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Efficacy of Botanical Extracts against Termites, *Macrotermes* spp., (Isoptera: Termitidae) under Laboratory Conditions

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ABSTRACT

Termite, *Macrotermes* spp., is economically the most important termite pests which create considerable damage on agricultural crops and domestic materials causing up to 100% loss in Ethiopia. Often, application of chemicals is the most commonly used control measure with harmful effect on the environments and non target organisms. An experiment with the objective to identify effective botanical and optimum concentration on *Macrotermes* spp., was conducted. Five botanicals (*Azadirachta indica, Jatropha curcas, Maesa lanceolata, Chenopodium ambrosoids, Vernonia hymenolepis*) each at 4 concentrations (10, 20, 30 and 35% (w/v)) were tested on worker caste of *Macrotermes* spp., using topical application. Untreated and standard (Diazinon 60% EC) checks/controls were used for comparison. The experiment was laid-out in Completely Randomized Design with three replications for each concentration. The result of the study revealed that all botanical extracts at all concentrations tested were able to cause mortality on *Macrotermes* with less lethal time (LT_{50}) than the untreated control. Among the botanical extracts, LT_{50} of 8.36 h was taken by *J. carcus* at 35% concentration followed by *A. indica* at 35% concentration and *J. carcus* at 30% concentration (both requiring 12.20 h). The untreated control resulted in no mortality of termites while the botanicals caused maximum mortality of 100% (*J. caracus* at 20-35% concentration) to minimum mortality of 88.33% (*C. ambrosoids* and *V. hymenolepsis* at 10% concentration) 72 h after exposure. In conclusions, the present study suggests that management of *Macrotermes* spp., using bio-termiticides plant extracts showed promising results that could be integrated in IPM of *Macrotermes*.

Key words: Termite, mortality, botanical extracts, *Macrotermes*, biotermiticide

INTRODUCTION

The species of *Macrotermes* have long been recognized as important agricultural, forestry and domestic pests (Engel and Krishna, 2004; Owusu *et al.*, 2008; Verma *et al.*, 2009; Samb *et al.*, 2011). Termites of the *Macrotermes* spp., are a member of fungus growing sub family of Macrotermitinae and family Termitidae. They are mostly mound building and are the largest termite species (Osipitan and Oseyemi, 2012). The species of termite under the genus *Macrotermes*, impact the economy negatively by causing damage to various agricultural crops, rang lands, wooden portions of buildings, furniture, books, utility poles and fence posts in several parts of Africa (Wong *et al.*, 2001; Mitchell, 2002; Cox, 2004). It has been reported that *Macrotermes* causes a complete damage (100% loss) to agricultural crops and various domestic products in the world (Michael, 2000; UNEP and FAO, 2000; Sekamatte, 2001; Nyeko *et al*., 2010). In some part of Africa *Macrotermes* do cause a yield loss of 30-60% (UNEP and FAO, 2000). In East Africa the loss caused on various crops and tree species due to termites vary ranging from 50-100% (Sekamatte, 2001; Nyeko *et al*., 2010). In Ethiopia, serious damage, with losses of up to 100% in some localities, occurred on Eucalyptus one to two years after transplanting, 45- 50% (on maize), 50-100% (on teff) and 25% (on sorghum); in highly termite infested districts of Western Wollega zone (Abdurahman, 1990, 2000; Gauchan *et al*., 1998; OADB, 2001).

Pesticide plays an important role in Integrated Pest Managements (IPM) on agricultural production and productivities. Often broad spectrum and persistent organo chlorinated hydrocarbon insecticides are used for management of termites in the world. However, some of the most potent insecticides used against termites such as aldrin and dieldrin were withdrawn from the market because of their increased cost from time to time; harmful effects on human health, non-target organisms and eventually environmental pollution and due to resistance development (Logan *et al*., 1990; Mulroney *et al*., 2005; Ahmed *et al*., 2006; Dhaliwal and Koul, 2007; Soomro *et al*., 2008; Sileshi *et al*., 2009).

