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# Study on termite damage to different species of tree seedlings in the Central Rift Valley of Ethiopia

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**A high density of termite mounds is common in the Maki-Batu area of the Central Rift Valley of Ethiopia. To determine whether farmers consider termites as one of their problems in growing trees and practices they use to manage termites, short semi-structured questionnaires were distributed to farmers selected randomly. To evaluate the efficacy of some non-chemical control methods, *Eucalyptus camaldulensis* seedlings of five months were transplanted from nursery beds at two experimental sites. The seedlings were planted in three blocks each containing 6 treatments with 3 replicates laid out in randomized complete block design (RCBD). The treatments were: wood ash, cow dung, maize stalk, wood ash + cow dung + maize stalk, Untreated/control and Diazinon 60% EC applied at 2 l/ha as spray on the soil surface and a soil pit drench as a standard check. Plant mortality assessment was recorded once every month for one year. Mortality data were analyzed by analysis of variance (ANOVA) with SAS at 5% probability level. To find out the impact of termites on tree seedlings after transplanting in the area, mortality assessment was conducted at five sites on 11 species of tree seedlings transplanted from nursery beds. Termite damage on the seedlings was recorded once every month. After 12 months, seedlings of each plant species damaged during each month were summed and results were computed as percentages. To assess farmers' perceptions of termites as pests, unstructured questionnaires were distributed to 64 farmers randomly selected. Eucalyptus seedling mortality was very low and there was no significant difference among the treatments (P > 0.05) except at one site in which wood ash + manure + maize stover showed higher mortality. Seventy-eight percent of the farmers mentioned that they had planted tree seedlings for different purposes and 72% of them considered termites as the major cause of seedling mortality. Although, higher density of *Macroterems* termite mounds were found in the area and most farmers considered termites as one of the major constraints in growing tree seedlings, this study showed very low termite damage to the tree seedlings studied for one year after transplanting.**

**Key words:** Eucalyptus, farmer, Maki-Batu, mortality, pest.

## INTRODUCTION

Termites by no means confine their attentions to dead plant tissues such as wood. Certain species of termites are serious pests of growing crops including living trees (Hickin, 1971) and they are one of the major agroforestry pests in the tropics (Nyeko and Olubayo, 2005). Many other insect pest species cause damage to various parts of the tree, but often they do not cause mortality (Logan et al., 1990; UNEP, 2000). However, termites are seldom

primary pests, only damaging the plant, shrub or tree when it has already been affected by fire, disease, drought, mechanical injury, bad planting or other insect pests (Harris, 1971; Hickin, 1971). Although, termites usually appear to be secondary pests, it does not make them of less importance. The initial defect affecting the plant is often of minor importance, after allowing ingress to termites, the effect may be the complete destruction of the plant or, at least, a reduction in its value as a crop (Hickin, 1971).

The extent to which termites are problems to trees and the nature of loss they cause are very much related to the geographic region concerned (Logan et al., 1990). In the tropical and sub-tropical regions of the world where rainfall is low and a dry savannah-type of situation has developed, termite attacks appear most acute and this has caused serious problems in the development of nurseries and young tree plantations. Another phase of the problem is the susceptibility to termite of a popular group of tree species for the tropical planting, the *Eucalyptus* (Hickin, 1971). *Eucalyptus* is preferred as compared to other plants such as *Cassia*, *Albizzia* and *Gmelina* species because of its more rapid growth potential (Harris, 1971). Eighteen termite species are recorded as damaging young trees in forest and plantation nurseries and there are a number of recorded instances of high percentage loss, even complete and total destruction of young trees, particularly *Eucalyptus* (Hickin, 1971). Moreover, Pearce (1997) noted that a high demand for timber in Africa has led to fast-growing trees such as *Eucalyptus*, being planted in poor soil areas where they are under stress and are therefore more susceptible to termites.

The main obstacle to afforestation in the dry areas of Africa is said to be the presence of termites (Harris, 1971; Hickin, 1971). However, not all species of termites present in a locality are destructive to forestry (Nair, 2007). The species ranking as forestry pests vary in different tropical areas. In Africa, the genera, *Macrotermes* and *Odontotermes* are implicated as well as the species *Pseudacanthotermes militaris* in Uganda. Throughout tropical Africa, losses are due exclusively to members of the subfamily: Macrotermitinae, all of which are fungus growers with large nests in mounds or underground (Harris, 1971; Hickin, 1971).

