Effect of Integration of Cultural, Botanical, and Chemical Methods of Mound Treatment on Termites (*Macrotermes subhyalinus* Rambur) Colonies in Ghimbi District of Western Ethiopia

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Abstract: A field experiment was conducted from November 2011 to June 2013 to evaluate the effects of botanical, cultural, and chemical methods on termite colony survival, crop and wooden damage, and other biological activities in Ghimbi district of western Ethiopia. The termite mounds were dug and the following treatments were applied. The treatments included queen removal + 250 g/mound of *Masea lanceolata* leaf powder, queen removal + 250 g/mound of *M. Lanceolata* leaf powder + chlorpyrifos 6 ml/mould, queen removal + chlorpyrifos 6 ml/mould, chlorpyrifos 12 ml/mould (recommended)/, queen removal alone and untreated check in 6×6 Latin Square Design. Data were collected on nest construction, foraging termites, crops and wooden damage within the radius of 50m from the treated mound. Queen removal + *M. Lanceolata* leaf powder + chlorpyrifos 6 ml/mould, queen removal + chlorpyrifos 6 ml/mould, and chlorpyrifos 12 ml/mould resulted in colony destruction, and reduced damage to crops and wooden materials significantly overall other treatments but no significant difference was observed amongst them. Queen removal as a component of integrated management is effective and eco-friendly. Therefore, it could be concluded that mound destruction using queen removal and lower rate of chemicals may be used for the management of termites. In areas where multiple species were involved in causing damage, it could be one of the major components of integrated termite management. The rate of the chemical to be used after queen removal could also be further studied and reduced to make it more environmentally friendly and economically affordable.

Keywords: chlorpyrifos; *Macrotermes subhyalinus; Masea lanceolata;* termite queen removal

1. Introduction

A great many species of termites build nests or mounds. These mounds or termitaria are constructed from chewed wood pulp to giant earth cement mounds that may be up to 3.6 m in diameter at the base and 6.1m high (Klots and Klots, 1959). Large mounds generally indicate large colonies that require a large amount of food materials. In cooler regions, no mounds are built and the termites remain underground. In sandy regions mound may again be built underground and may be smaller in drier areas to reduce water loss (Pearce, 1997).

Termites are very serious pests in several parts of Ethiopia, particularly in the western parts of the country. About 61 species of termites belonging to 25 genera and four families have been recorded in the country (Assefa, 1990; BARC, 1998). They cause considerable damage on agricultural crops, rangelands, forestry seedlings, and wooden structures such as rural houses, stores, fences and bridges crossing streams. Abraham (1998) reported 45, 50, and 18 % field losses of cereal crops due to termites at Bako, Didessa, and Asossa, respectively.

Abdurahman (1995) recorded 12 species of termites belonging to 9 genera in western Ethiopia. These include *Macrotermes subhyalinus* (Rambur), *Pseudacanthotermes militaris* (Hagen) pan African; *Astratotermes* sp. nr. *pacatus* (Silvestri) West African; *Microtermes* sp.nr. *Vadschagga*e (Sjostedt), *Adaiphrotermes* sp. nr. *scapheutes* Sands, *Alysocotermes trestus* Sands and *Ateuchotermes rastratus* Sands in East African; But *Microtermes aethiopicus* (Sjostedt) and *Firmitermes abyssinicus* (Sjostedt) are endemic to Ethiopia (Sands, 1976). Macrotermes species build large epigeal nests (known as mounds) from which they forage outwards for distances of up to 50 m in galleries (runways) either just below or on the soil surface (Darlington, 1982). *M. subhyalinus* is the dominant species in Western Ethiopia at altitudes below 2000 m. It builds short dome shaped mounds (Abdurahman, 1990).

