THE BIOLOGY, NUTRITION AND CONTROL OF

FORMICA EXSECTOIDES FOREL

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INTRODUCTION

Formica exsectoides, the Allegheny Mound Ant, was described by Forel in 1886 (21). Ten years prior to this, McCook (33) had studied these ants at Hollidaysburg, Pa. under the name *F. rufa*. While visiting America in 1899, Forel (22) mentions observing *F. exsectoides* at Worcester, Mass., Cromwell, and Hartford, Conn., and Black Mountain, N. C. In 1891, Dalla-Torre (15) lists this ant as occuring in "Am. North (New) Hampshire, Conn., Alleghanies". According to Wheeler (47), this species is distributed from Nova Scotia to Georgia and from the Atlantic coast to the western side of the Appalachian Mts. and occasionally as far west as Colorado.

In Maryland, mounds of *F. exsectoides* are known to exist in Baltimore, Howard, Montgomery, Prince George's, Garrett, Carroll, and Washington Counties. Probably they are present in other places especially in the western part of the state. These ants over run a considerable area, including all vegetation, near their mounds often annoying man and his animals. The mounds are sometimes built near cultivated fields and the ants are accused of causing damage. In New England, Peirson (37) reports that this species kills young trees. This has not been reported from Maryland but the relation of these ants to trees and insects on trees has not been adequately determined for this State.

If the entire life cycle and habits of this species were known in detail it might be possible to determine its value to man. Especially a knowledge of food used in nature and food acceptable in artificial colonies might lead to a better understanding of the species in Maryland. This information should lead to a better understanding of possible control.

With these points in mind, the field studies were developed along three lines; first careful observations on all activities of nests, second, tests to determine the most acceptable food, third, tests of methods of exterminating the ants in limited areas. The laboratory studies had two objectives; first to determine the details of the life history, second, to find what was the most nearly perfect food or foods for survival of individuals and for rearing young.

SUMMARY OF LITERATURE ON F. EXSECTOIDES.

McCook (33) was the first to count the number of F. exsectoides mounds in an area and to publish careful observations on the habits of this insect. 1300 mounds were counted in a 50 acre area northeast of Hollidaysburg, Pa.. At Warrior's Mark, there was another area averaging 30 mounds to the acre and at Pine Hill, the mounds averaged 59 per acre. McCook camped a week at Hollidaysburg making detailed studies of this ant and taking excellent pictures of the mounds both entire and in vertical section. The measurements of the mounds show that some were larger than any seen now but many were similar. Each mound was found to be friendly to all other mounds in that region. Very careful observations were made on the way F. exsectoides build "galleries" and repair the mound.

McCook's observations on food and feeding habits, while not extensive, are the best found in the literature. The "avenues" or paths of the ants to and from trees where they obtained honeydew from aphids and galls were watched. These ants were found to pay no attention to grain and grass seed but attacked a wolf spider, killing and carrying it into the mound.

McCook did not study F. exsectoides in the winter. Only tentative ideas about winter activities of this ant are given. Very meager comments are made on the larvae and cocoons. On the whole, McCook's studies of this ant are detailed and accurate. In 1879, he (34) made an observation, the significance of which was overlooked. He described finding F. exsectoides workers chewing pits in the bark of a tree near a mound.

Forel (22) made no extensive study of F. exsectoides. He (23) found a nest of this species in company with F. subsericae. This fact is one of the evidences used by Wheeler (48 p. 446) to prove that F. exsectoides queens found new nests by establishing themselves as temporary social parasites in the nests of other species.

Wheeler must have had a great deal of information on F. exsectoides. They are often mentioned in his discussion of some subject but in no place are they discussed in detail. In his book "Ants" (48), there are some fine pictures of mounds of this species. In this book the reasons for believing that F. exsectoides queens found nests by temporary social parasitism and a description of the swarming method of beginning new nests is given. F. exsectoides is not mentioned in his discussion of food.

Andrews has a number of articles on F. exsectoides. In 1925, he (1) describes a visit to Hollidaysburg where mounds were counted and measured in the same locality McCook had studied in 1877. The number and size of the mounds was much less than 58 years previously, partly due to the inroads of dwellings and other man-made destruction of the woodland. Andrews (3) made a study of a colony of mounds of F. exsectoides in Baltimore Co., Md. in 1905 and again in 1920. No decrease in the number and size of mounds was found here but a shift in concentration due in part at least to the development of trees. The young vigerous nests were near young woodland and the old nests in the mature stands of trees. He believes there is a definite correlation between size of trees and number of nests. His later (8) study of some of the food of F. exsectoides increased this belief. These ants depended upon two tree-hoppers, Vanduzea arquata Say. and Thelia bimaculata Fab. living upon black locust for their carbohydrate food. The colony used these insects on black locust more than the scale insects on tulip trees. They also used "beetles, flies, bees, bugs and especially the larvae of Lepidoptera" for food.

This author (2) also measured one mound at intervals during 19 years. The growth flucuated. While the mound was small, growth was slow and most of the material used was subsoil. Later, more vegetable matter and surface soil was used. Andrews (4) (7) also studied the temperature and strength of mounds. The upper part of the mound is warmer than the lower part and the entire mound warmer than the surrounding soil. Much depends upon the amount of sunlight received. The warmth is held in the mound because of the closed roof and inclosed air spaces. The strength of the mounds depends on the soil and vegetation used in the structure rather than any material that the ants might add.

Another problem with F. exsectoides that interested Andrews (6) was population. By timed counts of workers on food paths, the number foraging at one time was estimated. Using small area counts, the number working on the mound at a given time was determined and the pupal skins thrown out on the surface of the mound were counted. It was concluded that an accurate estimate could not be reached in this way. In the winter part of the ants in a hibernating nest were dug out and counted. In the spring, the rest were collected and counts made. Over 8000 workers and 11 queens were found in the nest. He concludes that F. exsectoides nests are not as populous as European mound-building ants.

In 1938 another study on the population of F. exsectoides was made by Cory and Haviland (14). A 19 inch high mound contained 237,103 workers and 1,407 queens, and a 11 inch high mound contained 41,326 workers and 40 queens. From a study of ten acres, averaging 7 mounds to the acre, and the above population figures, the F. exsectoides population of that area was estimated to be about twelve million.

At the time Andrews was studying F. exsectoides in Maryland, Peirson (37) was working with it in New England. He proved that these ants kill young white pine trees by chewing the bark a few inches above ground level and placing thereon their poison secretion. The same plant tissue injury was obtained by using formic acid solution. Peirson, Manter (32), Johnson and Friend (28) have done work on extermination of colonies of F. exsectoides.

Muckerman (35) describes excavations of the nests of this ant and Talbot (40) lists them in a survey of species in the Chicago area. This species is also given in various lists and mentioned by authors of general books on insects because of the conspicuous mounds. For information on the habits of F. exsectoides, McCook, Wheeler or Andrews should be consulted. Peirson and others from New England have done the only experimental work upon extermination of colonies of this ant.

BIOLOGY

Location and description of colonies.

The term colony of *F. exsectoides* is used here to include all nests, indicated in this species by mounds, in one locality. Colonies have been observed in four localities.

The most extensive is called the Beltsville Colony. Mounds can be seen in groups in the area from a half mile south and west of the Fairland Elementary School and south of the Columbia Road to the Powder Mill Road. In the higher parts where clearings have been made and later abandoned, the mounds are most numerous. Along parts of the roads that run from the Columbia Road south through a wooded area mounds are frequent. The mounds are not evenly distributed. There are often several within a few yards of each other and then none for a considerable distance. The Beltsville Colony has two sections about a mile apart. The sections are each along a road with various cleared or cut over uncultivated patches where the mounds are most numerous. Much of the intervening area is mature woodland including a wet valley. Mounds found in this intervening area are usually large but not numerous. All the mounds are near trees but most have open areas on one side at least. This gives most mounds several hours of sunlight each day.

The second colony observed is at Greenbelt. It is small in extent and seems to be a young colony. It is on the top of a partly wooded hill formerly the location of a house. Now locust, oak, ash, Virginia pine and other trees are gradually coming in but a few fruit trees, cedars and elms persist. No unusually large mounds were seen and no old mounds were detected. Of the 31 mounds seen, only ten were large and an equal number were under a foot in height. This colony is not more than ten miles from the Beltsville Colony and may be an offshoot from it especially since both are in the Paint Branch drainage basin.

The other colonies observed are in the Patuxent valley about three miles apart. The Brinklow Colony has developed on a northwest slope in a large abandoned orchard. Twenty years ago no mounds were known on that side of the Hollings River. One-half mile away on the north side of the stream, a nest of F. exsectoides has existed for years. A new nest has developed on that side recently and now 12 mounds are known to exist on the south side of the Hollings River.

The last colony is located about three miles up the Patuxent valley from the Brinklow area. It is about a half mile below the Brighton Dam on the west side of the Patuxent River. It is on a southeast slope abandoned as farming land after the top soil had eroded. It is now growing up to Virginia pine and hardwood trees. The extent of the area is not great and the 20 mounds are mostly of moderate size.

In all these mound locations, similar trees are growing but no extensive areas of mature trees are now present. The mounds are all on poor soil, mostly sandy loam over gravel or loam over rotten micaceous rock. The ecological needs of F. exsectoides seem to be complex; many localities that have the right trees, slope, soil and sunlight have no mounds. These four factors seem to be involved but whether there are other factors is not clear. The opportunity for queens or swarms to establish themselves may be lacking.

Life history.

F. exsectoides eggs (Fig. 1) are elongate eliptical in shape and white in color. They average 0.823 mm. long and 0.413 mm. wide at the widest point. The surface is slightly granular and sticky which makes the eggs adhere to each other easily. In 30 artificial nests, held at 70 F., eggs hatched in a range of 10 to 27 days, with an average of 19.4 days. In 19 artificial nests, with the temperature varying from 48 F. to 94 F., egg hatching ranged from 11 to 54 days with an average of 21 days.

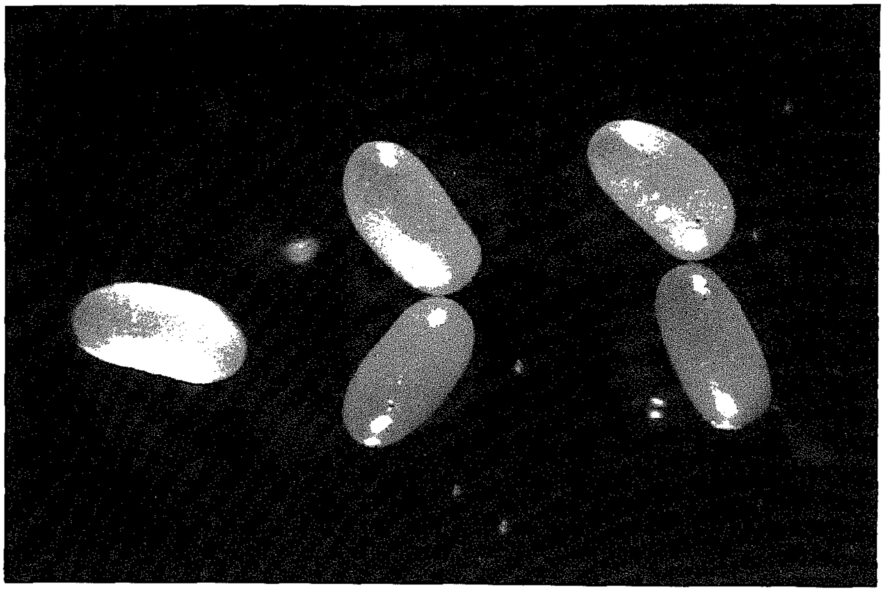


Fig. 1. Formica exsectoides eggs highly magnified.

The curved, legless, white larvae (Fig. 2) are kept in groups on the floor of the nest. In artificial nests, growth seems erratic. Sometimes larvae of 3 to 4 mm. length are present three days from hatching. At other times, several weeks may pass before large larvae are present. The workers have been seen eating larvae. This probably accounts for the apparent slow multiplication in these cases. Again and again a colony would have one large larva one day and two days later have none. There were many small larvae most of the time. The workers did not seem to devour them so readily. In 8 nests with temperatures varying from 48 F. to 94 F., it took from 11 to 53 days from the time the first larvae were noted until a pupa was formed or an average of 18.2 days. In 9 nests held at approximately 70 F., it took from 21 to 53 days or an average of 37.1 days from the appearance of the first larvae until a pupa was formed. Probably if all conditions were exactly satisfactory, the larval period would take from 10 to 14 days.

The cocoons (Fig. 3) are dirty white to tan in color depending on age. In 7 nests with temperatures varying from 48 F. to 94 F., the pupal period lasted from 22 to 35 days with an average of 27.3 days. In 4 nests held at approximately 70 F., the pupal period was 25 days in three cases and 30 days in the fourth or an average of 26.25 days.

In 11 nests for which the length of each stage is known, the total time required from first eggs to appearance of a callow was from 54 to 107 days or an average of 75.0 days (Table I). It has been pointed out that because of the cannibalistic habits of the workers, some nests were very slow to have larvae pupate. Nest 48-1 is a good example. Nests 13-1 and 33-2 illustrate the rapid completion of larval development which appears to be normal.

The callow (Fig. 4 a) is much lighter in color than the workers and for a period of about two weeks can be distinguished from the others.

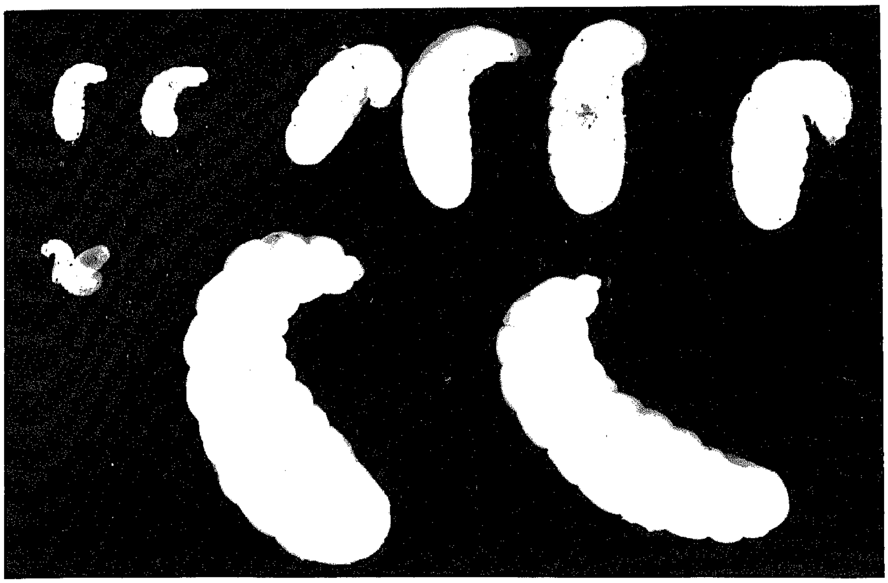


Fig. 2. Formica exsectoides larvae.

The 2 large ones will develop into winged adults. The rest are worker larvae of different stages of development.

