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EFFICACY OF SOME PLANT EXTRACTS AGAINST TERMITES UNDER CONTROLLED CONDITIONS

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ABSTRACT

Termites, particularly *Odontotermes* spp., are a severe pests of several crops in India. The usage of environmental friendly chemicals for termite management has been on the rise worldwide. This study examined the effects of various fresh and fermented plant extracts, viz. sweet neem (leaf), marigold (flower), tulsi (leaf), common lantana (leaf), neem (leaf), congress grass (leaf), and jatropha (seeds) at four distinct concentrations (5, 10, 15, and 17.5% w/v) on worker caste of *Odontotermes* sp. After 48 hr of exposure, the fresh extracts (5%) of neem and congress grass resulted in the highest mortality (93.30% and 90%, respectively), while the fermented extracts (5%) of neem and tulsi achieved 100% death at 12 hr only. They were at par with the standard check (imidacloprid 17.8 SL). Thus, neem, tulsi, and congress grass based extracts could be incorporated as effective botanicals into an integrated termite management program.

Key words: Termites, *Odontotermes* sp., workers, botanicals, mortality, management, lantana, tulsi, congress grass, jatropha, marigold, extracts, bioassy, evaluation

Termites are one of the most widespread eusocial isopterous insects, bearing complex division of labor within each colony (Eggleton, 2001). They are found in a wide range of terrestrial environments and diverse climatic conditions worldwide. Although important in ecosystems, termites are one of the most damaging pests to agriculture, forestry, and cellulosic materials used in household service (Enagbonma et al., 2019). There are over 2500 reported species of termites, of which 300 are considered pests (Rajagopal, 2002). In India, *Odontotermes* spp. is one of the most predominant and widespread termite that damage almost all major crops like wheat, maize, sugarcane, cotton, groundnut, pulses etc. (Narayanan and Thomas, 2016). The total yield loss due to termites has been estimated to be about 10-25% of most crops in the country, resulting in a huge monetary loss of several hundred million rupees every year (Ranjith et al., 2021). Termite control is a herculean task, and chemical pesticides are generally adopted. Many commercial termiticides are potential environmental contaminants with long persistence; therefore, recently, interest has been generated in using plant-based products as insecticide alternatives in pest control programs (Rana et al., 2021). These are considered a lucrative option because of their low mammalian toxicity and environmental safety. Furthermore, their techniques of preparation and application are more convenient for farmers. The deleterious effects of plant extracts on termites are manifested in several ways, including suppression of calling behaviour, growth retardation, toxicity, oviposition deterrence, feeding inhibition, reduction of fecundity and fertility and adverse effect on their gut microflora (Wallace et al., 2010). Several plant species have been explored for termite control in the past for their anti-feedant and insecticidal activities (Addisu et al., 2014). However, for their effective and economical management, locally available indigenous plant materials are required (Dubey et al., 2008). Cognizant of the above benefits regarding the use of botanicals and the meagre research findings on the use of botanicals for the management of termites in India (Paul et al., 2018), the present study was conducted to evaluate the efficacy of some locally available plants against *Odontotermes* sp. at different concentrations.

MATERIALS AND METHODS

Odontotermes sp. populations were collected from termitariums located at the premises of Rajiv Gandhi South Campus, Banaras Hindu University, Mirzapur during 2021-22, following Addisu et al. (2014). Termites with mound soil were kept in plastic boxes having moistened tissue papers at their base to maintain the required moisture level (more than 70%) for their survival. The boxes were covered with perforated lids for proper aeration. Tore tissue papers were also added as a feed for the termites. They were placed in a cool dark area of the laboratory (Crop Protection Laboratory, RGSC) until needed for the experiments.