As elsewhere in Africa, termite damage in Ethiopia is generally greater in rain-fed than irrigated crops, during dry periods or drought than periods of regular rainfall, in plants under stress (e.g. newly transplanted forest tree seedlings) than healthy or vigorous plants and exotic (e.g. *Eucalyptus*, maize) than indigenous plants (Wood, 1986, 1991). In western Ethiopia, termite damage on indigenous trees is insignificant. In contrast, serious damage is very common on exotic forestry trees, especially on *Eucalyptus*, one to three years after transplanting (Abdurahman, 1995). Soon after transplanting, seedlings suffer severely from moisture stress, because of soil compaction and low water holding capacity resulting from poor infiltration rates. The roots of such plants begin to dry out and this creates a favorable situation for termite infestation (Gauchan et al., 1998). In some localities up to 100% of *Eucalyptus* seedling loss is common (Abdurahman, 1995). In most areas of Uganda, an average of between 30 and 70% of planted *Eucalyptus* trees are killed by termites (Mazodze, 1995).

Control of termites as forest pests involves both chemical and traditional methods. Current chemical control methods employed are soil treatment, treatment of seedlings before transplanting and baiting techniques and the chemicals currently used include chlorpyrifos, imidacloprid and fipronil. In addition to the current chemical control methods employed, there are a number of alternative, traditional control methods, largely relating to silvicultural practices or plantation management, which are also very important, and should be considered before chemical intervention is attempted. Many traditional methods of control of termites in forest plantations have a sound basis in the principles of ecology (UNEP 2000). Logan et al. (1990), UNEP (2000) and Abdurahman et al. (2010) have reviewed a wide range of control of termites in crops and forestry with non-chemical methods which include cultural and biological control.

Though a high density of termite mounds was reported in the Maki-Batu (Batu formerly called Ziway) area of the Central Rift Valley of Ethiopia (CRVE), no data were available on the extent of termite damage on forestry tree seedlings after transplanting. Therefore, the main objectives of the study were to assess the impact of termites on some species of tree seedlings and test the efficacy of some non-chemical control methods on *Eucalyptus* seedlings after transplanting.

## MATERIALS AND METHODS

### Study area

The study was conducted between July 2012 and January 2014 in two districts (Bora and Adami Tullu-Jiddo Kombolcha) of East Shawa Zone of Oromia Regional State at six sites (Figure 1). The districts are located in the Central Rift Valley of Ethiopia. Maki is the capital of Dugda district and Batu is the capital of Adami Tulu Jido Kombolcha district. The capital towns of the two districts are about 30 km from each other along Addis Ababa - Shashemene high way. In the context of this study, Maki-Batu area therefore includes the two districts and neighboring districts where high density of

