Field Investigations on the Interrelationships of the Big-Headed Ant, the Gray Pineapple Mealybug, and Pineapple Mealybug Wilt Disease in Hawaii[1]

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ABSTRACT

The population density of the big-headed ant was higher during the second (ratoon) crop than during the first crop of pineapple at both Poamoho and Molokai. At Poamoho, no mealybug wilt plants were found in plots where ants had been controlled, while the number of such plants increased sharply during the second crop in plots where ants were not controlled. The incidence of mealybug wilt was higher at the edges of plots than toward the middle reflecting the greater abundance of ants and mealybugs on the margins on the plots. Wilt spread in a contagious manner with the number of diseased plants increasing at a logrithmic rate over time. The coefficient of correlation between the number of ants caught in pitfall traps and the percentage of mealybug infested plants was very high ($r = 0.97$).

Infestation of the Molokai experimental planting by big-headed ants started at the edges of plantings adjacent to abandoned fields and waste areas. Invasion progressed slowly, and two and one half years elapsed before all plots had become infested. Ant and mealybug populations in infested plots increased gradually and appeared to be strongly influenced by the phenology of the pineapple plants during the first fruit crop. Unusually heavy rainfall during March and April 1979 may have caused the dramatic reduction in ant populations observed then. Highest ant population levels occured about three years after planting when all untreated plots became nearly uniformly infested.

Pest management strategies for pineapple ants and mealybugs are discussed, and it is suggested that a program of ant surveillance using bait stakes, coupled with treatment of field margins and adjacent infested old fields or uncultivated areas when ants are discovered, can prevent migration of these pests into plantation fields.

Pineapple mealybug wilt disease occurs in most areas where pineapples are grown commercially (Carter 1973). The disease (figs. 1, 2A) is associated with the presence of certain mealybug species (Illingworth 1931, Carter 1932). In Hawaii, the gray pineapple mealybug, *Dysmicoccus neobrevipes* Beardsley (fig. 3), and the pink pineapple mealybug *Dysmicoccus brevipes* (Cockerell), are the principal species involved (Carter 1931, Zimmerman 1948, Beardsley 1959). Although the exact etiology of mealybug wilt is still a matter of controversy (Carter 1951, 1963, Ito unpublished[6]), commercial control has been achieved

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primarily by eliminating the field ants which attend mealybug populations, clean up the honeydew they secrete and interfere with their natural enemies (Carter 1973). The big-headed ant, *Pheidole megacephala* (Fabricius), is the dominant ant species in most of the pineapple fields in Hawaii (Phillips 1934).

The big-headed ant is a tropicopolitan species apparently native to Africa (Wilson and Taylor 1967). Although it is the dominant ground nesting species in most of the lowland agricultural areas of Hawaii (below about 700 m elevation), above 600 m it is sometimes replaced by the Argentine ant, *Iridomyrmex humilis* Mayr (Fluker and Beardsley 1970), and in very dry, open, lowland areas the fire ant, *Solenopsis geminata* Fabricius, may be dominant (Phillips 1934).

The big-headed ant is a polydomous species, characterized by mobile, ramifying, multiqueen colonies (Phillips 1934). Nuptial flights take place but mated queens must rejoin established colonies to survive. The inability of newly mated queens to individually found new colonies has important bearing on ant control practices where this species in dominant. In this respect the biology of the Argentine ant, the second most important species in Hawaiian pineapple fields, is similar. However, in *Solenopsis geminata* new colonies are initiated individually by newly mated queens.

On Hawaiian pineapple plantations control of field ants has been accomplished during recent years by applications of mirex bait at the rate of 2.24 kg 0.3% bait/ha, or broadcast sprays of heptachlor at the rate of 2.24 kg AI/ha. These insecticide programs were so effective that mealybug infestations and mealybug wilt became extremely rare and have remained so during the past three decades (Su et al 1981). However, mirex and heptachlor are degraded slowly in nature, and residues of these compounds or their breakdown products may appear in non-target organisms, sometimes with deleterious effects (Edwards 1973). Thus, in the United States, the registration for mirex was cancelled in 1977 and that of heptachlor is being phased out and will be completely eliminated at the end of 1982. Since the pineapple industry needs effective methods of ant control to prevent a resurgence of mealybug wilt, studies were initiated to find insecticides that could be used in an environmentally acceptable pest management program for control of the ants associated with pineapple culture in Hawaii, and to reinvestigate the role of these pests in the pineapple agroecosystem. Studies on chemical control of ants were reported previously (McEwen, et al 1979; Su et al 1981). We report here on the interrelationships of big-headed ants, mealybugs and spread of mealybug wilt disease. We also discuss how this knowledge can be applied in a pest management program.

MATERIALS AND METHODS

These studies were carried out in two locations. The first work on ant and mealybug ecology was begun in a small-plot experimental field at Poamoho, Oahu in January 1976.[7] In November 1976 a larger experimental planting was

[7]These studies were the basis of an M.S. Thesis titled "The Distribution of Ants and Mealybugs in a New Planting of Pineapple" by T.H. Su, submitted to the Graduate Division, University of Hawaii, 1977. A continuation of the Poamoho study and aspects of the work done on Molokai formed the basis of a Ph.D. dissertation titled "The Biology and Control of the Big-Headed Ant and its Associated Mealybugs in Hawaiian Pineapple Fields" by T.H. Su, submitted to the Graduate Division, University of Hawaii, in 1979. Data from both the M.S. Thesis and Ph.D. dissertation are included here.

