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SYMPATRIC ASSOCIATIONS AMONG SELECTED  
ANT SPECIES AND SOME EFFECTS OF ANTS  
ON SUGARCANE MEALYBUGS IN HAWAII.**

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SYMPATRIC ASSOCIATIONS AMONG SELECTED ANT  
SPECIES AND SOME EFFECTS OF ANTS ON SUGARCANE  
MEALYBUGS IN HAWAII

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## ABSTRACT

Sympatric associations of the ants *Pheidole megacephala* (F.), *Anoplolepis longipes* (Jerdon), and the Argentine ant--*Iridomyrmex humilis* (Mayr) were studied. The three ants are mutually exclusive of each other in areas where each ant is dominant. Of the three ants studied, *Pheidole* appears to be the most aggressive under normal conditions; however, during the "invasion cycle" of the Argentine ant, it is able to expand its territory into areas previously occupied by *Pheidole*. In other areas of the world where the Argentine ant has become established, it has eliminated *Pheidole*. However, 30 years after the Argentine ant was first reported in the Hawaiian Islands, *Pheidole* is still the dominant ant in much of the lowlands and shows no sign of being eliminated by the Argentine ant. *A. longipes* appears to be severely limited in its distribution in Hawaii because of its habit of nesting under large rocks or rock-lined irrigation ditches. Movements of the Argentine ant around the world during the last hundred years indicate it is most successful in areas situated at 30° to 36° latitude (north or south). This study has shown that of the three ant species the Argentine ant is best adapted for colonizing areas of Hawaii at elevations above 3,000 feet. These elevations in the Hawaiian Islands correspond to latitudes above 30°.

*Saccharicoccus sacchari* (Cockerell), the pink sugarcane mealybug has many natural enemies in Hawaii. Some of the effects that the Argentine ant, *Pheidole*, and *A. longipes* have on populations and parasitization of the pink sugarcane mealybug were investigated. The presence of *Pheidole* and *A. longipes* appeared to result in slightly larger populations of the pink sugarcane mealybug, whereas the presence of the Argentine ant resulted in significantly larger populations of the mealybug. During periods of unfavorable weather conditions, populations of the mealybug decreased irrespective of the presence or absence of the ants. The attending of the mealybugs by the Argentine ant appeared to be a detrimental factor in the parasitization of the mealybugs by *Anagyrus saccharicola* Timberlake. *Pheidole* and *A. longipes* attending the mealybugs did not seem to interfere with the ovipositional activities of the parasite. The mealybugs reach much higher numbers in sugarcane growing along the field perimeter regardless of which ant is tending them. Under the conditions existing at Waimanalo Experiment Farm during this study, population levels of the pink sugarcane mealybug appeared to have no effect on rate of parasitism by *A. saccharicola*.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT. . . . .	iii
ABSTRACT . . . . .	iv
LIST OF TABLES . . . . .	viii
LIST OF ILLUSTRATIONS. . . . .	ix
INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	12
MATERIALS AND METHODS. . . . .	19
Section I. Laboratory and Field Observations . . . . .	19
Section II. Waimanalo Experiment Farm Study. . . . .	24
Section III. Commercial Field Studies . . . . .	31
RESULTS, DISCUSSION, AND CONCLUSIONS . . . . .	34
Section I. Sympatric Associations . . . . .	34
Part 1. Studies Involving Colonies of Ants. . . . .	34
Part 2. Studies Involving Small Numbers of Ants. . . . .	53
Section II. The Ant <i>Pheidole megacephala</i> and Some Effects on Populations of Pink Sugarcane Mealybugs. . . . .	60
Part 1. Effect of the Presence or Absence of the Ant . . . . .	60
Part 2. Effect of the Ant as a Detri- mental Factor in the Para- sitization of the Pink Sugar- cane Mealybug by the Parasite, <i>Anagyrus saccharicola</i> . . . . .	67

Part 3.	Regression of Percent of Parasitization by <i>A. saccharicola</i> on Pink Sugarcane Mealybug Population Size. . . . .	73
Part 4.	Summary. . . . .	74
Section III.	Some Effects of <i>Anoplolepis longipes</i> and <i>Iridomyrmex humilis</i> on Populations of Mealybugs Attacking Sugarcane in Hawaii. . . . .	75
LITERATURE CITED	. . . . .	82

## LIST OF TABLES

TABLE		Page
I	POPULATIONS AND PERCENT PARASITISM OF <i>SACCHARICOCCUS SACCHARI</i> BY <i>ANAGYRUS</i> <i>SACCHARICOLA</i> IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED PLOTS LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERI- MENT FARM, OAHU, HAWAII. 1966 - 1968 . . .	61
II	POPULATIONS AND PERCENT PARASITISM OF <i>SACCHARICOCCUS SACCHARI</i> BY <i>ANAGYRUS</i> <i>SACCHARICOLA</i> IN 14 SAMPLES OF SUGARCANE FROM ANT FREE PLOTS LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968. . . . .	62
III	ANALYSIS OF VARIANCE OF POPULATIONS OF <i>SACCHARICOCCUS SACCHARI</i> IN ANT INFESTED AND ANT FREE PLOTS OF SUGARCANE LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERI- MENT FARM, OAHU, HAWAII. 1966 - 1968 . . .	63
IV	ANALYSIS OF VARIANCE OF PERCENT OF <i>SACCHARICOCCUS SACCHARI</i> PARASITIZED BY <i>ANAGYRUS SACCHARICOLA</i> IN ANT INFESTED AND ANT FREE PLOTS OF SUGARCANE LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERI- MENT FARM, OAHU, HAWAII. 1966 - 1968 . . .	71
V	POPULATIONS OF MEALYBUGS AND PERCENT PARASITISM BY <i>ANAGYRUS SACCHARICOLA</i> IN THREE FIELDS OF SUGARCANE, EWA PLANTATION COMPANY, EWA, OAHU, HAWAII, 1969. . . . .	76



## LIST OF ILLUSTRATIONS

FIGURE		Page
1	<i>PHEIDOLE MEGACEPHALA</i> (F.) MAJOR WORKER (SOLDIER) (FAMILY: FORMICIDAE; SUB- FAMILY: MYRMICINAE) . . . . .	3
2	<i>PHEIDOLE MEGACEPHALA</i> (F.) MINOR WORKER (FAMILY: FORMICIDAE; SUBFAMILY: MYRMICINAE) . . . . .	4
3	<i>IRIDOMYRMEX HUMILIS</i> (MAYR) WORKER (ARGENTINE ANT) (FAMILY: FORMICIDAE; SUBFAMILY: DOLICHODERINAE) . . . . .	5
4	<i>ANOPLOLEPIS LONGIPES</i> (JERDON) WORKER (FAMILY: FORMICIDAE; SUBFAMILY: FORMICINAE) . . . . .	6
5	SUGARCANE PLOTS AT THE UNIVERSITY OF HAWAII, HAWAII AGRICULTURE EXTENSION SERVICE, WAIMANALO EXPERIMENTAL FARM, WAIMANALO, OAHU, HAWAII. EACH PLOT MEASURED 60 FEET BY 30 FEET AND CON- TAINED FIVE ROWS OF CLONE H 50-7209 SUGARCANE. THERE WERE 30 FEET OF BARE SOIL SEPARATING EACH PLOT. . . . .	25
6	<i>PHEIDOLE MEGACEPHALA</i> WORKERS ATTACK- ING AN ARGENTINE ANT QUEEN. . . . .	55
7	<i>PHEIDOLE MEGACEPHALA</i> SOLDIER WITH ITS ANTENNAE AND MANDIBLES IN A DEFENSIVE POSITION. . . . .	56
8	POPULATIONS OF <i>SACCHARICOCCUS SACCHARI</i> IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED AND ANT FREE PLOTS LOCATED AT THE UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968. . . . .	68
9	PERCENT OF TOTAL POPULATION OF <i>SACCHARICOCCUS SACCHARI</i> PARASITIZED BY <i>ANAGYRUS SACCHARICOLA</i> IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED AND ANT FREE PLOTS LOCATED AT THE UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968. . . . .	69

FIGURE

Page

10	PERCENT OF POPULATION, EXCLUDING CRAWLERS, OF <i>SACCHARICOCCUS SACCHARI</i> PARASITIZED BY <i>ANAGYRUS SACCHARICOLA</i> IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED AND ANT FREE PLOTS LOCATED AT THE UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968 . . . . .	70
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## INTRODUCTION

Approximately ten thousand different species of ants are known in the world today (Hutchins, 1967). The ants have been collected, preserved, and described in minute detail and classified in families, subfamilies, genera, species, subspecies, races, and varieties. They are found in large abundance practically everywhere, are of considerable economic importance, and offer challenging problems to entomologists. Yet few people are studying the ants other than for describing and naming them.

In 1899, Forel, in *Fauna Hawaiensis*, listed twenty species of ants from Hawaii, three of which were considered as misidentifications (Wheeler, 1934). Gulick (1913) listed 23 species; and Wheeler in 1934 recorded 35 species. Wilson and Taylor (1967) listed 36 species of ants collected in the Hawaiian Islands none of which are considered to be endemic.

At the present time, there have been 42 species of ants recorded from the various Hawaiian Islands (Huddleston and Fluker, 1968). During the last survey of the six major Hawaiian Islands, only 36 of the 42 recorded species were collected. Of the 36 collected species, six were ants that had never before been collected from any of the Islands of Hawaii. Three of the species have not as yet been described and their biologies are unknown (Huddleston and Fluker, 1968).

One little studied problem involving ants is sympatric associations among different species of ants, particularly among ants of different subfamilies. I have selected three species of ants, each of a different subfamily, for this study. The ants are:

1. *Pheidole megacephala* (Fabricius); Subfamily: Myrmicinae. This is the most common and well-known ant of the Hawaiian Islands. It is a dimorphic ant having a major (commonly called soldier (Figure 1)) and minor worker form (Figure 2). It is an omnivorous feeder and a tender of honeydew secreting insects. No one knows when this ant was introduced into Hawaii; it is mentioned in some of the earliest literature pertaining to Hawaiian Entomology (Illingworth, 1917).

2. *Iridomyrmex humilis* (Mayr); Subfamily: Dolichoderinae (Figure 3). This ant, commonly called the Argentine ant, was accidentally introduced into Hawaii in 1939 or 1940 (Zimmerman, 1941). Since then, it has spread to all the major islands of Hawaii except Molokai (Huddleston and Fluker, 1968). The workers are monomorphic and omnivorous; although there is a distinct preference for sugars. The Argentine ant is an efficient tender of honeydew producing insects.

3. *Anoplolepis longipes* (Jerdon); Subfamily: Formicinae (Figure 4). This ant is the most recent arrival

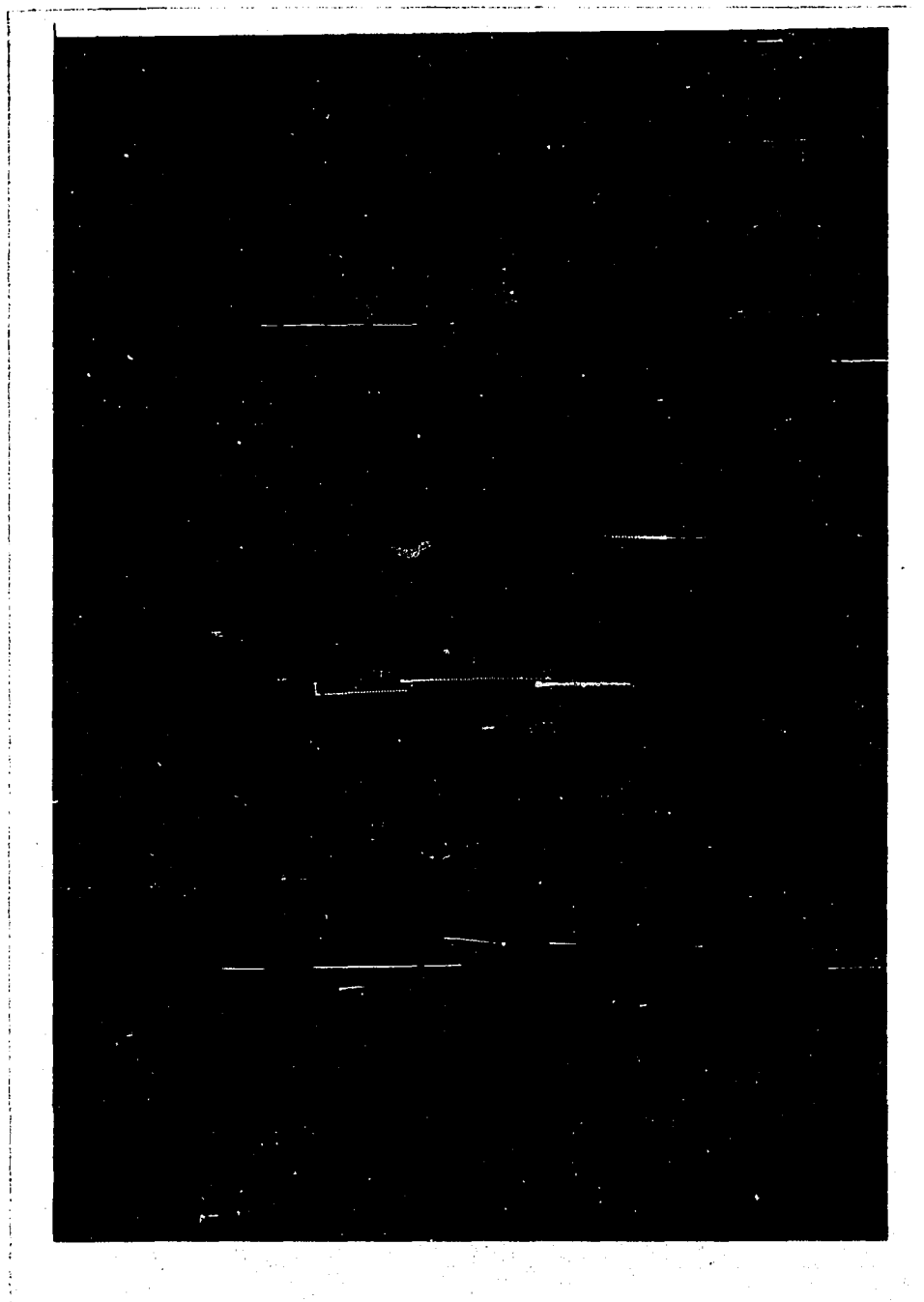


FIGURE 1. *PHEIDOLE MEGACEPHALA* (F.) MAJOR WORKER  
(SOLDIER) (FAMILY: FORMICIDAE: SUBFAMILY: MYRMICINAE)  
ACTUAL LENGTH: 3.4 mm.

