SOIL STRUCTURE MODIFICATION AND NEST DISRUPTION OF RED HARVESTER ANTS, *POGONOMYRMEX BARBATUS* (F. SMITH)

By

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CHAPTER I

INTRODUCTION

Pogonomyrmex barbatus (F. Smith), (Hymenoptera: Formicidae) is commonly known as the red harvester ant. They are soil nesting and seed feeding insects, typically found in bare areas of pastures, ranges and recreational lands. Nests are located in sunny sites with well drained soil. Once established the colony will seldom be moved. The ants denude the area surrounding the nest entrance and from there extend denuded trunk trails for seed foraging.

The nests of P. barbatus are complex, stable, well organized and generally greater than 1 m in depth. Soil texture for the nest sites range from clay to sand. However, the sites must be relatively dry and porous. The galleries or tunnels extend deep into the soil and expand laterally.

The ants respond to changes in the internal environment of the nest by adjusting the location of perishable items within the nest. Seeds are stored in the grainaries and must be kept dry. Moving them to dryer places within the nest prevents them from sprouting or decaying. The brood are kept in special chambers. When dry, warm conditions are not met at one place in the nest, the workers will move the brood to more suitable quarters.

The physical and environmental conditions of the nest are very important to the health of a colony. Studying the soil in which the ants nest and trying to manipulate the physical structure of the soil could show behavioral changes such as, inactivity, colony relocation or increased activity. Disturbances of harvester ant nests by water, the removal of foragers, insecticide applications and plowing does cause changes in ant behavior (Cole 1932, Crowell 1963, Whitford and Ettershank 1975, Gentry 1974). These disturbances either increase ant activity or cause the colony to move to another location.

Control of harvester ants has been throughly studied, but reliable and lasting chemical control is still difficult and costly. Harvester ants are medically and economically important pests. The female sterile workers possess a sting. They can be a major annoyance when they come in contact with people. The chances of being stung are greatest when these nests are located in recreational or densely populated areas. The impact of harvester ants on man is even greater when their nest numbers are great enough to cause considerable loss of grass and seeds in a pasture or range area.

Knowing what can change the behavior of P. barbatus will allow for a better understanding of their relationship with the environment and may lead to more effective control techniques.

The objective of this study was to observe the behavior of P. barbatus when mechanical, chemical or physical soil altering practices were applied to the nest. The long term effects of these disturbances on ant behavior and on the soil structure were analyzed to determine how effective these disturbances were in causing change in activity or movement of a colony.

CHAPTER II

LITERATURE REVIEW

Pogonomyrmex spp. are a predominate group of seed harvesting ants in the south-central United States. *P. barbatus* is the primary harvester ant of this genus in Oklahoma. This species extends westward to Arizona and southward into Mexico (Cole 1968, Young and Howell 1964).

The most serious aspects of *P. barbatus* behavior are their ability to sting, their seed foraging activity and their persistance in denuding vegetation around their nests.

Deaths have been reported in Oklahoma due to the stings of *P. barbatus* (Young and Howell 1964, Brett 1950). Hunter (1912) describes the pain of the sting as at least as severe as the bumblebee, and that the colonies located near houses became the greatest annoyance. Wildermuth and Davis (1931) and Barnes and Nerney (1953) also describe the annoyance of the sting and note that it is primarily a defensive weapon for intruders. *P. occidentalis* (Cresson), the western harvester ant, is also medically important and the process of and reaction to envenomization has been discussed by Weber (1959), Headlee and Dean (1908), Dean (1904) and Crowell (1963).

Being seed harvesters, *Pogonomyrmex* spp. may take newly seeded grain in fields or remove seeds from plants. Harvester ants derived their name from their seed harvesting activity. Bohart and Knowlton (1953), Cole (1932, 1934), Lavigne (1969), Box (1960), Dean (1904) and Michener (1942) are a few of those who have identified harvested seeds and noted the foraging behavior of these ants.

Denuding vegetation around the nest is a peculiar habit of most all species of harvester ants. Michener (1942) observed that P. californicus (Buckley) did not denude as large an area as the red or western harvester ant. Removing vegetation has caused these insects to become economically important in rangeland and pasture areas. The amount of grasses lost to harvester ant activity has been examined by Killough and Le Suer (1953), Willard and Crowell (1965) and Hull and Killough (1951). Sharp and Barr (1960) concluded that increased ant activity may be a result rather than a cause of poor range conditions.

The complexity of harvester ant nests has intrigued researchers and therefore caused an abundance of studies on the architecture of the nests. Chew (1960) excavated one colony of P. occidentalis in Arizona. He found the depth of the nest to be 1.7 m. The excavation was done in the spring so no brood were found. Chew observed but made no comments on the internal structure of the nest.

Lavigne (1969) excavated 33 nests of P. occidentalis and made a more thorough investigation of the internal structure of the nest. Lavigne stated that the size of the cleared area had no direct relation to the depth of the colony or the number of workers. The average nest depth was 1.9 m and the chambers in the nest were quite complex and linked with extensive tunneling.

Generally, the upper portion of the nest held chambers which served as nurseries for the brood and the deeper chambers were overwintering quarters. Seed chambers were found as deep as 43 cm. Seeds were not stored in the nests over the winter but the first granaries were situated from 3 to 15 cm below the surface. Up to 64 chambers, averaging 1.27 x 1.27 to 12.7 x 11.43 cm, were observed in some nests. The average queen depth was 1.2 m. Lavigne's dimensions of the chambers agreed with work done by McCook (1882) and Bohart and Knowlton (1953). As the soil warmed in the spring workers moved the eggs to various levels from the surface to 147 cm below the surface.

Cole (1932) worked with P. occidentalis and his findings were similiar to Lavigne's in 1969. Cole noted how the workers will move the brood up or down in the nest as the temperature fluctuates with the season. The brood will not mature in soils with high moisture content and the excess moisture will cause the stored seeds to germinate.

As with the brood, the workers transport the seeds to a dryer or more suitable part of the nest where the temperature is optimal. Cole states that germination of the seeds can be detrimental and may lead to the extinction of the colony.

MacKay (1981) studied the nest phenologies of three species of _Pogonomyrmex_. He concluded that soil type was very important for the level of moisture retained by the nest and humidity would determine the position of the brood within the nest. In addition he found sandy soil would release more water vapor than clay and fluctuation in soil moisture and temperatures were greatest in the upper levels and this accounted for the brood being kept in lower levels.

The ecology of _P. barbatus_ and _P. rugosus_ (Emery) was compared by Whitford et al. (1976). They were able to only excavate the nest to 1.8 m due to an impenetrable layer of hardpan caliche. No major nest differences existed between the two species. Descriptions of the nest were similiar to previous works.

Early insecticide studies on harvester ant control consisted of using inorganic material such as London Purple and Paris Green. These materials were used as dusts and sprinkled in a circle around the entrance of the nest. They were successful only in reducing activity but did not kill the entire colony. Carbon disulphide and calcium cyanide fumigants, which are no longer registered for use, were moderately successful in controlling the ants (Hunter 1912, Wildermuth and Davis 1931 and Brett 1950).

In the 1950's, Brett (1950), Young (1958) and List (1954) used different formulations of DDT, benzene hexachloride, chlordane, aldrin and dieldrin as control agents. Although the percent of control varied between researchers, only chlordane and aldrin provided satisfactory control.

Kepone and Mirex baits were tested for harvester ant control in the 1960's by Lavigne (1966) and Crowell (1963) and were found to be highly effective. These two products are no longer registered due to the high toxicity to nontarget organisms.

For the past five years, insecticide tests on P. barbatus were studied yearly by research workers at Oklahoma State University, Department of Entomology. Those products and formulations which were found to be at least 80% effective at controlling the ant activity were, drenches: chlordane and Orthene® (acephate) (Price et al. 1980); Liquid plum'r® (sodium hypochlorite, sodium hydroxide and sodium chloride) Supracide® (methidathion) and Precor® (methoprene) (Price et al. 1983) and granular forms: Larva-lur® (trichlorfon) (Price et al. 1980); Oftanol® (isofenphos) (Price et al. 1982) and corn meal grits (Price et al. 1983)

Current recommendations for homeowner use by Oklahoma State University extension service (Anonymous 1985) suggest using Diazinon 25 EC, 4 EC and 5 G, Sevin® (carbaryl) 50 WP, 80 SP or Chlorpyrifos 5.3 EC and 2 EC applied from early spring to fall.

The primary problem with insecticide applications is that liquid material does not penetrate into the nest deep enough to affect the brood or queen (Hunter 1912, Barnes and Nerney 1953, Wildermuth and Davis 1931). To aid in control of the ants, methods were employed to help the material penetrate the nests. Wildermuth and Davis (1931) and Barnes and Nerney

(1953) found that by removing the first 15 cm of soil, 60 to 90 cm in diameter and by applying carbon disulphide directly into the tunnels, control of the ant activity was very effective. Brett (1950) also found this method useful when applying calcium cyanide. Brett also felt that pouring 480 to 720 ml of water down the hole of the nest would make carbon disulfide more effective.

Young (1958) poured two liters of water directly into the nest entrance which permitted further penetration of the insecticide. List (1954) used a funnel to apply Chlordane into a nest at two different depths.

Unlike the imported fire ants (*Solenopsis invicta* Buren) which readily move their colony when disturbed (Williams and Lofgren 1983), most *Pogonomyrmex* spp. seldom move their colony. They only do so when greatly disturbed (Wilson 1971) or for no apparent reason (Van Pelt 1976). Just how frequently and why some move depends on the species.

