Academic Journal of Entomology 11 (1): 11-17, 2018
ISSN 1995-8994

DOI: 10.5829/idosi.aje.2018.11.17

Laboratory Evaluation of the Termiticidal Efficacy of Three Tropical Plant Oils on *Macrotermes bellicosus* (Blattodea: Termitidae)

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Abstract: The use of pesticides of plant origin in pest management is considered to be environmentally friendly unlike synthetic pesticides that pose great threats to the environment. The utilization of these botanical pesticides and their modes of application for effectiveness are of great importance to researchers and farmers. The focus of this study was to determine the anti-termitic efficacy of neem seed oil, *Jatropha* seed oil and palm kernel oil using two methods of application. Five aqueous concentrations, 0, 2.5, 5.0, 7.5 and 10.0 percent of the oil was applied to soil and a food source in plastic cages and thereafter, thirty adults worker caste of *Macrotermes bellicosus* were introduced. The treatments were replicated five times and arranged in a completely randomized design in a dark cupboard. Termite mortality was assessed at 2, 6, 12, 24, 48 and 72 hours after treatment. Data were analysed using ANOVA and means were separated using LSD at $p<0.05$. Probit analysis was carried out to determine the LC_{50} and LT_{50} of the oil at 24 hours post treatment and at concentration of 10%, respectively. The results showed that termite mortality in both soil and feeding experiments increased with increase in oil concentration and with increase in the period of exposure to oil. The estimated values of LC_{50} and LT_{50} were lower in soil bioassay than in feeding bioassay. Application of the three plant oils as soil treatment gave a higher and faster termite mortality than when applied directly to a food source. Hence, soil application of neem seed oil, *Jatropha* seed oil or /and palm kernel oil could be included in Integrated Pest Management of termites.

Key words: *Macrotermes bellicosus* · Mode of action · Termite Mortality · Plant Oil · Integrated Pest Management

INTRODUCTION

Termites are considered as serious pests to crops, rangeland and forestry in tropical Africa. Some of the deleterious species belong to the family Termitidae, which comprises of four subfamilies namely, Macrotermitinae, Nasutitermitinae, Termitinae and Apictotermitinae [1] Over 90% of the termite damage in agriculture, forestry and urban settings in Africa has been attributed to members of the subfamily Macrotermitinae [2-4]. Members of this family which include species from the genera *Macrotermes*, *Odontotermes*, *Ancistrotermes* and *Microtermes* have been reported to be associated with *Eucalyptus* plantations in Nigeria [5]. Many reports have also shown that Members of the genus *Macrotermes* caused a complete damage to agricultural crops and domestic products worldwide [6- 8]. Termites have been reported to cause 15-25% yield loss to maize in India [9] and similarly in Mali, Burkina-Faso, Niger and Nigeria, 10-30 percent of harvested kernels of groundnut were lost to termites [10].

Different methods have been used by local farmers in Africa in the control of termites. These include destruction of termite mound [11], application of wood ash [12, 13] and animal excreta [14, 15]. Synthetic pesticides remain the primary method use to prevent termite attack to wooden structures, agricultural crops and forest trees. They are applied directly to termite mound [13], plant or wood materials and also directly to soil. However, the persistent use of synthetic termiticides is of environmental concern and has resulted in the need to search for plant-derived compounds as an alternative for termite control.

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Many plants have been recognized to have anti-termitic activities [16-21] or repellent to the termites [22, 23]. The crude seed oil of *Piper guineense* at a 10% concentration significantly lowered damage by termites [24]. Neem seed oil has been reported to inhibit growth of termite surface-tunnels [25]. Soil treated with 2% solution of *Calotropis procera* L. and *Azadirachta indica* prevented damage by *Odontotermes obesus* (Rambur) to sugarcane setts [26, 27]. Extracts from leaves of *Tephrosia vogelii* have been reported to protect tree seedlings from termites infestation in Malawi and Zambia [28, 29]. Extract from *Lagenaria breviflora* fruit pulp has also been used as a wood protectant against termites [30]. The indiscriminate use of pesticides for the management of termites has generated a number of biological and environmental hazards in air, water, soil and in food chains [31]. Insecticides from plant materials are very common, environmentally friendly and reservoir of chemical compounds with anti-termitic properties. There is the need however, in addition to the identification of these plants to determine the effective rate and methods of application. The objective of this study therefore was to assess the anti-termitic efficacy of different concentrations and two methods of application of neem seed oil, Jatropha seed oil and palm kernel oil on adult worker caste of *Macrotermes bellicosus*.

