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Investigation on the foraging behaviour of *Monomorium pharaonis* (Hymenoptera: Formicidae)

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Abstract
Mass recruiting and ant pheromone trail is a characteristic behaviour of large ant colonies of *Monomorium pharaonis* commonly known as pharaoh ants, an invasive ant species with an efficient foraging strategy. The present study on pharaoh ants is to analyse ant trails when food material is placed at different distances from the ant colony (20 cm, 40 cm, 60 cm) keeping the amount of food constant, ant trail analysed when different food quantities (0.95g, 1.85g, 3.7g) were placed keeping the distance between the food material and the ant colony constant and also the change in the ant trail when an obstacle is placed in its path. Number of ants recruited to the food material and the corresponding time taken for recruitment were recorded. Significant behaviour shown by ants during trail formation and the number of ants feeding on the food material were also recorded. More ants were recruited to the food source when distance of food material from the ant colony was 60 cm. Time taken for recruitment was also more when compared to two other distances. Number of ants feeding on the food material and distance showed a positive correlation. More number of ants were recruited when the quantity of food material was 3.7g. Time taken for recruitment was also less when compared two other quantities. A positive correlation was seen between number of ants feeding and quantity of food material. Branching of trail was observed when distance was larger and quantity was higher. Characteristic behaviours that were observed when ant trail was exposed to repellent was cooperation, competition and necrophoresis. Their interaction with each other and by trail pheromone enables them capable of selecting the shortest possible path with greater reliability when an obstacle was placed on its path. Time taken to completely feed on a given quantity of food depended on its quantity. These experiments and their results highlight how rapidly the ants can adjust to the changes put forth in their environment by interacting with each other and also by their sophisticated trail system which have strongly contributed to their dominance over other ant species as a notorious home pest. The behavioural studies on these ants would enable better way to handle them and develop methods to keep them away from human habitation.

Keywords: foraging, *Monomorium pharaonis*, pheromone, trail, repellent

Introduction

Ants are eusocial insects. The word “Ant” is derived from related words in languages like middle English, old English, Dutch and Modern German. The original meaning of the word is
“the biter”. Ants belong to the family Formicidae and order Hymenoptera which includes other insects like bees, wasps etc. In 1966, E.D. Wilson and his colleagues discovered the earliest known fossils of ants that lived in the Cretaceous period. They were found to have features of wasps, but not of modern ants (Wilson *et al*., 1967) [39]. Ants are thought to have evolved after the emergence of flowering plants about 100 million years ago. The termites and ants have similar social structure and that is attributed to convergent evolution (Thorne, 1997).
Ants show cosmopolitan distribution and therefore found in all continents except Antarctica and few large islands like Greenland and Iceland (Jones and Alice, 2008). Most of the ant species are omnivorous but few show specific feeding habits. They occupy a wide range of ecological niches and take in a variety of food sources, they act as predators and scavangers as well. Ants are estimated to contribute 15-20 percentage of total terrestrial animal biomass, exceeding vertebrates (Shultz, 2000). Ants have a distinct morphology were the body segments include head, mesosoma and metasoma. An ant head contains many sensory organs. They have a pair of compound eyes, which helps them to detect acute movements that do not offer high resolution images. They also have three small ocelli otherwise known as simple eyes on top of the head that detect light levels and polarization (Fent and Wehner, 1985). Smaller species of ants tend to have blurry vision (Palavalli and Narendra, 2018). Few subterrareans are completely blind, however some ants such as the bulldog ants of Australia have excellent vision and are capable of discriminating different targets within the range of 5-80 cm that are moving nearly a meter away (Erikkson, 1985). Another important sense organ found in the head of the ants are a pair of antennae which helps them to detect chemicals, air currents, vibrations and are used to impart and receive signals through touch. The presence of two strong jaws and the mandibles helps them to carry food, move objects, construct nest and for defence (Borror *et al*., 1989). In some species infrabuccal chamber, which is located inside

the mouth stores food, and may be used to feed other ants or their larvae (Eisner and Happ, 1962). The mesosomal segments of ant bear legs and wings. The legs end in a hooked claw which helps them hook on and climb surfaces.

Mass recruiting and ant pheromone trail is a characteristic behaviour of large ant colonies with their biomass subdivided into many small workers. It is found in species like *Iridomyrmex*, *Solenopsis*, *Myrmica*, *Monomorium* etc. *Monomorium pharaonis* commonly known as pharaoh ants is an invasive ant species with cosmopolitan distribution. It is an important pest in homes and hospitals where it can transmit a variety of diseases. Pharaoh ants are thermophilous and are restricted to warm indoor locations in temperate areas (Beaton, 1972), it cannot survive winter without protection. *Monomorium pharaonis* has an efficient foraging strategy and they use chemical signals which gives them the ability to thrive even in areas dominated by other species of ants. Pharoah ants are notorious home pest whose foraging has been found to be more prevalent outside. Even inside, colonies are found to forage close to windows (David *et al*., 1994). Scouts of pharaoh ants search independently for food source, they use a distinct trail system that remains constant. Pharaoh ants are the most suitable animal model for studying ant trails as they have a distinct trail system that consists of one to four trunk routes. Each trunk divides into many branch routes and this is based on the availability of food (Sudd, 1960). In the absence of food, a colony would extend its trails to a wider radius around the nest (Fourcassie and Deneubourg, 1992). The fork in the trail system which spreads at an angle between 50˚ and 60˚ provides a different explanation of pharaoh ants foraging ability. The foraging behavior and the extensive ant pheromone trail system of pharaoh ants should be understood and studied precisely as they are the most notorious home pest and a great nuisance to humans since they feed and carry pathogens to prepared food and sterile equipments in hospitals. The behavioural studies on these ants would enable better way to handle them and also develop methods to keep them away from human habitation.

