Potential Use of Soil Organic Amendments for the Management of Up Country Live Wood Termite

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ABSTRACT

The Up country Live Wood Termite, *Postelectrotermes militaris* (UCLWT) makes entry through tea roots and feeds on the woody tissues of the roots, main stem and branches. Hence, its damage limits long-term sustainability and productivity of high grown tea. Further, the threat by UCLWT is significant as the spread is expanding hitherto high grown estates. User friendly chemical and/ or biological methods are not available for the control of UCLWT except extended grass rehabilitation of uprooted UCLWT affected tea extents for 4 - 5 years which is time and labor intensive. Hence, it warrants for an economically viable, environmentally friendly and practically feasible alternative method for the control of UCLWT.

The present study explored the termicidal properties of various soil amendments viz. Neem oil cake, Tea waste and Alocasia in the management of UCLWT at Gouravilla Estate, Upcot where the UCLWT damage is severe. The soil amendments were compared with Formalin treatment as a biocide and an untreated control.

The Neem oil cake + Tea waste and Alocasia at 200 g, 400 g and 2.6 kg per tea bush respectively incorporated to soil lowered UCLWT densities in soil six months after treatment. Alocasia and Neem oil cake + Tea waste applications also resulted in significantly ($F = 0.002$) increased soil microbial biomass as compared to untreated soil. Although not significant, the elevated micro arthropod and fungal communities in organic matter amended soils would have restricted UCLWT populations through predatory and/ or biological mechanisms. A negative correlation of 0.78 was exhibited with micro arthropod and UCLWT densities in soil. Importantly, these non-chemical soil treatments significantly ($F = 0.4464$) improved the crop of affected tea fields due to UCLWT.

The results revealed the potentials of incorporation of organic materials with termicidal properties in controlling both UCLWT and crop sustenance. The comparatively low cost

soil treatments resulted in long term financial benefits. The present approach will assure reduction of termite densities in the vicinity of tea, prevention of UCLWT access to tea roots through bio control mechanisms, compensation of crop loss and improvement of the vigor of tea bushes / tolerance to termite attack. Hence, this could be included in the Integrated Pest Management of UCLWT using Neem oil cake + Tea waste and Alocasia depending on the availability.

Key words: Extended rehabilitation, micro arthropods, soil amendments, termicidal properties, Up Country Live Wood Termite

INTRODUCTION

The overall productivity of tea depends on the interaction of plant populations with several environmental, physical, biological and managerial factors. Pests, diseases and weeds are the important biological components limiting the productivity in all tea growing regions. Amongst, Shot Hole Borer (*Xyleborus fornicatus*), Up country Live Wood Termite (*Postelectrotermes militaris*: UCLWT) and Low country Live Wood Termite (*Glyptotermes dilatatus* and *Neotermes greeni*: LCLWT) are considered the key insect pests in Sri Lanka.

At present, UCLWT and LCLWT cause unrecoverable and severe damages to tea grown in Maskeliya, Dickoya and Dimbula (Up country) and Rathnapura, Deniyaya and Galle (Low country) areas respectively (Vitarana, 2003). The areas and the extent of damage by the live wood termites are reported to be increasing and alarmingly attribute to unusual yield decline and loss of productivity of tea in Up and Low elevations.

The significance of the tea termites as a group of primary and injurious pests is apparent due to their severity of damage to the main stem of the bush but the entry into the bush differs with the species. UCLWT finds its way through the roots and moves up the main stem and branches forming a continuous gallery system while, LCLWT gains entry through exposed tea branches and the gallery system is discontinuous. Environmental factors such as rainfall, RH, temperature, soil organic matter status, moisture and predatory and biological control organisms however, govern the termite activity, distribution, population growth and behavior and thereby the pest potential on mature tea (Wood and Johnson, 1986; Vitarana and Mohotti, 2008).

