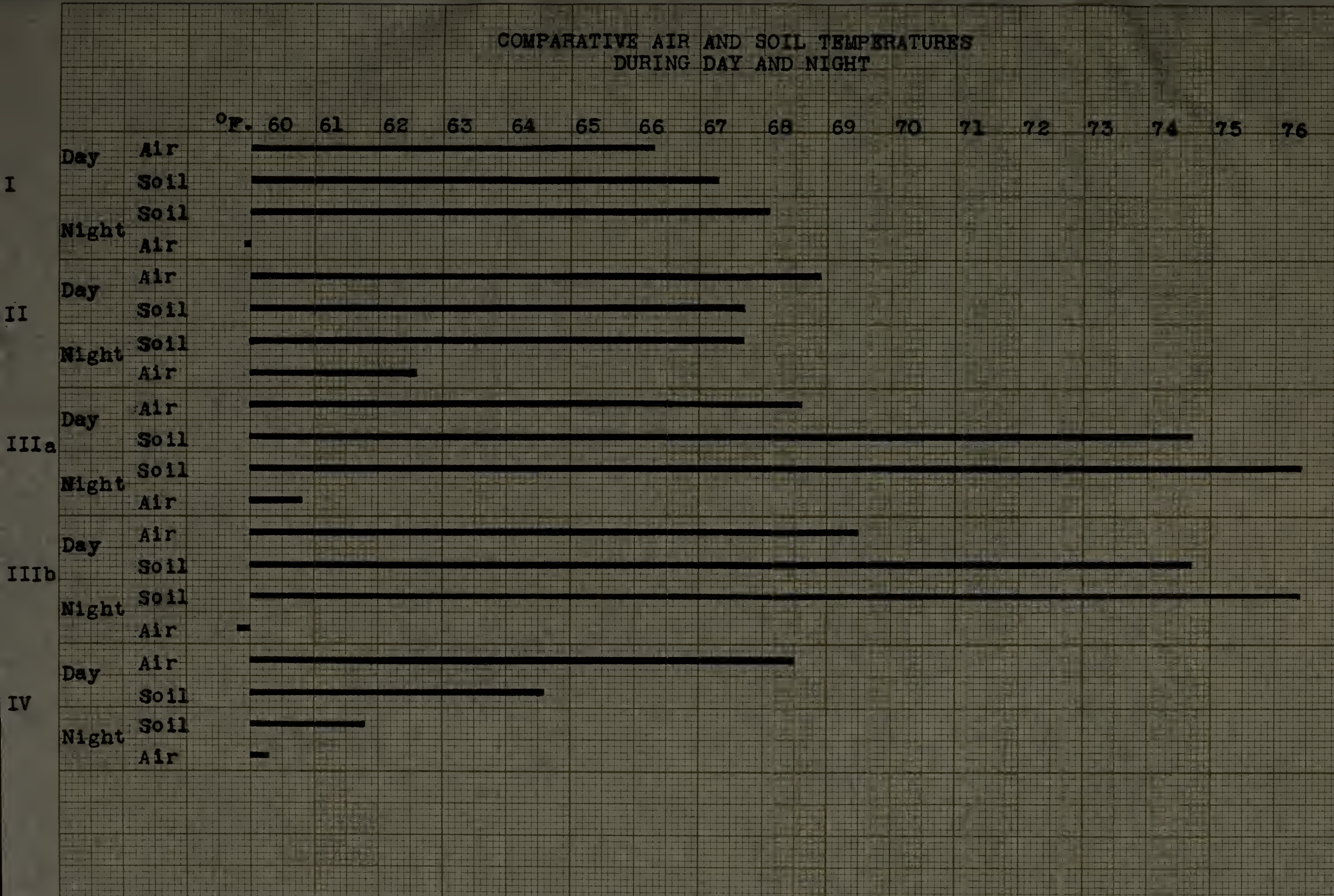
		Night		Day	
		Air	Soil	Air	Soil
I.		59.7	68.		
		59.7	69.7	67.	66.5
		60.5	69.2	66.3	69.
		59.5	67.7	67.7	68
		60.	66.	64.1	65.6
		59.6	68		
	Mean Temperature	59.9	68.1	66.3	67.3
II.		61.7	67.1		
		62.25	66.75		
		62.	66.5	70.75	72.
		63.75	70.	68.3	68.
		62.4	68.8	71.	67.
		63.4	67.4	65.6	64.
	Mean Temperature	62.6	67.7	68.9	67.7
III a.		60.3	73.85		
		60.	76.25	68.75	74.
		61.5	78.	67.6	74.
		61.	77.5	72.	75.25
		60.4	76.8	66.3	75.6
		61.6	76.8		
	Mean Temperature	60.8	76.4	68.6	74.7
III b.		60.1	73.85	70.75	74.
		59.75	76.25	69.	74.
		60.5	78.	73.25	75.25
		59.	77.5	65.1	75.6
		59.8	76.8		
		59.6	75.8		
	Mean Temperature	59.8	76.4	69.5	74.7
IV.		60.	62.		
		59.5	63.	69.	66.75
		61.5	60.75	68.3	65.3
		60.	60.75	70.75	63.75
		60.4	61.6	66.	62.6
		60.2	62.6		
	Mean Temperature	60.3	61.8	68.5	64.6

To the foregoing tabulation (Table I) a few remarks should be added. Station I is located on the center of the second bench at the north side of the house. The general locality is even colder than would appear from the presented record, because one steam pipe under this one bench is being used as a rule, raising the soil temperature above the average of this particular location (see fig. 7 for location of thermometers).

Station II is located near the crosswalk, where an accumulation of steam pipes tends to raise the air temperature, especially during the night. The soil temperatures for Stations IIIa and IIIb were obtained from a thermometer placed on the east end of bench Number 10. This was done purposely so as to determine the increased soil temperature in the vicinity of the steam-return ditch, while also partly opened steam vents create veritable tropical conditions. Since these soil temperatures are tabulated in IIIa and IIIb with air thermometers at some distance away, not a true picture of conditions is obtained, but merely a comparison.

In Station IV, situated in the approximate center of the house, the records bring out the fact that although the day air temperature compares favorably with those of other sections of the house - is even somewhat higher than the extreme north side of the house - the soil temperature is the lowest recorded, and loses nearly three degrees overnight due to the absence of steam through this section. The available heat in the house apparently does not circulate readily through the middle of the house, forming a cold stagnant air center, because the central overhead ventilator is used sparingly. The end ventilators provide the air when necessary and furnish the much needed though inadequate circulation of the total greenhouse air volume.

To illustrate the fluctuation of the greenhouse air temperatures with the comparative constant soil temperature, the following simple graph is presented.


COMPARATIVE AIR AND SOIL TEMPERATURES
DURING DAY AND NIGHT
°F. 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76
I
Day Air
Soil
Night Soil
Air
II
Day Air
Soil
Night Soil
Air
IIIa
Day Air
Soil
Night Soil
Air
IIIb
Day Air
Soil
Night Soil
Air
IV
Day Air
Soil
Night Soil
Air

The differences in air temperature during day and night are evident and considerable, whereas the soil remains constant, or even increases somewhat during the night due to the greater number of steam pipes radiating heat. The increased volume of heat is calculated to be just sufficient to maintain a minimum night air temperature of 60° F. but the average soil temperature is nearly eight degrees higher (67.7° F. for the limited number of records presented). The highest average soil temperature is 75.5° F. and the lowest average taken in the center of the house is 63.2° F. From another survey, conducted during the middle of January, the average night temperature was found to be 61.28° F. as compared to 68.85° F. in the soil, giving a 7.5° F. higher temperature in the bench soil.