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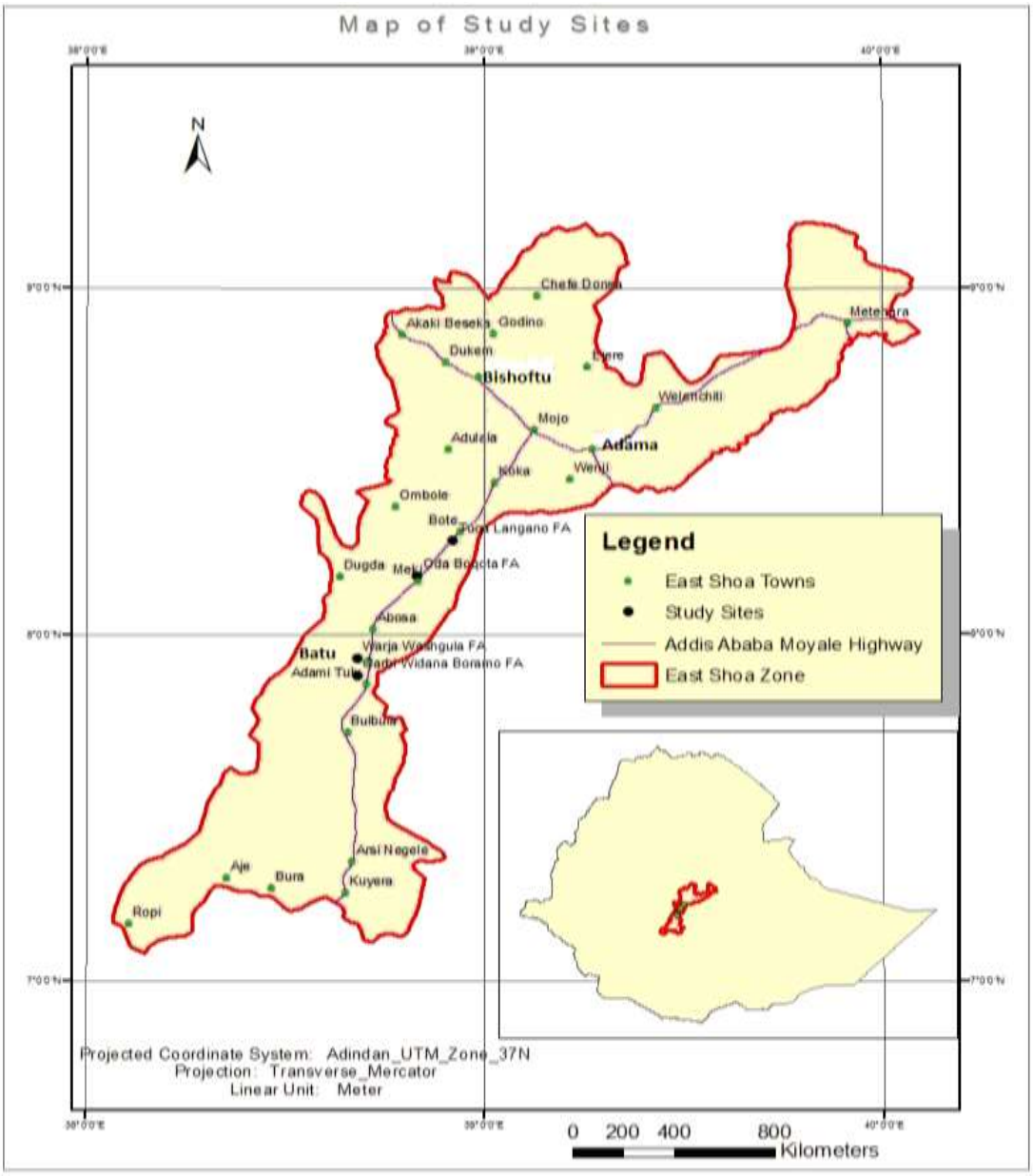


**Figure 1.** Map showing East Shawa Zone of Oromia Regional State (Source: Daniel and Emana, 2015).

Macrotermes termites are found.

The area has a semi-arid and arid climate and has a bimodal rainfall patterns (Mengistu, 2008). The highest precipitation occurs between July and September with some additional rainfall between February and the end of April, but this usually varies. Rain-fed crops are most often not planted until mid-June because of the unpredictable rainfall pattern in the preceding period (Haimanot, 2002). Coordinates, elevations, mean annual rainfall and temperatures of the capital towns of the three districts are shown in Table 1.

The vegetation in the CRVE is characterized by acacia open-woodland and savanna (Huib and Herco, 2006). The natural vegetation of the area is under high pressure due to the expansion of cultivated land, overgrazing and deforestation and thus the natural flora and fauna are disappearing rapidly (Huib and Herco, 2006; Mengistu, 2008).

## Data collection methods and analyses

### *Farmers' constraints in growing tree seedlings and termite management practices*

Short semi-structured questionnaires was dispatched to 64 randomly selected smallholder farmers focusing on general problems they faced in growing tree seedlings (to assess whether they consider termites as one of the problems) and practices they used to manage termites in tree seedlings. Farmers' responses were analyzed and reported as percentages.