According to the studies conducted in western Ethiopia, thatched roof huts are destroyed in less than five years and corrugated iron roof houses in less than eight years. Many of the wooden structures in the western parts of the country require maintenance every year. As a result, trees are cut frequently to replace the structures destroyed by termites. This would in turn lead to deforestation, erosion and environmental degradation. Termite, therefore, have been regarded as serious pests of agricultural crops, forest trees and building in west wellega than in other parts of the country (Abduraman, 1990; Abraham Tadesse, 2008). They contribute to severe soil degradation by reducing vegetation cover and leaving the soil surface barren and exposing it to the elements of erosion (Emana and Gure, 1997).

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ISSN 1992-0407

The termite control methods practiced in Ethiopia include mound treatment using aldrin 40% WP or heptachlor 40% WP, queen removal, mound flooding and to some extent use of botanicals. To cite a few of the termite control practiced in the last two decades in western Ethiopia, Diazinon 60% EC at 2 l/ha and Chlorpyriphos (pyrinex) 48% EC at 2.5 l/ha applied as soil treatments at the vegetative and flowering stages of hot pepper reduced termite damage and increased pod yield. Applications of chlorpyrifos at vegetative stage and diazinon during transplanting were found to be effective (BARC, 2004).

Similarly studies on the effects of mulching with maize stover at 26 kg/17m^2, haricot bean residues, grass and tef straw each at 15kg/17m^2 compared with diazinon 60% EC and untreated check indicated that the maize stover, haricot bean residue and grass mulches were as effective as the synthetic insecticide, and gave higher yields and lower rates of termite damage (BARC, 2004). The effects of 12 different botanicals were also compared with diazinon and untreated check in 2001 and 2003 seasons at Bako Research Center. *Maesa lanceolata* and *A. indica* leaves were found effective (BARC, 2003). The study also indicated that termites on hot pepper can be controlled by diazinon 60% EC at 2 l/ha and chlorpyrifos (pyrinex 48% EC) at 2.5 l/ha applied as soil treatments at the vegetative and flowering stages. Mulching with maize stover, haricot bean residues and grass also helped to minimize termite damage.

Over 90% of the termite damage in agriculture, forestry, and urban settings is attributed to members of the Macrotermitinae (Pomeroy *et al.,* 1991; Mitchell, 2002), which build large mounds (termitaria) that form spectacular features of the African landscape (Glover, 1967; Malaisse, 1978).

Several traditional methods of termite management were undertaken in the tropics and subtropics where termites have been a constant threat to crops, buildings, trees and any other materials made of wood. The major traditional management practices used by smallholder farmers in western Ethiopia include flooding mounds, digging mound and removal of the queens, excavating the top parts of the mounds and burning straw to suffocate and kill the colony, placing the harvest of different crops on wooden beds raised a few centimetres above ground, mound poisoning, and seed treatment. Mound poisoning is the most widely used method of termite management in western Ethiopia (Abdurahman, 1995; Gauchan *et al.,* 1998).

Resistant plant species and varieties, combined with appropriate cultural methods and, perhaps minimal use of modern pesticides in an integrated approach, would offer the greatest potential for a long term solution. The lack of critical scientific evaluation of non chemical control methods calls for further research (James *et al.,* 1990). According to Sileshi*et al.* (2009) management of termites in the future should be built on farmers' indigenous knowledge and adequate understanding of the ecology of the local termite.

But none of the termite management used so far in western Ethiopia attempted to integrate the different techniques in such a way that the termite pest species could be managed and the environmental consequences of using the chemicals could be reduced. Based on this justification, a field study was conducted with the prime objective of evaluating the effects of cultural (queen removal), botanical (*Masea lanceolata)*, lower rate of insecticide (chlorpyrifos 48 % E.C.) and their combination on termite colony survival and their biological activities.

