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Evaluation of toxicity effect of different insecticides against *Camponotus compressus*

Rimsha Waheed[1], NaheedBano[1*], Naeem Iqbal[2], Sheikh Muhammad Azam[3], Muhammad Asif Raza[1],Warda Khan[1], Nargis Naheed[1], Saima Samreen[1], Nazuk Kareem[3], Hassan Raza Javed[4], Qasim Raza[5], Muhammad Imran[6], Muhammad Ejaz[6], Muhammad Khalid[7]

[1]Faculty of Veterinary & Animal Sciences, MNS-University of Agriculture, Multan.
[2]Faculty of Agriculture, MNS-University of Agriculture, Multan.
[3]Department of Zoology, Division of Science and Technology, University of Education, Lahore, Punjab, Pakistan
[4]Department of Botany, Govt Graduate College Layyah, Punjab, Pakistan
[5]Department of Statistics, Govt Graduate Millat College, Multan, Punjab, Pakistan
[6]Department of Statistics, Bahauddin Zakariya University, Multan, Punjab, Pakistan
[7]Department of Zoology, Govt Graduate Millat College, Multan, Punjab, Pakistan

Corresponding author: naheed.bano@mnsuam.edu.pk

Abstract

Carpenter ant species play a significant ecological role and are widely prevalent. Ants contribute to safeguarding plants from sap-sucking pest insects through natural biological control mechanisms. The current study was conducted to collect ants from Block B farms at Muhammad Nawaz Sharif University of Agriculture, Multan (MNSUAM), Pakistan. In current study, various insecticides (such as Imidacloprid, Fipronil, Methoxyfenozide, Emamectin benzoate, and Flubendiamide) were formulated at different concentrations (including 160, 80, 40, 20, 10, 5, and 0 ppm) for evaluation against carpenter ants. Notably, Fipronil and Emamectin benzoate exhibited heightened toxicity, even at lower doses of 5 ppm and 10 ppm, resulting in the mortality of nearly all worker ants within 24 hours. In contrast, Imidacloprid displayed no distinct preference, as most worker ants remained alive even after 72 hours. These findings indicate that Fipronil and Emamectin benzoate may serve as effective active ingredients for controlling carpenter ants. The data was meticulously recorded and subjected to rigorous statistical analysis using specialized software.

Keywords: Ants, Toxicity, Synthetic insecticides, LC_{50}, *Camponotus compressus*

1. Introduction

In recent decades, there has been growing interest in eusocial insects owing to their remarkable social structures, their widespread presence and abundance in tropical regions.[1-2]Among eusocial insects, carpenter ant species having workers of different sizes which can be separated by their small (minor), medium (intermediate) and large (major) size.[3-4]Within the realm of terrestrial ecosystems, ants have garnered significant attention owing to their vital ecological contributions and their intricate relationships with a diverse array of organisms, including insects, plants, and microorganisms.[5-10]

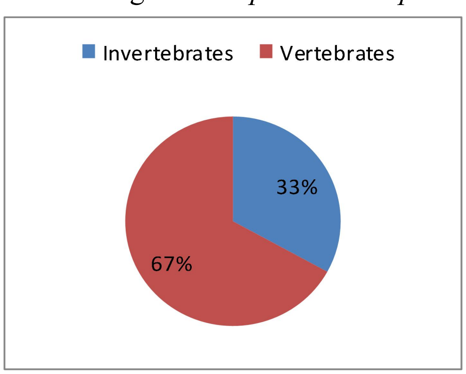
Ants considered as the social insects of family Formicidae and order Hymenoptera.[11] Currently study, total 1,058 species, 495 subspecies and 31 fossil species of *Camponotus* are known worldwide, with 62 species and subspecies reported from India.[12]Despite their large size and abundance, carpenter ants are difficult to identify. The Global Ant Biodiversity Informatics (GABI) represents the pioneering effort to compile a comprehensive worldwide database encompassing ant species records from accessible publications and existing databases.[13]

Large workers are called porters and foragers because they cut and bring food/vegetation to the nest, medium-sized workers cut that material into small pieces, and gardeners or small workers implant fungal strands on that material by applying their own fecal material and care for fungal growth. Bites of these ants can produce local pain from moderate to severe for some minutes and might be a link with erythema and local swelling, but anaphylaxis is rare. Moreover, ants also recognize and distinguish their nest mates by nest odor. *Camponotus* ants establish a nest in diverse locations and enjoy wide ecological alterations with unscrupulous habits and raised ability for raid/invasion.[14-15]Carpenter ants mostly prefer the moist wood (in a state of decay) and also establish a colony in dry wood. Carpenter ants live in huge communities and travelling from their nests to a long distance. These remain active day and nighttime. Worker carpenter ants cause huge damages. Nest of these ants found abundantly in loose sandy loam soil. However, they prefer to establish their nest near or at tree trunks because the nest at these sites helps them during the bad season and they can forage on grounds and trees. They prefer moist, dead wood to build their nest. In a wide variety of ecosystems, the nests of these species are found in annual and perennial agro-ecosystems.[16-17]