To evaluate the efficacy of some non-chemical control methods

**Table 1.** Coordinates, elevations, mean annual rainfall and temperature at the meteorological stations located in the capital towns of the three districts.

| District | Capital towns | Coordinates | Elevation (m) | Mean annual rainfall (mm)* | Mean annual temperature (°C) * | |
|---|---|---|---|---|---|---|
| | | | | | Maximum | Minimum |
| Bora | Bote | 8°29'N, 38°91'E | 1656 | 814.5 | 28.3 | 13.0 |
| Dugda | Maki | 8°15N, 38°82'E | 1662 | 762.8 | 27.8 | 14.4 |
| ATJK | Batu | 7°56'N, 38°43'E | 1650 | 742.4 | 27.2 | 14.0 |

Source: National Meteorological Agency of Ethiopia; *Average of many years; ATJK = Adami Tulu Jido Kombolcha.

in protecting tree seedlings and for the possible use of the effective method(s) as a management option, a field trial was carried out using *Eucalyptus camaldulensis* seedlings at two sites: Garbi Widana Boramo Primary School (GWPS) (7°53'N, 38°41'E, 1665 m.a.s.l) and Warja Washgula Kebele Administration Farmers Training Center (WWKAFTC) (7°56'N, 38°41'E, 1668 m.a.s.l.). *Kebele* is the lowest administrative level which is below district.

### *Eucalyptus* seedlings mortality under different control options

*E. camaldulensis* seedlings of five months old were planted in three blocks each containing six plots (2.5 x 2.5 m). Thirty-six seedlings were planted per plot (648 seedlings per site) with a spacing of 0.5 x 0.5 m and 1 m distance between blocks with 3 replications laid out in randomized complete block design (RCBD) based on Mazodze (1995). A total of six treatments were used: T1 (wood ash), T2 (cow dung), T3 (maize stalk), T4 (wood ash + cow dung + maize stalk), T5 (untreated/control) and T6 (Diazinon 60% EC) applied at 2 l/ha as spray on the soil surface and as a soil pit drench around the seedlings as a standard check. Six maize stalks of 40 cm length were buried 20 cm deep in the soil around each seedling in the treated plots; 0.5 kg of cow dung and 0.5 kg of wood ash were added around the base of the treated seedlings. The *Eucalyptus* seedlings raised in plastic bags on nursery beds were provided by Agricultural and Rural Development Bureau of Adami Tulu Jido Kombolcha district and transplanted to the site located at GWPS on July 14, 2012 and to WWKAFTC research site on July 16, 2012.

*Eucalyptus* seedlings mortality data were analyzed by analysis of variance (ANOVA) with SAS (SAS Institute, 2003). Significant differences between treatments were compared by the least significant difference (LSD) test at 5% probability level. Before analysis data were square root transformed $(X + 0.5)^{1/2}$ to stabilize heterogeneity of variation (Gomez and Gomez, 1984).

### Mortality of different species of tree seedlings due to termites

Eleven different species of tree seedlings were transplanted from nursery beds at five sites. *Eucalyptus* seedlings were planted by the researcher on three farmers' fields, while *Sesbania sesban* seedlings were planted on one farmer's field. The tree seedlings at Garbi Widana Boramo Kebele Administration Farmers Training Center (GWBKAFTC) site were planted by the workers of the Farmers Training Center (FTC) and those at Meles Green Park site were planted by the local community.

All the seedlings were raised in plastic bags on nursery beds and were provided freely by Agricultural and Agricultural and Rural Development Bureau of Adami Tulu Jido Kombolcha district. The seedlings were transported to sites by vehicles with care.

Termite damage on the seedlings was recorded starting one month after transplanting and continued every month for 12 months. After 12 months, the numbers of plant dried due to termite infestation of each plant species and site were summed and results were computed as percentages.

During each assessment, wilted and/or dried plants were checked for signs of termite attack above and below the ground. Causes of plant mortality were ascertained by lifting the dried plant and examining the root and stem for typical *Macrotermes* and *Microtermes* damage. The former species cut the base of well-established plants, while the latter species enter and consume the larger roots and prop-roots and continue their excavation into the stem, which can be excavated and packed with soil (Maniania, 2002). Termite species that were found attacking the saplings were collected and preserved in 80% ethanol. Taxonomic identification was done at the genus level using Keys to the Genera of Ethiopian Termites based on soldier characters (Abdurahman, 1991).