As a result of serious negative impacts of the use of persistent and deleterious insecticides, research on the identification of eco-friendly and locally available alternative tools for termites control has been an agenda of entomologist. The use of plant materials in the management of insect pests, including termite has been an old strategy in African. Among many botanicals used in insect pest management, plants such as neem (*A. indica*) leaves and seeds, garlic (*Allium sativum*) bulbs and physic nut (*Jatropha* spp.) seed have been successfully used to control *Macrotermes* spp. *Macrotermes* spp., is economically the most important termite because of the damage it causes on agricultural and domestic products. Thus, there is a need to control the pest with affordable and locally available indigenous plant materials (Doolittle *et al*., 2007; Dubey *et al*., 2008; Owusu *et al*., 2001, 2008; Muhammad, 2009). Some natural plants present toxic principles to insects including termite (Sakasegawa *et al*., 2003).

Therefore, now a days, in developing countries including Ethiopia, there is an increasing interest and experience in the use of different types of plant products for the management of insect pests because of drawbacks of conventional pest management options (Zewde and Jembere, 2010; Shaaya and Kostyukovysky, 2006). Generally, botanical extracts have safe insecticidal properties with broad spectrum of insecticidal activity, relatively specific mode of action, low mammalian toxicity and non persistence. Besides, their preparation and application method for farmers were more convenient. Cognizant of the above benefits of the use of botanicals in pest management and the meager research findings on the use of botanicals for the management of termites in Ethiopia, the present study was initiated with the objective to evaluate the efficacy of selected locally available botanical plants against worker termite, *Macrotermes* spp., at different concentrations.

MATERIALS AND METHODS

Description of the experimental area: The present research was conducted under laboratory conditions in Entomology and Plant Pathology Laboratory of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) located at 354 km in south west of Addis Ababa, the capital city of Ethiopia. The Study area is located at geographical coordinate of 7°42' N latitude and 36°50' E longitudes and at altitude of 1710 m a s l. The maximum and minimum temperatures of the area are 26.8 and 11.8°C, respectively, with the maximum relative humidity of 91% and the mean rain fall of 1500 mm annum^{-1} (Abera *et al*., 2011).

Termite collections and establishment for test: Populations of *Macrotermes* spp. were collected from two main sites, namely Saye Kebele of Mana and near Agaro town of Goma Woredas, Jimma Zone, Oromia regional state, Ethiopia. At these two localities, termite mounds were dug up using spade and soil containing termites were put on plastic sheets. Termite populations were collected from the plastic sheets using camel hair brush and placed in plastic boxes (polyethylene plastic box) ($22\times17\times7$ cm^3) as described by Gitonga *et al.* (1995).

Wooden plants (termites' preferred feed)) were added to the plastic boxes as feed for the termites. Then the top parts of the plastic boxes were covered with muslin cloth that allows air ventilation in and out easily but preventing the escape of the termites. Moistened wad of cotton was placed in to the plastic boxes to maintain the required moisture level (more than 60%) for the survival of termites. The boxes carrying the termites were transported to JUCAVM, Entomology and Plant Pathology Laboratory and placed in a cool and dark area until needed for the experiments. Continuously, dry wooden materials were provided to the termite's population and the plastic boxes were inspected for maintenance of the required moisture level.

Collection and preparation of botanical plants: For efficacy test, five locally available botanicals were collected from different sources and tested against worker caste of termites, *Macrotermes* spp. The botanicals were: *Azadirachta indica* (Neem), *Jatropha curcas* (physic nut), *Maesa lanceolata* (Abayi), *Chenopodium ambrosoids* (Gime), *Vernonia hymenolepis* (Sooyyoma). Leaf and seed parts of these botanicals were dried in a well-ventilated area under shade for few days at JUCAVM entomology and plant pathology laboratory.

