Annals of Phytomedicine 15(1): 710-719, 2026

DOI: http://dx.doi.org/10.54085/ap.2026.15.1.63

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885

Original Article : Open Access

Use of boric acid-based bait materials as attractants against red ant, *Dorylus orientalis* Westwood

Elangbam Bidyarani Devi*, Badal Bhattacharyya*◆, K. Sindhura Bhairavi*, Shimantini Borkataki*, Sanjay Hazarika* and Priyanka Borbaruah**

**Department of Entomology, Assam Agricultural University, Jorhat-785013, Assam, India*
***Department of Entomology, AAU-Citrus and Plantation Crop Research Institute, Tinsukia-786125, Assam, India*

Article Info

Article history
Received 13 April 2026
Revised 19 May 2026
Accepted 20 May 2026
Published Online 30 June 2026

Keywords
Attractant
Bait materials
Boric acid
Dorylus orientalis Westwood
Potato
Y-tube olfactometer

Abstract

This study was undertaken to evaluate the effects of boric acid-based materials as attractants of red ant, *Dorylus orientalis*. Four groups (sugar, lipid, protein and waste based) of bait materials combined with boric acid were assessed in laboratory and field conditions. In case of both laboratory and field experiments, the effectiveness of baits was evaluated based on the number of ants attracted to the bait station. Among the four groups of bait material tested, *D. orientalis* showed the highest attraction (96.67) to waste based bait material (sugarcane trash with boric acid) which was followed by sugar based bait materials (mixture of honey with boric acid, 83.00), oil based bait (mixture of rice bran oil with boric acid, 47.33) and protein based bait (mixture of gram flour with boric acid, 35.00), respectively. Based on the laboratory performance, the use of rice bran oil with boric acid was found to be most attractive with respect to mean number of *D. orientalis* trapped (1564.66, 1972.33 and 2636.33 during tuber formation, tuber maturity and harvesting stages of potato crop, respectively in field conditions). To evaluate the response of *D. orientalis* to different treatments, a series of single choice assays were carried out in a two arm Y-olfactometer. Additionally, *D. orientalis* recorded the highest attractiveness (86.66%) to rice bran oil in combination with boric acid in Y-tube olfactometer studies under laboratory conditions. The outcome of the current investigation can be explored for the management of the menace caused by *D. orientalis* in potato as well as other field crops, especially under organic cultivation approach. Moreover, the results obtained from the Y-tube olfactometer bioassays show that the three treatments had a positive influence on the olfactory behavior of *D. orientalis*. The GC-MS analysis indicated that aldehydes such as hexanal, pentanal, octanal and nonanal constituted the major volatile components of the bait formulations, suggesting that these compounds may contribute to the olfactory attraction of *D. orientalis* towards the bait materials.

1. Introduction

Potatoes are an important source of income and a staple food in the Indian diet and are widely grown in Northeast India. However, potato production has declined sharply in recent years (Gohain *et al.*, 2025). There are several biotic and abiotic factors that cause yield loss in potatoes and amongst different biological constraints, pest problems are the main factor. The red ant, *Dorylus orientalis* W. (Hymenoptera: Formicidae) has been reported across India as a pest of numerous commercially significant crops. It has long been regarded as a significant pest of potato in both plains and hills (Fletcher, 1914). It causes considerable damage to underground potato tubers with numerous small holes (2-3 mm in diameter) appearing in the damaged tubers. The peak infestation occurs during harvesting which reduces tuber quality and market price, rendering them unfit for human consumption (Bhandari, 2011). In severe cases, tuber infestation reaches 51.77-61.50% (Chowdhury, 1997). The pest usually appears in December and is active until April. Studies on the biology and seasonal abundance of *D. orientalis* indicated that high temperatures followed by dry weather favor population buildup and damage severity of this obnoxious pest. *D. orientalis* populations have also been documented to be highest in non-flooded potato growing areas as compared to the flood prone sites (Devi *et al.*, 2022). Moreover, the introduction of high yielding potato varieties without intensive monoculture and management strategies has contributed to the rapid colonization and spread of this pest. The dynamics of pest influxes and existing pest populations are also rapidly changing due to climate change.

Apart from a few insecticidal trials in Sri Lanka (Fernando and Manickavasagar, 1958) and Assam, India, practically very little work has been done so far to manage this significant soil dwelling pests (Rahman, 1967; Bhattacharyya *et al.*, 2014; Saikia and Deb Nath, 2017). The persistent use of common synthetic insecticides against *D. orientalis* on potatoes and other economically important crops initially managed the pest to an extent but posed long term threat to the ecosystem causing resurgence of other pest species like *Polyphagotarsonemus latus* B. (Trombidiformes: Tarsonemidae), *Bemisia tabaci* G. (Hemiptera: Aleyrodidae) and *Aphis gossypii* G. (Hemiptera: Aphididae) (David, 1991), in addition to harming the beneficial soil insect fauna. The long-term residual effects of synthetic

Corresponding author: Dr. Badal Bhattacharyya
Professor and Head, Department of Entomology, Assam Agricultural University, Jorhat-785013, Assam, India
E-mail: badalassam@gmail.com
Tel.: +91-9435648957

insecticides are known to pose various hazards to human and animal health. The available literature on the bioecology and integrated management of *D. orientalis* is very limited and leaves room for further work.

To achieve these goals, baits are the most effective means of managing pestiferous ants in both urban and agricultural environments. Earlier workers have also attempted food preference tests for other ant species like the Argentine ant, *Linepithema humile* M. (Hymenoptera: Formicidae) especially prefers a 25% honey solution and a 25% sucrose solution (Baker *et al.,* 1985; Krushelnycky and Reimer, 1998; Rust, *et al.,* 2000; Nyamukondiwa and Addison, 2014); red imported fire ant, *Solenopsis invicta* B. (Hymenoptera: Formicidae) preferred molasses (Ali and Reagan, 1986) and the tropical fire ant, *Paratrechina* spp. showing attraction to sugar based baits (Zakharov and Thompson, 1998). The red wood ants, *Formica rufa* L. (Hymenoptera: Formicidae) preferred sucrose to monosaccharides and was most attracted to solutions containing an amino acid source (Madsen and Offenberg, 2020). However, *Solenopsis geminate* F. (Hymenoptera: Formicidae) was attracted to protein or oil-based attractants (Lee and Kooi, 2004). With these facts in the backdrop, a holistic and effective approach of managing this serious soil dwelling insect pest especially in the commercial cultivation of potatoes and other crops needs to be embraced to boost up the productivity of the crops under various cultivation systems.