Insecticide treatments often cause colonies to move. Hunter (1912) found that persistant treatment of *P. barbatus* nests with arsenicals caused the ants to move to a new site and therefore did not recommend arsenicals for control. Willard and Crowell (1963) noted *P. owyheei* Cole, transfering to another site after an insecticide treatment had been made. Crowell (1963) observed a colony of *P. occidentalis* moving from an untreated area into a nest that had been treated.

P. badis (Latrielle), the Florida harvester ant, moves its location quite frequently under normal conditions. From 60 to 90% of the colonies move at least once a year (Gentry and Stiritz 1972). Under severe predation the colony will readily transfer to a new site to escape the intruder (Gentry 1974).

De Vita (1979) estimated that 6% of P. californicus colonies relocate each year. There was no apparent reason for the movement; however, De Vita did notice that the movement resulted in a 1.1 m increase in nearest-neighbor distance, which increases intraspecific competition. Michener (1942) observed a six year old colony of P. californicus. He altered the surroundings of the nest with irrigation and the planting of trees and shrubs to reduce the available seed foraging sites. No effect on the strength of the colony was ever observed, nor did the colony ever relocate.

A saturation of the nest with water either by rainfall or by direct application can damage the seeds in the grainaries by germinating the seeds stored within. High moisture content will cause the ants to move the seeds to a dryer place (Cole 1932, Hunter 1912, Wildermuth 1931).

Ant activity is often increased after direct application of water (Whitford and Ettershank 1975) or after a rainfall (Brett 1950, Schumacher and Whitford 1974). Swarming is sometimes signaled by a rainfall and the swarms have been observed by Barnes and Nerney (1953), Nagel and Rettenmeyer (1973) and Lavigne and Fisser (1966). Flooding of a field infested with harvester ants has been discouraged as an effective control measure by Wildermuth and Davis (1931) and Killough and Le Suer (1953).

Submerging ants in water has been studied by Boosma and Isaaks (1982) and Fielde (1904). *Lasius* spp., *Myrmica* spp., *Camponotus* sp. and *Stenamma* sp. were subjected to complete submergence under water for varying amounts of time. The mortality rates were extremely low in both studies and the survivors showed little or no deleterious effects, indicating that the ants were well adapted to periodic inundation of water into their nests. No mention was made of the effect of inundation on feeding activity or food storage.

CHAPTER III

METHODS AND MATERIALS

Introduction

Physical changes in the soil, such as wetting, particle deflocculation or pore space reduction can be applied to the soil of an ant nest, thereby creating an unfavorable nest site. Just how much soil disturbance the nest and the ants can tolerate was investigated.

Adding amendments which adversely affect soil structure can cause instability in the nest structure and render part of the nest uninhabitable. The response of the ants determines how much change was caused in the nest.

Trickle irrigation is commonly used in orchards. Where there is sandy, well drained soil, P. barbatus nests are easily established. Many nests are located at or near water emitter sites and the colonies show no detrimental effect. The flat surface of the nest does not allow water to pool on top, so, run off and evaporation lessens the effect of irrigation. Pooling the water over the nest during irrigation would artificially create an unfavorable soil site. Due to the constant moisture influx, the ants would be unable to keep the stored seeds and ant brood dry. A trickle irrigation system supplies a slow continuous amount of water to the soil. When irrigation tubing is put over an ant nest, the soil will, in time, become saturated. Repeated water applications would be effective in keeping the soil wet for a longer period of time.

Site Selection

The experiment was divided into two parts. Part one was the trickle irrigation experiment. Part two consisted of testing an insecticide and using a mechanical soil disruption and soil structure altering amendments. The experiments were conducted in three field sites. Two sites (1 and 2) were located at the Perkins Research Station, located 1.6 km north of Perkins, Oklahoma. The third site was located 8 km east of the research station, on highway 33. The trickle irrigation experiment was at site one. Sites two and three were used as the test area for the soil amendment study.

All sites were located on alluvial terrace deposits of the Cimmaron river. Site one was a naturally revegetated, cleared abandoned apple orchard on the Perkins Horticulture Research Station. The soil type was a Teller loam series covered with cheat (*Bromus* sp.), brome grass (*Bromus* sp.) and little barley (Hordeum sp.).

Site two was an uncultivated, unmanaged 6.0 ha pasture with sandy loam soil covered with the same grasses as site one (cheat, brome and little barley). Site three was an uncultivated, unmanaged strip of land bordering the western end of the Perkins Agronomy Research Station along highway

177. The soil type was a Teller sandy loam series. Cheat (*Bromus* sp.), brome grass (*Bromus* sp.) and little hop clover (*Trifolium procumbens*) covered the site.

Trickle Irrigation

At the start of the study an excess of thirty red harvester ant nests were present in the orchard (Site 1). Thirty active ant colony nests were selected and randomized. Species determination was made with the taxonomic keys of Cole (1968) and Young and Howell (1964).

The location of each nest was mapped and marked with a tin lid held in the soil with a 10 cm nail. To account for any nest movement which might occur after the study, all extra nests not used in the experiment were mapped but not marked with an 8 cm lid. The study was conducted from July to August, 1984.

Treatments

The trickle irrigation experiment was designed to observe ant behavior when the water was pooled at two different depths in an ant nest. Treatments consisted of (one) hand augering a 7 cm wide hole in ten nests, to a depth of 1.8 m, (two) hand augering 10 nests, 7 cm wide to a depth of 15 cm, and (three) a check which consisted of ten nests left undisturbed.

Trickle irrigation tubing was manipulated to cover the treatment nests throughout the field. Approximately 457 m of tubing was laid out and connected to the orchard's water supply. In order for this outlet to be turned on the entire orchard water system had to be activated. The water applications would be regulated by the moisture requirements of the orchard.

One Vortex Emitter® was installed in the tubing over the center of the augered hole in the nest. At the time of water application the water pressure was adjusted to 2.7 kg/cm^2 with a flow rate of 7.57 l/hr. The flow rate was established using a graduated cylinder and a stop watch. The nests were irrigated for 34 continuous hours, then allowed to dry for 12 days before the next application. The 1.8 m treatment nests were initially given 38 l of water at the start of each water application. This was to insure the start of an initial wetting front through the soil. Three applications of water were made in the field for both treatments over a period of two months.

The principle of water movement through the soil by trickle irrigation has been described theoretically and mathmatically by Clothier and Scotter (1982), Bresler et al. (1982) and by Lockington et al. (1984). The basic principle suggests that there are two moving moisture zones, saturated and unsaturated (Levin et al. 1979). A saturated zone of a particular radius develops around the point of injection. Due to the limitations of soil porosity water diffuses into the surrounding unsaturated soil from the surface of the saturated zone. The front then advances as adjacent pores are filled (Lockington et al. 1984) This principle of water movement was utilized in our experiment to insure the saturation of the nest to at least 1.8 m. The irrigation water would pool in the holes excavated for the treatments. Over time, the water would move through the soil from the pool and gradually saturate the nest around the ponded water. The water would continue to move into unsaturated zones of soil for as long as there was a medium to move through.

Observations and Analysis

Observations of ant activity were taken once during the first 24 hours of the water application. Four observations were taken on colony activity within five days after the first water application. A total of five observations were taken for each application period. Fifteen observations were made for ant activity during the course of the study. The level of activity was ranked as high--full foraging and/or movement of the ants around the nest, moderate--some activity around the nest but not with full foraging or activity, low--few ants active around the nest and no foraging, inactive--no active ants observed. For statistical analysis, activity levels were ranked as follows: 0--inactive colony, 1--low activity, 2--moderate activity and 3--high activity.

Soil samples were taken while the holes were being augered on July 10. Only the 1.8 m treatment nests were sampled at this time. Samples were collected in plastic bags, marked according to depth and nest, and stored for analysis.

Five of the ten augered nests were measured for soil moisture content. Samples were weighed then oven dried at 105°F and weighed again to determine the moisture content. Ten nests were used for soil color and texture analysis. Soil color was determined by comparing clods of soil with a Munsell Soil Color Chart. Soil texture was determined by the feel method using a modified soil textural triangle.

After all water applications were made, final moisture samples were taken on August 16. A random sample of five 1.8 m, 15 cm, and check nests were selected and sampled as previously described. The 1.8 m treatment nests were sampled by augering another hole juxtaposed to the original. All the remaining nests were augered down the center.

Analysis of the soil moisture and activity level was accomplished using SAS (1982), General Linear Models. Paired comparison t-tests were used to compare moisture content before and after the water applications. Duncan's Multiple Range Test was used to compare treatment moisture contents after water applications and ant activity level per treatment. Interaction between treatment, application, application x treatment and nest x treatment was evaluated.

<u>Amendments and Disruption</u>

Experiments consisted of using three soil amendments, an insecticide and a mechanical auger disruption in July, 1984. Two field sites were used and designated as blocks. The experiment was designed as a randomized complete block each with 30 nests. Five nests were randomly selected for each treatment or check.

All nests were determined to be active colonies. The location of each nest was marked with a wooden stake and a surveyor's flag. A map was drawn of each nest location along with other nests in the area that were not involved in the test. Nests were numbered and the diameter of each was recorded.

Soil Treatments

Each of the treatments chosen allowed for observations of ant behavior when the soil they were nesting in was disturbed. Treatments consisted of:

1) 1.575 kg of dry Wyoming bentonite mixed with 38 l of water applied into a 1.8 m augered hole in the center of each nest.
2) check (untreated)
3) Diazinon 25 EC at a rate of 7.9 ml/l. A total solution of 19 l was applied into the 1.8 m augered hole.
4) Instant Calgon®-177 g/l. A total solution of 19 l was applied into a 1.8 m augered hole. Bentonite solution (19 l) was applied the following day.
5) Instant Calgon® solution alone at 177 g/l.
6) 1.8 m auger hole alone, no amendments applied.