Insecticides have been used in different formulations including fumigants, dusts and granular baits. The effect of different groups of insecticides are used to control diversity of major predators such as insects and spiders.[18] Among these insrcticides, pyrethoids and fipronil are used to control ants around homes at outdoor hardscapes by homeowners and pest management professionals (PMPs). The ant population is controlled by using synthetic chemicals such as heptachlsulfluramid, chlorpyrifos, malathion, fipronil or perchlordecone.[19]Indoxacarb and lambda-cyhalothrin were found effective against rover antsas potential barrier treatment,[20] while quinalphos and imidacloprid are used against planthoppers.[21]Moreover, farmers also apply different insecticides at indiscriminate rates and frequencies to overcome pest problems, leading to pest resurgence and destruction of natural enemies.[22-23]

Ants are caught and dragged away from the predators from aphids in the field and disturb the biological control. The Association of ants with mealybugs is reported by[24-25] reported that in ant attended colonies population of mealybugs was found as highest. He also observed predatory population decreased where ant's association with mealybugs was present as compared to the unattended association. In the agriculture field, if the association between ant and aphid could be controlled then aphid population can be controlled easily.[26]

In a study, the lethal effects of thiacloprid on *Camponotus japonicus* were evaluated and they found more mortality of worker ants on dietary exposure.[27] They also showed abnormal behavior (impaired walking and paralysis) after few days. Similarly, imidacloprid influence the survivorships of fire ants (*Solenopsis invicta)* offspring at a sub-lethal dose which is 0.25µg/mL.[28]In pine forests, ants foraging behaviors was found lower in the bait cards area than the sprayed area of fenitrothion (an organophosphate insecticide).[29] Sugars containing liquid baits are attractive to Argentine ants and gave excellent control measures.[30] In the present study, different concentrations of five insecticides Imidacloprid, Fipronil, Methoxyfenozide, Emamectin benzoate, and Flubendiamide along with natural biological control againt *Camponotus compressus*were obervedand checked their level of toxicity.



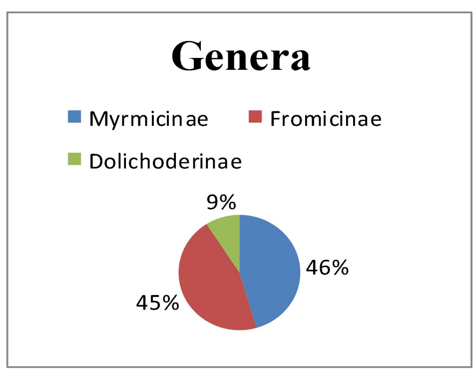


Figure 1: Contribution of Invertebrates and Vertebrates as Pests/Predators and Parasites

Figure 2: Contribution of 19 species and 11 genera among three subfamilies of ants

2. Methodology

2.1. Collection of Carpenter Ants

Carpenter ants were gathered from Block B farms at Muhammad Nawaz Sharif University of Agriculture, Multan (MNSUAM), without any soil, and placed in a plastic container. Subsequently, the ants were transferred to the ecology laboratory and subjected to a period of food deprivation to investigate the impact of an insecticide-containing diet shortly thereafter. All experiments were conducted using a Complete Randomized Design (CRD) and were performed in the Ecology laboratory at the Institute of Plant Protection within Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan.

2.2. Toxicity Test

Preparation of Insecticide Solution

Five different insecticides, namely Imidacloprid, Fipronil, Methoxyfenozide, Emamectin Benzoate, and Flubendiamide, were evaluated for their toxicity against ants across seven distinct dosage levels (160, 80, 40, 20, 10, 5, and 0 ppm). Control groups were established without the application of pesticides. In each replication involving an insecticide, seven pieces of naan bread were utilized, with each piece individually placed in a separate cylinder containing the specified pesticide concentration. After an interval of one minute and 30 seconds, all bread pieces were removed and set on tissue paper to allow the solution to dry. Subsequently, these dried pieces were placed individually in small airtight plastic containers (one piece per container) to proceed with the experiment. To minimize the activity of the ants, distribution of ant species **(**Table 1**),** they were briefly chilled in a refrigerator for 30 seconds. Afterward, ten ants were introduced into each container, which featured tiny holes in the lids to facilitate ventilation. The detrimental effects of consuming the treated naan were observed through the presence of deceased ants. Data collection was conducted over a three-day period, with readings taken at 12-hour intervals. The experiment was replicated four to five times.

Table 1. Distribution of ant species (Order: Hymenoptera) in subfamilies, and genera,in Pakistan.