Therefore the objectives of this project work is as follows:

- To analyze the pharaoh ant trail towards the food material placed at different distances from the colony with the constant food source.
- To evaluate the trail of the pharaoh ants when different quantities of food material are placed with constant distance from the colony.
- To observe the time taken by an individual pharaoh ant to locate the food and establish the trail.
- To study the pharaoh ant trail when an obstacle is kept in its path.
- To investigate the pharaoh ant trail when exposed to a repellent.
- To evaluate the time taken by the pharaoh ants to completely feed on a given quantity of food.

Materials and Methods

Analysis of the trail of pharaoh ants on constant quantity of food at different distances from the colony

Locating the pharaoh ant colony

A pharaoh ant trail can be easily spotted anywhere in the house where food is handled. One should find the origin of the ant trail. To locate the exact spot of the ant nest or ant colony careful observation of the ant trail, the route it draws to collect its food and back to its nest should be noted.

Experimental arena

Once the ant colony is located, a chart paper of size 70 x 56 cm was laid on the surface near the colony. Before laying the chart, it was made sure that no other ant trails were emerging from the located ant colony. A distance of 20 cm was measured using a measuring tape from ant colony where the food material was placed. The food material can be anything sweet and aromatic which attracts ants. The experiment was conducted using biscuit powder as the food material. The same was repeated with 40 cm and 60 cm from the ant colony. Fresh powdered biscuit of weight 3.5 gms was used for all the three distances.

Collection of data

The experiment was carried out in the morning hours, when pharaoh ants are generally active and ceases activity at night (Jackson *et al*., 2004). Once the experimental arena was set up, with food material placed at specific distances (20 cm, 40 cm and 60 cm) from the ant colony, the time taken to reach the food material was noted. Number of ants recruited to the food material was counted and the corresponding time taken for the recruitment was noted down. Other significant behaviors shown by ants during the trail formation were examined and noted. After 35 minutes of observation, using a magnifying glass the number of ants feeding on the biscuit powder was recorded. The present study of ant trail when food material was placed at three different distances (20 cm, 40cm and 60 cm) from the ant colony was performed on 3 days. A graph was plotted with the number of ants recruited versus time taken for distances 20 cm, 40 cm and 60 cm and was analyzed.

Evaluate the ant trail at constant distance with different food quantities.

Locating pharaoh ant colony

Pharaoh ant colony was located in the crevice of a concrete wall in the balcony by successfully following an active ant trail.

Experimental arena
A chart paper of size 70 x 56 cm was laid on the surface near to the ant colony. Using a measuring tape, a distance of 35 cm was measured from the ant colony and a spot was marked. At this spot, the same biscuit powder used in the previous experiment freshly powdered was placed as a food material to attract ants. Three different quantities (3.7gms, 1.85gms and 0.92gms) of biscuit powder was weighed using a weighing scale and was conducted as three separate experiments in which each quantity of biscuit powder was placed at a distance of 35 cm away from ant colony.

Collection of data
Once the experimental arena is ready, 3.7 gms of biscuit powder (food material) was placed at the spot marked, 35 cm away from the ant colony. As soon as the biscuit powder was placed, the time was noted. Number of ants recruited towards the biscuit powder was counted and the corresponding time taken for recruitment was also noted. Experiments were carried out in two different days for 1.85gms and 0.92 gms of biscuit powder by placing them 35 cm away from the ant colony. The other significant behaviors shown by ants during the trail formation were examined and noted. After 35 minutes of observation, using a magnifying glass, the number of ants feeding on the biscuit powder was recorded. With the number of ants recruited versus the time taken for three different quantities of biscuit powder, a graph was plotted and the results were analyzed.

To observe the time taken by an individual ant to detect the food with varying distance and quantity.
Locating the ant colony
Pharaoh ant colony was located in the crevice of a concrete wall in the balcony by successfully following an active ant trail.

Experimental arena
For distance: A chart paper of size 70 x 56 cm was laid on the surface near to the ant colony. Before laying the chart paper on the surface, it was made sure that no other ant trails were emerging from the located ant colony. A distance of 20 cm was measured using a measuring tape from ant colony where the food material (powdered biscuit) was placed. The experiment was carried out with 40 cm and 60 cm from the ant colony. Fresh powdered biscuit of weight 3.5 gms was used for all the three experiments.

