Research Article

Field Evaluation of Promising Botanical Extracts, Plant Essential Oils and Differential Chemistry Insecticides against Subterranean Termites *Odontotermes obesus* (Isoptera: Termitidae)

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Abstract | Subterranean termites are destructive pests of agricultural crops, forest and orchard plantations and wooden infrastructures. A wide range of persistent synthetic chemicals are employed to prevent and control the infestations of subterranean termites. Most of these chemicals have high mammalian toxicity and environmental hazards. This study was, therefore, aimed to evaluate the efficacy of some promising botanical extracts (*Dodonaea viscosa*, *Gardenia jasminoides* and *Nerium indicum*), plant essential oils (*Allium sativum*, *Citrus aurantium* and *Cymbopogon citratus*) and differential-chemistry insecticides (chlorantraniliprole, chlorfenapyr, emamectin, indoxacarb, pyriproxyfen and triflumuron) against subterranean termites (*Odontotermes obesus*) attacking sugarcane crop. Setts of sugarcane variety HSF555 were sown on the ridges under RCB design after treating them with 20% botanical extracts, 2.0% essential oils and differential-chemistry insecticides with their field recommended dose rates. Results revealed that as compared to control plots, all treatment plots exhibited reduced bud and shoot damage with maximum bud germination and minimum termite infestation. Maximum bud germination was recorded in chlorantraniliprole (92.99%) and chlorfenapyr (92.03%), followed by *C. aurantium* (92.84%) and *A. sativum* (85.78%) as compared to minimum bud germination in control (40.85%). Highest bud and shoot damage was recorded in control (61.92 and 48.15%, respectively), while the lowest was recorded in *C. aurantium* (16.18 and 15.56%, respectively). Similarly, minimum per sett termite counts was recorded in chlorantraniliprole (16.25) treated plots, followed by chlorfenapyr (22.83), pyriproxyfen (30.04), *A. sativum* (28.50) and *C. aurantium* (29.00), while maximum termite infestation was recorded in control (68.50 individuals per sett). In brief, chlorantraniliprole, chlorfenapyr and pyriproxyfen among differential-chemistry insecticides and *A. sativum*, *C. aurantium* and *G. jasminoides* among botanicals were the most effective at preventing the upsurge of termite infestation till 90 days of sett sowing, and are recommended to be used as eco-friendly options for controlling subterranean termites in sugarcane.

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Introduction

With approximately 3,500 described species, termites constitute an important insect fauna of tropical and temperate ecosystems (Engel, 2011; Majeed, 2012). Many termite species such as subterranean termites are destructive pests of agricultural crops, tree plantations and wooden structures (Rouland-Lefèvre, 2010; Buczkowski and Bertelsmeier, 2017). *Odontotermes, Microtermes* and *Coptotermes* are the most important genera of subterranean termites reported from Pakistan (Ahmed *et al*., 2005; Manzoor *et al*., 2011; Sattar *et al*., 2014) and *O. obesus* is the most common subterranean termite species attacking a number of agricultural crops including sugarcane, maize, sesame, cotton, wheat and gram (Sattar *et al*., 2014; Aihetasham *et al*., 2018).

Synthetic insecticides have been playing a major role in termite management all over the world including Pakistan. In Indo-Pak regions, a wide range of synthetic insecticides including DDT, thiodan, deltamethrin, carbosulfan and triazophos are applied against subterranean termites (Rana and Dahiya, 2001; Ahmed *et al*., 2006; Manzoor *et al*., 2012; Iqbal and Saeed, 2013). Most of these conventional synthetic insecticides are highly persistent with long residual effects causing the eradication of non-target organisms, including soil microbiota, predators and parasitoids, environmental contamination and insect pest resistance (Baker and Bellamy, 2006; Desneux *et al*., 2007; Edwards, 2013).