FIGURE 1. A, Thirteen month-old pineapple plant showing symptoms of mealybug wilt. B, Green spotting, indicative of feeding by *Dysmicoccus neobrevipes*, on leaves of wilted pineapple plant.

FIGURE 2. A, Old ratoon pineapple planting completely destroyed by mealybug wilt. B, Wild sisal infested with *Dysmicoccus neobrevipes* growing near a commercial pineapple field, Molokai.

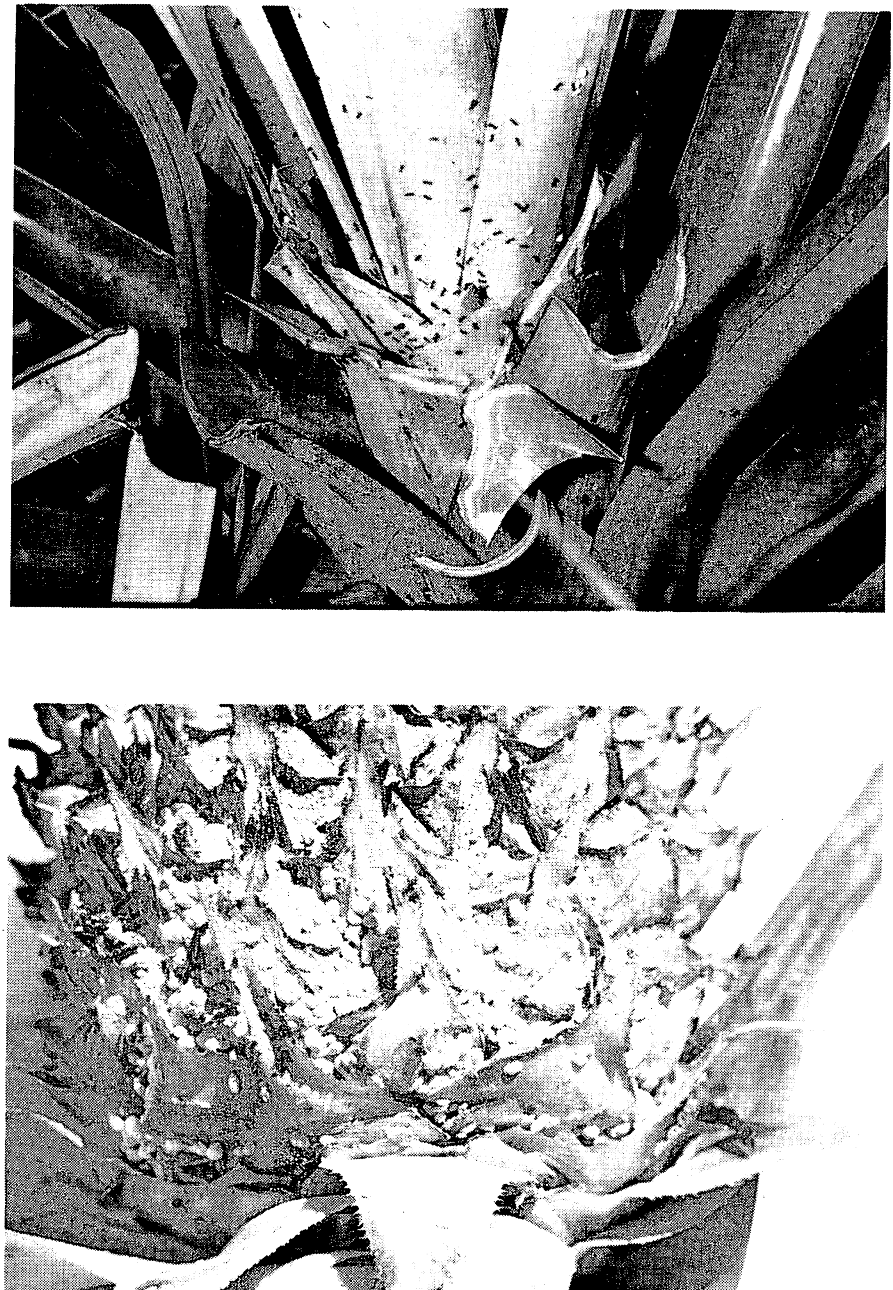

FIGURE 3. A, *Pheidole megacephala* tending *Dysmicoccus neobrevipes* on inner portions of pineapple leaves. B, Young pineapple fruit infested with *Dysmicoccus neobrevipes.*

established on Molokai, where we obtained additional data on ant ecology while conducting numerous ant control experiments during 1977 to 1981.

Poamoho Experimental Planting

The experimental planting was located on pineapple land adjacent to the Poamoho Farm of the University of Hawaii Agricultural Experiment Station and was situated between an abandoned pineapple field and a ten-month old commercial planting. Two plantation roads separated the experimental planting from the adjacent fields. The road adjoining the abandoned field was 3.7 m wide; that next to the commercial planting was 7.3 m wide. The field area was 0.14 ha, divided into eight plots each of which contained 12 plant beds, each 1.0 m wide by 9.1 m long. Beds were parallel to the plantation roads and each contained two rows of pineapple plants (fig. 4). Plots were planted with Smooth Cayenne variety pineapple slips, at the rate of 60 slips per bed, in January 1976, and were grown according to standard agronomic practices.