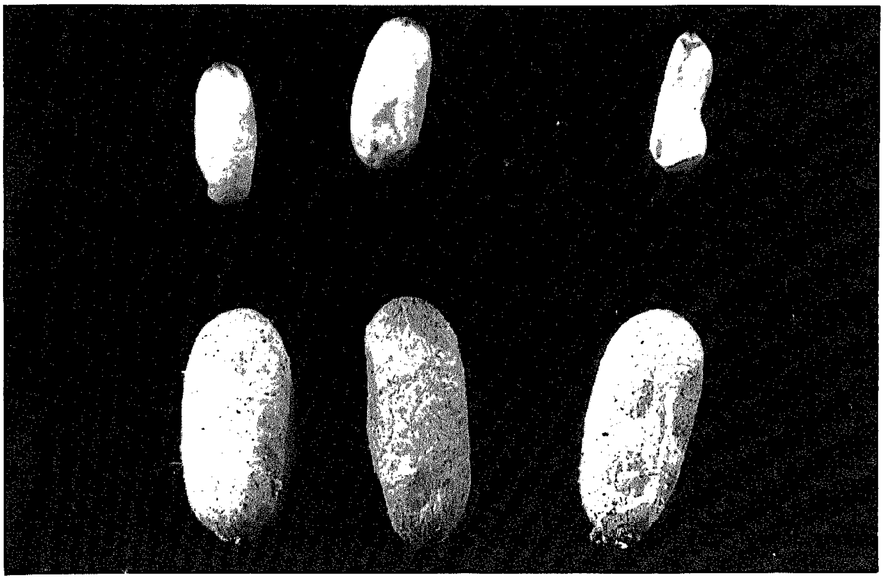
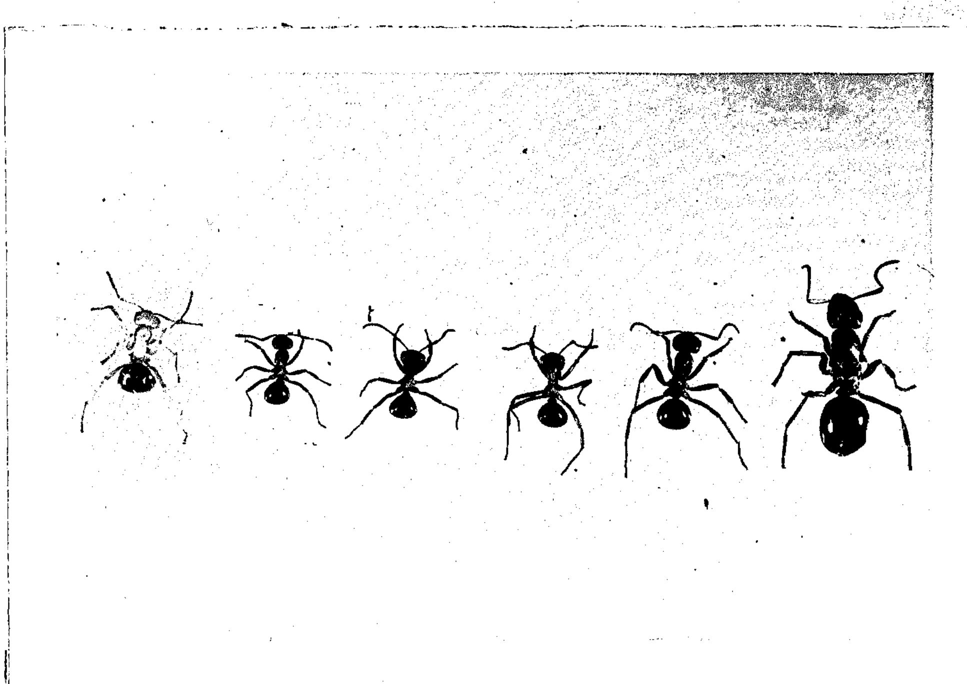


Fig. 3. Formica exsectoides pupae.

The upper row will develop into workers; the lower row into winged adults.



a b c d e f

Fig. 4. Formica exsectoides adults.

a- callow, b-e workers, illustrating the different sizes, f-dealated queen.

In less than a week they were seen carrying pupae. In nature the workers vary in size (Fig. 4 b-e). The largest are almost like soldiers. The smallest are two-thirds this size and lighter in color. Intermediate sizes are present but the gradation is too varied to make possible distinct groups. All those raised in artificial nests were the smaller type workers. All were raised in nests with one or two queens.

TABLE I. Data on Life History of 11 Artificial Nests.

Nest	Egg	Larval	Pupal	Total
13-1	17 Days	11 Days	26 Days	54 Days
14	24	12	27	63
15	13	32	35	80
35-1	23	19	25	67
48-1	28	53	26	107
33-2	20	12	22	54
35-4	19	28	25	72
41-4	16	41	25	82
43-4	16	45	25	86
45-4	14	52	25	91
49-4	19	21	30	70
Average	19	29.6	26.4	75.0

Workers alone will have eggs in the nest in about twice the time required for an artificial nest with a queen. The number of eggs is small and after about two weeks no more appear. In only one case did any of the larvae complete development and these were normal males.

The length of the various stages in the development of F. exsectoides are in accord with those found for other species by various workers. Fielde (18) found that for Stenamma fulvum the egg stage took 18 to 21 days, larval 20 to 97 days, pupal 15 to 20 days. For Camponatus herculaneus, Pricer (38) found that the egg stage took 24 days, larval 21 days, pupal 21 days.

Both of these workers mention the influence of temperature on all stages and food upon the length of the larval period. Wheeler (48 p.81) reviews two other studies. Fielde found that for Aphaenogaster fulva the egg period was 17 to 22 days, larval 24 to 27 days and pupal 13 to 22 days. Janet found for Myrmica rubra that the egg period was 23 to 24 days, larval 30 to 71 days and pupal 18 to 22 days.

Seasonal history.

Depending upon the season and the exposure of the mound, F. exsectoides hibernate from October until April at Beltsville, Maryland. In the spring, activity begins gradually. In 1944, dealated queens were found the last week of April near the surface of the mound. In 1945, the queens were near the surface by March 18 and eggs were found near the surface March 26 but this season was about four weeks early. For two weeks, activity increases gradually depending upon the temperature and the amount of sunlight. By the last week of May, mounds contain large numbers of larvae of all sizes. Large vigorous mounds contain hundreds of large larvae, which will develop into kings and queens, and many more smaller larvae that presumably develop into workers. Small nests do not have the large "royal" larvae as frequently, if at all.

During the months that the nests are active, the mound proper and the first 6 inches below soil level are used most. Larvae and pupae are gathered in the passageways with little segregation by sizes. In hot, dry weather, mounds fully exposed to the sun will have the brood below soil level on the north and east sides of the mound. In mounds only partly exposed to the sun or in cool weather, the brood will be on the sunny side in the mounds above soil level.

The first week of June pupae of various sizes are present. From then until September, pupae are present. In large mounds, at first most of the pupae are "royals". For 5 weeks "royal" pupae are present in diminishing numbers. In all mounds, worker pupae are to be found in hundreds usually on the sunny side of the mound just below its surface.

The last week of June, winged males (Fig. 5) and females are present near soil level in the mounds. These young queens never make any attempt to fly when a part of the nest is opened and they are thrown out but ran about quickly slipping into cracks and remaining quiet. The kings open their wings and fly a few inches before secreting themselves in some crevice. Winged forms disappear from mounds by the middle of July.

In August, the activities of mounds decrease gradually, few larvae are present and the number of pupae found becomes less and less. By mid-September, many of the ants are down in the tunnels below the mound proper entering hibernation. The numbers hibernating and their depth in the burrows increases as the season advances. No eggs, larvae or pupae are found in the mound from October to April. Workers and dealated queens are the only forms that hibernate. A populous nest will contain more queens in proportion to workers than a small mound. No aphid eggs, stores of food or anything except myrmechophiles are found in the mounds during the winter.

<u>Formation of new colonies.</u>

All nests excavated contained more than one queen. All the large nests contained numbers of queens. No records were kept since no effort was made to obtain all the queens in any nest but the results of the population study made in 1938 seem to be valid. (14)

In the spring of 1944, swarming was observed. It is a gradual process. The first indication is a few holes with pellets of dirt around them and workers moving in and out. This place may be from a few feet to some rods distant for the parent nest. Between this spot and the parent nest, the ants are more numerous than at other points on the entire surface of the ground. In a few days, a small loose mound has hidden the original holes. There is still a more dense line of ants traveling back and forth between

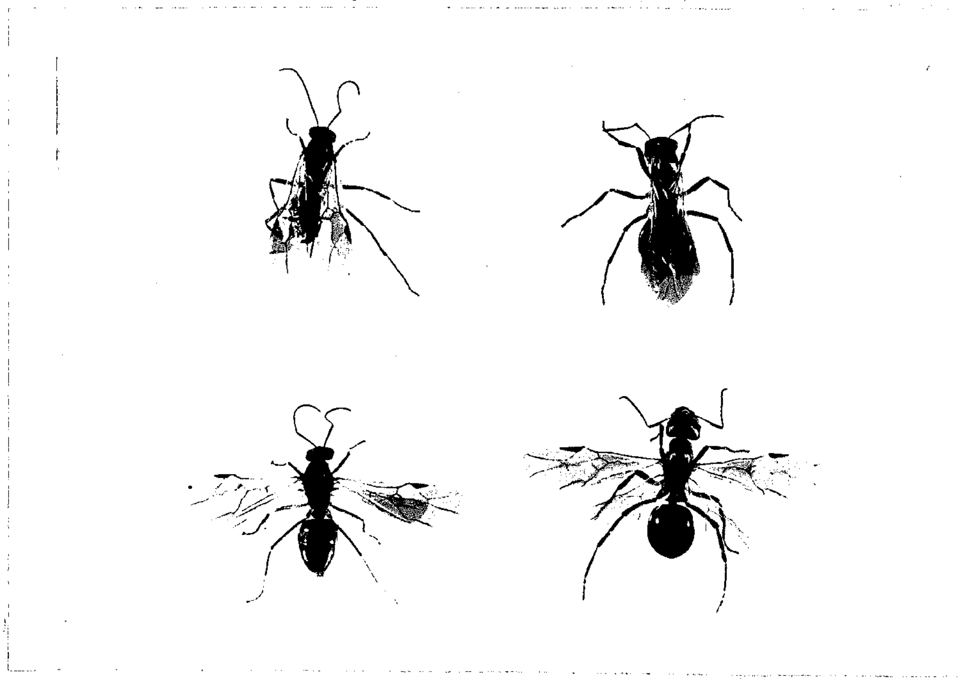


Fig. 5. Formica exsectoides winged adults.
left - males, right - winged queens.

the new mound and the parent one. In a 25 square yard area, burned over during the winter, 7 swarm nests were found. In other parts of this burned section, small new mounds were found that must have been started by ants from a distance of 30 yards at least. Wheeler (48 p.120) states that F. exsectoides spread in this way.

With this swarming activity in the spring, new mounds are started in the same area as the parent mound. In a place where all conditions are favorable, most of the swarms would become established. In other places, where conditions are not so favorable, either swarms do not try to establish themselves or else they are not able to become established. This activity helps explain the length of time colonies maintain themselves and for the gradual shift in their location as Andrews (3) found in a 15 year study of a colony in Baltimore Co.

Moving is another way in which these ants cope with adverse conditions. Andrews (6) observed the population of a nest move in 1926. The process took 12 days. We know of one case of a large mound developing in a spot where no mound had been the previous month. The migration was not witnessed but the evidence was conclusive. This explains the existence of large active mounds in places where there does not seem to have been time for slower types of growth as by swarming or development by a single queen. It is another way colonies shift their location with the gradual change in forest development.

During the winters of 1943 and 1944, all ants that escaped from artificial nests developed a small mound in the greenhouse where experiments were being conducted. Until the last week of May, they moved about the greenhouse feeding upon Japanese beetle grubs, mashed ants and any sweet or insect pieces put out for them. The last week of May, they began moving outside. Again indicating the habit of this species to move its colony site at will. The line of ants went around the wall and out a crack and to a small mound that they built. Some of the ants carried other ants in a curled up position. When the carrier was disturbed, she dropped her burden which at once uncurled and both ran away. It was a week before they left the greenhouse entirely. Neither mound persisted outside probably because there was no readily available source of honey-dew.

Small mounds have not been excavated in these studies. Perhaps because of this, no evidence has been found for Wheeler's (48 p.446) statement that F. exsectoides queens establish nests by being adopted in small F. subsericae nests. Certainly the Brinklow and Greenbelt colonies are difficult to explain by swarming.

Structure, care and defense of nests.

F. exsectoides mounds are rounded cones often asymmetrical because of vegetation, slope, injury or shading. Usually, part of the mound proper is bare unless the nest is very weak. Nests that have moved recently usually have grass, weeds and even a small tree growing through them. Most of the grass and weeds are dead by the next summer but the tree may persist. In the open, the ants may not keep the mound bare except near the top and southwest side. In shaded locations, the mound is kept entirely free of growing plants. Most nests have grass and weeds around the base obscuring the nest openings or the leaves and sticks of the forest litter comes up to the base of the mound.

All mounds opened during this study showed the same structural pattern as those studied earlier (14). External and sectional views of mounds have been photographed and descriptions written by McCook (33), Wheeler (48), Andrews (4) and others.

All nests opened show the same general structure. The passageways are roughly round and about one-half inch in diameter. In the mound, the wall between passageways is about one-half inch thick. The outer layer is almost twice that thick and of slightly firmer construction. In vertical section, the passageways of the mound appear arranged in stories. Each passageway slopes up or down after a few inches so that there are almost as many communications between stories as there are passageways. The passageways branch and unite frequently. There is no sharp dividing line between the mound which has been built by the ants and the region below which has been excavated.

For a foot below the soil level and a foot around the base of the mound, the passageways are as numerous as in the mound. Deeper in the soil, the passageways are farther apart and more of them are verticle. They extend to a depth of between $2\frac{1}{2}$ and 3 feet.

In the spring, the first outside activity of F. exsectoides is to repair the mound. Openings are made near the top of the mound and bits of soil are brought out. As the air warms up, bits of soil and vegetation are brought from the base of the mound and placed near the top. If some part of the mound has been destroyed, this is built more rapidly than the rest. On all nests, a new layer is added to the outside at this time. Grass and other plants that have sprouted on the mound are killed or die. Sometimes the vegetation is killed back as much as a foot around the base of a mound. Usually when the ants prune back encroaching vegetation, it is done gradually and is not noticable except that the plants never cover the mound. Andrews (5) reports watching this pruning process.

In this section, no evidence was found that these ants actively kill young trees, as Peirson (37) found in New England. He found that young white pine and other conifera were killed near the mounds of F. exsectoides. He watched them do it and presented experimental evidence in proof of it. In Maryland, mounds are usually found where there is some opening in the forest or at its edge. As the trees grow larger and the area becomes shady, the F. exsectoides colonies move or die out and no swarm nests become established. Isolated large nests may persist for several years in shady areas but no cases of efforts to kill young trees were noted. Perhaps the longer warm season in Maryland has some influence on the extent to which these ants control the growth of plants near their mounds.

All through the summer, the mound is cared for but no openings are made near the top. During dry weather, only a few ants carry on this work. After a rain, the mound may swarm with ants carrying soil and bits of vegetation. Any small damage to the mound is erased quickly by concentrated reconstruction. Half of the mound may be dug away and, if the ants do not move to another location, in a week a bushel of soil may be properly arranged.

During the active season, all openings of the mound are guarded by two or more workers. The large sized workers seem to be more aggressive but all workers are quick to grab with their mandibles and eject their poison. Any disturbance to the vegetation at the base of the mound, a tap on the bare part of it, or a slight breaking of the mound will cause the ants to boil out and over the surface of the mound and all surrounding objects. They zigzag about biting at the vegetation etc. and squirting their poison fluid. It may take half an hour for them to quiet down. When a mound is opened, some of the workers run to attack while others take the larvae and cocoons one by one and run to sheltered places. Dealeted queens always seek shelter at once.

During the winter, if a nest is dug out on a warm day, the first reaction of the disturbed inhabitants is defense. The second usually is a crawling upward action. Often a few ants will begin carrying bits of soil. The broken passageways are plugged in a nest partly excavated in the winter.

Temperature relations.

F. exsectoides seems to respond to flucuations in temperature more uniformly than to moisture or any other single stimulus. In the laboratory groups of ants collected in February and held at temperatures between 34 F. and 38 F., cluster in one place taking no food and water and only a few moving slowly to defense when disturbed. At temperatures above 40, more general activity is present but not much food is taken. With temperature ten degrees higher, activity is general and water and food are taken. Above 60 F., the ants carry on activities at a normal speed. When the temperature is held at 75 F., activity is rapid and is interrupted by repeated combing motions of the forelegs on the antennae. If held at such a temperature or higher, many of the ants will die in a few days.

Ants brought into the laboratory in November and December continue clustering without taking food or water for 3 to 5 weeks even when held at a constant temperature of 70 F. Ants brought inside in February require 1 to 2 weeks to become active while ants collected in March require only a few days. In this last case, queens will begin laying before the workers begin to feed. Queens collected early in the winter and kept with workers in artificial nests do not begin laying for 5 to 7 weeks. These responses to temperature are not evident the day ants are brought in from the field where they were hibernating. Time must be allowed for the breaking of their rhythm.