In connection with the culture of gardenias, it must be mentioned here that the aim of this particular grower is to maintain a winter soil temperature of from 68° to 72° F. This plant, being native to the Old World tropics, requires a warm soil and readily shows a chlorotic condition of the foliage, especially during midwinter, if temperature conditions are unfavorable. How difficult it is to obtain a uniform temperature of the soil with the present day methods of heating greenhouse ranges, and the response of the plants with a yellowing of the foliage and chlorotic appearance, is well illustrated on the enclosed work sheet (fig. 7). A possible correction of this condition may be found in the construction of solid benches in which steam pipes would allow an accurate regulation of the soil temperature, independent of the general atmospheric temperature of the greenhouse.

In some detailed and critical studies of the soil temperature relationships to chlorosis in the small-flowering Gardenia veitchii, Jones (1938) finds that a chlorotic condition of these plants can be induced at soil temperatures of 18° C. and less within a period of sixty days. On the other hand, the author finds that temperatures of 22° C. and higher produce plants with green foliage. These soil temperatures especially favorable to the culture of gardenias appear to approximate the temperature requirements of the greenhouse Pheidole. The presence of this ant is readily governed by the definite soil temperature variations, as it shows a decided preference to the warmest soil regions (see also fig. 2).

Distribution in Greenhouse.

Monthly surveys were made of one greenhouse section and the abundance plotted on charts (fig. 1). By this method fairly accurate records were obtained of the number of ants present at a given date and the seasonal movements could be followed. In all surveys a scarcity or total absence of ants was found on the northern exposure of the house, involving the first three benches, except for 25 feet on either end. Also the approximate center area of the house was found to be of too low a temperature to be suitable to the ant. On the other hand, the west and east ends of the benches were found to harbor always and at all seasons an abundant population favored by the accumulation of heat in the cross-walk where the steam enters the house, and on account of the condensation return ditch located at the east end. On the south side of the house, bench Number 11, is fully exposed to the sun and even in winter derives enough additional heat to make suitable temperature conditions available during most of the year.

With the advance of spring, and acceleration of the ants' metabolism, a greater territory for foraging and nesting sites becomes necessary and with the increase of the soil temperature a definite movement takes place (fig. 2). More and more of the greenhouse area becomes occupied until in August a peak of density is reached. During this period of optimum conditions it is striking to note the comparative sparcity of ants in the center of the house, and the aversion to the northern area of the house. Early in November the ants slowly recede, when the soil gradually cools off, and concentrate along the narrow margin of optimum soil temperature, to await the season of new abundance.

Relationship to Mealy Bugs.

The common greenhouse mealy bug, Pseudococcus citri, is the principal insect pest the grower of gardenias is concerned with. The sticky excretion of the insect soils the glossy foliage, which in turn develops a dark sooty fungus giving the leaves an unsightly appearance. Clusters of egg masses, young, and adults are apt to be found around the tender growing tips and the young buds, distorting the young growth in severe cases and lessening the sales value of the flowers (fig. 8).

Aside from a spray program with various insecticides, the greenhouse routine calls for syringing the plants weekly with water under high pressure. A specially designed nozzle with half-moon shaped opening is used to forcibly wash the plants (fig. 9) thus removing the more exposed mealy bugs and their egg sacs.

When the presence of ants in great numbers came to the attention of the greenhouse concern, the question was raised whether the ant might be instrumental either in protecting the mealy bug or in assisting it in its distribution, and by doing so, hamper the control measures applied.

Under the existing conditions mealy bugs can be found in limited numbers, especially on the older plants and after periods of cold and overcast weather, when syringing has to be delayed. To determine the extent of the infestation, periodical surveys were made at various times of the year and in different sections of the greenhouse range. Mealy bugs were found generally throughout the houses but no correlation appeared to exist with the temperature variations. Contrary to the idea that these insects were more numerous along the crosswalk and the slightly warmer regions of the houses, the surveys showed general but light infestations in all regions. This fact by itself would indicate the lack, or at least the insignificance, of a possible relationship with the ants. As has been shown previously, the ants congregate at the extreme ends of the benches, but in spite of this condition, no increase of mealy bugs was noticed. On the other hand, it was found that in the comparatively cooler sections of the house where ants may be absent or very limited in numbers, the mealy bugs were as uniformly distributed as elsewhere.

This species of Pheidole has been observed to feed, to a degree, on the sweet excretion of the mealy bugs, but should by no means be considered an equal to truly aphidicolous ants for which our common species of Lasius, Camponotus, Prenolepsis, etc., are well known. Rather may this fact be looked upon as a more recent adaptation and a supplementary source of food to its carnivorous diet. However, workers have been observed to stroke mealy bugs in the customary way, stimulating their host to secrete the desired droplet of honey-dew and imbibing the liquid eagerly. Efforts to induce the ants to feed on the body contents or maimed mealy bugs have been without success; in fact, definite signs of a repellent reaction have been noted. Sound specimens placed in trails of ants were either totally ignored or but casually examined.

Upon examination of foraging workers it has been found that first and second instar mealy bugs are very occasionally carried toward the nest. Whether these are taken in for food or for protection and cultivation has not been ascertained. Collembolans carried in a similar manner were found to be dead and frequently were preyed upon after syringing, when many of these delicate insects perish in the drenched soil. Many of the larger mealy bugs are washed off the plants as the result of this treatment, but a number survive. Of these, single individuals may be found walking along the bench boards or over the soil, and probably many find their way back on the gardenia plants. Some, however, remain at the base of the plant where they may be found in small numbers about the ground line.

It has been noticed further that one to two inch mounds of soil are constructed around the base of the plants, frequently containing mealy bugs. This occurrence has generally been interpreted as proof that the ants should build such shelters solely for the protection of mealy bugs. As high as forty percent of a series of twenty mounds examined contained mealy bugs. Numerous plants inspected had mealy bugs but no mounds present, and again, in others, small piles of soil had been made without any apparent connection with the protection of mealy bugs, as none were present. When a stunted plant was to be discarded as inferior, a more thorough examination of roots and soil could be made. The top of the plant, generally infested with mealy bugs, was visited by numerous ants feeding on the honey-dew from young mealy bugs. The base of the plant had an inch high mound of damp soil, through which passed a heavy traffic of workers. The bark at the ground level was cracked but no mealy bugs were found. After ten days the ants were still numerous, and not only was a new mound constructed, but the soil around a nearby wire stake was being excavated crater-fashion. When the plant was taken out, no signs of mealy bugs were found on the roots. A substantial ant colony was located not directly under the plant but some six to eight inches away along the bench boards.

The appearance of mounds has been noted after the greenhouses had been watered. A strong colony confined in a large glass jar built a mound against the side after being watered and similar constructions have been noticed in smaller colonies kept in soil. In potted gardenia plants, kept in a constant temperature chamber (fig. 6) the ants would excavate soil against the side of the pot, along a metal stake or at the base of the plant, in the absence of mealy bugs. Occasionally heaps of soil were found to be accumulated under feeding cups attached to the bench boards.