Big-headed Ant Population in the Poamoho Experimental Planting

Big-headed ant populations were monitored weekly with pitfall traps (140-ml baby food jars) contained a water solution of 3% formaldehyde and 0.3% detergent. Traps were installed between plant beds at four distances 2.7, 5.8, 11.6, and 14.3 m, respectively, from the road adjoining the abandoned pineapple field (fig. 4). Samples were collected weekly and stored in 70% alcohol for examination. Ants and other insects caught in the traps were identified under a binocular microscope in the laboratory. All eight plots were monitored in this manner during the first 13 months of this study. After January 1977, two plots on the west side of the planting were retained for ant population studies and were continuously monitored until December 1978. The other six plots were used for other studies.

Mealybug Populations in the Poamoho Planting

Beginning at the time of planting, visual observations for mealybug presence were made each week. Systematic sample counts of mealybug infested plants were begun in November 1976 when scattered small infestations were first found along the edges of the plots. Sample sites were selected in beds next to pitfall traps at four distances infield from the margin. At each site ten randomly selected plants between each two pitfall traps were examined for the presence of mealybug. Thus 32 samples were examined each week, with 80 plants at each of 4 distances infield being inspected. Mealybug samples were terminated after February 1977.

Epidemiology of Mealybug Wilt at Poamoho

The Poamoho experimental plots used for ant and mealybug population studies were also used to study the epidemiology of mealybug wilt. The incidence of mealybug wilt was surveyed weekly by means of visual inspection over the entire planting. After the first crop, two plots in the center of the planting were used as a buffer zone to separate ant-free and anti-infested plots so that the spread of wilt, as affected by the presence or absence of ants, could be observed. In August 1977, the two plots on the east side of the buffer were sprayed with heptachlor at the rate of 1.68 kg AI/ha to eliminate ants. The buffer zone and the plots on the west side of the buffer remained untreated. Mirex bait at the rate of 2.24 kg/ha was used as needed thereafter to eliminate incipient infestations of big-headed ants from the ant-free plots.

Molokai Experimental Planting

The Molokai experimental planting, about 20.3 ha, was located on Hawaiian Homes Commission land near the Molokai Airport. The planting was divided into 102 plots. The individual plot size was 33.6 m by 61.0 m, approximately 0.2 ha. Each plot was surrounded by a roadway 3.7 m wide. All plots were planted with Smooth Cayenne variety in December 1976, and the planting was maintained by Del Monte Corporation using standard agronomic practices, except that no insecticide applications were made other than those for experimental purposes.

Method of Field Sampling Big-headed Ant Populations at the Molokai Planting

A sample system was developed which made it possible to obtain quantitative data on ant populations at all stages in the development of the pineapple crop. Trap stakes, each consisting of a 91.4 x 3.8 x 1.0 cm redwood lath pointed on one end, were placed at regular intervals in two lines of five stakes each in each 0.2 ha plot. The lower end of each stake was painted white to facilitate counting ants. Honey/water (50:50), or peanut butter/soybean oil (50:50) were used as ant baits. Honey/water baited stakes were used until March 1978. At that time

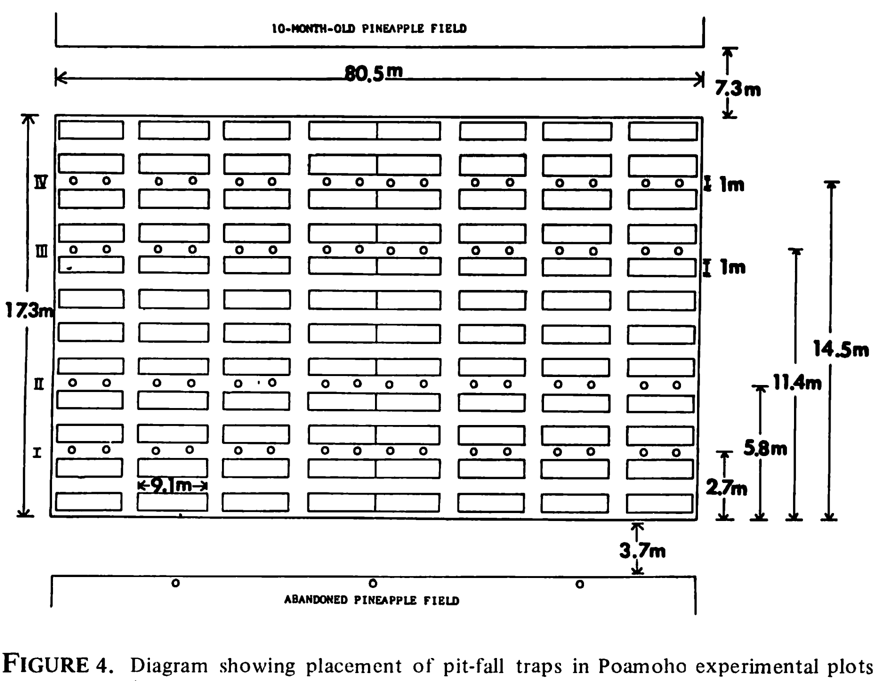

FIGURE 4. Diagram showing placement of pit-fall traps in Poamoho experimental plots (note that length and width dimensions are not to same scale).

we switched to a peanut butter/soybean oil bait because we found that in plots heavily infested with pineapple mealybugs, big-headed ants attending the mealybugs ignored the honey/water bait. The bait was applied by paintbrush to the lower 25 cm portion of each stake as the stakes were placed. Usually trap lines were placed in the afternoon (3:00-6:00 P.M.), and ant counts were made after dark (7:00-10:00 P.M.), as foraging activity of big-headed ants was maximum after sundown. A complete ant survey of all 102 plots of the Molokai experimental planting was taken every three to four months. The mean number of ants per stake in each plot was used as an index of the ant population density.