When workers in soil are brought into a higher temperature, they tend to come up on the surface and sides of the container. Presumably, they are responding to the warmer air temperatures. In the summer, ants placed at 40 F. will cluster. This tendency to move toward heat and to cluster when the temperature is lowered to around 40 F. is evident in the way _F. exsectoides_ hibernate.

Outdoors, many stimuli are acting together but the hibernation of _F. exsectoides_ is closely correlated with temperature. Table II gives a summary of soil temperatures for 1917-18, at College Park, Maryland.

The data, upon which this summary is based was obtained from Earl S. Johnson, formerly with the Maryland Agriculture Experiment Station. There are certain variations from year to year and for different soils but Bouyoucos (10 & 11) found in extensive studies of the problem, that the average temperature is the same for all types of soil except during thawing and that soil covered by sod is cooler in summer and warmer in winter than any type of bare soil. He also found that the deeper the soil readings were taken the less was the range of temperature.

TABLE II. Soil Temperatures Under Sodded Surface.

Month 1917-18	Range at depth of		Average of Daily Means at depth of	
	3 in.	12 in.	3 in.	12 in.
Aug.	81-64	75-68	72.9	71.7
Sept.	76-55	71-59	62.9	63.2
Oct.	60-44	60-48	52.2	53.5
Nov.	47-35	48-39	41.7	42.4
Dec.	39-30	40-33	32.8	36.1
Jan.	31-24	35-32	29.6	33.1
Feb.	42-30	38-32	31.5	33.1
March	50-35	47-36	42.8	41.7
April	61-39	54-40	50.5	47.4
May	73-50	67-51	63.1	60.1
June	79-58	69-61	67.9	65.7

Soil temperature readings taken at irregular intervals in mounds of *F. exsectoides* show that the averages given in Table II will be applicable to them. A difference of ten degrees sometimes exists between the south and north sides of a big mound, in the sun. On cloudy days or in shaded places, such variations are much less. Variations of from 1 to 5 degrees can be found between mounds at one time on the same day. All mounds tend to have higher temperatures than the soil nearby. Andrews (4) found these variations to exist in mounds he studied in 1927. Any deductions on the habits of F. exsectoides made from Table II can only be of a general character.

At a depth of 3 inches, the average of the daily mean temperatures for Sept. (Table II) is 10 degrees lower than that for August. At 12 inches, the average for September is 8 degrees lower than for August and is higher than that at 3 inches. From September through January, this average temperature at 12 inches is higher than at 3 inches but is lower than the previous month. The ants begin to hibernate in September when many are found clustered in the passageways below soil level. By the end of October, all the ants are clustered in the deeper passageways of the nest. From November to February, the ants do not come to the surface. Soil temperatures are just above freezing which is too low for the ants to be active.

Soil temperatures begin to rise in March. The average mean temperature at 3 inches is higher each month than at 12 inches. The rise is not as rapid as the decrease was in the fall but is steady. During March, temperatures above 40 F. are common and some of the ants become active during warm periods. During April, the trend is for increasingly higher temperatures. The ants become correspondingly more active. In May, temperatures near the surface are such that the ants can carry on normal summer activities.

The temperature and the rhythm of F. exsectoides are correlated. They gradually enter hibernation at the time soil temperatures begin to fall steadily and slowly begin activity as the soil temperatures rise. Dryer (16) in a study of the hibernation of Formica ulkei found temperature the primary factor involved in its hibernation.

Food

In April when the nests of F. exsectoides become active, foraging begins and increases until the middle of July. For the next two months foraging proceeds but in diminishing amounts. In sections of the

Beltsville colony, all tree trunks, bushes and other plants were inspected for the activities of F. exsectoides at intervals for two years. A few ants could usually be found running about on anything during the foraging months. One ant would run up a twig and out the petiole of a leaf and over several parts of its surface reaching over the edge to the under side more than once. It would do each leaf on a twig in much the same way. Maybe on the next twig some leaves would be missed but in general, foraging was thorough. The same type of inspection was made of all litter on the ground.

Workers have been found dismembering or carrying Japanese beetles, May beetles, small ground beetles, sow bugs, spiders, black crickets, small lepidopterous larvae, crane flies, grasshoppers, termites, small unidentified hymenopterous and dipterous insects. Apparently any insect found that can be overcome is used.

If a caterpillar is dropped on the ground near an ant, that ant may find it. Often the caterpillar may move around for several minutes before another ant appears and attacks it. When attacked, the caterpillar is bitten and at the same time the abdomen of the ant is turned under while a fine stream of poison fluid is directed at the spot being bitten. The ant may repeat this process several times or may leave, disappearing among the leaves and grass. In test cases, it was 3 seconds to 3 minutes before more than one ant found the caterpillar. All behave in the same way when they detect the caterpillar, biting where they happen to touch first. By the time 8 to 15 ants are there, it becomes apparent that they are attempting to cut the caterpillar into two or more pieces. After a time, some of the ants stop biting for a short time and attempt to drag the caterpillar away. There seems to be no plan in any of this. Other ants appear and may begin work like the rest or may touch antennae and go away. Some of the ants that have been working for awhile may stop and run off. The number on the caterpillar remains fairly constant. After half an hour or more the caterpillar is bitten into pieces. Now 4 or 5 ants attack one piece spending more time dragging than biting. They do not seem to cooperate but in one case a piece was moved 8 inches in 15 minutes. By the time the piece is well away from the rest usually only 2 ants will be left working on it. If the piece is not too large, the 2 working together make fairly rapid progress over, under or around obstacles in a surprisingly direct line toward the nest. In one case it took 65 minutes from the time the caterpillar was found by an ant until a piece of it was taken into one of the openings at the base of a nest 12 feet away.

If the insect is on bare ground, and not too far from the nest, it may be dragged there without being cut up. Apparently the method used depends upon the size of the insect and the type of obstructions that intervene.

Since the nest openings are covered with dead leaves, sticks or grass, the number of insects obtained in a given time is hard to estimate. Certainly they obtain a large number in the course of a day.

Insects are only part of the food of F. exsectoides. McCook (33) gives an accurate description of the way the workers obtain honeydew from "aphids" and "small oak galls" on the branches of trees. His description of the "avenues" to and from the trees conforms with present observations. At the Beltsville colony, the "avenues" are usually about 6 inches wide. There is frequently an excavated place at the base of the tree as McCook observed. This observer also describes clearly the way one ant gives another food.

During the summer of 1943 and 1944, F. exsectoides used the honeydew from two generations of Vanduzea arcuata Say. on black locust. The ants begin attending these leaf hoppers early in May. This continues until the adults disappear late in June. By the end of July, the ants are attending the next generation and continue to do so until the beginning of September.

Both years, the scale, Toumeyella liridendri Gmel. on the tulip poplar tree was a continual source of honeydew from May till September. In 1944, this scale appeared to be the only source of carbohydrate used by some nests. Other nests depended mainly upon aphids on various species of oaks. These two types of trees were used regularly all season both years.

In 1943, black aphids were thick on small Virginia pines in the open and were sources of honeydew for the ants from May until the middle of July. The next year, there were very few aphids on the Virginia pine in May but these were attended. By the first week of June, no aphids were present on these trees and the ants were few in number. By the middle of April in 1945, these black aphids were present and were a source of honeydew.

In 1943, aphids were thick on the twigs of some of the chinquapin bushes and these were attended by the ants. In 1944, no aphids were found on these bushes.

Both years, the aphids on the aspen leaves were used as sources of honeydew. These aphids are not present the entire season. In May of both years, the ants carefully went over aspen flowers. They seem to be getting nectar. In 1943, they were seen doing the same thing to chinquapin.

At no time were the ants seen to carry any of these honeydew producing insects. No evidence was found that they used them for food or placed them in more advantageous places. The aphids and leaf hoppers are not disturbed by the movements of the ants. The ants let the honeydew producers move about freely but are aggressive to any activity of other creatures. They defend the twig as they would do the mound.

Species of oak and the tulip poplar are the only large trees that the ants use. There are many tall Virginia pines in the Beltsville area but they are not used by the ants. The small Virginia pines on the edge of the woodland or in open spaces are used when the aphids are present. Black locust trees in this area are never very large but are used extensively. The aspen are all young trees. Chinquapin is the only bush used. Greenbriar, blackberry and other vines are common. Mounds are often surrounded by thickets of bushes and vines. The ants run over all of these as they do the entire surface of everything but never find anything in quantity enough to attract numbers. Once the ants were found in numbers on Canadian thistle. They seemed to be getting something from the leaves. There were neither insects upon the plants nor any honeydew from some overhanging source.

These observations show that F. exsectoides depends upon honeydew producing insects which live upon certain trees for part of its food. The balance of the food consists of insects.

NUTRITION

Introduction.

When studying any phase of nutrition of an animal, some standard or standards have to be set up in order to measure the results. In many studies with rats, variations in weight plotted against the time interval are often used as the measure. In studies with insects, weight gains or losses have been used by some workers. It is more common to use the length of time the insect survives, its ability to complete development or its ability to reproduce on the food used. At times, combinations are used.

With *F. exsectoides*, the length of time individuals can survive on a food should indicate its desirability as a source of energy for the workers, unless resistance and rhythms of the species complicate the results. In studies of the longevity of queens, the relation of food to survival is not very close except over long periods of time. In artificial nests, *F. exsectoides* queens begin laying eggs before the workers have broken hibernation. The energy for this must have been stored in the queen's body the previous summer. Queens confined without workers took food but never lived more than a month. Eggs have not been hatched without workers to care for them. The larvae require care and feeding by the workers.

The survival of artificial colonies and their ability to feed larvae until they spin cocoons presents more possibilities. If artificial colonies fed on a certain food had larvae spin cocoons, that food could be considered complete for energy and tissue building. This would be especially evident if larvae completed development in one colony on a certain food while another colony on a different food had no larvae pupate. If more than one colony had larvae complete development on a certain food, the evidence would be better. If artificial nests could be fed a certain food for several weeks without larvae completing development and then transfered to another food on which they completed development, the evidence for the latter would be strong. This ability of artificial colonies to feed larvae until they spin cocoons is used as the standard in determining which food or foods are the best.

Under natural conditions, F. exsectoides feed upon honeydew and insect bodies. The first is a sugar presumably supplying mainly energy. The second must supply the protein among other things. An examination of the composition of these, in so far as they have been determined, and some of the most likely substitutes will be helpful in evaluating results in survival tests with workers and in the determination of the best food for artificial colonies.

Honeydew and substitutes.

Honeydew is the natural energy food of F. exsectoides but no analysis of it was found in the literature. Honeybees sometimes collect honeydew and make a honey which has been studied. In bee literature honeydew honey is known simply as honeydew and is so used hereafter. There are a few instances of dried honeydew called manna being studied. Sometimes F. exsectoides feed upon the nectar of aspen. Nectar of a few flowers has been analysed. Honeys have been carefully studied by several workers. Table III gives the composition by average percents for honeys and honeydew as determined by Eckert and Allinger (17) and the percents for orange honey and orange nectar as given by Vansell (44).

It is apparent that honey is primarily a mixture of sugars, with levulose and dextrose making up the largest part. Honeydew has less of these two sugars than honey but the difference is not as great as between some honeys. The analysis of orange honey as given by Vansell shows more sucrose than in the average for honeydew. The dextrin in honeydew is about ten times that in honey. Unfortunately, Vansell does not list dextrin in his analysis of orange honey or nectar.

TABLE III. Composition of Some Honeys and Nectar

	Eckert & Allinger		Vansell Orange	
Components	Honey	Honeydew	Honey	Nectar
Moisture	16.50	15.72	16.	75.
Total Sugars	77.53	68.11	79.50	24.75
Levulose	40.41	37.50	40.86	6.46
Dextrose	34.54	27.20	34.23	5.42
Sucrose	2.53	3.45	4.13	12.87
Dextrin	0.91	9.21		
Ash	0.21	0.77	0.08	0.23
Acid	0.16	0.27	0.12	0.023
Undetermined	4.72	5.91		

The differences in composition of honey and nectar are seen when orange honey and orange nectar are compared. The fact that honey is not concentrated nectar is clear. Orange nectar has one-third the concentration of all sugars that are found in orange honey but the proportions are different.

Hudson and Sherwood (27) found the dried honeydew of aphids on the Douglas Fir contained melezitose 75-83%, sucrose 2.9%, reducing sugars 11.5%. Since melezitose is a complex sugar and one that is not commonly found, it is not likely that it would be indespensible for F. exsectoides. This study of the dried honeydew does not help any in determining the composition of honeydew.

Although honey is primarily a carbohydrate food, the mineral and vitamin content must be considered. According to Caillas (13), the minerals in honey are the same in kind and proportion as those found in nectar. Schuette and others working with him (39) found the amounts of minerals to vary in honeys. Dark honeys usually have higher mineral content than light ones. They found potassium to be present in larger amounts than any other mineral but phosphorus, calcium, magnesium, sodium, sulfur and chlorine were present. Minerals have to be considered when pure sugars are given instead of honey.

Kitzes, Schuette and Elvehjem (29) found thiamine, riboflavin, niacin (nicotinic acid), pantothenic acid, pyridoxine, biotin and folic acid in honey. They found great variation in these vitamins between samples due in part to the age and treatment of the honey. Griebel is reported by Kitzes et al (29) to have found ascorbic acid in some European honeys. Thus, vitamins of the B-complex and Vitamin C are present in honeys in varying amounts. They must be considered in analysing food used. When pure sugars are used to supply the energy portion, these vitamins may need to be supplied in some other way.

Insect bodies and substitutes.

When the composition of the other part of the food of *F. exsectoides* is examined, greater difficulties are found. The variation in the composition of insects is great and the analyses that have been made are incomplete. Uvarov (43) summarizes the results of research on the composition of insects. He points out that the differences in percent of protein in various developmental stages of one species probably exceeds that between species. He gives examples that range from 13.2% to 18.11% protein. The fluctuation in the amount of fat is even greater between developmental stages. Silkworm larvae range from 4 to 21.3% fat.

The ash of a number of insects have been studied but the findings are not of much value in estimating the minerals utilized by ants since exoskeleton, digestive tract contents and stored waste products are included. Potassium, sodium, magnesium, calcium, phosphorus and iron have been found in most insects analysed. The amounts and kinds of carbohydrates in insect bodies has received scant attention. No reference was found to the vitamin content of insect bodies.

Since occasionally F. exsectoides feed upon small dead mammals, various parts of raw or cooked beef might be possible substitutes. Beef liver has been used successfully in many cases as a substitute food for ants. Other meats, yeast and meat extracts are other possible sources of protein, minerals and vitamins. Table IV has been compiled to show the amounts of various constituents in equal quantities of ground beef muscle (hamburger), beef liver and brewers yeast. The figures given were taken from "Tables of Food Values" by Alice V. Bradley (12). The cooked meats were fried but no values for any of the minerals and vitamins were found for these foods cooked in water.

TABLE IV. Food Values for 100 Gram Amounts

Component	Beef Raw	Hamburger Cooked	Beef Liver Raw	Beef Liver Cooked	Dried Brewers Yeast
Protein Gm.	17.	34.	19.7	23.5	46.1
Fat Gm.	23.7	47.4	3.2	5.8	1.6
Carbohydrate Gm.	-	-	6.	7.2	37.4
Calcium Gm.	.012	.024	.008	.03	.087
Phosphorus Gm.	.1977	.3952	.373	.446	2.946
Iron Gm.	.00284	.00668	.0121	.0135	-
Vitamin A I. U.	10-50	10-50	5000-10000	5000-10000	-
Thiamin Mg.	.11-.48	.05-.24	.3-.45	.18-35.	5.-8.
Riboflavin Mg.	.18-.54	.18-.51	1.8-3.7	3.6-1.8	4.5-2.5
Ascorbic Acid Mg.	-	-	45.	10-28	-

From the figures in Table IV, it is clear that liver supplies more of each of the minerals and vitamins listed than beef. Dried brewers yeast is higher in protein, carbohydrate, phosphorus and thiamin but contains no iron, Vitamin A or Vitamin C. Comparing cooked beef liver with insect bodies, it is noted that the protein is higher in the former. The minerals given are also found in insect bodies. Potassium, sodium and magnesium, which are found in insect bodies, are not mentioned for beef liver but are present in honey.