Plant mortality assessment was started on the first month after planting, and continued once a month for one year. The numbers of plant that dried due to termite infestation of each plant species and site were summed and results were computed as percentages.

## RESULTS

Seventy-eight percent of the respondent farmers mentioned that they had planted tree seedlings for different purposes such as house construction, shade, and for creating good air condition, beauty and environmental rehabilitation. Farmers mentioned that they had faced certain constraints which hinder the establishment of the seedlings after transplanting and their further growth. Of those farmers that planted tree seedlings, 72% considered termites as the most serious problems causing tree seedling mortality followed by livestock (browsing), mole rats and drought (Table 2).

### Farmers' termite management practices

Forty percent of those respondent farmers who mentioned termites as problems in growing tree seedlings used different methods of indigenous control, mainly a combination of two or more methods which include good silviculture, cow dung, wood ash and queen removal (Table 3). No one used chemical control method (synthetic termiticide). Application of cow dung and wood ash around base of plants were the major practices used by farmers. Respondents mentioned that termites do not appear in areas where decomposing manure is found.

**Table 2.** Problems mentioned by farmers in growing tree seedlings after transplanting at Central Rift Valley of Ethiopia.

| Response options | Percentage of respondents |
|---|---|
| Termites | 72 |
| Mole rats | 28 |
| Drought | 20 |
| Domestic animals | 60 |
| Salinity | 12 |
| Cutworm | 4 |

*The percentages do not sum up to 100 because some individuals mentioned more than one problem they faced in growing tree seedlings.

**Table 3.** Percentage of respondent farmers that used different indigenous termite management practices against tree seedlings in the Central Rift Valley of Ethiopia.

| Management options | Percentage of respondents |
|---|---|
| Good silviculture and sanitation | 17 (6) |
| Cow dung | 56 (20) |
| Wood ash | 61 (22) |
| Used engine oil | 6 (2) |
| Queen removal and adding hot ash to mound | 6 (2) |
| Opening mound and adding cow dung and wood ash | 6 (2) |

*The percentages do not sum up to100 because some individuals mentioned that they used more than one management options.

**Table 4.** *Eucalyptus* seedlings mortality (mean ± SE) one year after transplanting to WWKAFTC site and GWPS site in the Central Rift Valley of Ethiopia.

| Treatment | Study sites | |
|---|---|---|
| | GWPS | WWKAFTC |
| Wood ash | $0.71 \pm 0.00^{b}$ | $0.71 \pm 0.00^{a}$ |
| Manure | $0.71 \pm 0.00^{b}$ | $0.71 \pm 0.00^{a}$ |
| Maize stover | $0.88 \pm 0.12^{ab}$ | $0.88 \pm 0.12^{a}$ |
| Wood ash + Manure + Maize stover | $1.05 \pm 0.12^{a}$ | $0.88 \pm 0.12^{a}$ |
| Control | $0.71 \pm 0.00^{b}$ | $0.71 \pm 0.00^{a}$ |
| Diazinon 60% EC at 2 l/ha | $0.71 \pm 0.00^{b}$ | $0.71 \pm 0.00^{a}$ |
| LSD | 0.30 | 0.30 |

Means within a column followed by the same letter do not differ significantly by least significant difference (LSD) test at 5% of probability level

### *Eucalyptus* seedling mortality under different control options

Seedling mortality due to termites under the different treatments is shown in Table 4. Seedling mortality due to termites under all the treatments was very low. However, higher mortality was recorded in plots treated with combined wood ash, manure and maize stover at GWPS site. There was no significant difference among the treatments at WWKAFTC site.