Sr.no	Name of Subfamily/Genera		Species
1	Myrmicinae	Atopomyrmex	*A. ceylonicus*
		Cardiocondyla	*C. mauritanica*
			*C. subnuda**
		Crematogaster	*C. rothneyi*
		Holcomyrmex	*H. galber*
			H. scabriceps
		Meranoplus	*M. bicolor**
		Messor	*M. instabilis*
			M. aberrans
			M. dichroum
		Monomorium	*M. indicum*
			M. longi
			M. schurii
		Paratopula	*P. ceylonica*
			P. binghami
			P. fergusoni
			P. indica
			P. latinoda
		Pheidole	*P. sulcaticeps*
			P. nietneri
			P. pronotalis
			P. mus
		Rhopalomastix	*Only genus described*
		Solenopsis	*S. geminate*
		Stenamma	*S. jeriorum*

		Tetramorium	*T. smithi* *T. nursei* *T. sulcinode*
2	Formicinae	Camponotus	*C. compressus* *C. confucii* *C. japonicus* *C. oblongus* *C. sericeus*
		Cataglyphis	*C. setipes* *L. alienus* *L. brunneus* *L. carniolicus* *L. hirsutus* *LasiusL. lawarai* *L. niger* *L. talpa* *L. wittmeri*
		Lepisiota	*L. frauenfeldi* *M. aimonissabaudiae* *M. brancucci* *M. pseudorugosa*
		Myrmica	*M. rigatoni* *M. vittata* *M. wardi* *M. wittmeri*
		Paratrechina	*P. longicornis* *P. hauxwelli*
		Polyrachis	*P. hodgsoni*
3	Dolichoderinae	Tapinoma	*T. melanocephalum*
4	Ponerinae	Diacamma	*D. scalpratum*
5	Pseudomyrmecinae	Tetraponera	*T. allaborans*
			T. nigrans *T. rufonigra*
6	Proceratiinae	Proceratium	*P. confinium*

2.3. Repellency Test

Preparation of Insecticide Solution

Imidacloprid, Fipronil, Methoxyfenozide, Emamectin benzoate, and Flubendiamide were subjected to testing to evaluate their repellent properties against ants, thereby examining their responses to various pesticide concentrations (160, 80, 40, 20, 10, 5, and 0 ppm). Following the preparation of these insecticidal concentrations, six uniformly sized pieces of naan bread were procured and immersed in separate cylinders, each containing a distinct concentration (160, 80, 40, 20, 10, and 5 ppm). Additionally, identical pieces of naan bread were submerged in a cylinder solely containing a sugar solution without any pesticide (0 ppm insecticide). After an immersion period of one minute and 30 seconds, the bread pieces were removed and allowed to dry on tissue paper. Subsequently, these pieces were randomly arranged at the four corners of a large plastic container. To reduce the activity of the ants, they were briefly placed in a refrigerator for 30 seconds. After this, a container containing the naan bread pieces treated with various insecticidal concentrations was introduced with 50 ants. The container's lid featured small ventilation holes. Repellency was measured by monitoring the number of ants avoiding the treated naan bread pieces. Data was collected at 30-minute intervals for duration of three hours, with additional readings taken at 12 and 24 hours following the experiment. This experimental procedure was replicated three times.

2.4. Statistical Analysis

LC_{50} and LC_{90} measurements were obtained using Statistical Package for the Social Sciences (SPSS) version 23 to ascertain the most effective concentrations of pesticides for ant control. Furthermore, an Analysis of Variance (ANOVA) was performed using Statistical software version 8.1 to compare the various pesticides.

3. Results

3.1. Lethal Concentration and Estimation (LC_{50})

The 95 percent confidence intervals highlight significant variations in the toxicity of insecticides, as observed in the LC_{50} of C. compresses-treated workers at 12, 24, 36, 48, 60, and 72 hours. Among the pesticides tested, flubendiamide exhibited the lowest LC_{50}, indicating its high toxicity. In contrast, Imidacloprid had a high LC_{50}, suggesting a delayed onset of action as no worker fatalities was observed even after 72 hours. For Fipronil, the LC_{50} at 12 and 24 hours stood at 219.02 and 9.08 mg/L, respectively. It's worth noting that all employees exposed to almost all concentrations of Fipronil had perished after 24 hours. The raw LC_{50} values for Imidacloprid over the 12-72 hour period ranged from 25.25 to 564.96 mg/L **(Table 2)**

Table 2. Toxicity (LC50) of five insecticides against workers of *C. compressus*atdifferentexposuretimes (hours) on treated food.