Boric acid has been used to control ants and cockroaches since late 1800's (Quaries, 1993; Riley, 1889; Rust, 1986). It is slow acting and non-repellent, so long term use is recommended (Klotz and Moss, 1996; Klotz *et al.,* 1997). Boric acid baits have been shown to be effective against Pharaoh ants (Newton, 1980), Argentine ants (Olkowski *et al.,* 1991) and Florida carpenter ants (Klotz and Williams, 1996) both in laboratory as well as in field conditions. Similar results were obtained using liquid boric acid baits to control pharaoh ants (Klotz *et al.,* 1997). The boric acid in sucrose solutions also relaxes the water regulatory mechanism, causing the ants to consume more bait to compensate for water loss (Klotz *et al.,* 1996). Although, little is known about the mode of physiological action of boric acid in insects, borate ions have shown to form strong complexes with sugar alcohols and other organic functional groups (Klotz *et al.,* 2000). Boron may be involved in the disruption of intercellular adhesion as saturated solutions of boric acid can be used to dissociate cells (Harper *et al.,* 2012). Boric acid is non-volatile and acts as a stomach poison and may be toxic to the insect's nervous system. Additionally, it is a stable and naturally occurring compound, which is easily degradable in soil and water, as compared to synthetic pesticides (Alanazi, 2023). The present study has been conducted to evaluate several boric acid-based bait materials as *D. orientalis* attractants, to explore eco-friendly, cost effective and safe management strategies.

2. Materials and Methods

Laboratory and field experiments on evaluation of some bait materials (sugar, lipid, protein and waste based) as attractant for *D. orientalis* was carried out at Soil Arthropod Pests Laboratory, Department of Entomology, Assam Agricultural University (AAU), Jorhat (26.7509°N, 94.2037°E and 98 m) and in the farmer's field of Charaibahi Village, Jorhat (26.6665 °N, 94.14753 °E and 98 m), Assam. For the preparation of sugar-based bait materials, sugar, honey, molasses and sucrose solution were used to test the food preferences of *D. orientalis*. In a beaker, 25 parts of boric acid was added in 50 parts of distilled water with continuous stirring. Then, 25 parts of sugar-based materials was added slowly while stirring to make a 100 ml stock solution from which 5 ml of aliquot were used for laboratory evaluation. For the preparation of lipid-based bait materials, 50 parts of lipid test samples (oils of rice bran, coconut, soybean and mustard) were taken and then 50 parts of boric acid was added, stirred to make a 100 ml stock solution and then 5 ml of aliquot were used for laboratory evaluation. Then, for the preparation of protein-based bait materials, soybean powder, groundnut powder, dog biscuits and gram flour were taken individually in 25 parts each, of which 25 parts of boric acid was added to 50 ml of distilled water, stirred thoroughly to make a 100 ml stock solution and then 5 ml of aliquot was used. Similarly, waste-based bait materials (fish waste, chicken waste, banana peel and sugarcane trash) and boric acid were added in 25 parts, each to 50 ml of distilled water, stirred to make a 100 ml stock solution and 5 ml of aliquot was used for laboratory evaluation (Kafle, 2020; Stanley, 2004).

2.1 Laboratory evaluation of bait materials

D. orientalis adults were dug up from heavily infested potato fields of Instructional cum Research Farm, AAU, Jorhat and carried to the laboratory for rearing. Large colonies were maintained in plastic containers (70 cm diameter) and fed with cut potato pieces at room temperature (25 ± 5°C temperature, 50-70% RH). After two days of laboratory rearing, 300 fully matured ants of almost uniform sizes (6-7 mm) were released into four plastic containers (group wise based bait materials) each containing four baits along with one untreated control (Choe *et al.,* 2010; Hossain *et al*., 2021). The bait materials were loaded in urine pots (5 cm × 4 cm) as bait stations and were placed at an equal distance from each other in the arenas. The number of ants attracted to the bait stations was recorded at 1, 3 and 5 days after treatment (DAT). This experimental set up was replicated three times during the potato growing season in the first year. The data obtained were analyzed using completely randomized design (CRD). Based on attractiveness, two superior bait materials from each group were selected for further field evaluation in the second year.

2.2 Field evaluation of bait materials

A field trial was conducted to determine the effectiveness of promising baits (2 superior baits from each group) in a chronically *D. orientalis* infested potato field (25 ± 5°C temperature, 50-70% RH) in the second year. Nine different treatments including an untreated control were evaluated for their attractiveness to *D. orientalis* (Table 5). The experiment was conducted in a randomized block design (RBD) with an individual plot size of 4 × 3 sq.m with three replicates each. The bait material @ 25 ml/bait or 25 g/bait was loaded in a plastic container (8 cm × 7 cm). Fresh bait stations were randomly placed at a depth of 15 cm and replaced at each of the three different growth stages of the potato crop (tuber formation, tuber maturity and harvesting stage). The observations consisted of counting the number of ants attracted/present in the bait station at the end of each growth stage. Subsequently, the *D. orientalis* population was statistically analyzed by counting the number of ants attracted to each bait station using IBM SPSS version 22.

2.3 Y tube-olfactometer bioassay

A series of single choice assays were carried out in a two arm Y-olfactometer to evaluate the attraction response of *D. orientalis* to different treatments. Adult ants, freshly collected from potato fields, were kept under laboratory conditions at room temperature (25 ± 2°C, 50-70% RH) for 2 h, following which, the active ants were selected for the olfactory experiments. Thirty adult ants were tested against three treatments namely rice bran oil, boric acid and rice bran oil in combination with boric acid with distilled water as control. The treatments were placed in the designated olfactometer arms @ 2 µl each on a filter paper. The adults were placed in the release chamber and were allowed 5 min to determine their choice. The olfactometer was cleaned using acetone after each treatment and the treatments were relocated after every five replicate to eliminate any source position effect. The data were analyzed (through IBM SPSS version 22) using chi-square (χ^2) tests to determine significant differences of adult ants towards different treatments.

2.4 Characterization of volatile compounds using GC-MS

The volatiles present in the three treatments namely rice bran oil, boric acid and rice bran oil in combination with boric acid was carried out with the help of a Thermo Scientific TRI Plus 500 autosampler coupled with a Thermo Scientific Trace 1300 gas chromatograph (GC) and ISQ 7000 mass spectrometer (MS). 1 ml of each sample was incubated at 80°C for 10 min, under a pressure of 100 kPa, with an equilibration time of 0.20 min prior to analysis. Helium was used as the carrier gas at a constant flow rate. Separation of volatile compounds was performed using a TG-5 capillary column (30 m × 0.25 mm × 0.25 mm). The GC oven temperature was initially set at 40°C and held for 5 min, followed by a temperature ramp of 10°C min^{-1} to 150°C, and then 25°C min^{-1} to 250°C with a final hold of 5 min. The MS transfer line temperature was maintained at 250°C, and ionization was carried out in electron impact (EI) mode. Compounds were tentatively identified using NIST library, and peak areas were used to determine the relative abundance of compounds.