RESULTS

Poamoho Planting: Population Trends of the Big-headed Ant at Different Distances from the Field Edge

The number of big-headed ants caught in pitfall traps was consistently greatest in the trap row nearest the road adjoining the abandoned pineapple field (fig. 5). An average of 29.4 ants/traps/week for the first month were caught in the trap row 2.7 m from the field edge, as compared to 11.9, 2.2, and 1.3 ants/trap/week in pitfall traps located 5.8, 11.6, and 14.3 m infield, respectively. The numbers of ants caught reflected the location of the ant colonies as well as the activity of foragers within the field. Differences between the total numbers of ants caught at different distances from the field edge during the first 12 months were statistically significant at 1% confidence level.

Mealybug Populations in the Poamoho Planting

Small scattered infestations of gray pineapple mealybugs were first found along the outer edges of the field about 5 months after planting. The percentage of plants infested with mealybugs remained low until November 1976 (11 months after planting) when 8% of the sampled plants in the plant bed next to the road near the abandoned field were infested (Table 1). By February 1977 64% of the plants in the outer bed were infested. However, only 8% of the plants in the rows at the center of the field were infested at that time. There was close correlation between the number of ants caught in pitfall traps and the percentage of mealybug infested plants, based on weekly counts ($r = 0.97$).

Seasonal Fluctuations of Big-headed Ant Populations During a Three-Year Period at Poamoho

The total numbers of big-headed ants collected in pitfall traps fluctuated widely during the three-year period of monitoring (fig. 6). In the first year (1976) weekly trap catches were maximum in May and minimum in September. During the second year, (1977), as the pineapple plants approached maturity, the overlapping leaves shaded most of the field, and ant populations were generally higher, with seasonal trends similar to those of the first year. In September 1977 the first fruit crop was harvested, and this was preceded by a marked decrease in trap catches beginning July. Within two months after the harvesting, new growth again provided mealybug habitat, and peak trap catches occurred again during a short period in November 1977. Although trimming of pineapple slips in November was accompanied by a sharp decrease in ant populations, these gradually built up again following the growth of new slips. Trap catches