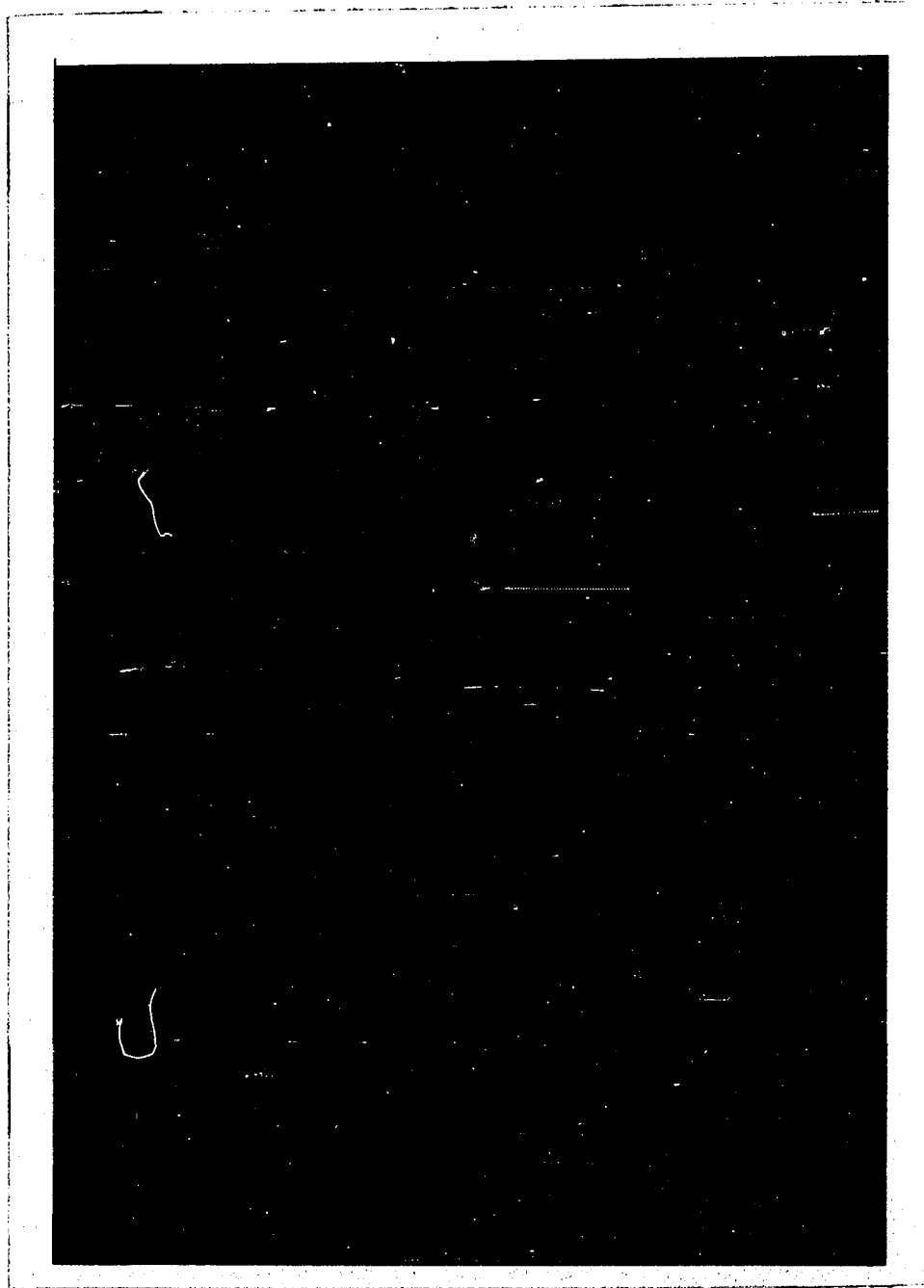


FIGURE 2. *PHEIDOLE MEGACEPHALA* (F.) MINOR WORKER (FAMILY:  
FORMICIDAE: SUBFAMILY: MYRMICINAE)  
ACTUAL LENGTH: 2.2 mm.

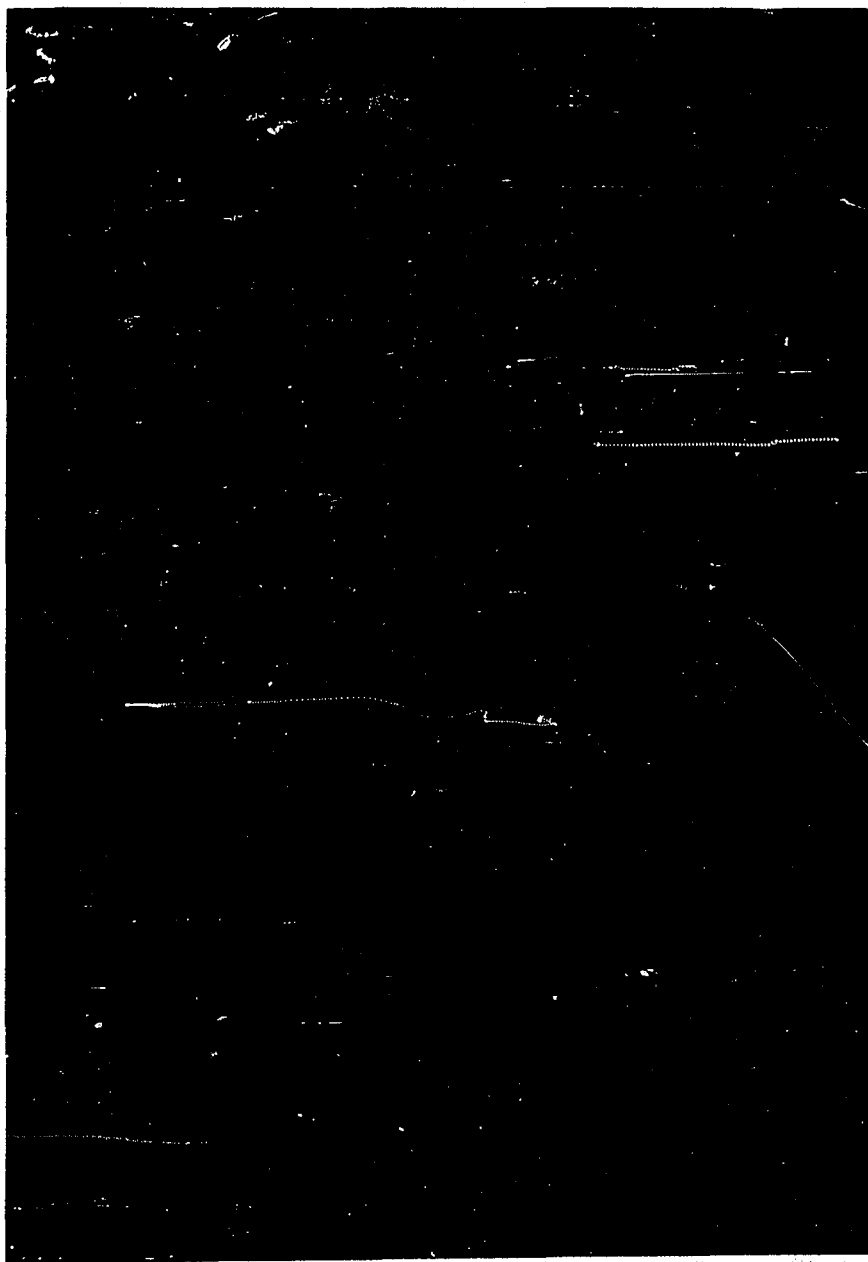


FIGURE 3. *IRIDOMYRMEX HUMILIS* (MAYR) WORKER (ARGENTINE ANT) (FAMILY: FORMICIDAE; SUBFAMILY: DOLICHODERINAE)  
ACTUAL LENGTH 2.5 mm.



FIGURE 4. *ANOPLOLEPIS LONGIPES* (JERDON) WORKER (FAMILY:  
FORMICIDAE; SUBFAMILY: FORMICINAE)  
ACTUAL LENGTH: 4.0 mm..



of the three species. It was first reported in 1952 (Zimmerman, 1953). The ant is monomorphic in form and an omnivorous feeder; although, like the Argentine ant, it has a marked preference for sugars. At present, this ant is reported from the Islands of Oahu and Hawaii only (Huddleston and Fluker, 1968). It also tends honey-dew producing insects.

Since *Pheidole* has been well established in Hawaii for many years, and *A. longipes* and the Argentine ant are recent introductions, this study was undertaken to:

1. Determine the sympatric associations between the three species of ants.
2. Evaluate the effect of *A. longipes* and the Argentine ant on populations of mealybugs attacking sugarcane (*Saccharum* sp. hybrids).
3. Determine the extent and degree of penetration by the three ants into commercial sugarcane fields and the subsequent effect on populations of mealybugs in the fields.
4. Evaluate the effect of *A. longipes* and the Argentine ant on the parasite *Anagyrus saccharicola* Timberlake.

Prior to this study, very little information was available on the relationships between ants, sugarcane pests, and their predators and parasites. Most previous

studies on the effect of ants on parasites and predators of coccids concerned pests of citrus. This portion of the study was undertaken with the following objectives and is a continuation and completion of the study by Fluker, et. al., 1967.

1. To determine the effect of the presence or absence of the ant, *Pheidole megacephala*, on populations of the pink sugarcane mealybug.

2. To determine if *Pheidole* is a detrimental factor in the parasitism of the pink sugarcane mealybug by *Anagyrus saccharicola*.

3. To evaluate the effect of pink sugarcane mealybug population size on the percent of parasitism.

Williams (1931) listed fifteen insects and invertebrates that are or have been pests of sugarcane in Hawaii. The pink sugarcane mealybug was included in this list.

In 1959, Bearásley listed five species of mealybugs known to attack Hawaiian sugarcane as:

1. *Antonina graminis* (Maskell).
2. *Trionymus rostellum* Lobdell.
3. *Dysmicoccus brevipes* (Cockerell).
4. *Dysmicoccus boninsis* (Kuwana).
5. *Saccharicoccus sacchari* (Cockerell).

The first two species listed are considered to be of no economic significance; and the third, the pineapple

mealybug *Dysmicoccus brevipes* (Cockerell), is considered to be of minor importance only. *Dysmicoccus boninsis* (Kuwana), the gray sugarcane mealybug, is usually found only in conjunction with the presence of the Argentine ant (Beardsley, 1959).

The pink sugarcane mealybug is considered to be the most widely distributed and to reach the highest population levels of any of the cane infesting mealybugs in Hawaii. On occasion, there have been outbreaks of the pink sugarcane mealybug even though it is considered to be under economic biological control in Hawaii by the introduced host specific encyrtid parasite, *A. saccharicola*.

Although no method has been devised that can satisfactorily measure the loss of sugar due to the feeding of the pink sugarcane mealybug, it is believed that value is lost.

Although no studies have been documented, there has been much speculation on the role that the ant, *Pheidole*, plays in the biological control of the pink sugarcane mealybug in Hawaii. It is generally believed that *Pheidole* tends the pink sugarcane mealybugs for the honeydew they secrete.

Koebele (1896) was the first to report the pink sugarcane mealybug in Hawaiian sugarcane fields. Beardsley

(1959) listed the following as natural enemies of the pink sugarcane mealybug in Hawaii:

1. Two species of entomogenous fungi, *Aspergillus parasiticus* Speare and *Entomophthora pseudococci* Speare.
2. A drosophilid fly larva, *Gitonides perspicax* Knab.
3. Several coccinellid beetles of the genus *Scymnus* and the mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant.
4. A host specific encyrtid wasp, *Anagyrus saccharicola* (Timberlake).

Of all the above listed natural enemies of the pink sugarcane mealybug, this study concerned only *A. saccharicola*. This parasite was introduced into Hawaii from the Philippine Islands in 1930 as a biological control agent (Pemberton, 1948).

According to Beardsley (1959) the ant, *Pheidole megacephala*, is by far the most widespread and common ant tending mealybugs in Hawaii. During my observations in commercial sugarcane fields, ants seen most often tending mealybugs were:

1. *Pheidole megacephala* (Fabricius).
2. *Iridomyrmex humilis* Mayr (Argentine ant).

3. *Solenopsis geminata* Fabricius (Fire Ant).
4. *Anoplolepis longipes* (Jerdon).

## REVIEW OF LITERATURE

The term sympatric as defined by Mayr, Linsley, and Usinger (1953) "...applies to two or more populations which occupy identical or broadly overlapping geographical areas." Although the ants *I. humilis*, *P. megacephala*, and *A. longipes* occupy identical or broadly overlapping geographical areas, within these areas the three species of ants have separate and distinct territories that appear to never overlap except for occasional foraging workers.

Some authors have speculated on the effect the Argentine ant and *Pheidole* would have on each other as well as other species of ants if either ant was introduced into areas that it had not previously occupied (Wheeler, 1906, 1910, and 1934; and Illingworth, 1917).