Insecticide	Time(h)	LC50mg/L (95%FL)	d.f.	χ2	P	N
Imidacloprid	12	564.96(223.79-9335.61)	3	0.498	0.919	350
Fipronil	12	219.02(133.69-582.54)	3	0.082	0.994	350
Methoxyfenozide	12	114.42(66.28-321.24)	4	0.13	0.998	350
Emamectin benzoate	12	23.01(15.56-32.87)	4	2.66	0.615	350
Flubendiamide	12	15.46(6.95-26.04)	4	0.178	0,996	350
Imidacloprid	24	338.32(149.04-4138.59)	3	0.014	1	350
Fipronil	24	9.08(4.52-13.44)	3	3.76	0.288	350
Methoxyfenozide	24	84.07(48.54-235.34)	4	0.387	0.984	350
Emamectin benzoate	24	9.07(4.48-14.04)	4	1.53	0.821	350
Flubendiamide	24	3.33(0.56-7.12)	4	0.4	0.982	350
Imidacloprid	36	174.34(93.71-855.14)	3	0.075	0.995	350
Fipronil	36	-	-	-	-	350
Methoxyfenozide	36	25.36(15.11-40.17)	4	0.344	0.987	350
Emamectin benzoate	36	6.35(2.79-10.23)	4	3.63	0.458	350
Flubendiamide	36	1.74(0.11-4.73)	4	0.117	0.998	350
Imidacloprid	48	75.26(49.85-145.60)	3	0.16	0.984	350
Fipronil	48	-	-	-	-	350
Methoxyfenozide	48	13.86(5.74-23.67)	4	0.106	0.999	350
Emamectin benzoate	48	3.02(0.92-5.55)	4	1.29	0.863	350
Flubendiamide	48	1.32(0.09-3.63)	4	1.14	0.889	350
Imidacloprid	60	52.18(33.23-93.15)	3	0.013	1	350
Fipronil	60	-	-	-	-	350
Methoxyfenozide	60	11.22(4.25-19.26)	4	0.896	0.925	350
Emamectin benzoate	60	1.63(0.25-3.68)	4	3.13	0.536	350
Flubendiamide	60	1.02(0.06-2.92)	4	3.82	0.43	350
Imidacloprid	72	25.25(12.53-39.91)	3	0.315	0.957	350
Fipronil	72	-	-	-	-	350
Methoxyfenozide	72	9.42(3.14-16.62)	4	0.723	0.949	350
Emamectin benzoate	72	0.57(0.01-2.06)	4	2.36	0.669	350
Flubendiamide	72	0.85(0.04-2.51)	4	3.26	0.515	350

3.2. Repellency of Imidacloprid

Food was treated with varying quantities of imidacloprid pesticide to test the effectiveness of the insecticides against carpenter ants, and data was recorded after 30 minutes and for the next three hours. After being put into a plastic box for 30 minutes, ants settled in various densities. Most of the ants had settled at 0 ppm after 30 and 60 minutes. The number of ants declined at a rate of 0 ppm after 90 minutes. As many of the ants were present at 0 ppm, the number of ants gradually grew at 0 ppm after 120 minutes, followed by 150 minutes. When compared to the previous time, the number of ants declined at a rate of 0 ppm after 180 minutes. Most of the C. compresses employees had chosen various imidacloprid concentrations after 60 minutes. After 60, 90, 120, 150, and 180 minutes, the number of employees in the various concentrations had not considerably changed (figure3). The greatest number of workers, however, were discovered on food that had been exposed to 0, 5, and 10 ppm after 60 minutes. At 5 and 10 ppm, the number of workers was statistically different. More employees were feeding at 0 ppm than at 10 ppm after 30 and 60 minutes. The number of workers who were feeding at 0 ppm was larger than the number of workers feeding at 10 ppm after 90, 120, 150, and 180 minutes. Additionally, several of the employees were seen. The number of workers on the plastic box was altered from greater to lower after 90 minutes to 80 minutes. Some employees were between 20 and 40 ppm. Between 30 and 180 minutes, the less workers were fed at 20 and 40 ppm. Since the fewest workers were fed at 80 and 160 ppm even after 180 minutes, here is where the repellency was primarily noticed.