Control of live wood termites of tea poses limitations as the termite colonies are well protected within the host plant (Pearce, 1997; Vitarana and Mohotti, 2008). Although, various non-chemical control methods *i.e.* use of tolerant cultivar selections, cultural and biological methods have been tested as environmentally friendly IPM measures, their

bioefficacy on termites is inadequate and not cost effective (Stoll, 1986; Vitarana and Mohotti, 2008). Various measures tested for early detection, trapping and control of termites etc. have also been identified as not user friendly (Vitarana, 2003).

Attempts have also been made in deploying fungal pathogens such as *Metarrhizium anisopliae* and *Beauveria bassiana* and entomopathogenic nematodes in the control of termites. However, their direct contact with termites and micro environmental conditions for survival pose constraints (Amarasinghe and Hominick, 1993). The soil inhabiting organisms such as micro arthropods, bacteria and fungi etc. are effective as regulating live wood termite species although not adequately researched (Pearce, 1997). The present UCLWT management mainly include deep forking, uprooting of tea bushes along with a concentric circle of neighboring bushes until two circles of unaffected bushes, *in situ* burning and extended period of grass rehabilitation of the land for 4 - 5 years. These are expensive, laborious, time consuming and hence practically ineffective and economically not feasible.

Various plant materials such as Tea waste, Neem, Caster, Calotropis, Wild sunflower and Alocasia *etc.* are reported to be termicidal (Stoll, 1986). Alocasia (*Alocasia alba*) showed termite repellent properties (http.//www.forums.gardenweb.com/forums/pest – 42k). Termicidal properties of Tea waste, Neem oil cake and Alocasia on UCLWT were proved under laboratory conditions (Mohotti *et al.*, unpublished data).

Importance of incorporation of various soil organic amendments has been well documented as pesticidal besides improving crop growth and tolerance against pests. In tea, organic soil amendments have been proved to suppress soil nematodes and pathogens through encouraging soil inhabited macro and micro organisms and building up of plant resistance (Mohotti *et al.*, 1999; Gnanapragasam and Mohotti, 2005). The influence of organic amendments in insect pest management however, has not been explored. In this connection, a new area in termite control as described by Stoll (1986), was identified as a researchable area. More emphasis on integrating methods considering the ecology and behavior of the termites and using safe and local biological, cultural and physical methods to alter the pest potential of the total termite colony is envisaged.

Hence, the objectives of the present exercise were to:

- evaluate the efficacy of incorporation of locally available organic materials with termicidal properties such as Alocasia, and Neem oil cake and Tea waste against UCLWT,
- study the natural control mechanism of UCLWT encouraged through incorporation of soil amendments and

- estimate the cost benefit analysis of the user friendly soil treatments.

MATERIALS AND METHODOLOGY

Location

Field No. 2B of Cruden Division of Gouravilla Estate, Upcot (elevation 1143 m amsl, extent 4 ha) with heavy damage by the UCLWT with about 15% plant vacancies was chosen for this study. The tea plants of the cultivar selection LD 999 were about 45 years and at the second year of the eleventh pruning cycle.

Field experimentation

The experimental plots covering a minimum of 100 tea plants were marked. They were subjected to three different soil treatments *viz.* FOR: 40% Formalin (6 ml/ bush: sprayed on soil), NOC+TW: Neem oil cake (200 g/ bush: incorporated into soil) and Tea waste (400 g/ bush: incorporated into soil) and ALO: Chopped leaves and rhizomes of Alocasia (2.6 kg/ bush: incorporated into soil) with an untreated control (CON). The treatments were arranged in a Randomized Complete Block Design (RCBD) with three replicates. To avoid contamination of different treatments, each plot was separated with drains and guard rows. General crop and soil management practices recommended by TRI were adopted in all experimental plots.

Assessment of termites

To assess the termite densities in soil, 'hand sorting technique' was used. Soil samples from the planting squares of three random locations from each plot were taken. The number of UCLWT was counted per kg of soil basis. The assessments were done 6 months after treatment application. Soils were also used to assess micro arthropod densities, fungal colonies and total soil biomass.

Damage assessment in tea roots by UCLWT was not done as it involves destructive sampling. Hence, the response to treatment applications was assessed indirectly using growth compensation and yield as a measure of altered pest potential of UCLWT.