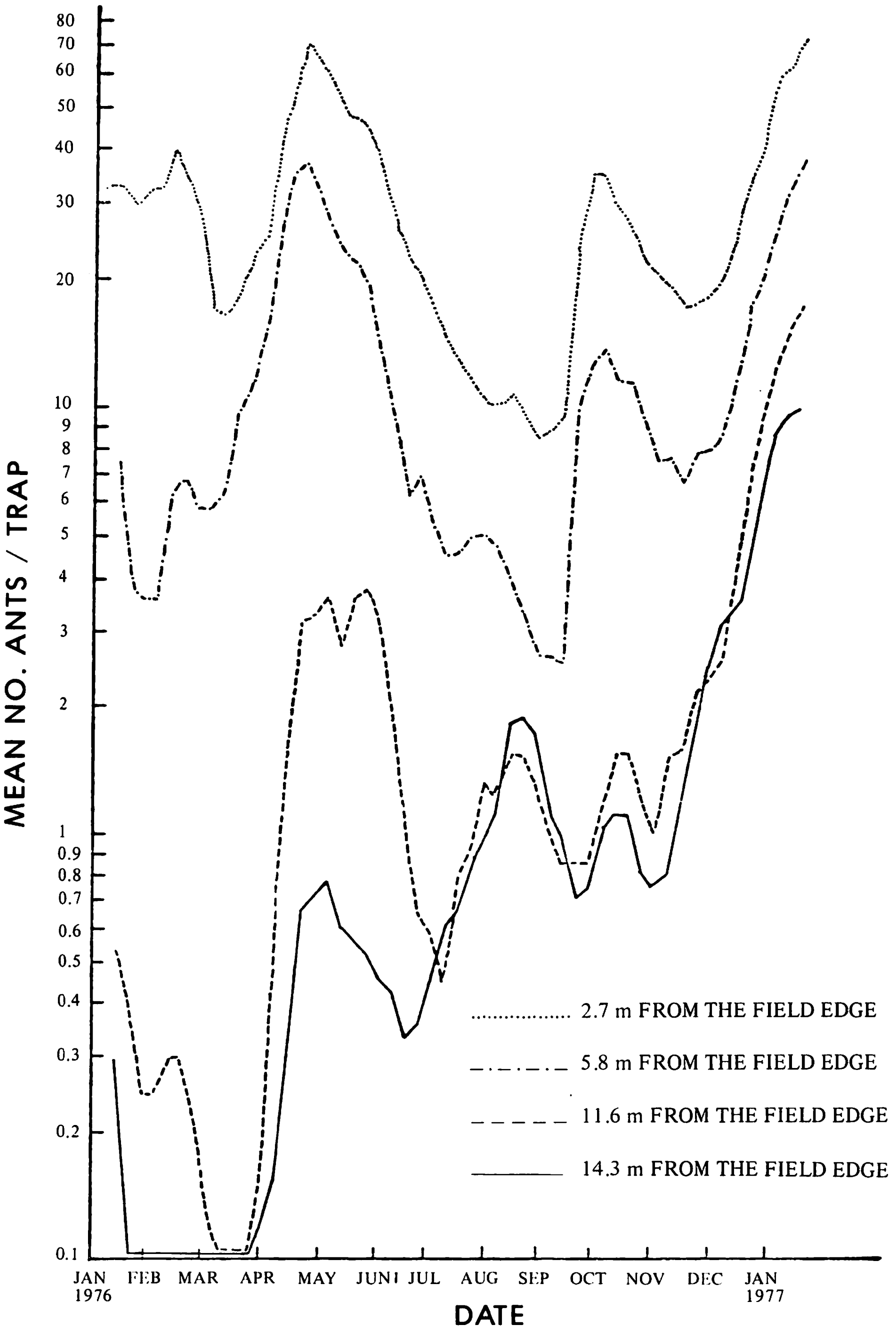

FIGURE 5. Numbers of big-headed ants caught in pitfall traps at different distances from the field margin at Poamoho, January 1976 to February 1977.

continued to increase until November 1978. During the entire three-year period the mean numbers of the big-headed ants caught per trap week were 9.9, 24.7, and 45.8 for 1976, 1977 and 1978 respectively.

Epidemiology of Mealybug Wilt at Poamoho

In June 1976, about six months after planting, four plants showing symptoms of mealybug wilt were found. Two of these were adjacent in one area and the other two were located in two additional areas. Big-headed ants were present in the planting at the time, but mealybug populations were low with only 0.5% of the plants infested. Seven months later, January 1977, when the pineapple plants were at the inflorescene stage, a few new mealybug wilt plants were found near the original wilt plants, and the number of wilted plants subsequently increased (fig. 7). Following harvest of the first fruit crop, heptachlor was used to eliminate the ants in the two ant control plots. No additional mealybug wilt plants were found in the ant control area after that time (fig. 7). The number of wilted plants in the untreated plots continued to increase until April 1979 when the second crop fruit matured and the experiment was terminated. The mealybug wilt in area B was located at the middle of the plot. Both the number of wilted plants and the ant population density were lower there than in area A. The distribution of wilt-affected plants in area A at different times during the pineapple growth cycle is shown in figure 8.

Population Trends of Big-headed Ants in the Molokai Planting

The bait stake method of ant population assessment employed in the Molokai experimental planting was much more rapid but inherently less precise than the

TABLE 1. Percentages[a] of mealybug infested plants at each of four distances from the field edge, Poamoho, Oahu.

Date	Distances (m) from the field edge				
	2.7	5.8	11.6	14.3	Average
1976					
November 9	8.0	2.0	0	0	2.5
November 25	14.0	4.0	0	0	4.5
December 2	14.0	4.0	0	0	4.5
December 9	14.0	4.0	0	0	4.5
December 16	14.0	4.0	0	0	4.5
December 23	16.0	4.0	0	0	5.0
December 30	22.0	6.0	0	0	7.0
1977					
January 6	24.0	8.0	0	0	8.0
January 13	30.0	10.0	0	0	10.0
January 20	40.0	10.0	0	0	12.5
January 27	58.0	28.0	8.0	0	23.5
February 3	64.00	38.0	8.0	0	27.5

[a]Data based on periodic examination of 10 plants between each pair of pitfall traps; a total of eight 10-plant samples at each distance interval.