3. Results

3.1 Laboratory performance of different bait materials as attractant for *D. orientalis*

Experimental results obtained from the laboratory evaluation of four sugar-based bait materials for different exposure periods against *D. orientalis* are presented in Table 1. Among the four sugar-based bait materials, the highest (25.00) mean number of ant attraction was recorded in the mixture of boric acid with honey followed by molasses (18.33), sugar (7.33) and sucrose solution (5.00) as compared to untreated control at 1 DAT. At 3 DAT, the highest mean number of attraction (80.67) was recorded from the mixture of boric acid with honey followed by molasses (52.67) and sugar (13.33), respectively. The same trend of attraction of ants was also seen at 5 DAT. However, sucrose solution and boric acid showed very low levels of attraction to ants at various exposure days.

Table 1: Evaluation of sugar based bait materials against *D. orientalis* in laboratory conditions

Treatments	Dosages	Exposure (in days)		
		1 DAT	3 DAT	5 DAT
T_1: Sugar + Boric acid	5 ml	7.33	13.33	15.67
T_2: Honey + Boric acid	5 ml	25.00	80.67	83.00
T_3: Molasses + Boric acid	5 ml	18.33	52.67	55.00
T_4: Sucrose solution + Boric acid	5 ml	5.00	9.00	11.67
T_5: Untreated control (water)	5 ml	0.00	0.00	0.00
S.Ed (±)	-	1.25	1.37	1.25
CD (p=0.05)	-	2.67	2.92	2.67

*Data are mean of three replicates, DAT: Days after treatment.

Table 2: Evaluation of lipid based bait materials against *D. orientalis* in laboratory conditions

Treatments	Dosages	Exposure (in days)		
		1 DAT	3 DAT	5 DAT
T_1: Rice bran oil + Boric acid	5 ml	23.33	42.67	47.33
T_2: Coconut oil + Boric acid	5 ml	4.00	6.67	10.33
T_3: Soybean oil + Boric acid	5 ml	5.00	10.00	17.00
T_4: Mustard oil + Boric acid	5 ml	19.00	33.33	37.00
T_5: Untreated control (water)	5 ml	0.00	0.00	0.00
S.Ed (±)	-	0.84	1.74	1.49
CD (p=0.05)	-	1.80	3.72	3.19

*Data are mean of three replicates, DAT: Days after treatment.

Analysis of the data shows the attraction of *D. orientalis* to lipid-based baits materials at different exposure periods (Table 2). The highest (23.33 numbers) attraction was found in the mixture of boric acid with rice bran oil, followed by mustard oil (19.00), soybean oil (5.00) and coconut oil (4.00) at 1 DAT. The mixture of rice bran oil with boric acid was found to be statistically superior to rest of the mixtures, showing the greatest attraction (42.67 and 47.33 numbers) of ants at 3 and 5 DAT, respectively. For protein-based baits, gram flour with boric acid mixture was significantly superior to other treatments with mean number of ants (20.67, 30.00 and 35.00) at 1, 3 and 5 DAT which was followed by mixture of dog biscuits with boric acid (13.00, 21.67 and 27.67) and groundnut powder with boric acid mixture (9.33, 14.00 and 18.67), respectively (Table 3).

Data on evaluation of four waste-based bait materials reveals that the highest (22.67, 89.67 and 96.67) number of attractions was obtained from sugarcane trash with boric acid mixture followed by banana peel with boric acid mixture (17.00, 32.33 and 36.67) and fish waste with boric acid mixture (9.33, 12.33 and 15.00) at 1, 3 and 5 DAT, respectively (Table 4). The lowest numbers of ants were recorded in chicken waste with boric acid mixture.

Table 3: Evaluation of protein based bait materials against *D. orientalis* in laboratory conditions

Treatments	Dosages	Exposure (in days)		
		1 DAT	3 DAT	5 DAT
T_1: Soybean powder + Boric acid	5 g	6.67	11.00	15.33
T_2: Ground nut powder + Boric acid	5 g	9.33	14.00	18.67
T_3: Dog biscuits + Boric acid	5 g	13.00	21.67	27.67
T_4: Gram flour + Boric acid	5 g	20.67	30.00	35.00
T_5: Untreated control (water)	5 ml	0.00	0.00	0.00
S.Ed (±)	-	1.10	1.23	1.21
CD (p=0.05)	-	2.34	2.63	2.59

*Data are mean of three replicates, DAT: Days after treatment.

Table 4: Evaluation of waste based bait materials against *D. orientalis* in laboratory conditions

Treatments	Dosages	Exposure (in days)		
		1 DAT	3 DAT	5 DAT
T_1: Fish waste + Boric acid	5 g	9.33	12.33	15.00
T_2: Chicken waste + Boric acid	5 g	5.00	9.00	12.33
T_3: Banana peel + Boric acid	5 g	17.00	32.33	36.67
T_4: Sugarcane trash + Boric acid	5 g	22.67	89.67	96.67
T_5: Untreated control (water)	5 ml	0.00	0.00	0.00
S.Ed (±)	-	1.35	1.46	0.97
CD (p=0.05)	-	2.89	3.13	2.07

*Data are mean of three replicates, DAT: Days after treatment.

Table 5: Evaluation of bait materials against *D. orientalis* under field conditions in potato crop

Treatments	Dosages	Mean number of attractions of red ant, *D. orientalis*		
		Tuber formation stage	Tuber maturity stage	Harvesting stage
T_1: Honey + Boric acid	25 ml	347.66	488.66	675.66
T_2: Molasses + Boric acid	25 ml	326.33	501.33	575.66
T_3: Rice bran oil + Boric acid	25 ml	1564.66	1972.33	2636.33
T_4: Mustard oil + Boric acid	25 ml	14.00	39.00	50.66
T_5: Dog biscuits + Boric acid	25 ml	86.33	101.33	134.33
T_6: Gram flour + Boric acid	25 ml	55.66	73.66	126.33
T_7: Banana peel + Boric acid	25 g	134.33	196.66	272.00
T_8: Sugarcane trash + Boric acid	25 g	234.00	283.66	379.00
T_9: Untreated control (water)	25 ml	2.00	1.66	2.33
S.Ed (±)	-	3.07	4.19	3.61
CD (p=0.05)	-	6.58	9.00	7.75

*Data are mean of three replicates.

3.2 Field evaluation of selected bait materials as attractant for *D. orientalis*

To determine the efficacy of superior bait materials (2 from each group), a field trial was conducted in *D. orientalis* affected potato fields. Experimental results indicated that all treatments were significantly superior as compared to untreated control (Table 5). Among the 8 treatments, use of boric acid with rice bran oil attracts maximum numbers of *D. orientalis* (1564.66, 1972.33 and 2636.33) on potato crop as compared to other bait materials which was followed by mixture of boric acid with honey (347.66, 488.66 and 675.66 numbers) at tuber formation, tuber maturity and harvesting stages, respectively. However, boric acid treated with molasses attracted 326.33, 501.33 and 575.66 numbers of *D. orientalis* at the aforementioned stages, respectively. The present study indicates that in case of laboratory evaluation of bait materials, sugarcane trash and boric acid mixture attracted more red ants than other bait materials. However, in field evaluation, it was found that the use of boric acid with rice bran oil was far superior to other bait materials in attracting the maximum numbers of *D. orientalis* in potato crops.