MATERIALS AND METHODS

Sources of Oils: Neem and *Jatropha* oil extracts were obtained from National Research Institute for Chemical Technology (NARICT), Zaria, Kaduna State and Palm kernel oil was obtained from local producers in Ekiti State, Nigeria.

Collection of Termites for Laboratory Studies: Worker caste of *Macrotermes bellicosus* were collected from *Macrotermes* mounds in the experimental fields of Institute of Agricultural Research, Ahmadu Bello University, Zaria, Savanna Forestry Research Station office premises and Kurumi Bomo village, Zaria in Zaria North Local Government Area of Kaduna State, Nigeria. The termites were maintained in the laboratory on Sugar cane strips for 72 hours prior to use. The moribund termites were removed and only active ones were used for the experiments.

Mortality of Termite on Food Source Treated with Different Plant Oils: Feeding deterrence bioassay was conducted to determine the effects of different concentrations (0%, 2.5%, 5% 7.5% and 10%) of Neem seed oil (NSO), *Jatropha* seed oil (JSO) and Palm kernel oil (PKO) on termite mortality. The experiment was carried out in plastic containers of 15 cm in diameter and 10 cm high using sugar cane strip as a source of food on sand substrate. River sand was collected and oven-dried at 100°C for 6 hours. After cooling, 30 g of sand was weighed into each plastic container and moistened with 6 ml of sterile distilled water using hypodermic syringe. The sand was stirred with a rod for uniform distribution of water in the soil. Sugar cane strip cut to 6 x 2 x 1cm in size was individually soaked in different concentrations of the oils for five minutes. The sugar cane strips were allowed to drain for another 10 minutes before being introduced into the plastic cages. Thirty adults worker caste of *M. bellicosus* were introduced into each plastic container and covered with a perforated lid. Each treatment was replicated five times and arranged in a dark cupboard in a Completely Randomized Design. Termite mortality was assessed at 12, 24, 48 and 72 hours. All dead termites were removed at each time of counting.

Mortality of Termites on Soil Treated with Different Concentrations of Plant Oils: The soil that was used for the experiment was the same as in feeding bioassay experiment. Thirty grams of oven-dried river sand was weighed into plastic cages and treated with 3 ml of different concentrations (0%, 2.5%, 5%, 7.5% and 10%) of NSO, JSO and PKO using hypodermic syringe. The soil was stirred with a stirring rod for uniform distribution of oil in the sand medium. Thirty workers caste of *M. bellicosus* were introduced into each plastic cage and sugar cane strip was added as food. Each treatment was replicated five times and arranged in a Completely Randomized Design in a dark cupboard. The number of dead termites was counted at 12, 24, 48 and 72 hours. Data on percentage termite mortality for the two experiments were corrected using [32] formula thus:

$$P_r = \frac{Po - Pc \; x \; 100}{100 - Pc}$$

where,
P_T = Corrected mortality (%)
P_O = Observed mortality (%)
P_C = Control mortality (%)

Data on termite mortality was analyzed using ANOVA and means were separated using LSD at $p<0.05$. Probit analysis of termite mortality was carried out to determine

the LC_{50} and LT_{50}. Significant differences in LC_{50} and LT_{50} were determined by the overlapping and non-overlapping of the 95% confidence intervals (CI) [33].

RESULTS

Mortality of Termite on Food Treated with Different Concentrations of Neem, *Jatropha* and Palm Kernel Oils The highest mortality of termite (79.85% - 100.00%) recorded in 10% NSO at 24 and 48 hours after application was significantly higher than average mortality of termites in 0% - 5.0% NSO (Table 1). However, the mean mortalities of termites between 7.5% and 10.0% NSO were not significantly different at 24 and 48 hours after application. In addition, at 72 hours after termite exposure to NSO, termite mortalities at concentrations of 5% to 10.0% were not significantly but significantly higher than mortalities at 0% and 2.5%. Sugarcane strips treated with 7.5% and 10.0% JSO caused more than 50% termite mortality at 24, 48 and 72 hours after application. Termite mortalities in 7.5% and 10.0% JSO were significantly higher ($p<0.05$) than average mortalities in 0%, 2.5% and 5% JSO.

