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Evaluation of chemical, botanical and cultural management options of termite in Tanqua Abergelle district, Ethiopia

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The study was carried out to evaluate the effect of botanical, chemical and cultural methods on the management of termite in seedling beds of hot pepper in Tanqua Abergelle district of Sheka Tekli during 2015-2016. The experiment comprised of treatments including Neem Leaf extract, wood ash, Dursban and control and each treatment was applied at 40 kg ha^{-1}, 10000 kg ha^{-1}, and 0.5 L ha^{-1} respectively. The experiment was designed through Randomized Complete Block Design and each treatment was replicated thrice. The treatments were applied directly on seedling beds while seeds were sown. Data was collected after six weeks of sowing pepper seeds. The numbers of healthy seedlings were significantly affected by the application of treatments. Hence, the highest number of seedlings at six weeks after sowing (1658250 seedlings ha^{-1}) and transplanting (1505490 seedlings ha^{-1}) were recorded on plots treated with dursban and neem leaf extracts respectively. Likewise, lower NUMBER of seedlings damage was recorded on beds treated with dursban (504510 seedlings ha^{-1}) and Neem leaf powder (623100 seedlings ha^{-1}) compared with untreated experimental plots. The highest net return (74020 Birr) with a marginal rate of return (42.64 Birr) was obtained with application of neem leaf extract. Thus, the application of neem leaf extract alone or interchangeably with dursban should be promoted to farmers of Tanqua Abergelle district and other location with the same environmental conditions to easily manage termite on the seedling of hot pepper.

Key words: Termite, pepper seedling, damage percentage, control method.

INTRODUCTION

Termites are social insects that belong to the Isoptera order. They are occasionally associated with severe damage to rangeland vegetation, particularly, in degraded arid and semi-arid ecosystems. Termites are destructive structural pests as well as agricultural pests found primarily in the tropical regions of the world, where they play an important ecological role in the recycling of Wood and other cellulose-based materials (Abdurahaman,

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1990). There are currently approximately 2,800 named termite species in 282 genera worldwide. Of the most economically important termite spp. *Macrotermes subhyalinus* (Rambur) and *Microtermes adschaggae* (Sjosted) are widely observed in the region (Abdurahman, 1990).

Currently, many regions of the world are subjected to expansions and/or invasions of subterranean termites. In some areas, including Ethiopia, termite constitutes a significant pest problem in agriculture. In general, plants exotic to the specific area and water-stressed plants are most prone to attack by termites. They are serious pests of a wide range of crops, forest trees and buildings in Western Ethiopia (Hailemichael Taye et al., 2013; Legesse et al., 2013). It is also the most economically important insect pest of many crops in Tanqua Abergelle district.

Termite infestation and damage starts while plants are standing in the field. A soil infested with termite mostly resulted in distortion of soil structures and compactions. Hence soil becomes difficult to plough, this in turn results in a reduction of productivity of crops. Termites are devastating insect pests which caused 36 to 62% reduction in yields of hot pepper and maize, respectively. Termites also cause severe devastations on the forest, and thus soil remains bare and exposed to elements of soil erosion (Abraham, 1990; Kumar and Pardeshi, 2011; Bong et al., 2012). As a result, farmers are forced to leave their farmlands (Abraham and Adane, 1995). Yield loss depends on the type of crop, the extent of stand reduction and the attack at the different growth stage of the crops by termites. Abdurahaman (1990), stated that 45% crop removal at the six-leaf resulted in 16.5% of yield loss, whereas the same reduction at the tasseling stage caused 39.9% yield loss. Addisu et al. (2014) also stated that severe infestation of termite spp. could cause up to 100% crop losses in Ethiopia.