Extraction and isolation of the botanicals: The dried seed and leaf of the botanicals were grinded with micro plant grinding machine and were sieved through a 0.25 mm pore size mesh sieve to obtain uniform fine dust particle (Jembere *et al.*, 2005; Selase and Getu, 2009). The resulting powders were kept separately in glass containers with screw cap and stored at room temperature in dark prior to use. The amounts of powder mixed with the 100 mL of water were calculated on weight by volume bases that is weight of powder/volume of water. As 10, 20, 30 and 35 g of each grinded plant materials (powder) were soaked in 100 mL of water to obtain crude extracts of four concentration levels of 10, 20, 30 and 35% (w/v). Each mixture was filtered with clean cheese cloth after 24 h and applied topically on worker termites.

Bioassay procedures for botanicals toxicity: The prepared botanical extracts were weighed and incorporate in to flask containing 100 mL of sterile distilled water. The flask containing botanical powder was shaken thoroughly for about 5 min to ensure uniform distribution of the solute. Whatman No. 1 filter papers of 9 cm diameter were placed in Petri dishes and treated separately with 2 mL of the water extracts of each of the 4 concentrations. Twenty collected worker termites were randomly selected from stock population and kept into the Petri dishes containing the treated filter papers. In all experiments 0.21% of Diazinon EC 60% and water served as a standard check and negative control, respectively.

All the treated Petri dishes were covered with a double play of black plastic sheet to simulate the dark galleries of termites. The treatments (4 concentrations for each botanical) were replicated three times. Mortality of termite was recorded at 24 h intervals for three days after treatment application. The experiment was conducted under laboratory conditions (25 ± 3°C and 60-70% Rh).

Mortality with botanical extracts: For the assessment of the mortality of worker termites, the botanical extracts were incorporated in to the diet, at a concentration of 10, 20, 30 and 35% for each extracts (seed and leaf) with two controls, a negative (sterile water) and a commercial insecticide (Diazinon). The petridishes having treated filter pepper with botanical extracts were held at temperature of 25±3°C and relative humidity of 60-70% for three days. Mortality was recorded at 24 h interval. Live and dead workers *Macrotermes* spp. were counted and percent mortality was calculated according to the following equation and corrected using Abbott (1925) equation:

$$\text{Percent mortality} = \frac{\text{No. of dead termite}}{\text{Total No. of termite}} \times 100$$

Median lethal concentration (LC_{50}) and median lethal time (LT_{50}): Median lethal concentration (LC_{50}) and median lethal time (LT_{50}) were determined for each concentration by taking in to account, respectively the concentration and time in which the botanical extracts caused mortality of 50% of termite's population. Probit analysis (Finney, 1971) was used to determine LC_{50} and LT_{50}.

Termite repellency test due to botanical extracts: For repellency assay, four solution of (10, 20, 30 and 35% w/v) each botanical extracts were prepared. Petri dish having Whatman No. 1 Filter paper with a 9 cm diameter was cut into two equal parts (half part was treated and the remaining half part was left untreated). Treated portion consisted of botanical extract treated filter paper and untreated part contained distilled water treated filter paper and placed about 2 cm apart from each other in petridishes. Twenty termites were introduced at the center of both treated and untreated filter paper and the petridishes with termites were placed in darkness in order to minimize the effect of light on the termites. Three replications were used for each concentration of botanical extracts. Number of termites on both treated and untreated filter paper was recorded from each Petri dish starting 30 min after treatment application. Based on the number of termites which stay on the extract-treated filter paper, repellency was determined. Percentage repellency was calculated by the equation:

$$\text{Repellency (\%)} = \frac{(C - T)}{(C)} \times 100$$

Where:

C = No. of termite collected from the untreated filter papers

T = No. of termite collected from the treated filter papers

Experimental designs and treatments details: All the experiments were laid out using Completely Randomized Design (CRD) with three replications. In all cases, 0.21% Diazinon was used as standard check and distilled water as a control for comparison. Each treatment was tested at four concentrations (10, 20, 30 and 35% (w/v)) (Table 1).