REPELLENCY OF IMIDACLOPRID

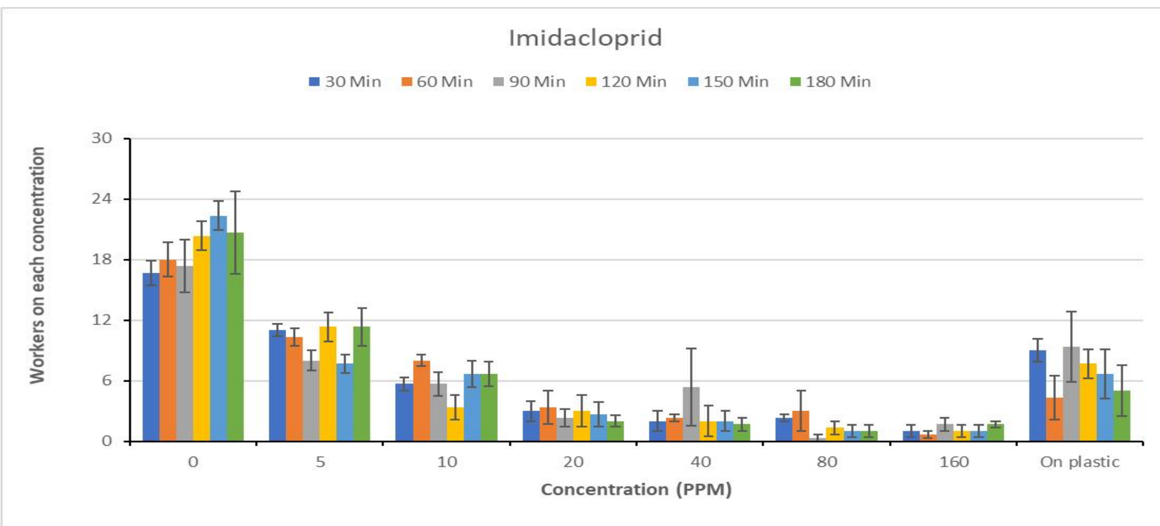


Figure3. Graphical representation of the number of workers (Mean ± SE) of *C. compresses* food treated with imidacloprid over time in a laboratory repellency experiment. The ants that were not feeding were considered as on plastic.

3.3. Repellency of Fipronil

After 60 minutes, there was very little movement of the employees inside the fipronil-treated crates. After 60, 90, 120, 150, and 180 minutes, there was no statistically significant difference in the number of employees who had settled on food that had been treated with 0–10 ppm (figure4). Following 30, 60, and 90 minutes, more workers were eating at 0 ppm. After 120 minutes, the greatest number of employees continued to feed at 0 ppm for 150 minutes. At 180 minutes, there were no more employees than 0 ppm. The number of employees who consume food at 5 and 10 ppm fluctuates over time. More employees were feeding at 5 ppm than at 10 ppm after 30 and 60 minutes. Similarly, the number of workers decreased after 90, 120, and 150 minutes.More employees arrived to the plastic box after 30 minutes. A smaller number of employees were seen on the plastic box after 60 to 180 minutes. From 30 to 180 minutes, the minimal number of workers was noted at 20 and 40 ppm. After 150 minutes, more employees who were fed at 40 ppm than at 20 ppm were present. Workers were found to be repellent at 80 and 160 ppm since those concentrations were where they were most frequently seen. The lowest worker counts were reported at food treated with 40, 80, and 160 ppm of fipronil, indicating that carpenter ants were found to be repellant at high concentrations of the chemical.The fact that the greatest concentration of workers was detected between 0 and 10 ppm indicates that carpenter ants were drawn to lower levels of fipronil. After 24 hours of exposure to fipronil, almost all of the workers who were fed at a higher dose of the drug were discovered dead. Fipronil kills substantially all test subjects in tests for toxicity and repulsivity, demonstrating that it is a very lethal pesticide for carpenter ants.

REPELLENCY OF FIPRONIL

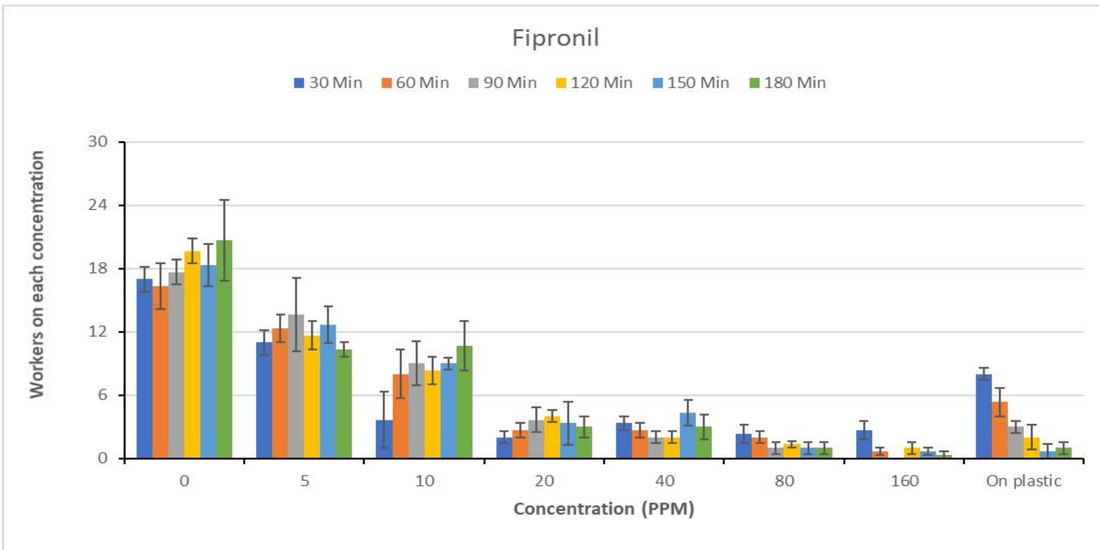


Figure 4. Graphical representation of the number of workers (Mean ± SE) of *C. compresses* on food treated with fipronil over time in a laboratory repellency experiment. The ants that were not feeding were considered as on plastic.

