Eco. Env. & Cons. 26 (August Suppl. Issue) : 2020; pp. (S210-S215)
Copyright@ EM International
ISSN 0971–765X

Evaluation of toxicity of botanicals and essential oils against *Solenopsis geminata* (Fabricius) (Hymenoptera: Formicidae)

T. Nalini * and S. Sasinathan

Department of Entomology, Faculty of Agriculture, Annamalai University, Chidambaram 608 002, Tamil Nadu, India

(Received 23 October, 2019; accepted 12 February, 2020)

ABSTRACT

Solenopsis geminata is an invasive ant species which affect plant health by tending sucking insects and prevent pollination. Laboratory experiments were carried out to test the toxicity of botanicals *viz*., clove, cinnamon, coriander powder and essential oils *viz*., pepper mint, clove, eucalyptus in the Department of Entomology, Faculty of Agriculture, Annamalai University. In toxicity tests on *S. geminata* with botanicals 100 percent mortality was caused in clove powder at the dose of 81mg after 120 minutes; Cinnamon powder at 108 mg dose after 240 minutes; Coriander powder at the dose of 108 mg after 240 minutes. In toxicity tests on *S. geminata* with essential oils 100 per cent mortality was obtained in clove oil at 2 and 2.5 per cent concentrations after 30 minutes; Peppermint oil at 1.5, 2 and 2.5 per cent concentrations after 60 minutes; Eucalyptus oil at 2 and 2.5 per cent concentrations after 120 minutes.

Key words: *Toxicity, Solenopsis geminata, Botanicals, Essential oils.*

Introduction

Solenopsis geminata is a non – native ant species reported in twenty two states of India including Andaman and Nicobar islands (Bharti *et al*., 2016). The tropical fire ant, *S. geminata*, has out competed and eliminated many native species in rural, urban and agricultural lands (Whitcomb *et al*., 1972). It is considered to be an economically very important pest (Lakshmikantha *et al*., 2001). *Solenopsis geminata* is reported to occur in many crops (avocado, banana, cabbage, citrus, cocoa, corn, cotton, coffee, cucumber, eggplant, mango, okra, papaya, pastureland, pineapple, sorghum, soybeans, strawberries, sugarcane, tobacco, tomato, rice and vegetables) and in cultivated land, it is seldom reported to be a direct pest of these crops and seed loss to crops like cabbage, corn, sorghum and tomato can be significant. On the other hand this species also found to girdle plants, imbibes sap, and bites branches, shoots, buds, flowers and fruits (Hill, 1975).

Many insecticide products are available for fire ant control, most of them are synthetic organic insecticides. These chemicals create public health and environmental concerns. To resolve that new eco-friendly strategies for controlling the tropical fire ant should be developed. Keeping in mind the importance of *S. geminata* management the present investigation was initiated to evaluate the toxicity of selected botanicals and essentials oils against *S. geminata* under laboratory conditions.

Materials and Methods

Rearing of *Solenopsis geminata*

The tropical fire ant colonies were collected from the fields of Sivapuri using 25 liters plastic buckets. Talcum powder was applied (baby powder) liberally to the inner surface of the bucket. The ants can't climb dusted vertical surface as long as the surface remains dry. The ant mound was shoveled quickly into the bucket. After collecting the ants it was made sure to cut any grass that may form a bridge to the top of the bucket and recoated with talcum powder. The bucket was transferred to the laboratory. Bucket was left to remain undisturbed for few days for the ants to organize their colony in the bucket. For extra protection the bucket was placed in a larger container (or) tray filled with soapy water. To extract the ant colony from the soil, slowly water was dripped into the buckets, constantly observing the water level. The ants (workers, queen[s], winged males, and female reproductives) and worker ants carrying brood (eggs, larvae, and pupae) was moved to the top of the soil and ultimately floated or "raft" on the water's surface. Using a slotted spoon, the ants and broods were scooped out and placed into a plastic colony tray (35×24×17 cms) with the inside surface coated with a substance like talcum powder, which prevented the ants from escaping. The colony tray was placed inside a larger pan contain-ing soapy water about one inch deep, which helped to drown any escaping ants. Colonies were maintained at room temperature and constant moisture was provided by sprinkling water frequently whenever needed. Honey and water mixture at 1:3 ratio was prepared and offered to the colony in a bottle cap at a rate of about half table spoon per day and two leeches or snails were provided at two days interval (Banks *et al*., 1981)

All laboratory tests were conducted at Department of Entomology, Faculty of Agriculture, Annamalai University during January – March 2018. The studies were conducted under ambient temperature and relative humidity, averaging 27 $\pm 1^0$ C and 50 ± 3% RH, respectively, under a photoperiod of 12:12 LL: DD h. Ants were reared as per the procedure mentioned above were used in both toxicity and repellency tests. The laboratory reared ants were kept separated from the original colonies and each colony was kept in a separate container for three hours before each test.