### Mortality of different species of tree seedlings due to termites

The mean percent mortality of different species of tree

**Table 5.** Mean percent mortality of tree seedlings due to termites after transplanting to different sites in the Central Rift Valley of Ethiopia.

| District | Tree seedling species | Site | Number of seedlings transplanted | Percent mortality (n) |
|---|---|---|---|---|
| ATJK | *Eucalyptus camaldunsis* | $FF_1$ | 153 | 1.3 (2) |
| | | $FF_2$ | 54 | 0.0 (0) |
| Bora | *Eucalyptus camaldunsis* | $FF_3$ | 136 | 6.6 (9) |
| ATJK | *Acacia albida* Del. | GWBFTC | 53 | 0.0 (0) |
| | *Jacaranda mimosifolia*D.Don | GWBFTC | 131 | 0.0 (0) |
| | *Sesbania sesban*(L.) | $FF_1$ | 54 | 0.0 (0) |
| Bora | *Acacia albida* Del. | MP | 171 | 0.6 (1) |
| | *Acacia senegal*(L.) Willd | MP | 200 | 0.5 (1) |
| | *Olea africana* Miller | MP | 20 | 0.0 (0) |
| | *Ficus vista* | MP | 66 | 0.0 (0) |
| | *Cordia africana*Lam. | MP | 40 | 0.0 (0) |
| | *Leacaena leucocephala*(Lam.) de Wit | MP | 54 | 0.0 (0) |
| | *Juniperusprocera*Hochst. | MP | 40 | 0.0 (0) |

ATJK = Adami Tullu Jido Kombolcha; FF = farmer's field; GWBFTC= Garbi Widana Boramo Farmers Training Center; MP = Meles Park; n = number.

seedlings due to termites is shown in Table 5. No mortality was recorded in most of the species of the tree seedlings. However, a relatively higher mortality (6.6%) was recorded only on *Eucalyptus* at $FF_3$. Damage was caused mainly by *Macrotermes* and to less extent by *Odontotermes* and *Microtermes*.

## DISCUSSION

Most of the respondent farmers considered termites as one of the major problems in growing tree seedlings and this is basically in agreement with Sileshi et al. (2008) who reported similar results consistent with evidence from literature. For instance, Ugandan farmers ranked termites as the most serious problems in growing trees. However, damage of termites on the tree seedlings, even on the most susceptible exotic plant, *Eucalyptus*, was very low and this was contrary to a wide range of literatures (Hickin, 1971; Harris, 1971; Abdurahman, 1990; Pearce, 1997) and farmers' report in this study. High demand for timber in Africa has led to fast-growing trees, such as *Eucalyptus,* being planted in poor soil areas where they are under stress and are therefore more susceptible to termites (Pearce, 1997). In Cameroon, 100% losses were recorded with *Eucalyptus saligna*, and 60 to 80% with other species; in the drier areas of Uganda between 50 and 70% of transplants were regularly lost; in Northern Nigeria, *E. camaldulensis* had a failure rate of between 68 and 74% in the first eighteen months and 86% after thirty months (Harris, 1971). Cowie and Wood (1989) reported that in some areas in southern, western and eastern Ethiopia, some forest trees are seriously damaged and attack is usually on newly-transplanted seedlings, particularly *Eucalyptus*, and losses could exceed 90%. Further, Abdurahman (1995) noted that in western Wallaga (Ethiopia), termite damage on indigenous trees is insignificant but serious damage is very common on exotic forestry trees, especially on *Eucalyptus*, one to three years after transplanting. In some localities up to 100% of *Eucalyptus* seedling loss is common (Abdurahman, 1995). As per the personal communication made with experts of Asosa Plant Health Clinic, Asosa Zone-, Mana Sibu- and Ayira- districts of Agricultural and Rural Development Offices, termites ranked as number one of all the existing pests. They claimed that there would be total losses in *Eucalyptus* unless chemical termiticides are used. The critical period to prevent termite attack in young plantations of tree seedlings is during the first year in the nursery and a few months after planting out. Later on, as the trees get older, termite infestation may increase, but once a good canopy is formed, attack is often greatly reduced. A positive correlation exists between the presence of drought conditions and incidence of attack (Pearce, 1997).

Tree species like *Acacia senegal*, *Acacia albida, Cordia africana, Ficus vista* and *Olea africana* are all indigenous and the absence of damage be attributed to this factor. Pearce (1997) noted that some of the common tree species seen today in some regions have resulted from selection by termites, that is, the more susceptible ones have been eaten to extinction many years ago. Many of these indigenous trees are therefore more resistant to

termite attack and have developed chemical defenses to protect themselves.