Data analysis: The data recorded for different response variables in the study were analyzed statistically by using analysis of variance for one-way ANOVA using SAS version 9.2 Software

Table 1: Description of botanical plants used for the experiments and their concentrations

Botanicals	Conc. (g mL^{-1})	Local name	Common name	Parts used
J. curcas	10.00	Ayderke	Physicnut	Seed extracts
	20.00			
	30.00			
	35.00			
A. indica	10.00	Mimi zaf/kinin	Neem	Seed extracts
	20.00			
	30.00			
	35.00			
M. lanceolata	10.00	Kelewa/Abayi	-	Leaf extracts
	20.00			
	30.00			
	35.00			
C. ambrosoids	10.00	Gime/Ajaye	Mexican tea	leaf extracts
	20.00			
	30.00			
	35.00			
V. hymenolepis	10.00	Soyoma	-	Leaf extracts
	20.00			
	30.00			
	35.00			
Diazinon (%)	0.21	-	-	-
Water (mL)	2.00	-	-	-

packages. Based on significant differences, mean separation was done using Tukeys' studentized (HSD) test to determine statistical significance of the treatments. Mortality rate were corrected using Abbott (1925) equation. United State Environmental Protection Agency (USEPA) probit analysis version 1.5 was used for analyzing median lethal time and median lethal concentration (Finney, 1971).

RESULTS AND DISCUSSION

The results and discussions of the experiments conducted to assess the efficacy of five locally available botanical insecticides at different concentrations are presented under different sub-tittles as follows.

Efficacy of botanicals against *Macrotermes* spp.

Percentage mortality of worker termite: Percent mortality of *Macrotermes*, at different time intervals (24, 48 and 72 h) due to the potency (termiticidal effect) of the botanicals at different concentrations were significant ($p<0.01$) (Table 2). No mortality of *Macrotermes* was observed in negative control (distilled water treatment) over the entire exposure period of 72 h. Maximum percentage mortality (100%) of the worker termites was registered from the positive control (Diazinon) followed by and non-significantly different from *J. curcas* with 93.33, 98.33 and 100% mortality percentage at 35% concentration 24, 48 and 72 h after exposure, respectively.

As indicated in Table 2, after 24 h of exposure, maximum mortality (100%) was registered from standard check. This was significantly different from all botanical extracts at different concentration except *J. curcas* at 35% concentration, which registered 93.33% mortality of worker

Table 2: Percent mortality (%) of termite due to water extracts of different botanicals at different concentration over time

		Mean mortality (%) over time (h)		
Botanicals	Conc. (%)	24	48	72
J. curcus	10.00	71.67^{def}	91.67^{abc}	96.67^{ab}
	20.00	76.67^{de}	98.33^{a}	100.00^{a}
	30.00	86.67^{bc}	98.33^{a}	100.00^{a}
	35.00	93.33^{ab}	98.33^{a}	100.00^{a}
A. indica	10.00	68.33^{ef}	81.67^{d}	93.33^{abc}
	20.00	76.67^{de}	96.67^{a}	98.33^{ab}
	30.00	80.00^{cd}	98.33^{a}	98.33^{ab}
	35.00	86.67^{bc}	98.33^{a}	100.00^{a}
M. lanceolata	10.00	68.33^{ef}	83.33^{cd}	91.67^{bc}
	20.00	73.33^{de}	93.33^{ab}	96.67^{ab}
	30.00	73.33^{de}	98.33^{a}	98.33^{ab}
	35.00	78.33^{cd}	98.33^{a}	98.33^{ab}
C. ambrosoids	10.00	56.67^{ghi}	83.33^{cd}	88.33^{c}
	20.00	58.33^{gh}	86.67^{bcd}	91.67^{bc}
	30.00	68.33^{ef}	96.67^{a}	96.67^{ab}
	35.00	71.67^{def}	96.67^{a}	98.33^{ab}
V. hymenolepsis	10.00	48.33^{i}	71.67^{e}	88.33^{c}
	20.00	53.33^{hi}	78.33^{de}	91.67^{bc}
	30.00	55.00^{ghi}	81.67^{d}	91.67^{bc}
	35.00	63.33^{fg}	91.67^{abc}	91.67^{bc}
Diazinon	0.21	100.00^{a}	100.00^{a}	100.00^{a}
Control (mL)	2.00	0.00^{j}	0.00^{f}	0.00^{e}
CV (%)		4.39	3.15	2.85
HSD		5.40	5.40	5.40
p-value		<0.0001	<0.0001	<0.0001