Toxicity test on *Solenopsis geminata* with botanicals

To determine the toxicity of clove, cinnamon and coriander powder they were ground using a blender to a fine powder. Sieved using sieve mesh of size 212 MICS. Finely ground botanicals were used. Beakers (9cm diameter) were used for the toxicity tests of the test materials. The inside vertical wall of each beaker was coated with a talcum powder to prevent the *S. geminata* from escaping. Each at the botanicals were dusted on the bottom surface inside the beaker and then 20 *S. geminata* workers were transferred into each beaker. The botanicals were tested at five concentrations (3.06, 9, 27, 81 and 108mg /9cm^2) and replicated three times. The beaker for the control study contained only ants and no botanicals. Ant mortality was accounted by counting the dead ants at 30, 60, 120, 180, 240 and 360 minutes after treatment. During the tests, no food was given to the *S. geminata* (Modified Kafle and Shih, 2013). Finally cumulative percent mortality was calculated by the formula given below.

$$\text{Cumulative mortality (\%)} = \frac{\text{Number of dead ants}}{\text{Total number of test ants}} \times 100$$

Toxicity test on *Solenopsis geminata* with essential oils

The essential oils viz., pepper mint, clove and eucalyptus were purchased from Allin Exporters. To determine the toxicity of the essential oils of pepper mint, clove and eucalyptus, Each of the essential oils were diluted in solvent (EtOH) and sprayed inside bottom surface of the beaker and kept under fan until the sprayed essential oil has dried. Then, 20 *S. geminata* workers were transferred into each beaker containing each of the essential oil mentioned above. The three essential oils were tested at the concentrations of 0.5%, 1%, 1.5%, 2%, and 2.5% in EtOH. The beakers for the control study were only sprayed with solvent. Each test was replicated three times. Ant mortality was accounted by counting the dead ants at 30, 60, 120, 180, 240 and 360 minutes after treatment. During the tests, no food was given to the tropical fire ants (Modified Kafle and Shih, 2013). Finally cumulative percent mortality was calculated.

Results and Discussion

The data on toxicity of different botanicals against

workers of *S. geminata* are presented in Table 1 – 3. The effect of clove powder tested against *S. geminata* workers resulted in 100 per cent mortality after 120 minutes at the dose of 81 mg followed by 108mg and after 240 minutes at 27 mg dose. Lowest mortality was recorded as 3.3 per cent after 30 minutes at the dose of 3.06 mg. No mortality was noticed in control throughout the study period (Table 1). Cinnamon powder caused 100 per cent mortality after 240 minutes at 108 mg dose, while 3.06 mg dose re-

Table 1. Effect of toxicity of clove powder against *Solenopsis geminata*

Treatment	Dose	*cumulative per cent mortality of *Solenopsis geminata* after					
No	(mg)	30 MAT	60 MAT	120 MAT	180 MAT	240 MAT	360 MAT
T_1	3.06 mg	3.33(8.61)	15.00(22.58)	63.33(52.85)	80.00(63.52)	86.66(68.82)	93.33(75.21)
T_2	9 mg	4.333(9.78)	18.33(25.29)	73.33(59.03)	88.33(70.08)	95.55(82.85)	97.77(85.00)
T_3	27 mg	10.00(14.99)	43.33(41.05)	91.66(90.00)	98.33(85.68)	100.00(90.00)	100.00(90.00)
T_4	81 mg	63.33(52.85)	78.33(62.37)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_5	108 mg	73.33(58.98)	88.33(70.08)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_6	Control	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(d)	7.02	5.53	5.30	3.16	4.83	3.36	
C.D	15.86	12.50	11.97	7.14	10.91	7.60	

MAT – Minutes after treatments
*Mean of three replications
Data in parentheses are arcsine transformed values