For the efficacy study, seven different plant sources namely, sweet neem (*Murraya koenigiii*; fam. Rutaceae) leaf, marigold (*Tagetes erecta*; fam. Asteraceae) flowers, tulsi (*Ocimum tenuiflorum*; fam. Lamiaceae) leaf, lantana (*Lantana camara*; fam. Verbenaceae) leaf, neem (*Azadirachta indica*; fam. Meliaceae) leaf, congress grass (*Parthenium hysterophorus*; fam. Asteraceae) leaf and jatropha (*Jatropha curcas*; fam. Euphorbiaceae) seeds were used. The plant parts were washed properly with water, dried in a hot air oven at 60°C for 3-4 hr, and ground. The powdered plant components were kept separate in zippered polythene bags. To prepare fresh extracts, 5, 10, 15, and 17.5 g of each ground plant material were soaked in 100 ml of water to generate crude extracts at four different concentration levels of 5%, 10%, 15%, and 17.5 % (w/v). The soaked material was shaken at 150 rpm for 45 min. After 24 hr, each mixture was filtered using a clean cloth and then filtered using Whatman No. 1 filter paper. The filtered fresh extracts were then stored at -20°C for further use. For the preparation of fermented extracts, 100 ml of sterilized fresh plant extracts were added with 2 ml of molasses. This mixture was allowed to ferment for 10 days and then used for further bioassay study**.**

The efficacy was tested on the worker caste of the termite. Plastic jars were sterilized by cleaning with the 90% ethanol. A double layer of tissue paper was placed at the bottom and side of the jar. Ten randomly selected workers were kept in the jar, and the botanical extract was applied topically using spray bottles. After the treatment, some tore tissue paper were again placed in the jar and moistened with the distilled water to maintain the humidity. These jars were then covered with the perforated lid. In the experiment, 0.21% of imidacloprid 17.8SL and water served as a standard check and control, respectively. The treatments i.e. four concentrations for each botanicals were replicated three times in a completely randomized design. Observations for the mortality were recorded after 12, 24, 36, and 48 hr of exposure, and % mortality was calculated (Salem et al., 2020). The laboratory conditions for conducting this experiment were 19±2°C and 70-80% RH. The data were analysed statistically with one-way ANOVA using SPSS software packages following Chakravarty et al. (2020). Duncan's Multiple Range Test (DMRT) was used to determine statistical differences (p=0.01).

RESULTS AND DISCUSSION

The potency (termiticidal action) of the fresh botanical extracts at varying concentrations, viz. 5%, 10, 15, and 17.5% (w/ v) caused considerable mortality of *Odontotermes* sp. workers at 12, 24, 36, and 48 hr of exposure (Table 1). The concentration of imidacloprid used was 0.21%. After 12 hr of exposure, the lowest mortality (3.3%) at 5% was recorded from three treatments viz. T1 (sweet neem), T4 (lantana), and T7 (jatropha). Treatment T5 (neem) and T6 (congress grass) showed 23.3% mortality after 12 hr which was higher; at 10% mortality showed by sweet neem and jatropha was 10% and at par with water. The highest mortality (33.3%) was recorded from treatment T6 (congress grass). A similar trend was observed at 15% and there were no significant variations among the extracts. At 24 hr after exposure, among the botanicals tested, the lowest mortality (10%) was from T4 (lantana), while T6 (congress grass) showed the highest mortality (50%). All the treatments were statistically at par with each other at 10% and showed mortality in the 20-50% range. The only treatment that showed 100% mortality was T8 (imidacloprid). At 15 % concentration, the lowest mortality was recorded from T7 (jatropha), which was 16.7% but was at par with other treatments except for imidacloprid. No significant variations were observed among the botanicals tested at 17.5% with mortality lying in the 20- 50% range.

At 36 hr of exposure, the lowest mortality (23.3%) with 5% was recorded from T9 (water) and T4 (lantana). Treatments T5 (neem) and T6 (congress grass) showed 66.7 and 70% mortality, respectively, which were at par with T8 (imidacloprid) which showed 100% mortality. At 10 and 15% concentrations, mean mortality ranged from 23.3 to 60% compared to 100% mortality in the check. There were no significant variations among all the treatments at 17.5%, and mortality ranged from 23.3 to 56.7% except the treatment T6 (congress grass), which showed 66.7% mortality which was at par with the treatment T8 (imidacloprid). During the whole 48-hr exposure, very less (33.3%) mortality was detected in the negative control T9 (water), which was at par with T4 (lantana) (33.3%), T3 (tulsi) (40%), T1 (sweet neem) (56.7%), T7 (jatropha) (53.3%) at 5%. Treatment T2 (marigold) showed 50% mortality after 48 hr of exposure period at 10% concentration, which was at par with T9 (water) (33.3%) and T1 (sweet neem) (60%).