Branches covered with mealy bugs were tied down close to the surface of the soil and in reach of the ants. Other likely attractive food substances were placed in similar positions. The food was eventually consumed but no "protective shelters" were ever built in any of these experiments.

Early in January a mound was examined about the base of a plant lightly infested with mealy bugs which were being attended by workers. At the base of this plant there were no mealy bugs, but numerous winged males were found in the dry soil of the mound, again indicating the presence of a strong colony nearby.

Especially after watering the beds, excavation to renew the runways is necessary. Solid objects on, or projecting into, the soil are followed in excavation and frequently serve as an apparent support to the mound. On the other hand, the thigmotropic response of mealy bugs expresses itself in their locations in young buds, under bracts, and in the axils of the branches; protected in cracks of the bark, under burlap, or other places, providing they are in reach of food. The space between soil line and plant stem affords immediate protection and food, for which the ants are not responsible.

From these observations and limited experiments, there appears to be a definite indication that the presence of mealy bugs in soil mounds at the base of gardenia plants should be looked upon as coincidental rather than the primary cause for such response.

Relationship to other Arthropods.

Being primarily carnivorous in its feeding habits, the greenhouse Pheidole attacks other arthropods, as cockroaches and Collembolans. Any creature that has become entangled in the condensation water on the sides of the greenhouse falls easy prey. The common sowbugs and pillbugs know how to avoid the active ants, but are readily attacked when incapacitated, as are also the millipedes. Pheidole seems to monopolize its territory, as no other species of ants have been encountered. During summer, single specimens of our native ants have been seen to explore the very ends of the greenhouses, but apparently for very brief visits only. Slugs and earthworms are unmolested, the former freely feeding with the ants on the same bait.

A very active Thysanura, closely related to the so-called "silverfish," is frequently associated with the ants. This species of Nicoletia (Phytophila ? Gervais), being of a pale cream color, blind, rather swift and delicate, is found in the nesting sites in the soil, but also mingles with the ants in their runways under damp boards. Whether they are strictly myrmecophiles and actually nursed by the ants has not been determined. Escherich (1904) in his monograph of the Lepismatidae states: "Lebensweise der Nicoletien ist vornehmlich eine unterirdische, Sie leben aber nicht, wie ihre Verwandten, die Ateluren, in Gesellschaft von Ameisen oder Termiten, sondern unabhängig und frei unter groszen Steinen mehr oder weniger tief in der Erde, oder auch in Höhlen" (p. 133). Quoting Gervais, the habitat is given to be "dans les serres chaudes du Museum sous les pots it dans la tannée qiu sert à les placer." Being swift runners, they are able to avoid too close a contact with the ants. When injured, ants have been observed to prey upon them, and after drenching the soil it is not rare to see dead specimens being carried off for food. It is possible that Nicoletia is merely a scavenger, feeding upon the excrements of the ants or perhaps soil fungi growing in the damp environment. Specimens have been kept in the laboratory for several months in moist earth without the association of ants and therefore may be considered tolerated lodgers to which the ants are possibly indifferent.

A single specimen of a minute wingless species of Proctotrupidae was taken in December, while being tended by a worker. Wheeler (1910, p. 419) does not mention any species of these entoparasites, but it is believed to be a species of Belyta of which Donisthorpe (1927a) lists two (p. 105) as being new to the British Isles.

Relationship to Plant Diseases.

As is frequently the case with uninvited persistent newcomers, most anything could be blamed on the presence of this newly acquired pest. The question arose immediately with the growers whether the ants could be responsible for the "buddrop" in gardenia plants. This ailment, however, appears to be of a plant physiological nature, caused by an irregularity in the sap flow due to alternate retardation and increase of growth, not fully understood as yet, but not directly due to fungi as causal agents.

Incidentally, Gravatt and Marshall (1917) definitely showed the possibility of transmitting pathogenes by insects, spiders, sowbugs, and even slugs. In their investigations of Cronartium ribicola conducted in greenhouses in Washington, D. C., it was found that spores would adhere to the bodies of the animals for at least a week under certain conditions. Among the insect carriers are listed "a cockroach and a small red ant, Pheidole anastasii." This would seem to indicate that this species has all ready, and could in certain other instances, function as a mechanical carrier of plant diseases.

Nutritional Requirements

Artificial Foods.

Early observations of the ants feeding habits indicated a strong carnivorous diet. In addition statements were received concerning its supposedly close association with the greenhouse mealy bugs. Several of our common native species draw the public's attention especially while visiting aphid colonies and it was therefore only natural to suspect that a preference for sweet substances would exist in the greenhouse ant to be investigated. This suspicion was strengthened by the fact that the ants were reported to invade the lunch boxes of the workmen in a similar manner as the Argentine ant does in the Gulf States and California. For I. humilis, Newell and Barber (1913) published an extended food list, including honey, syrups, preserves, candy, and cakes. These ants are of constant annoyance in restaurants, groceries, and confectionery shops. Their diet includes further fats, vegetable oils, fish, and meat, so that also butcher shops and home refrigerators are frequently invaded. In fact, they are omnivorous to such an extent that practically everything edible for human beings is also attractive to this true household plague.

In some preliminary trials with the greenhouse Pheidole, honey, sugar solutions, bacon grease, peanut butter, apple, and banana were offered. The peanut butter had suggested itself when it was found that sandwiches with this material appeared especially attractive to the ants. The fruit seemed of little interest and very much against expectation, the honey and sugar solutions were visited by few ants. The bacon grease and peanut butter, on the other hand, were greatly favored, indicating that fats and oils were preferred to sweet food substances. Initially the materials were placed on wax-paper squares. Considerable feeding would take place underneath, after the soldiers had chewed holes in the paper squares. Glass squares were then substituted but the objection here was that the transparency made the observations and estimating the number of feeding ants difficult. Finally, microscope slides, made opaque with a coating of white paint on one side, were used and proved very satisfactory.

To determine what animal fats or vegetable oils would be fed upon and attract the greatest number of ants, one of the following series of materials was placed on a bench containing gardenia plants and periodical counts of the number of visiting ants were made.

Table II

Material	Number of ants feeding after 5 min.	15 min.	30 min.	60 min.	Remarks July 1, 1938
Soybean oil	0	1	5	50	
Rape oil	1	25	35	60	
Corn oil	1	21	50	70	
Coconut fat	2	4	25	50	
Ricinus	6	2	7	12	
Peanut oil	50	100	100	Clean	
Olive oil	30	100	Clean	Clean	
Cocoa butter	15	6 c.	10 c.	Clean	Carrying the material
Codliver oil	5	40	60	60	Many drowned
Haliver oil	0	0	0	0	
Spermaceti	0	0	0	0	
Lanolin	0	0	0	0	
Palm oil	10	75	15 c.	Clean	
Bacon fat	35	80	60	60	Cleaning it up
Lard	2	80	60	60	Cleaning it up
Crisco	3	80	60	60	Cleaning it up
Honey	0	40	50	50	

In analyzing these feeding trials, and some preliminary series tested previously, the following conclusions were made:

(1). Haliver oil, spermaceti, and lanolin are not attractive. (During the preceding winter three or four ants had been observed feeding on the haliver oil, but even then it was not especially liked.)

(2). Of doubtful attraction were ricinus oil and coconut fat. Although fifty ants were observed feeding on the latter material after a one-hour period, no ants had been attracted to it in previous tests.