Table 2. Effect of toxicity of cinnamon powder against *Solenopsis geminata*

Treatment	Dose	*cumulative per cent mortality of *Solenopsis geminata* after					
No.	(mg)	30 MAT	60 MAT	120 MAT	180 MAT	240 MAT	360 MAT
T_1	3.06 mg	0.00(0.00)	8.33(16.59)	20.00(26.44)	51.66(45.94)	68.33(55.74)	76.66(61.12)
T_2	9 mg	0.00(0.00)	13.33(21.32)	21.66(27.69)	58.33(49.78)	71.66(57.88)	80.00(63.52)
T_3	27 mg	0.00(0.00)	16.66(24.03)	35.00(36.22)	70.00(56.94)	80.00(63.52)	91.66(73.37)
T_4	81 mg	0.00(0.00)	23.33(28.84)	40.00(39.19)	75.00(60.05)	86.66(68.63)	93.33(75.21)
T_5	108 mg	0.00(0.00)	31.667(34.21)	58.33(49.81)	86.66(68.63)	100.00(90.00)	100.00(90.00)
T_6	control	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(d)	1.16	1.94	2.69	3.07	2.17	2.22	
C.D	2.62	4.37	6.07	6.93	4.91	5.02	

MAT – Minutes after treatments
*Mean of three replications
Data in parentheses are arcsine transformed values

Table 3. Effect of toxicity of coriander powder against *Solenopsis geminata*

Treatment	Dose	*cumulative per cent mortality of *Solenopsis geminata* after					
No	(mg)	30 MAT	60 MAT	120 MAT	180 MAT	240 MAT	360 MAT
T_1	3.06 mg	0.00(0.00)	3.33(8.61)	28.33(32.12)	51.66(45.93)	75.00(59.97)	83.33(65.92)
T_2	9 mg	0.00(0.00)	8.33(16.59)	35.00(36.22)	60.00(50.76)	78.33(62.26)	88.33(70.08)
T_3	27 mg	0.00(0.00)	11.66(19.87)	45.00(42.10)	70.00(56.81)	93.33(75.21)	98.33(85.68)
T_4	81 mg	3.33(6.14)	21.66(27.58)	58.33(49.81)	88.33(70.08)	98.33(85.68)	100.00(90.00)
T_5	108 mg	21.66(27.58)	35.00(36.22)	76.66(61.12)	90.00(71.53)	100.00(90.00)	100.00(90.00)
T_6	Control	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(d)	4.17	3.62	2.43	1.91	3.05	2.98	
C.D	9.41	8.17	5.49	4.31	6.89	6.74	

MAT – Minutes after treatments
*Mean of three replications
Data in parentheses are arcsine transformed values

corded 68.33 per cent mortality. The doses like, 9, 27 and 81 mg recorded 71.66, 80.00 and 86.66 per cent mortality after 240 minutes respectively. No mortality was observed in all the doses up to 30 minutes whereas in control even after 360 minutes. Lowest mortality was recorded as 8.33 per cent after 60 minutes at 3.06mg dose (Table 2). Cent per cent mortality was recorded at the dose of 108 mg; 81mg of coriander powder against *S. geminata* after 240; 360 minutes respectively. Lowest mortality was recorded at 3.06mg after 60 minutes. No mortality was observed in 3.06, 9, 27mg up to 30 minutes whereas in control even after 360 minutes (Table 3).

The data on toxicity of different essential oils against workers of *S. geminata* were given in Tables 4– 6. The efficacy of clove oil against *S. geminata* workers obtained 100 per cent mortality after 30 minutes at 2 and 2.5 per cent concentrations. The lowest per cent mortality (81.66 per cent) was observed after 30 minutes at 0.5 per cent concentration followed by 86.66 percent at 1 per cent concentration after 30 minutes. No mortality was observed in control even after 360 minutes (Table 4). Peppermint oil caused 100 per cent mortality of workers of *S. geminata* after 60 minutes at 1.5, 2 and 2.5 per cent concentrations followed by 98.33 per cent mortality after 30 minutes at 2.5 per cent concentration. Lowest mortality was recorded as 63.33 per cent after 30 minutes at 0.5 per cent concentration. No mortality was occurred in control even after 360 minutes (Table 5). Mortality of *S. geminata* workers was recorded as 100 per cent at 2 and 2.5 per cent concentrations of eucalyptus oil after 120 minutes. The concentration like 0.5, 1 and 1.5 per cent recorded 87.14, 94.76 and 97.85 per cent mortality after 120 minutes respectively. Lowest mortality was observed in 0.5 per cent concentration as 73.09 after 30 minutes. No mortality was noticed in control even after 360 minutes (Table 6).