2. Materials and Methods

A field experiment was conducted starting from November 2011 to June 2013 in Ghimbi district of western Ethiopia to evaluate the effects of the following treatments on termite colony survival. The indicators were mound reconstruction, foraging termites, damaging crops and wooden materials. The experiment was laid out in 6×6 Latin Square Design as there was variation among the peasant associations (PA) and within peasant association with regard to soil types, vegetation and moisture that are critical for termite survival. The treatments include:

1. Queen removal + 250 g/mound of *Masea lanceolata* leaf powder, (QR & Ml)
2. Queen removal + 250 g/mound of *M. lanceolata* leaf powder + half the rate of chlorpyrifos 48 % E.C. (12.5 ml/mound) (QR & Ml& half the rate of chlorprifos 48% E.C.)
3. Queen removal + half the rate (12.5 ml) of chlorpyrifos 48 % E. C. (QR & half the rate of chlorpyrifos 48 % E. C.
4. Recommended rate of chlorpyrifos 48 % E.C. (25 ml per mound) (Recommended chlorpyrifos 48 % E.C.)
5. Queen removal alone (QR alone) and
6. Untreated check. (untreated check)

Leaves of *M. Lanceolata* were collected from actively growing trees present in the PAs. It was dried under shade and grounded to make the powder. The botanical (250 g) was used alone and in combination with other treatments. The treatments were applied at 36 different sites in six PAs. Six farmers' gardens of different land uses were randomly selected from each PA for the application of the treatments. Water and chemical, or water and botanical or water and both chemical and botanical were added in a 15 L knapsack sprayer for addition into the opened mound. The PAs considered were Cuta Sodu, Lalisa Yesus, Cuta Goci, Ghimbi (kebele 05), Waligala Daloo and Melka Gasi. The different land uses were forest area, crop field, residence area, fallow land, *Eucalyptu*s and Cupressus plantations. The termite mounds present in the farmers' garden were dug and the reproductives (queens, kings and supplementary reproductives) were removed and stored in ethyl alcohol. Thereafter, the treatments were added to the opened mound. Only one treatment was applied to all the mounds present in a farmer's garden (usually 1-3). But the reproductives were not removed from the farmers' garden that received recommended rate of chlorpyrifos 48 % E. C. (25 ml per mound) and that was considered as a check. The mounds of the farmer's garden that was considered as a check were counted and marked. Incentive (money) was given for the farmer in order to make him/her keep the live mounds until the end of the experiment. Any small growing nest, apart from the big visible nest was also searched carefully and destroyed following foraging galleries before the application of the treatments.

Data on the presence of construction of the nest, fungal germination from the treated nest, damaged crops, damaged wooden structure, presence of natural enemies (such as ants (Formicidae), birds, echidnas) and presence of foraging termites 50 m away from the nest were collected starting from one month after application of treatments and continued at three months intervals until the end of the experiment. The collected data were on fungal germination (black fungus mycelia like structure emerges from mound from which termite colony is destroyed), construction of nest, foraging termites, damaged crops and wooden structures. The collection of data was along a 50 m transect. The collected data was analyzed using NCSS software for analysis of variance.

3. Results and Discussion

The presence of fungal germination was statistically significant among the treatment means as summarized in Table 1. Queen removal + *M. Lanceolata* leaf powder + half the rate of chlorpyrifos 48 % E.C. (12.5 ml/mound), queen removal + half the rate of chlorpyrifos 48 % E. C., and recommended rate of chlorpyrifos 48 % E. C. (25 ml per mound) differed significantly from all others but no significant difference was observed amongst them. On the rest of the treatments no fungal germination was observed. This means neither queen removal alone nor its combination with the botanicals differed significantly from the untreated check.

Table. 1. The effect of mound treatment on presence of fungal germination, construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities a month after application of treatments (January 2012: mean± se).