Table 1. Effect of fresh plant extracts on *Odontotermes* sp.

Treatments	Mean Percent Mortality															
	After 12 hr of exposure				After 24 hr of exposure				After 36 hr of exposure				After 48 hr of exposure			
	5%	10%	15%	17.50%	5%	10%	15%	17.50%	5%	10%	15%	17.50%	5%	10%	15%	17.50%
T1	3.33	10.00	13.33	16.67	30.00	26.67	26.67	43.33	43.33	46.67	36.67	53.33	56.67	60.00	70.00	73.33
(Sweet neem)	*(6.14)a	(11.07)a	(21.14)a	(23.36)a	(31.92)ab	(30.79)a	(30.79)a	(40.07)a	(41.07)abc	(42.70)ab	(36.93)a	(47.00)ab	(48.93)abc	(51.14)abc	(57.00)ab	(59.21)bcd
T2	6.67	23.33	30.00	10.00	26.67	36.67	43.33	33.33	56.67	40.00	50.00	46.67	70.00	50.00	53.33	46.67
(Marigold)	(8.86)b	(28.29)ab	(32.71)a	(15.00)a	(30.29)ab	(36.85)a	(41.07)a	(35.21)a	(48.93)abc	(38.85)ab	(45.00)a	(43.00)ab	(57.00)bcd	(45.00)ab	(47.21)a	(42.00)ab
T3	6.67	23.33	26.67	23.33	13.33	43.33	36.67	30.00	26.67	66.67	43.33	46.67	40.00	80.00	53.33	73.33
(Tulsi)	(8.86)ab	(28.78)ab	(31.00)a	(24.15)a	(17.71)a	(41.07)a	(36.84)a	(32.21)a	(26.15)a	(55.78)b	(40.86)a	(43.07)ab	(33.93)ab	(68.06)bcd	(47.00)a	(59.70)bcd
T4	3.33	20.00	20.00	23.33	10.00	30.00	30.00	36.67	23.33	50.00	40.00	56.67	33.33	73.33	50.00	63.33
(Lantana)	(6.14)a	(26.07)ab	(21.93)a	(28.07)a	(15.00)a	(33.21)a	(32.30)a	(36.93)a	(28.78)a	(45.00)ab	(38.15)a	(48.93)ab	(35.00)a	(59.70)bcd	(45.78)a	(53.06)abc
T5	23.33	20.00	13.33	13.33	50.00	30.00	23.33	16.67	66.67	53.33	50.00	30.00	93.33	73.33	73.33	53.33
(Neem)	(28.29)b	(26.57)ab	(21.14)a	(17.71)a	(45.08)b	(33.00)a	(28.78)a	(23.85)a	(55.07)bcd	(47.00)ab	(45.00)a	(33.00)ab	(81.14)d	(59.00)bcd	(59.21)ab	(47.00)abc
T6	23.33	33.33	36.67	26.67	50.00	50.00	43.33	50.00	70.00	60.00	56.67	66.67	90.00	86.67	76.67	83.33
(Congress Grass)	(28.07)b	(35.22)b	(36.14)a	(30.29)a	(45.00)b	(45.00)a	(40.78)a	(44.70)a	(57.00)cd	(50.85)b	(49.14)a	(60.00)bc	(71.56)cd	(72.29)cd	(61.92)ab	(70.78)cd
T7	3.33	10.00	16.67	23.33	30.00	20.00	16.67	33.33	33.33	33.33	23.33	40.00	53.33	76.67	50.00	53.33
(Jatropha)	(6.14)a	(15.00)a	(19.22)a	(18.93)a	(28.07)ab	(21.14)a	(19.22)a	(30.00)a	(30.00)ab	(34.22)ab	(23.85)a	(38.85)ab	(46.92)ab	(61.22)bcd	(44.21)a	(48.00)abc
T8 (Imidacloprid	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
17.8 SL)	(90.00)c	(90.00)c	(90.00)b	(90.00)b	(90.00)c	(90.00)b	(90.00)b	(90.00)b	(90.00)d	(90.00)c	(90.00)b	(90.00)c	(90.00)d	(90.00)d	(90.00)c	(90.00)d
T9	10.00	10.00	10.00	10.00	20.00	20.00	20.00	20.00	23.33	23.33	23.33	23.33	33.33	33.33	33.33	33.33
(Distilled Water)	(15.00)ab	(15.00)a	(15.00)a	(15.00)a	(21.93)ab	(21.93)a	(21.93)a	(21.93)a	(23.85)a	(23.85)a	(23.85)a	(23.85)a	(34.63)a	(34.63)a	(34.63)a	(34.63)a
SEM ±	6.60	5.75	7.23	9.48	8.51	7.15	7.18	9.34	8.83	7.18	8.78	8.98	8.06	7.36	8.13	7.26
CD 1%	26.89	23.40	29.43	38.56	34.63	29.11	29.24	38.03	35.95	29.23	35.73	36.53	32.84	29.95	33.12	29.54