Heer (1855) described an ant from the Islands of Madeira as being an extreme nuisance in homes and gardens. The ant was incorrectly called *Oecophora pusilla*, but was later identified as *Pheidole megacephala*. Heer did not know when the ant had become established on Madeira, but was of the opinion that *Pheidole* had successfully eliminated all endemic species of ants, as well as other endemic insects--notably various beetles and flies.

Illingworth (1917) believed that *Pheidole* was responsible for the eradication of large numbers of endemic insect species in Hawaii. Wheeler (1910) voiced the same opinion in regard to Bermuda.

The Argentine ant was described by Mayr (1868) from specimens sent to him from Argentina. The Argentine ant was brought into New Orleans sometime in 1891 (Wheeler, 1906). The ant spread rapidly across the southern part of Southeastern United States, becoming a pest wherever it became established. The Argentine ant became established on Madeira sometime shortly before the turn of the century. Wheeler (1906) states that the Argentine ant completely eliminated *Pheidole* from its original strong position on Madeira. Wheeler (1906) also states that the Argentine ant replaced *Pheidole* in the Canary Islands.

Many workers felt that if the Argentine ant became established in Hawaii, it would completely replace *Pheidole* as the dominant ant (Wheeler, 1934; Illingworth, 1917; and Zimmerman, 1941). The Argentine ant was first reported as being established in Bermuda in 1957 (Haskins and Haskins, 1965). Surveys of the territory occupied by the Argentine ant and *Pheidole* in Bermuda by Haskins and Haskins (1965) and Crowell (1968) indicate that the Argentine ant is slowly expanding its territory at the expense of *Pheidole*.

Jerdon (1851) described *A. longipes* from specimens taken in Africa. This ant has become widespread and abundant in Indo-Malaya, Indonesia, and Polynesia, including Samoa and Fiji (Dammerman, 1929). It has been reported as being the dominant ant in disturbed areas of Micronesia (Wheeler, 1934; and Wilson and Taylor, 1967). *A. longipes* seems to require different habitats for its nests than either the Argentine or *Pheidole* ants; but because their feeding habits are similar, there is contact and antagonism between the three species of ants.

Ants have long been known to be attracted to honeydew producing insects. As early as 1758, Linne' observed ants being attracted to aphids, mealybugs, and scale insects (Jones, 1929; and Wheeler, 1910). Ants have also been observed tending species of cicadellidae and membracidae (Beamer and Michener, 1950). Philips (1934) demonstrated that the presence of ants attending homopterous insects caused them to feed at a greater rate thus exerting more pressure on the host plant.

McCook (1882) believed that ants are efficient predators of certain crop pests. Swezey (1913) stated that *Pheidole* was always present in Hawaiian sugarcane fields and although they were feeding largely on the honeydew excreted by the mealybugs, occasionally some mealybugs were eaten by the ants.



In certain cases, the presence of ants is considered beneficial as they can maintain a small colony of the homopterous pests which will in turn serve as nucleus of a food supply for natural enemies (Flanders, 1951).

Annecke (1959) theorized that *Pheidole* seems to interfere more with predators than parasites of the soft brown scale. However, the ants may be beneficial because by interfering with the feeding of the predators they cause the predators to partially eat more soft brown scale. This partial eating kills the soft brown scale just as effectively as if the scales were eaten entirely.

Ayre (1963) suggested that certain species of ants could be used as effective predators of harmful insects, especially the larvae of insects attacking trees. Studies using the Argentine ant and various scale insects of citrus in California have shown that the ant causes considerable increases in the scale populations because of their antagonism towards the predators and parasites of the scale insects (DeBach, et. al., 1951; and Flanders, 1943, 1951, and 1958). Studies on the green scale, *Coccus viridus* (Green), demonstrated that populations of that scale would completely disappear without the presence of ants (Bess, 1958). Way (1954) demonstrated that without the presence of the ant, *Oecophylla longinoda* (Latr.), the scale

insect, *Saissetia zanzibarensis* Williams, was unable to maintain a constant population on clove trees.

In studies of ants associated with tea plants in India, it was shown that without the ants in attendance, coccid colonies soon were completely destroyed (Das, 1959). Steyn (1954 and 1958) using the ants, *Pheidole megacephala* and *Anoplolepis custodiens* Smith, in citrus groves found a direct correlation between the number of ants on a tree and the number of citrus red scale. Carter (1932) has shown that control of the pineapple mealybug, *Dysmicoccus brevipes* (Cockerell), in pineapple fields of Hawaii is dependent on control of ants attending the mealybugs. In sugarcane fields of Louisiana, control of the Argentine ant drastically reduced the mealybug population (Barber, 1923). Some predators and parasites are not affected as much as others by ants; the larval stages of the predators are affected least of all (Flanders, 1951).

In "Y" tube tests, certain parasites of scale insects were not sensitive to odors produced by ants. It is believed that the sensitivity of parasites to ants is an inherent response to any moving object and not to ants alone (Bartlett, 1961).

Nixon (1951) in his extensive review of ant associations with coccids and aphids, believes that the idea of

ants actively protecting the coccids and aphids from attack by parasites and predators is not a simple matter of protecting their food source, but rather a complex of factors is involved.

Koebele (1896) first reported the pink sugarcane mealybug in sugarcane fields of Hawaii; but, Beardsley (1959) thought that the pink sugarcane mealybugs probably had been in Hawaii as long as sugarcane. *Anagyrus saccharicola* was introduced into Hawaii by the Hawaii Sugar Planters' Association in 1930 as a biological control agent of the pink sugarcane mealybug (Pemberton, 1948).

Smith and DeBach (1942) were the first workers to use the experimental check method for the evaluation of natural enemy effectiveness. They eliminated the host and natural enemies from citrus branches by fumigating closed cloth sleeves fitted around the citrus branches. The branches were then reinfested with the host. Subsequently, they opened half of the sleeves to permit entry of the natural enemies of the host. The two treatments were compared to determine trends in populations of the host.

This method has been modified by many workers for use with different pests and natural enemies in the evaluation of effectiveness (DeBach, et. al., 1949; Franz, 1958;

and Way and Banks, 1958). DeBach et. al., (1951) referred to the natural enemy inhibition by ants as the biological check method because of the fact that ants seeking honeydew constantly kill or interfere with natural enemies of the honeydew producing insects. In their studies, barriers were placed around citrus trees in such a manner to prevent ants from infesting the trees.

DeBach and Bartlett (1964) noted that comparisons between ant free and ant infested treatments could be used to demonstrate whether or not natural enemies are producing biological control of the honeydew producing insect. They also noted that microclimate is not affected by ants as it is with other evaluation methods, e.g. chemical exclusion and using sleeves or cages. This would appear to make the use of ants the most desirable check method. However, natural enemies are never completely excluded even in the heaviest ant infestation; therefore this method will not show how high the host population would go if natural enemies were excluded completely. Obviously, the biological check method is limited to situations where ants can be utilized.

## MATERIALS AND METHODS

Section I: Laboratory and Field Observations

Ant nests of various sizes were constructed using plaster of paris. The largest nest was 14" X 18" X 1 1/2" deep and contained four chambers. Three of these chambers were designed for use as brood chambers and were covered with red plexiglas which effectively filtered the shorter wave lengths of the light spectrum to which ants are most sensitive. Passage ways were provided between all brood chambers to enable the ants to select the chamber best suited for brood rearing. The end chamber was used as a water trough and was constructed approximately 3/4" deeper than the brood chambers. This enabled water to be placed in the trough to translocate through the plaster so that relative humidity would vary from high in the chamber closest to the water trough to low in the chamber farthest from the water. Sides and bottoms of the nests were coated with shellac to prevent percolation of water through the plaster.

Smaller nests 1/2" X 3" X 1" deep were made using a similar design, but containing only one brood chamber and one water trough. The brood chamber of these nests contained an opening for entering and exiting.

Legs were attached to the bottom of each large nest and coated with Tanglefoot to prevent ants from escaping. The smaller nests were placed on wooden trays to which legs were attached and treated as above.

Large nests of the Argentine ant, *Pheidole*, and *A. longipes* were collected in the field and taken to the laboratory for transfer into the artificial nests. Collections were made from various locations on the Island of Oahu (Huddleston and Fluker, 1968).

Since the Argentine ant and *Pheidole* have a preference for old, partly decomposed sugarcane root stumps, it was found that by digging up such clumps most of the nest complex could be obtained. By taking the complete stump, injury to the workers, brood, and queens of the nest was minimized. When the ant nests were removed from the surrounding soil, they were immediately placed into heavy gauge plastic bags to prevent the ants from escaping.

Because *A. longipes* prefers to nest under large rocks, a different method was used for collecting. When a nest was located under a rock, a "D-Vac" machine was used to collect large numbers of queens, workers, and all stages of brood in a nylon organdy collection bag. By using the D-Vac, there was some injury to the workers and queens caused by the suction force of the machine and the debris from around the nest which was also collected by the machine.

Although the use of the D-Vac was not entirely satisfactory for collecting *A. longipes*, it was found that other methods, such as using mouth aspirators or the use of baits, were complete failures. They are extremely fast running ants, and within a matter of seconds after the nests were disturbed, there would be only a few workers and very little brood left to collect. Therefore, to acquire a colony of these ants, a collecting method that will collect large numbers of ants in a very short time is required. Also, when using a mouth aspirator, it was found that after aspirating a very small number of workers, the amount of defensive spray substance inhaled caused nausea. Baits were unsuccessful because only workers were attracted to the bait. So, even though the D-Vac injured some of the ants, it was considered the best alternative since it was powerful enough to collect almost all inhabitants of the nests before they could escape.

*A. longipes* were left in the nylon organdy bags in which they were collected and brought to the laboratory for transfer to the artificial nests. When large numbers of *A. longipes* were placed in sealed plastic bags, the defensive spray of the workers was highly toxic to the entire colony.

Many authors have published detailed methods of the best way to transfer ants from one nest to another (Wheeler,

1910; Gregg, 1952; Skaife, 1961; Hutchins, 1967; Sudd, 1967; Costello, 1968; and Markin, 1968). Most methods require either considerable time, complicated procedures, or the use of equipment that could very easily cause harm to the user, e.g. hotwire barriers. In transferring the Argentine ants, *Pheidole*, and *A. longipes*, the soil nests (or ground debris and ants in the case of *A. longipes*) were placed in a dry battery jar which had previously been placed in a shallow plastic pan containing two or three inches of water. The water created an effective barrier to keep the ants from escaping the battery jar. A runway was placed so that there was a connection between the jar and the artificial nest. Water was then slowly added to the battery jar. Since the three species of ants studied show a strong negative response to water, the workers would immediately begin moving the brood to a dryer, hence a higher, position in the battery jar. Once scent trails had been made by the exploring workers along the runway to the artificial nests, there would be an immediate exodus of queens and workers carrying brood onto the artificial nests. By slowly increasing the water level in the battery jar, complete colonies could be transferred in three to four hours. This was accomplished with almost no loss of brood or mature ants due to drowning.



As the ants moved to the artificial nests, there was some hesitancy in moving the brood into the covered brood chambers. However, in no case did more than 24 hours elapse before the brood was placed in the chambers by the workers. Each nest was provided with water, honey, and a sugar-water mixture. In addition, every seven days the ants in each nest was supplied with live fruit fly (*Tephritidae*) larvae to satiation.

## Section II: Waimanalo Experiment Farm Study

A plot of land at the University of Hawaii, Hawaii Agriculture Extension Service, Waimanalo Experimental Farm, Waimanalo, Oahu, Hawaii, was plowed with the rows sloped for irrigation. The land was divided into three blocks 150 feet by 45 feet. Each block was further divided into two plots 75 feet by 45 feet. In order to isolate each plot from the other, a 15-foot strip of bare ground completely encircling each plot was used as a barrier. Each plot then consisted of five rows of sugarcane 60 feet long with at least 30 feet of bare ground separating each plot from any other. The blocks and plots were designated with numbers and letters as shown in Figure 5. Plots A, D, and E were maintained as ant infested plots while plots B, C, and F were treated with ten pounds of 2.5% dieldrin granules per plot to eliminate any ants in the plots and prevent the future establishment of colonies.

The dieldrin was placed directly on the soil before the sugarcane seed pieces were planted; and at periodic intervals after planting, it was placed around the perimeter of the plots with an "Ortho Whirley Bird" granule spreader. Later, the "Ortho Whirley Bird" granule spreader was replaced by the P.C.B. (Borax Corporation) granule spreader which has a larger capacity and better calibration for proper dosage rates.