Unlike the effect on the environment and cost, the use of some chemical insecticides are highly effective against termite (Kumar et al., 2012). Chemical spray with Dursban is highly effective in the management of wood destroying termites (Roll, 2007). The possibilities of using different control measures such as fungal insecticides, bio-insecticides and botanical method rather than chemical insecticides have been reported (Silva et al*.,* 2012; Sujatha et al*.,* 2012). The application of crop residue and cattle manure reported reducing the number of termites on crop fields' by 21.6 and 29.7% compared to non-treated fields (Legesse et al., 2013). There are also many plant-based botanicals that could act against termites in crop fields and vegetations. The latex and quinines of some botanicals like *Calotropis procera*, *Ipomoea fistulosa*, *Maesa lanceolata*, *Croton macrostachyus*, *Tegetes minuta*, *Datura stramonium* and *Azadirachta indica* are reportedly used for the management of termites throughout the world (Derbalah et al*.,* 2012; Singha et al., 2013; Upadhyay, 2013). The use of indigenous plant extracts as an alternative for insect pest control also reported (Abdullahi et al., 2011; Sathyaseelan et al., 2008). The use of leaf powders of *Azadirachta indica* and *Maesa lanceolata* were found to be effective in controlling termite on hot pepper at Bako (Sisay, et al., 2008). According to Venmalar and Nagaveni (2005), Neem extract contains toxic constituents exhibiting high toxicities against different microbes and insect pests.

Some research works had been conducted to investigate the effectiveness of biopesticides against termite. However, the assortments of best commercial products are limited and insufficient to fulfil the requirements of small-scale farmers throughout Tigray region. Hence, the study was initiated to evaluate the performance of the application of chemical, botanical, and cultural control methods with respect to plots maintained with no termite control activities to screen the best termite control strategies.

MATERIALS AND METHODS

Description of study area

The experiment was carried out during 2015/2016 production season for two years. It was undertaken at Sheka Tekli kebele of Tanqua Abergelle district where termite is the main production constraints of pepper seedlings. The study area is located at 13°14'06" N Latitude and 38°58’50”E longitudes and its average altitude are below 1500 m above sea level (Figure 1). The area is characterized as hot warm sub-moist low land (SML-4b) and the average annual rainfall ranges from 350 -700 mm with minimum and the maximum temperature is 24 and 41°C respectively.

Experimental materials and design

The experiment comprised four types of management methods including chemical, botanical treatment, the cultural method using Wood ash and termite infested checks. The treatments were arranged using a Randomized Complete Block Design (RCBD) and each treatment was replicated thrice. Twelve experimental plots including check were used. Finally, all experimental units were treated uniformly at the same time. Dursban, Neem leaf extract, and wood ash were treated at a rate of 0.5 L, 24 and 6 kg per hectare basis respectively. The spacing between plants, rows, pathway and block were 2, 15, 50 and 100 cm respectively.

Preparation and application of Neem extracts and Wood ash

Fresh leaves of Neem were collected, sun-dried for three days and ground into powder using mortar and pistol. Likewise, 12 g of Neem leaf powder was weighed and dissolved in 120 mL of water. The suspension was fermented for half a day, eventually strained and poured into a liter of water. 20 g of detergent (emulsifier) was measured and thoroughly mixed with the extract to ensure uniform distribution of active ingredients while seedling beds were treated. Seedbeds were immediately covered with a layer of soil after the extract was sprayed to reduce rapid evaporation of extracts from the bed.

On the other hand, a well-prepared 5 kg of wood ash was weighed and spread uniformly to the seedling beds. Eventually, the