Nevertheless, plant based insecticides and differential chemistry synthetic insecticides are emerging as relatively safer pest control tactics than conventional ones. Plants extracts and essential oils would be suitable alternate of synthetic insecticides (Ahmed *et al*., 2007; Isman, 2008; Dubey *et al*., 2010). Plant derived compounds are considered as a pool of chemical substances which have potential uses against a wide range of insect pests including subterranean termites (Bläske and Hertel, 2001; Peterson and Ems-Wilson, 2003; Ahmed *et al*., 2007). For instance, essential oils extracted from eucalyptus, vetiver plant, clove bud, cedar wood, lemongrass, geranium etc. have been found exhibiting certain deterrent and poisonous effects against the subterranean termites (Isman, 2000; Zhu *et al*., 2001; Ahmed *et al*., 2007; Ibrahim and Demisse, 2013).

Similarly, synthetic insecticides with differential chemistry and mode of action than the conventional insecticidal groups are emerging as promising tools to mitigate the problems of pest resistance and environmental contamination. These pesticides such as chlorantraniliprole, chlorfenapyr, emamectin benzoate, indoxacarb, pymetrozine, pyriproxyfen etc. are less persistent and more target specific and are safer to non-target fauna (Grafton-Cardwell *et al*., 2005; Ishaaya and Degheele, 2013). Many previous studies have demonstrated the efficacy of differential chemistry insecticides against different termite species (Mao *et al*., 2011; Rashid *et al*., 2012; Iqbal and Saeed, 2013).

Therefore, in order to avoid the above cited detrimental effects of conventional synthetic insecticides, these should be replaced with environment friendly and biorational tactics for the control of subterranean termites. To this end, the present study was conducted to evaluate the field efficacy of some selected botanical extracts, plant essential oils and differential chemistry insecticides against subterranean termites (*O. obesus*) in a sugarcane field with an ultimate objective to find out the most effective treatments which can be recommended to the indigenous sugarcane growers for better management of termite infestations.

Materials and Methods

Experiment site

The experiment was conducted from October, 2016 to January, 2017 in a village Chak No. 101 (31°58'5.6" N; 72°45'9.4" E) located at Kandiwal Road, Sargodha (Punjab, Pakistan). The average annual rainfall and temperature of this area is 410 mm and 23.8ºC, respectively (Zaka *et al*., 2004). Wheat, rice, maize and sugarcane are main agricultural crops of the area. Soil texture is sandy loam. The sugarcane field selected for the experiment was ensured to have severe termite infestation each year and it did not receive any pesticidal application for last 4 to 5 months prior to the experiment.

Treatments

Botanical extracts and essential oils (Table 1) were prepared in the laboratory of the Department of Entomology, College of Agriculture, University of Sargodha. In brief, different plant parts as described in Table 1 were collected from the vicinity of the College of Agriculture, University of Sargodha and were washed with distilled water and were air-dried at room temperature (27°C) for few days followed by grinding of plant material to course powder form. Extraction of plant extracts was carried out through Soxhlet apparatus (Sigma-Aldrich, Germany) using 1:10 (w/v) methanol as extraction solvent. In brief, 50 g of plant powder was extracted using 500 mL of methanol. Plant essential oils were extracted by the hydro distillation process using Clevenger-type apparatus. Formulations of differential chemistry insecticides (Table 2) were purchased from authorized dealers of multinational companies from the local pesticide market of the Sargodha district.

Experimental protocol

The experiment was laid out in a randomized complete block design (RCBD). Sugarcane variety HSF555 was sown on well-prepared soil ridges. Plant to plant and row to row distance was maintained at 20 and 90 cm, respectively. At the time of sowing, sugarcane setts (each having 3 bud-eyes) were dipped for two minutes in solutions of six botanicals including three essential oils (*C. citratus*, *C. aurantium* and *A. sativum* @ 2%), three crude plant extracts (*G. jasminoides*, *D. viscosa* and *N. indicum* @ 20%) and six differential-chemistry insecticides. Each treatment was independently and randomly replicated thrice in three blocks of the experiment. A distance of 10 ft was maintained in between two replication plots as buffer zone. The total study area was 5,715 ft^2 and the dimension of each plot was 8 x 10 ft. All routine agronomic practices were carried out for all plots.

Data collection

Bud germination: Germination of buds on the sown sugarcane setts was recorded by tallying the germinated buds out of total setts sown in each plot. Bud germination data was taken after 30 days of planting.