While screening plant materials for potential use

Table 4. Effect of toxicity of clove oil against *Solenopsis geminata*

Treatment No.	Concentration (%)	*cumulative per cent mortality of *Solenopsis geminata* after					
		30 MAT	60 MAT	120 MAT	180 MAT	240 MAT	360 MAT
T_1	0.5%	81.66(64.66)	90.00(71.55)	90.00(71.53)	93.33(75.21)	95.00(77.09)	96.66(81.36)
T_2	1%	86.66(68.63)	96.66(81.36)	98.33(85.68)	98.33(85.68)	98.33(85.68)	100.00(90.00)
T_3	1.5%	93.33(75.21)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_4	2%	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_5	2.5%	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_6	Control	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(d)			2.73	2.96	2.73	2.73	
C.D			6.16	6.69	6.16	6.16	

MAT – Minutes after treatments
*Mean of three replications
Data in parentheses are arcsine transformed values

Table 5. Effect of toxicity of pepper mint oil against *Solenopsis geminata*

Treatment No	Concentration (%)	*cumulative per cent mortality of *Solenopsis geminata* after					
		30 MAT	60 MAT	120 MAT	180 MAT	240 MAT	360 MAT
T_1	0.5%	63.33(52.72)	80.00(63.40)	86.66(68.63)	90.00(69.21)	93.33(75.21)	96.66(81.36)
T_2	1%	66.66(54.72)	90.00(71.92)	96.66(83.84)	98.33(85.68)	98.33(85.68)	100.00(90.00)
T_3	1.5%	76.66(61.12)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_4	2%	85.00(67.37)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_5	2.5%	98.33(85.68)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_6	control	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(d)	3.31	1.80	3.99	3.75	12.96	2.73	
C.D	7.48	4.07	9.02	8.46	16.69	6.16	

MAT – Minutes after treatments
*Mean of three replications
Data in parentheses are arcsine transformed values

against the red imported fire ant, both clove powder and clove oil have shown promising results. Biological activity of clove oil has been investigated for use against several insect pests, and it exhibits insecticidal activity against *Anopheles dirus* Peyton and Harrison, *Culex pipiens* (L.), *Dermatophagoides farina* Hughes, *Dermatophagoides pteronyssinus* (Trouessart), *Pediculus capitis* de Geer, *Psoroptes cuniculi* Delafond, *Sitophilus zeamais* Motschulsky, and *Tribolium castaneum* (Herbst) (Chaieb *et al*., 2007). Clove oil has been tested against a number of urban and agricultural pests, and it has been found to have pesticidal properties against some pests (Ho *et al*., 1994; Perrucci *et al*., 1995; El Hag *et al*., 1999; Kim *et al*., 2003; Yang *et al*., 2003; Trongtokit *et al*., 2005; Chaieb *et al*., 2007). The above studies are in supportive with the present study results.

Similar to the present findings Kafle and Shih (2013) also reported that clove powder applied at 3 and 12 mg/cm^2 provided 100% ant mortality within 6 h, and repelled *Solenopsis invicta* by 99% within 3 h. Eugenol was the fastest acting compound against red imported fire ant compared with eugenol acetate, beta-caryophyllene, and clove oil. The LT50 values inclined exponentially with the increase in the application rate of the chemical compounds tested. However, repellency did not increase with the increase in the application rate of the chemical compounds tested, but did with the increase in exposure time. Eugenol, eugenol acetate, as well as beta-caryophyllene and clove oil may provide another tool for red imported fire ant integrated pest management, particularly in situations where conventional insecticides are inappropriate.

Essential oils widely used a fragrances and flavors in the perfume and food industries, have long been reputed to repel, contact, fumigate itself, and control some important plant pathogens (Koul *et al*., 2008) but the fumigant activities of essential oil against red imported fire ants were rarely reported Zhou *et al.* (2012).