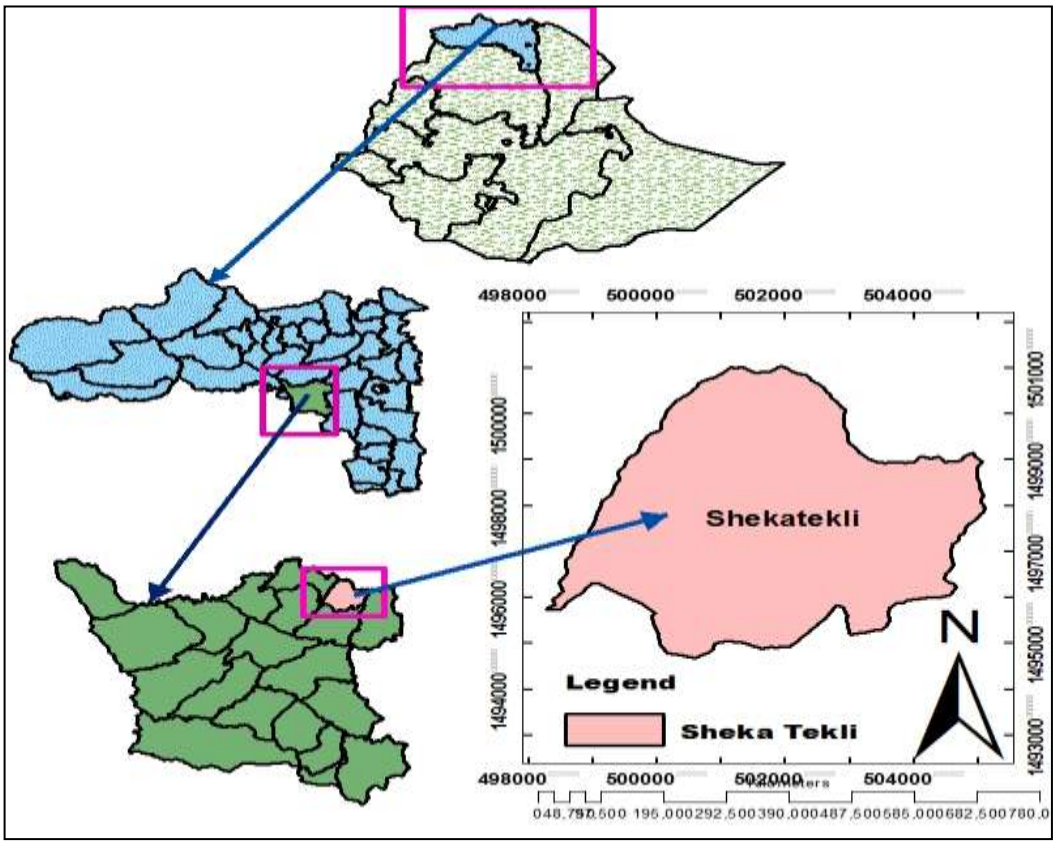

Figure 1. Geographic map of the study site location (Sheka Tekli kebele).

ashes were properly mixed with the soil ahead of sowing the seeds of hot pepper. Unlike the botanicals, the ash was spread a day ahead of sowing the seeds of the vegetable crop.

Data collection and analysis

The seedling beds were regularly monitored every seven days until seedlings were ready for transplanting. Basic data such as the number of seedlings at 75% seedling emergence, number of seedlings at 16 days after seedling emergence, seedling survival rate at 16 days after seedling emergence, number of seedlings at transplanting and number of damaged seedlings at transplanting were collected and subjected to statistical software for analysis. SAS Statistical Software Package (SAS, 2001) was employed both for analysis of variance and for determination of mean separation among differently treated seedling beds. The prevention and infestation rate (percentage) of management practices were determined based on the following formula:

$$\text{PR}\ (\%) = \frac{\text{DS UTSB} - \text{DS TSB}}{\text{DS UTSB}} \times 100$$

$$\text{IR}\ (\%) = \frac{\text{DS TSB}}{\text{DS UTSB}} \times 100$$

Where, PR (%) = stands for prevention rate; DS UTSB= number of damaged seedlings on untreated seedling beds; DSTSB= Number of damaged seedlings on treated seedling beds, IR (%) = stands for infestation rate respectively.

Cost-benefit analysis

The partial budget analysis was manipulated to assess the economic feasibility of new management options of termite to be imposed on the agricultural business. It was implemented to organize data and generate information about the cost incurred and the benefits gained from various agricultural options. The marginal rate of return was used to measure the effect of investing additional capital on net returns of the newly implemented management options compared with the existed practices. It provides the value of the benefit obtained from the additional cost being incurred. The partial budget analysis was done based on the additional cost incurred to the variable and fixed costs to each of the management practices. Nevertheless, it was considered that the total costs incurred for land rent were equal to both management practices. Therefore, the impact on the additional rate of return remains constant among management options. The price of the input (cost of chemicals, botanicals, ash and the labour cost) and the products (seedling price) were determined based on the seasonal market prices at the local market. Finally, the marginal rate of return (MRR) was determined as suggested (Kelly et al., 2005) as below:

$$\text{MRR} = \frac{DNI}{DIC}$$

Where, MRR = Marginal rate of return, DNI = Difference in net

Table 1. Expected number of pepper seedlings and actual number of seedlings at 16 days after emergence.