Bud and shoot damage: Bud damage was assessed by exposing the buds in each plot randomly. From each plot, randomly five sugarcane setts were excavated and examined for damage of buds by subterranean termites. The bud damage data was assessed after 50 days of planting. Similarly, percentage of shoot damage was assessed after 70 days of planting.

Table 1: *Different botanical extracts and essential oils evaluated under field conditions against subterranean termites (Odontotermes obesus) in sugarcane crop.*

Plants extracted	Major bioactive constituents	Extraction type
Bulbs of garlic (*Allium sativum*)	Diallyl di- and tri-sulfides, dipropyl di-sulfides (Zhao *et al*., 2013)	2% essential oil
Fruit peels and seeds of sour orange (*Citrus aurantium*)	Flavanone, β-pinene, α-terpineol, limonenes (Ibrahim *et al*., 2001)	2% essential oil
Leaves of lemon grass (*Cymbopogon citratus*)	Citral, citronellol, citronella, myrcene (Dodia *et al*., 2010)	2% essential oil
Stems of sanatha (*Dodonaea viscosa*)	Flavonoids, phenols, tannins, saponins, lupeol, and stigmasterol (Al-Snafi, 2017)	20% aqueous extract
Leaves and stems of gardenia (*Gardenia jasminoides*)	Iridoid glycosides (Li *et al*., 2018)	20% aqueous extract
Leaves of oleander (*Nerium indicum*)	Oleandrin and oleandrigenin (Dodia *et al*., 2010)	20% aqueous extract

Table 2: *Different insecticidal formulations evaluated under field conditions against subterranean termites (Odontotermes obesus) in sugarcane crop.*

Chemical Name (active ingredient)	Chemical family*	Mode of action	Brand Name	Company	Label dose (a.i. ha^{-1})
Chlorantraniliprole	28 (diamides)	Ryanodine receptor modulators	Coragen® 18.5 SC	DuPont	375 ml
Chlorfenapyr	13 (pyrroles)	Uncoupler of oxidative phosphorylation	Pirate® 360 SC	Swat Agro Chemicals	500 ml
Emamectin	6 (avermectins)	Glutamate-gated chloride channel (GluCl) allosteric modulators	Proclaim® 1.9 EC	Syngenta	500 ml
Indoxacarb	22A (oxadiazines)	Voltage-dependent sodium channel blockers	Steward® 150 EC	DuPont	375 ml
Pyriproxyfen	7C (pyriproxyfens)	Juvenile hormone mimics (IGR)	Admiral® 10 EC	FMC	75 ml

**According to insecticide resistance action committee (www.irac-online.org) IRAC MoA classification version 8.3, July 2017.*

Table 3: *Comparison of percent mean bud germination, bud damage, shoot damage and termite count recorded in sugarcane plots treated with different botanical extracts, plant essential oils and synthetic insecticides.*

Treatments	Bud germination (%)		Bud damage (%)		Shoot damage (%)		Termite count	
Gardenia jasminoides	83.22	±7.25 ab,*	30.09	±1.74 cd	30.27	±0.95 bcd	31.75	±6.29 bc
Dodonaea viscosa	70.33	±20.07 abc	34.99	±3.44 cd	24.82	±7.49 cde	33.75	±4.11 bc
Nerium indicum	76.03	±14.44 abc	40.85	±1.31 b	36.90	±2.04 b	37.50	±3.42 b
Citrus aurantium	90.84	±8.11 a	16.18	±2.35 f	18.04	±4.15 ef	29.00	±5.60 bcd
Allium sativum	85.78	±10.86 a	18.96	±3.34 ef	21.49	±2.47 def	28.50	±7.94 bcd
Cymbopogon citratus	77.70	±8.99 abc	32.18	±6.19 bcd	21.85	±2.12 def	36.50	±5.45 bc
Triflumuron	45.63	±16.64 bc	27.63	±3.65 cde	29.60	±2.23 bcd	34.75	±6.08 bc
Indoxacarb	66.88	±16.96 abc	35.23	±3.44 bcd	18.30	±5.67 ef	32.50	±4.80 bc
Pyriproxyfen	72.26	±13.25 abc	28.82	±2.21 cd	35.79	±1.53 b	29.50	±6.56 bcd
Chlorfenapyr	92.03	±8.88 a	25.97	±4.12 def	27.98	±3.03 bcd	22.50	±2.89 cd
Chlorantraniliprole	92.99	±7.47 a	18.67	±2.52 ef	15.56	±2.80 f	16.25	±4.11 d
Emamectin	71.49	±20.06 abc	37.41	±2.47 bc	32.04	±3.01 bc	32.00	±5.35 bc
Control	40.85	±10.18 c	61.92	±3.50 a	48.52	±2.83 a	68.50	±8.66 a