(3). Soy bean, rape-, corn-, and codliver-oils were moderately attractive. Cocoa butter had given but little results during the winter, whereas in the present test from 6 to 10 ants were found to be carrying off the material. Also soybean oil attracted ants after more choice food had been taken.

(4). Of the three fats, bacon grease, lard, and crisco, the first named seemed to attract ants at once, but after fifteen minutes all three materials appeared equal and constant.

(5). Outstanding as being the most favored food materials were peanut oil, attracting foraging ants within five minutes; olive oil, and palm oil. Honey always attracts a certain number of ants, but it is slow and little pronounded.

Other materials were further tested, such as bananas with and without yeast and honey, eggyolk, and white of egg, without giving encouraging results. Yeast or some inert material, it was felt, might act as added attraction, function as suitable carrier, or increase the availability of the food. This deduction was made from a duplicate series of the more promising oils as compared to the same materials to which yeast was added. In practically all oils containing yeast, the feeding ratio was increased fifty percent after one hour. To determine whether this increase in attractiveness is actually due to the yeast, or merely to the change in consistency, walnut shell flour was added as a triplicate set.

Table III

October 26, 1938 Materials	Number of ants feeding after 1 hr.	1 1/2 hr.	2 hr.	7 hr.
Peanut oil	19	80	100	Clean
Peanut oil with yeast	5	26	38	Clean
Peanut oil with WSF*	32	40	64	Clean
Olive oil	6	40	100	Clean
Olive oil with yeast	3	3	25	Clean
Olive oil with WSF	5	7	22	40 Cleaning
Palm oil	1	2	5	12
Palm oil with yeast	10	3	10	14
Palm oil with WSF	21	10	3	30
Porcine (bacon fat)	0	3	24	60 Cleaning
Porcine with yeast	6	5	32	50
Porcine with WSF	1	24	47	40
Lard	0	0	0	0
Lard with yeast	0	0	0	2
Lard with WSF	0	1	2	2
Crisco	0	0	12	50
Crisco with yeast	0	4	12	60 Trail
Crisco with WSF	20	33	34	40
Honey	2	1	0	6
Honey with yeast	1	0	0	3
Honey with WSF	0	3	4	7
Sugar solution	0	0	0	4
Sugar solution with yeast	1	1	0	0
Sugar solution with WSF	0	0	0	4
Yeast (dry)	0	0	0	0
WSF (moist)	0	0	0	0
Yeast - WSF 50-50	0	0	0	0

Note: * Walnut shell flour, Agicide Laboratories, Los Angeles.

The 27 slides were placed in a wooden flat (fig. 10) on the south side of a bench and among the gardenia plants. As the ants are present all over the bench soil and the food is accessible from all directions, the relative position of the slides appears to make little difference. The ant population was light but general, and this location was selected so as to better be able to note preferences and specific choice of food. At the two-hour reading, peanut oil and olive oil are the prominently outstanding materials, while the addition of yeast or walnut shell flour does not seem to give significant differences.

Food Preferences.

Numerous other combinations of oils and fats, mixed with Fuller's earth, talcum, walnut shell flour, and dried fish meal, were tested and the consistency of the materials noted and compared.

Table IV

Relative Attractiveness of Dry-pasty vs Oily Food Substances

No.	Materials	Number of ants feeding after 1 hr.	2 hr.	3 hr.	4 hr.
A1d	Olive oil - peanut butter	100	100	100	75
A1l	Olive oil - peanut butter	100	100	100	100
A2d	Olive oil - WSF*	100	50	75	50
A2l	Olive oil - WSF	100	100	100	45**
A3d	Olive oil - fish meal	100	50	60	30
A3l	Olive oil - fish meal	75	100	100	Clean
A4d	Olive oil - talcum	50	40	45	20
A4l	Olive oil - talcum	100	50	30	Clean
A5d	Olive oil - crisco	50	50	75	50
A5l	Olive oil - crisco	50	60	85	75
A6d	Olive oil - Fuller's earth	50	50	50	30
A6l	Olive oil - Fuller's earth	75	100	100	70
B1d	Peanut oil - peanut butter	75	50	50	35
B1l	Peanut oil - peanut butter	50	100	100	100
B2d	Peanut oil - WSF	50	50	40	25
B2l	Peanut oil - WSF	50	100	100	30**
B3d	Peanut oil - fish meal	50	50	50	20
B3l	Peanut oil - fish meal	40	100	100	Clean
B4d	Peanut oil - talcum	17	30	40	14
B4l	Peanut oil - talcum	60	100	100	Clean
B5d	Peanut oil - crisco	29	50	100	100
B5l	Peanut oil - crisco	100	100	100	100
B6d	Peanut oil - Fuller's earth	28	30	20	10
B6l	Peanut oil - Fuller's earth	30	100	100	Clean
C1d	Fish oil - peanut butter	100	100	100	100
C1l	Fish oil - peanut butter	50	100	100	100
C2d	Fish oil - WSF	50	60	76	Clean
C2l	Fish oil - WSF	100	100	100	Clean
C3d	Fish oil - fish meal	50	50	40	18
C3l	Fish oil - fish meal	100	60	35**	Clean
C4d	Fish oil - talcum	50	50	60	Clean
C4l	Fish oil - talcum	75	75	20**	Clean
C5d	Fish oil - crisco	50	50	100	100
C5l	Fish oil - crisco	100	100	100	100
C6d	Fish oil - Fuller's earth	50	50	60	20
C6l	Fish oil - Fuller's earth	100	100	40**	Clean

Note: All materials were offered in duplicate but differed in consistency; d represents the dry-pasty form, and l the liquid oily substance.

*WSF - walnut shell flour, Agicide Laboratories.
peanut butter (Swifts)

** Bait nearly gone.

Remarks: Counting the individual feeding ants if often difficult, if not impossible, and the numbers given here are close estimates.

The order of preference in the beginning of feeding is as C - A - B. All the liquid materials are more attractive after the two-hour period. The fish oil appears the most outstanding.

From these feeding tests the final deduction was made that the greenhouse *Pheidole* under local greenhouse conditions is strongly oleophilous, being attracted equally to olive oil, fish oil, and peanut oil. The first one named, perhaps due to a lesser surface tension, has a tendency to cause some of the feeding ants to drown, but in all instances heavy oils or thin pastes are preferred and most readily accessible to the worker. Although fishmeal is attractive to the ants, a finely ground peanut butter was more suitable to use as a base for poison bait, is readily available, and can be better mixed with small amounts of poison. Even if the material dries the ants will carry small particles to the nest to extract the last remains of oil, deriving the full effect of the material supplied.

CONTROL INVESTIGATIONS

Repellents

Under the conditions in which the gardenia plants are grown and the ants are situated, little hope was held for the possibility of using repellents. The approximate four inches of soil in the benches is filled with the dense and somewhat fleshy roots of the gardenias. The ants are located either in the solid root-sod or upon the bottom and side boards of the wooden benches. The use of strong chemicals or large enough amounts so as to insure penetration might also prove detrimental to the plant growth. No valuable bench space could be requested for such experiments but a limited number of small tests were made.

Small dosages of naphthalene flakes and paradichlorobenzine crystals were applied at ten-day intervals on the ends of heavily infested benches over a period of two months, and enough to maintain a continuous supply of fumes. No distinct effect was obtained in this time of application and the test was discontinued. Simultaneously two established plants in the benches were treated with these materials. Mounds of soil were present at the bases and numerous ants were passing in and out of the soil. After the first month of application the excavations were discontinued but the ants were little affected. Soon after the treatments were stopped, normal activities were resumed and further investigations were suspended.