The absence of damage or the incident of little damage recorded both on indigenous and exotic tree seedlings may also be attributed to the absence of pest species, low termite population density, and presence of amble food. Abdurahman et al. (2010) reported that in western Wallaga, *Macrotermes subhayalinus, Microtermes, Ancictrotermes, Pseudacanthotermes militaris, Odontotermes* are the most damaging species. However, in the current study, *Ancictrotermes* and *Pseudacanthotermes* spp. were not recorded in the CRVE. All the study sites contained amble wood and grass litter and these might provide sufficient food for termites and thus diverted termites' attention from attacking the tree seedlings. In western Wallaga, where termite damage on *Eucalyptus* seedlings is very high, farmers weed the seedlings and remove the debris out of the fields which leave termites with little food and thus force them to attack the seedlings.

On the other hand, significantly higher termite damage in the plots of *Eucalyptus* seedlings treated with combined wood ash, manure and maize stover than the other treatments at GWPS site might be attributed to the attraction of termites to manure and maize stover. Animal dung and wood are ideal foods for *Macrotermes* termites. In the present study, all the termite species recorded in the area were sampled by using maize stover used as baiting than the other treatments Logan et al. (1990) reported that there are conflicting views on the use of crop residues and other organic matter in termite control. The addition or removal of organic matter from the field has been suggested as methods of reducing levels of attack. Essentially, the conflicting principles are (1) the removal of residues and other debris from the field will reduce potential termite food supplies and hence lead to reduction in termite numbers and subsequent attack; and (ii) that leaving residues in the field or adding further organic matter will provide alternative food to which the termites will be attracted, thereby reducing levels of attack. The respective counter-arguments are (i) that removal of alternative food sources will concentrate termite activity on the crops/trees, leading to increased damage; (ii) that leaving residues and other food sources in the field will provide extra resources and allow termite populations to build up, again to increase damage. There is evidence supporting both views and a generalization may not be possible, different methods being appropriate in different places with different termite species and different crops/trees. The authors have also reported that the use of wood ash is a common practice which demands proper evaluation.

For damage to crops and trees, the first sign of termite presence, especially in seedlings, is wilting. Also, soil runways or sheeting on the soil surface, plants or trees indicates that termites are present. Termites can be collected from the runways and identified. To check for the presence of termites in the field, samples of unhealthy looking plants from the crop should be taken (Pearce, 1997). In the current study, mostly termites of the genus *Macrotermes* were found damaging tree seedlings. Termites of the genus *Macrotermes* are the most common termites in the Central Rift Valley of Ethiopia responsible for lodging of maize plants which cut the plants at ground surface (Daniel and Emana, 2015). Rural houses in the area are mostly damaged by *Macrotermes* (Emana and Daniel, 2014). The genus *Macrotermes* includes several important pests of a wide range of field crops and trees. They attack plants by cutting off young seedlings or mature plants at soil level (Nyeko and Olubayo, 2005).

## Conclusion

Although, higher density of *Macroterms* termite mounds are found in the area and most farmers considered termites as one of the major constraints in growing tree seedlings, this study showed very low termite damage to the tree seedlings. The reason for the low damage may be that the termite population is low and/or the termites had enough other food options to eat and thus avoided attacking the seedlings.

## Conflict of Interests

The authors have not declared any conflict of interests.

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## REFERENCES

Abdurahman A (1990). Foraging Activity and Control of Termites in Western Ethiopia, Ph.D. Thesis, University of London 277 p.

Abdurahman A (1991). Keys to the Genera of Ethiopian termites. Crop Protection bulletin No.1. Crop Protection and Regulatory Department, Ministry of Agriculture. Addis Ababa 15 p.

Abdurahman A (1995). Termites of Agricultural Importance and their Control in Western Ethiopia. In: Proceedings of Second Regional Workshop on Termite Research and Control, held at National Agricultural Research Laboratories, Nairobi pp. 13-17.

Abdurahman A, Abraham T, Mohammed D (2010). Importance and Management of Termites in Ethiopia. Pest Manage. J. Ethiop. 14:1-18.