Mean with in a column followed by the same letter (s) are not significantly different, p<0.001%, Tukey student test (HSD)

termites. On the contrary, zero mortality was registered from untreated control (water). All the test botanicals (botanicals) have shown good level of mortality, ranging from 48.33% (*V. hymenolepsis* at 10% concentration) to 93.33% (*J. carcus* at 35% concentration), which is significantly different from the untreated control. *J. curcas* at 35% concentration is the best botanical that cased maximum mortality of worker termite 24 h after exposure. With an increase in the concentration of the botanical extracts there is an increasing potency of each botanical after 24 h of exposure time.

Similarly, after 48 h of workers termite exposures, there was highly significant difference in toxicicity among the botanicals at different concentrations. Maximum percentage mortality (100%) was recorded from Diazinon followed by and non-significantly different from *J. curcas* at all concentrations; *A. indica* and *M. lanceolata* at 20-35% concentrations; *C. ambrosoids* at 30 and 35% concentration and *V. hymenolepis* at 35% concentration. It is revealed from the result that most of the botanicals tested become more potent at increased concentrations against worker termite after 48 h of exposure than 24 h of exposure. This indicates that as time of exposure and concentrations of the botanicals increases the efficacy of the botanicals also increases. On the other hand, there was no mortality registered from untreated control which was significantly different from all the treatments.

Seventy two hours after exposure, percent mortality of termite registered from Diazinon was still maximum (100%). But *J. curcas* at 20 to 35% concentration and *A. indica* at 35% concentration also caused 100% mortality, the same with the standard chemical. Statistically, most of the botanicals at different concentration showed similar efficacy with the standard chemical 72 h after exposure of termites to the extracts. *J. curcas* and *A. indica* at all concentration, *M. lanceolata* at all concentrations except 10% and *C. ambrosoid* at 30 and 35% concentrations are all non-significantly different from the standard check 72 h after exposure of termites to the botanicals. Though there was significant efficacy from all botanicals throughout the exposure period, the toxicity of *V. hymenolepsis* is found to be minimum and significantly less than all botanicals at different concentrations. Greater termite mortality due to the application of the botanicals at different concentration was observed as the exposure time of the pest to the treatment increased. As exposure time increased, there was a progressive increase in the toxicity of the botanicals to the test insect recording considerable control of termite. Besides, the more the concentration was the better the efficacy of each botanical. Therefore, it can be said that mortality percentage of worker termites due to the five botanical tested was found concentration and time dependent as it was found to increase with an increase of the concentration and exposure time.

The seed extracts of *J. curcas* at 20-35% concentrations and *A. indica* at 35% concentration had potent bio-termiticidal effect on *Macrotermes* with the same efficacy with Diazinon inducing 100% mortality to the test insect over three days exposure time. The present investigation is in agreement with Habou *et al.* (2011) who reported oil from seeds of *J. curcas* was effective against many insect pests associated with cow peas under laboratory and field conditions.

Water extract of *J. curcas* and *Milletia ferruginea* has also been found effective as termiticides and caused higher toxicity to all the castes of alates of the termite, *Macrotermes* in which 93-100% mortality was recorded at different concentration levels (Jembere *et al.*, 2005; Yohannes, 2006). The insecticidal activity of seed oil of *J. curcas* has been reported, due to the presence of several sterols and terpene alchohols, on subterranean termites (Adebowale and Adedire, 2006; Nisar *et al.*, 2012).

Maximum wood protection against *O. obesus* and *Microcerotermes beesoni* termites by *J. curcas* oil and its toxic fraction were obtained at their highest concentration i.e., 20% (Singh and Kumars, 2008). Botanical materials with insecticidal properties provide small-scale farmers with locally available, biodegradable and inexpensive method of pest control including termite. Botanical plants insecticidal properties and application have drawn attention for extensive research, which are now highly encouraged in order to meet the demands of Integrated Pest Management and environmental safety (Mulungu *et al.*, 2007). It has been stated that the toxicity of *J. curcas* can be attributed due to the toxic principle "jatrophine" which is the dominant compound found in the seeds of this well-known botanical insecticide with contact and stomach poisoning mode of action (Bekele, 2002; Jembere *et al.*, 2005; Acda, 2009).