For quantity of food: Using a measuring tape, a distance of 35 cm was measured from the ant colony and a spot was marked. At this spot, the same biscuit powder used in the previous experiment freshly powdered was placed as a food material to attract ants. Three different quantities (3.7gms, 1.85gms and 0.92gms) of biscuit powder was weighed using a weighing scale and was conducted as three separate experiments in which each quantity of biscuit powder was placed at a distance of 35 cm away from ant colony.

Collection of data
For distance: The time taken by individual ant to locate food material was noted down. The experiment was conducted by placing one distance per day. The experiment was designed in such a way to get accurate results.

For quantity of food
The time taken by individual ant to locate food material was recorded. The same procedure was followed in two different days for 1.85 gms and 0.92 gms of biscuit powder respectively.

To study the effect of repellent on ant trail
Locating the pharaoh ant colony
Pharaoh ant colony was located in the crevice of a concrete wall in the balcony by successfully following an active ant trail.

Experimental arena
It was made sure that no other ant trails emerge from the crevice of the concrete wall while setting up the experimental arena. A chart paper of size 70 x 56 cm is laid on the surface near to the ant colony. At any distance, away from the ant colony, a spot is marked where powdered prawns of unknown quantity is placed. Powdered prawn is a very good attractant to ants. It helps in fast formation of an active ant trail.

Experiment
Approximately 20-25 minutes was taken for an active trail to be formed from ant colony to the powdered prawn. Once the active trail was formed, using an ant repellent chalk a circle was drawn around the powdered prawn enclosing it.
The following was noted down and analyzed:

- The immediate change in the ant trail just after the repellent was applied around the prawn powder (food material).
- The immediate behavioral changes of ants feeding on the prawn powder.
- Changes in ant trail and behavior of ants after 10-15 minutes.

- Changes in ant trail and its behavior after 30 minutes of exposure to the repellent.

To study the ant trail, when an obstacle is placed on its path.
Locating the pharaoh ant colony
Pharaoh ant colony was located in the crevice of a concrete wall in the balcony by successfully following an ant trail.

Experimental arena
It is made sure that no other ant trails emerge from the fissure of the concrete wall while setting up the experimental arena. A chart paper of size 70 x 56 cm is laid on the surface near to ant colony. Using a measuring tape, a distance of 40 cm is measured from the ant colony where the food material is placed.

Experiment
Once an active ant trail is formed to the food source from the ant colony, a 15 cm ruler is placed on the path of ants, which acts as an obstacle to the ants path. The behaviour of the ants towards the obstacle placed on its path was closely observed and recorded.

To evaluate the time taken by ants to completely feed on a given quantity of food
Finding ant colony
Pharaoh ant colony was located in the crevice of a concrete wall in the terrace.

Experiment
An unknown quantity of biscuit powder (food material) is placed near the ant colony and was left undisturbed for some time. The initial quantity of the biscuit powder was observed, when ants were just attracted to the powdered biscuit. Similarly the quantity of biscuit powder and the ants recruited were observed after 110 minute. Observations were made after 170 minutes, 235 minutes, 250 minutes, 270 minutes, 275 minutes and finally at 280 minutes.

Result
Analysis of the trail of pharaoh ants on constant quantity of food at different distances from the colony.
At 20 cm
Pharaoh ants were able to locate the food material and the recruitment of the ants towards the food source was very fast which resulted in formation of a rapid ant trail. The number of ants feeding on the powdered biscuit (food material) was found to be 40.

At 40 cm
Pharaoh ants took more time to locate the food material and recruit ants to it than when the food material was placed 20 cm away from the ant colony. Ants showed a tendency to split the single trail that was initially formed and followed, into two separate ant trails. The number of ants feeding on the powdered biscuit (food material) was found to be 105 when observed through a magnifying glass.

At 60 cm
It was observed that ants took more time to locate the food material, once over 20 ants were recruited to the food material, there was a fast recruitment of ants without much delay, with 45 ants emerging from the nest within one minute.
A long ant trail was observed from the nest. The number of ants feeding on the powdered biscuit (food material) was found to be 160 when observed through a magnifying glass.
Highest recruitment of ants were observed when distance between the food material and ant colony was 60 cm. The number of ants feeding on the food material was also high at this distance. A correlational study was done between the number of ants feeding on the food material and the distance. The Karl Pearson's coefficient of correlation (r) was determined, by the following formula which projects the magnitude of correlation between two variables in numerical terms.

$$(r) = \frac{\Sigma (x-\bar{x})(y-\bar{y})}{nS_xS_y}$$

Where; x = Distance, $\bar{x}$ = Average distance, y = Number of ants feeding on the food material $\bar{y}$ = Average number of ants feeding on the food material n = Number of variables
S_x = Standard deviation of variable x
S_y = Standard deviation of variable y

The Karl Pearson's coefficient of correlation is 0.92, indicating a positive correlation.

Evaluate the ant trail at constant distance with different food quantities.

Food quantity - 0.92 gms

Pharaoh ants drew a single ant trail while foraging. They used this single trail to reach the food material and get back to the colony with the food. The number of ants feeding on the powdered biscuit (food material) was found to be 25.