*Figures in parentheses angular transformed values; Values in a column followed by common letter (s) not significantly different ($p \leq 0.01$).

Table 2. Effect of fermented plant extracts on *Odontotermes* sp.

Treatments	Mean Percent Mortality															
	After 12 hr of exposure				After 24 hr of exposure				After 36 hr of exposure				After 48 hr of exposure			
	5%	10%	15%	17.50%	5%	10%	15%	17.50%	5%	10%	15%	17.50%	5%	10%	15%	17.50%
T1	16.67	100.00	100.00	100.00	26.67	100.00	100.00	100.00	30.00	100.00	100.00	100.00	46.67	100.00	100.00	100.00
(Sweet neem)	*(19.22)a	(90.00)d	(90.00)c	(90.00)d	(26.07)a	(90.00)c	(90.00)c	(90.00)b	(28.07)a	(90.00)c	(90.00)c	(90.00)c	(43.08)b	(90.00)b	(90.00)c	(90.00)b
T2	10.00	80.00	63.33	36.67	13.33	96.67	66.67	40.00	26.67	96.67	76.67	53.33	56.67	100.00	76.67	60.00
(Marigold)	(15.00)a	(68.07)c	(53.15)b	(36.14)bc	(21.14)a	(83.85)c	(55.07)b	(38.36)a	(30.29)a	(83.85)c	(61.22)b	(47.70)b	(48.92)c	(90.00)b	(61.21)b	(51.64)a
T3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100 .00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
(Tulsi)	(90.00)c	(90.00)d	(90.00)c	(90.00)d	(90.00)c	(90.00)c	(90.00)c	(90.00)b	(90.00)c	(90.00)c	(90.00)c	(90.00)c	(90.00)d	(90.00)b	(90.00)c	(90.00)b
T4	80.00	93.33	26.67	10.00	93.33	100.00	70.00	16.67	100.00	100.00	73.33	20.00	100.00	100.00	76.67	46.67
(Lantana)	(63.93)bc	(81.14)cd	(26.15)a	(11.07)a	(81.14)c	(90.00)c	(56.79)b	(19.92)a	(90.00)c	(90.00)c	(59.00)b	(26.07)a	(90.00)d	(90.00)b	(61.71)b	(43.07)a
T5	100.00	100.00	100.00	40.00	100.00	100.00	100.00	80.00	100.00	100.00	100.00	86.67	100.00	100.00	100.00	96.67
(Neem)	(90.00)c	(90.00)d	(90.00)c	(38.85)c	(90.00)c	(90.00)c	(90.00)c	(68.06)b	(90.00)c	(90.00)c	(90.00)c	(72.78)c	(90.00)d	(90.00)b	(90.00)c	(83.85)b
T6	23.33	43.33	46.67	13.33	56.67	56.67	76.67	30.00	63.33	76.67	83.33	36.67	90.00	86.67	83.33	43.33
(Congress Grass)	(23.85)a	(41,07)b	(43.07)b	(21.14)ab	(48.93)b	(48.84)b	(65.85)b	(33.00)a	(52.86)b	(65.85)b	(70.07)bc	(37.14)b	(75.00)d	(72.29)b	(70.07)b	(41.07)a
T7	56.67	100.00	100.00	96.67	83.33	100.00	100.00	100.00	93.33	100.00	100.00	100.00	100.00	100.00	100.00	100.00
(Jatropha)	(49.92)b	(90.00)d	(90.00)c	(83.85)d	(66.14)c	(90.00)c	(90.00)c	(90.00)b	(81.14)c	(90.00)c	(90.00)c	(90.00)c	(90.00)d	(90.00)b	(90.00)c	(90.00)b
T8	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
(Imidacloprid 17.8SL)	(90.00)c	(90.00)d	(90.00)c	(90.00)d	(90.00)c	(90.00)c	(90.00)c	(90.00)b	(90.00)c	(90.00)c	(90.00)c	(90.00)c	(90.00)d	(90.00)b	(90.00)c	(90.00)b
T9	10.00	10.00	10.00	10.00	13.33	13.33	13.33	13.33	26.67	26.67	26.67	26.67	36.67	36.67	36.67	36.67
(Disstilled water)	(15.00)a	(15.00)a	(15.00)a	(15.00)a	(17.71)a	(17.71)a	(17.71)a	(17.71)a	(30.00)a	(30.00)a	(30.00)a	(30.00)ab	(37. 22)a	(37. 22)a	(37. 22)a	(37. 22)a
SEM ±	7.96	5.67	5.66	6.69	6.49	3.64	5.33	7.48	6.61	5.25	4.40	6.27	5.04	3.03	4.05	5.74
CD 1%	32.37	23.07	23.04	27.23	26.43	14.85	21.71	30.45	26.91	21.38	17.92	25.53	20.50	12.31	16.72	23.37