Several studies have shown action of botanical extracts when applied on filter paper or mixed in soil causing mortality and repellant effect on termite indicating their effectiveness against several species of termites and fulfilled that botanical extracts have the potential for under and above-ground application for the management of termite due to the presence of toxic and insect-repelling compounds (Blaske and Hertel, 2001; Blaske *et al.*, 2003; Jembere *et al.*, 2005).

The main toxic principles of *Azadracta indica*, azadirachtin acts has contact poison and also has systemic effect when applied to the foliage. The substance is generally nontoxic to beneficial insects and non-target organisms. Azadirachtin has broad mode of activity, working as a feeding deterrent, insect-growth regulator, repellent, sterilant and it may also inhibit oviposition of insect pests (Isman, 2006). The substance from this botanical was with synergistic effects on a wide range of insect pests, including stored grain pests, aphids, caterpillars, mealy bugs (Morgan, 2009) and maize weevil and Angoumois grain mouth (Fekadu *et al.*, 2012).

According to the survey conducted by Mendesil *et al.* (2007) in south western Ethiopia, *M. lanceolata* and *A. sativum* were among the dominant plant used as insect pest protectants for sorghum grain in storage. In addition, application of 30 g kg^{-1} dosage of *M. lanceolata* plant seed powder greatly reduced the emergence of bruchid and any loss of stored bean stocks (Lambert *et al.*, 2009). Treatments of *C. ambrosoids*, *J. curcas*, *Datura stramonium* and *Phytoloca dodecondra* at the rate of 15/150 g of grain were capable of inducing 90-100% mortality against *Zabrotes subfasciatus* on haricot bean within 96 h after treatment application (Selase and Getu, 2009). Tapondjou *et al.* (2002) tested the powder and essential oil obtained from dry ground leaves of *C. ambrosioides* at rates ranging from 0.8-6.4% against six insect pests including granary and maize weevils on wheat and maize and reported that the highest dosage of 6.4% induced 100% mortality of both species on day two after treatment, although mortality of the larger grain borer was only 44%. Tadesse and Basedow (2005) also reported that higher rate of *Chenopodium* (20%) concentration caused mortality of 22.7 and 76.7%, within two and four days after treatments to storage insect pests of maize in Ethiopia.

Determination of median lethal concentration (LC_{50}) for each botanical: The results of the probit analysis for the determination of Median lethal concentration (LC_{50}), their 95% fiducial limits and the slope of regression line at 24 h after treatment for the mortality of termite were presented in Table 3. Minimum concentration required to kill 50% of the test worker termites was determined for each botanical. The LC_{50} values for *J. curcas*, *A. indica*, *M. lanceolata*, *C. ambrosoids* and *V. hymenolepis* 24 h after treatments indicated that *J. curcas* (6.73 mg L^{-1}) was the most toxic at minimum concentration and *V. hymenolepis* (14.46 mg L^{-1}) was the least toxic botanicals at lower concentration. This indicates that though all the botanicals were toxic to termite, the degree of toxicity depends on the concentration applied. From the above result, it is clear that all the tested botanicals were more or less effective for controlling termite, *Macrotermes* but *J. curcas* was the most effective followed by *A. indica* with minimum concentration.

Determination of LT_{50} for the botanicals at different concentration: The lethal time (LT_{50}), the time required to kill 50% of worker termite due to different botanical extracts at different concentration (10-35%) were found to be significantly different (p = 0.05). The least time was

Table 3: Median lethal concentration (LC_{50}) of different botanical extracts on worker *Macrotermes* spp. after 24 h of exposure