3.3 Response of *D. orientalis* to different treatments

Overall, when tested against a control treatment of distilled water, *D. orientalis* had more than 70% attractiveness towards all the three treatments. *D. orientalis* showed highest level of attraction towards the combination treatment of boric acid and rice bran at 86.66%, this was followed by boric acid at 76.66%. The lowest attraction was recorded towards rice bran oil at 73.33% (Figure 1). The results obtained from the Y-tube olfactometer bioassays show that the three treatments had a positive influence on the olfactory behaviour of *D. orientalis*. This further establishes the superiority of rice bran oil and boric acid as potential baits. Ant baits are designed for specific purposes using traditional control methods and have been found to be cost effective. Baits are very effective tools for eradication of various ant species. Based on the experiments undertaken during the current study, rice bran oil and boric acid mixture can be used in potato fields as a potential attractant for trapping of *D. orientalis*.

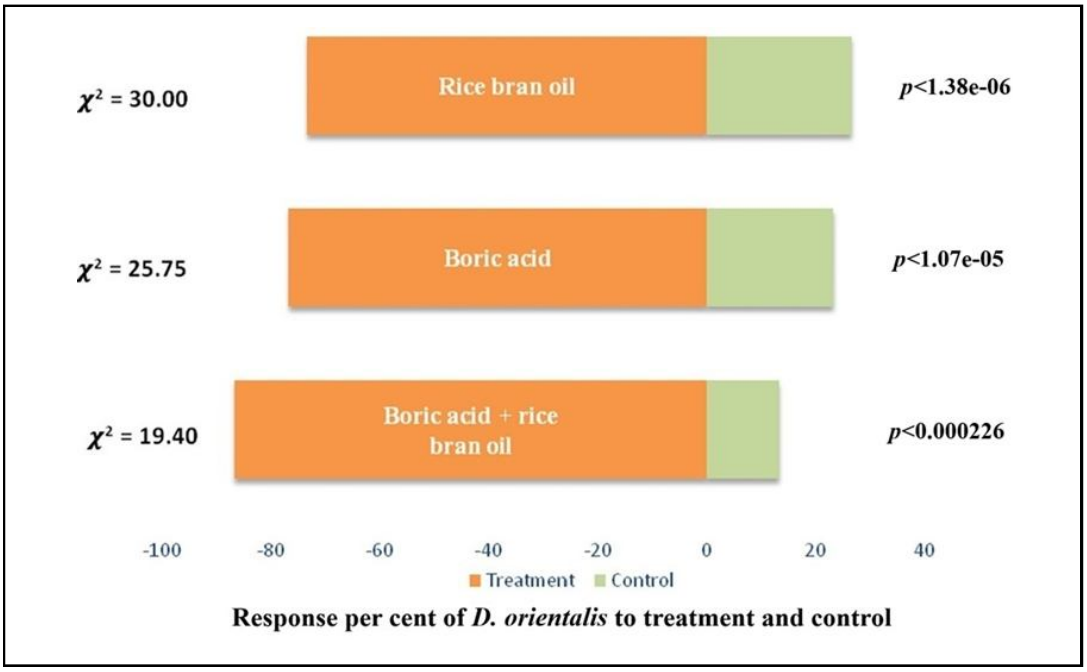

Figure 1: Per cent response by *D. orientalis* adults.

3.4 GC-MS characterization of volatile compounds from bait formulations

GC-MS analysis of the three treatments namely rice bran oil, boric acid and combination of boric acid and rice bran oil revealed the presence of several volatile organic compounds, commonly associated with insect attractants and plant semiochemicals. In samples containing boric acid, varying but significant peaks were detected for azulene (37.16%), acetic acid (21.44%), diethyl phthalate (5.79%), dibutyl phthalate (4.56%), and (+)-2-bornanone (camphor) (4.39%) (Table 6, Figure 2). In the rice bran oil sample, hexanal represented the most abundant compound with a combined relative peak area of approximately 13.55%, followed by pentanal (3.59%) and acetic acid (3.09%) (Table 7). Other compounds such as 2-heptanone, heptanal, 2-heptenal, octanal and nonanal were detected in smaller quantities, each contributing less than 2% of the total chromatographic area (Figure 3). The combination treatment consisting of rice bran oil and boric acid exhibited the most pronounced volatile profile (Table 8), with hexanal alone contributing approximately 35.86% of the total chromatographic area (Figure 4). In addition to hexanal, several other behaviourally active aldehydes including pentanal (4.35%), nonanal (0.51), octanal (0.33) and 2-heptenal (1.31%) were detected. These compounds are widely reported as plant-derived volatiles that play an important role in insect host location and foraging behaviour. Overall, the GC-MS analysis indicated that aldehydes such as hexanal, pentanal, octanal and nonanal constituted the major volatile components of the bait formulations, suggesting that these compounds may contribute to the olfactory attraction of *D. orientalis* towards the bait materials.

Table 6: Volatile compounds detected through GC-MS analysis of boric acid

Retention time (min)	Compound	Relative peak area (%)
2.174	Acetic acid	21.44
2.358	2-ethyl-oxetane	3.08
12.959	2,5-furandione	2.89
13.789	(+)-2-Bornanone (Camphor)	4.39
14.418	Azulene	37.16
18.765	Diethyl phthalate	5.79
20.690	Dibutyl phthalate	4.56