*Figures in parentheses angular transformed values; Values in a column followed by common letter (s) not significantly different ($p \leq 0.01$).

At 15% concentration, treatments T6 (congress grass) showed 76.7 % mortality, followed by T5 (neem) (73.3 %), T1 (sweet neem) (70 %), however, they were not at par with the standard check (imidacloprid) showing 100% mortality. The highest mortality after standard check, even at 17.5%, was observed in T5 (neem) (93.3%), closely followed by T6 (congress grass) (90%). The present result agree with Addisu et al. (2014), on the seed extract of *A. indica* at 35% concentration Singh et al. (2010) and Himmi et al. (2013) also reported neem as an effective food deterrent, oviposition, and growth inhibitor, and also contact poison for termites. Reddy et al. (2018) also found congress grass as highly effective against *Plutella xylostella* and *Aphis craccivora.*

Greater termite mortality due to the application of botanicals was observed as the exposure time increased; there was a progressive increase in the toxicity. Therefore, it can be said that the mortality of worker termites due to the botanicals tested was time-dependent as also suggested by Addisu et al. (2014). However, concentrations of extracts were not found to be positively correlated with the mortality. Certain plant extracts, like that of marigold and tulsi, were more effective at lower concentrations. There are reports regarding their effectiveness as termiticides— Fabrick et al. (2020) reported that French marigold plants have insecticidal constituents that might be identified and developed as novel alternatives to conventional treatments. Similarly, the leaf extracts of tulsi caused more mortality in termites due to the presence of high contents of complex mixture of toxic materials in the leaves (Manzoor et al., 2011).