Stomach Poisons

Some commercial preparations, such as were available locally, were tested.

"Key-brand Ant-killer," a white powder containing 19 percent sodium arsenite, was tested on young gardenia plants in four-inch pots. A series of twelve plants was given approximately 25 m. gr. dosages at weekly intervals and in gradually increasing amounts. After two applications, a leaf burn became apparent, indicating that even in small dosages it is very toxic to gardenia plants.

"Peterman's Ant Food," containing 48 percent sodium fluoride, is specifically recommended for indoor use, burns plants severely, and should be used indoors and in dry surroundings.

"Ant Buttons" are prepared from a sweetened material containing sodium arsenate. The few used were only slightly attractive and soon exhausted due to the constant wet condition of the greenhouse.

"Antsix" consists of a sweetened jelly containing one percent thallium sulphate. Being again primarily prepared for sweet-feeding ants, the ants were only moderately interested. In commercial containers the material is too expensive for greenhouse use and is quickly washed away during syringing. In combination with peanut butter at the rate of 1:2 the ants fed abundantly, carrying particles of the mixture and indicating that this poison was not objectionable. Thallium sulphate, as will be discussed later, has proved to be one of the most effective poisons.

"TAT" a commercial ant poison contains 1.3 percent thallium sulphate. It is said to destroy both sweet and grease feeding ants and may be of value for home use. A sample can, upon examination, contained two food substances. The greenhouse Pheidole fed abundantly upon the black material, but it seemed to lose its attractiveness after two days, while numerous ants remained in the vicinity.

Making use of the standard poison bait applied by greenhouse men, and consisting of the simple 1:10 paris green and sugar mixture, this poison was used in the same pDoportion with corn-, soybean-, olive-, and rape-oils, honey, bacon grease, and peanut butter. Feeding was satisfactory, except on the honey. The solid materials were carried off but many ants were drowned in the thin liquid oils and eventually the paris green was left as a residue after the oils had been consumed. A second application was made, adding a small length of lampwick to the oils to provide a footing for the foraging ants. More material was left and although some ants were still taking the clear oil, the presence of the poison appeared to make the bait distasteful. Also the bacon grease and peanut butter became dry and less attractive in time, so that the use of this material was discontinued.

After various and further preliminary tests, it was decided to concentrate on the use of three of the more promising poisons with ordinary peanut butter as a base. The latter was found to have the best lasting qualities in the greenhouse, was easily applied, and is always attractive. The poisons selected were thallium sulphate, barium fluosilicate, and tartar emetic. Certain modifications were made of published formulae which were adapted to the bait to be used. Popenoe (1926) first brought thallium sulphate to the attention of entomologists as having a limited use as an insecticide. The material had previously been used successfully in rodent control, but Popenoe reported favorable results with thallium sulphate as an ant poison. The formula given is as follows:

1 pint water	27 grains thallium sulphate
1 pound sugar	3 ounces honey

C A U T I O N

THALLIUM SULPHATE - Tl_2SO_4

In handling thallium compounds great precautions should be taken, as they are powerful poisons. Thallium and its salts are accumulative poisons, causing extravasation of the blood, toxic gastroenteritis, bloody dejections, falling out of hair, etc. It also is very toxic to plant life, rendering soils sterile at 35 parts to 1,000,000.

The thallium appeared to act as a slow accumulative poison. Flint and McCauley (1936) raised the amount of thallium to 2 grams and added 45 cc. of glycerine to Popenoe's formula.

Marcovitch (1933) recommended as a good ant poison the following mixture:

6 grains sodium fluosilicate dissolved in

1 pint water

1/2 pound sugar and 1/2 pound honey, thoroughly mixed

Sodium fluosilicate has been reported as not always favorable and the barium compound being more soluble, was substituted in the present tests.

Although tartar emetic was not entirely satisfactory for the control of Argentine ants, Thompson and Johnson (1936) recommended it as being superior in the control of Monomorium pharaonis; and also Flint and McCauley suggest this material at the rate of 1 to 9 parts of lard or bacon grease.

The initial applications of the original thallium sulphate formula were made in the greenhouse service room and potting shed. The poison bait appeared attractive, was readily taken by the ants, and replenished at weekly intervals. After about six weeks the heavy invasion had subsided and the ants' trails were coming from the opposite direction, entering from the greenhouses to forage on the bait in the service room.

The bait was fully acceptable and attractive to the ants and the three poisons above mentioned were now given a comparative test in a whole greenhouse section.

The poison bait was prepared at the following rates:

A. Thallium sulphate - 2 grams per 2 lbs. peanut butter.
B. Barium fluosilicate - 6 grams per 2 lbs. peanut butter.
C. Tartar emetic - 45 grams per 1 lb. peanut butter.

Each material tested in duplicate series, and each series of two beds was divided in (1) daily, and (2) four-day applications. The object was to determine the relative merit of these three poisons on a commercial scale. One half the number of benches was supplied daily with fresh bait; the other half every four days; the purpose being to compare the matter of availability of the poison to the ants.

The first application was made during the end of May. By the middle of June an appreciable reduction in ant population was evident with all materials and in all time periods of applications. It was decided that a four-day schedule of reserviceing the bait would be adequate, as no material difference in the two schedules had occurred. A survey of the house gave further indications that the baits B and C, containing barium fluosilicate and tartar emetic, respectively, were as good or more effective than A, containing thallium sulphate. This may have been due to the slower, accumulative action of the small amount of thallium sulphate. It was planned to continue three-fifths of the greenhouse section as scheduled, including practically all of the generally infested territory, and to keep a small nucleus of ants at the east end of the house under observation, without applying more poison.

By the middle of July, after six weeks of this control campaign, a survey of the population was again made. The before-mentioned nucleus of ants had greatly increased by this time, since the poison had been withheld (approximately for four weeks), proving the effectiveness of the bait. The population of the remainder of the house showed a striking decrease in density. Except for the extreme southwest corner, where many ants still could be found, the general population hadbecome very slight. At many stations in the survey only single specimens were noted. However, a distressing observation was made in that upon several occasions these few individuals ignored the fresh peanut butter (not containing the poison) and appeared to have become either tired or suspicious of this type of food. They may have been affected by the poison. In the one section persisting with a fair abundance of ants, feeding on the peanut butter continued satisfactorily and plentifully.

The population remained slight and to reduce the amount of time necessary for reserviceing all stations, it was decided to maintain a weekly schedule. Unforeseen, the supply of bait became exhausted during the middle of August and also the weekly intervals between renewal of the poison proved to be too long. The ants increased again when baiting had been discontinued, or the schedule had been slackened.

During the preceding months, palm oil, a pasty oily substance, had been tested for attractiveness to the ants. It appeared to be very much liked, readily taken and carried off by the ants. To test if this material would retain its attractive qualities, a new supply of poison baits was prepared during the latter part of August, with palm oil as a base. A survey made in the middle of September showed an unchanged condition; that is, no particular further reduction of ants was noted, but the new bait seemed satisfactory and applications were continued. However, by October 18, six weeks after the palm oil bait had first been supplied, the material seemed to have lost its appeal for the ants. From the original orange-brown color it had become creamy-white, as if oxydized or leached out by the exposure to the greenhouse atmosphere. The ants, when present, were found to be fairly few in numbers and interested in peanut butter, but only sparsely feeding upon the palm oil.