In Table IV, the beef and liver were cooked in fat. The analysis includes the solid parts of the tissue. F. exsectoides take mostly liquids therefor broths might be more satisfactory and certainly it would be easier to control the quantity fed, determine the amount used and keep the artificial colonies more sanitary. In feeding tests with the ants, all these preparations need to be tried in various combinations.

Field feeding tests.

The first feeding tests were carried out in the field near a number of F. exsectoides mounds. The foods listed in Table V were tried. These foods were put out in aluminum tubes 6 cm. high and 3 cm. in diameter with lids and 3 round holes near the top of one side. F. exsectoides passed in and out of the holes freely. The tubes were hung on a nail in a tree, set slightly pressed into the ground or among ground litter. 20 cc. of all liquids or liquid and solid were put in a tube each time. If the food was in liquid form, excelsior or some similar material was placed on top to prevent the ants from drowning. An equal bulk of the finely chopped solid meats was placed in each tube. Regardless of the food used, tubes in any situation on the ground were partly or entirely filled with dirt and trash. This made it impossible to ascertain whether all the food was taken. With allowances for evaporation, tubes on tree trunks could be checked at intervals to determine the amount of food taken.

In Table V, 20 cc. of the foods listed with "A" following were usually totally consumed within 48 hours. Those with "B" following were taken to varying extents but rarely consumed in 48 hours. The others were taken slightly or not at all. The beef and liver were chewed into small pieces and the juice sucked out by the ants. The pieces were left in the tube. All foods, except honey, spoiled in 2 days. The ants would not eat spoiled food but remained on the tubes. A few tubes of animal fat and honey were tried. One test of a large quantity of honey solution was tried. Both of these were ignored by the ants. This series of tests continued until the latter part of the active season with no change in results.

TABLE V. Foods used in Field Tests in 1943.

Solid		Broth		Diluted with water	
Raw beef		Beef	B	Honey	A
Cooked beef	B	Liver	A	Honeydew honey	A
Raw liver	B	Lamb		Sucrose	B
Cooked liver	A	Pork		Lactose	
		Chicken		Levulose	
				Dextrose	

A - usually consumed in 48 hours.
B - partly consumed in 48 hours.

The next May, tubes of the foods used the previous summer, poisoned honey solutions and the mixtures found satisfactory for artificial nests were all tried. On the tree trunks, where the tubes were placed, the ants moved up and down between the sources of honeydew and the nest. They moved over the tubes but took very little of the foods offered. After a day, they ceased staying on the tubes even when fresh food was placed in them.

Although some of the foods were consumed, the ants continued using all natural sources of food. Considering the number of ants in a nest, only a small fraction of the population fed on these bait foods even when consideration is given to the feeding by the workers of other workers and larvae. It is apparent therefore that baits either with or without poisons do not attract a sufficient proportion of any colony to make control by poison baits feasible.

Literature on ants in captivity.

Ants have been kept in captivity since early times in a great variety of containers and have been fed on various foods. Wheeler (48 p. 549-556) has given a clear summary of the various types of artificial nests used for ants up to 1913. He includes a detailed bibliography. Each worker modified the older types of artificial nests better to meet the needs of the species with which he was working and the particular observations which he desired to make. Always an effort was made to have conditions natural for the ants yet allow observations which he desired to make. Always an effort was made to have conditions natural for the ants yet allow observations of as many of their activities as possible. Some artificial nests had plaster of Paris floors and walls and glass roofs. Others had glass floor, walls and roof with some cloth padding between walls and roof. Partitions, runways and other devices were often added.

Lubbock (30) and Fielde (19) developed glass nests which were easier to handle. Newell (36) used leather to separate glass from wood in his study of the Argentine ant. He made a convenient stand to hold the nest above running water to prevent the escape of the ants.

Most of these artificial nests were used with small species of ants. The species were not only comparatively small in size but the number of individuals in a colony was small. The species were not aggressive and had strong negative phototropism making it possible to move them from place to place without great loss in numbers. This made feeding, cleaning and experimenting easier.

Andrews (9) and Holmquist (26) used metal containers with water moats in studies of large species having more populous colonies. Both allowed the ants soil which prevented detailed observations but left the ants to live more normally. They had difficulty with the ants escaping. Andrews also used various metal containers connected by tubes for F. exsectoides.

Most workers have fed ants in artificial nests to make possible the study of the insects for other facts. No effort has been made to analyse the food or seek the reasons for its success or failure. In one study, Fielde (19) fed ants honey, molasses, banana, apple, mashed walnut, larvae of insects and muscular parts of insects. In another study, she (18) observed that Stenamma fulvum never raised larvae to pupae when fed only sweets. Newell (36), while studying the Argentine ant, found that sweets were not a sufficient food indefinitely. The animal food he found satisfactory was beef or veal. Pricer (38) found sugar-water and insect pieces complete food for Camponotus herculaneus. While studying the corn-field ant, Tanquary (41) fed them sugar-water, egg yolk, boiled beef, white grubs, flies, beetles and other insects. All these are small or species that never have large populations in one colony.

Holmquist (25) fed Formica ulkei fruit, honey and other sweets and insect bodies. He had difficulty with the ants consuming their larvae. Weber (45), while studying Formica rufa obscuripes used honey, sugar solution and any insects obtainable as food. He found this species could live for months on a sweet or insect meat. These two are studies with larger ants that live in large colonies more like F. exsectoides.

A few studies have been attempted to see how food affects castes in ants. Gregg (24) found that with Pheidole morrisi, the number of soldiers raised depended upon the number of that caste present in the nest. Trager (42) reports that Goetsch found that with Pheidole pallidula, large eggs developed into soldiers if the nest was fed pieces of insects, meat or coagulated egg white; and into workers if fed sugar solution or fluid protein.

Description of artificial nests used.

In this study, nests with soil could not be used because detailed observations could not be made. Open nests with barriers of sticky material or moats did not effectively confine the ants. Therefore, naturalness of habitat was sacrificed for certainty of confinement, ease of handling and clear vision.

Three models of glass and plaster of Paris nests were used. The first was a plaster of Paris sheet with $2\frac{1}{2}$ inch wide pieces of glass, set on edge in it while still soft, for walls. Two corners were made of small blocks of plaster of Paris having had a glass tube imbedded in them when made. These were made before the floor sheet and set in the soft plaster of Paris before the glass sides were inserted. A piece of glass was used for the roof. It was kept covered with cardboard or some similar opaque material. It was very difficult to get the corners tight and the walls level in these nests. The ants often escaped as will be noted in the tables later. The walls of this nest were much higher than necessary and made observations difficult.

The second type of nest (Fig. 6) followed closely the Fielde nest (19) and was made of two sheets of window glass 10 by 12 inches, and several pieces of glass one inch wide and as long as needed. The walls were made by glueing three thicknesses of the one inch pieces near the border of one of the large sheets of glass. The corners at one end were made tight but at the other end, two openings were left. When dry, 4 thicknesses of cheesecloth were glued to the top of the wall upon which the other sheet of glass rested for the roof. One of the openings was used to admit $\frac{1}{2}$ of a 12 inch piece of plant wick. The rest of the opening was exactly filled by a wooden block. The other opening, in some of the nests, was closed by a wooden plug only, which was removed slightly to insert food. In others, part of the opening was occupied by a bent glass tube that was drawn out to a small opening at its inside

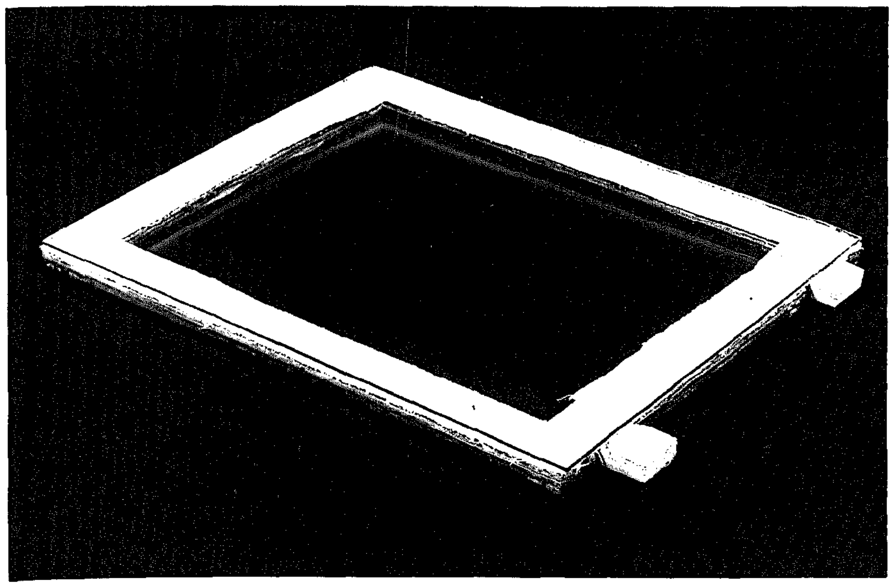


Fig. 6. Artificial nest of the second type.

end. The rest of the opening was fitted with a wooden block and the slight openings around the glass tube were kept filled with cotton.

The third type (Fig. 7) was much like the second but the floor was a smooth sheet of plaster of Paris to which the glass walls were glued. The openings, cheesecloth layers and the roof were as in the second type of nest. When detailed observations of white eggs and larvae are to be made, the plaster of Paris should be colored. If these nests were kept too damp, the glue loosened quicker than in the second type.

Methods of establishing artificial colonies.

Ants for all artificial colonies were obtained from eight nests in the western half of the Beltsville area. Any time during the winter when the air temperature was above freezing, the ants could be dug from below the mound. The soil was removed to a depth where the ants were packed in all the passageways. With as little soil as possible, the largest number of ants were taken up quickly with a trowel and placed in tins. These were closed tightly while the ants were being transported to the laboratory. The ants could be kept in these closed tins. For ease of handling, a storage temperature of about 40°F. was found to be best.

Before setting up an artificial colony, the nest and all the jars to be used were set in a room with a temperature of 50° - 60°F. The tin of ants was kept in this room for about an hour before handling. The air being warmer than the soil caused many of the ants to come to the surface where they were picked up more easily.

The ants could not be handled at high temperatures because they moved too rapidly and killed themselves with the fumes of their poison when in closed spaces. Maloeuf (31) found that *Formica fufa* had more than twice as much poison at high temperatures and in dry weather, it was stronger. *F. exsectoides* certainly had stronger poison in the

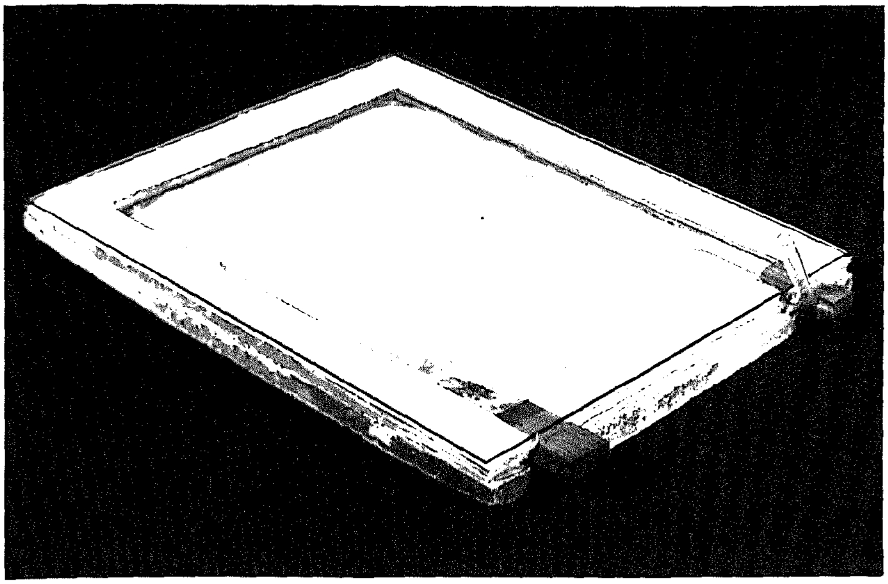


Fig. 7. Artificial nest of the third type.

spring and were much quicker to use it. Because of these things, artificial nests were more easily started in the winter.

At temperatures between 50° and 60°F., the ants were sluggish and often a hundred or so could be picked up with the tweezers at one time. This reduced the time that was necessary to get together in small glass jars the quantity of ants needed for one artificial colony. When enough were collected in these small glass jars with glass covers, since a few of the ants were always active enough to crawl up the sides of any container, the roof of the artificial nest was removed and all the jars of ants were quickly dumped in and the roof immediately put in place and covered with a cardboard. The nest was set in a cool place for several hours or until the ants had clustered in one place. Always some ants were killed by some step in this process and a few pieces of dirt were inadvertantly left in the mass. Many artificial nests containing between 500 and 1000 ants were established in this way. A queen or two could be added at the time the colony was established or after the group had become settled. The queens seemed able to stand more of the fumes than any of the workers. The smaller workers were killed most easily, either by the fumes or the handling process.

After the ants became settled in a cluster, the nest could be placed where it was wanted. Nests with plaster of Paris bottoms were usually placed in soil in a greenhouse bed or flat. The nests with glass floors were kept in a rack in the greenhouse or temperature control room or on a shelf in a temperature cabinet.

Care of artificial colonies.

In caring for any of the artificial colonies, disturbances of all kinds are to be avoided. These ants are especially sensitive to jaring. When jarred, they run about frantically, squirting their poison and many may be killed by the fumes. Larvae and eggs disappear overnight from nests that have been handled roughly. If an active, apparently happy colony manages to make a hole and part of the ants escape, the larvae and eggs disappear and the colony takes from 3 to 5 weeks to begin rearing young again.

Darkness or partial light does not seem to make any difference to these ants. Most of the time, the nests were kept in the dark but when handled without jaring, the cardboard cover could be removed and the ants watched without exciting them.

As might be expected, humidity is an important factor. Without food or water and with low humidity, most of the workers die within 48 hours. With higher humidity, they can survive 3 to 7 days. In these studies, the humidity was not entirely regulated. The nests with plaster of Paris bottoms were set on damp soil and in this way, the humidity was kept high and comparatively even. In the glass nests, the wick was kept damp at all times which kept the humidity near saturation most of the time. Inside many of these nests, drops of condensation moisture were present at times. Under these conditions, the ants were much less excitable than when the humidity was low. Care had to be exercised however to be sure the nests did not become too wet as mold and other forms of decay developed. These caused colonies to die out as the ants seemed unable to destroy the molds. In nests that were too damp, the ants had difficulty caring for the eggs, larvae and pupae, especially the pupae, which stuck to the glass. The pupae did better if kept at lower humidities.

Humidity and free water needs are closely related. These ants need free water to drink even when the humidity is high. It was found best to give about 2 cc. of water two or three times a week to each artificial colony. In the winter, artificial colonies can live for two months or more without food if the humidity is satisfactory and water is given 2 or 3 times a week.

The importance of temperature has been shown in the explanation of establishing artificial colonies. Although never completely inactive at temperatures above freezing, these ants do not carry on summer activities in artificial nests unless the temperature is above 60°F. A temperature of 68° to 72°F. allows optimum activity and does not shorten the life of the artificial colony. If the temperature is between 72° and 78°F., many ants die in the artificial nests.

During the winters of 1942-43 and 1943-44, the artificial colonies used in these studies were kept in a greenhouse where the air temperatures ranged from 48°F. to 94°F. The nests with plaster of Paris floors had a more even temperature since they were on soil. The soil temperatures remained between 60°F. and 75°F. In all these artificial colonies, temperature is a variable which has to be considered in evaluating results with food tests. In 1944-45, the artificial nests were all kept at temperatures between 56°F. and 73°F. during November, December and January. After that, the temperature remained between 67°F. and 73°F.

About 2 cc. of food was given three times a week. If fed daily, overfeeding was likely with decay of the unused portion resulting. If left more than 3 days, the ants consumed their larvae regardless of the food they had been having. Eating larvae was a problem in many cases and was used as an indication that the food was unsatisfactory. A colony that had been eating larvae for weeks was likely to continue even when given food for many weeks that was entirely satisfactory for other nests.