Treatments	Fungal germination	Nest Construction	Damaged crops	Damaged wooden material	Foraging termites	Presence of natural enemies
QR & ML	0.2±0.2a	1.0± 0.1a	0.5± 0.2a	1.0 ± 0.2a	0.6 ± 0.2a	0.3± 0.2a
QR & ML & half dose Chlorprifos 48% E.C.	0.8± 0.2b*	0.3± 0.1b*	0.3± 0.2a	0.5± 0.2a	0.6± 0.2a	0.2±0.2a
QR & half dose of chlorpyrifos 48 % EC	0.7± 0.2b*	0.2± 0.1b*	0.3± 0.2a	0.8± 0.2a	0.8±0.2a	0.2± 0.2a
Recommended chlorpyrifos 48 % EC	0.8± 0.2b*	0.2± 0.1b*	0.2± 0.2a	0.3 ± 0.2a	0.5± 0.2a	0.1± 0.2a
(QR alone)	0.2± 0.2a	1.0± 0.1a	0.3± 0.2a	1.0± 0.2a	0.6± 0.2a	0.3± 0.2a
Untreated	0.2± 0.2a	1.0± 0.1a	0.5± 0.2a	0.8± 0.2a	0.8± 0.2a	0.2± 0.2a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's; studentized range test (HSD).

Queen removal + *M. Lanceolata* leaf powder + half the rate of chlorpyrifos 48 % E. C. (12.5 ml/mound), queen removal + half the rate of chlorpyrifos 48 % E. C., and recommended rate of chlorpyrifos 48 % E. C. (25 ml per mound) differed significantly from the other three treatments with regard to construction of the nest which was similar to fungal germination parameter over the period of study as presented in Tables 1 - 7. But there was no significant difference among the three treatments. Besides, the rest of the treatments were at par with untreated mound as shown in Table 1.

The effect of the different mound treatments on termite colony destruction and consequent impact on crop damage is presented in Tables 1 - 7. All the treatments that significantly differed from the untreated ones in the colony destruction also significantly reduced damage to crops and wooden materials three months after application of treatments (Table 2).

Table 2. The effect of mound treatment on presence of construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities three months after application of treatments (March 2012: Mean ± se).

Treatments	Construction of the nest	Damaged crops	Damaged wooden material
QR & ML	1.0 ± 0.2a	0.9 ± 0.1a	0.9 ± 0.1a
QR & ML & half dose chlorpyrifos 48% E.C.	0.3 ± 0.2b*	0.3 ± 0.1b*	0.4 ± 0.1b*
QR & half dose of chlorpyrifos 48 % EC	0.3 ± 0.2b*	0.2 ± 0.1b*	0.3 ± 0.1b*
Recommended chlorpyrifos 48 % EC	0.2 ± 0.1b*	0.5 ± 0.1b*	0.5 ± 0.1b*
(QR alone)	1.0 ± 0.2a	0.7 ± 0.1a	0.7 ± 0.1a
Untreated	1.0 ± 0.2a	0.9 ± 0.1a	0.9 ± 0.1a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's studentized range test (HSD).

The combination of queen removal and lower rate of chlorpyrifos 48 % E. C., the combination of the botanical, queen removal and the lower rate of chlorpyrifos 48 % E. C. as well as the recommended rate of chlorpyrifos 48 % E. C. resulted in colony destruction and reduced damage to crops and wooden material in the transect during the study period. Queen removal alone or in combination with botanicals did not differ significantly from the untreated check both in its impact on the termite colonies and the damage to crops and wooden materials.

Table 3. The effect of mound treatment on presence of construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities six months after application of treatments (June 2012: Mean ± se).

Treatments	Construction of the nest	Damaged crops	Damaged wooden material
QR & ML	1.0 ± 0.2a	0.9 ± 0.1a	0.9 ± 0.1a
QR & ML & half dose chlorpyrifos 48% E.C.	0.3 ± 0.2b*	0.4 ± 0.1b*	0.4 ± 0.1b*
QR & half dose of chlorpyrifos 48 % EC	0.3 ± 0.2b*	0.3 ± 0.1b*	0.3 ± 0.1b*
Recommended chlorpyrifos 48 % EC	0.2 ± 0.2b*	0.3 ± 0.1b*	0.4 ± 0.1b*
QR alone	1.0 ± 0.2a	0.7 ± 0.1a	0.8 ± 0.1a
Untreated	1.0 ± 0.2a	0.9 ± 0.1a	0.9 ± 0.1a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's studentized range test (HSD).