Food quantity - 1.85 g

Two ant trails were observed from the ant colony to the food material. One trail was used by the unfed ants from the colony to the food material and the other trail directed ants back to the colony. The number of ants feeding on the biscuit powder (food material) was found to be 35.

Food quantity - 3.7 g

On observing the ant trail, it was found that ants reached the food material not by single trail but from two trails emerging from the colony, from two different directions. The number of ants feeding on the biscuit powder (food material) was found to be 45.

More number of ants were recruited to the food material when the quantity was higher in a shorter duration. Ants showed the tendency to form multiple trails from ant colony when the quantity of food was more. A correlational study was done between the number of ants feeding on the food material and its quantity. The Karl Pearson's coefficient of correlation (r) was determined, by the following formula which projects the magnitude of correlation between two variables in numerical terms.

$$(r) = \frac{\Sigma (x-\bar{x})(y-\bar{y})}{nS_xS_y}$$

Where; x = Quantity of food material (powdered biscuit)

$\bar{x}$ = Average quantity of food material

y = Number of ants feeding on food material $\bar{y}$ = Average number of ants feeding on the food material

n = Number of variables

S_x = Standard deviation of variable x

S_y = Standard deviation of variable y

The coefficient of correlation between the number of ants feeding on the food material and the quantity of food material is 0.98, which indicated a positive correlation.

To observe the time taken by an individual ant to detect the food with varying distance and quantity.

To study the extent of correlation between distance and time taken by individual ant to locate food, a scatter diagram was constructed. The time taken was depicted on the X axis and distance on Y axis. The results show a positive correlation. To study the extent of correlation between the quantity of food material and time taken by an individual ant to locate the food, a scatter diagram was constructed. The time taken is depicted on the X axis and quantity of food on the Y axis. The results show a negative correlation.

To study the effect of repellent (deltamethrin and cypermethrin) on ant trail.

Change in the ant trail.

The entire ant trail got disturbed, the ants approaching food material paused for a second like they have sensed some danger and moved back towards their nest. This stimulated the other ants approaching the food material to get back to the colony. Ants which were feeding on the food material, stopped feeding and moved quickly away from the food source.

Behavioural changes on feeding.

Few seconds after applying the repellent, some ants that were feeding on the food material moved very fast, crossing the repellent without carrying food. One or two ants were observed to carry food material across the repellent with the help of two or three other ants. Some ants crossed the repellent and this crossing of ants was at points where the application of the repellent was minimal. Ants were not able to cross the area highly concentrated with the repellent. Most of the ants that were feeding on the food material stopped feeding and moved slowly around the food material and became inactive.

Changes in the ant trail and behaviour of ants after 10-15 minutes of exposure to the repellent

Many ants that crossed the repellent died on their way back to the ant colony, many dead ants were seen around the repellent, within the repellent and near the colony. All the ants near the food material were also found dead (Figure 16).

Changes in the ant trail and its behaviour after 30 minutes of exposure to the repellent.

One ant was observed to carry a dead ant far away from the experimental arena and from the located ant colony. The little black ants which are a different species of *Monomorium* were found to invade the experimental arena.

More pharaoh ants were recruited from its ant colony and they were looking for an alternate path to the food material which was enclosed within the repellent.

To study the ant trail, when an obstacle is placed on its path.

As soon as the obstacle (15 cm ruler) was placed on the path of the ants, the active ant trail got disturbed. Ants started to move away from the trail. After five minutes, two or three groups of ants started to stroll around the obstacle (ruler), in order to re-establish the ant trail. The ants were found to concentrate on a particular region of the obstacle, which seems to lead them to the shortest possible path they can take either to reach the colony or towards the food source. After a couple of minutes, the active ant trail that was disturbed by an obstacle was reestablished. It was observed that ants took the shortest possible path.

To evaluate the time taken by ants to completely feed on a given quantity of food.

A total of 4 hours 40 minutes were taken by ants to completely feed on the food material. The initial quantity of food material and the number of ants recruited was recorded (Figure 21). The quantity of food material and the number of ants recruited after 110 minutes, 170 minutes, 235 minutes, 250 minutes, 270 minutes, 275 minutes and 280 minutes were depicted (Figure 22, 23, 24, 25, 26, 27, 28). It was observed that over a period of time the number of ants recruited increases, but after 170 minutes there was a rapid decrease in the number of ants recruited with decrease in the quantity of food.

Table 1: Number of ants recruited and the time taken for recruitment to reach a distance of 20 cm between the food material and ant colony

Number of ants recruited	**1**	**3**	**10**	**15**	**20**	**25**	**30**
Time taken (minutes)	2	5	6	7	8	9	10

Table 2: Number of ants recruited and the time taken for recruitment when distance between the food material and ant colony is 40 cm

Number of ants recruited	**1**	**2**	**8**	**12**	**20**	**27**	**35**
Time taken (minutes)	5	8	10	11	12	13	14

Table 3: Number of ants recruited and the corresponding time taken for recruitment when distance between the food source and ant colony is 60 cm

Number of ants recruited	**1**	**6**	**13**	**20**	**24**	**35**	**50**
Time taken (minutes)	6	20	23	24	25	26	27