If the food was in solid form, small pieces of it were slipped quickly into the nest as the wooden block was carefully removed. Practice made it possible to do this without letting any ants out. If the food was a liquid, a medicine dropper was used to inject the food through a small opening made by slipping out the wooden block. Sometimes, it was easier to carefully slip aside the glass roof enough to admit the tip of the dropper and inject the food in this way.

In the artificial colonies, the ants placed the dead and debris in piles as soon as they broke hibernation completely. This material was piled on the food if the quantity was too great or not acceptable. For this reason, feeding the ants through the glass tube was not satisfactory in many cases. The ants plugged the small opening after being fed so that the tube had to be removed and cleaned. Often so much of the waste material had been piled at that spot that the tube could not be used again.

Not long after an artificial colony becomes active, they dismember the dead, piling the pieces with other debris, probably sucking out any liquid food in the bodies as they do this. All artificial colonies did this regardless of the food given. Often part of the wick was cut through in one or more places. Usually, the first cut was made where the wick entered the nest.

With F. exsectoides, it was never found possible to clean an occupied nest. Fielde (20) removed the cover and cleaned one compartment of the nest while the ants were in the darkened other part. Then the darkened portions could be reversed and the ants would move to the cleaned part. F. exsectoides never left any part of their artificial nest unguarded unless the temperature was below 40°F. Even then, any jar would cause a few to run about.

With this species, it was never found possible to get an artificial colony (queen, workers, eggs and larvae) to move from a soiled nest to a clean one, even if it was darkened, more moist, warmer, contained food, or any combination of these. The workers would quickly go through the tubes (glass and rubber) to the food and then return to feed the rest. A few would remain in the new nest but no complete transfer was effected. In spite of this, nests were kept alive, with slowly diminishing numbers, for over a year.

Preparation of Foods Used.

LIVER BROTH. One-half pound of beef liver was chopped finely and left in 500 cc. of distilled water overnight in a refrigerator. The nest day, it was allowed to warm before being cooked over water. The water was heated slowly and then allowed to boil for one-half hour. The liver and broth was stirred occasionally. At the end of the half hour, the liver and broth was removed and allowed to partly cool. The broth was strained off through four thicknesses of cheesecloth.

BEEF BROTH. One-half pound of ground beef was used instead of liver and the same procedure followed.

YEAST JUICE. Ten grams of dry brewers yeast were placed in 1000 cc. of distilled water and allowed to stand with occasional stirring for 14 hours at room temperature. Then, it was filtered with a suction filter and the filtrate stored.

HONEY 50. This was made by adding 50 cc. of honey to 50 cc. of distilled water. The mixture was shaken until well mixed.

HONEY 25. The same kind of honey was used for this dilution but 75 cc. of distilled water was used with 25cc. of honey.

YEAST. When the word yeast appears in a mixture, it means that one gram of dry brewers yeast was added to each 100 cc. of the mixture. These mixtures had to be carefully stirred before each use so that some of the yeast cells would be fed each time.

LIVER EXTRACT. The liver extract used was Liver Extract Lilly put out by Eli Lilly & Co. In a personal letter, they say it is "a water soluble, heat (85°C) 70 to 90% alcohol precipitate of ground fresh raw liver. No ether is used in the processing." This product was used in two quantities. In the tables, L.E. 1 means that 250 milligrams of the liver extract was added to each 100 cc. of the liquid in use. L.E. 2

means that 500 milligrams of it was added to each 100 cc. of liquid.

L.D.S. 20 - LIVER. This was a mixture of 11.25 gms. levulose, 8 gm. dextrose, 1.25 gm. sucrose, 29.5 cc. water and 50 cc. liver broth.

HONEY 25 - LIVER 75. This was a mixture of 25cc. of honey and 75 cc. of liver broth mixed.

Cane sugar, sucrose, dextrose and levulose were diluted as desired. The amount of dilution is indicated in the tables by the number after the word. It indicates the percent of that sugar in the mixture.

In the tables, the sweet (honey, sucrose, etc.) with the number showing the percent of it present is placed first. Following is the other part or parts of the mixture. The word liver is used for liver broth and beef for beef broth. In the tables where the word "meat" is used, it means that that colony was fed fresh insects or pieces of raw or cooked liver.

Each year, only one lot of honey was used. Dark clover honey of that season was chosen. It was kept at ordinary room temperatures. All the dry foods were kept in glass. Any foods that spoiled easily were kept in the refrigerator if it was not possible to use them at once.

At frequent intervals, the stock solutions and the various other materials used were mixed. How long these were kept depended upon how rapidly they spoiled. Mixtures with Honey 50 or any of the liver extract mixtures kept fairly well. Honey 25 or any of the pure sugars and liver broth spoiled quickly. They were made up in small quantities every few days.

Pollen, oyster meal, raw liver juice, grub broth and egg yolk were tried but since the results are negative, they are not given.

Methods used in survival tests.

The ants for these tests were taken from the same mounds as were those used in the artificial nests. They were cared for in the same way and handled under the same conditions when possible. During the hot months, the ants were handled during the coolest hours of the day.

For these tests, bowls 6 inches in diameter and 2 inches high covered with a square of glass were used. Several drops of the food being tested was placed on a one-half inch square of absorbent cotton and dropped in the bowl just before the ants were introduced.

The worker ants were picked up one by one from the edge of the large tin in which they were kept and slipped quickly into the bowl. Ten bowls containing 10 ants each formed one test. The bowls were placed on shelves in a dark cabinet or on shelves in the temperature control room. The temperature ranged from 65F. to 80F. but most of the time, it was held close to 70F.

Three times a week, a drop or two of the food was added to the cotton. When the food soaked cotton became sour or moldy, it was removed and a fresh piece properly moistened was inserted. Some of the tests were run until the last ant died, but 30 days proved to be ample to show which foods best sustained life under these conditions. Each day, dead ants were removed and the number tabulated. This information is given in Tables VI to XX.

At first, only a few tests were started at a time. Later, because there was so much variation between survival in one test and the next on similar food, tests were run in sets to reduce the variables. In each set, one test with no food or water, one with water only and one with Honey 25-liver were used as checks. The results of these sets of tests are included in Tables VI to XX.

Graphs were made of each test. On them, the days were plotted on the abscissa and the total number dead on the ordinate. In order to make comparisons easier, a numerical value for each curve was obtained by counting the squares of the graph paper between the curve and the abscissa. If no ants died during the 30 days of the test, the curve would coincide with the abscissa of the graph and no squares could be counted. A numerical value of 0 would result. On the other hand, if all the ants in a

TABLE VI. Survival of Workers Given --

No Food or Water

Test Designation		C-120	B-110	A-0	230	520	530
Date Test Started		4-3	3-3	1-25	5-31	9-16	9-16
Mortality, day	1	69	11	89	1	80	92
	2	4	21	8	2	20	5
	3	8	19	3	24	#	1
	4	9	25	#	16		1
	5	6	19		28		#
	6	2	5		19		
	7	1	2		3		
	8	#	#		1		
					#		

TABLE VII. Survival of Workers Given --

Water

Test Designation	C110	B0	A10	590	250	420	320	470	550
Date Test Started	4-3	3-3	1-25	1-4	5-31	8-16	6-29	9-5	10-11
Mortality, day 1	22	2	17	9	0	39	28	55	41
2	0	1	2	0	0	14	18	30	22
3	1	4	0	10	0	4	12	6	3
4	2	4	0	8	1	8	9	2	9
5	0	1	0	1	3	4	0	4	10
6	0	3	0	2	17	5	12	2	3
7	1	4	0	1	18	5	4	0	7
8	0	4	0	1	12	3	5	0	3
9	1	2	0	3	10	7	2	0	1
10	0	1	0	2	6	1	0	0	0
11	2	0	0	4	5	3	2	1	1
12	1	0	0	7	6	0	0	#	3
13	3	0	2	1	0	1	1		0
14	2	2	3	0	8	0	#		1
15	2	4	1	2	1	0			#
16	2	0	2	3	2	0			
17	3	4	1	3	0	0			
18	1	3	0	3	3	0			
19	3	2	2	4	#	0			
20	2	2	5	2		0			
21	0	2	0	0		0			
22	3	6	3	1		0			
23	2	6	0	1		0			
24	2	2	0	3		0			
25	0	0	4	3		1			
26	8	1	2	2		#			
27	2	1	3	2					
28	5	0	4	4					
29	5	0	5	0					
30	3	6	3	0					
Survival	22	33	41	18					

TABLE VIII. Survival of Workers Given --

Honey 50

Test Designation	340	390	480
Date Test Started	6-28	7-19	9-5
Mortality, day 1		9	18
2	15	3	62
3	27	15	21
4	15		2
5	3	40	#
6	6	11	
7	2	5	
8	1	4	
9	0	5	
10	1	0	
11	2	0	
12	1	0	
13	3	2	
14	2	2	
15	1	#	
16	3		
17	0		
18	1		
19	1		
20	2		
21	1		
22	2		
23	2		
24	1		
25	2		
26	0		
27	4		
28	#		
29			
30			
Survival			

TABLE IX. Survival of Workers Given --

Honey 25

Test Designation	A20	380	630	440	500
Date Test Started	1-25	7-19	11-24	8-16	9-5
Mortality, day 1	35	11	1	16	20
2	18	2	0	1	11
3	10	1	15	5	12
4	2	0	7	0	14
5	5	2	9	0	13
6	6	0	4	0	15
7	0	3	2	1	5
8	3	4	0	8	5
9	1	6	2	4	2
10	0	6	2	3	0
11	5	6	2	7	0
12	0	10	2	4	0
13	2	2	5	20	0
14	3	4	2	14	1
15	1	4	4	12	#
16	3	8	8	3	
17	0	0	0	0	
18	2	0	1	0	
19	3	9	4	6	
20	0	3	0	#	
21	0	1	0		
22	2	1	0		
23	#	2	2		
24		0	1		
25		0	2		
26		2	1		
27		#	3		
28			1		
29			0		
30			0		
Survival			10		

TABLE X. Survival of Workers Given --

Honey 25-liver

Test Designation		CO	B10	A30	300	260	620	750
Date Test Started		4-3	3-3	1-25	6-22	6-13	11-24	1-15
Mortality, day	1	7	2	26	9	6	6	20
	2	0	0	9	4	7	0	8
	3	3	0	6	0	5	11	7
	4	1	0	8	0	2	4	1
	5	4	1	6	5	1	0	11
	6	2	0	9	1	1	6	2
	7	0	0	2	2	0	1	0
	8	0	0	1	0	0	1	2
	9	0	0	3	4	1	0	1
	10	0	0	7	2	1	2	1
	11	0	0	5	0	2	1	2
	12	0	24	3	1	0	1	2
	13	0	13	1	6	0	2	0
	14	0	3	3	0	0	1	3
	15	0	8	0	5	11	0	4
	16	0	8	0	1	19	2	2
	17	1	4	1	0	2	0	8
	18	1	9	1	1	0	0	2
	19	0	4	0	0	1	2	1
	20	0	3	3	0	2	0	4
	21	1	2	2	0	0	0	2
	22	0	6	2	0	0	4	4
	23	0	2	0	0	1	2	1
	24	0	1	0	11	1	3	0
	25	0	1	0	1	1	13	3
	26	0	0	0	2	0	4	0
	27	0	2	1	0	0	2	2
	28	0	0	#	0	1	3	0
	29	0	0		0	0	0	0
	30	0	2		1	0	0	0
Survival		80	5		44	34	19	7

TABLE XI. Survival of Workers Given --

Honey 25- L.E.1

Test Designation	C20	B100	A70	740
Date Test Started	4-3	3-3	1-25	12-26
Mortality, day 1	40	5	20	1
2	2	14	13	0
3	3	2	6	1
4	0	4	9	1
5	4	2	7	0
6	2	1	0	1
7	3	1	2	3
8	2	2	1	2
9	3	0	3	9
10	5	0	4	5
11	1	2	5	3
12	3	0	4	4
13	1	2	5	7
14	0	0	5	2
15	1	1	4	2
16	0	0	3	6
17	0	0	2	3
18	0	0	4	3
19	0	0	1	4
20	0	2	2	4
21	0	0	#	4
22	0	0		1
23	1	1		5
24	0	1		4
25	0	3		0
26	2	2		0
27	0	0		6
28	1			7
29	1			3
30	0	15		2
Survival	25	40		7

TABLE XII. Survival of Workers Given --

Honey 25- L.E.2

Test Designation	B90	A40	460	610	680
Date Test Started	3-3	1-25	8-16	11-24	12-4
Mortality, day 1	6	21	14	9	6
2	7	4	2		7
3	3	10	3	31	8
4	2	8	5	5	9
5	3	1	2	13	13
6	2	2	1	8	11
7	0	1	2	4	4
8	1	0	1	7	13
9	2	1	0	4	4
10	0	4	15	4	9
11	1	7	3	5	5
12	2	6	15	0	4
13	3	2	10	0	3
14	1	7	3	1	0
15	1	4	5	#	1
16	1	4	4		2
17	1	2	0		#
18	6	3	0		
19	2	2	5		
20	1	3	0		
21	1	1	0		
22	1	0	1		
23	1		0		
24	5		0		
25	1	5	0		
26	1	0	2		
27	5	0	1		
28	0	0	0		
29		0	1		
30	7	1	0		
Survival	33	1	5		

TABLE XIII. Survival of Workers Given --

Honey 50- L.E.2

Test Designation	270	280	350	430
Date Test Started	6-13	6-21	7-6	8-16
Mortality, day 1	6	2	28	15
2	17	8	5	29
3	9	12	28	38
4	8		18	17
5	18	22	7	2
6	10	25	4	2
7	0	9	1	#
8	1	3	4	
9	4	4	1	
10	1	1	#	
11	3	#		
12	0			
13	1			
14	0			
15	0			
16	0			
17	1			
18	1			
19	1			
20	4			
21	0			
22	2			
23	2			
24	2			
25	0			
26	1			
	#			

TABLE XIV. Survival of Workers Given --

	Honey 50-yeast			Honey 25-yeast
Test Designation	310	600	370	690
Date Test Started	6-24	11-24	7-8	12-6
Mortality, day 1		42	23	9
2	15		38	3
3	14	45	25	1
4	12	7	5	6
5	8	1	5	4
6	6	0	1	6
7	8	1	1	1
8	2	2	#	9
9	8	#		8
10	0			0
11	16			6
12	2			3
13	2			9
14	1			11
15	0			3
16	2			5
17	2			0
18	1			0
19	#			0
20				17
21				#
22				
23				
24				
25				
26				
27				
28				
29				
30				
Survival				

TABLE XV. Survival of Workers Given --

	Honey 50- L.E.2 -Yeast			Honey 25- L.E.2-Yeast	
Test Designation	360	330	570	A50	700
Date Test Started	7-6	6-29	10-11	1-25	12-8
Mortality, day 1	32	14	72	35	7
2	8	5	15	25	6
3	16	8	7	11	10
4	26	15	4	11	18
5	4		2	4	4
6	2	39	#	3	3
7	5	15		1	1
8	0	1		1	7
9	0	0		1	1
10	2	1		4	3
11	#	#		1	0
12				0	2
13				2	1
14				0	1
15				1	
16				#	
17					
18					10
19					0
20					2
21					2
22					0
23					2
24					0
25					0
26					1
27					1
28					0
29					1
30					2
Survival					15

TABLE XVI. Survival of Workers Given --

	Honey 25- L.E.1-Y.juice			Sucrose 12- L.E.1-Y.juice	
Test Designation	B70	A60	770	B80	780
Date Test Started	3-3	1-25	1-15	3-3	1-15
Mortality, day 1	2	32	6	2	10
2	0	21	3	12	1
3	3	7	2	2	3
4	0	8	0	3	4
5	1	7	0	0	0
6	0	1	0	0	0
7	0	1	2	1	0
8	0	1	2	1	0
9	0	2	2	1	0
10	0	2	0	0	0
11	3	5	0	1	0
12	1	5	1	2	0
13	0	1	1	0	0
14	4	4	1	0	1
15	2	2	1	1	0
16	0	1	9	0	1
17	0	#	6	0	0
18	0		3	0	0
19	0		3	0	0
20	4		3	0	0
21	2		1	0	2
22	0		2	0	7
23	1		3	0	2
24	1		4	0	0
25	1		2	1	1
26	1		3	0	1
27	1		3	0	0
28	0		2		0
29	0		0		0
30	1		0	11	0
Survival	72		35	72	67