This control experiment was discontinued to re-check and further investigate oil attrahents and their consistency in relation to their availability to the ants.

As has been shown in Table IV, the additional feeding tests brought out strongly the fact that liquid foods are greatly preferred. Olive oil, peanut butter, fish meal (dried ground sardines), and "fish oil"* are the outstanding food substances.

On this evidence, the last materials prepared have been considerably liquified by using one part of olive oil to two parts of solid material. The baits used were peanut butter, crisco, and fish meal, with enough olive oil to give the mixture a thin pasty consistency. General feeding on these materials has been very satisfactory, except for the crisco in which the dry pasty base is being left after the oil has been extracted by the ants. The amount of 0.27 percent thallium sulphate seems acceptable to the ants, although after four weeks the decrease in population is fairly slow but well in evidence. For this reason a new supply of the same materials was prepared early in February with 0.33 percent poison and a small sample of one-half a percent

* The "fish oil" was procured by draining the oil off canned sardines, and thus is virtually olive oil with a certain amount of fish substance.

was tested. Feeding has remained satisfactory, even the higher percentage of poison being readily taken. Since the poison apparently is not detected, and so as to decrease the time necessary to reach a lethal dose in the ant populations, the final peanut butter and olive oil baits have been prepared early in April with 0.5 percent, 0.75 percent, and 1 percent thallium sulphate. These are being supplied to three separate greenhouse sections at four-day intervals to bring out whether the higher poison concentration remains attractive and to determine the time necessary to cause a material reduction in the ant population.

A final check made four weeks after the first applications with these three baits was made, and shows a tremendous reduction in numbers of ants. Where previously 200 ants would be attracted, a dozen or two would be found now. The 1 percent thallium sulphate bait has been most outstanding in its effect and is still very attractive to the ants. It seems evident that the ant population can be kept under control. Whether eradication of this insect can be accomplished eventually will depend upon consistency and thoroughness of the applications, and a continued attractiveness of the bait.

Trapping

The possibility of reducing the population of ants in the greenhouse had been suggested by the results obtained in experimental work with the Argentine ant in California. Woglum and Borden (1921) advocated the use of trapnests, wooden boxes filled with suitable material, to attract the congregating ants during the rainy season. Following the idea under greenhouse conditions, a series of experimental "trap nests" were placed upon and under the benches so as to determine the value of such a method. Six-inch flower pots were used in the first trials, filled with (1) sphagnum; (2) straw (cut); (3) straw and peat; (4) peat; (5) manure (rotted); (6) potting loam; (7) cinders. These pots were turned bottom side up, on the benches and among the plants. In this position a fairly constant humidity would be maintained. After six weeks the contents of each pot was examined. Pot Number 1 was quite wet, due to water dripping nearby from the roof. It contained a number of Nicoletia and a few Pheidole workers. Numbers 3 and 7 harbored a few stray workers in the lower and damper parts of the pot contents. Pot Number 2 with coarsely cut straw contained ants and a small quantity of brood, showing that a method of trapping ant colonies would be possible, although perhaps not practical under greenhouse conditions. Numbers 4, 5, and 6 had not attracted any ants.

Another test was made by placing a number of short lengths of old boards under the benches. Two pieces were tied together in all cases, some provided with damp burlap, but in none did any ants occur. Although decaying planks in the beds are favored nesting sites, the temperature is considerably higher than directly on the solid ground, and this only would be against the offered nesting location.

Attempts to improve methods and investigate further possibilities were abandoned.

Cultural and Natural

Little can be suggested as to a cultural control method for the ant so long as their habitat is maintained at a temperature never reaching a point lower than 60° F. and so long as the greenhouses are continually occupied with growing plants. Good growing conditions for gardenias means practically optimum living conditions to this species of *Pheidole*. During the winter the plants are not disturbed and during early summer two- or three-year-old plants are replaced by young stock. This cultural practice involves only a certain number of benches; never is an entire house completely cleaned out.

In an effort to use the old soil over again and avoid the labor of replacing it by fresh earth, the grower decided to clean and rejuvenate the soil in one bench by steam sterilization (fig. 11). This method has been in use for a number of years by many greenhouse concerns. In solid ground benches permanent tiling and steam pipe connections are frequently available. After the beds are covered with some heavy tarpaulin, tarpaper, or the like, live steam is turned into the soil for a certain length of time.

Before sterilization of the gardenia soil, a survey showed that ants were numerous at the east end of the bench, and well established on either side. After sterilizing the soil, the bench was planted with young gardenias and after two months the soil still appeared fresh and had very few weeds. Much within that period of time, however, the ants had reestablished themselves and were as numerous as before the treatment. As stated before, if an entire house can not be treated in one operation, local cultural operations are of little avail.

Although ants do have natural enemies, and one parasite, in fact, has been reported in the foregoing pages, control by biological means would have but little likelihood. If under a "natural" control the lowering of the temperature could be employed, such a measure might be highly effective.

CONCLUSIONS

The species of ant under consideration is of neotropical origin and requires comparatively high temperatures. It can maintain itself in greenhouses with a minimum of not less than 60° F. Temperature studies and distribution records give strong evidence that it may live outdoors in some of the southern parts of the United States. It is felt that under the mild and temperate climatical conditions of the sonoral regions in California, a survival there would perhaps not be impossible.

The ants are very sensitive to temperature changes and concentrate during the winter months at the southern exposure and warmer sections of the greenhouses. The temperature variations due to construction and manipulation of the heating system are fully recognized by the ants and can be correlated with their distribution. Seasonal temperature fluctuations also influence the abundance and spread of populations within a greenhouse.

Temporary trails are established to newly-found sources of food only and no distinct and permanent exit holes are made under greenhouse conditions.

The construction of earthen mounds (referred to as the "wet-weather sheds" of the Argentine ant) are not interpreted as being built to shelter mealy bugs. The response seems rather due to natural excavation activities of strong colonies, perhaps stimulated by the suitable physical qualities of the soil, or the ants are forced into action after water damage of the nest has occurred. That such soil structures frequently harbor mealy bugs appears coincidental and due to the thigmotropism of the mealy bugs rather than to the predetermined motive of their construction.

Since mealy bugs were found generally throughout the houses regardless of temperature variations, whereas the presence of ants is closely correlated with such temperature differences, it is felt that an interrelation between these insects is not significant in the control of the mealy bugs.

Many members of the genus Pheidole are seed feeders, but this neotropical species is largely carnivorous in its feeding habits. Aside from preying upon disabled arthropods, it has a great liking for certain vegetable oils and animal fats, the former which may be used as a base for the preparation of poison baits. The sweet excretions of mealy bugs are fed upon to a limited extent and it is possible that there exists a seasonal or developmental relationship with the food requirements.

The consistency of the poison baits is of prime importance as only liquid substances are taken as food.

SUMMARY

From the investigations set forth in this report, it has been brought out that Pheidole anastasii, v. cellarum Forel is now a cosmopolitan ant, found in the warmer greenhouses of several botanical gardens in Europe and with some commercial florists in the United States. This little-known ant had become so abundant in a local greenhouse that a biological study was undertaken to determine its significance, ecological relationships, and feeding habits, and to develop a possible means of control. Since the species was described originally from Costa Rica and has established itself in greenhouses which are maintained at high temperatures, the name TROPICAL GREENHOUSE PHEIDOLE has been proposed.