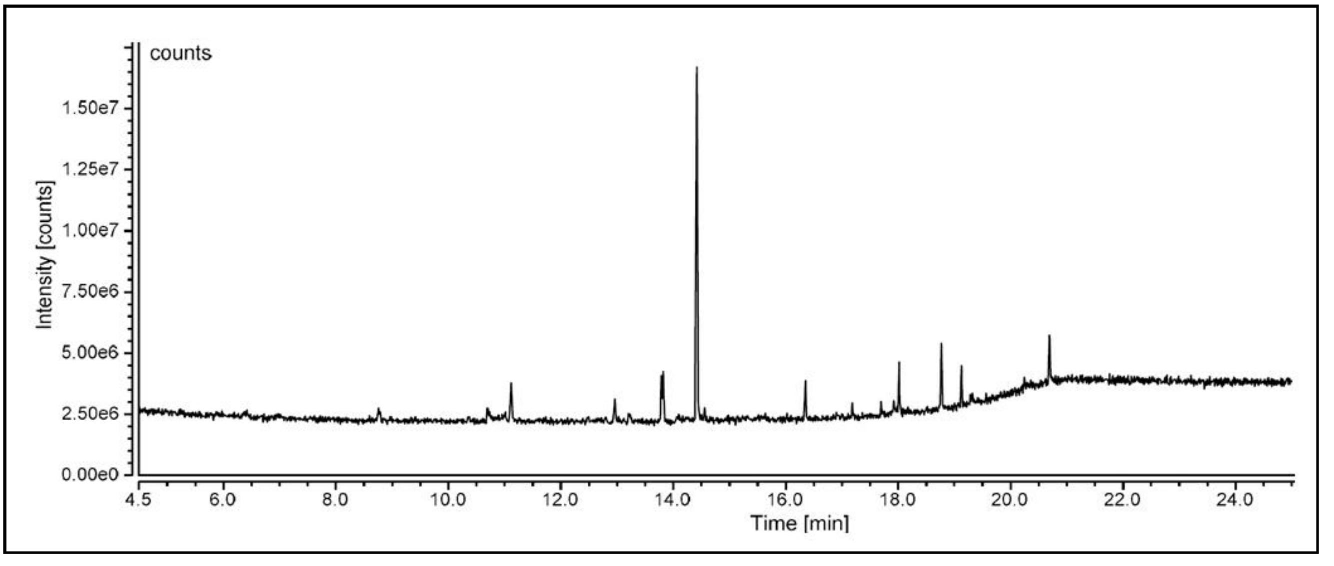

Figure 2: Volatile compounds present in boric acid.

Table 7: Volatile compounds detected through GC-MS analysis of rice bran oil

Retention time (min)	Compound	Relative peak area (%)
2.140	Acetic acid	3.09
3.045	3-penten-2-one	1.57
3.415	Pentanal	3.59
6.266	Hexanal	13.55
8.789	2-heptanone	0.99
9.031	Heptanal	0.89
10.258	2-heptenal	0.98
10.701	Hexanoic acid	0.56
10.901	6-methyl-5-hepten-2-one	0.53
11.088	2,4-heptadienal	0.70
11.201	Octanal	0.26
12.024	2-octenal	0.37
13.037	Nonanal	0.37
14.428	Napthalene	0.87

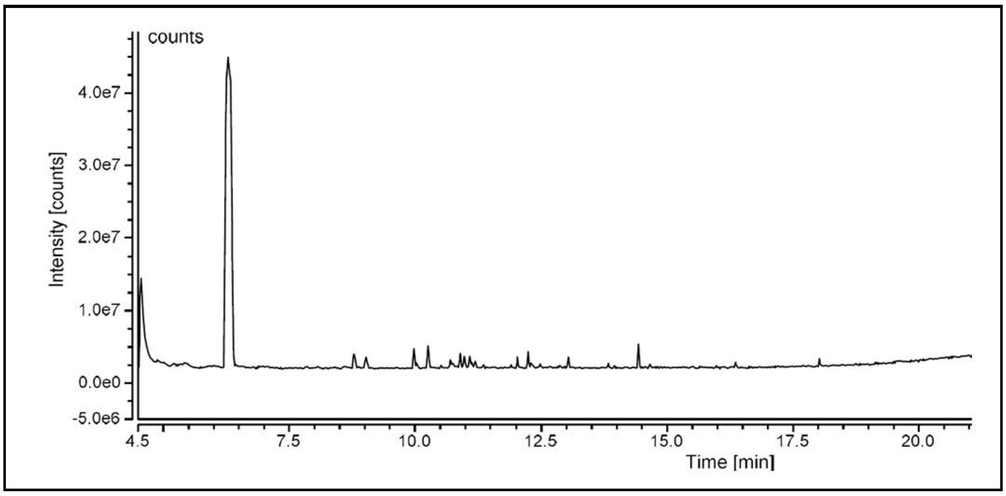

Figure 3: Volatile compounds present in rice bran oil.

Table 8: Volatile compounds detected through GC-MS analysis of rice bran oil + boric acid

Retention time (min)	Compound	Relative peak area (%)
2.215	Acetic acid	8.52
3.024	3-methyl-3-buten-2-one	1.20
3.402	Pentanal	4.35
6.300	Hexanal	35.86
8.789	2-heptanone	1.22
9.027	Heptanal	1.00
10.265	2-heptenal	1.31
10.714	Hexanoic acid	0.81
10.901	6-methyl-5-hepten-2-one	0.70
11.092	2,4-heptadienal	0.89
11.201	Octanal	0.33
12.027	2-octenal	0.47
13.037	Nonanal	0.51
14.428	1-methylene-1H-indene	1.42

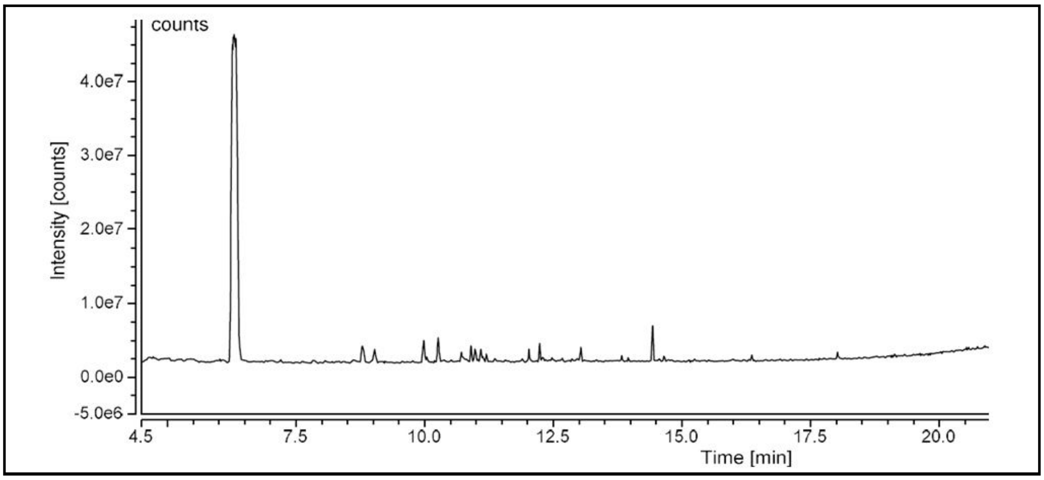

Figure 4: Volatile compounds present in rice bran oil + boric acid.

4. Discussion

The present study indicates that in case of laboratory evaluation of bait materials, sugarcane trash and boric acid mixture attracted more red ants than other bait materials because sugarcane trash contains sugars, amino acids, waxes, phenols, lignins and acids (Shinitzer, 1991); sugarcane trash also contains 45-50% water, 2-5% dissolved sugars, 40-45% fiber and 60-80% carbohydrates (Ungureanu *et al.,* 2022). However, in field evaluation, it was found that the use of boric acid with rice bran oil was far superior to other bait materials in attracting the maximum numbers of *D. orientalis* in potato crops. This may be because rice bran oil has a high smoke point (232°C) and is less likely to break down in sunlight (Muralikrishna and Nirmala, 2005). Since, as a carrier material, boric acid destroys the ant's stomach, inhibits its nervous system and also damages its exoskeleton, the authors hypothesize that in field conditions, foraging worker ants which are attracted to bait containing boric acid might carry pieces of the bait back to the nest. The boric acid bait thus can be transferred between the mouth of the insects in the nest, effectively killing other ants and even the queen herself. Also, in case of the tested colonies, ant mortality could have an effect on the subsequent experiments that might be carried out in the same colony. However, further studies need to be carried out to confirm any such hypothesis.