Similarly, PKO concentrations of 5.0, 7.5 and 10% gave significantly higher ($p<0.05$) termite mortalities than PKO concentration of 2.5%. In all cases, higher termite mortality was recorded with increase in the period of termite exposure to treated food.

Mortality of Termite on Soil Treated with Different Concentrations of Neem, *Jatropha* and Palm Kernel Oils: Termite mortality recorded on sand treated with NSO at concentrations of 7.5% and 10% between 24 and 72 hours were not significantly but significantly ($p<0.05$) higher than termite mortality at 2.5% NSO concentration (Table 2). Across the three periods of termite exposure to sand treated with JSO, the mean mortality of termite at the concentration of 2.5% were significantly lower than mortality recorded at the concentrations of 5.0, 7.5 and 10.0%. Termite mortality on sand treated with different concentrations of JSO at 24 hours after application were significantly different. However, at 48 and 72 hours after application, the mean mortality of termite observed at the concentrations of 5.0 to 10.0% JSO were not significantly different.

Termite mortality at 24, 48 and 72 hours in all the concentrations of PKO were significantly different except at 48 hours where mean termite mortality of 71.51% and 71.53% recorded at PKO concentrations of 5.0% and 7.5%, respectively were not significantly different.

Lethal Concentration (LC_{50}) and Median Lethal Time (LT_{50}) of Neem, *Jatropha* and Palm Kernel Oils: The median lethal concentration (LC_{50}) of NSO, JSO and PKO on termite at 24 hours of exposure in feeding and soil bioassays is shown in Table 3. In feeding bioassay, LC_{50} of 5.19%, 7.12% and 7.38% estimated for NSO, JSO and PKO respectively were not significantly different. However, the estimated LC_{50} in NSO was lower than in JSO and PKO. In soil experiment, the values of LC_{50} in NSO (2.22%) and JSO (3.17%) were not significantly different, but each was significantly lower than the value of LC_{50} in PKO (7.39%). In feeding experiment, the time estimated to cause 50% termite mortality in NSO (18.37 hours) was shorter than the time estimated to cause the same mortality in JSO (26.19 hours) and PKO (25.27 hours) but were not significantly different. The longest time, 18.68 hours estimated for PKO in soil bioassay to cause 50% mortality was significantly higher ($p<0.05$) than 4.26 hours and 4.29 hours estimated respectively for NSO and JSO which were not significantly different (Table 4).

Table 1: Mortality (%) of worker castes of *Macrotermes bellicosus* on food treated with different concentrations of Neem, *Jatropha* and Palm kernel oils

	Period of exposure (hour)								
	Neem seed oil			*Jatropha* seed oil			Palm kernel oil		
Oil concentration	24	48	72	24	48	72	24	48	72
0%	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2.5%	16.81±3.00	40.43±3.05	52.94±3.75	13.47±5.18	32.11±2.73	48.87±2.55	13.80±4.50	36.12±2.93	50.00±2.53
5.0%	54.85±13.75	80.14±11.30	86.03±10.49	39.58±9.73	63.50±2.00	72.93±3.23	27.59±5.67	60.56±3.41	71.66±3.02
7.5%	61.81±8.14	92.91±3.17	99.26±0.74	53.47±6.64	71.53±2.92	89.47±1.41	53.11±4.31	66.20±3.95	86.59±1.50
10.0%	79.85±5.95	100.00±0.00	100.00±0.00	60.42±4.34	73.72±2.13	96.99±2.19	64.14±4.83	75.36±1.11	93.31±2.73
LSD(0.05)	23.08	16.00	14.73	17.92	6.53	6.43	12.80	8.03	6.62

Table 2: Mortality (%) of worker caste of *Macrotermes bellicosus* on sand treated with different concentrations of Neem, *Jatropha* and Palm kernel oils