3.4. Repellency of Emamectin Benzoate

The fact that the greatest concentration of workers was detected between 0 and 10 ppm indicates that carpenter ants were drawn to lower levels of fipronil. After 24 hours of exposure to fipronil, almost all the workers who were fed at a higher dose of the drug were discovered dead. Fipronil kills substantially all test subjects in tests for toxicity and repulsive, demonstrating that it is a very lethal pesticide for carpenter ants.There were more employees present at the meal treated at 5 ppm after 90 minutes than at the food treated at 10 ppm. The minimal workforce at food treated with 5 and 10 ppm was measured after 120, 150, and 180 minutes. Even after 120, 150, and 180 minutes, minimum worker counts of 20 and 40 ppm demonstrated that ants were deterred from consuming the meal that had been exposed to a high dosage of emamectin benzoate (figure5). In contrast to the other dosages of 20, 40, 80, and 160 ppm, the highest worker numbers were seen at 0, 5, and 10 ppm after 90, 120, and 150 minutes. At 80 and 160, the workers were discovered to be repulsive. Since their numbers were higher than the employees discovered on plastic after 60, 90, 120, 150, and 180 minutes, some of the workers who were still unfed after 30 minutes were noted on the plastic box. Carpenter ants were repulsive at greater concentrations of abamectin benzoate, as evidenced by the presence of workers at lower concentrations. Most of the workers were discovered dead in meals that had received higher concentration treatment after 24 hours.

REPELLENCY OF EMAMECTIN BENZOATE

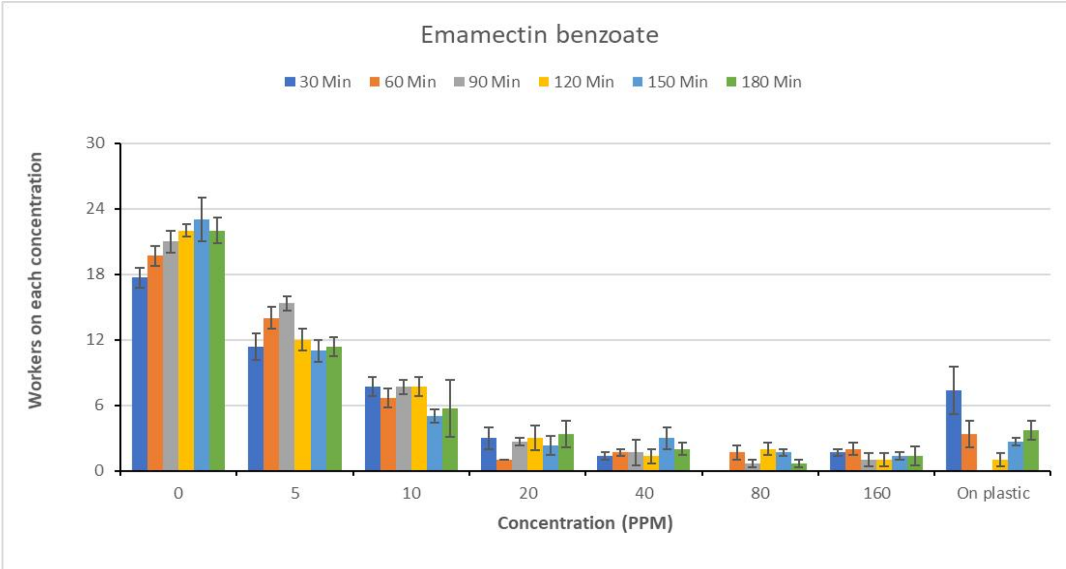


Figure 5. Graphical representation of the number of workers (Mean ± SE) of *C. compresses* on food treated with emamectin benzoate over time in a laboratory repellency experiment. The ants that were not feeding were considered as on plastic.

3.5. Repellency of Flubendiamide

Belt ants, or carpenter ants, landed on various concentrations of the flubendiamide-treated food after being released into the plastic container containing the meal. After 30 minutes in a treated control box, worker mobility had decreased to a minimum. After 60 minutes, the majority of the workers had gathered at every flubendiamide-treated meal concentration. After 30 and 60 minutes, several workers settled down to consume food that had not been flubendiamide-treated or that was taken as a control. The number of employees at 0 ppm increased after 90 minutes and then declined after 120 and 150 minutes.The highest number of workers was recorded at 0 ppm after 180 minutes. The maximum number of workers was found at 5 ppm after 30 and 60 minutes followed by 90 and 120 minutes. Most of the workers were observed at food treated at 5 ppm after 150 minutes as compared to the number of workers at food treated with 10 ppm. The minimum numbers of workers were observed at food treated with 20 and 40 ppm after 60, 90, 120, and 180 minutes. The lowest number of workers were observed at food treated with 80 and 160 ppm of flubendiamide after 60 and 180 minutes. While the small number of workers were observed at food treated with 80 and 160 ppm of flubendiamide after 30 minutes which showed that in early exposure carpenter ants feed at a higher concentration of flubendiamide. Some of the workers were recorded on plastic boxes considered as resting workers who were not fed after 180 minutes. The presence of most of the workers at lower concentrations shows that carpenter ants were repellent against high doses of flubendiamide (figure 6). As the minimum number of workers observed at food treated with a higher concentration of flubendiamide and insecticide.