Treatments	Parameter			
	ESE ha^{-1}	ASE ha^{-1}	SSC 16 DAE ha^{-1}	SSR 16 DAE
Neem leaf extract	2,010,000	1996600^{b}	1497450^{b}	0.75^{b}
Dursban	2,010,000	1997892^{ab}	1658250^{a}	0.83^{a}
Wood ash	2,010,000	1996419^{c}	1477350^{c}	0.74^{c}
Control	2,010,000	1998176^{a}	1358760^{d}	0.68^{d}
LSD(0.05)	ns	57.7	57.7	5.77
CV (%)	5	4.2	4.2	4.2

*Treatment means where different letter stands for statistical difference among treatments using Fisher least significant difference at α = 0.05; ESE Ha-1 = Expected number of seedling emergence per hectare; ASE Ha-1 = Actual number of seedlings per hectare; SSC 16 DAE Ha-1 = seedling stand to count at 16 days after emergence per hectare.

income compared with control (untreated plots) and DIC = Difference in input cost compared with control (untreated plots).

RESULTS AND DISCUSSION

Expected and actual number of seedling at 16 days after emergence

The germination and emergence status of seedlings were relatively good while seeds were sown until few weeks after emergence. Two weeks later (16 days after emergence), a number of seedlings in some beds showed wilting symptoms due to termites and eventually some of them died due to severe infestation by termites. Despite this, there was a relative difference in the level of infestation among management practices; both termite and the damaged seedlings were observed in all beds treated with dursban, neem leaf extract, and wood ash. However, the infestation prevailed in those beds treated with wood ash and the untreated checks. Based on the result of the experiment indicated in Table 1, a statistically significant difference was observed among seedling beds treated with neem leaf extract, dursban (48%), wood ash and the untreated beds for the number of seedlings at emergence. Initially, a relatively highest number of seedlings emerged on beds treated with dursban (1997892 seedlings ha^{-1}) and on the untreated beds (1998176 seedlings ha^{-1}). In the contrary, lower number of seedlings was recorded on beds treated with wood ash and neem leaf extract (Table 1). The analysis of variance result indicated that all pepper seedling beds treated with dursban, neem leaf and wood ash had a significant number of seedling at emergence compared to the untreated nursery beds. The highest number of the seedling counts at 16 days after sowing were recorded on nursery beds treated with dursban (1658250 seedling ha^{-1}) followed by beds treated with neem leaf extract (1497450 seedling ha^{-1}). Conversely, the lowest numbers of seedlings per hectare (1358760 seedlings ha^{-1}) were recorded on untreated nursery beds (control). The current result confirmed that dursban is also highly effective in the management of termites on hot pepper seedling beds beside its effectiveness on the management of wood destroying termites (Roll, 2007). Several other authors also stated that botanicals like *Calotropis procera*, *Ipomoea fistulosa*, *Maesa lanceolata*, *Croton macrostachyus*, *Tegetes minuta*, *Datura stramonium* and *Azadirachta indica* were reportedly used for the management of termites throughout the world (Derbalah et al., 2012; Singha et al., 2013; Upadhyay, 2013).