In similar to the present study results Kafle and Shih (2013) also stated that at 0.5 ml km^2 clove oil killed 59% of *S. invicta* at 6 hours after treatment. The followed by pepper mint oil is next high toxic for the *S. geminata* workers on 2.5% concentration on 100% mortality for 60 minutes after treatment. In same mint oil vapour has fumigant effects against both american and german cockroaches (Appel *et al*., 2001). Even though fumigation and direct mound injection is a rarely used tactic for red imported fire ant control (Dress *et al*., 2000), used mounds opened were abandoned rapidly (67% at day and 100% at day 5 and 100% of their mound had relocated or formed satellite mounds 2 days after treatment.

Experiments were conducted by Vogt *et al*. (2002) to assess efficacy of raw citrus peel extract (orange oil) and a commercial citrus oil formulation for control of *S. invicta* Buren, the red imported fire ant in that they prepared a recipe containing orange oil (equal parts orange oil, cattlemen's molasses, and compost tea at 47 mL L^{-1} water), orange oil premixed with water to form an emulsion, and the commercial product all resulted in 80% or greater control when applied in 3.8 L of water as a mound drench. In most trials, the level of activity in mounds receiving citrus oil alternatives was statistically comparable with conventional diazinon formulations.

Similar to the present observations Kumar *et al*. (2012) also stated that, the insecticidal activity of the

Table 6. Effect of toxicity of Eucalyptus oil against *Solenopsis geminata*

Treatment No	Concentration (%)	*Cumulative per cent mortality of *Solenopsis geminata* after					
		30 MAT	60 MAT	120 MAT	180 MAT	240 MAT	360 MAT
T_1	0.5%	73.09(52.72)	84.28(61.12)	87.14(65.92)	91.19(70.08)	93.33(75.21)	95.00(79.52)
T_2	1%	78.09(54.72)	91.66(67.18)	94.76(71.53)	96.19(75.21)	98.33(85.68)	100.00(90.00)
T_3	1.5%	86.19(61.12)	95.00(70.08)	97.85(71.04)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_4	2%	92.14(64.66)	97.14(75.21)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_5	2.5%	95.00(70.08)	99.28(85.68)	100.00(90.00)	100.00(90.00)	100.00(90.00)	100.00(90.00)
T_6	Control	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(d)	1.67	3.18	0.79	1.48	2.96	3.46	
C.D	3.77	7.19	1.79	3.34	6.69	7.81	

MAT – Minutes after treatments

* Mean of three replications

Data in parentheses are arcsine transformed values

oil of *E. globulus* has already been observed for some insect pests. But they believed that the higher insecticidal activity of the *Eucalyptus* oil to *S. invicta* workers is due to its major compound 1,8-cineole (94.30%), as this molecule is highly active against housefly (*Musca domestica* L.) (Kumar *et al*., 2014).

In agreement with present findings, Wang *et al*. (2014) stated that feeding and climbing abilities directly determine the *S. invicta* survival. They concluded that, mugwort and *Eucalyptus* oils could be used as natural repellents and natural fumigants because of their inhibitory effects on *S. invicta* feeding and climbing abilities, which could indirectly lead to the decline of the entire colony.

References

Appel, A.G., Gehret, M. J. and Tanley, M. J. 2001. Repellency and toxicity of mint oil to American and German cockroaches (Dictyoptera: Blattidae and Blattellidae). *Journal of Agricultural and Urban Entomology.* 18 : 149-156.

Banks, W.A., Lofgren, C.S., Jouvenaz, D.P., Stringer, C.E., Bishop, P.M., Williams, D.F., Wojcik, D.P. and Glancey, B.M. 1981. Techniques for collecting, rearing, and handling imported fire ants. USDA/SEA publication AAT-S-21, April.

Bharti, H., Guenard, B., Bharti, M. and Economo, E.P. 2016. An updated checklist of the ants of India with their specific distributions in Indian states (Hymenoptera: Formicidae). *Zoo Keys*. 551 : 1-83.

Chaieb, K., Hajlaoui, H., Zmantar, T., Kahla–Nakbi, A. B., Rouabhia, M., Mahdouani, K. and Bakhrouf. A. 2007. The chemical composition and biological activity of clove essential oil, *Eugenia caryophyllata* (*Syzigium aromaticum* L. Myrtaceae): a short review. *Phytotherapy Research.* 21 : 501-506.

Drees, B.M., Barr, C. L., Vinson, S. B., Gold, R. E., Merchant, M. E., Kostroun, D., Sparks, B., Pollett, D., Shanklin, D., Vail, K., Flanders, K., Horton, P. M., Oi, D., Koehler, P., Vogt, J. T., Riggs, N., Lennon, L., Russell, S and Nester, P. 2000. Managing imported fire ants in urban areas. *Journal of International Agricultural and Extension Education.* B-6043, 24 pp.