Further, fermented botanical extracts were found to be more effective as compared to the studied fresh extracts (Table 2). At 5% the lowest mortality (10%) was recorded from T2 (marigold), followed by the treatment T1 (sweet neem) (16.7%) and T6 (congress grass) (23.3%). T4 (lantana), T3 (tulsi), and T5 (neem), along with the standard check (imidacloprid), had 100% mortality. The lowest mortality at 10% (other than control) was recorded from T6 (congress grass) (43.3%). When tested at 15%, lowest mortality was recorded from T4 (lantana) (26.7%). Treatments T1 (sweet neem), T3 (tulsi), T5 (neem) and T7 (jatropha) showed 100% mortality which was at par with the T8 (imidacloprid). A similar trend was also recorded at 17.5%. After 24 hr, the lowest mortality at 5% was recorded from T2 (marigold) (13.3%) and T1 (sweet neem) (26.7%); 100% mortality was recorded from T3 (tulsi) and T5 (neem), which was at par with T4 (lantana) (93.3%), T7 (jatropha) (83.3%). Treatment T6 (congress grass) showed 56.7% mortality after 24 hr. All the treatments except T9 (water) (13.3% mortality) and T6 (congress grass) (56.7% mortality) were statistically at par with each other at 10%. At 15 and 17.5%, the lowest mortality was from T2 (marigold) (66.7%), while the highest (100%) was recorded in T1 (sweet neem), T3 (tulsi), T7 (jatropha), and standard check T8 (imidacloprid). Alshehry et al. (2014) also found leaf extracts of lantana as highly effective against the subterranean termite, *Psammotermes hybostoma*.

The lowest mortality (26.7%) at 5% after 36 hr was recorded from T2 (marigold), while T3 (tulsi), T4 (lantana), and T5 (neem) showed 100% mortality. At 10 % concentration, all treatments except T2 (marigold) (96.7%), T6 (congress grass) (76.7%), and T9 (water) (23.3%) showed 100% mortality. Lowest mortality was recorded from T4 (lantana) (73.3%) at 15% which was at par with T2 (marigold) (76.7%) and T6 (congress grass) (83.3%). Treatment T1 (sweet neem), T3 (tulsi), T5 (neem), T7 (jatropha), and T8 (imidacloprid) showed 100% mortality; a similar trend was recorded at 17.5%. Even after 48 hr of exposure, termite mortality was very low (36.7%) in the negative control T9 (distilled water), While congress ,grass showed 90% mortality. Treatment T1 (sweet neem), T2 (marigold), T3 (tulsi), T4 (lantana) and T7 (jatropha) showed 100% mortality at 10%, which was similar to T8 (imidacloprid) (100%). At 15% concentrations, treatments T1 (sweet neem), T3 (tulsi), T5 (neem) and T7 (jatropha) were found statistically similar to standard check, imidacloprid (100% mortality). Sweet neem, tulsi, jatropha, and neem fermented extracts gave 100% mortality at 17.5%. In comparison, congress grass (43.3%) and lantana (46.7 %) were found to be least effective and were also significantly at par with the control T9 (water) (36.7%). Habou et al. (2011) also reported that the oil from seeds of *J. curcas* was effective against many insect pests associated with cowpeas under laboratory conditions, while Devendra et al. (2019) found crude extracts of lantana to be highly effective against cotton mealy bug.

The ability of various plant based extracts observed now to elicit termite mortality is in agreement with earlier studies of Singh and Kumar (2008), Shiberu et al., (2013), and Ekhuemelo et al. (2017). However, the termite mortality rate depends on the caste of the termite, the chemical composition of the plant product, and exposure time (Ajayi et al., 2020). The higher potency of neem (fresh and fermented extracts) and tulsi (fermented extracts) to *Odontotermes* sp. in the present study may be attributed to presence of insecticidal compounds like azadirachtin in neem (Gold et al., 1991) and essential oils like eugenol and β-caryophyllene in tulsi (Bhavya et al. 2018). The easy and cheap availability of these two plant sources make them a good choice as eco-friendly termite control agents. Further, the fresh and fermented extracts of a noxious weed like congress grass were also very effective against termites. Thus, if we can use it to manage termites, it can also be a solution to manage this weed. It is important to promote the use of botanical plants and natural pesticides in termite-infested areas (Ahmed et al., 2016). In the absence of more effective alternatives, farmers can use these botanicals (Paul et al., 2018). The presence of these botanical species in/around India's common farmland makes them important against termite's integrated management strategies. However, greater investigation into the active components of each botanical is necessary to create commercial products and increase their use (Salem et al., 2020).

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AUTHOR CONTRIBUTION STATEMENT

KGP conceived and designed research. KGP and SC conducted experiments, analyzed data and wrote the manuscript. CPS reviewed and edited the manuscript. All authors read and approved the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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