	Period of exposure								
	Neem seed oil			*Jatropha* seed oil			Palm kernel oil		
Oil concentration	24	48	72	24	48	72	24	48	72
0%	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2.5%	57.72±4.32	84.50±2.86	92.54±3.92	42.86±3.94	56.71±8.05	74.73±7.56	17.01±3.33	44.45±3.64	65.40±6.58
5.0%	79.20±4.16	97.89±2.11	100.00±0.00	62.58±1.52	93.28±2.94	100.00±0.00	38.77±2.40	71.51±2.31	83.06±2.59
7.5%	95.31±2.28	100.00±0.00	100.00±0.00	82.99±1.08	100.00±0.00	100.00±0.00	48.94±3.40	71.53±1.30	95.14±2.05
10.0%	97.32±0.67	100.00±0.00	100.00±0.00	90.48±2.72	100.00±0.00	100.00±0.00	60.54±2.31	82.64±3.80	100.00±0.00
LSD(0.05)	8.51	4.69	5.18	6.78	11.33	9.97	7.67	7.78	9.72

Table 3: Median lethal concentrations (LC_{50}) of three plant oils on adult worker caste of *M. bellicosus* in feeding and soil assays after 24 hours of exposure

	Feeding bioassay		Soil bioassay	
Plant oil	LC_{50} (%)	95% Confidence Interval	LC_{50} (%)	95% Confidence Interval
Neem seed oil	5.19a	4.09 – 6.36	2.22a	1.10 – 3.00
Jatropha seed oil	7.12a	5.59 – 10.21	3.17a	1.93 – 4.09
Palm kernel oil	7.38a	5.93 – 10.23	7.39b	5.64 – 10.85

Table 4: Median lethal time (LT_{50}) of three plant oils on adult worker caste of *M. bellicosus* in feeding and soil bioassays at 10% concentration

	Feeding bioassay		Soil bioassay	
Plant oil	LT_{50} (hour)	95% Confidence Interval	LT_{50} (hour)	95% Confidence Interval
Neem seed oil	18.37a	13.38 – 27.67	4.26a	2.97 – 5.55
Jatropha seed oil	26.19a	22.23 – 30.98	4.29a	2.94 – 5.65
Palm kernel oil	25.27a	21.33 – 30.10	18.68b	12.04 – 35.06

DISCUSSION

The application of botanical pesticides in the management of termites and other insects in agriculture and forestry holds a promise for reducing threats posed to the environment by synthetic pesticides and also has prospects for increasing crop yield. From this study, application of NSO, JSO and PKO to a food source and soil showed that mortality response of termite is dose and time dependent. Mortality of termite increased with increase in oil concentration and with increase in the period of exposure to oil. The mortality response of *Odontotermes obesus* to leaf extract of *Cordia dichotoma* has been reported to be dose and time dependent [34]. The formation of thin oil layer on termite cuticle when in contact with oil may also be a contributory factor to termite mortality. The covering of respiratory opening on termite body with oil could prevent passage of oxygen into the insect respiratory organs and also prevent exit of carbon dioxide from the body. The accumulation of carbon dioxide in insect tissues and low supply of oxygen to internal tissues reduce insect metabolism and also lead to suffocation which could lead to eventual death. Insect mortality has been reported to be increased with lower oxygen concentrations [35].

Probit analysis of termite mortality in NSO, JSO and PKO showed that the three oil sources were effective against termite as indicated by the low values of LC_{50} both in soil and feeding bioassays. However, the LC_{50} in NSO and JSO were lower than LC_{50} in PKO indicating that NSO and JSO were more toxic than PKO. The lower LT_{50} values observed in NSO indicates that the application of NSO caused termite mortality faster than JSO and PKO in soil and feeding bioassays. The lower values of LC_{50} and LT_{50} in soil bioassay compared to feeding bioassay is an indication that the three oils are more potent when applied as soil termiticides than when applied directly to plant materials.

The presence of oil in the soil and the contacts made with termite body could have caused termite mortality and could also deter termites from constructing tunnels in the soil. It has been suggested that inhibition of tunneling may be exploited in agricultural ecosystem to prevent termites from access to seed and plant parts [36]. Similarly, the result of feeding bioassay suggested that NSO, JSO and PKO could serve as deterrent to feeding by termites on plant materials. The inability of termites to feed might lead to starvation and eventual death.