Its nesting sites in the greenhouses under observation are situated in the damp warm soil of the plant benches and consist of indistinct chambers and galleries some four to five inches in the earth. The ants are very sensitive to temperature conditions which finds its expression accordingly in a very definite distribution throughout the greenhouse habitat. The species is of a timid nature, the queens being strongly photophobic, and hastily withdraws upon being disturbed rather than taking a definite stand in defense. Mounds of soil particles are occasionally constructed at the base of plants, against the bench boards, around wire stakes, or free on the soil. This response is believed to be due to renewed excavation activities after the soil has been watered thoroughly and mainly occurs in the presence of strong colonies.

Swarming of the young alate queens and males has not been observed. Copulation occurs within the nest and the dispersal of the colonies is believed to take place, either underground or under protection of darkness during night, as the queens are strongly photophobic and rarely, if ever, appear above ground in the full day light.

Various types of artificial nests have been described and figured; the main considerations being temperature, moisture, and an adequate food supply. The workers hunt independently and do not follow distinct trails unless a large supply of food has been located. The large-headed soldiers function mainly to demolish the food so as to make it accessible to the small workers, but do not carry the food, nor do they seem to actually defend the colony. The feeding habit of the genus is, to a large extent, graminivorous, but some species are primarily carnivorous or have adopted a more diversified diet, thereby changing their importance in the economy of agricultural practices. In the case of cellarum the ants are predominantly carnivorous, make use of the sweet excretions of mealy bugs to a limited extent, and are attracted to several animal fats and vegetable oils. Making use of this fondness of oils, several poison baits have been tested with the result that a combination of materials has been developed which is eagerly sought and fed upon by the ants, has good lasting qualities, and is suitable as a base for poison.

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Note: * Original publication not read.

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ILLUSTRATIONS

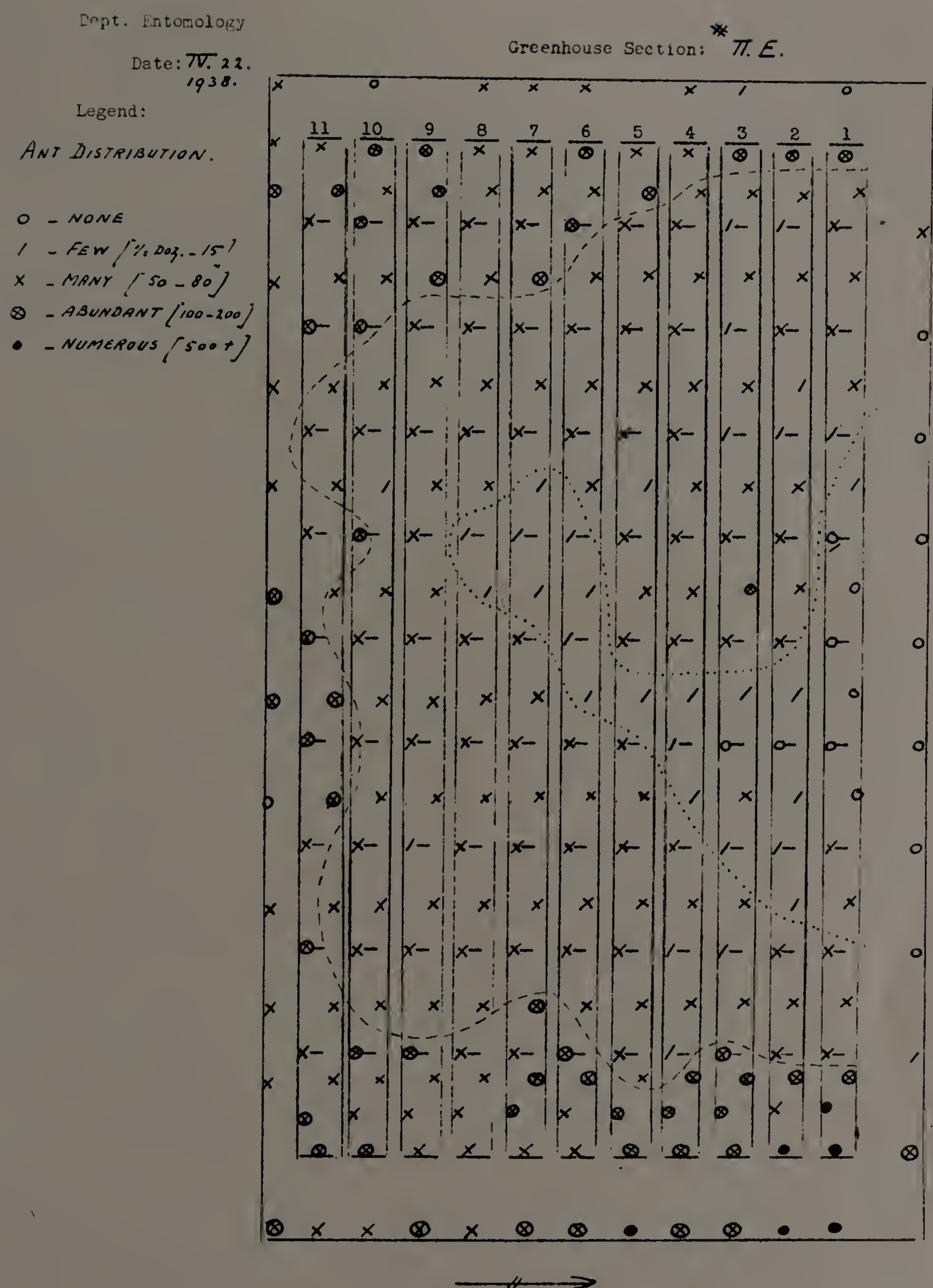

Fig. 1. Greenhouse survey map, showing areas of distribution and density of ant population