Scale 1/8" = 4'

B A N A N A      H E D G E

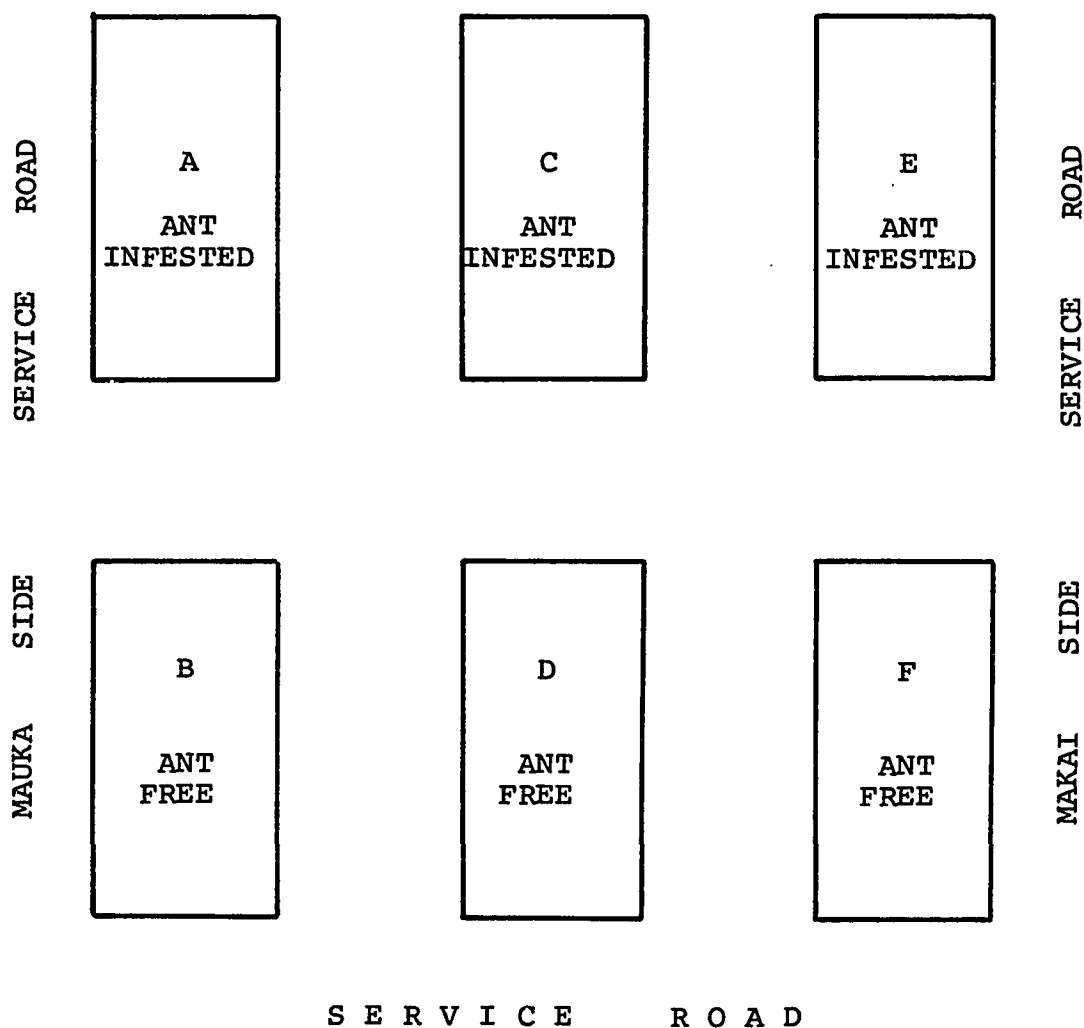


FIGURE 5. SUGARCANE PLOTS AT THE UNIVERSITY OF HAWAII, HAWAII AGRICULTURE EXTENSION SERVICE, WAIMANALO EXPERIMENTAL FARM, WAIMANALO, OAHU, HAWAII. EACH PLOT MEASURED 60 FEET BY 30 FEET AND CONTAINED FIVE ROWS OF CLONE H 50-7209 SUGARCANE. THERE WERE 30 FEET OF BARE SOIL SEPARATING EACH PLOT.

The plots were hand planted using approximately 30 three-to-four-eye seed pieces per row of sugarcane clone H 50-7209. The seed pieces were obtained from the Experiment Station, Hawaii Sugar Planters' Association, Kunia Substation, Oahu, Hawaii. As soon as the planting was completed, the plots were irrigated. Two days after the seed pieces were planted, atrazine was applied to all the plots at a rate of one-third pound per plot as a preemergence herbicide.

Because the plots were isolated from commercial sugarcane fields, it was found that no pink sugarcane mealybugs were moving into the plots. Two and one-half months after the sugarcane was planted, all of the plots were artificially seeded with pink sugarcane mealybugs. This seeding was accomplished by collecting a large number of gravid female mealybugs from a heavily infested field. Six gravid female mealybugs were placed in a one dram lip vial which had absorbant paper on the bottom. The vials were then covered with a double thickness of cheesecloth and secured to a stalk of sugarcane. The cheesecloth was used to prevent the escape of any parasites that might emerge from the gravid females, and at the same time allow the crawlers produced by the gravid females to escape the vials and start colonizing the sugarcane plots. A vial was placed on each of five individual plants in each row of every plot.

Three months after the sugarcane was planted, *Pheidole* was observed to be widely distributed with numerous colonies in all ant infested plots except Plot D. A large colony of *Pheidole* was transferred from a nearby field and placed in the middle of Plot D. Three queens were seen in the colony when it was transferred and later surveys revealed numerous colonies and a general distribution of ants over Plot D.

Seven months after the sugarcane was planted, sampling of each plot was begun to determine population levels and amount of parasitism of the pink sugarcane mealybug for each plot. Sampling consisted of samples from each plot taken at four week intervals from December, 1966, to January, 1968. All of the plots were burned and cut in February, 1968. A sample from a plot consisted of ten stalks of sugarcane selected at random in the plot, with each stalk being approximately the same age. Each sample was bundled, labeled, and brought to the laboratory for counting. Stalks were examined for the presence of pink sugarcane mealybugs by carefully cutting the leaf at the base and removing the leaf from the stalk. Removing one leaf at a time exposed the next higher node of the stalk without disturbing the mealybugs which were feeding around the node. Because the first instar nymphs

of the mealybugs do not start feeding as soon as they hatch from the egg and the gravid females stop feeding shortly after reproduction begins, four categories of mealybugs were established for this study. The categories do not coincide exactly with the different stages in the life cycle. Both the crawlers and the small nymphs can be in the first instar, the only difference being that the small nymphs are feeding. Also, the small nymph and large nymph categories both overlap into the second and third instars because of the wide range in size that occurs in mealybugs from the beginning to the end of the instar. The mature female category embraces only the fourth instar female mealybugs. The categories were:

1. Crawlers - 0.5 millimeters in length.
2. Small nymphs - 0.5 to 1.2 millimeters in length.
3. Large nymphs - 1.3 to 2.5 millimeters in length.
4. Mature females - 3.0 to 5.0 millimeters in length.

As the pink sugarcane mealybugs were counted, they were categorized and placed into one dram vials containing absolute alcohol. The vials with the mealybugs were then placed in numbered wooden racks to await further study to determine the amount of parasitism.

To determine if the pink sugarcane mealybugs were parasitized, they were allowed to remain in the absolute alcohol for at least 48 hours, and as long as a week. It was found that at least 48 hours were needed for the absolute alcohol to completely penetrate and replace all the water in the mature female. Because of the time required to count and classify the mealybugs, they were sometimes allowed to remain in alcohol for longer periods.

At the end of the dehydration period, the alcohol was drawn out of the vial with a modified glass eye dropper. Care was taken to minimize the danger of losing any of the pink sugarcane mealybugs during the process of removing the alcohol.

Xylene was then put in the vial containing the mealybugs, and the vials were shaken vigorously for a few seconds to completely dissolve the waxy covering of the insects. The xylene was removed and replaced with fresh absolute alcohol.

A number of methods were used to prepare the mealybugs for parasitism examination. A method using acid fuchsin as described by Maple (1947) to dye the aeroscopic plate of the encyrtid egg was tried but was found to be unsatisfactory because the procedure was too time consuming. Originally, 95% alcohol was used, but when xylene

was added the resulting solution was cloudy even though as much alcohol as practical was removed. By using absolute alcohol, there was no cloudiness in the mixture. Using a dissecting scope at 30 X magnification, the aeroscopic plate of the encyrtid egg or larvae was readily visible. Dissection revealed that the presence of an aeroscopic plate externally on the host integument was a positive identification of host parasitism.

All statistical methods used in this study are adequately covered in the book, *Statistical Methods*, by George W. Snedecor (1956).



### Section III: Commercial Field Studies

Three fields of commercially grown sugarcane belonging to Ewa Plantation, Ewa, Oahu, Hawaii, were selected for sampling. All fields were of the variety 50-7209 growing and maintained under similar conditions in regard to soil type, elevation, irrigation, and fertilization. The fields were selected for sampling because each field had either *A. longipes*, *Pheidole*, or the Argentine ant as the dominant ant species which were attending the mealybugs.

Each field was sampled at three week intervals beginning January 13, 1969, and ending April 7, 1969. Sampling consisted of taking all mealybugs from fifty stalks of sugarcane in each field. Twenty-five of these stalks were selected from the outside perimeter of the fields and 25 were selected 60 feet inside the field. Each 25 stalk sample was maintained separately.

Without removing selected stalks from the fields, each leaf sheath was carefully removed to reveal any mealybugs feeding around both the node and internode. The mealybugs were then removed from the stalks using a 12-volt portable vacuum cleaner. The standard dust bag in the vacuum cleaner had been removed and replaced with nylon organdy in which to trap the mealybugs.

The vacuum cleaner used was a portable automobile model to which 90 feet of 16-gauge lamp cord was added to the existing 15 feet of cord. The cigarette lighter plug was removed from the vacuum cleaner and replaced by two alligator clamps which were used to connect the cleaner directly to the poles of an automobile battery. The 105 feet of cord allowed me to attach the cleaner to the car battery outside the field and enter the field to a depth of at least 60 feet. The cord was marked at ten foot intervals as a measuring device to indicate distance inside the field.

After all mealybugs were removed from each group of 25 stalks, the nylon organdy trap containing the insects was removed from the vacuum cleaner and placed in an eight ounce wide-mouth bottle containing absolute alcohol.

All samples were labeled and then taken to the laboratory where the mealybugs were counted and placed in one of four categories:

1. Crawlers - 0.5 mm. long.
2. Small nymphs - 0.5 to 1.2 mm. long.
3. Large nymphs - 1.3 to 2.5 mm. long.
4. Mature females - 3.0 to 5.0 mm. long.

After at least 48 hours in absolute alcohol, the mealybugs were examined to determine the number which were parasitized. The same procedure for determining

parasitism was used as described in the Experiment Station Studies.

## RESULTS, DISCUSSION, AND CONCLUSIONS

Section I: Sympatric Associations

Part 1. Studies Involving Colonies of Ants: Life cycle studies were conducted to determine the length of time necessary for a worker ant to develop from the day the egg was laid to its emergence as a callow adult. Attempts were not made to determine the longevity of adult workers. These studies were conducted in an air conditioned laboratory with a temperature range of 20°C to 22°C.

Large colonies of each ant which had been maintained in the laboratory for at least four weeks were anesthetized with CO<sub>2</sub>. One queen and 15 to 20 workers were taken from each colony and placed in separate, small plaster nests. After each queen had deposited 30 to 50 eggs, she was removed from the nest. The days required for each species of ant to reach maturity are shown below:

<u>Species</u>	<u>Egg Stage</u>	<u>Larva Stage</u>	<u>Pupa Stage</u>	<u>Total Days from Egg to Adult</u>
<i>P. megacephala</i>	19-23	28-32	19-23	66-78
<i>I. humilis</i>	16-17	25-29	23-25	64-71
<i>A. longipes</i>	18-20	26-30	32-34	76-84

The shorter length of time required for the Argentine ant to develop to adult stage suggests that it is possibly better adapted to lower temperatures than either *Pheidole*

or *A. longipes*. Although the Argentine ant is found at low elevations on the Hawaiian Islands, its largest and fastest expanding areas on Oahu are on the cooler north shore between the Koolau and Waianae Mountains.

Argentine ants have been found in Hawaii at much higher elevations, therefore at lower temperatures, than either *Pheidole* or *A. longipes*. Huddleston and Fluker (1968) collected Argentine ants from the Kokee Park area of Kauai at an elevation of 4,000 feet; on the Island of Maui at the Hosmer's Grove Picnic Area on the slopes of Haleakala at an elevation of 5,800 feet; at Volcanoes National Park on the Island of Hawaii at an elevation of 4,000 feet, and various other sites. *Pheidole* was never found above the 3,000 feet level. *A. longipes* is a low elevation ant found below 2,000 feet.

Hertzer (1930 a and b) demonstrated that if given a choice of temperatures and relative humidity, the Argentine ants would move their brood to an area of high humidity with the temperature of 25 to 27°C. Her studies also showed that the correct humidity was more important to the ants than temperature.

During 2 1/2 years of observations in areas where the Argentine ant and *Pheidole* were in contact along the north shore and on the Wahiawa plateau in pineapple fields, the Argentine ant was able to enlarge its territory at the

expense of *Pheidole*. In lower, drier areas such as Ewa Plantation's field numbers 1, 26, and 28 which are west of Pearl Harbor, the territory of each ant seems to be fairly stable. Possibly the Argentine ant is losing territory in this area at a very slow rate. Thomsen and Pemberton (1950) reported that the Argentine ant was found in great numbers around Ewa Plantation, Pump 10, and that the infestation extended westward along the service road to the end of it--a distance of over two miles. At the present time, Argentine ants are found in this area only in field numbers 1 and 2 which are located at the west end of the service road. In the area formerly occupied by Argentine ants, species of ants belonging to such diverse genera as *Solenopsis*, *Paratrechina*, *Tetramorium*, *Momomorium*, *Plagiolepis*, *Pheidole*, and possibly others can now be found. No one species seems to be dominant at this time.

The invasion of the Argentine ant into *Pheidole* territory was not a slow steady invasion. Weekly and bi-monthly observations of Argentine ant movement revealed that the Argentine ants made no new territory invasions for periods of time ranging from four to six months. During this time, I was able to find large Argentine ant and *Pheidole* colonies as close together as ten feet. Even though the ants were found in very close proximity to each other, I could never

find any overlapping of territories. On numerous occasions I found halfway between the nests, piles of dead ants; both Argentine and *Pheidole*. The piles of ant bodies were not in heaps but rather in straight lines five to ten millimeters deep, approximately five to ten millimeters wide, and as long as 50 to 60 centimeters. This appeared to be the "battleground" as I could never find any ants of one species in the territory of the other species.