The observed variation between the laboratory attractiveness of sugarcane trash based bait materials and superior field performance of rice bran oil based mixture may be assigned to differences in environmental complexity and insect behavior under natural conditions. In laboratory experiments, the insects are committed to a controlled environmental condition with limited sensory cues which can magnify responses to certain olfactory stimuli, such as those from sugarcane trash. However, field conditions involve multiple competing odors, variable temperature, humidity, and wind which may increase the efficacy of rice bran oil based bait materials due to greater volatility, persistence or broader spectrum attractiveness to target insects. Additionally, behavioral factors such as feeding preference, mobility and interaction with plant surfaces could favor the field performance of rice bran oil bait materials despite laboratory based bait materials.

In addition to being toxic to the stomach, most borate salts are also abrasive to the exoskeleton of insects. *Monomorium chinensis* S. (Hymenoptera: Formicidae) and *Anoplolepis gracilipes* J. (Hymenoptera: Formicidae) are regular feeders seeking carbohydrates, lipids and proteins as food sources (Vanderwoude *et al.,* 2006). To meet their nutritional needs for various macro and micro-nutrients, ant colonies are completely dependent on foragers. Foragers locate and assess the food quality based on the presence of carbohydrates, proteins, lipids, vitamins and salts (Renyard *et al.,* 2024). Ants are ideal pests for bait control because of their highly social habits, such as chemically recruiting food sources using odour trails and sharing food among nest mates (trophallaxis). If, the bait is attractive to foraging ants, it is quickly collected and carried back to the nest to be distributed throughout the entire colony. The nutrient preference of an ant colony is species specific and is influenced by many factors such as availability of nutrients in the local habitat and seasonal shifts (Cook *et al.,* 2011). Although, it is unfair and difficult to generalize the feeding preferences of ants towards a particular bait material, ants have been known to prefer essential and non-essential amino acids (Csata *et al.,* 2020). Additionally, their preference to certain essential oils has also been demonstrated (Cornelius *et al.,* 1996). Few studies have documented the attractiveness of complex blends to different ant species. Bait formulations containing sucrose and essential amino acids were preferred by *Camponotus modoc* W. (Hymenoptera: Formicidae) and *Myrmica rubra* L. ((Hymenoptera: Formicidae) under laboratory and field conditions (Renyard *et al.,* 2024). A novel boric acid gel bait was developed for household ant species namely the Asian needle ant, *M. chinensis* and the Yellow crazy ant, *A. gracilipes* and found to be a potential alternative to chemical control strategies (Kafle *et al.,* 2020). Since the bait preference of ants is influenced by a range of factors like species specificity, geographical location and climate, the current experiment attempts to make a similar bait specifically for red ant, *D. orientalis.* In case of chemical cues, variations in behavioral response of insects have been associated with the composition and concentration of chemical compounds (Ab Majid *et al.,* 2018). The percentage response of *D. orientalis* to the treatments in the current study indicates a similar pattern. The combination treatment of boric acid and rice bran oil had higher attraction than either of the individual treatments. Often, synergistic interactions between the different components of an odor mixture enhance the attraction of insects to their hosts (Pinero *et al.,* 2019). The presence of several lipid-derived volatile compounds including hexanal, pentanal, heptanal, octanal, nonanal, 2-heptanone, 2-heptenal and 2-octenal might contribute to the attraction of *D. orientalis* to the treatments. Such compounds play a significant role in mediating insect-plant interactions and often act as chemical cues guiding insects to suitable food sources or hosts (Bruce *et al.*, 2005). Hexanal and pentanal are frequently emitted from damaged plant tissues and stored plant products and have been reported to influence insect host-location and feeding behaviour (Pickett *et al*., 1997). While the volatile profile of boric acid alone was relatively limited, consisting mainly of acetic acid and a few aromatic compounds, it notably contained acetic acid, which is a fermentation volatile known to attract insects searching for food resources (Becher *et al.,* 2018). The volatile aldehydes such as hexanal, pentanal, octanal and nonanal play an important role in the olfactory mediated foraging and host location behavior of *D. orientalis*. These compounds are commonly emitted from damaged plant tissues, insect cuticles and decomposing organic matter serving as kairomonal cues that signals the presence of prey or resource rich habitats. Detection of these aldehydes through antennal olfactory receptors likely facilitates prey localization, short range orientation and recruitment during collective foraging. The differential volatility of these compounds may provide both immediate and persistent environmental cues, suggesting their integration with pheromone-based composition enhances foraging efficiency and ecological adaptation in this ant species (Bruce *et al.,* 2005; Holopainen and Gershenzon, 2010; Hansson and Stensmyr, 2011; Wyatt, 2014; Sharma *et al.,* 2015). The combination of rice bran oil and boric acid produced a more complex volatile blend containing both lipid-derived aldehydes and organic acids, which likely enhanced the olfactory cues available to foraging ants. Insects often respond more strongly to mixtures of volatiles rather than to individual compounds because such blends resemble natural food odours (Bruce *et al*., 2005). Lipid-rich food sources are known to attract several ant species due to their high energy content and nutritional value (Cook *et al*., 2011).

Rice bran oil contains a biologically active phytochemicals in higher level. Crude rice bran oil contains was (1.5-4%), free fatty acids (59.19%) and phosphatides (0.5-1.5%). They include oryzanols

(1.2-1.8%), phytosterols (1.5-0.2%) and tocopherols and tocotrienols (0.15-0.2%). It also contains essential fatty acids like linoleic acid, linolenic acid, oliec acid, arachidonic acid, stearic acid and palmitic acid. Crude rice bran oil contains 0.2% tocols, from which 70% is tocotrienols. These compounds provide several significant health benefits: a) Disease prevention: They act as potent antioxidants and antitumor agents, helping to delay the onset of cancer, inflammatory issues, neurological disorders and cardiovascular diseases; b) Heart health: Oryzanols and tocols help lower plasma and serum cholesterol levels and reduce platelet aggregation (Maurya and Kushwaha, 2018).

Boric acid functions as a slow acting, non-repellant toxicant. This delayed pharmacological action is essential as it allows foraging ants to consume the bait and survive long enough to carry it back to their nest. There, the toxicant is shared ultimately leading to the death of the worker ants and the queen (Su and Scheffrahn, 1998; Rust *et al.,* 2004). The rice bran oil effectively acts as a carrier that protects the active ingredient and enhances its overall availability to the target pests. From toxicological standpoint, this mixture has low toxicity to non-target organisms compared to traditional chemical pesticides, which is why it is recommended as a safer alternative for integrated pest management (IPM) in organic farming (Pimental, 2005; Isman, 2006).