Table 4: Number of ants recruited and the time taken for recruitment when the quantity of food material placed is 0.92 gms

Number of ants recruited	**1**	**2**	**4**	**8**	**11**	**15**	**25**
Time taken (minutes)	4	6	8	9	9	10	11

Table 5: Number of ants recruited and the time taken for recruitment when the quantity of food material placed is 1.87gms

Number of ants recruited	**1**	**4**	**6**	**8**	**21**	**30**	**38**
Time taken (minutes)	2	3	4	6	7	7	8

Table 6: Number of ants recruited and the time taken for recruitment when the quantity of food material placed is 3.7 gms

Number of ants recruited	**1**	**5**	**7**	**10**	**25**	**30**	**50**
Time taken (minutes)	1	2	3	4	6	7	8

Table 7: Time taken by an individual ant to locate the food when placed at different distances from the ant colony

Distance (cm)	**Time taken (minute)**
20	2
40	5
60	6

Table 8: Time taken by an individual ant to locate the food material placed at a distance of 35 cm from the ant colony at different quantities

Weight (grams)	Time taken (minute)
0.92	4
1.85	2
3.7	1

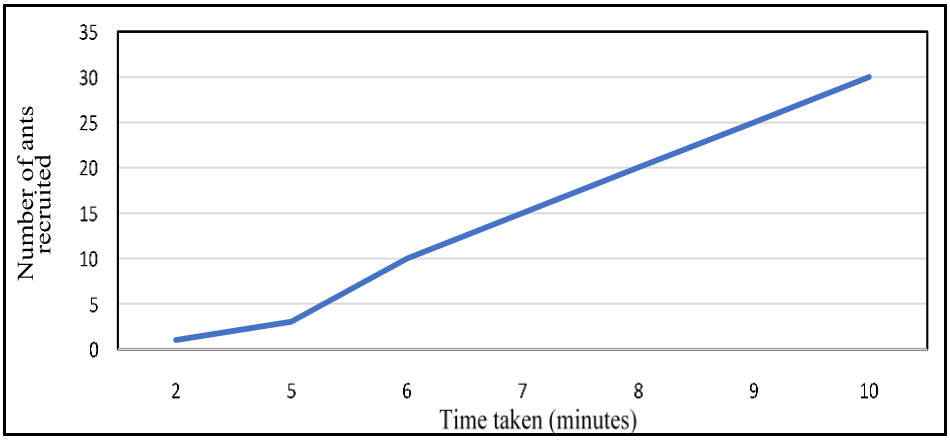

Fig 1: Number of ants recruited Vs time taken when distance is 20 cm

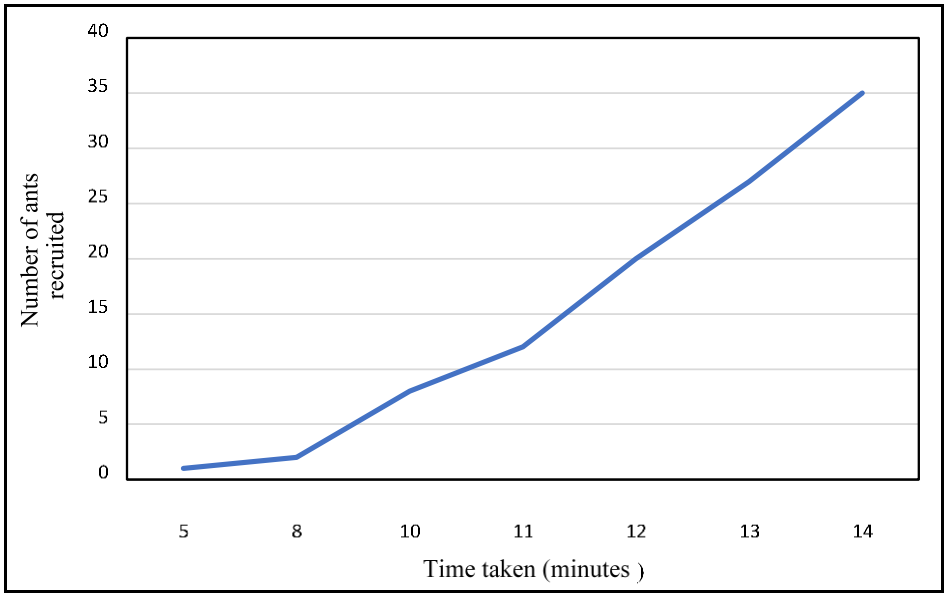

Fig 2: Number of ants recruited Vs time taken when distance is 40 cm

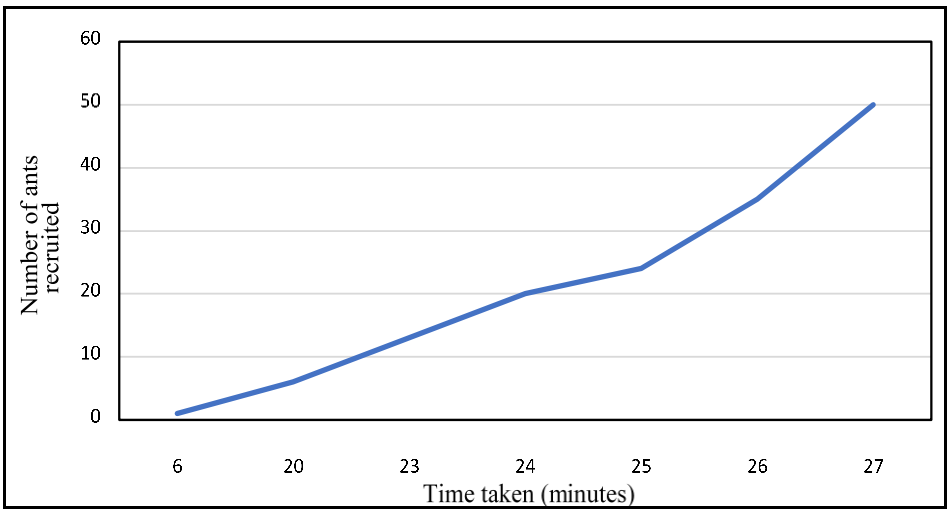

Fig 3: Number of ants recruited Vs time taken when distance is 60 cm

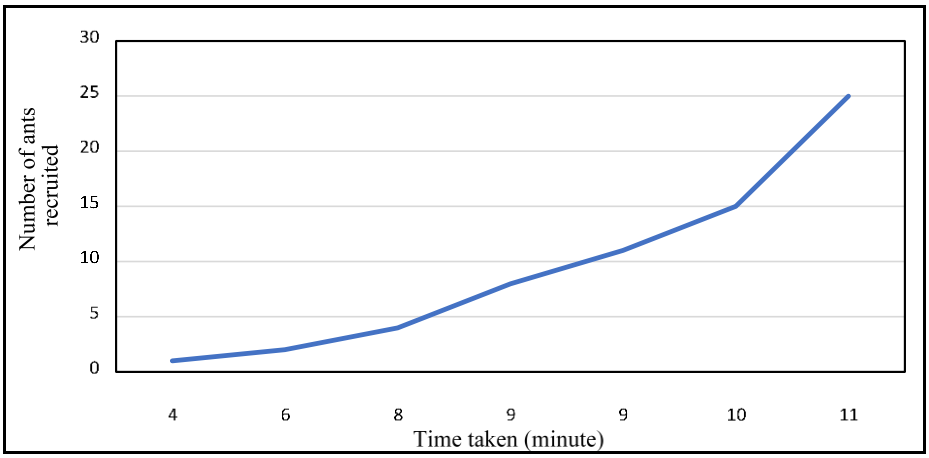

Fig 4: Number of ants recruited Vs time taken when the food quantity is 0.92 gms

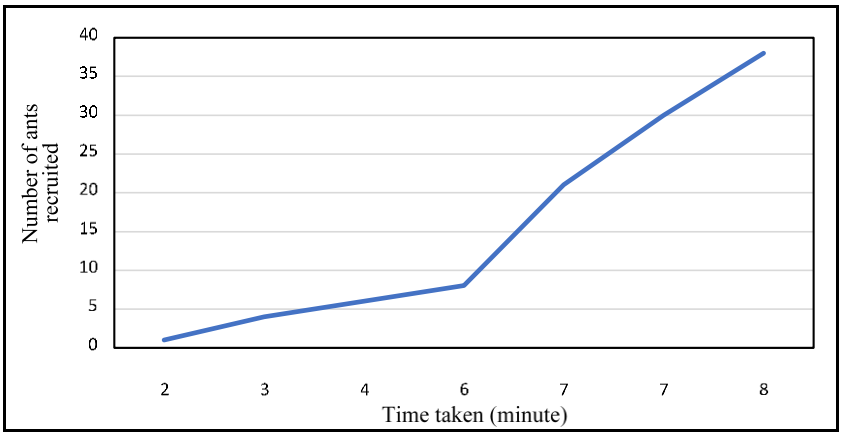

Fig 5: Number of ants recruited Vs time taken when food quantity is 1.85 gms

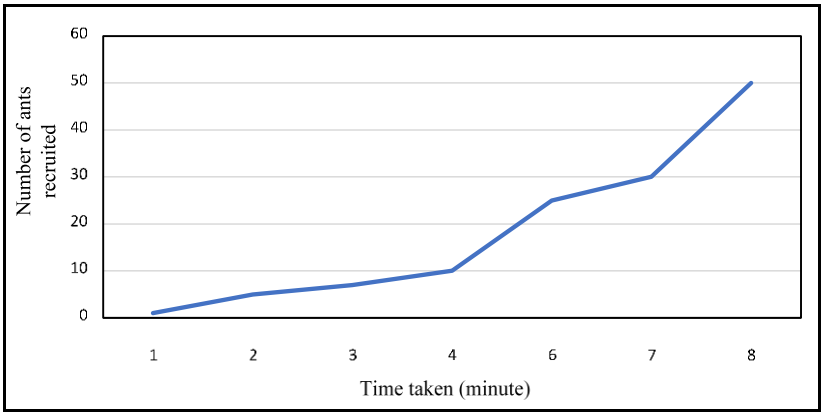

Fig 6: Number of ants recruited Vs time taken when food quantity is 2.7 gms

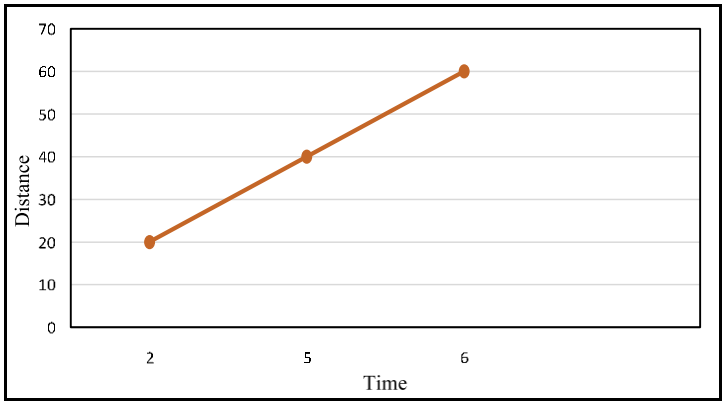

Fig 7: Distance and time taken by an individual ant to locate food material (Positive correlation)

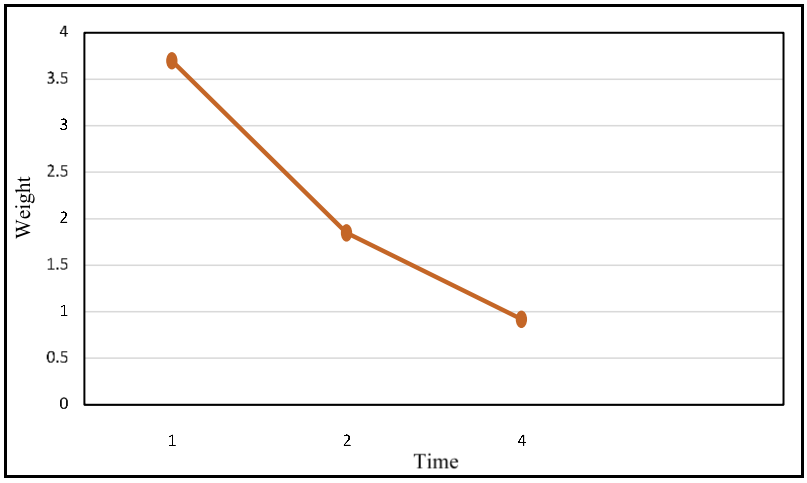

Fig 8: Food quantity and time taken by an individual ant to locate food material (Negative correlation)