During the time that the Argentine ant was static in its movement, there seemed to be a buildup in the size and number of colonies. As the Argentine ants started to invade new territory, *Pheidole* colonies and foragers would vanish from the immediate area. The following ant species could then be found in the areas previously occupied by *Pheidole*.

1. *Cardiocondyla nuda* (Mayr).
2. *Monomorium* spp.
3. *Tetramorium* spp.
4. *Solenopsis geminata* (F.) (Fire Ant).

Although all of these species of ants were found in this area, I was never able to find the nests of any except *Solenopsis geminata*. Since all of the ants listed except the fire ant are small and inconspicuous, it is highly probable that the nests were overlooked. Even

though these other ants were found in the areas where previously only *Pheidole* had been found, the invasion by the Argentine ant was not stopped, not even by the formidable fire ant.

My observations revealed that the Argentine ant would attack the nests of the fire ant. The Argentine ants always seemed to be the aggressor. They were observed moving in large numbers to the nests of the fire ant. As the Argentine and fire ants encountered each other, they locked in mortal combat. During these battles no major workers of the fire ant were seen, only minor workers.

An individual fire ant generally was able to kill one or two Argentine ants before it was injured so badly that it could no longer defend itself from the overwhelming numbers of Argentine ants invading its nest. There seemed to be general confusion and panic exhibited by the fire ants as they were being invaded, while the Argentine ants displayed no undue excited behavior and seemed intent on one thing--eliminating the colony of fire ants.

As the battle progressed and there became fewer fire ants and more Argentine ants around the nest sites, Argentine ants were seen entering the fire ant nests. Closer observation revealed that the Argentine ants were removing the brood of the fire ants and taking it back to their own nests. The brood of the fire ants apparently



served as a source of food for the Argentine ants. In studies conducted in the laboratory, it was found that Argentine ants readily accepted all stages of other ants as food.

It required approximately ten to fourteen days for the Argentine ants to eliminate the fire ants and move a distance of 75 to 100 feet. At this point in time, the Argentine ants would halt all advances. Within seven to ten days, *Pheidole* colonies would reappear in the areas unoccupied by the Argentine ants and the cycle would then begin anew.

Even though observations were made frequently, it was impossible to find any *Pheidole* in the immediate vicinity of the Argentine ants while they were in the process of expanding their territory. However, *Pheidole* could be found in large numbers 100 to 150 feet distant from the Argentine ants. It appears that *Pheidole* does not defend their territory against the Argentine ants during the latter's invasion phase. Instead *Pheidole* apparently vacates the area rather than be overrun by the Argentine ants.

The territorial acquisition pattern displayed by the Argentine ants was observed in four widely separated areas on Oahu.

1. Ewa Plantation Field Number 1.

2. Summit of Mauna Kapu on the Palihua Trail.
3. Kunia Road one-fourth mile Ewa of Schofield Barracks.
4. Dole Pineapple Field Number 4109 above the Pineapple Research Institute in Waipio.

The same pattern of invasion was followed at all locations. The only exception was that *Cardiocondyla* "A" (an unnamed species close to *venustula*) was present at two of the locations in the "Buffer Zone" between the two dominant species instead of *Solenopsis geminata*.

The observations of the past two and one-half years suggests that in Hawaii there appears to be a more or less fixed pattern in the behavior of the Argentine ant with regard to competitive replacement. The Argentine ant does not invade territory occupied by another dominant ant species without overwhelming superiority in numbers. This seems to be brought about because natural dispersal of the Argentine ant is outward from the center of established foci. This dispersal is accomplished by slow ground movement of young queens and splinter colonies of workers. Although Argentine ants produce winged males and queens in their colonies, it is thought that dispersal does not take place by nuptial flights (Wynne-Edwards, 1963). I have never seen a nuptial flight of Argentine ants. Neither have queens or males been found in light

traps as other ants often are. Crowell (1968) and Haskins and Haskins (1965) observed similar behavior in the Argentine ants in Bermuda.

Since *A. longipes* was first found established in Hawaii in 1953 at the Barbers Point Naval Air Station, it has enlarged its territory greatly. Huddleston and Fluker (1968) reported sixteen collection sites on Oahu for *A. longipes*.

Observations made in the field on the territorial behavior of *A. longipes* revealed that it tended to coexist with both the Argentine ant and *Pheidole* in areas where neither ant was dominant. However, in areas where suitable nesting sites for *A. longipes* are abundant, it becomes the dominant ant of the three species. As in earlier reports (Wilson and Taylor, 1967; and Dammerman, 1929), this always seems to be in disturbed areas, especially where there are rock walls and/or deep rock lined irrigation ditches.

In tests conducted in the laboratory, it was found that when colonies of Argentine ants or *Pheidole* were placed in contact with a colony of *A. longipes*, the workers and queens of *A. longipes* were always destroyed and the brood was taken as food by the other ant. *A. longipes* seemed to make no effort to defend itself or the brood. Instead the workers would run about the enclosure in panic

and most would be killed by running into the "Tanglefoot" barrier rather than in fights with the other ants.

Colonies of Argentine ants and *Pheidole* which had been maintained in the laboratory for three weeks were put together so that there was continuous contact along one side of the nest platforms. Within ten minutes, the whole colony of Argentine ants had crossed over to the *Pheidole* platform. This invasion included not only workers but the brood and many queens as well.

There seemed to be no concentrated attack by the Argentine ants; however, there were chance encounters caused by the Argentine ants scurrying about. An occasional Argentine ant would go into the area where the *Pheidole* colony was concentrated. It would be immediately attacked by one or more *Pheidole* workers and usually would be killed. The only unusual excitement in the *Pheidole* nest was caused by the occasional invasion by an Argentine ant. However, there seemed to be a response to the invasion throughout the *Pheidole* colony whereby the *Pheidole* began to seal the entrances to the nest with trash as a protective measure.

In less than 90 minutes, the Argentine ants had moved all their brood and queens back into their original colonies with only an occasional Argentine ant venturing onto the *Pheidole* platform. When an Argentine ant would cross

over to the other platform, it would only go to the outer perimeter.

After four hours, there was no sign that either ant would attack the other in sufficient numbers to eliminate the colony. The Argentine ants still moved about their platform in the usual foraging manner, occasionally crossing over to the *Pheidole* platform. The *Pheidole* were still in the process of sealing the entrances to their nest. There were a few soldiers and workers of *Pheidole* on the Argentine platform.

At five hours after beginning the experiment, the Argentine ants began moving their brood from one nest to another. In a short time the colony became very excited and started moving the brood out of both nests and eventually settled down at the opposite end of the platform from the nests. This excitation of the colony seemed to have been preceded by the invasion of the Argentine ant colony by four or five *Pheidole* soldiers. The Argentine ants seemed to go out of their way to avoid contact with the soldiers, even when the soldiers were injured. *Pheidole* soldiers are much slower in their movements than the Argentine ant workers; but they snap their mandibles at any moving object which is near. They will do this to even their own species when they are very excited.

After a 12 hour period had elapsed, the Argentine ant colony was still grouped with their queens and brood at

the corner of the platform farthest from the nests. After the lights in the laboratory had been on for five to ten minutes, the Argentine ants began to move back into the two nests. Within a period of ten minutes, they had moved all of their brood back into the nests. At this time there was very little disturbance of the Argentine ant colony by *Pheidole*.

At 24 hours from the beginning of the experiment, the complete Argentine ant colony had moved again. This time they moved from the nests into the corner farthest from the *Pheidole* and their own nests. At this point in time, the former Argentine ant nests were occupied by six to ten *Pheidole* soldiers and approximately fifteen workers in each nest. The Argentine ants appeared to be very sluggish in their movements and were making no attempt to re-establish themselves in their nests. Even when a 75-watt light was turned on directly above them, no attempt was made to protect themselves or their brood from the light. The colony of *Pheidole* seemed to be engaged in its normal activities without undue excitement.

Late in the morning of this second day of observations, another artificial nest was put on the platform containing Argentine ants. The colony immediately began moving into the nest. In less than 20 minutes, the entire colony of Argentine ants was inside the nest.

Approximately four hours later, the colony of Argentine ants was still in the new nest with *Pheidole* occupying the original Argentine ant nests.

At eight o'clock in the morning of the following day, it was observed that the Argentine ants had moved out of the new artificial nest and were on top and to one corner of the nest. Shining bright lights on the colony did not force them to move. Only one *Pheidole* was seen in the nest which the Argentine ants had vacated.

The experiment explained above was repeated in the laboratory four times. Each experiment ended with *Pheidole* having possession of the nests and the Argentine ants huddled in a corner as far away from *Pheidole* as they could possibly get.

A later experiment consisted of placing a small colony of Argentine ants in an artificial nest with sand completely covering the floor of the platform to a depth of one-half inch. This platform was connected to another platform containing a very large colony of *Pheidole*. The Argentine ants immediately began to cross over to the *Pheidole* platform. There were so many *Pheidole* at the base of the bridge that the Argentine ants were unsuccessful in crossing over to the other platform. When one would try to make the crossing, it would be immediately attacked by *Pheidole* soldiers and workers. This situation

was observed for one hour. The following morning, it was noted that the complete colony of Argentine ants had been killed by the *Pheidole* ants. The nest which had been originally occupied by the Argentine ants was inhabited by *Pheidole*. Upon close examination, it was observed that numerous *Pheidole* workers were carrying brood to their original nests. It was determined that this was the Argentine ant eggs, larvae, and pupae which were probably used as food by the *Pheidole* colony.

In efforts to establish Argentine ants in the ant infested plots of sugarcane at the Waimanalo Experiment Station, two large colonies of Argentine ants were brought from Wailua Agriculture Company Field Opaepala Number Nine to the Waimanalo plots. The ants were transported from Wailua to Waimanalo in heavy plastic bags. The two plastic bags containing the ants were placed at the edge of the plot and a hole was punched in each bag. This hole was made to allow the insertion of a sugarcane leaf into the bags. The leaf was positioned so that the ants would move along the leaf to a horizontal cane stalk which was lying on the ground. Some loose soil had been previously placed over a portion of the stalk about three feet from the plastic bags as a possible nest. The ants immediately began moving their brood from the plastic bags to the



place where the soil was covering the stalk. By close observation, it was noted that the workers would take the brood to the soil covering the stalk and return to the plastic bags for more brood.

During six hours of almost constant observation, there was a steady stream of workers with brood going to the new nest from the plastic bags and returning empty to the bags after more brood. At the end of six hours, it was noticed that some *Pheidole* soldiers and workers were at the base of the sugarcane stalk approximately two feet from the nest. At the same time, large numbers of *Pheidole* soldiers and workers were observed on the ground about one foot from the Argentine nest. Within four hours after the first *Pheidole* was seen in the vicinity of the Argentine ant nest, the *Pheidole* ants had moved into the Argentine ant nest with the result that the Argentine ants had moved their brood out of the nest and through an area which had been treated with 2.5% Dieldrin granules. The Argentine ants moved even though they outnumbered *Pheidole* tremendously. There were close to ten thousand Argentine workers in the nest and less than one hundred *Pheidole* near the area.

Argentine ants were introduced to the Waimanalo Experiment Station plots on several occasions prior to this using similar methods. Each time they disappeared,

so this particular attempt was made to determine their actions and movements.

The behavior exhibited by *Pheidole* and the Argentine ants suggests that glandular secretions are involved and play a large role in the behavior on one ant toward the other. Crowell (1968) theorized that the Argentine ant released some type of glandular secretion which was very repugnant to *Pheidole*, causing *Pheidole* to move away from concentrations of Argentine ants. If indeed there is a chemical repellent released by the Argentine ants, my studies seem to indicate that only under certain conditions do the Argentine ants release this glandular secretion. This appears to be during the time immediately preceding an invasion of new territory by the Argentine ants. If a glandular secretion is produced by the Argentine ants, this could account for the "Buffer Zone" that is commonly found separating the Argentine ants and *Pheidole* during the former's "invasion cycle." At other times, Argentine ant and *Pheidole* colonies are found very close together.

The studies conducted in the laboratory and sugarcane plots at Waimanalo Experiment Station appear to indicate that the *Pheidole* soldier may release a glandular secretion that is offensive to the Argentine ants. The action of the Argentine ant in the presence of the *Pheidole*

soldier suggests this possibility. Although the Argentine ant will attack and kill *Pheidole* workers and will continue to mutilate their bodies after death, the Argentine ant appears to go to great extremes to avoid a *Pheidole* soldier. Even if the Argentine ants far outnumber the *Pheidole* soldiers, they will make no attempt to attack. No attempt was made to determine if the *Pheidole* soldier has a glandular secretion that was responsible for the actions of the Argentine ants. However, I find it difficult to believe that the mere physical presence of a few *Pheidole* soldiers is all that is needed to cause a colony of thousands of Argentine ants to abandon otherwise suitable nesting sites.

This study has shown that the Argentine ant is slowly expanding its territory on Oahu at the expense of the *Pheidole*. However, *Pheidole* does not appear to be even remotely approaching extermination from the Hawaiian Islands at the present. Although, *Pheidole* is slowly losing territory to the Argentine ant, it appears that most of the territory being lost is of marginable suitability to *Pheidole*. It is highly unlikely that *Pheidole* was ever able to occupy the areas above 3,000 feet in which Argentine ants are now found.

The Argentine ant apparently eliminated *Pheidole* from the Island of Madeira and the Canary Islands approximately

60 or 70 years ago (Wheeler, 1906). The same phenomenon appears to be taking place on the Islands of Bermuda at the present time (Haskins and Haskins, 1965; and Crowell, 1968).

Skaife (1961) records the Argentine ant from such widely separated areas as:

1. Argentina.
2. Chile.
3. Southeastern United States and California.
4. Canary Islands.
5. Cape Town, Union of South Africa.
6. Melbourne, Perth, and Sidney, Australia.
7. Madeira Island.