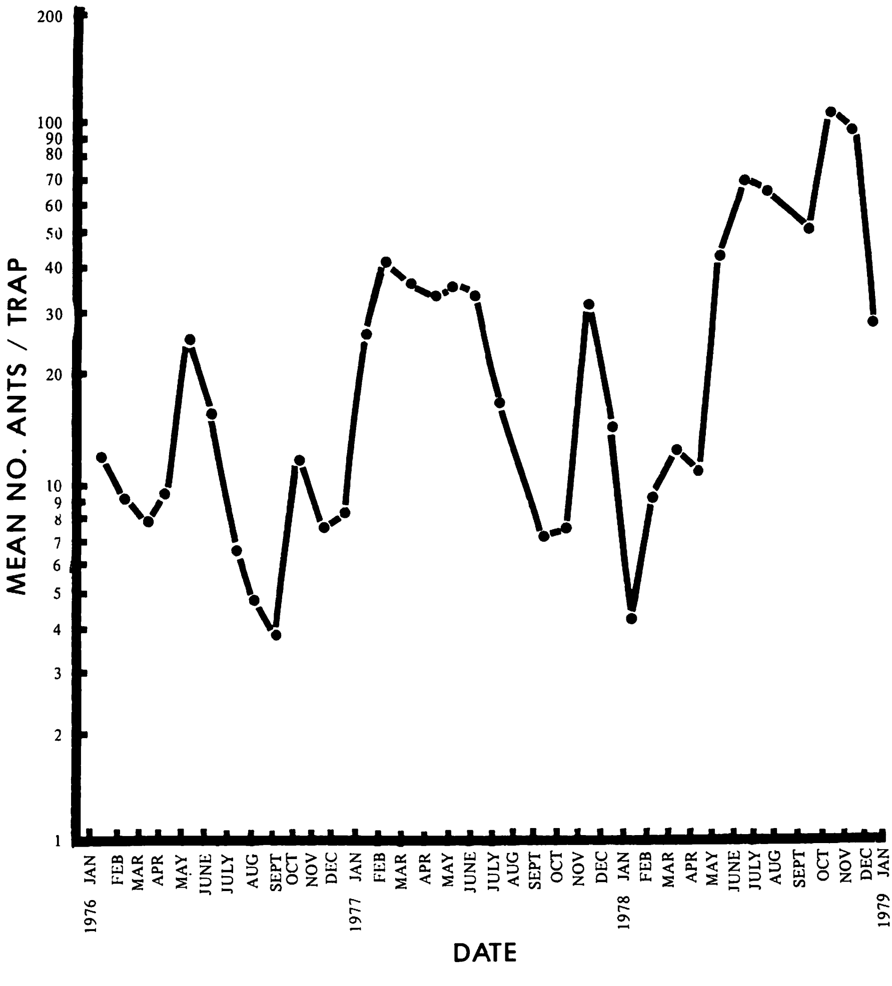

FIGURE 6. Mean numbers of ants per pitfall trap caught at Poamoho, Oahu, January 1976 through January 1979.

pitfall method used at Poamoho. Bait stakes attracted and concentrated ant populations over distances of several meters in a relatively short time, whereas the pitfall traps trapped ants moving through the field in random manner during a one week exposure period. Because of the short exposure period of the bait stakes, ant counts from these were likely to the influenced strongly by chance discovery of the bait by foragers, and by ambient environmental factors such as temperature, the availability of other food sources, nutritional needs related to the phenology of the ant colonies, etc.

Despite the weaknesses of the bait stake method of ant population assessment, periodic surveys of the entire planting and data from plots used as untreated checks in insecticide experiments provided some useful insights into the dynamics of big-headed ant populations. In general, the trends in ant and mealybug populations were correlated with the phenology of the pineapple crop on Molo-

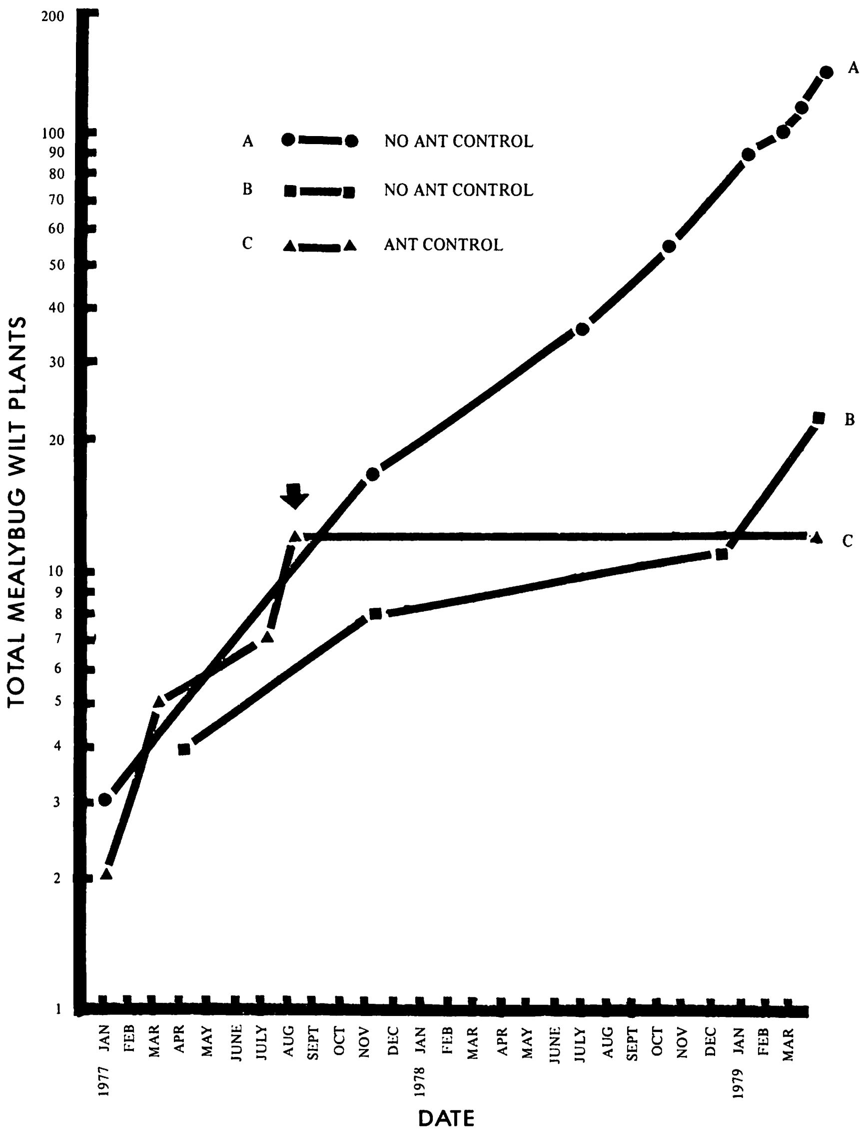

FIGURE 7. Numbers of plants affected by mealybug wilt in an area where ants were eliminated (C) compared with numbers of wilt-affected plants in two untreated areas, (A, B) at Poamoho.

kai in a manner similar to that observed at Poamoho.