From the foregoing, it is clear that the three oils tested were effective for the control of termite, but NSO

was the most effective followed by JSO. It should however be noted that though, all the oils were toxic to termite; the degree of toxicity depends on the concentration applied and the period of exposure. Extracts of neem and *Jatropha* seeds have been reported to be effective as termiticides at concentrations of 10 - 35% [37].

The insecticidal activity of seed oil of *J. curcas* has been attributed to the presence of sterols and terpene alchohols in the seed [38, 39] and has been reported as contact and stomach poison insecticides [18, 40, 41]. The main active ingredient of *Azadirachta indica*, azadirachtin has been reported as contact poison [37]. It has been reported that azadirachtin has broad mode of activity and demonstrated feeding deterrence, insect growth regulator, repellent, sterilant and may also inhibit oviposition of insect pest [42]. Other locally sourced plant materials such as ethanolic, African locust bean, *Parkia biglobosa* [43], *Moringa oleifera* [44], *Curcuma longa* (Turmeric), *Nerium indicum* (Oleander) and *Melia azedarach* (Derek) [45] have been reported to possess anti-termitic properties in Nigeria.

In conclusion, the application of Neem seed oil, Jatropha seed oil and palm kernel oil as soil termiticides could be utilized by poor resource farmers in the management of termites in agriculture and forestry in sub-Saharan Africa.

REFERENCES

1. Mugerwa, S., D. Mpairwe, E. Zziwa, K. Swaans and D. Peden, 2014. Integrated termite management for improved rainwater management: A synthesis of selected African experiences. NBDC Technical Report 9. Nairobi, Kenya: ILRI.
2. Sileshi, G., P. Nyeko, P. Nkunika, B. Sekematte, F. Akinnifesi and O. Ajayi, 2009. Integrating ethno-ecological and scientific knowledge of termites for sustainable termite management and human welfare in Africa. Ecol. Soc., 14(1): 48.
3. Adekayode, F.O. and M.O. Ogunkoya, 2009. Comparative study of clay and organic matter content of termite mounds and the surrounding soils. Conference Proceedings. African Crop Science, Uganda, 9: 379-384.
4. Abdurahman, A., T. Abraham and M. Dawd, 2010. Importance and management of termites in Ethiopia. Pest Management Journal of Ethiopia, 14: 1-18.
5. Alamu, O.T., 2017. Ecology and control of termite species in Eucalyptus plantations in Afaka, Kaduna State, Nigeria. PhD. Thesis, University of Ibadan, Ibadan, Nigeria, pp: 127.
6. Michael, L., 2000. Biology and ecology of termites. Report of UNEP/FAO/Global IPM Facility Termite Biology and Management Workshop, Geneva, Switzerland.
7. Sekamatte, M.B., 2001. Options for integrated management of termites (Isoptera: Termitidae) in smallholder maize based cropping systems in Uganda. Ph.D. Thesis, Makere University, Uganda.
8. Nyeko, P., L.S. Glohole, N.K. Maniania, H. Agaba and B.M. Sekamate, 2010. Evaluation of Metarhzium ansophiliae for integrated management of termite on maize and Grevillea rebusta in Uganda and Kenya. Proceedings of the 2nd RUFORUM Biennial Meeting, September 20-24, 2010, Entebbe, Uganda, pp: 333-336.
9. Joshi, P.K., N.P. Singh, N.N. Singh, R.V. Gerpacio and P.L. Pingali, 2005. Maize in India: Production Systems, Constraints and Research Priorities. D.F. CIMMYT, Mexico, pp: 22.
10. Umeh, V.C., F. Waliyar, S. Traore and E. Egwurube, 1999. Soil pests of groundnut in West Africa-species diversity, damage and estimation of yield losses. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), B.P. 320 Bamako, Mali. Insect Science and its Application, 19: 131-140.
11. Mugerwa, S., M. Nyangito, D. Mpairwe and J. Nderitu, 2011c. Effect of biotic and abiotic factors on composition and foraging intensity of subterranean termites. African Journal of Environmental Science and Technology, 5: 579-588.
12. Nyeko, N. and F.M. Olubayo, 2005. Participatory assessment of farmers' experiences of termite problems in agroforestry in Tororo district, Uganda. Agricultural Research and Extension Network Paper No. 143, Overseas Development Institute, London, UK.
13. Mugerwa, S., M. Nyangito, D. Mpairwe, C. Bakuneeta, J. Nderitu and E. Zziwa, 2011b. Farmers' Ethno-ecological Knowledge of the Termite Problem in Semi-arid Nakasongola. African Journal of Agricultural Research, 6: 3183-3191.
14. Banjo, A.D., O.A. Lawal, O.E. Fapojuwo and E.A. Songonuga, 2003. Farmers' knowledge and perception of horticultural insect pest problems in southwestern Nigeria. African Journal of Biotechnology, 2: 434-437.
15. Mugerwa, S., D. Mpairwe, D. Mutetikka, G. Kiwuwa, E. Zziwa, B. Owoyesigire and D.Peden, 2008. Effect of cattle manure and reseeding on pasture productivity. Paper presented in the Challenge Programme on Water and Food" workshop held between 10th - 15th November 2008, Addis Ababa, Ethiopia.