Discussion

When the colony was in need for food, an individual ant gets out of the colony in search of food. Distance travelled by the individual ant depends on the availability of food. Ants have a good sensory system which enables them to easily sense the presence of food from their scent. The recruitment of foragers to the site of food depends on the ant species, its size, density and quality of food. The food intake by the foragers also depends on the colony's current nutritional status (Traniello, 1989) [37]. The present study brings the importance of another factor in recruitment of foragers to the food site which is the distance between the food material and the ant colony. If the distance between the food material and the ant colony is larger it takes more time to get to the food and to take it back to the colony in order to feed the queen and larvae in the nest. A collective behaviour was observed in ants where they recruit more number of foragers to collect food from the site efficiently. The recruitment of ants to the food site took time initially, but after a group of 20 or more ants were recruited, a fast recruitment of many ants per minute were observed. And its mainly because a group of ants have already formed an ant trail, which could be easily followed by other foragers emerging from the ant colony. The foraging workers of pharaoh ants are oriented to the trail scents laid by other workers returning from the nest after locating the food. The recruits while following the trail, reinforce it with new scent which enables many more recruits to follow the trail to the food material. When distance between the food material and ant colony was larger, splitting of single ant trail into two or more branch routes were observed. The branch they followed was based on the availability of the food material (Sudd, 1960). Due to more number of ants recruited it brought in forager traffic near a food source, as a result a single ant trail was divided into two or more branch routes.