The 1.8 m auger hole was used so that the test materials could be thoroughly incorporated into the soil of the nest. Also, the auger hole alone would show how the removal and replacement of a large portion of soil would affect the colony.

The insecticide treatment was used as a standard to judge low and inactive colony responses.

Soil Amendments

The soil amendments were selected because of their soil structure disrupting properties.

Bentonite is a clay type which when mixed with water becomes viscous. Different bentonite and water solutions were mixed to determine which mixture would penetrate easily into the galleries of the nest. Bentonite clay swells with moisture and blocks open air spaces, thus reducing air space and soil pores (Brady 1974, Rengasamy 1982).

Instant Calgon® is sodium hexametaphosphate ($NaPO_3$). This material is used in soil laboratories for dispersing small quantities of clay in soil particles (Day 1965, Kilmer and Alexander 1949). The amount of material used in the treatments was determined from calculations used in soil laboratories for small soil quantities. These calculations were then extrapolated to estimate the amount of material needed to disperse a much larger soil sample in the field (a harvester ant nest 0.9 x 1.8 m). The rationale for use of this treatment was based on the reaction of $NaPO_3$ with clay in the soil. The effect being a dispersed soil which will disrupt the structure of the nest each time water moves through the nest.

A combination of the two products, Instant Calgon® applied first then the bentonite solution, would close the soil pores and seal off the nest tunnels.

Soil Observations and Analysis

Periodic observations were made from June to September 1984 and again from April to May of 1985. Ant activity levels were recorded as high, moderate, low or inactive.

Soil samples were taken at the beginning of the experiment when the nests were first augered. Samples were taken every 15 cm. At each site, 15 nests were randomly sampled. A Munsell Soil Color Chart and a modified soil textural triangle was used agian to determine soil color and soil texture, respectfully.

Analysis of the data was accomplished by using SAS (1982), General Linear Models. Duncan's Multiple Range Test was used to compare activity levels per treatment. Interaction of Julian day, block, treatment, Julian day x treatment, and block x treatment was also evaluated. All statistical analysis was performed on the Oklahoma State University Computer Center mainframe.

CHAPTER IV

RESULTS AND DISCUSSION

Part One-Trickle Irrigation Experiment

Activity

The mean activity of *P. barbatus* after three water applications over a 40 day period is presented in Table I. After 15 observations over the course of the study no significant differences in mean activity between the two treatments were found. Both, however, were significantly lower than the check which received no direct water application.

There was no significant difference in mean activity between the 1.8 m and 15 cm treatments or the check during the five observations of an application period (Table II). Each treatment did respond with lower activity than the check.

The change in activity levels throughout the experiment for each treatment is illustrated in Figure 1. Applications were made between July and August 1984. Each application period consisted of the actual application of water and five visual observations before the next application. Though there were no significant differences between the mean of all the observations of each treatment during each application period, there were significant differences between the treatments and the check for specific observation periods (Table III).

The first observation during each application period was taken as the water was being applied. The four other observations were taken after the water had been discontinued. The first three observations of the first application period showed significant differences ($P \leq 0.05$) between the two treatments and control. The 15 cm treatment responded with a significant increase in activity while the water was being applied. The control colonies were totally inactive at this time due to the warmer midafternoon temperatures. Harvester ant colonies typically become inactive as afternoon temperatures increase. Due to the time of irrigation, the first observation was taken past noon. All other observations taken during the following application periods were before noon. This was the only period where the 1.8 m treatment also was more active than the check. This does reconfirm the observations previously discussed by Brett (1950), Schumacher and Whitford (1974), and Whitford and Ettershank (1975), that water applied to <u>P. barbatus</u> nests does stimulate activity.

The second and third observation showed a significant decrease in activity of the 1.8 m treatment compared with the check. During the first observation of the second water application there again was a significant difference in activity between the 1.8 m treatment and the check. This seems to indicate that initially, with significant amounts of water accumulating in the nesting area, activity within a 1.8 m treatment can be significantly reduced. This is only a temporary reduction in activity. This may be due to the initial movement of a new water front through the nest. The ants respond to the change in moisture by moving brood and seeds to dryer areas. If the excess moisture remains a problem for brood and seed storage, the ants may move these items to the most suitable place, resume normal activity and leave the brood and seeds in that area until the moisture flow has subsided.

After the third application of water there was no significant difference between any of the treatments or the check. Overall, the 15 cm treatment maintained a lower activity level throughout the experiment, though not statistically significant from the check or 1.8 m treatment.

The auger treatment, from the soil amendment study, showed no significant effect on the ants from the removal of soil from the nest. This was helpful in assessing colony behavior due to the accumulation of water and not due to the removal of soil.

Mating Activity and Colony Relocation

Mating flights from *P. barbatus* nests are most normally associated with and stimulated by rainfall. Apparently, the first application of water simulated natural rainfall enough to cause the stimulation of a mating flight from the 15 cm treated nests. Within 21 hours after initiating the application, alates were observed exterior of the nest and flying from the tops of grass blades. Approximately 159 l of water had been applied at this time and approximately 0.16 m^3 of pore space in 0.39 m^3 of soil was available for saturation in an estimated nest bulk volume of 1.2 m^3. Alates were not observed in the check, or the 1.8 m treatment.

The water in the 1.8 m treatment was received in the auger hole at 1.8 m and ponded at a depth of 0.9 m. The distribution of water in the soil of this treatment was unlike that of the 15 cm treatment. In the 15 cm treatment the water ponded on the surface and the rainfall effect of water infiltration from the surface downward was simulated. Whereas with the 1.8 m treatment, the water never filtered through the soil from the surface and the water ponded deeper in the profile.

The female alates that took flight before an actual rainfall were likely to be unsuccessful in establishing a colony. Even when the ground is moist from a rainfall, few queens are successful burrowing into the soil and establishing a brood. With no moisture in the soil except where the original home nest was established, the queens' chances of survival were further reduced.

Alates did occur out of the nest on both the treatments immediately after the second application. The ants in the check colonies exhibited an increase in worker activity during this time but alates still were not present.

A drop in activity occurred in all treated and untreated colonies well into the third application period. A rainfall of 1.8 cm then occurred over a two day period which brought activity up to higher levels. At this time, immediately after the rainfall, the check colonies produced their alates and swarmed. The treatments did not produce alates but were as active as the check colonies.

The 15 cm treatment appeared more disruptive than the 1.8 m treatment. Fifty percent of the 15 cm treated colonies had relocated by the end of the study and 20% mortality occurred. One colony began to relocate after the first application and the other four relocated after the third application. The distribution of water was in the critical brood and seed storage area of the nest, from 0.3 to 1.2 m deep. Thirty percent of the 1.8 m treatment nests relocated and 10% mortality occurred. All three colonies relocated after the third application. The water distribution in this treatment was at a lower level and possibly not as threating to the brood and seeds. No mortality or relocations occurred in the check colonies.

Water Movement

There was no significant difference in the percent air space between soil samples taken before and after the 1.8 m treatment (Figure 2). However, there was lower air space below 1 m after the application. The 1.8 m treated nests were kept at the same moisture level during the experiment as was found in the field before the experiment started. As would be expected, the mean percent air space in the treatment (22.44%) was lower than the check (27.04%).

There was a significant difference ($P \leq 0.05$) in air space between both treatments and the check at the conclusion of the study (Table IV). Measurements of the air space were made from the surface to 1.8 m. Much of the water accumulating in the 1.8 m treatment passed below a 1.8 m depth. It was decided that determining the amount of air space in the soil affecting the upper 1.8 m would be more informative than measuring the change in air space below this level. The effect of the water was intended for only the upper 1.8 m where brood and seed storage is primarily located.

The 15 cm treatment had the lowest mean air space measurement of 19.4% in the entire profile. The bulk density of the field was calculated to be 1.6 g/cm^3 with 40% total porosity. A total of approximately 772 l of water was applied and estimated to saturate 0.76 m^3 of pore space in 1.9 m^3 of soil. The 1.8 m treatment had more air space available due to only the bottom half of the hole receiving direct contact with water. Evaporation may have moved some of the water into the upper 0.9 m of the nest. Estimated bulk volume of soil in a harvester ant nest 0.9 x 1.8 m was 1.2 m^3.

The mean air space of the 1.8 m treatment was 22.4%. A total of approximately 810 l of water was applied to the

1.8 m treatments and estimated to saturate 0.80 m^3 of pore space in 2.0 m^3 of soil. The control had the highest mean air space at 27.04%.

The 1.8 m treatment held no less air space than it did before the treatment. However, there was still reduction in activity and colony relocation. The effect of the physical presence of water in the 1.8 m portion of the nest was less dramatic than the 15 cm treatment but there still were disturbances. The greater moisture in the upper 1.8 m of the nest likely caused these differences.

The presence of water and the subsequent lower air space in the soil of the 15 cm treatment seems to have been the major cause for 50% of the treated colonies to relocate and the 20% mortality. Since the water flowed down the center of the nest for 34 hours, insufficient drying of the tunnels and grainaries and potential seed damage was likely to occur. Also, the brood was exposed to excessive moisture and this may have caused a problem for the workers to regulate the microclimate for brood rearing.