5. Conclusion

The present investigation demonstrates that boric acid-based baits effectively attract *D. orientalis* under both laboratory and field conditions. Among the tested treatments, rice bran oil combined with boric acid showed the highest overall attractiveness, particularly in Y-olfactometer assays and across different crop stages. The GC-MS analysis indicated that hexanal, pentanal, octanal and nonanal contribute to the olfactory attraction of *D. orientalis* towards the bait materials. These findings indicate that rice bran oil based boric acid bait can serve as a promising eco-friendly management strategy for controlling *D. orientalis* in potato and other field crops, especially in organic farming systems.

Acknowledgments

The authors acknowledge to the Networking Unit, All India Network Project on Soil Arthropod Pests, Indian Council of Agricultural Research (ICAR), Jaipur, Rajasthan, India for providing the necessary help support to carry out this study.

Author contributions

Elangbam Bidyarani Devi: Methodology, Investigation, Data analysis, Writing-Original draft. **Badal Bhattacharyya:** Conceptualization, Writing-Review and editing. **K. Sindhura Bhairavi:** Investigation, Data analysis, Writing-Review and editing. **Shimantini Borkataki:** Data analysis, Writing-Review and editing. **Sanjay Hazarika:** Data collection, Writing-Review and editing. **Priyanka Borbaruah:** Data collection, Writing-Review and editing

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

Ab Majid, A. H., Dieng, H., Ellias, S. S., Sabtu, F. S., Abd Rahim, A. H. and Satho, T. (2018). Olfactory behavior and response of household ants (Hymenoptera) to different types of coffee odor: A coffee-based bait development prospect. Journal of Asia Pacific Entomology, **21**(1):46-51.

Alanazi, N. A. (2023). Boric acid as a safe insecticide for controlling the Mediterranean fruit fly *Ceratitis capitata* Wiedemann (Diptera: Tephritidae). Engineering, Technology and Applied Science Research, **13**(5):11860-11864.

Ali, A. D. and Reagan, T. E. (1986). Comparison of baits for monitoring foraging activity of the red imported fire ant (Hymenoptera: Formicidae). Journal of Economic Entomology, **79**(5):1404-1405.

Baker, T. C., Van Voris Key, S. E. and Gaston, L. K. (1985). Bait-preference test for Argentine ant (Hymenoptera: Formicidae). Journal of Economic Entomology, **78**(5):1083-1088.

Becher, P. G., Hagman, A., Verschut, V., Chakraborty, A., Rozpêdowska, E., Lebreton, S., Bengtsson, M., Flick, G., Witzgall, P. and Piskur, J. (2018). Chemical signaling and insect attraction is a conserved trait in yeasts. Ecology and Evolution, **8**(5):2962-2974.

Bhandari, M. R. (2011). Assessment of red ant organic management options in potato field of Dhading, Nepal. Nepalese Journal of Agricultural Sciences, **9**:90-94.

Bhattacharyya, B., Bhuyan, U. and Pujari, D. (2014). Management of red ant, *Dorylus orientalis* Westwood (Hymenoptera: Formicidae) in potato. Journal of Entomological Research, **38**(4):265-267.

Bruce, T. J. A., Wadhams, L. J. and Woodcock, C. M. (2005). Insect host location: a volatile situation. Trends in Plant Science, **10**(6):269-274.

Choe, D. H., Vetter, R. S. and Rust, M. K. (2010). Development of virtual bait stations to control Argentine ants (Hymenoptera: Formicidae) in environmentally sensitive habitats. Journal of Economic Entomology, **103**(5): 1761-1769.

Chowdhury, H. M. (1997). Effects of irrigation and liming on the incidence of soil insect pests on potato. M.Sc. Thesis, Assam Agricultural University, Assam, Jorhat.

Cook, S. C., Eubanks, M. D., Gold, R. E. and Behmer, S. T. (2011). Seasonality directs contrasting food collection behavior and nutrient regulation strategies in ants. PLoS One, **6**(9):e25407.

Cornelius, M. L., Grace, J. K. and Yates, J. R. (1996). Acceptability of different sugars and oils to three tropical ant species (Hymen., Formicidae). Journal of Pest Science, **69**:41-43.

Csata, E., Gautrais, J., Bach, A., Blanchet, J., Ferrante, J., Fournier, F., Lévesque, T., Simpson, S. J. and Dussutour, A. (2020). Ant foragers compensate for the nutritional deficiencies in the colony. Current Biology, **30**:135-142.

David, P. M. M. (1991). Resurgence of yellow mite, *Polyphagotarsonemus latus* (Acarina: Tarsonemidae) on chilli following application of insecticides. Madras Agricultural Journal, **78**:88-91.

Devi, E. B., Bhattacharyya, B. and Bhagawati, S. (2022). Population dynamics of red ant *Dorylus orientalis* in potato crop grown under flood free/ prone conditions. Indian Journal of Entomology, **84**(4):942-946.

Fernando, H. E. and Manickavasagar, P. (1958). Investigation on potato insects and their control with special reference to *Dorylus orientalis*. Tropical Agriculture, **114**:127-139.

Fletcher, T. B. (1914). Some south Indian insects and other animals of importance. Madras. pp:274.

Gohain, T., Kehokhunu., Sakhong, R. and Goud, A. S. (2025). A study on growth, yield and quality traits of potato (*Solanum tuberosum* L) varieties under the agro-climatic regions of Nagaland, India. Environment and Ecology, **43**(4):1005-1010.

Harper, B., Gervais, J. A., Buhl, K. and Stone, D. (2012). Boric Acid Technical Fact Sheet. National Pesticide Information Center, Oregon State University Extension Services. http://npic.orst.edu/factsheets/archive/borictech.html. 2012.

Hansson, B. S. and Stensmyr, M. C. (2011). Evolution of insect olfaction. Neuron, **72**(5):698-711.

Holopainen, J. K. and Gershenzon, J. (2010). Multiple stress factors and the emission of plant VOCs. Trends in Plant Science, **15**(3):176-184.

Hossian, M. F., Ghosh, A., Hossian, M. A. and Seheli, K. (2021). Efficacy of boric acid as an attractive toxic sugar bait on laboratory reared *Aedes aegypti* Linnaeus (Diptera: Culicidae). International Journal of Mosquito Research, **8**(4):47-52.

Isman, M. B. (2006). Botanical insecticides, deterrents and repellents in modern agriculture and on increasingly regulated world. Annual Review of Entomology, **51**:45-66.