**Values are means (±SE) of five setts/plants randomly selected from three independent replications. Different alphabets indicate the statistical significance among treatment means within each column (two-way factorial ANOVA; Tukey HSD at α = 0.05).*

Termites count: The termite population was counted after 90 days of planting. For determining the termite population, sown setts were excavated out and the total individuals of subterranean termites on each plant (sett) were enumerated. Termites were identified by the termite experts as *O. obesus*.

Statistical analysis

Using Statistix® 8.1 (Analytical Software, 2005), data regarding bud germination, bud and shoot damage and termite infestation were subjected to statistical analyses by two-way ANOVA. Treatment means were compared using Tukey HSD at 0.95% level of significance.

Results and Discussion

Table 3 shows the effect of differential-chemistry insecticides, plant extracts and essential oils on sugarcane bud germination, bud and shoot damage and termite infestation. According to data analysis, there was a significant effect of all treatments (insecticides and botanicals) on the bud germination ($F_{12, 38}$ = 4.52; $P < 0.01$), bud damage ($F_{12, 38}$ = 36.23; $P < 0.001$) and shoot damage ($F_{12, 38}$ = 18.95; $P < 0.001$) of sugarcane setts and on the termite infestation level ($F_{12, 38}$ = 21.41; $P < 0.001$) (Supplementary Table 1).

Bud germination varied from maximum (92.99%) for chlorantraniliprole to minimum (45.63%) for triflumuron as compared to control plots which exhibited 40.85% bud germination, statistically lower than that of other treatments. In case of botanicals, *C. aurantium* and *A. sativum* exhibited highest mean bud germination (*i.e.* 90.84 and 85.78%, respectively) and were statistically different from other botanicals (Table 3). Among insecticides, chlorantraniliprole exhibited minimum bud damage (18.67%) followed by chlorfenapyr (27.63%) and pyriproxyfen (28.82%), while maximum bud damage (~38%) was recorded in plots treated with emamectin and indoxacarb. Among botanicals, bud damage varied from maximum (40.85%) for *N. indicum* to minimum (16.18%) for *C. aurantium* as compared to control plots which showed maximum (61.92%) bud damage, statistically different from other treatments (Table 3). Similarly, shoot damage varied from maximum (36.90%) for *N. indicum* to minimum for *C. aurantium* and *A. sativum* (*i.e.* 18.04 and 21.27%, respectively). Among insecticides, chlorantraniliprole showed significantly less shoot damage (15.56%) than all other treatments. Maximum shoot damage (48.52%) was observed in control plots and was statistically different from all other treatments.

At 90 days of sett sowing, infestation of termites was assessed by counting termite individuals on sugarcane plants. Highest mean termite count was recorded in control plots (68.50 individuals per sett) and was statistically different from all other treatments. Among synthetic insecticides, lowest termite count was recorded in chlorantraniliprole treated plots

(16.25 individuals per sett), followed by chlorfenapyr (22.83 individuals per sett) and pyriproxyfen (30.04 individuals per sett). While among botanical treatments, essential oils of *C. aurantium* and *A. sativum* exhibited minimum termites counts (~29.42 individuals per sett), followed by botanical extract of *G. jasminoides* (31.75 individuals per sett) (Table 3).