Compared to the check, the 15 cm treated nests sustained an 11% air space reduction in the first 0.9 m of soil after the water of the last application had drained through the soil (Figure 3). The lowest amount of air space occurred 0.45 m below the surface. This depth corresponds to the primary location of brood rearing and major seed storage areas in the nests. Therefore, the water accumulated at a critically sensitive area and caused the significant effects on the behavior of the colony.

As discussed by MacKay (1981) the soil type is critical to the moisture retained in the nest and fluctuations in moisture and humidity in the upper levels keep the brood in lower levels of the nest. However, to minimize fluctuations in moisture, humidity, and temperature during an inundation of water, which occurred during this test, the workers probably moved the brood to the dryest places in the nest. Dryer soil is more temperature stable than wet soil. This would have been in the top 0.3 m where the soil could dry faster or 1 to 1.2 m where the soil was sandier and could drain easier.

There was a significant difference in the clay content by depth in the field. The highest percentage of clay was found in the first 0.9 m of soil. This correlates with the lowest percent air space found in the field after the applications. Due to a greater surface area, clay material will hold more water than sandy material. The highest percentage of sandier soil was from 1 to 1.8 m and a higher percentage of air space occurred at this level. This clay accumulation aided in our attempts to saturate the soil at a critical area of the nest by restricting permeability at that level (Figure 4).

With this information, a new technique for control of harvester ants could be employed for small scale use. The workers and the brood would be more susceptible to insecticides when higher soil moisture from water infiltration is present. The workers would be moving these perishables to the dryer portions of the nest which would be nearer the surface where an insecticide could penetrate more easily.

Part Two-Soil Amendment Study

There was no significant difference in mean activity between the bentonite plus $NaPO_3$, check, $NaPO_3$, and the auger treatments (Table V). The insecticide treatment had a significantly lower mean activity level ($P \leq 0.05$) than all the other treatments except the bentonite treatment. There was no significant difference in activity between the bentonite and insecticide treatment.

The $NaPO_3$ and bentonite, $NaPO_3$, and auger treatments appeared to increase activity slightly above the level of the control colonies. This could indicate increased worker activity to either repair damage to the nest or replace disturbed or contaminated seeds in storage.

The bentonite treatment presented a direct physical barrier into the tunnels of the nest and prevented worker movement through the center portion. The main tunnel of the nest, which extended vertically, was destroyed and the walls of the 1.8 m hole were coated with a layer of bentonite. This caused greater difficulty in making nest repairs than would a treatment that left no physical barrier.

There was a significant increase in worker activity in August for all treatments (Figure 5). Worker activity increased as alate activity increased during the first of

August. A mating flight occurred after a 1.65 cm rainfall on August 9 (Julian day 222) and then worker activity decreased and gradually leveled to moderate activity from Julian day 231 to 271 (August 18 to September 26). There appeared to be no effect of the treatments on the presence or flight of the alates.

Soil Work

The mean clay content of the soil ranged from 17 to 28% (Figure 6). The highest percentage of clay occurred from 0.9 to 1.35 m below the surface crust.

The clay content affected the treatment applications by slowing the movement of the material through the soil. A more porous material at the greatest depth of the hole allowed the $NaPO_3$ and insecticide application to flow through more freely and penetrate deeper into the nest area. Both the $NaPO_3$ and the insecticide had only 19 l of water in the treatment which would be enough liquid to saturate 0.02 m^3 of pore space in 0.05 m^3 of soil. The bentonite material being less viscous, would minimally penetrate a porous material. The 38 l of water used with the bentonite treatment could eventually move through the soil and saturate 0.04 m^3 of pore space in 0.09 m^3 of soil taking some of the bentonite with it, but the bentonite settled out in more open spaces.

The daily activity response for each treatment throughout the experiment is presented in Figures 7 and 8. The bentonite had an initial effect of greatly reducing *P. barbatus* activity. Within two weeks, activity was resumed at a less than moderate or normal level (Figure 7). Upon excavation of a sample of bentonite treated nests in May, 1985, it was clearly visible that the material was able to coat only the side of the auger hole and at the greatest depth, 1.8 m, the material pooled and did not penetrate into the tunnels or galleries of the nest, as was expected. Trash material of seed hulls and stems were found in great numbers in the filled auger hole. This accumulation of trash material was noted to only occur in the bentonite treated nests. The clay lined soil filled area from the auger hole may have been unsuitable for tunneling. Spaces or gaps in this disturbed area may have been more suitable for refuse disposal than other areas of the nest.

The insecticide treated colonies were greatly reduced to low activity throughout the experiment except before the mating flight where a characteristic increase in activity was observed between Julian day 211 and 221 (Figure 7). No physical effect on the soil was observed from the insecticide treatment as was intended by the $NaPO_3$, bentonite and combination treatment.

The response of the colonies to the $NaPO_3$ and bentonite combination was not significantly different from the response of the control colonies (Figure 7). A residual effect of the treatment, however, was evident in the soil. A white crust was present on the surface from the salt accumulation. A layer of clay lined the auger hole and the soil around the hole was massive (structureless), compacted and had a very brittle moist soil consistency. This lack of structure was a indication that the soil did disperse when contacted by the salt.

There was no indication that the salt solution penetrated the horizontal tunnels extending from the main vertical tunnel. Before the solution could soak into the walls of the auger hole, most of the material probably flowed through the bottom of the hole into the deeper portion of the nest. The effect of this movement of material was negligible on the ants. The $NaPO_3$ was applied first and dispersed the soil which left no spaces available for the bentonite material to penetrate. Half the amount of bentonite material was used in this treatment as opposed to the bentonite treatment alone, and due to this, the effect of a physical barrier from the material was reduced.

The $NaPO_3$ treatment had a similiar effect on the soil as previously described in the combination treatment. However, the first 0.3 m of the auger hole had a very loose sandy like homogenous soil material which appeared to be due to worker activity. This loose material was not observed below 0.3 m. The massive soil structure lining the remnant auger hole extended to 1.8 m and penetrated the walls to 5 cm. This massive structure was not as noticable in site two, which in the upper 0.3 m of the field, had sandier soil than did site three.

There was a significant decrease in P. barbatus activity on August 15 (Julian day 228) for all treated and untreated colonies. This was five days after a mating flight on August 9 (Julian day 222) (Figure 8). The other colonies, treated and untreated, experienced a similier drop in activity and it should not be assumed that the $NaPO_3$ treatment caused the significant decrease in activity.

The augered nest, without a soil amendment or chemical application, and the check (Figure 8) had no significant change in activity, although some variation did occur.

An above average total rainfall of 93.42 cm was reported by the Perkins Agronomy Research Station, from June 29, 1984 to May 1985. The bentonite and $NaPO_3$ treatments were given adequate moisture to react with the soil, move through and penetrate the nest. The bentonite treatment, however, was not viscous enough to penetrate into the nest as was originally desired.

1985 Observations

Final observations and nest excavations were made in May, 1985. Though long term suppression of activity was not observed in all but the insecticide treatments, two colonies of the $NaPO_3$ and bentonite treatments, one colony of the $NaPO_3$ treatment and one colony of the bentonite treatment failed to show activity in the spring. Ants in one control and three insecticide treated nests also died. Colonies will normally be inactive during the winter months and resume activity when the soil warms.

Observations were taken through September when nightly temperatures started to decline. From observations made in the field, colonies take from 14 to 21 days to relocate a colony. There is little likelihood that any of the colonies would attempt a relocation with the probability of frost and a rapid decline in temperatures likely to occur. The death of one check colony would not be unusual for an experimental test site, however, it is unlikely that the soil treatment colonies died from natural mortality.

Of the eight mortalities, ants in the three insecticide treated nests, the one bentonite nest and one of the $NaPO_3$ plus bentonite nests were all inactive by September (before the onset of winter) and their mortality was determined the following spring. Ants in the control nest, $NaPO_3$ plus bentonite nest, and $NaPO_3$ nest were active through September but succumbed after the winter months.

It is thought that the extreme winter temperatures and precipitation from November to April 1985, aided in the colony extinction of the $NaPO_3$ plus bentonite and $NaPO_3$ treated nests over the winter. These treatments may have damaged the galleries in these nests below 1.8 m and prevented movement of the ants away from the cold and moisture. The nests which were inactive before winter may have been damaged so that direct mortality occurred from the treatment alone.

CHAPTER V

SUMMARY AND CONCLUSIONS

The bentonite soil amendment was the only treatment in the soil amendment study which reduced *P. barbatus* activity for a significant period of time aside from the insecticide treatment. The bentonite acted as a direct physical barrier to the ants and seems to have prevented movement through the main portion of the nest. Preparing a more viscous solution of bentonite may have increased penetration into the soil pores. All remaining soil amendments showed no significant difference in activity from the check. No treatments were severily detrimental to the nests over the course of this study.

The 15 cm trickle irrigation experiment showed that harvester ant activity is stimulated by a slow, continuous direct application of water. An application such as the one conducted can simulate, to the ants, the movement of water through the soil as occurs with rainfall thus stimulating a mating flight. Both the 15 cm and the 1.8 m treatment created enough disturbance to cause some relocation of colonies. The presence of water in the nest seems to be the primary reason for the movement of the colonies in both treatments. Reduction of air space is a direct result from the water accumulation and thereby a secondary reason for the activity response.

The clay content of the field was greatest from 0.3 to 0.9 m and the lowest percentage of air space was also found at this depth. In the 15 cm treatments, water primarily accumulated at this depth and created a constant moisture problem with brood and seed storage.

If this test was performed earlier in the year (April to May) the effects seen in this study might not have been observed. Less seeds are stored early in the year and brood production would be minimal. Whereas, later in the year (September to November), more seeds are stored but brood rearing would be declining with the onset of winter.