In such widely separated, diverse areas there appears to be one thing that is common to all localities--either all or part of all the localities listed are situated between 30° and 36° latitude in either the northern or southern hemisphere. The Bermuda Islands are also situated in these latitudes. The first specimens of the Argentine ant which was described by Dr. Mayr in 1868 came from Buenos Aires, Argentina (Mayr, 1868), which is at 35° south latitude.

This suggests that the Argentine ant is most successful in its activities in the latitudes between 30° and 35° north or south. *Pheidole megacephala*, however, appears

to be restricted principally to humid tropical regions of the world (Wilson and Taylor, 1967). I surmise that even though *Pheidole* is found at latitudes out of the tropics and the Argentine ant is found at latitudes in the tropics, when this takes place both ants are in areas in which they are not well adapted. This I believe puts each ant at a disadvantage when confronted by another ant better adapted to the particular area. Because of the apparent differences in preferred latitudes between *Pheidole* and the Argentine ant, I believe that *Pheidole megacephala* and *Iridomyrmex humilis* (the Argentine ant) will eventually reach a state of semi-equilibrium in the Hawaiian Islands. The Argentine ant will occupy the higher, cooler elevations which compensate somewhat for the lower latitudes, and *Pheidole* will occupy the lower elevations. I base my theory on the past history of the movement of the Argentine ant around the world and on the following information furnished me by Mr. Sol Price, Environmental Science Services Administration, Weather Detachment, Honolulu. From sea level each 333 feet increase in elevation is equivalent to a one degree increase in latitude. As mentioned earlier, the Argentine ant is apparently most successful between 30° and 35° latitudes. On the Islands of Kauai, Maui, and Hawaii the Argentine

ant is found with numerous thriving colonies at altitudes above 3,000 feet. This, in essence, puts the ants in environments climatically similar to latitudes above 30°, which could account in part for their success in colonizing the higher elevations of the Hawaiian Islands.

Part 2. Studies Involving Small Numbers of Ants:

Experiments were conducted to determine the aggressiveness and fighting ability of the Argentine ant, *A. longipes*, and *Pheidole* (both soldiers and workers). Two or more ants of different species were placed in a glass covered Syracuse watch glass. Actions of the ants were observed through a B & L stereozoom dissecting scope.

Experiment #1: One Argentine ant and one *Pheidole* worker were placed in the watch glass. The first time the ants contacted each other, the *Pheidole* immediately attacked the Argentine ant. *Pheidole* seemed to be intent on only one thing - destroying the Argentine ant. Although *Pheidole* usually succeeded in clamping its mandibles on a leg or antenna of the Argentine ant, rarely did *Pheidole* manage to secure a hold on the abdomen or thorax. In less than two minutes, the Argentine ant would crush the thorax and abdomen of the *Pheidole* ant, killing it. Even though dead, the *Pheidole* would remain attached to the Argentine ant. If another *Pheidole* worker was placed in the watch glass with the original Argentine ant, it would usually succeed in killing the Argentine ant. This occurred in 28 of 30 tests conducted using the above procedures. In two of the tests, it took up to four *Pheidole* to kill one Argentine ant.

The attack pattern of the *Pheidole* worker appears to be characteristic whether one worker or many workers are involved. The workers appear to deliberately attack other ants about the extremities. Creighton and Creighton (1959), and Creighton (1966) have demonstrated similar attack patterns and defense postures in other *Pheidole* species. When large numbers of *Pheidole* workers attack another ant, they attach themselves to all the legs as well as antennae and mandibles of the ant attacked (Figure 6). The constant pulling by the *Pheidole* workers apparently is sufficient to kill the attacked ant, although I have observed that the constant pulling may last two to three hours.

Experiment #2. One Argentine ant and one *Pheidole* soldier were placed in the watch glass. Upon contact between the two ants, the *Pheidole* soldier would immediately attack. Because the Argentine ant is much faster in its movement, it was usually able to avoid the soldier for some time. During this time, the movements of the soldier were very slow and deliberate. As it moved about, its mandibles were open very wide and the antennae were held with the scapes along the outer margins of the mandibles in the defensive position (Figure 7) instead of the normal extended position (Figure 1). Eventually, the Argentine ant would approach the soldier too closely



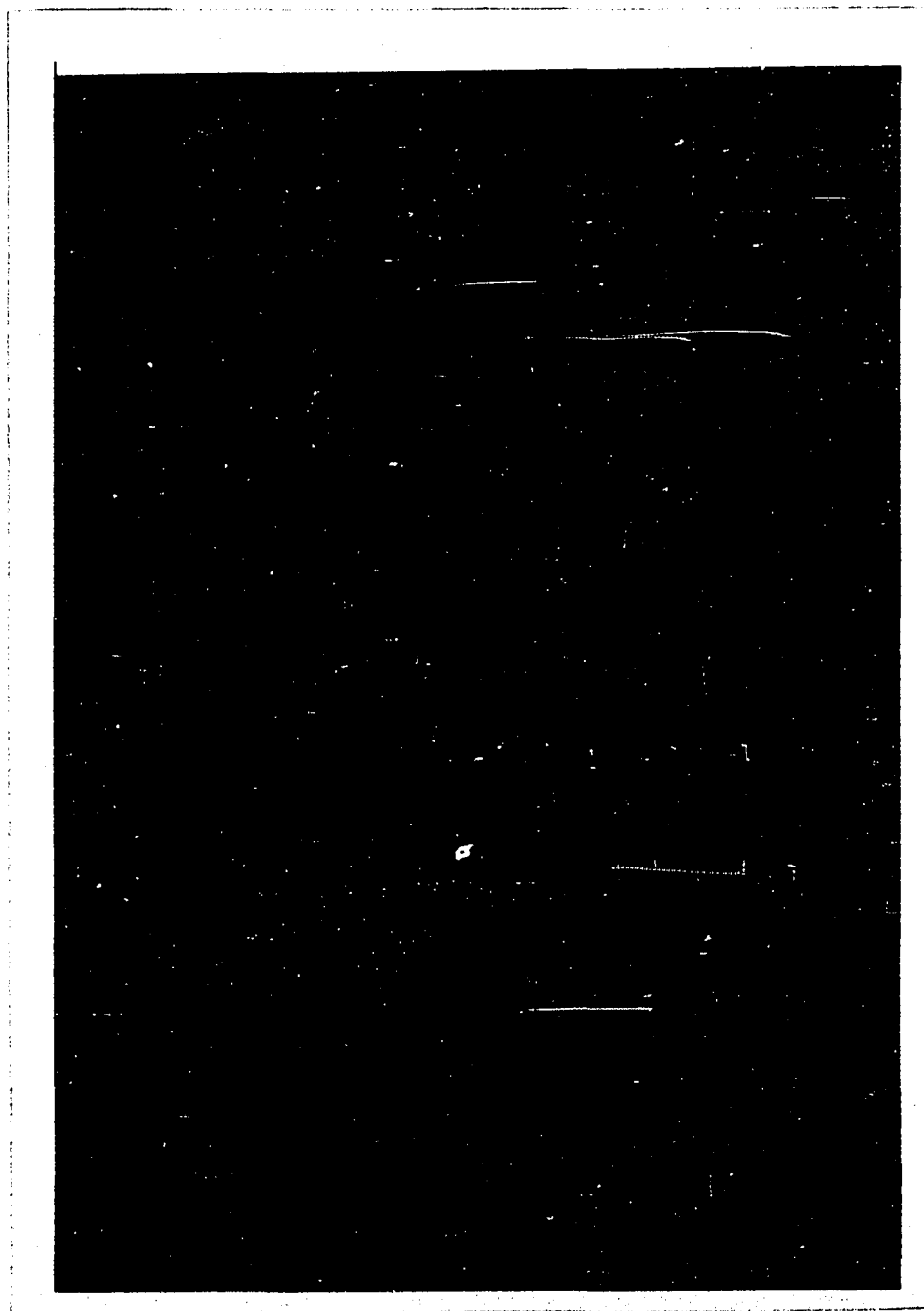


FIGURE 6. *PHEIDOLE MEGACEPHALA* WORKERS ATTACKING AN ARGENTINE ANT QUEEN



**FIGURE 7.** *PHEIDOLE MEGACEPHALA* SOLDIER WITH ITS ANTENNAE AND MANDIBLES IN A DEFENSIVE POSITION

and the soldier would immediately lunge, closing its mandibles with enough force to sever any part of the Argentine ant which the mandibles struck. The Argentine ant was always killed, and even after the victim had stopped all visible body movements, the soldier continued to crush, sever and/or dismember its body. As additional Argentine ants were placed one at a time in the watch glass, the same sequence of events took place. This would continue until six or seven Argentine ants had been mutilated and killed by the *Pheidole* soldier. Even though the soldier was able to kill up to seven Argentine ants, this usually was not without injury to itself. The soldier would have two or three of its legs severed during the fights and occasionally an Argentine ant was able to mutilate or sever the abdomen of the soldier. As the soldiers received more and more injuries, they became less and less efficient in destroying the Argentine ants. Ultimately the soldiers became unable to make attacks at the Argentine ants. At this stage, the Argentine ants did not attack the soldiers, but remained at a distance even when the latter were dead.

Experiment #3. One *A. longipes* ant and one of either *Pheidole* (soldier or worker) or Argentine ant were placed in the watch glass. *A. longipes* is very fast in its movements, and even though there was frequent contact between

the ants, *A. longipes* usually managed to escape. *A. longipes* showed no aggressiveness toward the other ants and seemed to be intent only in escaping. When *A. longipes* and one of the other ants did lock in battle, *A. longipes* would curve its abdomen forward between its legs with the posterior end pointing cephalad. In this position it was able to spray its defensive substance at its attacker. Blum (1966) and Cavill and Robertson (1965) state that ants of the subfamily Formicinae are the only ones that regularly use their poison gland secretions as defensive sprays. Unlike most ants in other subfamilies, the poison gland secretions of Formicinae are non-proteinaceous. However, the substance seems to be quite toxic to other ants, as well as to itself. In tests where Argentine ants and *Pheidole* were placed together, death of the ants appeared to be caused exclusively by bodily injury. In all tests using *A. longipes* as one of the ants, death of the ants seemed to be caused not by bodily injury but by toxicity of the poison gland secretions of *A. longipes*. The toxin even killed the soldiers of *Pheidole*. This poisonous secretion was toxic not only to other ants but to *A. longipes* as well when the ants were kept in a small sealed container.

From these experiments the following conclusions can be drawn:

1. With individual ants or small numbers, *Pheidole* is the most aggressive of the three ant species tested. The workers, because of their size, are hardly a match against the Argentine ant; however, the disadvantage of small size is partly compensated for in aggressiveness and tenacity.

2. Under the conditions of these tests, the Argentine ant did not appear to be very aggressive, although they would fight when attacked.

3. *A. longipes* is by far the least aggressive of the three species tested. However, of the three ants tested, the toxic spray of *A. longipes* appears to provide the most effective defense.

Section II: The Ant, *Pheidole megacephala*, and Some  
Effects on Populations of Pink Sugarcane Mealybugs

Part 1. Effect of the Presence or Absence of the

Ant: Beardsley (1959) demonstrated that there are monthly fluctuations in the number of pink sugarcane mealybugs per stalk of sugarcane. Mealybug populations, which were sampled at four week intervals during the present study, showed strong monthly fluctuations with the largest populations present during the months of December 1966, January 1967, and February 1967. The March 1967 and April 1967 samples showed a marked decrease in numbers per stalk. There was a slight increase in mealybug numbers starting in May and generally continuing until November when the mealybug numbers began decreasing again.

Although populations of mealybugs in both treatments declined rapidly beginning in March, populations in the ant infested treatment showed a strong trend toward higher numbers at each sampling date (Table I and II). An analysis of variance of population differences between the two treatments from month to month produced a significant F value at the 75% confidence interval (Table III). The analysis of variance also showed a significant difference at the 99% confidence interval in the size of the overall populations of mealybugs from month to month. The

TABLE I. POPULATIONS AND PERCENT PARASITISM OF *SACCHARICOCCUS SACCHARI* BY *ANAGYRUS SACCHARICOLA* IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED PLOTS LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII 1966 - 1968

MONTH	L I V I N G					PARASITIZED				% PARASITIZED		
	CRAWLERS	SMALL NYMPHS	LARGE NYMPHS	MATURE FEMALES	TOTAL	SMALL NYMPHS	LARGE NYMPHS	MATURE FEMALES	TOTAL	SMALL NYMPHS	LARGE NYMPHS	MATURE FEMALES
Dec. '66	313	1823	1768	84	3988	326	559	39	924	18	32	46
Jan. '67	1989	2319	166	154	4628	20	73	94	187	1	44	61
Feb. '67	870	2896	958	34	4758	111	233	21	365	4	24	62
Mar. '67	194	256	353	41	844	13	108	34	155	5	31	83
Apr. '67	8	43	47	1	99	1	1	0	2	2	2	0
May '67	22	322	206	23	573	15	36	19	70	5	17	83
Jun. '67	259	841	53	10	1163	6	19	7	32	1	36	70
Jul. '67	15	535	164	14	728	2	14	6	22	4	9	43
Aug. '67	421	741	80	11	1253	5	19	7	31	1	24	64
Sep. '67	823	577	669	88	2157	75	224	44	343	13	33	50
Oct. '67	1468	877	316	38	2699	92	140	30	262	10	44	79
Nov. '67	1016	624	215	47	1902	56	50	3	109	9	23	6
Dec. '67	346	542	274	223	1385	11	43	24	78	2	16	11
Jan. '68	795	231	87	46	1159	10	18	10	38	4	21	22
Total	8539	12627	5356	814	27336	743	1537	338	2618	6	29	42