		95% F limit				
Treatments	LC_{50} (mg L^{-1})	Lower	Upper	Slop±SE	χ^2	Tabular value
J. curcas	6.73	0.04	11.92	1.79±0.75	1.10	5.99
A. indica	7.61	0.00	13.41	1.58±0.72	0.74	5.99
M. lanceolata	9.00	0.00	15.37	1.45±0.70	0.56	5.99
C. ambrosoids	10.95	0.00	18.04	1.37±0.68	0.45	5.99
V. hymenolepis	14.46	0.00	23.75	1.34±0.68	0.84	5.99

χ^2: Goodness of fit. The tabular value of x^2 is 5.99 at 0.05 probability level. Slope value, were significant at all probability levels (95%)

required for seed extracts of *J. curcas* (8.36 h) at higher concentration (35%) while *V. hymenolepis* at 10% took significantly the lomgest time (25.3 h) to kill 50% of the target insect pests (Table 4) among the botanicals.

Though, the botanical extracts were found to be promising bio-pesticide, the minimum time, 0.65 h, was taken by the standard check, Diazinon. Among the treatments, the most promising botanicals were *J. curcas* and *A. indica* in reducing termite population at all concentrations within short period of exposure. It appears therefore that the botanical extracts screened have termiticidal properties and effectiveness against *Macrotermes* spp. and could be of use in termite management.

Repellence test due to different botanicals at different concentration: Repellency effects of botanical extracts on worker *Macrotermes* spp. was significantly different ($p<0.05$) (Table 5). The highest and significant insect repellence (90%) was induced by the synthetic insecticide (0.21% Diazinon). This was followed and non-significantly different from seed extract of *J. curcas* (83.33%) at 35% concentrations. On the contrary, no repellency (0%) was observed in control treatment followed by *V. hymenolepsis* at 10% concentration (21.67% repellency). As the concentration of each botanical increase the percentage repellency also increases indicating dependency of the repellency on the concentrations.

In a choice and non-choice experiment on pulses weevil, Zewde and Jembere (2010) reported that percent repellence was higher in a choice test than without choice. It has been known that botanicals with repellent effects do cause minimum negative impact on the environment because they drive the pests by stimulating their sensory organs before the damge is caused to plants. Repellents from plant origins are natural products and are relatively safe to the environments

Table 4: Median lethal time (LT_{50}) of different botanicals at different concentration against *Macrotermes* after 24 h of exposure

Treatments	Conc. (%)	LT_{50} (h)	95% CI limit (LCL×UCL)	Slop±SE	p-value
J.curcas	10.00	17.90	16.48-17.48	2.723±1.10	0.013
	20.00	17.20	16.43-17.45	3.250±1.48	0.028
	30.00	12.20	15.50-17.70	2.512±1.57	0.095
	35.00	8.36	14.16-18.27	2.006±1.54	0.194
A.indica	10.00	17.20	16.33-17.54	2.266±0.94	0.016
	20.00	16.20	16.43-17.45	3.250±1.48	0.028
	30.00	15.10	16.09-17.52	2.911±1.90	0.050
	35.00	12.20	15.50-17.70	2.512±1.50	0.095
M.lanceolata	10.00	19.90	17.48-19.48	2.723±1.10	0.013
	20.00	19.00	16.62-19.42	3.552±1.48	0.016
	30.00	17.20	16.43-17.45	3.225±1.48	0.028
	35.00	15.10	16.09-17.52	2.911±1.49	0.050
C.ambrosoid	10.00	22.00	16.96-22.49	3.482±1.11	0.001
	20.00	21.00	16.84-21.47	3.237±1.10	0.003
	30.00	19.00	16.65-19.42	3.552±1.48	0.016
	35.00	17.20	16.43-17.45	3.250±1.48	0.028
V.hymenolepis	10.00	25.30	17.01-25.63	2.639±0.80	0.001
	20.00	23.10	16.90-23.57	2.676±0.85	0.001
	30.00	21.30	16.78-21.53	2.759±0.94	0.003
	35.00	20.50	16.69-20.47	2.986±1.10	0.069
Diazinon	0.21	0.65	-	-	-
Water (mL)	2.00	72.00	-	0.000	1.000

*UCL: Upper confidence limit, LCL: Lower confidence limit

Table 5: Mean percentage (%) repellency of *Macroterms* spp. due to different botanicals at different concentrations