In the winter months (November to March), the ants are deeper in the nest and less exposed to freezing weather. Water accumulating below the freeze line of soil in an open hole might bring colder temperatures to the ants and cause some mortality. The presence of water below 1.8 m would cause an undesirable overwintering site, out of which the ants could not move due to the cold temperatures. However, the ants would not be moving or respiring as they would when temperatures are warmer, so, the effects of water may be negligible.

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APPENDIX A

TABLES

TABLE I

MEAN ACTIVITY OF *P. BARBATUS* AFTER THREE WATER APPLICATIONS OVER A 40 DAY PERIOD, PERKINS, OKLA. 1985

Treatment	Mean Activity/[1]
(1)1.8 m	1.92/[2] a
(2)15 cm	1.93 a
(3)Check	2.38 a

/[1] Means followed by the same letter are not significantly different ($P \leq 0.05$), Duncan's Multiple Range Test.
/[2] Mean activity level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity.

TABLE II

MEAN ACTIVITY/TREATMENT OF FIVE OBSERVATIONS TAKEN DURING EACH APPLICATION PERIOD OF THE TRICKLE IRRIGATION STUDY, PERKINS, OKLA. 1985

Application	Treatment	Mean Activity/[1]
1	(1)1.8 m	1.34/[2] a
	(2)15 cm	1.84 a
	(3)Check	2.02 a
2	1.8 m	2.40 a
	15 cm	2.18 a
	Check	2.76 a
3	1.8 m	2.02 a
	15 cm	1.76 a
	Check	2.36 a

/[1] Means followed by the same letter are not significantly different ($P \leq 0.05$), Duncan's Multiple Range Test.
/[2] Mean activity level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity.

TABLE III

STATISTICAL COMPARISON OF TRICKLE IRRIGATION TREATMENTS BY OBSERVATION DURING EACH APPLICATION PERIOD, PERKINS, OKLA. 1985

Application	Treatments/[1]	Pr>t Observations				
		1	2	3	4	5
1	1 and 2	0.229	0.068	0.541	0.676	0.850
	1 and 3	0.065	0.007*	0.024*	0.106	0.055
	2 and 3	0.002*	0.443	0.070	0.295	0.197
2	1 and 2	0.850	0.569	0.552	0.431	0.687
	1 and 3	0.034*	0.121	0.387	0.330	0.775
	2 and 3	0.133	0.070	0.172	0.093	0.796
3	1 and 2	0.794	0.794	0.192	0.210	0.863
	1 and 3	0.105	0.105	0.777	0.602	0.389
	2 and 3	0.189	0.189	0.099	0.066	0.304

/[1] 1=1.8 m treatment, 2=15 cm treatment, 3=check
* Values are significant at $P \leq 0.05$ using a paired comparison t-test.

TABLE IV

MEAN PERCENT AIR SPACE/TREATMENT TAKEN AFTER THE COMPLETION OF THE TRICKLE IRRIGATION STUDY, PERKINS, OKLA. 1985

Treatment	Mean Percent Air Space/[1]
check	27.04 a
1.8 m	22.44 b
15 cm	19.41 c

/[1] Means followed by the same letter are not significantly different ($P \leq 0.05$), Duncan's Multiple Range Test.

TABLE V

MEAN ACTIVITY LEVEL OF P. BARBATUS/TREATMENT DURING THE SOIL AMENDMENT STUDY, PERKINS, OKLA. 1985/[1]

Treatment	Mean Activity/[2]	
$NaPO_3$	2.42/[3]	a
Auger	2.32	a
$NaPO_3$ and Bentonite	2.28	a
Check	2.10	a
Bentonite	1.83	ab
Insecticide	0.97	b

/[1] Through September 1984.

/[2] Means followed by the same letter are not significantly different ($P \leq 0.05$), Duncan's Multiple Range Test.

/[3] Mean activity level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity.

APPENDIX B

FIGURES

Figure 1. Mean Activity for *P. barbatus* After Three Irrigations Over a 40 Day Period, Perkins, Okla. 1985 (Mean Activity Level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity)