TABLE XVII. Survival of Workers Given --

	Honey 25-liver 75		Sucrose 25-liver 75
Test Designation	C10	C100	C30
Date Test Started	4-3	4-3	4-3
Mortality, day 1	5	7	20
2	1	0	1
3	0	0	0
4	8	1	0
5	3	1	0
6	2	2	2
7	0	4	0
8	1	7	0
9	0	5	0
10	2	2	0
11	1	6	0
12	0	5	0
13	0	0	0
14	0	1	0
15	0	4	0
16	0	7	1
17	1	3	0
18	1	0	0
19	0	2	0
20	1	0	1
21	0	0	2
22	1	0	2
23	0	2	0
24	0	0	0
25	0	0	0
26	2	4	0
27	0	0	0
28	1	1	0
29	0	1	0
30	0	5	0
Survival	70	30	71

TABLE XVIII. Survival of Workers Given --

	L.D.S.-liver	Sucrose 12-liver		
Test Designation	710	C40	B20	760
Date Test Started	12-15	4-3	3-3	1-15
Mortality, day 1	17	18	1	14
2	7	1	1	0
3	9	1	0	1
4	13	0	1	1
5	9	0	0	0
6	8	2	0	0
7	5	1	0	1
8		0	0	0
9		0	0	0
10		0	0	0
11	16	1	0	0
12	2	0	0	0
13	2	0	0	0
14	1	0	0	0
15	2	1	1	1
16	0	0	0	1
17	0	0	0	0
18	1	0	0	1
19	0	0	1	2
20	0	1	0	0
21	0	0	0	0
22	0	0	0	1
23	0	0	0	0
24	0	2	0	2
25	0	0	0	0
26	0	1	0	0
27	0	1	0	1
28	0	1	0	0
29	0	1	0	1
30	0	0	0	0
Survival	8	68	95	73

TABLE XIX. Survival of Workers Given --

	Dextrose 12-liver			Levulose 12-liver		
Test Designation	C60	B50	B40	C80	B60	B30
Date Test Started	4-3	3-3	3-3	4-3	3-3	3-3
Mortality, day 1	22	2	0	36	2	0
2	1	0	2	0	1	0
3	0	1	0	0	0	0
4	2	0	0	0	0	0
5	1	0	0	1	1	0
6	0	0	0	0	0	1
7	0	1	0	0	1	0
8	1	1	1	1	0	0
9	2	0	1	0	0	0
10	5	0	1	0	0	0
11	3	1	0	0	2	0
12	5	2	0	0	0	2
13	2	1	2	0	0	0
14	0	1	0	1	0	2
15	4	1	0	0	0	0
16	4	0	0	0	0	0
17	4	0	0	1	0	0
18	3	0	0	0	0	1
19	1	2	0	1	3	0
20	0	1	0	0	0	0
21	0	1	0	2	0	0
22	1	0	0	0	0	0
23	3	0	0	2	1	0
24	1	0	0	1	0	0
25	0	1	0	0	1	0
26	1	3	0	1	1	0
27	0	1	0	0	0	0
28	0	0	0	1	0	0
29	0	0	0	0	0	0
30	0	4	0	1	4	0
Survival	34	76	93	51	83	94

TABLE XX. Survival of Workers Given --

	Sucrose -- 25-L.E.1	Dextrose -- 25-L.E.1	Levulose -- 25-L.E.1
Test Designation	C50	C70	C90
Date Test Started	4-3	4-3	4-3
Mortality, day 1	31	18	7
2	1	1	1
3	0	1	1
4	0	0	0
5	0	0	5
6	1	0	3
7	0	4	3
8	2	1	4
9	0	3	5
10	0	4	8
11	2	4	5
12	1	3	6
13	1	2	8
14	2	0	4
15	3	2	12
16	2	3	5
17	6	5	6
18	1	0	5
19	4	1	4
20	9	0	0
21	2	0	2
22	3	0	3
23	4	2	1
24	1	0	0
25	0	0	0
26	4	2	1
27	1	0	#
28	3	4	
29	3	4	
30	3	1	
Survival	10	35	

test died in one day, the curve would coincide with the ordinate. In this case, the number of squares on the paper, which is 6000, would represent that fact. With curves that are intermediate, the smaller the number the better the survival. An explanation using Fig. 8 will make this clear.

Curve A30 shows that 26 ants were dead the first day. The second day, 9 ants died which makes a total of 35. In this way, the curve was completed showing that 99 ants had died by the 27th day. There are 4652 squares between this curve and the abscissa. This is the numerical value for this test. Curve CO illustrated good survival with 20 ants dead by the 30th day. In this case, there are 1065 squares between the curve and the abscissa. This is the numerical value for this curve. The other curves in Fig. 8 show that for most tests with Honey 25-liver, survival was intermediate. Curves 260 and 300 vary less than the rest but the numerical values of 2420 and 2032, respectively, show that #300 had better survival. On the 30th day, test # 750 and B10 had almost the same number surviving but the ants in # 750 had died more rapidly at first. The numerical values for # 750 is 3777 and for #B10, 3000 which brings out this difference. The numerical values for the 40 separate tests are given in Table XXI and those for the three sets are presented in Table XXII. For comparisons of the various foods tested, the averages of the numerical values for each food was found. These values arranged according to survival value are presented in Table XXIII.

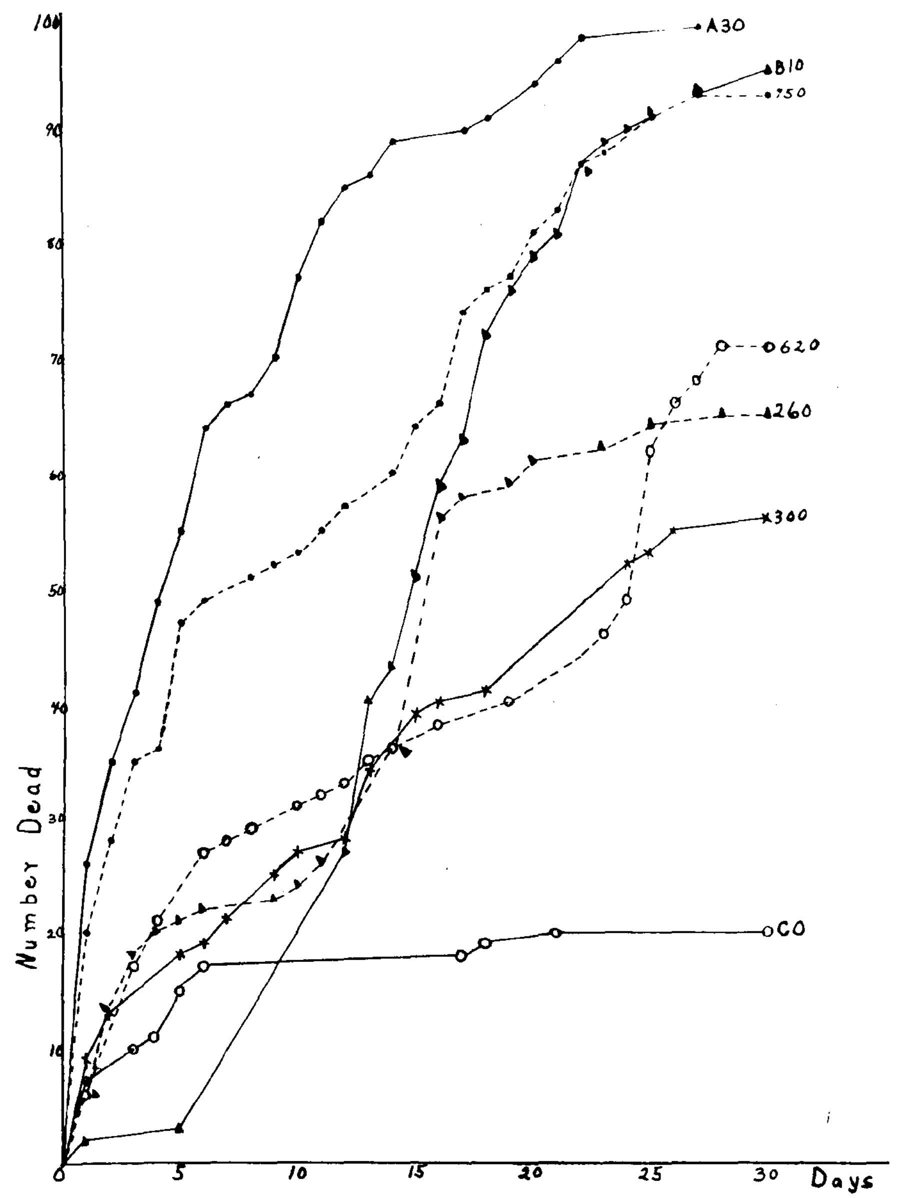


Fig. 8. Graph showing survival of <u>Formica</u> <u>exsectoides</u> workers given Honey 25-liver.

TABLE XXI. Numerical Values for Separate Survival Tests According to Food Used

Food used	Numerical Values					
No food or water	5120	5844	5843			
Water only	4095	5223	5135	5505	5714	3006
Honey 25-liver	2420	2032	3777	2302		
Honey 50	4409	5018	5669			
Honey 25	3240	3895	5241	3641		
Honey 50-yeast	4751	5598	5670			
Honey 25-yeast	4008					
Honey 50-L.E.2	4285	4921	5399	5580		
Honey 25-L.E.2	3852	4952	4736			
Honey 25-L.E.1	2447					
Honey 50-L.E.2-yeast	5156	5417	5785			
Honey 25-L.E.2-yeast	3680					
Honey 25-L.E.1-Y.juice	1905					
Sucrose 12-L.E.1-Y.juice	1320					
Sucrose 12-liver	1181					
L.D.S.20-liver	4706					

TABLE XXII. Numerical Values for Sets of Survival Tests According to the Food Used.

Food used	Date : Set A 1-25-45	Set B 3-3-45	Set C 4-3-45
No food or water	5853	5418	5703
Water only	1750	2039	2416
Honey 25-liver	4652	3000	1065
Honey 25-L.E.1	5067		
Honey 25	4208	2130	
Honey 25-L.E.2	4519	2046	3766
Honey 25-L.E.2-yeast	5444		
Honey 25-L.E.1-yeast	5130	905	
Sucrose 12-liver		235	1477
Dextrose 12-liver		615	2390
Levulose 12-liver		504	2412
Sucrose 25-L.E.1			3099
Dextrose 25-L.E.1			2441
Levulose 25-L.E.1			3522
Sucrose 25-liver 75			1476
Honey 25-liver 75			1325
Sucrose 12-L.E.1-Y.juice		2053	

TABLE XXIII. Average of Numerical Values According to Foods.

Food Tested	No. tests	Average
No food or water	6	5630
Honey 50-L.E.2-yeast	3	5450
Honey 50-Yeast	3	5340
Honey 50-L.E.2	4	5050
Honey 50	3	5030
L.D.S.20-liver	1	4710
Honey 25-L.E.2-yeast	2	4560
Honey 25	5	4220
Honey 25-yeast	1	4010
Honey 25-L.E.2	5	3980
Water	9	3880
Levulose 25-L.E.1	1	3520
Honey 25-L.E.1	4	3190
Sucrose 25-L.E.1	1	3100
Honey 25-liver	7	2750
Honey 25-L.E.1-Y.juice	3	2650
Dextrose 25-L.E.1	1	2440
Honey 25-liver 75	2	2050
Sucrose 12-L.E.1-Y.juice	2	1690
Sucrose 25-liver 75	1	1480
Dextrose 12-liver	3	1110
Levulose 12-liver	3	1050
Sucrose 12-liver	3	960

Results of Survival Tests.

Survival on 21 foods, water and no food or water were determined in a total of 73 tests. Using the averages (Table XXIII) of the numerical values for survival, survival was best on Sucrose 12-liver. Levulose 12-liver and Dextrose 12-liver have about the same survival value. These three foods molded quickly necessitating changing the cotton squares every week. Sucrose 25-L.E.1 and Levulose 25-L.E.1 were the only foods containing a pure sugar with a value above 3000. L.D.S. 20-liver, a mixture of the three pure sugars and liver broth, gave poorer results than any one sugar. All the foods using Honey 50 showed low survival. Honey 25 in a food gave better survival but was not as good as that for a sugar in combination with liver broth.

A study of the protein part of the foods shows that liver broth gave better survival than any of the substitutes. In only one case did the carbohydrate dilution and liver give a poorer result than that carbohydrate and any protein substitute. This case is Honey 25-L.E.1-Y.juice which has a value next lower than that of Honey 25-liver. The survival on Honey 25-L.E.1 was poorer than on Honey 25-L.E.1-Y.juice. This suggests that the liver extract lacks something which the yeast juice supplies. Yeast used with either honey dilution gave lower survival than with liver extract added or the honey dilution alone therefore the yeast cells are not a complete food. None of the foods containing yeast were as satisfactory for survival as water. 250 milligrams of the liver extract per 100 cc. of food was better than twice that amount but not as good as liver broth.

When the sets of tests using various foods but all started at the same time and kept under identical conditions are analysed, a few differences are noted. In Set A, ants given water only survived best and better than on water in Set B or C. Honey 25-liver gave strikingly better survival in Set C than in either Set A or B and better than in any of the separate tests (Table XXI). Sucrose 12-liver, Levulose 12-liver and Dextrose 12-liver have nearly the same survival value in Set B and C but survival was better in Set B. Honey 25-L.E.1 gave better survival in Set B but in each set, it had a value near that of several other foods. Some of the lower survival in Set C is due to the ants killing themselves with their poison within a few hours after the test was started.

Results with Artificial Colonies 1942-43.

During the winter of 1942-43, eight artificial colonies kept in artificial nests of the first type were fed Honey 50 and beef, liver or insect pieces. The beef and liver were fed raw part of the time. Table XXIV gives a summary of the results. Half of the nests had larvae spin up. Three of these had queens and the larvae developed into workers. The other one (#1) reared 3 kings. The nests with queens were more satisfactory for testing foods because eggs were present more quickly and for a longer time. The number of eggs present was much greater. Three of the nests that were not successful died partly because Collembola and scavanger ants invaded the nests. These pests were attracted to the food given the ants especially when more than the ants consumed was placed in the nest.

Some insects given for food were attacked more quickly than others. It was impossible to tell how much of this food was consumed. Sometimes after feeding raw beef or liver, a number of dead ants were noted. This did not happen with the cooked beef or liver. Honey 50 was a satisfactory substitute for honeydew.

The abnormal conditions of confinement, without soil did not prevent the ants from feeding larvae until they completed development. Under such conditions, artificial colonies lived from 49 to 313 days. With better artificial nests and more carefully controlled conditions, a larger proportion of the artificial colonies should live 5 or 6 months. In this time, further facts about the food requirements of this species could be determined.

TABLE XXIV. Summary of Results with Artificial Colonies 1942-43

Nest #	Date started	Queen given	Pupal period	Length of Time in captivity
1	3-10	-	35 days	147
2	3-5	3-15	Had pupae	213
3	2-1	2-1	Had pupae	57*
4	12-27	12-27	51 days	150*
5	2-10	2-22		49
6	2-24	2-25		35*
6-2	4-3	4-3		126
7	1-16	-		77

* Ants escaped from the artificial nest.

Results with Artificial Colonies in 1943-44.

During the winter of 1943-44, ten artificial nests of the first type (#11 to 17), 32 of the second type (#31 to 57), and 2 of the third type (#20 and 21) were fed various foods. Each colony was given only water until the ants broke hibernation which was indicated by sustained movement about the nest by all of the ants. After that a food was given for 70 to 100 days depending on how rapidly the ants began to die and whether any of the larvae grew. Every opportunity was given the colony to have larvae complete development on that food. If, after this length of time, large larvae were never seen or large larvae were being eaten by the workers, another food was tried.

In Table XXV, the food used first is listed first. The number of days from the time eggs were present in the nest until a pupa was formed is given as the best indication of the degree of success for that food. When pupae did not develop, the length of time larvae were present indicates in a degree the efforts made by the colony to feed the larvae. In some unsuccessful colonies, eggs were present part of the time. All this information is summarized in Table XXV.