When the distance between the food material and ant colony was short, the ants were recruited to the food material fast as they were able to locate the food easily by its scent since they were placed near to the ant colony. As the distance between the food source and ant colony was shorter, not much labor was needed, therefore less number of ants were recruited. To reduce the travel time or search time there was a direct channelling of foragers of other colony to the food source.

Studies prove that, the recruitment of ants to the food site depends on the density or quality of food (Traniello, 1989) [37]. The present study indicates that the quantity of food material also played a role in the recruitment of ants. An individual ant locates food material, examines the quantity of the food material and transfers the information to other foragers when they reach the nest which influences the recruiting behavior of foragers. Ant trail differs for different quantities of food material. Rich quantity of food was exploited by majority of workers, with strong trails and high response. It was discovered that two different pheromones were used which regulates the behavior of ants during exploration of food material. One is the long-lasting pheromone which induces less response and the other the short-lasting pheromone laid on exploration of food which elicits greater response (Dussutour *et al.*,2009) [11]. A significant branching of the trail was observed when the quantity of food material was 3.7g. A single trail was observed when quantity was 0.92 g, this single trail was used by the ants to get to the food and to return to the colony. But as the number of ants recruited increased, more than one trail was observed emerging from the ant colony to the food source. This, may be to maintain the forager traffic. Increase in the quantity of food material can also directly channelize foragers from other ant colonies in course of time.