Kafle, L. N., Neupane, A. C., Wang, Y. M. and Gangai, S. R. (2020). Development of new boric acid gel baits for use on invasive ants (Hymenoptera: Formicidae). Sociobiology, **67**(1):59-64.

Klotz, J. H., Greenberg, L., Amrhein, C. and Rust, M. K. (2000). Toxicity and repellency of borate-sucrose water baits to Argentine ant (Hymenoptera: Formicidae). Journal of Economic Entomology, **93**(4):1256-1258.

Klotz, J. H. and Moss, J. I. (1996). Oral toxicity of a boric acid-sucrose water bait to Florida carpenter ants (Hymenoptera: Formicidae). Journal of Entomological Science, **31**(1):9-12.

Klotz, J. H., Oi, D. H., Vail, K. M. and Williams, D. F. (1996). Laboratory evaluation of a boric acid liquid bait on colonies of *Tapinoma melanocephalum* Argentine ants and Pharoah ants (Hymenoptera: Formicidae). Journal of Economic Entomology, **89**(3):673-677.

Klotz, J. H., Vail, K. M. and Williams, D. F. (1997). Toxicity of a boric acid-sucrose water bait to *Solenopsis invicta* (Hymenoptera: Formicidae). Journal of Economic Entomology, **90**(2):488-491.

Klotz, J. H. and Williams, D. F. (1996). New approach to boric acid ant bait. The IPM Practitioner, **18**(8):1-4.

Krushelnycky, P. D. and Reimer, N. J. (1998). Bait preference by the Argentine ant (Hymenoptera: Formicidae) in Halaekala National Park, Hawaii. Environmental Entomology, **27**(6):1482-1487.

Lee, C. Y. and Kooi, T. E. (2004). Guide to urban pest ants of Singapore. Singapore, SPMA for Pest Management Professionals. pp:40.

Madsen, N. and Offenberg, J. (2020). Seasonal changes in sugar and amino acid preferences in red wood ants of the *Formica rufa* group. Sociobiology, **67**(2):144-152.

Malukrishna, G. and Nirmala, P. (2005). Rice bran oil: Composition, nutritional and therapeutic aspects: A review. Food Chemistry, **90**(4):477-482.

Maurya, N. K. and Kushwaha, R. (2018). Pharmacognosy of rice bran oil-A review. International Journal of Green Pharmacy, **12**(4):S784-S789.

Newton, J. (1980). Alternatives to chlordecone for Pharaoh's ant control. International Pest Control, **22**:112-114.

Nyamukondiwa, C. and Addison, P. (2014). Food preference and foraging activity of ants: Recommendations for field applications of low-toxicity baits. Journal of Insect Science, **14**:1-13.

Olkowski, W., Daar, S. and Olkowski H. (1991). Common Sense Pest Control. Taunton Press, Newton, CT, pp:715.

Pickett, J. A., Wadhams, L. J. and Woodcock, C. M. (1997). Developing sustainable pest control from chemical ecology. Agriculture, Ecosystem and Environment, **64**(2):149-156.

Pimental, D. (2005). Environmental and economic costs of the application of the pesticides primarily in the United States. Environmental Development and Sustainability, **7**:229-252.

Pinero, J. C., Barrett, B. A., Bolton, L. G. and Follett, P. A. (2019). b-cyclocitral synergizes the response of adult *Drosophila suzukii* (Diptera: Drosophilidae) to fruit juices and isoamyl acetate in a sex-dependent manner. Scientific Reports, **9**:10574.

Quaries, W. (1993). Boric acid and household pests. The IPM Practitioner, **15**:1-11.

Rahman, A. (1967). Studies on the efficacy of some chlorinated insecticides in controlling soil insects of potato with special reference to *Dorylus orientalis* Westw. M.Sc. (Ag.) Thesis, Dibrugarh University, Assam Agricultural College, Assam, Jorhat.

Renyard, A., Gooding, C., Chalissery, J. M., Petrov, J. and Gries, G. (2024). Effects of macro-and micro-nutrients on momentary and season-long feeding responses by select species of ants. Scientific Reports, **14**:5727.

Riley, C. V. (1889). The little red ant. In: Insect Life, pp:106-108.

Rust, M. K. (1986). Managing household pests. In: Advances in Urban Pest Management (Eds.) Bennett, G. W. and Owens, J. M. Van Nostrand Reinhold, New York, pp: 335-368.

Rust, M. K., Reierson, D. A., Paine, E. and Blum, L. J. (2000). Seasonal activity and bait preferences of the Argentine ant (Hymenoptera: Formicidae). Journal of Agricultural and Urban Entomology, **17**:201-212.

Rust, M. K., Reierson, D. A. and Klotz, J. H. (2004). Boric acid: Effective ant control through delayed toxicity and social transfer. In: Urban entomology: Insects and mites in the human environment (Ed.) Klotz, J. H. CRC Press, pp:187-202.

Saikia, N. and Deb Nath, K. (2017). Efficacy of various pesticides against red ant (*Dorylus orientalis*, Westwood) of potato. Journal of Applied and Natural Science, **9**(4):2350-2352.

Schnitzer, M. (1991). Soil organic matter: The next 75 years. Soil Science, **151**(1):41-58.

Sharma, K. R., Enzmann, B. L., Schmidt, Y., Moore, D., Jones, G. R., Parker, J., Berger, S. L., Reinberg, D., Zwiebel, L. J., Breit, B., Leibig, J. and Ray. A. (2015). Cuticular hydrocarbon pheromones for social behavior and their coding in the ant antenna. Cells Reports, **12**(8):1261-1271.

Stanley, M. C. (2004). Review of the efficacy of baits used for ant control and eradication. Summary Final Report-Operational Research.

Su, N. Y. and Scheffrahn, R. H. (1998). Boric acid and borates for termite and ant control. Pest Management Science, **54**(1):2-10.

Ungureanu, N., Vladut, V. and Biris, S. S. (2022). Sustainable volarization of waste and by-products from sugarcane processing. Sustainability, **14**(17):11089.

Vanderwoude, C., Siolo, S., Sio, F. and Tupufia, S. (2006). Assessment of yellow crazy ants (*Anoplolepis gracilipes*) on Nuulua Island, Aleipata. A status assessment report, pp:1-30.

Wyatt, T. D. (2014). Pheromones and animal behavior: Chemical signals and signatures. Cambridge University Press.

Zakharov, A. A. and Thompson, L. C. (1998). Effects of repeated use of fenoxycarb and hydramethylnon baits on nontarget ants. Journal of Entomological Science, **33**:212-220.

Citation **Elangbam Bidyarani Devi, Badal Bhattacharyya, K. Sindhura Bhairavi, Shimantini Borkataki, Sanjay Hazarika and Priyanka Borbaruah (2026). Use of boric acid-based bait materials as attractants against red ant, *Dorylus orientalis* Westwood. Ann. Phytomed., 15(1):710-719, http://dx.doi.org/10.54085/ap.2026.15.1.63.**