Two artificial colonies given only water lived 63 and 81 days. Two colonies were fed beef broth and two others liver broth. The survival was about the same as that for colonies given only water. None of these colonies had eggs present at any time.

Five colonies were fed the entire time some dilution of sugar as the carbohydrate food. All had eggs present in the nest and two had larvae part of the time. The nest (#38) fed Sugar 25-liver survived over 200 days. Four other colonies started on some mixture of sugar and a protein were later shifted to honey and a protein because large larvae did not remain in the nests. No colony given food containing sugar all or part of the time lived more than 282 days or had larvae spin cocoons. All had eggs present part of the time and 4 had larvae for awhile.

Two colonies (#47 and 49) were fed Melezatose 25, part of the time. Neither lived 200 days and only one had larvae. Feeding Melezatose 25 alone in one case and Melezatose 25-beef in the other make deductions difficult.

Honey was given in two dilutions. Four artificial colonies were given Honey 50 and a protein the entire time. Three of them lived over 200 days. None of them had larvae pupate but 3 had larvae present part of the time. A colony (#53) given Honey 50-L.E.2 part of the time survived 239 days and one (#36) given Honey 50-L.E.2-yeast survived 330 days. Larvae did not complete development in either. Ten colonies received, as their carbohydrate food, Honey 50 part of the time and Honey 25 the rest of the time. Each dilution was fed in combination with some protein. Three of these colonies fed larvae successfully and had pupae in the nest.

Two (#20 and 48-1) were fed Honey 50-meats and later Honey 25- liver. The other (#35) received Honey 25-meats and then Honey 50-L.E.2. None of these colonies had pupae while being fed meats. Of these 10 colonies, 4 survived over 200 days, 3 over 300 days and 1 over 400 days.

Fourteen colonies received Honey 25 and a protein their entire life in captivity. Of these, one (#16) never had eggs and died out in 38 days. The protein given was beef. Two other colonies (#41 and #42) were given beef part of the time. Large larvae were never found in nests fed Honey 25-beef. Eight colonies received their proteins from liver the entire time. Three of them had pupae and 4 larvae part of the time. The pupae were produced in a shorter time than in colonies fed on any other food.

Of the two other colonies that reared young, one (#33-2) was fed Honey 25-oyster meal broth 3 months and then transferred to Honey 25-liver. After the transfer larvae completed development. The other (#14) had larvae pupate on Honey 25-L.E.2-yeast. Both colonies lived over 300 days.

Of the 44 colonies kept during 1943-44 seven lived more than 300 days. Three of these lived over a year. After being in captivity 306 days, the queen of one colony (#33-2) again began to lay eggs. The eggs hatched but the larvae did not complete development. This colony was fed Honey 25-liver most of its life.

Of the 8 colonies that had pupae form, each was fed some dilution of honey all the time. Six were receiving Honey 25-liver when larvae completed development. The other two were receiving liver extract or liver extract and yeast. This indicates that these two are possible substitutes for liver broth. Of the foods tested, Honey 25-liver was the most satisfactory for feeding larvae until they spun cocoons.

TABLE XXV. Summary of Feeding Tests with Artificial Colonies during 1943-44

Nest No.	Date Started	Days Lived	Efforts to rear young	Foods used
A. No carbohydrate.				
11	10-30	63	-----	Water
31	10-30	81	-----	Water
12	10-30	55	-----	Beef broth
32	10-30	61	-----	Beef broth
13	11-12	78	-----	Liver broth
33	10-30	62		Liver broth
B. Sugar.				
43	11-19	92	Eggs present 5 days	Sugar 50
37	11-12	167	Larvae 7 days	Sugar 50 Sugar 50-meats
39	11-12	83	Eggs present 10 days	Sugar 25-beef
38	11-12	222	Larvae 56 days	Sugar 25-liver Sugar 25-L.E.2-yeast Honey 25-liver
44	11-25	261	Larvae 43 days	Sugar 25-L.E.2-Yeast Honey 50-L.E.2
45	11-25	282	Larvae 15 days	Sugar 25-L.E.2 Honey 25-L.E.2
52	12-28	161	Eggs present 35 days	Sugar 25-yeast Honey 25-grub broth.
C. Melezatose.				
47	12-4	190	Larvae 17 days	Melezatose 25 Honey 25-liver
49	12-13	154	Eggs present 16 days	Melezatose 25-beef Honey 25-grub broth

TABLE XXV. Summary of Feeding Tests with Artificial Colonies during 1943-44

Nest No.	Date Started	Days Lived	Efforts to rear young	Foods used
D. Honey 50.				
12-1	3-31	30*	Eggs present 12 days	Honey 50
32-1	2-21	195	Larvae 26 days	Honey 50-pollen Honey 50-L.E.2
34	10-30	227	Eggs present 22 days	Honey 50 Honey 50-meats
40	11-12	244	Larvae 41 days	Honey 50 Honey 50-meats Honey 50-L.E.2
50-1	1-26	227	Larvae 118 days	Honey 50-yeast Honey 50-L.E.2
E. Honey 50 or Honey 25.				
20	2-21	297*	Pupae 61 days from eggs	Honey 50-meats Honey 25-liver
35	11-12	245*	Pupae 81 days after first eggs	Honey 25-meats Honey 50-L.E.2
36	11-12	330	Eggs present 78 days	Honey 25-beef Honey 50-L.E.2-yeast
39-1	2-21	326	Larvae 70 days	Honey 50-oyster Honey 25-liver
43-1	2-21	201	Larvae 76 days	Honey 50-L.E.2-yeast Honey 25-liver
48-1	2-21	180	Pupae 81 days after first eggs	Honey 50-meats Honey 25-liver
51-1	2-24	344	Larvae 29 days	Honey 50-meats Honey 25-liver
53	1-26	239	Larvae 22 days	Honey 25-pollen Honey 50-L.E.2
54	3-15	84	Larvae 7 days	Honey 50-meats Honey 25-liver
46-1	2-21	428	Larvae 72 days	Honey 50-meats Honey 25-grub Honey 25-liver

TABLE XXV. Summary of Feeding Tests with Artificial Colonies during 1943-44

Nest No.	Date Started	Days Lived	Efforts to rear young	Foods used
F. Honey 25.				
16	11-25	38	------	Honey 25-beef
41	11-19	135	------	Honey 25-liver Honey 25-beef
42	11-19	238	Larvae 49 days	Honey 25-beef Honey 25-liver
33-2	2-24	374	Pupae 102 days after first eggs	Honey 25-oyster Honey 25-liver
31-1	1-26	396	Larvae 76 days	Honey 25-meats Honey 25-liver
14	11-19	333	Pupae 117 days after first eggs **	Honey 25-L.E.2-yeast
13-1	3-31	81*	Pupae 26 days after first eggs	Honey 25-liver
15	11-25	214*	Pupae 47 days after first eggs	Honey 25-liver
16-1	4-31	60*	Larvae 31 days	Honey 25-liver
17	5-1	57*	Larvae 8 days	Honey 25-liver
21	3-15	114*	Larvae 30 days	Honey 25-liver
35-1	4-4	132*	Pupae 42 days after first eggs	Honey 25-liver
55	3-15	183	Larvae 24 days	Honey 25-liver
57-1	5-24	116	Eggs present 17 days	Honey 25-liver

* Ants escaped from the artificial nest.

** After 75 days, part escaped and all larvae disappeared prior to the change to pupae.

Results with Artificial Colonies in 1944-45.

During the winter of 1944-45, 29 artificial nests of the second type and 5 of the third type were fed various foods. The colonies were kept in a control room where the temperature was approximately 70 F. The details of care were like those of the previous year except that, when the food was changed, it was done in from 40 to 60 days. All the colonies were still active when the tests were terminated. Table XXVI presents a summary of the important points.

Five colonies were fed Honey 25-liver the entire time. One (41-4) reared 9 workers with the first pupa present 56 days after eggs appeared in the nest. The rest had larvae for varying lengths of time.

Three colonies were fed Honey 25-L.E.2-yeast. One (45-4) had pupae in 65 days but the others had larvae only. Another (#56-4) was fed Honey 25-L.E.1-Y.juice and raised 3 workers the first larvae spinning up 74 days after eggs were present.

Honey-L.E.1 was fed 4 colonies for the entire time. One (#49-4) raised more workers than any colony. Two colonies (#54-4 and #22-4) had large larvae when the tests were terminated.

The food was changed at least once for all the rest of the colonies, 5 of which had at least one pupa formed. Two received Honey 25-yeast for 60 days and then were changed to Honey 25-L.E.1. One other (35-4) was changed from Honey 25-liver to Honey 25-L.E.1. Larval development was rapid after these changes. Colony (#36-4) had one pupa while receiving Honey 25-yeast but it disappeared in 2 days. The remaining colony (#40-4) was the only one that had pupae without being fed honey. It received L.D.S.20-liver 60 days and then Sucrose 25-L.E.1-Y.juice.

Four colonies received Honey 25 and some protein the entire time. All had larvae but none completed development. Seven colonies were fed Honey 25 or some sugar with a protein. Some received the sugar first and for others the order was reversed. All but one which had no larvae, had larvae for a longer period than any other colonies which were not successful in rearing young. Often large larvae were present in the nests but after a day or two disappeared.

The remaining 5 colonies never received any honey. All except one (25-4) had larvae for a comparatively short time. These colonies rarely had large larvae.

In 1944-45, nine colonies raised young, eight of which were receiving Honey 25 and a protein when larvae completed development. The protein that gave the best results was liver extract at the rate of 250 milligrams per 100 cc. of liquid. Six colonies were receiving liver extract when pupae were formed. Honey 25 proved to be the best source of carbohydrate as was true the previous year. This year liver extract was better for the protein part of the food although liver broth, yeast and yeast juice were satisfactory sometimes.

Discussion of results.

Since *F. exsectoides* has a wide range of foods in nature, it is not surprising that in artificial nests they can feed larvae until they spin cocoons on more than one food combination. Neither is it surprising that a sugar or honey is not a complete food alone. Tests with a protein alone gave negative results. All successful food were mixtures of a honeydew substitute, a carbohydrate, and an insect substitute, a protein. As was anticipated, the food requirements were different for artificial colonies that fed larvae successfully than for mere survival of workers.

When comparing the results of survival tests and of artificial colonies, the rhythm of this species must be remembered. The survival tests were conducted with ants taken from the mounds at various times of the year while the artificial colonies were forced into activity and kept that way by summer temperatures. After six months of this warmth, the ants stopped raising young regardless of the food. The queen layed

TABLE XXVI. Summary of Feeding Tests with Artificial Colonies during 1944-45.

Nest No.	Date Started	Days Kept	Efforts to rear young	Food used
A. Colonies fed Honey 25-liver.				
21-4	2-27	62	Larvae 32 days	
39-4	2-15	74	Larvae 42 days	
41-4	11-17	164	First pupa in 56 days	
48-4	11-20	161	Larvae 82 days	
65-4	2-20	69	Larvae 42 days	
B. Colonies fed Honey 25-L.E.2-yeast				
24-4	2-24	65	Larvae 28 days	
45-4	11-18	163	First pupa in 65 days	
53-4	12-4	147	Larvae 66 days	
C. Colonies fed Honey 25-L.E.1-Y.juice				
56-4	12-8	143	First pupa in 74 days.	
D. Colonies fed Honey 25-L.E.1				
22-4	2-22	67	Larvae 35 days	
49-4	11-29	152	First pupa in 40 days (Had at least 30 pupae)	
54-4	12-4	147	Larvae 77 days	
60-4	12-27	124	Larvae 73 days	
E. Successful colonies on two or more foods.				
35-4	11-6	175	First pupa in 47 days	Honey 25-liver Honey 25-L.E.1
36-4	11-15	166	One pupa in 35 days	Honey 25-yeast Sucrose 12-liver Sucrose 25-L.E.1
40-4	11-17	164	Two pupa in 51 days	L.D.S.20-liver Sucrose 25-L.E.1-Y.juice
43-4	11-18	163	One pupa in 60 days	Honey 25-yeast Honey 25-L.E.1
50-4	12-2	149	First pupa in 79 days	Honey 25-yeast Honey 25-L.E.1

TABLE XXVI. Summary of Feeding Tests with Artificial Colonies during 1944-45

Nest No.	Date Started	Days Kept	Efforts to rear young	Food used
F. Other colonies on Honey 25 and various proteins.				
32-4	11-17	165	Larvae 7 days	Honey 25-L.E.2 Honey 25-liver
42-4	11-25	156	Larvae 58 days	Honey 25-L.E.2 Honey 25-L.E.1-Y.juice
52-4	12-2	149	Larvae 15 days	Honey 25 Honey 25-liver
61-4	12-27	124	Larvae 45 days	Honey 25-L.E.1-Y.juice Honey 25-L.E.1
G. Other colonies on Honey 25 or pure sugar and proteins.				
23-4	2-22	67	Eggs present 61 days	Sucrose 12-L.E.1-Y.juice Honey 25-liver
34-4	11-1	181	Larvae 91 days	L.D.S.20-liver Honey 25-liver Honey 25-L.E.1
37-4	11-15	166	Larvae 105 days	Honey 25 Sucrose 12-liver Sucrose 25-L.E.1
38-4	11-17	164	Larvae 107 days	Honey 25-L.E.2-yeast Sucrose 12-liver Sucrose 25-L.E.1
44-4	11-18	163	Larvae 90 days	Honey 25 Sucrose 25-L.E.1
47-4	11-20	161	Larvae 84 days	L.D.S.20-liver Honey 25-liver Dextrose 25-L.E.1
58-4	12-20	131	Larvae 91 days	Sucrose 12-L.E.1-Y.juice Honey 25-L.E.1

TABLE XXVI. Summary of Feeding Tests with Artificial Colonies during 1944-45

Nest No.	Date Started	Days Kept	Efforts to rear young	Food used
H. Other Colonies receiving no honey.				
25-4	2-24	65	Eggs present 17 days	L.D.S.20-liver Sucrose 25-L.E.1
55-4	12-8	143	Larvae 65 days	Sucrose 12-liver Levulose 25-L.E.1
59-4	12-22	129	Larvae 75 days	Sucrose 12-liver Dextrose 25-L.E.1
12-4	12-27	124	Larvae 35 days	Sucrose 12-liver Sucrose 25-L.E.1
63-4	12-28	123	Larvae 33 days	Sucrose 12-L.E.1-Y.juice Sucrose 25-L.E.1

no eggs and in a number of cases died. In only one case did the queen resume laying under these warm conditions. Survival tests gave the poorest results in the fall which is the time that the ants are entering hibernation. Results were best in the spring when they are ready to feed.

The fact that the food which gave the best results in survival tests spoiled most quickly is important. In the survival tests, the spoiled excess was removed. This was not possible in the artificial nests. Sodium benzoate, sodium propionate, calcium propionate and citric acid were unsuccessful in controlling molds and decay in strengths tolerated by the ants. The foods containing honey did not spoil as quickly as those containing a pure sugar.

Of the seven foods upon which artificial colonies lived and fed larvae to spinning up all except 2 had survival values between 2650 and 4560. One of the exceptions was Honey 50-L.E.2 upon which one colony was successful and which had a survival value of 5050. The other exception was a colony which had larvae spin up on Sucrose 12-L.E.1-Y.juice. The survival value for this food was 1690.

The good survival on the pure sugars, especially sucrose indicates that is spoiling of mixtures containing it can be controlled and the minerals and vitamins supplied in correct quantities, it might be possible as a substitute for honey which is so complex and variable.

Honey 25, which is a dilution having approximately the same total sugar concentration as nectar, was the most satisfactory of the dilutions tried. Fifteen colonies had larvae complete development on this dilution and a protein but 5 others were successful on Honey 50 and some protein. The low survival values of foods containing Honey 50 as well as fewer successful artificial colonies indicate that it is less satisfactory than Honey 25.

Three insect meat substitutes were satisfactory when combined with Honey 25. Seven artificial colonies had larvae complete development on Honey 25-liver while 4 were successful on Honey 25-L.E.l. In 1943-44 liver broth was most satisfactory but the next year only 1 colony did well on this food. One colony was successful on a combination of liver extract and yeast juice but since more colonies were successful on liver extract alone the yeast juice is apparently not essential. Three nests had larvae complete development when the liver extract factor was doubled. Two of these also received yeast cells. The value of yeast cells is doubtful although one colony had one larvae complete development with yeast cells as the only source of protein. The survival value of Honey 25-yeast is better than two other foods upon which colonies were successful.