Cowie RH, Wood TG (1989). Damage to Crops, Forestry and Rangeland by Fungus-Growing Termites (Termitidae: Macrotermitinae) in Ethiopia. Sociobiology 15(2):139-153.

Gauchan D, Ayo-odongo J, Vaughan K, Lemma G, Mulugeta N (1998). A Participatory Systems Analysis of the Termite Situation in West Wallaga, Oromia Region, Ethiopia. Working Document Series 68, ICRA, Wageningen, Netherlands 158 p.

Daniel G, Emana G (2015). Farmers' Knowledge, Perceptions and Management of Termites in the Central Rift Valley of Ethiopia. Afr. J. Agric. Res. 10(36):3625-3635.
Gomez AK, Gomez AA (1984). Statistical Procedures for Agricultural Research (2nd edn.). John Wiley and Sons, New York 680 p.
Emana G Daniel G (2014). Preliminary studies of termite damage on rural houses in the Central Rift Valley of Ethiopia. Afr. J. Agric. Res. 9(39):2901-2910.
Haimanot A (2002). Potential of entomopathogenic fungi for the control of *Macrotermes subhyalinus* (Isoptera: Termitidae). PhD Thesis. Universität Hannover P 161.
Harris WV (1971). *Termites:* Their Recognition and Control (2nd edn.). Longman Group Ltd., London 186 p.
Hickin NE (1971). *Termites:* The World Problem. Hutchinson & Co. Ltd. London 232p.
Huib H, Herco J (2006). Agricultural Development in the Central Ethiopian Rift Valley: A Desk-study on Water-related Issues and Knowledge to Support a Policy Dialogue. Note 375. Plant Res. Int. B.V., Wageningen, Netherlands 32 p.
Logan JWM, Cowie RH, Wood TG (1990). Termite (Isoptera) Control in Agriculture and Forestry by Non-chemical Methods: A Review. Bull. Entomol. Res. 80:309-330.
Maniania NK, Ekesi, S, Songa JM (2002). Managing Termites in Maize with the Entomopathogenic Fungus *Metarhiziumanisoplia.* Insect Sci. Appl. 22(1):41-46.
Mazodze R (1995). Fipronil Trial Results: Control of termites in Eucalyptus. In: Proceedings of Second Regional Workshop on Termite Research and Control, held at National Agricultural Research Laboratories, Nairobi, 7-9 March pp. 48-50.
Mengistu A (2008). Socio-economic Assessment of Two Small-scale Irrigation Schemes in Adami Tullu Jido Kombolcha Woreda, Central Rift Valley of Ethiopia. MSc Thesis. Wageningen University 102 p.
Nair KSS (2007). Tropical Forest Insect Pests Ecology, Impact, and Management.Cambridge University Press, New York, USA 424 p.
Nyeko P, Olubayo MF (2005). Participatory Assessment of Farmers' Experiences of Termite Problems in Agroforestry in Tororo District, Uganda. Agricultural Research and Extension Network Paper 143:13.
Pearce MJ (1997). Termites: Biology and Pest Management. CAB International, New York 172 p.
Sileshi GW, Elias K, Patric M, Philip ON (2008). Farmers' Perceptions of Tree Mortality, Pests and Pest Management Practices in Agroforestry in Malawi, Mozambique and Zambia. Agrofor. Syst. 72:87-101.
UNEP (United Nations Environment Programme) (2000). Finding Alternatives to Persistent Organic Pollutants (POPS) for Termite Management. Prepared by members of the UNEP/FAO/Global IPM Facility Expert Group on Termite Biology and Management - established in 2000 to support international activities on Persistent Organic Pollutants (POPs) covered by the Stockholm Convention. Available at: http://www.avrdc.org/pdf/BW_brochure.pd
Wood TG (1986). Assessment of Termite Damage in Ethiopia and Recommendations for Short-term Control and Development of Long-term Pest Management Practices. Report prepared for the World Bank 58 p.
Wood TG (1991). Termites in Ethiopia: The environmental impact of their damage and resultant control measures. Allen Press Royal Swedish Acad. Sci. 20(3/4):136-138.