REPELLENCY OF FLUBENDIAMIDE

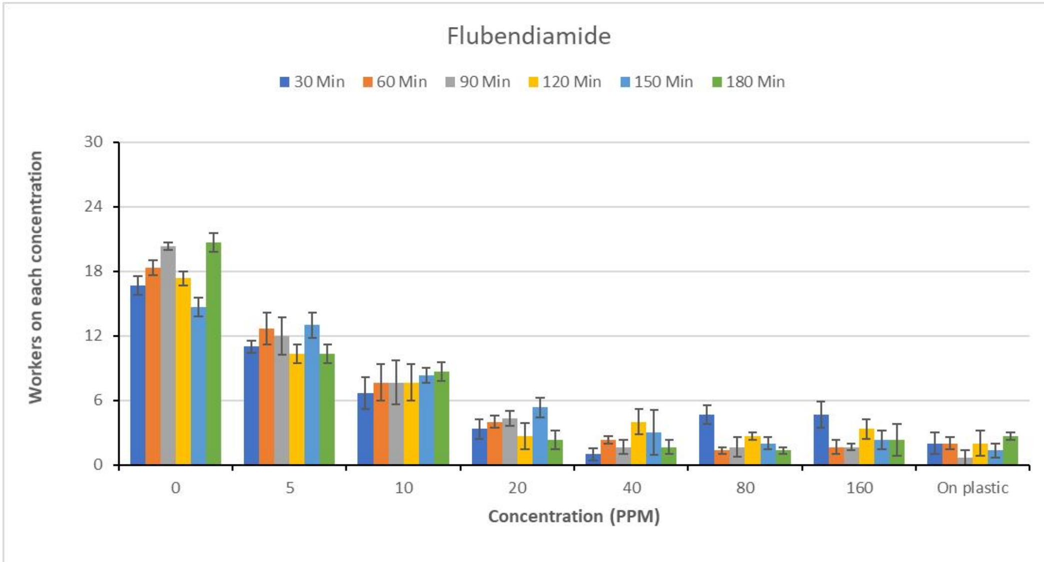


Figure 6. Graphical representation of the number of workers (Mean ± SE) of *C. compresses* on food treated with flubendiamide over time in a laboratory repellency experiment. The ants that were not feeding were considered as on plastic.