16. Sakasegawa, M., K. Hori and M. Yatagi, 2003. Composition and anti-termite activities of essential oils and Melaleuca species. Journal of Wood Science, 49: 181-187.
17. Park, I.K. and S.C. Shin, 2005. Fumigant activity of plant essential oils and components from garlic (Allium sativum) and clove bud (Eugena caryophyllata) oils against the Japanese termite (Reticulitermes speratus Kolbe). Journal of Agriculture, Food and Chemistry, 11(53): 4388-4392.
18. Jembere, B., D. Getahun, M. Negash and E. Seyoum, 2005. Toxicity of Birbira (Milletia ferruginea) seed crude extracts to some insect pests as compared to other botanical and synthetic insecticides. 11th NAPRECA (Natural Products and Drug Discovery) Symposium Book of Proceeding, Antananarivo, Madagascar: 88-96.
19. Cheng, S.S., H.T. Chang, C.L. Wu and S.T. Chang, 2007. Anti-termitic activities of essential oils from coniferous trees against Coptotermes formosanus. Bioresource Technology, 98: 456-459.
20. Ding, W. and X.P. Hu, 2010. Antitermitic effect of the Lantana camara plant on subterranean termites (Isoptera: Rhinotermitidae). Insect Science, 5(17): 427-433.
21. Supriadi, O. and A. Ismanto, 2010. Potential Use of Botanical Termiticide. Perspektif, 9(1): 12-20.
22. Zhu, B.C.R., G. Henderson, F. Chen, H. Fei and R.A. Laine, 2001a. Evaluation of vetiver oil and seven insect active essential oils against the Formosan subterranean termite. Journal of Chemical Ecology, 8(27): 1617-1625.
23. Zhu, B.C.R., G. Henderson, F. Chen, L. Maistrello and R.A. Laine, 2001b. N ootkatone is a repellent for Formosan subterranean termite (Coptotermes formosanus). Journal of Chemical Ecology, 3(27): 523-531.
24. Umeh, V.C. and M.F. Ivbijaro, 1999. Effect of termite damage to maize and seed extracts of Azadirachta indica and Piper guineense in farmers' fields. Journal of Agricultural Science, 133: 403-407.
25. Yashroy, R.C. and P.K. Gupta, 2000. Neem-seed oil inhibits growth of termite surface tunnels. Indian Journal of Toxicology, 1(7): 49-50.
26. Deka, M.K. and S.N. Singh, 2001. Neem formulation in the management of sugarcane insects and pests. Proceeding of 63rd American Convention Sugar Technologist Association, 27th - 28th August, Jailpur, India, pp: 33-38.
27. Singh, M., K. Lal, S.B. Singh and M. Singh, 2002. Effect of Calotropis (Calotropis procera) extract on infestation of termite (Odontotermes obesus) in sugarcane hybrid. Indian Journal of Agricultural Sciences, 7(72): 439-441.
28. Nkunika, P.O.Y., 1998. Termite survey, identification, damage and control in southern province. Land Management and Conservation Farming, Soil Conservation and Agroforestry Extension Report, Lusaka, Zambia.
29. Sileshi, G., E. Kuntashula, P. Matakala and P.O. Nkunika, 2008. Farmers' perceptions of pests and pest management practices in agroforestry in Malawi, Mozambique and Zambia. Agroforestry Systems, 72: 87-101.
30. Emerhi, E.A., G.A. Adedeji and O.Y. Ogunsanwo, 2015. Termites' resistance of wood treated with Lagenaria breviflora B. Robert fruit pulp extract. Nature and Science, 13(5): 105-109.
31. Abdullah, Z.A., A.Z. Ahmed and A.A. Refaat, 2014. Insecticidal activities of some plant extracts against subterranean termites, Psammotermes hybostoma (Desneux) (Isoptera: Rhinotermitidae). International Journal of Agricultural Sciences, 4(9): 257-260.
32. Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology, 18: 265-267.
33. Appel, A.G., M.J. Gehret and M.J. Tanley, 2001. Repellency and Toxicity of Mint Oil to American and German Cockroaches (Dictyoptera: Blattidae and Blattellidae). Journal of Agriculture and Urban Entomology, 18(3): 149-156.
34. Pal, M., T. Mishra, R. Kumar and S.K. Tewari, 2013. Antitermite activity of Cordia dichotoma. International Journal of Scientific and Innovative Research, 1(2): 57-61.
35. Hoback, W.W. and D.W. Stanley, 2001. Insects in hypoxia. Journal of Insect Physiology, 47: 533-542.
36. Ahmed, S., R.R. Khan and M.A. Riaz, 2007. Some studies on the field performance of plant extracts against termites (Odontotermes guptai and Microtermes obesi) in sugarcane at Faisalabad. International Journal of Agriculture and Biology, 9: 398-400.
37. Addisu, S., D. Mohamed and S. Watoke, 2014. Efficacy of botanical extracts against termites, Macrotermes spp., (Isoptera: Termitidae) under laboratory conditions. International Journal of Agricultural Research, 9(2): 60-73.