Treatment	Concentration (%)	Mean repellency (%)
J. curcus	10.00	51.670^{fg}
	20.00	58.330^{ef}
	30.00	75.000^{c}
	35.00	83.330^{ab}
A. indica	10.00	41.670^{h}
	20.00	55.000^{fg}
	30.00	63.330^{de}
	35.00	76.670^{bc}
M. lanceolata	10.00	23.330^{ef}
	20.00	41.670^{h}
	30.00	51.670^{fg}
	35.00	66.670^{d}
C. ambrosoids	10.00	23.330^{jk}
	20.00	30.000^{ij}
	30.00	48.330^{gh}
	35.00	63.330^{de}
V. hymenolepsis	10.00	21.670^{k}
	20.00	30.000^{ij}
	30.00	33.330^{i}
	35.00	50.000^{g}
Diazinon	0.21	90.000^{a}
Control (mL)	2.00	0.001
CV (%)		4.863
HSD		5.406
p-value		<0.0001

Mean with in a column followed by different letters are significantly different, p<0.001, Tukey student test (HSD)

when used for pest managements. The botanical extracts, powders and essential oil from the different bioactive plants were reported as repellent against stored grain insect pests (Owusu, 2001; Talukder, 2004; Talukder *et al*., 2006). Khan and Marwat (2006) also reported the repellency of leaves, seeds and bark powders of *A. indica* and *Nerium oleander* against *Rhizopertha Dominica* in wheat grains. Zaidi *et al*. (2003), Papachristos and Stamopulous (2002) and Fekadu *et al*. (2012) reported repellency effect of different botanicals against storage insect pests under laboratory conditions. Acda (2009) also evaluated oil of the physic nut, *J. curcas* under laboratory for its barrier and repellent activity against the Philippine milk termite *Coptotermes vastator* and reported that *J. curcas* oil had anti-feeding effect with reduced tunneling activity and increased mortality on *C. vastator*.

CONCLUSION

The present findings demonstrated that most of the botanical extracts tested against termite, *Macrotermes* possess termiticidal properties that can be used in the management of *Macrotermes* spp. From the botanicals extracts, *J. curcas* was observed to be the most bio-potent botanicals at higher concentration (35%) tested. The next best botanicals were seed extracts of *A. indica* as well as leaf extracts of *M. lanceolata* as these also caused higher mortality among the remaining botanicals at maximum concentration (35%) tested.

The other botanicals were found to be moderately toxic to termite over 72 h of exposure. The availability of these botanical plants in/or around the common farm area in Ethiopia makes them of significance in termite integrated management options. The present results showed that the mortality of termite is the function of time and concentration. Even though mortality was observed as a result of all the botanicals at different concentrations over time, as concentrations of botanical extract increased and time of exposure progressed, there was a promising progressive potency of the botanicals against *Macrotermes* spp.

RECOMMENDATIONS

Laboratory bioassays with few plant extracts indicated the efficacy of some of the botanicals better than the others as termiticides. Botanical extracts used in the present studies had repellency and toxicity effect on termites. Thus, they can be used to manage/control termites in agricultural crops and domestic materials. Seed extracts of *J. Curcas, A. indica* and leaf extracts of *M. lanceolata* and *C. ambrosoids* can be good candidates for termite management at 35% concentration. However, it is deemed necessary to further investigate on the active principles of each botanical for commercial product development and further utilization.

There is no denial that potential field application of the botanical extracts against termites would require large volume of plant materials, thus a field study need to be conducted further apart from testing of large number of plants. Water extracts of botanicals may be used for delivery into the soil to directly kill termites, or a paint-on material which may prevent termites from infesting domestic materials and agricultural crops which also need further investigation.

Though further study is highly relevant, in the absence of other options, farmers can use these botanicals in steady of costly, toxic, unsafe and unavailable synthetic insecticides to control termite attack on their domestic materials and agricultural products. Hence, the use of botanical plants and natural insecticides in termite infested area should be encouraged and research should be pressed forward to identify and formulate such natural insecticides and their use.

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