TABLE II. POPULATIONS AND PERCENT PARASITISM OF *SACCHARICOCCLUS SACCHARI* BY *ANAGYRUS SACCHARICOLA* IN 14 SAMPLES OF SUGARCANE FROM ANT FREE PLOTS LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII 1966 - 1968

MONTH	L I V I N G					PARASITIZED				X PARASITIZED		
	CRAWLERS	SMALL NYMPHS	LARGE NYMPHS	MATURE FEMALES	TOTAL	SMALL NYMPHS	LARGE NYMPHS	MATURE FEMALES	TOTAL	SMALL NYMPHS	LARGE NYMPHS	MATURE FEMALES
Dec. '66	92	1003	681	62	1838	254	239	22	515	25	35	35
Jan. '67	402	470	122	33	1027	7	31	20	58	2	25	61
Feb. '67	238	688	411	13	1350	95	168	8	271	14	41	62
Mar. '67	268	62	73	12	415	1	26	9	36	2	36	75
Apr. '67	11	38	16	1	66	5	6	1	12	13	38	100
May '67	2	7	10	0	19	0	1	0	1	0	10	0
Jun. '67	331	323	49	4	707	38	19	2	59	12	39	50
Jul. '67	35	154	58	12	259	1	4	5	10	1	7	42
Aug. '67	67	417	27	3	514	51	24	3	78	12	89	100
Sep. '67	690	728	984	80	2482	33	220	72	325	5	22	90
Oct. '67	685	937	215	31	1868	139	104	14	257	15	48	45
Nov. '67	800	432	127	24	1383	85	39	12	136	20	31	50
Dec. '67	31	335	101	16	483	37	1	6	44	11	1	37
Jan. '68	101	88	34	16	239	3	20	8	31	3	59	50
Total	3753	5682	2908	307	12650	749	902	182	1833	13	31	59



TABLE III. ANALYSIS OF VARIANCE OF POPULATIONS OF *SACCHARICOCCUS SACCHARI* IN ANT INFESTED AND ANT FREE PLOTS OF SUGARCANE LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968

<u>Treatments</u>	<u>Month</u>	<u>Block I (Plot A)</u>	<u>Block II (Plot D)</u>	<u>Block III (Plot E)</u>
Ant Infested Plots	December, 1966	1,125	773	2,090
	January, 1967	1,280	1,369	1,979
	February, 1967	1,613	435	2,710
	March, 1967	173	62	609
	April, 1967	12	27	60
	May, 1967	534	10	29
	June, 1967	607	176	380
	July, 1967	178	225	325
	August, 1967	646	314	293
	September, 1967	403	662	1,092
	October, 1967	634	659	1,406
	November, 1967	423	464	1,015
	December, 1967	48	418	919
January, 1968	58	327	774	
		<u>(Plot B)</u>	<u>(Plot C)</u>	<u>(Plot F)</u>
Ant Free Plots	December, 1966	689	325	824
	January, 1967	96	664	267
	February, 1967	70	604	676
	March, 1967	39	330	46
	April, 1967	1	34	31
	May, 1967	5	11	3
	June, 1967	68	519	120
	July, 1967	49	122	88
	August, 1967	53	373	88
	September, 1967	173	1,197	1,112
	October, 1967	207	641	1,020
	November, 1967	102	887	394
	December, 1967	261	131	91
January, 1968	114	57	68	

ANALYSIS OF VARIANCE USING LOGARITHMIC TRANSFORMATION OF DATA FROM ABOVE

	<u>Source</u>	<u>d. f.</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Main Plot	Treatment	1	3.98335	3.98335	3.12912
	Blocks	2	5.39570	2.69785	2.11930
	Main Plot Error	2	2.54599	1.27299	
Sub Plots	Months	13	28.27586	2.17506	20.29731**
	Treatment Times Month	13	1.91872	0.14759	1.37728
	Sub Plot Error	52	5.57243	0.10716	

monthly differences in population size are attributed to both biotic and abiotic factors. From an examination of the actual numbers, it appears that greater significant differences between treatments probably do exist (Tables I and II). A possible reason why the analysis of variance did not detect greater differences could be lack of enough replicates in the experiment.

Fluctuations in the numbers of *S. sacchari* for the samples taken in December 1966, January 1967, and February 1967, can be attributed to sampling variation since the fluctuations are small. The severe drop in populations indicated in the March and April samples coincides with unfavorable climatic conditions at Waimanalo Experimental Farm. During these two months there was a great increase in rainfall with a corresponding increase in relative humidity.

Speare (1912) has shown that the parasitic fungi, *Aspergillus parasiticus* and *Entomophthora pseudococci*, are much more effective in reducing populations of mealybugs when the relative humidity is high for prolonged periods of time. While counting the individual mealybugs from the samples of sugarcane in March and April, large numbers of dead mealybugs were observed, apparently killed by one or both of these parasitic fungi.

Examination of Tables I and II reveals that *Pheidole* gives about the same amount of protection to all categories of mealybugs. From month to month there were fluctuations in the ratios of the different categories to the total population, both in the ant free and ant infested treatments. For the entire study period, these ratios are extremely close as expressed in percentages below:

<u>Treatment</u>	<u>Crawlers</u>	<u>Small Nymphs</u>	<u>Large Nymphs</u>	<u>Mature Females</u>
Ant Infested	31%	46%	20%	3%
Ant Free	30%	45%	23%	2%

From the data obtained from 14 samples of sugarcane taken at four week intervals and observations of the sugarcane over a 14 month period, it appears that the presence of *Pheidole* ants enables the pink sugarcane mealybugs to maintain larger populations than when the ant is absent. Even though *Pheidole* seems to serve some useful function in maintaining the mealybugs at higher densities, their usefulness to the mealybugs is negligible during periods when abiotic environmental conditions are unfavorable.

Since no factors were measured or observed that could contribute to the consistently larger populations of pink sugarcane mealybugs in the ant infested treatment, this

would indicate that the presence of *Pheidole* ants has some effect on pink sugarcane mealybug numbers. This, I believe, was due to the suppressive effect on predators of *S. sacchari*, particularly the various coccinellid beetle larvae. I have observed on several occasions *Pheidole* ants attacking larvae of these beetles.

Part 2. Effect of the Ant as a Detrimental Factor in the Parasitization of the Pink Sugarcane Mealybug by the Parasite, *Anagyrus saccharicola*: As the populations of the pink sugarcane mealybug fluctuated with time in the different treatments, the percent of parasitization of the mealybug by the parasite, *A. saccharicola*, also varied from month to month (Figures 8 and 9). An analysis of variance (Table IV) of percentage of mealybugs parasitized in each plot for each sample showed an extremely small F value and no significant difference in the percent of parasitized mealybugs in the two treatments. The analysis of variance did show, however, that the percent of parasitized mealybugs from month to month was significantly different and above the 99% confidence interval. This difference was originally thought to be due to the number of crawlers present (Figure 10), since *A. saccharicola* does not parasitize the crawlers. However, an analysis of variance of the data without crawlers indicated a significant difference between months also. Factors such as weather, position of the plots in relation to surrounding vegetation that might serve as barriers to the parasite, disease, and predators probably were involved.

From the data of the 14 samples, it appeared that the ant, *Pheidole megacephala*, had no appreciable effect

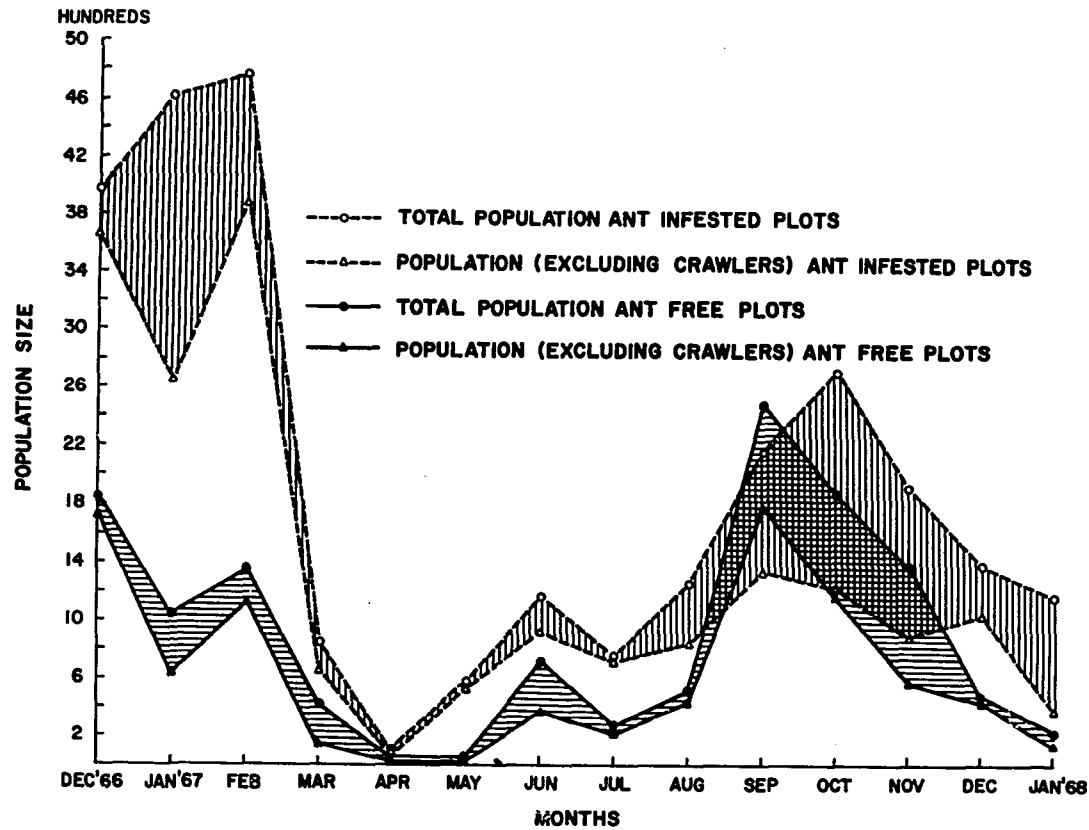


FIGURE 8. POPULATIONS OF *SACCHARICOCCUS SACCHARI* IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED AND ANT FREE PLOTS LOCATED AT THE UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968

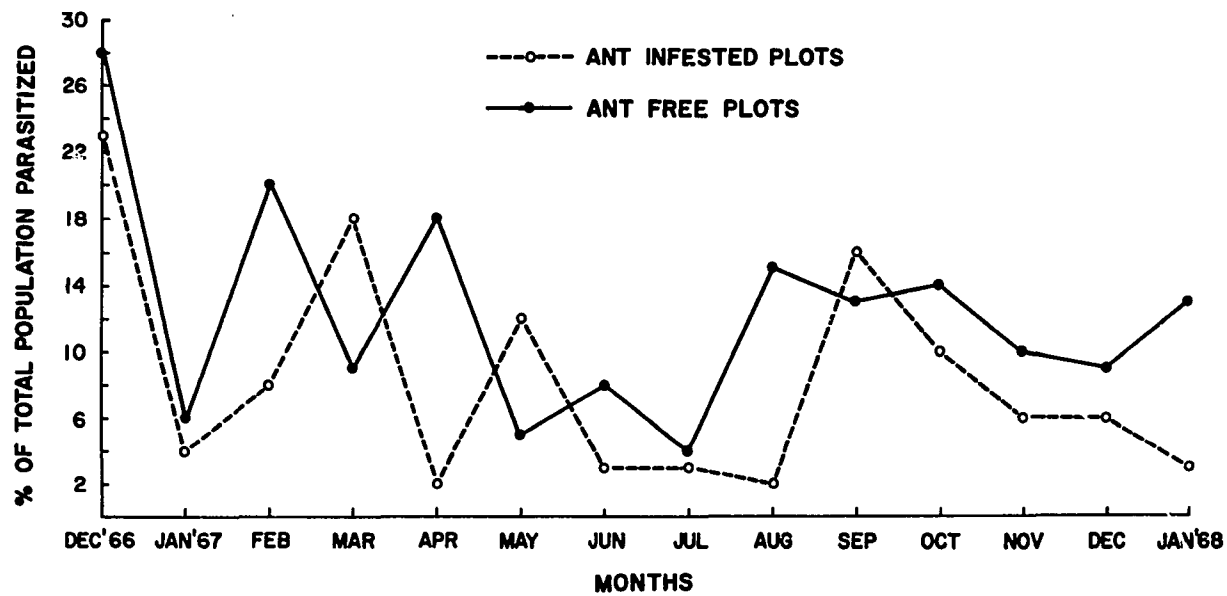


FIGURE 9. PERCENT OF TOTAL POPULATION OF *SACCHARICOCCUS SACCHARI* PARASITIZED BY *ANAGYRUS SACCHARICOLA* IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED AND ANT FREE PLOTS LOCATED AT THE UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968