4. Discussion

The five new insecticides were evaluated against *C. compresus*to determine their slow action and non-repellent properties under laboratory conditions. Baehaki, et al.,[31] reported that among the insecticides, emamectin benzoate (1.75-1.76) treatment recorded maximum Shannon index and least diversity was recorded in lmbdacyhalothrin 5% EC and chlorpyriphos 20% EC treated plots. He also reported that emamectin benzoate was highly safe while imidacloprid was moderately so. According to Satpathi.[32]The insecticides like fipronil was found to be toxic. Moreover, the predator diversity was maximum in emamectin benzoate treatment and least in case of imidacloprid. This study shows the preliminary findings of fipronil and emamectin benzoate which caused high mortalities and are fast-acting, whereasmethoxyfenozide, imidacloprid and flubendiamide were comparatively less toxic and slower-acting. Imidacloprid is slow-acting and non-repellent to various carpenter ants shows similar results to the experiment against termites.[33-35]In another study, it has been observed that imidacloprid is a slow-acting insecticide against termites when their colonies are exposed to imidacloprid baits no mortality is seen in *M. gilvus*colonies. Imidacloprid would be taken as a suitable choice.[36]Imidacloprid baits were not eaten, that's why less activity was observed in colonies treated with imidacloprid. In another study, the newly mated queens of *S. invicta*feed on water containing 0.01 or 0.25 µg/mL of imidacloprid. It has been observed that at both concentrations of imidacloprid there is no increase in queen mortality.[37] Therefore, this study clearly shows that imidacloprid at sublethal concentrations has a detrimental impact on *S. invicta* queens and the development of emerging colonies. However, according to the present study imidacloprid is less effective because no mortality occurs even after 72 hours. In another study, it has been reported that imidacloprid and other neonicotinoid insecticides show sub-lethal effects, especially in honeybees. The effect of these insecticides includes disorientation, erratic and unusual behaviors among other effects.[38,39] The treatment of imidacloprid confuses workers and workers start moving erratically until death even after exposure to a small quantity of imidacloprid. In the present study, the workers of *C. compressus*were not found dead shows that imidacloprid is not likely to be an effective insecticide against carpenter ants. Imidacloprid negatively affects the foraging behavior of the workers of *Coptotermesformosanus.* The workers show the abnormal searching pattern and the antenna of the treated termites becomes fixed at the right angle of their heads. Imidacloprid is found to be an effective soil treatment according to other studies, with the absorption instead of by consumption and the foraging workers acquiring a lethal dose through cuticle contact.[40,41] It has been observed that the workers which feed on plants treated with fipronil concentrations (5 ppm and 10 ppm) showed 90% mortality. Another study reported that if baits of fipronil (10-5%) were administered for 24 hours to Argentine ants, it results in 100% mortality of workers.[42] The continuous exposure of lower concentrations of fipronil (10-5%) can cause 100% mortality in both queens and workers. According to Buczkowski,[43]Fipronil is highly toxic in field experiments as it is horizontally transferred for the control of ants. Ants can be controlled using three different methods such as trapping, treatment and release. The current study was done under laboratory conditions. The results indicated that fipronil has the highest mortality rate (almost 50% mortality seen after 12 hours, and all workers were dead after 24 hours).According to another study it has been observed that fipronil is highly toxic against termite colonies when exposed to the field. In the field experiment, most of the colonies of *M. gilvus* were eliminated by fipronil. This occurs because fipronil baits were eaten in an average of 4.5% of 16 ppm and 2.5% of 64 ppm of fipronil treated paper over 28 days, which was sufficient to eliminate all the five colonies, two colonies in 28 days and three colonies in 56 days.[44]Fipronil baits successfully suppressed the activity of fungus-growing termites in the fields of China and Pakistan. In China, when the baited colonies of *Odontotermesformosanus* (Shiraki) were treated with 40 ppm of fipronil then two of three baited colonies of *Odontotermesformosanus* stopped foraging in trees and bait stations after 120–150 days.[44]Similarly, in Pakistan when the colonies of *Microtermesmycophagus* (Desnoux) were treated with 10 and 30 ppm of fipronilall the colonies of *M. mycophagus*stopped foraging in baits after 45-90 days.[45]Mthoxyfenozide is an insect growth regulator which is classified due to its interference in selective targets in insects. Only 47% of tested compounds were found to be non-toxic. Three different groups can be distinguished within IGR, chitin synthesis inhibitor, juvenile hormone analogs and molting accelerating compound. Methoxyfenozideis less toxic in the early 24 hours for carpenter ants. However, later it shows higher toxicity, and most of the workers were found dead in the next 72 hours which shows that methoxyfenozide is effective after 48 hours. It has been observed that the methoxyfenozide is highly toxic to other lepidopteran pest insects.[46] In the present study, methoxyfenozide is less effective in 24 hours' timeperiod, it shows that methoxyfenoxide is less effective in the early 24 hoursbecause no mortality is seen in the early 24 hours. Methoxyfenozide is found to be resistant in some noctuid pests that have been confirmed in beet armyworm *Spodopteraexigua*and cotton leafworm*Spodopteralittoralis.*[46-48] It has also been observed in another study that the population of beet armyworm collected from Thailand is found to be 9.7- and 7.3-fold resistant to methoxyfenozide at the LC_{50} and LC_{90} levels respectively[46].Methoxyfenozide has detected the highest significant mortalities effect as general residual as compared to other insecticides. It is both stomach and contact insecticide used primarily for the control of caterpillars. It is observed to be most effective if ingested. However, it also showed contact activity.[47]Flubendiamide is considered a more toxic and slow-acting insecticide against carpenter ants because the mortality rate is low 12 hours after exposure. However, after 12 hour workers were found dead, and their mortality rate was spontaneous. Workers were dying spontaneously and after 72 hours almost all the workers were found dead. In some studies, it is observed that flubendiamide causes paralysis and the death of lepidopterous insect pests. In which flubendiamide binds with ryanodine receptors results in the opening of muscle channels and release of calcium ions in the cytoplasm. Similar results were observed when tobacco cutworm (*S. litura*) is treated with different sub-lethal concentrations of flubendiamide 0.002%, 0.004%, 0.006%, and 0.008% prepared in distilled water increase larval mortality when exposed to 5^{th} instar larvae of *S. litura.*[49]

5. Conclusion

Based on the findings of the current study, it can be concluded that imidacloprid exhibited a delayed and relatively low level of toxicity when used as an insecticide against carpenter ants. Nearly all of the worker ants remained alive even after a 72-hours exposure period. On the other hand, both fipronil and emamectin benzoate were characterized by their rapid action and high toxicity, with worker ants showing decreased mobility within 12 hours and a substantial mortality rate within 24 hours. In contrast, methoxyfenozide displayed a slower onset of action during the initial 24 hours, but it proved to be highly effective after 48 hours, resulting in a significant mortality rate, with almost all worker ants being deceased after 72 hours of exposure. As for flubenduamide, it was observed to be a less immediately lethal insecticide against carpenter ants, with no fatalities recorded within the first 12 hours of exposure. However, worker ants' mortality began after 12 hours and continued spontaneously until the 72-hours mark.

6. References

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