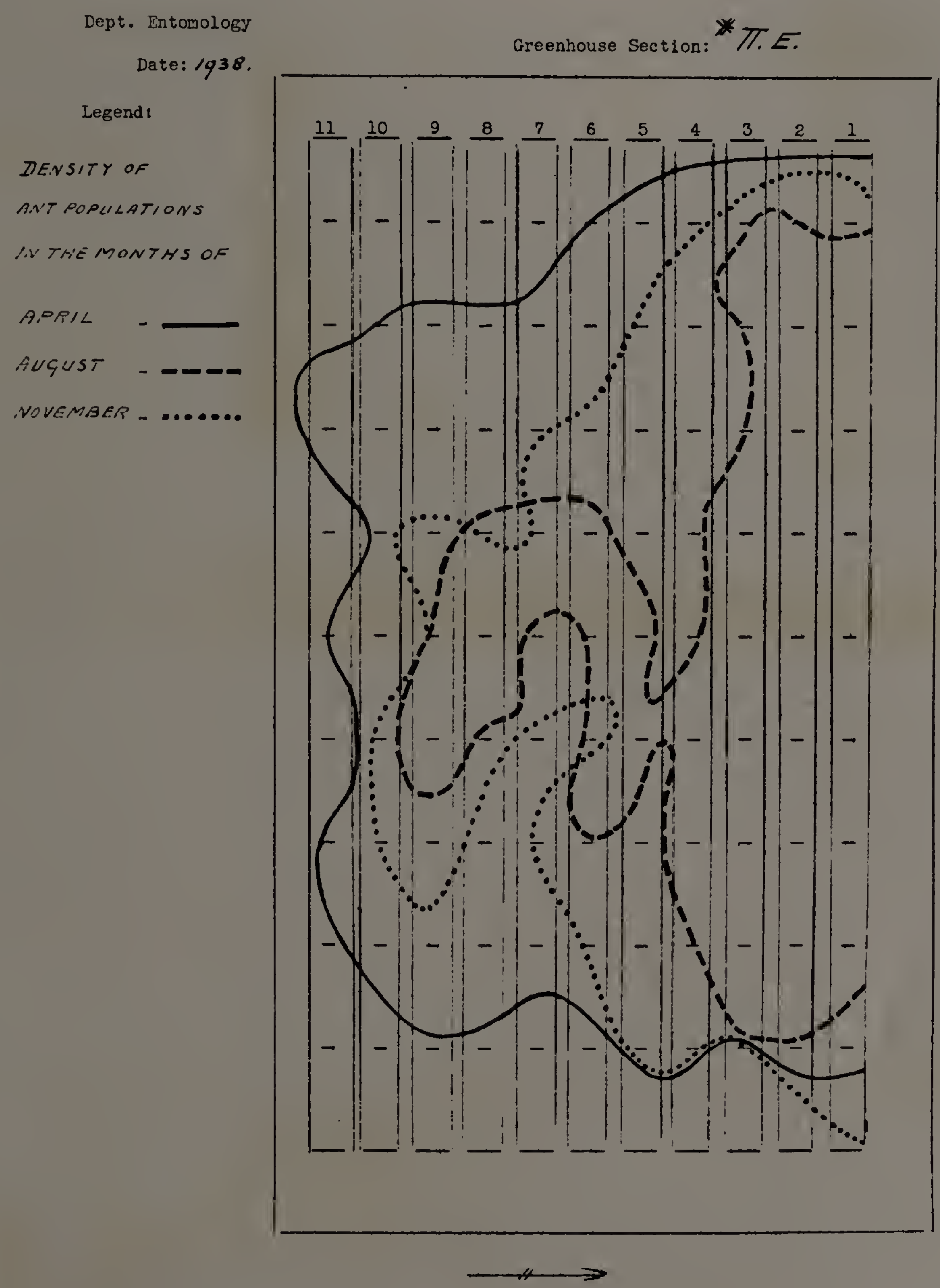

Fig. 2. Seasonal fluctuation in greenhouse ant population

(Note the preference of the southern exposure and the ends of the house, as compared to the colder north side and center of house)

Fig. 3. Janet plaster of paris nest block

(Water reservoir at extreme left)

Fig. 4. Observation nest after Wheeler, modified from Ohio State University

(A, brood chamber; b, food chamber; C, water reservoir)

Fig. 5. Upright formicary

(Containing a Pheidole colony in three soil types, - peat, loam, and sand)

Fig. 6, Electrically controlled constant temperature chamber in which some of the investigations were made

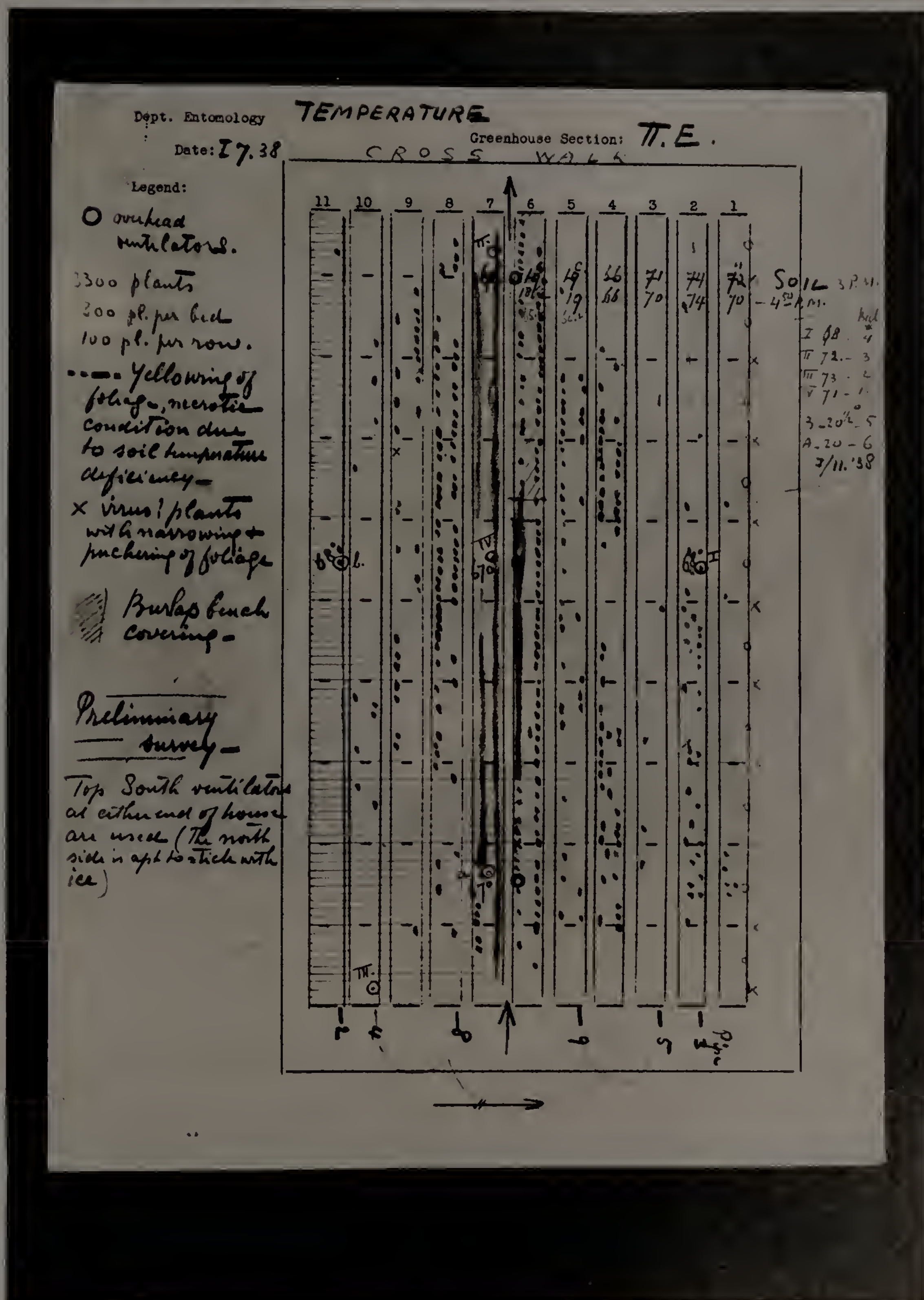

Fig. 7. Worksheet showing the distribution of chlorosis of gardenia plants in correlation to soil temperature

(Locations where serial temperature readings were made are marked in red)

Fig. 8. Gardenia buds severely infested with

Pseudococcus citri

Fig. 9. Method of syringing gardenia plants to check mealy bug infestations and remove the sooty mildew from the foliage

Fig. 10

Arrangement of food materials in feeding tests

Fig. 11

Method of steam sterilizing greenhouse soil

Approved by

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