The reduction in damage was higher during the dry season than with rainy season (Table 4). The reduction in damage nine months after application of treatments was not significantly different among all the treatment means and the untreated check. The damage done to crops and wooden materials during the wet season (June, July and August) was at its minimum and as a result, the treated and untreated did not significantly differ. But the damage caused to crops and wooden materials by *M. subhyalinus* increased and significantly differed among the treatments twelve months after application of treatments (which was the beginning of the dry season).

Table 4. The effect of mound treatment on presence of construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities nine months after application of treatments (September 2012: Mean± se).

Treatments	Construction of the nest	Damaged crops	Damaged wooden material
QR & ML	1.0 ± 0.1a	0.9 ± 0.2a	0.7 ± 0.1a
QR & ML & half dose chlorpyrifos 48% E.C.	0.3 ± 0.1b*	0.7 ± 0.2a	0.7 ± 0.1a
QR & half dose of chlorpyrifos 48 % EC	0.2 ± 0.1b*	0.7 ± 0.2a	0.7 ± 0.1a
Recommended chlorpyrifos 48 % EC	0.2 ± 0.1b*	0.7 ± 0.2a	0.7 ± 0.1a
QR alone	1.0 ± 0.1a	0.8 ± 0.2a	0.8 ± 0.1a
Untreated	1.0 ± 0.1a	0.9 ± 0.2a	0.9 ± 0.1a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's studentized range test (HSD).

Table 5. The effect of mound treatment on presence of construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities twelve months after application of treatments (December 2012: Mean ± se).

Treatments	Construction of the nest	Damaged crops	Damaged wooden material
QR & ML	1.0 ± 0.1a	0.8 ± 0.1a	0.9 ± 0.1a
QR & ML & half dose chlorpyrifos 48% E.C.	0.3 ± 0.1b*	0.4 ± 0.1b*	0.5 ± 0.1b*
QR & half dose of chlorpyrifos 48 % EC	0.5 ± 0.1b*	0.4 ± 0.1b*	0.4 ± 0.1b*
Recommended chlorpyrifos 48 % EC	0.0 ± 0.1b*	0.4 ± 0.1b*	0.3 ± 0.1b*
QR alone	1.0 ± 0.1a	0.7 ± 0.1a	0.8 ± 0.1a
Untreated	1.0 ± 0.1a	0.9 ± 0.1a	0.9 ± 0.1a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's studentized range test (HSD).

All the treatments that had combination of lower rate of chlorpyrifos 48 % E. C. and recommended rate significantly reduced damage to crops and wooden materials from twelve months to eighteen months after application of the treatment (Tables 5 - 7). Queen removal alone or its combination with the botanical was at par with the untreated check throughout the study period in reducing damage to crops and wooden materials.

Table 6. The effect of mound treatment on presence of construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities 15 months after application of treatments (March 2013: Mean ± se).

Treatments	Construction of the nest	Damaged crops	Damaged wooden material
QR & ML	1.0 ± 0.1a	0.8 ± 0.1a	0.9 ± 0.1a
QR & ML & half dose chlorpyrifos 48% E.C.	0.3 ± 0.1b*	0.5 ± 0.1b*	0.6 ± 0.1b*
QR & half dose of chlorpyrifos 48 % EC	0.3 ± 0.1b*	0.5 ± 0.1b*	0.4 ± 0.1b*
Recommended chlorpyrifos 48 % EC	0.0 ± 0.2b*	0.5 ± 0.1b*	0.6 ± 0.1b*
QR alone	1.0 ± 0.1a	0.7 ± 0.1a	0.8 ± 0.1a
Untreated	1.0 ± 0.1a	0.9 ± 0.1a	0.9 ± 0.1a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's studentized range test (HSD).

Table 7.The effect of mound treatment on presence of construction of the nest, wooden and crop damage, foraging termites and natural enemies' activities 18 months after application of treatments (June 2013: Mean ± se).