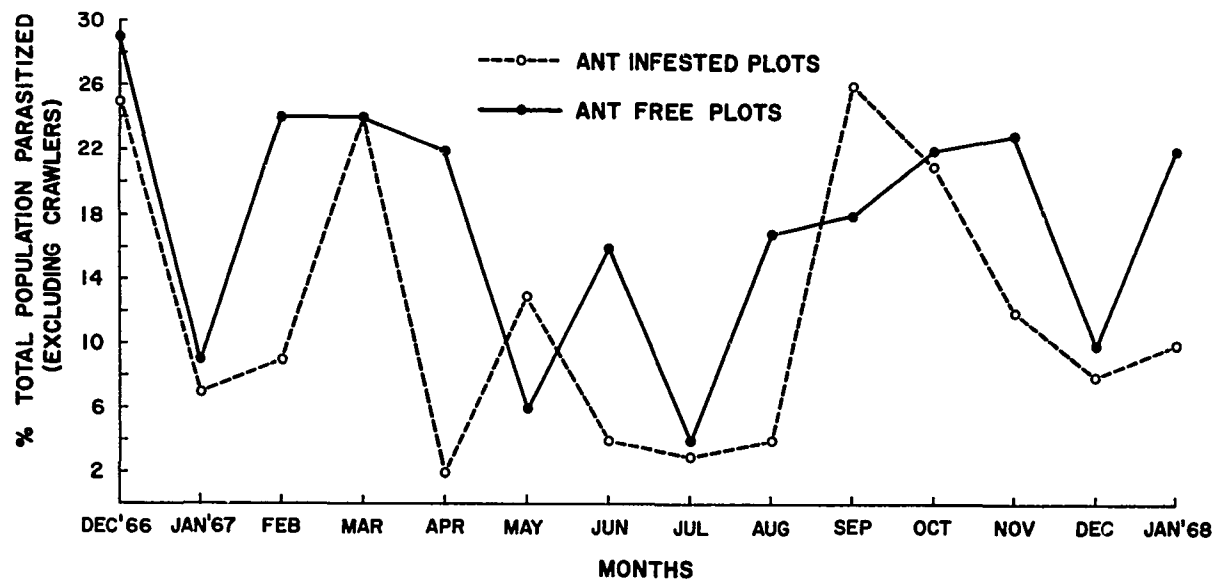


FIGURE 10. PERCENT OF POPULATION, EXCLUDING CRAWLERS, OF *SACCHARICOCCLUS SACCHARI* PARASITIZED BY *ANAGYRUS SACCHARICOLA* IN 14 SAMPLES OF SUGARCANE FROM ANT INFESTED AND ANT FREE PLOTS LOCATED AT THE UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968



TABLE IV. ANALYSIS OF VARIANCE OF PERCENT OF *SACCHARICOCCUS SACCHARI* PARASITIZED BY *ANAGYRUS SACCHARICOLA* IN ANT INFESTED AND ANT FREE PLOTS OF SUGARCANE LOCATED AT UNIVERSITY OF HAWAII WAIMANALO EXPERIMENT FARM, OAHU, HAWAII. 1966 - 1968

<u>Treatments</u>	<u>Month</u>	<u>Block I (Plot A)</u>	<u>Block II (Plot D)</u>	<u>Block III (Plot E)</u>
Ant Infested Plots	December, 1966	30%	35%	16%
	January, 1967	7%	2%	3%
	February, 1967	11%	18%	4%
	March, 1967	43%	25%	11%
	April, 1967	8%	0%	1%
	May, 1967	13%	0%	0%
	June, 1967	1%	7%	3%
	July, 1967	11%	4%	2%
	August, 1967	1%	3%	26%
	September, 1967	5%	30%	11%
	October, 1967	6%	24%	5%
	November, 1967	9%	8%	3%
	December, 1967	4%	10%	3%
January, 1968	19%	1%	3%	
Ant Free Plots	December, 1966	18%	41%	32%
	January, 1967	11%	5%	4%
	February, 1967	21%	14%	26%
	March, 1967	0%	9%	11%
	April, 1967	0%	0%	33%
	May, 1967	0%	0%	33%
	June, 1967	3%	10%	2%
	July, 1967	3%	5%	1%
	August, 1967	0%	13%	11%
	September, 1967	15%	16%	9%
	October, 1967	9%	13%	15%
	November, 1967	15%	8%	12%
	December, 1967	21%	2%	0%
January, 1968	14%	18%	7%	

ANALYSIS OF VARIANCE USING ARCSIN  $\sqrt{\text{PERCENTAGE}}$  TRANSFORMATION OF DATA FROM ABOVE

	<u>Source</u>	<u>d. f.</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Main Plot	Treatment	1	17.9	17.9	0.08
	Blocks	2	8.8	4.4	0.02
	Main Plot Error	2	405.2	202.6	
Sub Plots	Months	13	3143.9	241.8	26.28**
	Treatment Times Month	13	530.1	40.8	4.43**
	Sub Plot Error	52	480.4	9.2	

on the ovipositional activities of the female parasite,  
*Anagyrus saccharicola*.

Part 3. Regression of Percent of Parasitization by  
*A. saccharicola* on Pink Sugarcane Mealybug Population  
Size. The encyrtid parasite, *A. saccharicola*, showed a  
tendency to operate with equal effectiveness on large  
populations of *S. sacchari* as well as small populations.  
Computation of regression coefficients of percent pink  
sugarcane mealybug parasitization on pink sugarcane mealy-  
bug population size resulted in extremely small, non-  
significant, "b" values for both the ant infested and ant  
free treatments.

Because the data indicate no regression of percentage  
of parasitization on population size of *S. sacchari*, the  
parasite would have to be considered as only partially  
successful in controlling the population size of the pink  
sugarcane mealybug at the population levels which existed  
during this experiment. The percent of parasitism should  
increase with population size, if the parasite is an  
effective control agent. It follows that with a larger  
population of pink sugarcane mealybugs, the parasite would  
be able to find a larger number of hosts to parasitize.  
The regression coefficients indicated that this was not  
so.

Part 4. Summary. The pink sugarcane mealybug has many natural enemies in Hawaii. The endoparasite, *A. saccharicola*, which is host specific for the pink sugarcane mealybug, was introduced to Hawaii from the Philippine Islands in 1930 as a biological control agent.

Of the ants in Hawaiian sugarcane fields, *Pheidole megacephala* is the most wide-spread. This study was conducted to investigate some of the effects that *Pheidole* has on populations and parasitization of *S. sacchari*. The following results were obtained:

1. The ant, *Pheidole megacephala*, offers the pink sugarcane mealybug, *Saccharicoccus sacchari*, appreciable protection from its natural enemies, principally predators.

2. During periods of unfavorable weather conditions for the pink sugarcane mealybug, their populations decreased considerably regardless of the presence or absence of the ants.

3. The presence of the ant, *Pheidole megacephala*, attending the pink sugarcane mealybug, *Saccharicoccus sacchari*, did not seem to be a detrimental factor in the parasitization of the mealybug by *Anagyrus saccharicola*.

4. The pink sugarcane mealybug parasite, *Anagyrus saccharicola*, was able to parasitize large populations of the mealybug with the same degree of effectiveness as small populations.

Section III. Some Effects of *Anoplolepis longipes* and  
*Iridomyrmex humilis* on Populations of Mealybugs Attack-  
ing Sugarcane in Hawaii

The samples taken during this study using Ewa Plantation Company Field Numbers 20.2, 27, and 28 appear to show that the presence of the Argentine ant has a profound effect on mealybug population levels. The Argentine ant seems to be extremely detrimental to the mealybug parasite and its ovipositional activities as well as to the predators of the mealybugs.

As shown in Table V, the number of mealybugs taken in each sample from the Argentine ant infested field was significantly larger than the corresponding samples taken from sugarcane fields infested with the other ants. The difference in population samples taken from nearly identical fields suggests that the Argentine ant is much more effective in its protection of the mealybugs. The much lower parasitization rate in the Argentine ant infested field indicates that the Argentine ant interferes with the activity of *A. saccharicola*. This study did not show if the Argentine ant exhibits aggressive behavior towards the parasite or if its presence merely upsets the parasite, preventing ovipositing.

TABLE V. POPULATIONS OF MEALYBUGS AND PERCENT PARASITISM BY *ANAGYRUS SACCHARICOLA* IN THREE FIELDS OF SUGARCANE, EWA PLANTATION COMPANY, EWA, OAHU, HAWAII, 1969

Date Sampled	Field No. 28 Infested With <u><i>I. humilis</i></u>			Field No. 27 Infested With <u><i>P. megacephala</i></u>			Field No. 20.2 Infested With <u><i>A. longipes</i></u>			Waimanalo Experiment Farm Ant Free Plots B, C, & F		
	No. Living	No. Parasitized	% Parasitized	No. Living	No. Parasitized	% Parasitized	No. Living	No. Parasitized	% Parasitized	No. Living	No. Parasitized	% Parasitized
Perimeter	3399	28	1	382	23	6	246	44	18			
Jan. 13 60' In Field	407	48	12	17	14	82	20	2	10	88	12	13
Perimeter	2467	51	2	461	47	10	247	38	15			
Feb. 3 60' In Field	397	74	19	27	18	67	27	7	26	110	19	17
Perimeter	1706	39	2	395	51	14	238	36	15			
Feb. 25 60' In Field	449	82	18	38	24	63	40	10	25	172	24	14
Perimeter	1235	43	3	353	60	17	207	31	15			
Mar. 17 60' In Field	518	102	20	16	10	63	21	11	52	39	8	21
Perimeter	1503	31	2	401	71	18	199	39	20			
Apr. 8 60' In Field	598	65	11	20	14	70	24	14	58	61	16	26
Perimeter	10310	192	2	1992	258	13	1137	118	10			
TOTAL 60' In Field	2369	371	16	118	80	68	132	44	33	470	79	17

Studies conducted in the laboratory have shown that the Argentine ant is extremely aggressive toward any lone insect with which it comes in contact other than the honeydew producers which it tends. I believe the major reason the parasite oviposition is reduced is that the Argentine ant tends the mealybugs in such large numbers that the parasite is constantly being annoyed by the ant and is therefore unable to oviposit as frequently as if ants were absent. I have never observed the Argentine ants killing the parasites. It is believed that the parasite is so tiny and quick that the Argentine ants seldom are able to capture them.

During the period of sampling neither larvae nor pupae of the predaceous drosophilid fly, *Gitonides perspicax* were seen or collected in the Argentine ant infested field. However, in every sample of the other fields, numerous larvae and pupae of the fly were collected. This suggests that the Argentine ant not only suppresses the activities of the parasite but interferes with predators as well.

Whereas *A. longipes* is considered an efficient tender of honeydew producing insects, the samples of mealybugs taken from the field infested with this ant indicate the ants have little or not effect on the activity of the parasite or mealybug predators. The percentage of mealybugs

parasitized tended to fluctuate somewhat, but generally remained close to the percentage parasitized in the ant free plots at Waimanalo.

On occasion while sampling, a colony of mealybugs was encountered on a stalk of sugarcane which had 10 to 15 *A. longipes* in attendance. Parasites were seen moving about the colony of mealybugs and crawling under the ants in search of suitable hosts. At no time during the observations were the ants seen paying the slightest attention to the presence of the parasites. Numerous drosophilid larvae were taken in the samples and an occasional coccinellid larva was seen near mealybugs that had many *A. longipes* tending them. The general disposition of *A. longipes* seems to be the one of curiosity to other insects rather than the aggressive behavior exhibited by *Pheidole* and the Argentine ants.

The perimeter samples taken from the field infested with *Pheidole* show striking similarities in the percentage of mealybugs parasitized when compared with the ant free plots at Waimanalo (Table V). However, the number of mealybugs taken in each perimeter sample at Ewa was appreciably larger than the sample taken at Waimanalo. This suggests that *Pheidole* interferes with the activities of the parasite very little, if any.



The data of Table V show the largest populations of mealybugs are concentrated on the sugarcane growing on the perimeter of the field. At no time during sampling did the numbers of mealybugs in samples taken 60 feet inside the field approach those of the perimeter samples. This would seem to indicate that the ants are not present throughout the field, thus letting the parasite and predators control the mealybugs more effectively. However, this is not the case. At no time was there an absence of ants inside the fields. Admittedly, fewer ant colonies were found inside the field, but foragers were seen in great numbers at each sampling date. A possible reason why more colonies of ants were not found inside the field was the extreme difficulty in locating nest openings in the soil because of the large amount of lodged sugarcane stalks and leaf debris.

Factors that were undetermined in this study appear to affect the number of mealybugs that can survive inside a sugarcane field. This could be due to such things as lack of suitable nesting sites for the ants inside the field; the parasite and predators being able to operate more effectively inside the field; and abiotic conditions inside the field being less favorable to the mealybugs.

Although ants were found inside each field, the number present differed markedly depending upon the species

of ant. Huddleston and Fluker (unpublished study) found in baiting tests conducted in sugarcane fields that there was little difference in the number of ants attracted to the bait inside the field as opposed to baits placed along the perimeter of the field, in fields infested with either the Argentine ant or *Pheidole*. However, in the fields that had *A. longipes* as the dominant ant, much greater numbers were trapped along the outside.

In sugarcane fields, *Pheidole* and the Argentine ant prefer to nest in dead root systems of old sugarcane stools. Because of this nesting preference, there apparently exists in the fields many suitable nesting sites. Although there appeared to be many suitable nesting sites inside the field only a small percentage of these are utilized by the ants. This is attributed to the heavy undercover that effectively blocks out almost all sunlight. Along the perimeter of sugarcane fields, an old root system can seldom be overturned without disturbing a colony of ants. Whereas both *Pheidole* and the Argentine ant appear to shun direct rays of the sun, it seems they prefer sunlight on their nests.

As mentioned earlier, *A. longipes* prefers to nest under large rocks or along rock walled irrigation ditches. The nesting preference of this ant would directly influence

its penetration into a sugarcane field. Most large rocks are removed from the fields by the plantations, and very few rock walled irrigation ditches transverse a field. Because of this, the number of nesting sites suitable for *A. longipes* nests is severely limited. Thus, these ants are found only around the perimeters of the sugarcane fields where there are suitable nesting areas. No colony of *A. longipes* was ever found inside a field unless an irrigation ditch cut through the field.

This study indicates that the use of the ant infested--ant exclusion check method to evaluate natural enemies of sugarcane pests would be highly influenced by the species of ant employed in the study. The data of Table V strongly suggests that *Pheidole* and *A. longipes* have little, if any, influence on the activities of *A. saccharicola*; whereas the Argentine ant appears to exert considerable pressure on the parasite. Also, Flanders (1958) suggested that different parasites are affected differently by ants.

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