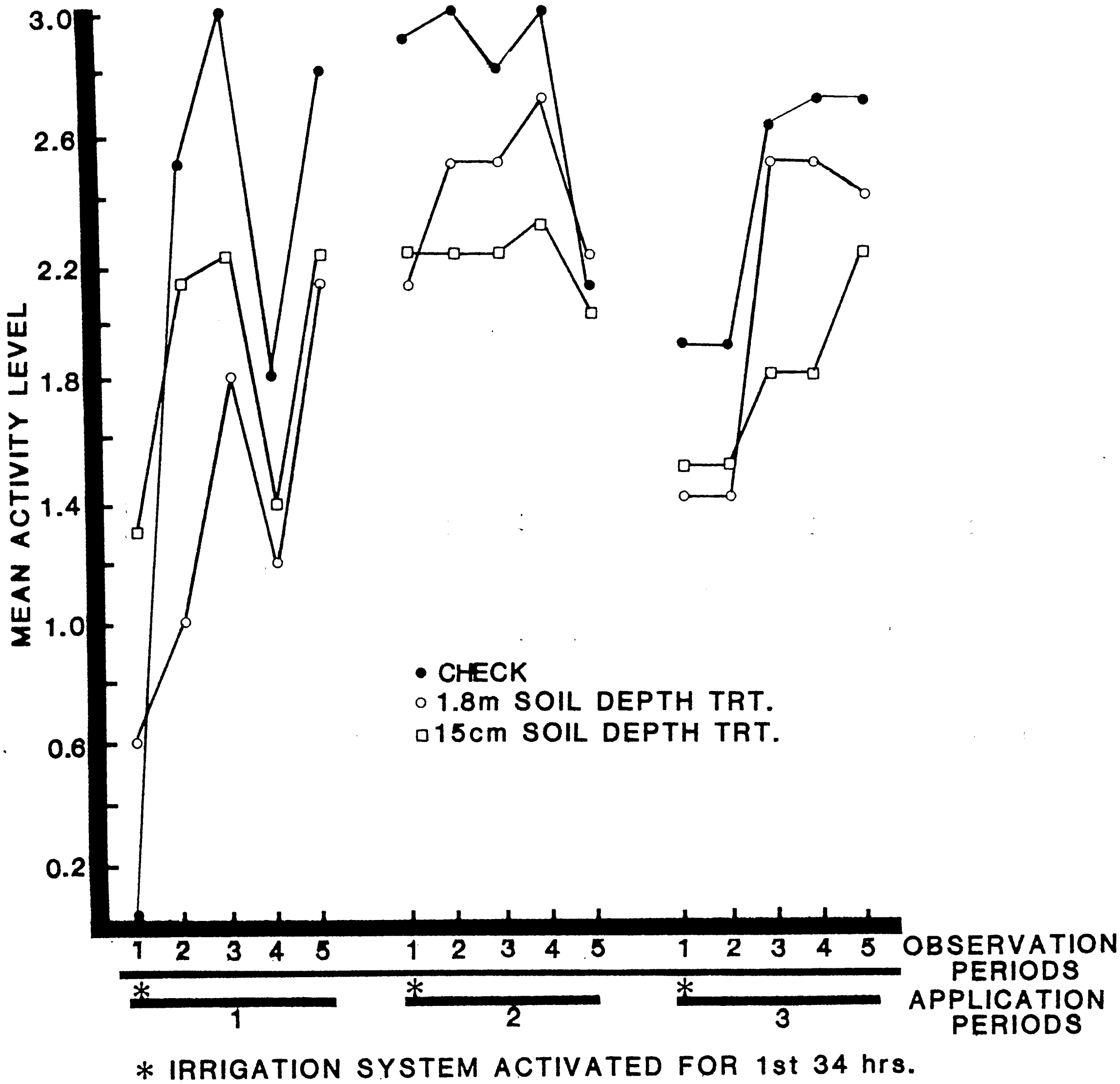
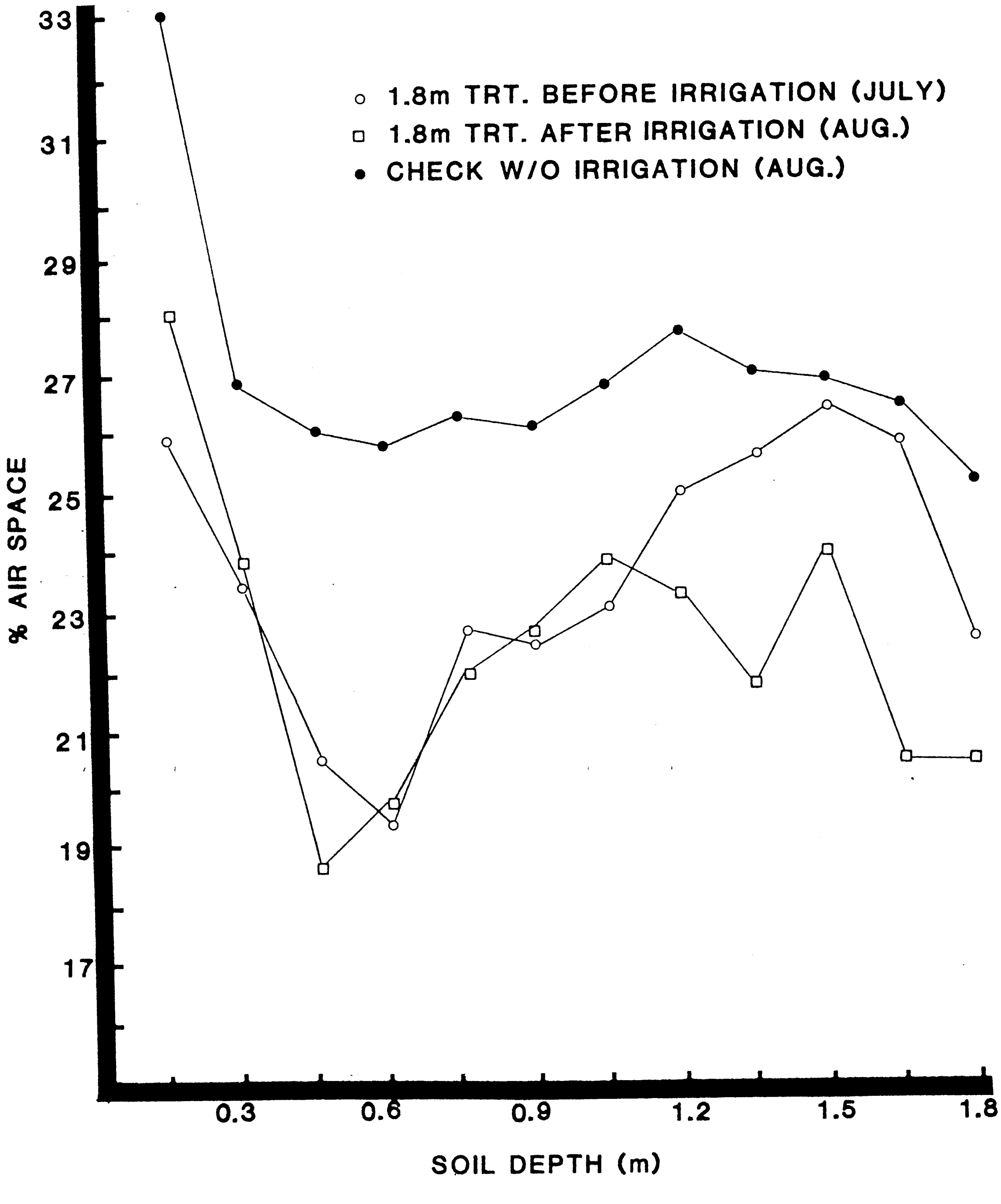
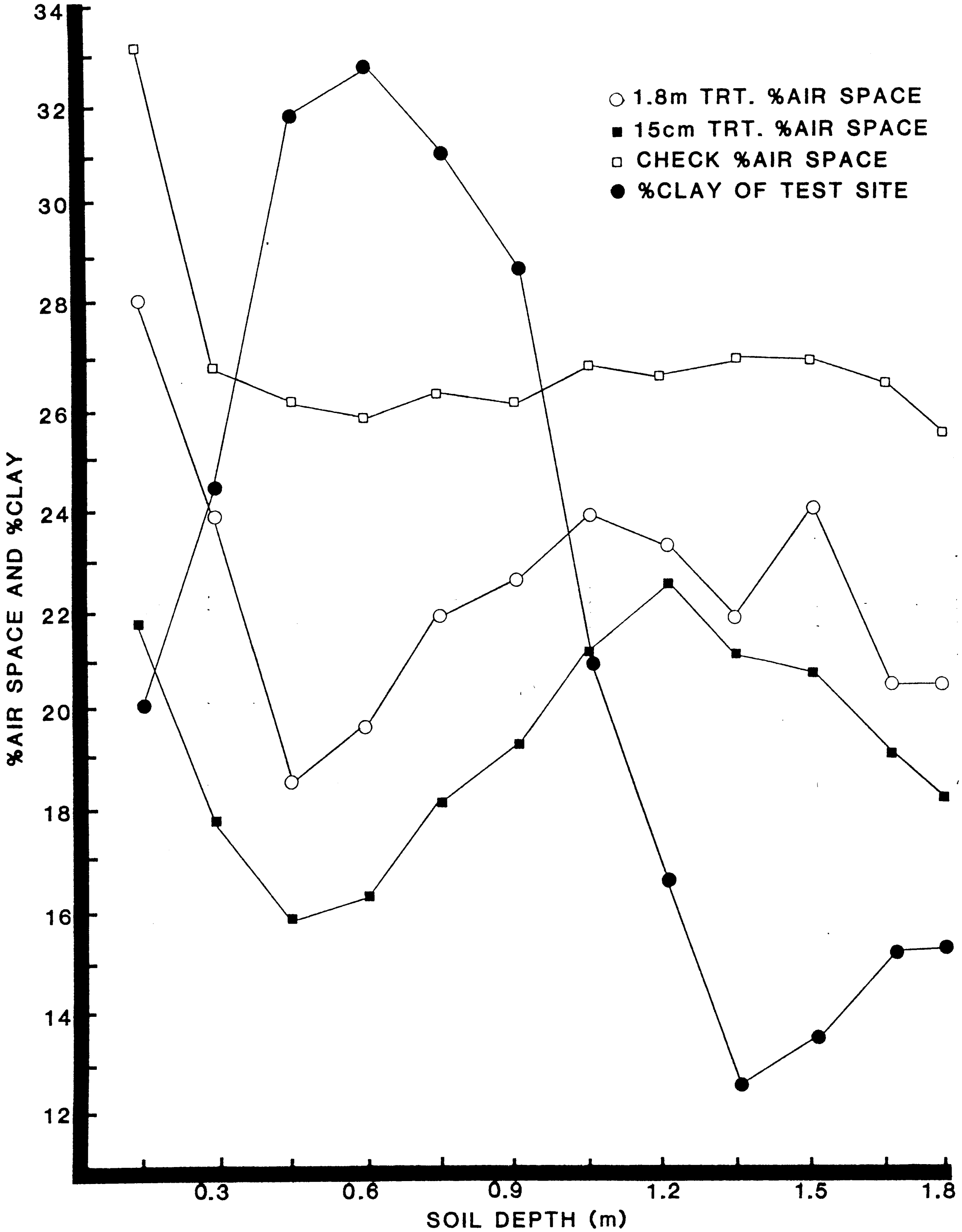

3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
MEAN ACTIVITY LEVEL
• CHECK
○ 1.8m SOIL DEPTH TRT.
□ 15cm SOIL DEPTH TRT.
1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 OBSERVATION PERIODS
* * *
1 2 3 APPLICATION PERIODS
* IRRIGATION SYSTEM ACTIVATED FOR 1st 34 hrs.

Figure 2. Comparison of Percent Air Space in the 1.8 m Treatments Taken in July, Before Irrigation and in August, After Three Irrigations, Perkins, Okla. 1985



1.8m TRT. BEFORE IRRIGATION (JULY)
1.8m TRT. AFTER IRRIGATION (AUG.)
CHECK W/O IRRIGATION (AUG.)
% AIR SPACE
33
31
29
27
25
23
21
19
17
0.3
0.6
0.9
1.2
1.5
1.8
SOIL DEPTH (m)

Figure 3. Comparison of Percent Air Space/Treatment After Three Irrigations and of Percent Clay Content of the Soil, Perkins, Okla. 1985



○ 1.8m TRT. %AIR SPACE
■ 15cm TRT. %AIR SPACE
□ CHECK %AIR SPACE
● %CLAY OF TEST SITE
%AIR SPACE AND %CLAY
34
32
30
28
26
24
22
20
18
16
14
12
0.3
0.6
0.9
1.2
1.5
1.8
SOIL DEPTH (m)

Figure 4. Soil Profile Comparison of Percent Air Space/Treatment by Depth After Three Irrigations in a 40 Day Period, Perkins, Okla. 1985