38. Adebowale, K.O. and C.O. Adedire, 2006. Chemical composition and insecticidal properties of the underutilized Jatropha curcas seed oil. African Journal of Biotechnology, 5: 901-906.
39. Nisar, M.S., S. Ahmed, M. Ashfaq and S.T. Sahi, 2012. Effect of Leaf and Seed Extracts of Jatropha curcas Linn. On Mortality and Tunneling of Subterranean Termites, Odontotermes obesus (Ramb.) (Termitidae: Isoptera). Pakistan Journal of Life and Social Sciences, 10(1): 33-38.
40. Bekele, J., 2002. Evaluation of the toxicity of Milletia ferruginea (Hochest) Baker against Sitophilus zeamais (Motsch.). International Journal of Pest Management, 48: 29-32.
41. Acda, M.N., 2009. Toxicity, tunneling and feeding behavior of the termite, Coptotermes vastator, in sand treated with oil of the physic nut, Jatropha curcas. Journal of Insect Science, 9: 1-8.
42. Isman, M.B., 2006. Botanical insecticides, deterrents and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology, 51: 45-66.
43. Olugbemi, B., 2012. Termiticidal Activity of Parkia biglobosa (Jacq) Benth Seed Extracts on the Termite Coptotermes intermedius Silvestri (Isoptera: Rhinotermitidae)," Psyche, vol. 2012, Article ID 869415, 5 pages, 2012. doi:10.1155/2012/869415.
44. Janfa, N., B.C. Falemara, O. Mathias, A.A. Akpala and C. Kambai, 2015. Termiticidal effects of Moringa oleifera seed oil extract on Gmelina arborea wood. Journal of Environmental Science, Toxicology and Food Technology, 8(9): 95-100.
45. Manzoor, F., M. Pervez, M.M.H. Adeyemi and S.A. Malik, 2011b. Effects of three plant extracts on the repellency, toxicity and tunneling of subterranean termite Heterotermes indicola (Wasmann). Journal of Applied Environmental and Biological Sciences, 7(1): 107-114.