Big-headed ants were first detected during March 1977, three months after planting, in several peripheral plots of the Molokai experimental planting. As was the case at Poamoho, migration of ants into the plots was from infested old fields surrounding the planting. Although this planting had been established in an abandoned pineapple field heavily infested with ants, it appeared that infield

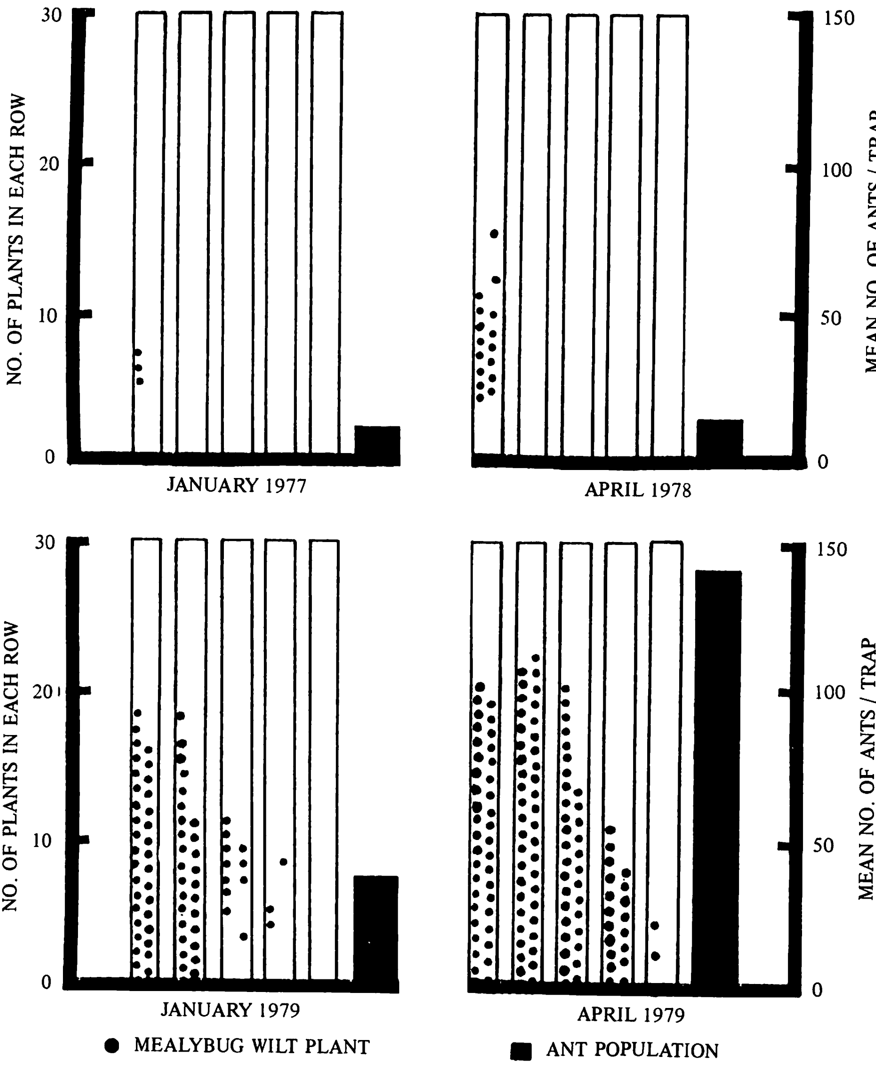

FIGURE 8. Distribution of mealybug wilt-affected plants (dots) in area A of the Poamoho planting at four sample dates during a 27-month period. Solid bar at right gives relative ant density as indicated by pitfall trap catches.

ant populations were unable to survive land preparation and planting procedures, followed by several months of slow initial growth of the crop. Establishment of permanent ant populations within experimental plots proceeded slowly; 20% of the plots were infested in June 1977, 31% in August 1977, 49% in January 1978, 72% in July 1978 and 93% in February 1979. Using the field sampling data to analyze the relationship between the percentage of ant-infested plots and the age of the pineapple planting, a highly significant linear correlation, ($r = 0.995$), and a regression equation ($Y = -28.82 + 3.81\ X$) were calculated.

Population levels in ant-infested plots (based on average counts from ten bait stakes per plot) were very low at first (7 ants per stake in March 1977), but gradually increased, reaching 18 ants/stake in September and 48 ants/stake in January 1978. However, as the first fruit crop approached maturity during March, April and May, there was an apparent decrease in ant numbers to 15 ants/stake in May. A post-harvest survey in mid-July found ant populations in infested plots to be about the same level (15 ants/stake). Mealybug populations in infested plots also declined during the period of fruit maturation and harvest. The reasons for the declines in ant and mealybug populations at that time are unclear, but may have been associated with changes in the physiological state of the pineapple plants which may have become unsuitable to support large mealybug populations during the later stages of fruit maturation and ripening. A similar decline in ant and mealybug populations occurred at the time of maturation and harvest of the first fruit crop at Poamoho.

Following harvest, with the development of new shoots, both ant and mealybug populations increased, to 145 ants/stake in September, 1978. Infestations in untreated check plots remained at about this level until mid-March 1979 when they again declined, to 88 ants/stake on March 15, and 10 ants/stake on April 19. Exceptionally heavy rainfall during March and April may have caused this very marked decline in ant populations. By May 30, 1979 ant populations in the untreated check plots were 50 ants per stake and remained at approximately this level through July 1979, at which time the ratoon fruit crop was harvested.