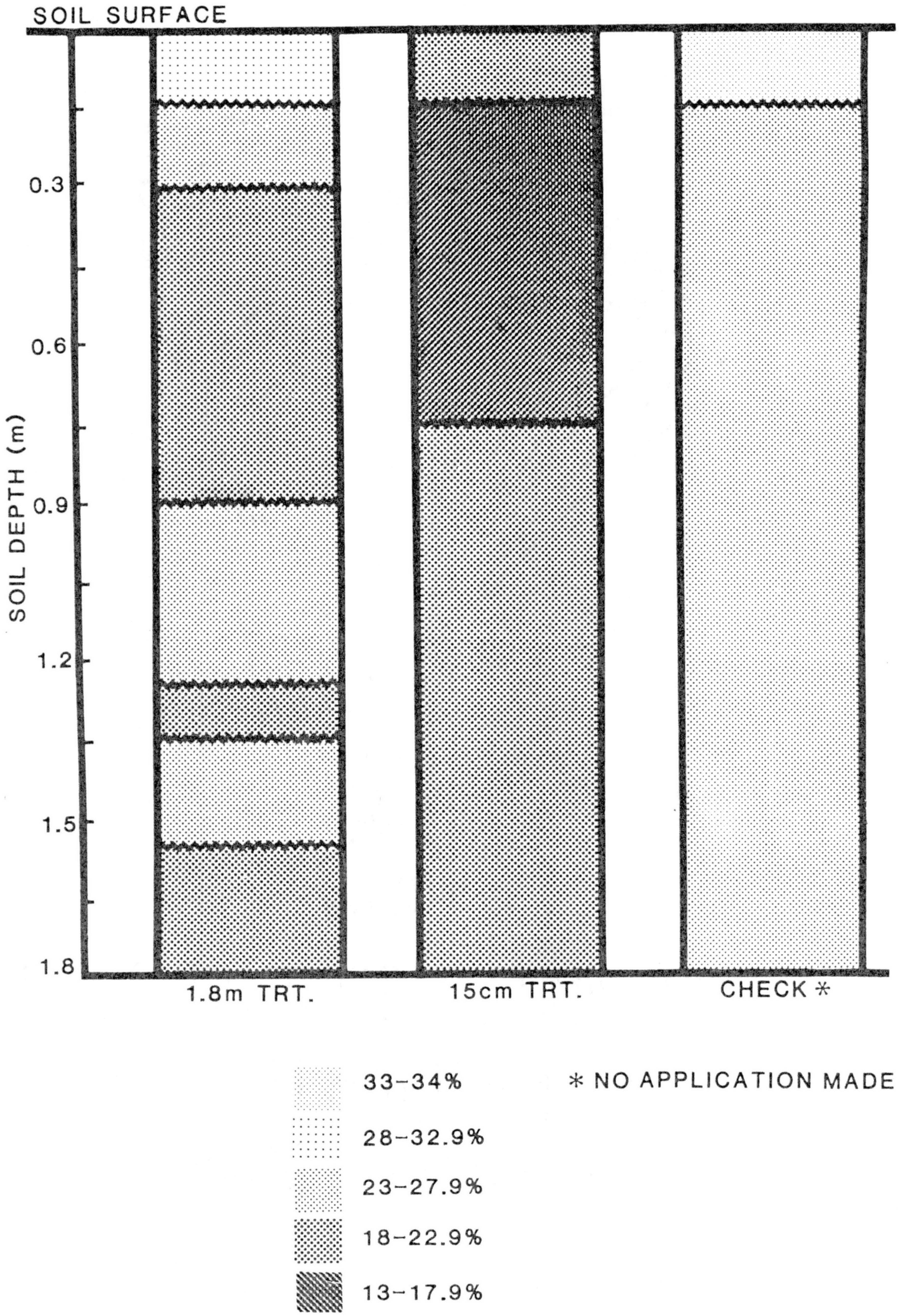

SOIL SURFACE
SOIL DEPTH (m)
0.3
0.6
0.9
1.2
1.5
1.8
1.8m TRT.
15cm TRT.
CHECK *
33-34%
28-32.9%
23-27.9%
18-22.9%
13-17.9%
* NO APPLICATION MADE

Figure 5. Mean Activity of P. barbatus For All Treatments Throughout the Soil Amendment Study, Perkins and Ripley, Okla. 1985 (Mean Activity Level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity)

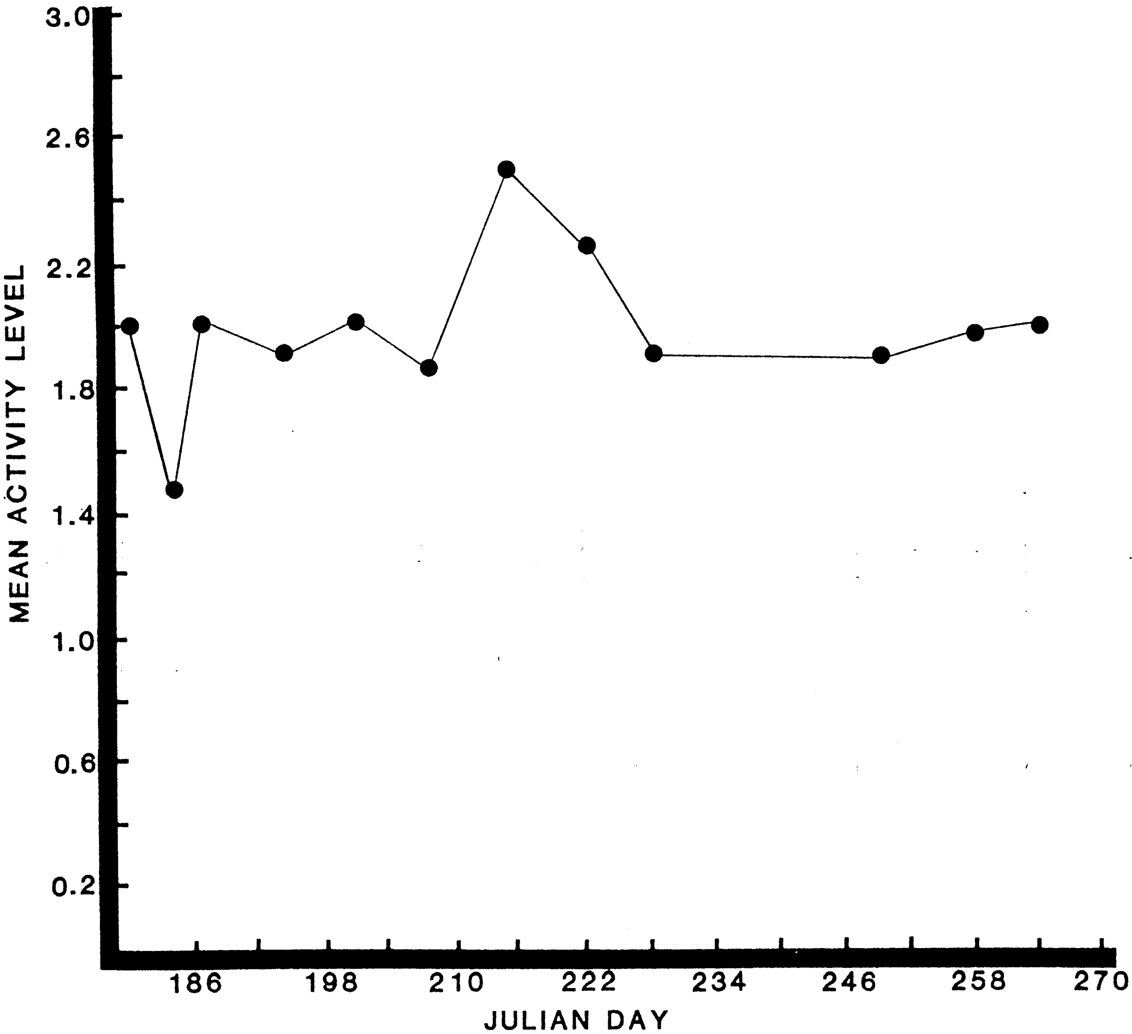

3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
MEAN ACTIVITY LEVEL
186
198
210
222
234
246
258
270
JULIAN DAY

Figure 6. Mean Percent Clay of Soil Amendment Study Sites, Perkins and Ripley, Okla. 1985

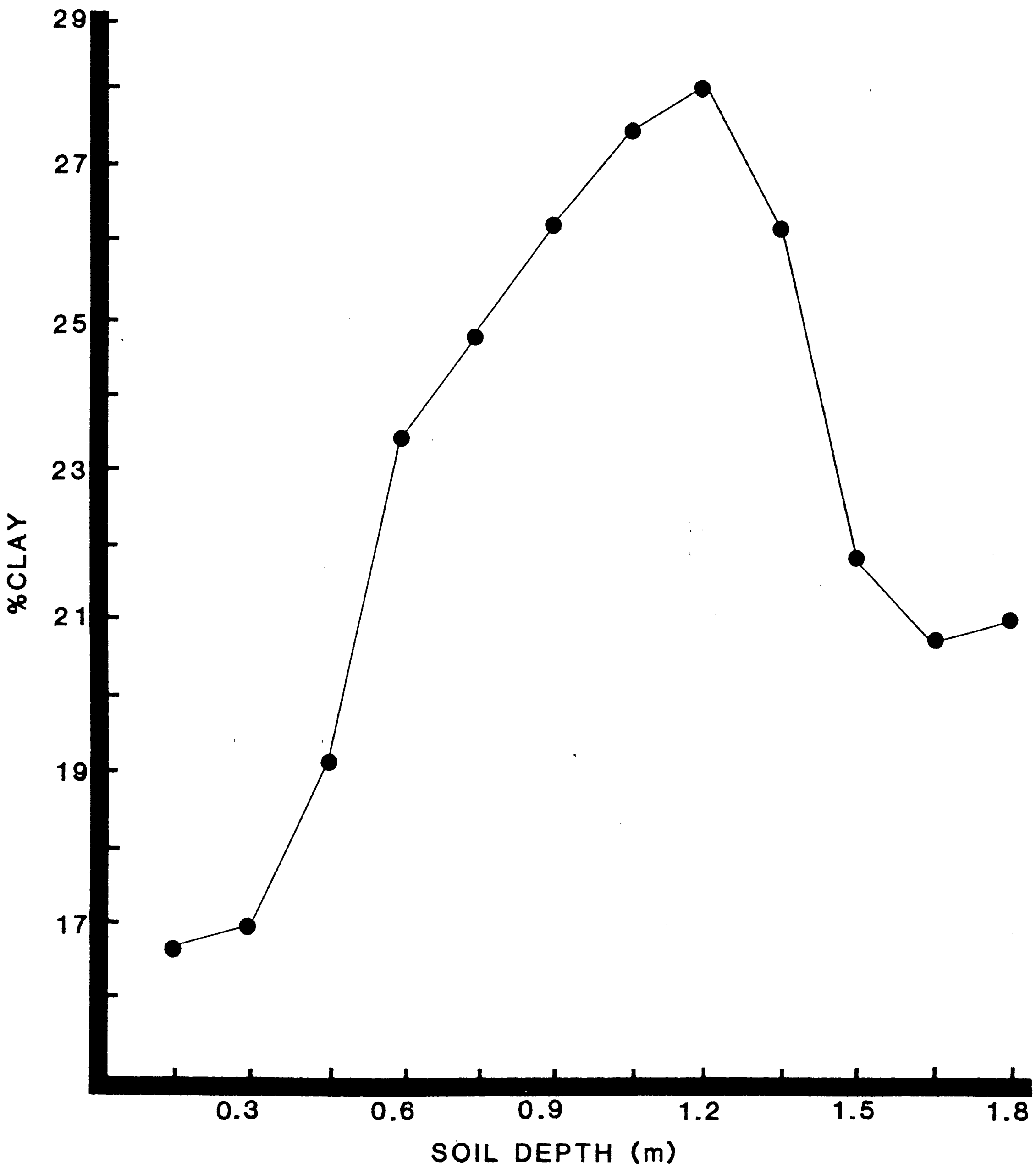

29
27
25
23
21
19
17
%CLAY
0.3
0.6
0.9
1.2
1.5
1.8
SOIL DEPTH (m)