Number of healthy and damaged seedling during transplanting

Statistically, a significant difference was observed among seedling beds treated with dursban (48%), neem leaf extract, wood ash and the untreated beds (termite-infested beds). Likewise, the highest number of seedlings count at transplanting were recorded at seedling beds treated with Dursban (1505490 seedling ha^{-1}) followed by neem leaf extract (1487400 seedling ha^{-1}) while the lowest number of seedling stands were recorded on untreated beds (1181880 seedling ha^{-1}). The lowest numbers of seedlings having termite damage symptoms were recorded on beds treated with dursban (504510 seedling ha^{-1}) than those beds treated with wood ash (709530 seedling ha^{-1}) and the untreated seedling beds (829125 seedling ha^{-1}) respectively (Table 2). In contrast, the highest rates of seedling death during transplanting seedling were recorded on untreated beds (control). The independent uses of wood ash on pepper seedling beds remain ineffective compared to the treatment of seedling beds with dursban and neem leaf extract as management option of sub-terrain termites. Hence, the result is in line with the finding of Abdurahaman (1990) who also stated that the use of some cultural control methods such as mound distraction, removal of the queen, flooding water into the mound, use of wood ash and hot pepper

Table 2. Average number of healthy and damaged seedlings during transplanting.

Treatments	Parameter	
	Number of healthy seedlings at transplanting (45 DAE)	Number of damaged seedlings at transplanting (seedling ha^{-1})
Neem leaf extract	1487400^{ab}	623100^{ab}
Dursban48%EC	1505490^{a}	504510^{a}
Wood ash	1300470^{c}	709530^{c}
Control	1181880^{d}	829125^{d}
LSD(0.05)	61.8	61.8
CV (%)	5.11	9.28

*Treatment means where different letter stands for statistical difference among treatment means using Fisher's least significant difference at α = 0.05 probability level; DAE= stands for days after emergence.

Table 3. Prevention and infestation rate of termite on pepper seedlings expressed in percent.

Treatments	Parameter	
	Prevention rate (%)	Infestation rate (%)
Neem leaf extract	25	75
Dursban48%EC	39	61
Wood ash	14	85
Control	0	100

independently, are not effective. However, Sisay et al. (2008) stated that the use of leaf powders of *A. indica* was effective in the management of termite on the hot pepper.

Prevention and infestation rate of termite on hot pepper

There was a difference in prevention and infestation rates of termite among differently treated seedling beds. Chemical spray with dursban was effective in the management of termite followed by seedling bed treatment with neem leaf extract. It had been observed that chemical treatment of seedling beds with dursban was relatively effective at preventing early deaths of pepper seedlings (39%) by termite compared to wood ash and the untreated seedling beds. Besides, the lowest rate of termite infestation was observed on beds that were treated with dursban 48% (61%) and Neem leaf extracts (75%). The treatment of seedling beds with neem leaf extract was reduced the expected seedling damage due to termite by 25%. Conversely, the lowest prevention and the higher rate of termite infestation were recorded on beds treated with wood ash and untreated beds (Table 3).

The trend of the graph also entailed that the prevention rate of termite management methods differed among neem leaf extract, dursban (48%) and wood ash with reference to the untreated beds (control). Though dursban and neem leaf extract were not the same at prevention of termite, the graph had shown an increasing trend of protection from seedling bed treatment with neem leaf extract to dursban (48%). Relatively, there was a decreasing trend in preventing rates of termite with independent use of wood Ash. Unlike neem leaf extract and dursban, the infestation rate of termite increased with the use of wood ashes and infested checks (Figure 2).

Cost-benefit analysis of management practices

The cost-benefit analysis result provides the necessary information about the economic feasibility of management practices and to reach possible recommendations. It was noticed that any management options with net benefits less than or equal to those options with lower cost were considered to be inferior (dominated). Accordingly, the highest net benefit was gained on management options with additional expenditures of 450 Birr. However, the expenditure that appeared to be more attractive was determined based on the result of the marginal rate of return. Thus, the maximum net benefit of 74020 Ethiopian Birr with the average marginal rate of return (42.64 Birr) was generated from application of neem leaf extract compared to the use of chemical spray with dursban (35 Birr). That means for every one Birr additional investment on using neem leaf extract for management of termite will result in 42.64 and 74020 Birr of return and net benefits