Following harvest of the ratoon crop the old planting was maintained without the application of fertilizer or fruit forcing compounds. Even though the plants in these plots deteriorated, ant populations continued to increase. During an ant bait test conducted on these plots in the period of December 1979 through March 1980, the average bait stake ant counts in four untreated check plots, taken at weekly intervals, ranged between 200 and 300 ants per stake. (These differences were not considered to be significant since with such heavy infestations the numbers of ants per stake could only be estimated). Ant populations continued at very high levels in these old plantings until they were plowed out in May 1981.

Epidemiology of Mealybug Wilt at the Molokai Planting

In the Molokai experimental planting a few mealybug wilt plants were found in three untreated plots in the first crop. However, during the ratoon crop, areas of serious mealybug wilt developed in eight plots which had been used either as untreated check plots or treated with experimental insecticides which failed to provide ant control (fig. 2A). In one area which was plowed out and replanted in April 1980, ants and mealybugs reinvaded the new planting from an adjacent uncultivated area and serious wilt had developed in beds near the margins of the plots adjacent to the fallow field before the planting was one year old. These results again demonstrated that the occurrence of mealybug wilt is correlated with the presence of ant populations and that this disease is still a potential threat to pineapple culture in Hawaii.

DISCUSSION AND CONCLUSIONS

Results at both our Poamoho (Oahu) and Molokai experimental plantings have again demonstrated that infestations of pineapple mealybugs and attendant big-headed ants originate along field margins and gradually move inward, as reported previously by Illingworth (1931) and Carter (1932). The rate at which permanent ant colonies became established within these experimental plantings was much slower than anticipated; fully two and one-half years were required for all of the Molokai plots to become infested.

At both Poamoho and Molokai ant and mealybug populations were correlated with the phenology of the pineapple crop. *Dysmicoccus neobrevipes* populations were confined largely to the most actively growing portions of the plant; the young leaves and the developing fruit (fig. 3). However, as the first fruit crop approached maturity neither the fruits nor the foliage appeared suitable for the support of mealybug populations, and both these and the attendant big-headed ants declined dramatically. We hypothesize that the ants, being dependent on relatively high mealybug populations for food, were unable to sustain themselves when deprived of mealybug honeydew, and either migrated out of the fields or died off to a level which could be sustained by the existing food resources. Following the harvest of the first fruit crop new shoot growth could again support large mealybug populations, and both mealybug and ant populations increased. At Poamoho, the subsequent trimming of slips from the ratoon crop plants was also followed by a decrease in ant populations, but this was not noticed on Molokai where systematic slip trimming was not carried out. Ant populations did not decline appreciably at the time of ripening of the ratoon fruit crop, presumably because of the presence in the ratoon of suckers and slips which continued to support mealybug populations.

Sustained heavy rainfall may also cause appreciable reductions in big-headed ant and mealybug populations. Unusually heavy rainfall during March and April 1979 on Molokai was accompanied by a more than ten-fold decrease in ant populations. Populations subsequently increased following the return of drier weather.

The census of plants affected by mealybug wilt in the Poamoho planting (fig. 7, 8) showed clearly that the disease spread from single infested plants to adjacent plants and so throughout the field in a contagious manner. At wilt site A, which had the greatest incidence of the disease, the increase in the number of wilted plants over time followed a typical epidemic curve, with the numbers of diseased plants increasing at a nearly constant proportional (logarithmic) rate (fig. 7). Similar epidemic spread of mealybug wilt from individual point sources was seen in several plots of the Molokai planting.

In view of the need to develop environmentally acceptable methods for the control of pineapple ants and mealybugs in Hawaii, the results obtained from the observations and experiments discussed in this paper suggest some tentative pest management recommendations. An earlier report (Su et al. 1981) indicated that a new ant bait toxicant, AMDRO®, appears likely to provide a replacement for the mirex bait formerly used.

Big-headed ant colonies are largely destroyed during land preparation and planting procedures and reinvasion of newly planted fields occurs slowly by colonies from adjacent infested fields, fallow, or uncultivated areas. Therefore it appears that treatment with a suitable ant-bait or broadcast spray applied to the margins of new plantings, or a bait applied to margins of infested old fields or uncultivated areas adjacent to them, would effectively prevent the establishment of ant populations in new plantings. Small populations of ants sometimes survive within the fields during land preparation and replanting, although our findings suggest such populations normally die out from exposure and lack of food during the very early stages of the crop. If there is evidence that infield populations do survive, then a post-planting prophylactic ant-bait or spray applications over the entire planting would be justified. Otherwise, a post-planting peripheral treatment coupled with a simple program of ant detection by means of bait stakes should suffice. Our work on Molokai with trap stakes baited with peanut butter/soy oil suggests that placement of such stakes at intervals of about 30 m (100 feet) along the margins of new plantings would be sufficient to detect significant ant populations moving into new fields. We recommend that the first such survey be done about three months after planting, and at intervals of about three months thereafter. Bait stakes should be placed during late afternoon and examined three or four hours later, after sundown, as big-headed ants tend to avoid direct sunlight, and foraging activity appears to be greatest at dusk or later. When ants are detected they could be controlled readily by localized applications of ant bait or spray. The destruction of volunteer pineapple plants in fallow fields and of wild sisal plants (*Agave sisalana,* an important reservoir host of *Dysmicoccus neobrevipes*) in areas closely adjacent to pineapple fields (fig. 2) are measures which also may help to reduce the movement of ants and mealybugs into newly planted fields.

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