Figure 7. Mean Activity of *P. barbatus* for the Bentonite, Insecticide, and $NaPO_3$ Plus Bentonite Treatments Over 12 Observation Periods, Perkins and Ripley, Okla. 1985 (Mean Activity Level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity)

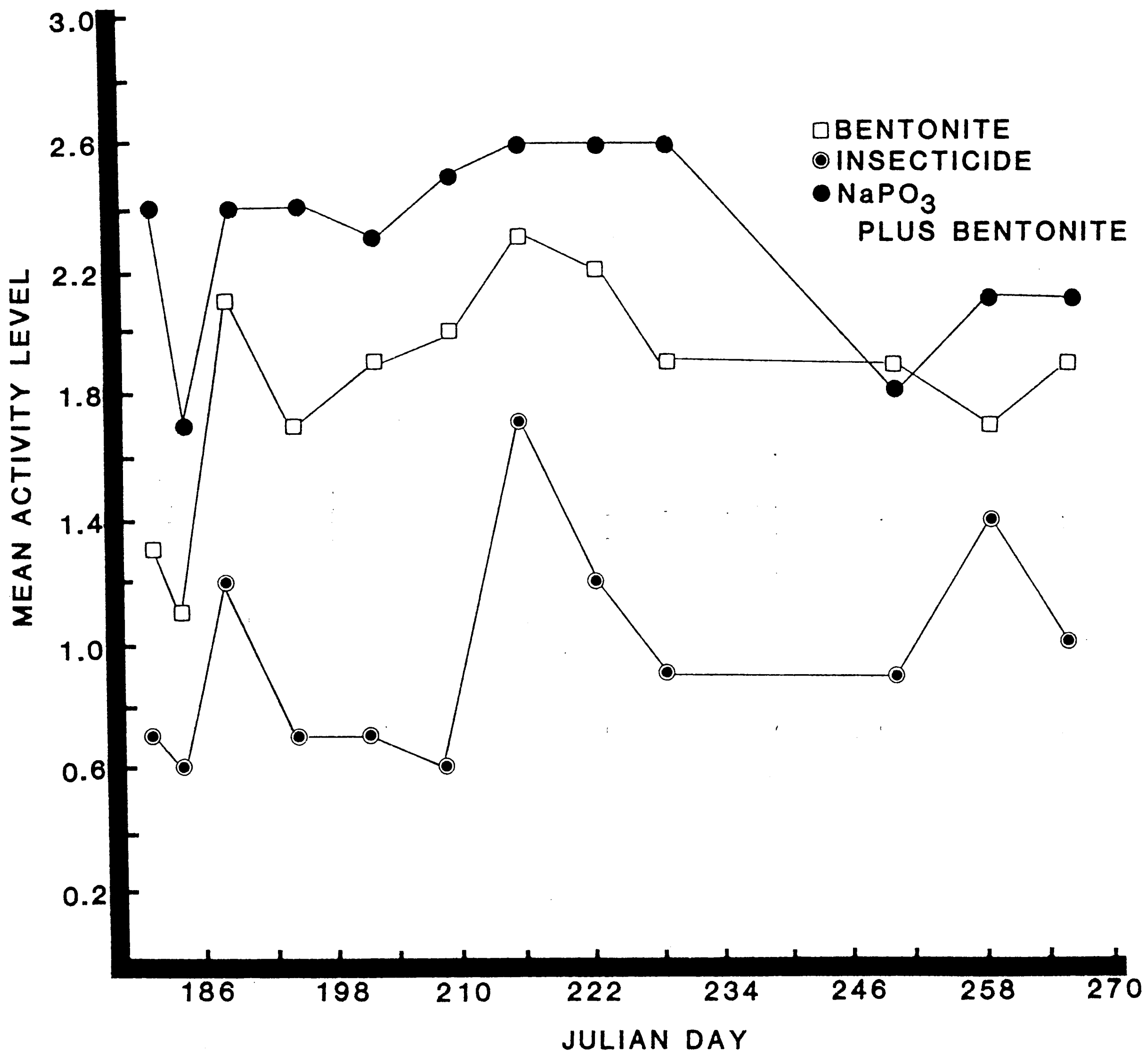
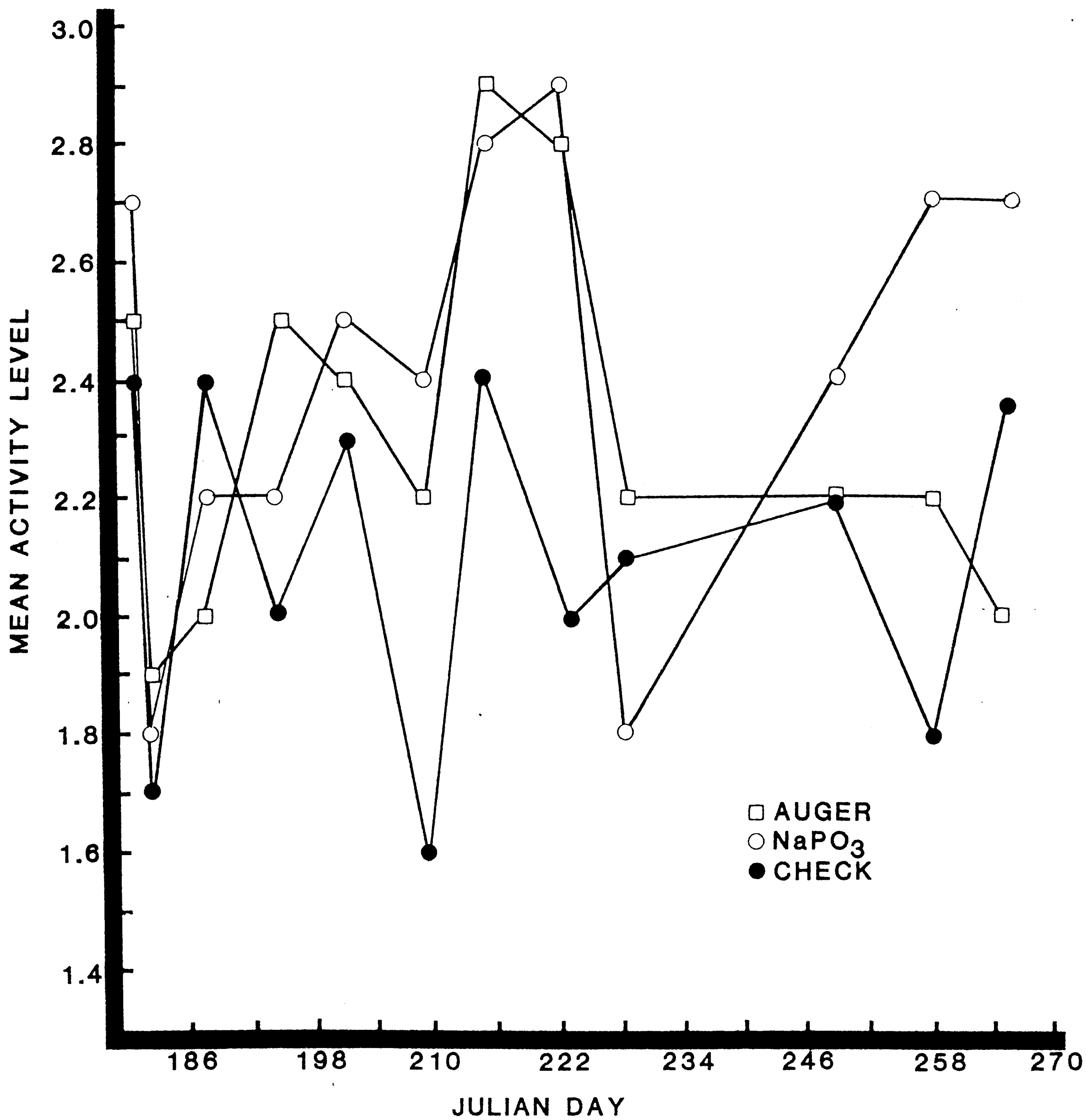

3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
MEAN ACTIVITY LEVEL
186
198
210
222
234
246
258
270
JULIAN DAY
BENTONITE
INSECTICIDE
NaPO3
PLUS BENTONITE

Figure 8. Mean Activity Level of *P. barbatus* for the Check, Auger, and $NaPO_3$ Treatments Over 12 Observation Periods, Perkins and Ripley, Okla. 1985 (Mean Activity Level, 0=inactive, 1=low activity, 2=moderate activity, 3=high activity)


3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
MEAN ACTIVITY LEVEL
186
198
210
222
234
246
258
270
JULIAN DAY
AUGER
NaPO3
CHECK

VITA

Jodie Rae Gladin

Candidate for the Degree of

Master of Science

Thesis: SOIL STRUCTURE MODIFICATION AND NEST DISRUPTION OF RED HARVESTER ANTS, POGONOMYRMEX BARBATUS (F. Smith)

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Professional Association: Entomological Society of America.