Subterranean termites are destructive pests of agricultural crops including sugarcane, maize, sorghum, rice, wheat, cotton, gram and groundnut in Pakistan (Ahmed *et al*., 2011). To control these pests, famers primarily rely on extensive and irrational application of persistent synthetic insecticides and most of these chemicals are notorious for their hazards to human health and environment (Mulrooney *et al*., 2006; Edwards, 2013). To mitigate pesticidal side-effects, searching for relatively safer and target-specific insecticidal tactics has been a core area of plant protection research. Wherefore, this study evaluated the efficacy of some promising indigenous botanicals (including plant extracts and essentials oils) and differential-chemistry insecticides (which are less persistent and comparatively safer than conventional ones) against subterranean termites under field conditions.

Results of the study showed that among botanicals, essential oils of *C. aurantium* and *A. sativum* were the most effective to suppress subterranean termite infestation under field conditions. Our results are in agreement with Ahmed *et al*. (2005) and Owusu *et al*. (2008) who demonstrated *in-situ* efficacy of different indigenous plant extracts against sugarcane infesting termites (*Microtermes* spp.) suggesting that these indigenous plant materials could be utilized for effective and biorational management of subterranean termites (Ahmed *et al*., 2007). Nevertheless, extracts of *C. aurantium* and *A. sativum* have been found effective against many insect pests (Hollingsworth, 2005; Samarasinghe *et al*., 2007; Siskos *et al*., 2009; Zhao *et al*., 2013) including subterranean termites (Park and Shin, 2005; Osipitan *et al*., 2013).

Our results demonstrated that botanical extracts and essential oils showed more or less similar results as compared to differential chemistry synthetic insecticides although the later were statistically more effective. This is in accordance with Ibrahim and Demisse (2013) who used two plant extracts (*Maesalan ceolata* and *A. indica)* and a synthetic insecticide Diazinon 60EC against termites and found that botanicals were as effective as synthetic chemical. Our results are also in line with those of Daniel and Bekele (2006) who demonstrated the efficacy of plant extracts statistically similar to chlorpyrifos against *Macrotermes* spp.

In case of differential chemistry insecticides, chlorantraniliprole and chlorfenapyr appeared to be the most effective insecticides against *O. obesus* termite infestation in sugarcane field. These results corroborate the findings of Spomer *et al*. (2009), Mao *et al*. (2011), Neoh *et al*. (2012) and Ma and Sui (2013) who demonstrated that these differential-chemistry insecticides are highly effective against subterranean termites. Apart from chlorantraniliprole and chlorfenapyr, indoxacarb and pyriproxyfen were also effective differential chemistry insecticides causing minimum bud and shoot damage concomitantly with minimum termite infestation. These results are in line with those of Rust and Saran (2006), Rai (2014), Misbah-ul-Haq *et al*. (2016), Lewis and Forschler (2017), Akbar *et al*. (2018) and Sapkota (2018).

Conclusions and Recommendations

In brief, this study was aimed to evaluate *in-situ* efficacy of different biorational insecticides against subterranean termite infestation in sugarcane crop. Based on results of the study, essential oils of *A. sativum* and *C. aurantium* and differential chemistry insecticidal formulations of chlorantraniliprole, chlorfenapyr, indoxacarb and pyriproxyfen are recommended as biorational control options for the management of *O. obesus* and other subterranean termites. In short, the study corroborates the effectiveness of indigenous botanical extracts and differential chemistry insecticides against subterranean termite infestations in sugarcane under field conditions.

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Novelty Statement

This comparative *in-situ* evaluation of different biorational pesticides against subterranean termites infesting sugarcane crop demonstrated that chlorantraniliprole, chlorfenapyr and pyriproxyfen among the differential chemistry insecticides and *A. sativum*, *C. aurantium* and *G. jasminoides* among the botanicals are effective at preventing termite infestation suggesting their future use as environmental-friendly termite management options in the field.

Author's Contribution

MSA and MZM conceived the idea and planned the experiment. MSA and FS performed experiments and wrote first draft of the manuscript. MAR and ML performed statistical analyses. MAR and MA technically revised the manuscript. MA provided technical assistance and proofread the manuscript.

Supplementary Material

There is supplementary material associated with this article. Access the material online at: http://dx.doi.org/10.17582/journal.sja/2021/37.1.120.127

Conflict of interest

The authors have declared no conflict of interest.

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