El Hag, E.A., El Nadi, A. H. and Zaiton, A. A. 1999. Toxic and growth retarding effects of three plant extracts on *Culex pipiens* larvae (Diptera: Culicidae). *Phytotherapy Research.* 13 : 388-392.

Hill, D.S. 1975. *Agricultural Insect Pests of the Tropics and their Control.* Cambridge University Press. Cambridge UK, [12 +] 516 pp.

Ho, S.H., Cheng, L.P.L., Sim, K. Y. and Tan, H.T.W.1994. Potential of cloves (*Syzygium aromaticum*) (L.) Merr. and Perry as a grain protectant against *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. *Postharvest Biology and Technology*. 4 : 179-183.

Kafle, L. and Shih, C.J. 2013. Toxicity and repellency of compounds from clove (*Syzygium aromaticum*) to red imported fire ants *Solenopsis invicta* (Hymenoptera: Formicidae). *Journal of Economic Entomology*. 106 (1): 131-135.

Kim, E.H., Kim, H. K. and Ahn, Y. J. 2003. Acaricidal activity of clove bud oil compounds against *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus* (Acari: Pyroglyphidae). *Journal of Agricultural and Food Chemistry*. 51 : 885-889.

Koul, O., Suresh, w. and Dhaliwal, G. S. 2008. Essential oils as green pesticides: potential and constraints. *Journal of Biopesticides Insecticides*. 4 : 63-84.

Kumar, P., Mishra, S., Malik, A. and Satya, S. 2014. Biocontrol potential of essential oil monoterpenes against housefly, *Musca domestica* (Diptera: Muscidae). *Ecotoxicology and Environmental Safety*. 100 : 1-6.

Kumar, P., Mishra, S., Malik, A. and Satya, S. 2012. Compositional analysis and insecticidal activity of *Eucalyptus globules* (family: Myrtaceae) essential oil against housefly (*Musca domestica*). *Acta Tropica*. 122(2): 212-218.

Lakshmikantha, B.P., Kumar, A. R. V. and Veeresh, G. K. 2001. Emergence of reproductives of the fire ant, *Solenopsis geminata* (Fabricius) (Hymenoptera: Formicidae), and its sex ratio. *Pest Management and Economic Zoology*. 9(2) : 129-133.

Perrucci, S., Macchioni, G., Cioni, P. L., Flamini, G. and Morelli, I. 1995. Structure/activity relationship of some natural monoterpenes as acaricides against *Psoroptes cuniculi. Journal of Natural Products.* 8 : 1261-1264.

Trongtokit, Y., Rongsriyam, Y., Komalamisra, N. and Apiwathnasorn, C. 2005. Comparative repellency of 38 essential oils against mosquito bites. *Pharmacological Research*. 19 : 303-309.

Vogt, J.T., Shelton, T.G., Merchant, M.E., Russell, S.A., Tanley, M.J. and Appel, A.G. 2002. Efficacy of three citrus oil formulations against *Solenopsis invicta* Buren (Hymenoptera: Formicidae), the red imported fire ant. *Journal of Agricultural and Urban Entomology*. 19: 159-171.

Wang, K., Tang, L. and Zhang, N. 2014. Repellent and fumigant activities of *Eucalyptus globulus* and Artemisia carvifolia essential oils against *Solenopsis invicta*. *Bulletin of Insectology*. 67: 207-211.

Whitcomb, W.H., Denmark, H. A., Bhatkar, A. P. and Greene, G. L. 1972. Preliminary studies on the ants of Florida soybean fields. *Florida Entomologist*. 55: 129-142.

Yang, Y.C., Lee, S. H., Lee, W. J., Choi, D.H. and Ahny, J. 2003. Ovicidal and adulticidal effects of *Eugenia caryophyllata* bud and leaf oil compounds on *Pediculus capitis*. *Journal of Agricultural Food Chemistry*. 51: 4884-4888.

Zhou, A.M., Lu, Y. Y., Zeng, L., Xu, Y. J. and Liang, G. W. 2012. Effects of honeydew of *Phenacoccus solenopsis* on foliar foraging by *Solenopsis invcta* (Hymenoptera: Formicidae). *Sociobiology*. 59 : 71-79.