In these studies 25% honey and liver broth or 250 milligrams of liver extract per 100 cc. of liquid contained all essential elements for F. exsectoides to feed larvae until they spun cocoons. Both constituents in these mixtures help supply minerals and vitamins. The honey mainly supplies the carbohydrate though it contains varying amounts of protein from included pollen grains. The liver or liver extract supplies the protein plus minerals and an extremely complex group of vitamins.

CONTROL

Introductory discussion.

Poisoned food is used to control some ants but the habits of *F. exsectoides* with their wide variety of food and the wide distribution of the colonies make poisoning difficult. During the winter of 1943-44 a small nest of *F. exsectoides*, formed by ants that escaped from artificial nests, was tested. These ants foraged over the greenhouse but the food supply was often limited in spite of Honey 25-liver being placed near the mound occasionally. One day an arsenite of soda ant poison was set out instead of Honey 25-liver. The workers fed as usual for several hours and then stopped although plenty of the solution remained and no other food was offered. The next day several hundred dead ants were on the mound. The nest was weakened but not killed as later when the colony moved they carried away pupae. For two weeks after being fed the poisoned food these ants ignored any food from the spot used for the poison. It was six weeks before they would touch a sugar-water solution in any spot. The poisoned solution was consistently refused regardless of container or place.

This evidence from a nest that did not have adequate food and the unpromising results from field trials with foods, indicate that poisoned food is not a possible method of control of *F. exsectoides*.

Peirson (37) tried potassium cyanide, corrosive sublimate, carbolic acid, kerosene, gasoline, napthalene and carbon disulfide to kill *F. exsectoides*. Carbon disulfide was the only effective one. Manter (32) used carbon disulfide and the calcium cyanide. About one pound of carbon disulfide was required to kill the ants in an average sized mound and the mound had to be covered for the poison to be effective. Two ounces of granular calcium cyanide was sufficient to kill the same sized nest and the mound did not have to be covered. In 1941 Johnson and Friend (28) treated 3 mounds with methyl bromide, 250 - 520 cc. each; 2 with carbon disulfide; and 1 with 1 pound 4% rotenone spread in a band around the base of the nest. In these experiments methyl bromide was more effective than carbon disulfide and rotenone showed promise.

The aim in choosing a method or material for control is to find the most effective, safest, cheapest and most easily applied material. Of the materials that have been used, carbon disulfide has been most successful. It is inflammable, poisonous to man and animals in confined spaces, voltalizes slowly at low temperatures and requires a large dose to be effective. Calcium cyanide does not require such a large dose to be effective but is a violent poison and works best at fairly high temperatures. Methyl bromide, as Johnson and Friend used it, was effective. Paradichlorobenzene is not poisonous to man, is easy to handle and lethel to many insects. The chemical DDT is easy to handle, and not very poisonous to man. During 1944-45, tests with methyl bromide, paradichlorobenzene and DDT were conducted.

Tests with methyl bromide.

During the summer of 1944 and the spring of 1945, 31 mounds of *F. exsectoides* were treated with methyl bromide. The methyl bromide in 1 pound tins was applied through a graduated truck applicator. The applicator nozzle was placed in a tube inserted 6 to 18 inches in the mound obliquely toward the center. The amount of the chemical was varied according to the size of the nest. Two medium size but active nests were treated first. One received 50 cc. and the other 100 cc. of methyl bromide. Two days later hundreds of ants were moving about on the outside of the mound. They were not repairing the mound or carrying on any usual activity. A week later the base and lower half of the mounds were covered with dead ants. There has been no further activity in these mounds.

Later 25 mounds located in and on the edge of a grassy clearing on a hill in a woods were treated. Table XXVII gives a summary of the size and condition of the mounds, the amount of poison and the effect of the poison. The condition of the mound is given since even large nests were killed by one application if the mound was well shaped and unbroken by injury such as animal tracks. The tube and applicator nozzle were easier to insert into these mounds which helped give better results. The mounds with steep sides are kept so by the large number of ants in them. Killing such large mounds with 100 cc. shows that that amount of the poison is ample. Low mounds are usually inhabited by smaller numbers of ants. The survival of some of these nests points to the escape of the gas before it had killed the inhabitants.

One month after treatment, 12 nests were active. Eleven of these had low or broken mounds. The other was a mound (#20) three times as long as wide with a steep almost separate cone at one end. Only one end was treated in order to determine whether the gas would penetrate to the separate cone. Failure to eradicate all the ants indicates that the mound structure was discontinuous. Treatment the following spring of the nearly separate part killed the ants in it but a few ants survived in between.

52% of the 25 nests treated showed no activity one month after treatment, but 6 very old mounds resumed activity. One new mound was being formed by ants which were moving from a treated nest. Probably the old reopened nests were efforts of escaped ants to reestablish themselves.

The next spring, seven months after treatment, 60% of the treated nests were dead and 3 of the reopened old nests had not survived. Two new nests were found, one of which was being made by ants from a large partly killed nest (#5).

TABLE XXVII. Summary of Tests Using Methyl Bromide.

A. Large mounds

Mound No.	Condition of mound	Amount in cc.	Activity after 1 mo.	Activity after 7 Mo.	Retreatment Amount	Activity after 1 Mo.
3	Old-broken	50	Slight	Slight		
5	Normal	100	Inactive	Moderate	50cc.	Inactive
6	Old-broken	50	Inactive	Dead		
7	Old-broken	50	Moderate	Normal		
8	Broken	70	Moderate	Normal		
9	Perfect	100	Inactive	Dead		
10	Perfect	100	Inactive	Dead		
13	Normal	100	Inactive	Dead		
20	Long-normal	70	Moderate	Moderate	50cc.	Slight
21	Normal	100	Moderate	Slight		
22	Perfect	100	Inactive	Dead		
25	Old-low	50	Inactive	Dead		

B. Medium sized mounds.

Mound No.	Condition of mound	Amount in cc.	Activity after 1 mo.	Activity after 7 Mo.	Retreatment Amount	Activity after 1 Mo.
1	Low-broken	50	Slight	Dead		
2	Low-broken	50	Slight	Slight		
12	Old-low	50	Moderate	Dead		
15	Broken	80	Moderate	Normal	120cc.	Slight
17	Normal	50	Inactive	Dead		
18	Normal	50	Inactive	Slight	25cc.	Slight
23	Broken	50	Slight	Normal	30cc.	Slight
24	Normal	50	Inactive	Dead		
26	Old-low	-	Moderate	Moderate		
27	Old-low	-	Moderate	Slight		
29	Old-low	-	Moderate	Dead		
32	Old-low	-	Moderate	Normal	20cc.	Dead

TABLE XXVII. Summary of Tests Using Methyl Bromide.

C. Small sized mounds.

Mound No.	Condition of mound	Amount in cc.	Activity after 1 mo.	7 Mo.	Retreatment Amount	Activity after 1 Mo.
4	Normal	50	Inactive	Dead		
11	Low-broken	50	Normal	Dead		
14	Low	30	Normal	Dead		
16	Low	25	Inactive	Dead		
19	Low	33	Inactive	Moderate	25cc.	Slight
28	Old-low	-	Moderate	Dead		
30	Old-low	-	Moderate	Dead		
31	New	-	Normal	Normal	25cc.	Inactive
33	New			Moderate	25cc.	Slight
34	New-double			Moderate	50cc.	Inactive

Of the 16 nests active in the spring 6 were retreated as shown in Table XXVII. Four of the nests that became active after the first application had been made were treated. One month later four of these nests appeared dead. The rest showed some activity. Two new mounds were being developed in new places and two mounds that had shown no activity earlier in the spring showed slight activity.

These tests show that methyl bromide is an effective fumigant for F. exsectoides nests when properly applied. With well shaped mounds, 50 to 100 cc. applied in one spot through an efficient applicator should be enough. In low or broken mounds smaller amounts applied in 3 to 5 places would be better. A total dose of 100 cc. should be ample. When control in a limited area is desired, care should be taken to treat all nests. This includes very old apparently unused mounds as well as all sizes of active mounds.

Tests with paradichlorobenzene.

During the summer of 1944 paradichlorobenzene crystals were placed in one or more holes in each of 8 mounds of various sizes. The hole was made with a trowel, the crystals poured in and the hole filled and pressed down quickly. Table XXVIII shows how much was used in each mound as well as the size and condition of the nest and the results. All except 2 nests showed some damage a month after treatment. One long low nest in a shaded situation (P9) was killed by the application of 1 pound of paradichlorobenzene which had been placed by handfulls in holes well distributed over the mound. This was the only instance of success with this chemical. It was the only nest treated with more than ½ pound of the chemical.

The following spring 5 of the treated nests showed normal activity. Two were moderately active and one nest was weak; the weak colony may have been the result of other factors than the poison.

TABLE XXVIII. Summary of Tests With Paradichlorobenzene

Mound No.	Size of Mound	Date Treated	Amount in Lbs.	Activity after 1 Mo.	Activity after 7 Mo.	Retreatment Amount in Lbs.	Retreatment Activity after 1 Mo.
P1	Large	5-23-44	0.25	Normal	Moderate		
P6	Large	5-28-44	0.50	Normal	Normal		
P2	Medium	5-23-44	0.25	Moderate	Normal		
P3	Medium	5-23-44	0.25	Moderate	Normal	0.25	Normal
P4	Medium	5-23-44	0.25	Moderate	Normal	0.25	Normal
P5	Medium	8-28-44	0.50	Slight	Normal	0.50	Normal
P7	Medium	8-28-44	0.25	Moderate	Slight		
P8	Medium	8-28-44	0.25	Moderate	Moderate		
P9	Medium	6-28-44	1.	Inactive	Dead		
P12	Medium	3-20-45	0.50	Normal			
P10	Small	3-20-45	0.25	Normal			

In the spring of 1945 three of these nests were retreated and two others treated for the first time. After a week, the mounds were not being used much where the chemical had been placed but there was plenty of activity on and about the mounds. No dead ants were seen. A month after treatment, no difference could be seen between treated and untreated nests.

Paradichlorobenzene is not an effective poison to use with F. exsectoides when placed in the mound in one or more spots in one-fourth and one-half pound amounts. With mounds of small and moderate size, a pound of the poison might be effective, if used when soil temperatures were high.

Tests with DDT.

Tests were made with 20% DDT in pyrophyllite and a few strengths of DDT emulsion. The emulsion was made by dissolving 20 parts of DDT in 60 parts of xylol and emulsifying with 20 parts of Triton. This emulsion was diluted to the percent of DDT desired.

On May 3, 1944, 4 mounds were dusted with 20% DDT in pyrophyllite. A summary of conditions and results is given in Table XXIX. Two weeks after treatment, activity of these nests was not greatly changed. One mound (D10) was dusted a second time but activity of the nest remained normal. The others were sprayed with 2% DDT in August. The next spring all were inactive.

On May 3 the same year, 4 mounds were sprayed with .002% DDT emulsion. Two weeks later the nests were all active. Three were re-treated with .002% DDT. The rest of the summer these nests showed activity but the mounds were not repaired or kept free of growing plants. The following spring, one (D1) showed some activity. The other two appeared dead.

In April, 1945, 9 nests were sprayed. (Table XXX). 5 of them were sprayed heavily with .004% DDT emulsion. 3 of these (D16, D17, D18) were low mounds in a grassfield. A week after treatment, dead ants were present on the mound but some of the ants were still carrying on the usual activities of the nest. The other two nests showed no reduction in activity. The same day, four mounds were sprayed with .002% DDT. Dead ants were not found on these mounds and after one month no reduction in activity was apparent.

These tests show that DDT as a dust is ineffective for F. exsectoides. In the emulsion used some ants were killed by .004% DDT. When a .002% spray was used, no great change could be seen. In cases where two applications of this strength were made, small nests were killed. 2% spray after 20% dust killed 3 nests. DDT emulsion shows promise as a poison for F. exsectoides. It has the advantage of not being very poisonous to man and is not dependent on temperature for volatilization.

TABLE XXIX. Summary of 1944 Tests Using DDT.

Mound No.	Mound size	Strength DDT used	Activity after 1 Mo.	Date Re-treated	Strength DDT used	Activity in 6 Mo.
D10	Large	20% Dust	Normal	7-5	20% Dust	Normal
D11	Medium	20% Dust	Normal	8-28	2% Spray	Inactive
D13	Medium	20% Dust	Moderate	8-28	2% Spray	Inactive
D12	Small	20% Dust	Moderate	8-28	2% Spray	Inactive
D4	Medium	.002% Spray	Normal			
D3	Medium	.002% Spray	Moderate	5-23	.002% Spray	Inactive
D2	Small	.002% Spray	Moderate	5-23	.002% Spray	Inactive
D1	Medium	.002% Spray	Moderate	5-23	.002% Spray	Slight

TABLE XXX. Summary of 1945 Tests Using DDT.

Mound No.	Mound Size	Strength of Spray	Activity in 1 Mo.
D14	Small	.004%	Normal
D15	Medium	.004%	Normal
D16	Medium	.004%	Slight
D17	Small	.004%	Slight
D18	Medium	.004%	Slight
D19	Small	.002%	Moderate
D20	3 Small	.002%	Normal
D21	Medium	.002%	Normal
D22	Medium	.002%	Normal

CONCLUSIONS

Under natural conditions, F. *exsectoides* are active from April to October. During this time new colonies are established by swarming, winged males and females develop, and large numbers of young workers are raised. Food is the honeydew obtained from honeydew producing insects found on the trees and the soft parts of insects picked up on the ground. Because part of their food is obtained upon trees, and because warmth, obtained by exposure of the mound to sunlight is necessary, the mounds are found near trees but not in dense forests.

The seasonal rhythm of these ants is correlated with soil temperatures. The ants move toward warmer parts, down in the soil to hibernate in the fall and up to the surface in the spring.

Groups of F. *exsectoides* workers with 1 or 2 queens can be placed in artificial nests of the Fielde type and when the temperature, moisture and food are correct, eggs will be laid, hatch, larvae be fed until they spin up, and pupae emerge as callows. For best results, the artificial nests should be started in Nov. or Dec. When held at approximately 70F., such groups of F. *exsectoides* will break hibernation in about 4 weeks. Activities approximating those of colonies in nature during May and June will be carried on for 6 months. In artificial nests, temperatures above 75 F. are detrimental while normal activities are not carried on at temperatures below 60 F.

In artificial nests held at approximately 70 F., eggs require an average of 19.4 days to hatch, larvae complete development in an average of 37.1 days and pupae need an average of 25.1 days before callows emerge. Two weeks are required for the callows to darken into normal workers.

With low humidity and no food or water, most F. *exsectoides* workers die in 48 hours. With high humidity many can survive for 5 to 7 days.

High humidity is necessary for artificial nests to continue normal activities. Given water alone, artificial nests may survive 2 months. Water is necessary even when liquid food is given.

In feeding artificial colonies of F. exsectoides, liquid food is more satisfactory than solids. Artificial colonies given a protein only survived 2 months. Colonies fed only diluted honey survived longer but larvae never completed development. All successful foods were mixtures of a carbohydrate and a protein. Twenty-five percent honey was the most satisfactory dilution. The honey supplies the carbohydrate and some of the minerals and vitamins since similar strengths of the pure sugars do not enable larvae to complete development. Liver broth or 250 milligrams of liver extract per 100 cc. of liquid satisfactorily supply the rest of the minerals and vitamins as well as the proteins.

Since F. exsectoides has been shown to be of economic importance because it injurs young trees in the north and annoys man in the south control becomes necessary. Because the food used is varied and this species is discriminating, poisoned bait was unsatisfactory as a method of extermination. Fumigation with one-fourth and one-half pounds of paradichlorobenzene was unsuccessful. DDT as a dust was ineffective but as a spray was promising. Regulated according to size and properly applied, 25 to 100 cc. of methyl bromide per mound was effective. In attempting control in a limited area, inactive as well as all active mounds should be treated at one time to reduce reinhabitation by foraging and escaped ants.

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