The time taken by an individual ant to locate the food material would be the search time taken by ants. It was discovered that search persistence increases with the distance of the food from the nest (Hempel, 1984) [36]. The scatter diagram was constructed to show the correlation between distance and time taken by individual ant which indicated a positive correlation. The recruitment behaviour of ants entirely depends on the quantity and quality of food material presented. Greater food availability, leads with shorter foraging trip (Beverly *et al.*, 2009) [1]. Greater the quantity of food material higher the concentration. It was found to emit more scent than less quantity food material. Ants have good sense organs to locate the food quickly. The scatter diagram constructed to show the correlation between the quantity of food and time taken by an individual ant indicated a negative correlation.

Four significant observations were made when a repellent (chalk-deltamethrin and cypermethrin) was applied on the path of the ant trail. The first observation noted was the immediate change on the ant trail when repellent was just applied around the food material. The notable changes were, ants stopped feeding on the food material and started to move away from the food source back to the colony. This behavior was exhibited due to an unknown material which brought in repellence and its harmful effects were exposed to the ants. In the second observation, ants were identified to carry the food and cross the repellent with the help of other ants. This exhibits the cooperative behaviour of ants. The effect of repellent depends on the substrate on which it was applied (Buckzkowski, 2005) and the application of the repellent onto the substrate evenly. Repellents applied thin exhibited less effect to the ants than applied thick.

The ants were dead after 15 minutes of exposure to the repellent. Since the repellent chalk contains deltamethrin and cypermethrin and are neurotoxins that can cause paralysis and dehydration in insects (Guoping *et al*., 2005).

Three significant behaviours were shown by ants after 30 minutes of exposure to the repellent. One is necrophoresis, an important behaviour carried out by social insects like ants, bees, wasps etc., where they carry the dead bodies of the members of the same colony from the nest or the foraging area. Dead ants were carried by other healthy workers away from the experimental arena as a sanitary measure to keep the foraging area and nest clean. As the effect of the chalk powder gets reduced it results in re-emerging of pharaoh ants from the colony, where they begin to forage and find alternate paths to reach the food source. The little black ants belonging to the genus *Monomorium* starts to invade the foraging area of the pharaoh ants, as they are generally weak. This invasion by the little black ants would not happen if the pharaoh ants trails were active.

Ants find the shortest possible path to deposit pheromones on the new identified path so as to enable the foragers to realign and to establish a new trail. Ants were found to be slightly efficient on their way back to the nest than to the food source. As the probability of choosing the shortest possible path to nest was more than to a food source (Vittori *et al*., 2005) [38]. Ants in general travel long distances between their colony and the food source. They may encounter innumerable obstacles in their path, though they are capable of visual communication. Their interaction with each other and by trail pheromone enables them capable of selecting the shortest possible path with greater reliability.

The time taken by ants to feed on a given quantity of food depends on the quantity of food provided. If more quantity of food more recruitment of ants to the food material and takes more time to completely feed on the given quantity of food. In due course of time the quantity of food decreases, as it is being carried by foragers to their nest in their crop. As the quantity of food material decreases, the number of ants recruited also decreases, to save labor and energy of the ant colony. Once the ants have completely fed on the food material, two or three groups of ants explore around, to locate unattended food particles if any. They completely clean up the site, with no food particles around.

Conclusion

Ants are said to be one of the true social insects that are best studied among social insects like wasps, bees and termites. Ants have an established colony with thousands of individuals that live and work together to perform different tasks. The queen's job is to lay eggs, whereas the workers collect the food to the colony, take care of the young and protect the colony. This collective behavior is due to the interactions among individuals. Collective behavior in ants is related to the environmental conditions. Different behaviors like foraging trail networks, other foraging behaviors, defensive behavior, reflect the ecological factors such as climate, resource distribution, risk of infection etc. Mass recruiting and ant pheromone trail are characteristic behaviors of large ant colonies with many small workers. Many species of ants create networks of foraging trail, among them the most intensively studied species are *Monomorium pharaonis*, an invasive species that is distributed worldwide. They have a large colony, that bud easily and compete strongly with other species. They are considered as the most suitable animal model for studying the ant trail as it has a distinct trail system that consists of one to four trunk routes. The trail network connects the ant colony to the food source and are easily established and increases the foraging rates, as pheromones are used to create an elaborate system of ant trail. Apart from this pharaoh ants are one of the few ant species that can be reared in the laboratory for many generations and is possible to do control crosses between the colonies. They are easy to keep in lab and can be easily induced to do things one wants to study, such as to form trails. This is because they are easily evolved to deal with rapid changes in the environment. The present study shows how rapidly they can adjust to the changes put forth in their environment by interacting with each other and by their sophisticated ant trail system, which have strongly contributed to their dominance over other ant species as a notorious home pest.

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