Treatments	Construction of the nest	Damaged crops	Damaged wooden material
QR & ML	1.0 ± 0.1a	0.8 ± 0.1a	0.8 ± 0.1a
QR & ML & half dose chlorpyrifos 48% E.C.	0.3 ± 0.1b*	0.4 ± 0.1b*	0.5 ± 0.1b*
QR & half dose of chlorpyrifos 48 % EC	0.2 ± 0.1b*	0.5 ± 0.1b*	0.5 ± 0.1b*
Recommended chlorpyrifos 48 % EC	0.1 ± 0.1b*	0.3 ± 0.1b*	0.4 ± 0.1b*
QR alone	1.0 ± 0.1a	0.7 ± 0.1a	0.7 ± 0.1a
Untreated	1.0 ± 0.1a	0.9 ± 0.1a	0.9 ± 0.1a

Means with in a column followed by the same letter(s) is not significantly different at 5% using Tukey's studentized range test (HSD).

The current finding is, therefore, in agreement with the study of Schutterer (1969) who reported inefficiency of queen removal because of the ability of some termite species to develop substitute queens under favorable conditions. It is also in partial agreement with findings of Harris (1954) and Darlington (1985) who reported that occasionally several queens may be found in one colony either due to the replacement of the original queen or merging of two or more colonies.

The result was in accordance with the finding of Harris (1971) who recommended the destruction of mounds to protect crops and buildings. Schutterer (1969) also recommended destruction of termite colonies in areas where mound building termites are involved in losses of crops. However, the findings is in disagreement with Sands (1976) who reported that most of the termite species that cause crop damage in western Ethiopia are completely subterranean and the one species that build mound also exist as subterranean at its earlier stage of development. It is known that the subterranean species (*Microtermes* spp.) are largely involved in causing damage to crops and wooden materials more during the wet season and also *M. subhyalinus* exist as subterranean in its earlier stage. But most of the damage that occurred to crops and wooden material during the dry season was attributed to this mound building species according to these findings.

The study is also in partial agreement with Abdurahman (1990) who reported ineffectiveness of queen removal as termite management and also effectiveness of chlorpyrifos for mound treatment for termite colony destruction. He also reported while mound poisoning kills old colonies the young termite colonies can continue to cause crop losses to which the present findings partially agree. According to present findings though mound treatment targets the old colonies that actually houses would be millions of kings and queens after nuptial flight, it also aims to reduce termite population, as insect pests in general are the function of their population. Mound treatment resulted in reduction in population of *M. subhyalinus* and consequently reduced crop and wooden materials damage three months after treatment. The young termite nests were also located using foraging tunnels and destroyed a month before the application of the treatments which contributed to the reduction in damage.

Macrotermes spp. build large epigeal nests (mounds) from which they forage outwards for distances of up to 50 m in galleries/ runways/ either just below or on the soil surface (Darlington, 1982). However, foraging termites and natural enemy activities on the foraging termites 50 m away from the treated nest was at par with the untreated check throughout the period of study (Tables 1- 7).

4. Conclusion

The findings of this study showed that queen removal and use of half the rate of chlorpyrifos 48 % E. C. resulted in *M. subhyalinus* colony destruction and consequent reduction in crops and wooden materials damage from their nest to their foraging limits. Destruction of small growing nests following forging tunnels also supplemented to the method. Therefore, it was concluded that mound destruction using queen removal and lower rate of chemicals could be used for the management of the species. In areas where multiple species were involved in causing damage, it could be one of the major components of integrated termite management. The rate of the chemical to be used after queen removal could also be further studied to reduce to the best minimum to make it more environmentally friendly and economically affordable.

5. Acknowledgements

The authors extend their thanks to Addis Ababa University and Haramaya University for the financial support and Dr. Abebe Getahun for facilitating the research work. Finally, the authors extend their thanks to Ghimbi District Agricultural Development Department staff for providing all the necessary materials and information, including field staff and motor bicycles.

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