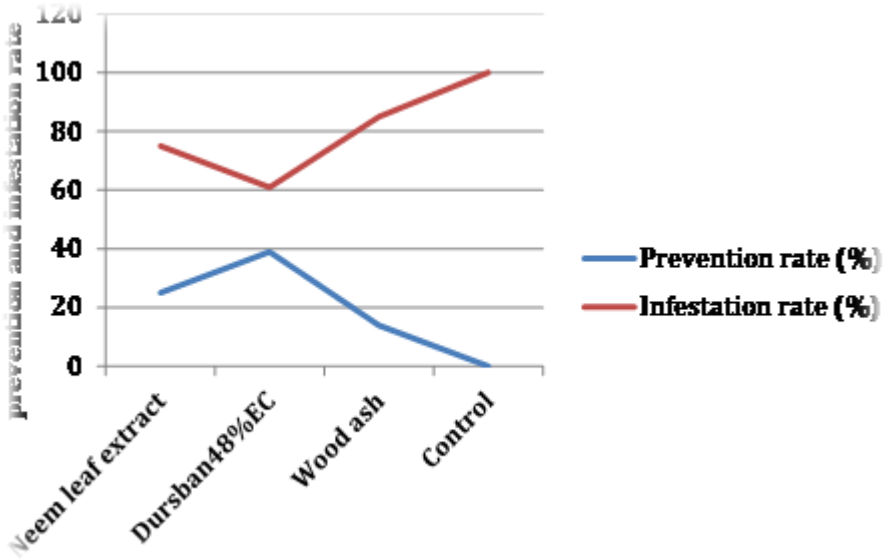

Figure 2. The graphical illustration of the effect of botanical, chemical and cultural management practices on termite infestation and prevention rate.

Table 4. Costs benefit analysis of applying Neem leaf extract, Durban and Wood ash treatments on the management of termites.

Treatments	Cost-benefit data				
	Seedling ha^{-1}	Price per seedling (cents)	MVP (E Birr)	TVC cost (Birr ha^{-1})	
Neem leaf extract	1487400	5	74370	350	
Dursban48%EC	1505490	5	75274.5	450	
Wood ash	1300470	5	65023.5	500	
Control	1181880	5	59094	0	
	MC (Birr ha^{-1})	NB (Birr ha^{-1})	MB (Birr ha^{-1})	MRR (%)	Dominated
Neem leaf extract	350	74020	14926	4264	No
Dursban48%EC	450	74824.5	15730.5	3500	No
Wood ash	500	64523.5	5429.5	1086	Yes
Control	0	59094	0	0	

MC = marginal cost in Ethiopian birr; **MB =** Marginal benefit in Ethiopian birr; **MRR =** marginal rate of return. **MVP =** marginal value product in Ethiopian birr; **TVC =** total variable cost in Ethiopian Birr.

gain, respectively. This implied that the use of neem leaf extract to manage termite was economically feasible compared to additional investment in chemical spray using dursban. For every one-birr investment in application of Dursban, there was 35 Birr rate of return plus 15730.5 Birr net benefit (Table 4). In general, the higher net benefit was gained through application of neem leaf extract with minimum input difference. This indicated that farmers would be profitable if they apply Neem leaf extract as management options of termite on seedling beds of hot pepper throughout Tanqua Abergelle district and in other locations where termite is a serious constraint in production pepper.

CONCLUSION AND RECOMMENDATION

The result of the experiment indicated that dursban was effective in the management of termite in seedling beds of hot pepper followed by the use neem leaf extract compared to the treatment of beds with wood ash. The highest number healthy seedlings at 16 days after emergence and during transplanting were recorded in seedling beds treated with dursban followed by neem leaf extract treatment. Furthermore, the highest rate of prevention and the lower rate of termite infestation were also seen at beds treated with dursban with the exception of neem leaf extract. In contrast, the highest rate of return

was generated with application of neem leaf extract followed by spraying of dursban. Therefore, the applications of neem leaf extract and dursban on seedlings beds of hot pepper are economically feasible, effective and advisable to farmers of Sheka Tekli and other locations with similar conditions to manage termite and maximize production of hot pepper.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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