Assessment of yield

In order to assess the impact of UCLWT damage in mature tea, yield records of Field No. 2B, Cruden Division and weather data of the estate for the period 1999-2003 were studied.

The fresh weight of green leaf in each experimental plot was recorded at weekly intervals for 33 weeks from soil treatment after commencement of the experiment.

Assessment of soil biological activity and micro-arthropods

Soil micro arthropods were extracted in water using a simple modification of Berlese apparatus at the Nematology Laboratory of the TRI. The numbers of insects, mites, collembolans and myriapods were recorded under a compound microscope.

The total soil biomass was measured using the method described by Anderson (1982).

The numbers of the resulting fungal colonies were recorded using the technique described by Grifftin (1972), preparing a dilution series of soil, incorporating into just molten agar and incubation at 25 ± 2 ^{0}C.

Cost benefit analysis

In view of assessing the long term impacts of incorporation of various soil organic amendments on UCLWT affected mature tea, the income generated with the yield increment achieved through treatments and the extra costs incurred due to soil treatments were calculated.

Data analysis

Data were analyzed by using Statistical Analyze System (SAS) soft ware package. Duncan's Multiple Range Test (DMRT) was followed for mean separations.

RESULTS AND DISCUSSION

The data on UCLWT population, micro arthropod density, fungal growth and biological activity in soils and the yield of tea in the treated plots are described below.

Termite populations in soil

All treatments lowered the UCLWT populations significantly compared to that of untreated plots (Figure 1). Amongst, Neem oil cake + Tea waste and Alocasia incorporation into soil proved termicidal properties. Interestingly, incorporation of Neem oil cake + Tea waste into UCLWT infested soils has given similar effects exhibited by the known biocide, Formalin treatment.

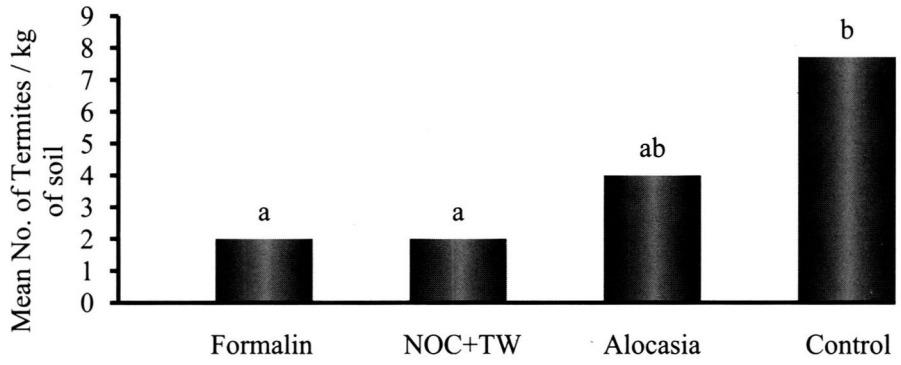

Figure 1. Mean population density of UCLWT in soils six months after treatment with various soil organic amendments
(Means of four replicates are given and the columns with same letter are not significantly different at p=0.05 level)

Direct contact of Formalin with absolute biocidal properties, would have reduced the UCLWT populations in soil resulting in the lowest termite density in soils. The combination of Neem oil cake and Tea waste too exhibited termicidal properties against UCLWT populations. The mortality of UCLWT corroborated with the preliminary *in vitro* experimentations with the same treatments (Mohotti *et al.*, unpublished data). Neem oil cake has antifeedent, insecticidal, metamorphosis and disruption properties while Tea waste with high polyphenolic compounds is known to have termicidal properties (Stoll, 1986).

Alocasia is being locally used in agricultural fields and buildings as a termite repellent. The results of the present study validated the termite repellent activity in Alocasia in managing UCLWT populations. However, the potentials are limited owing to availability of Alocasia in the high elevations. Further, due to its watery nature, the requirement is bulky. Hence, a feasible approach for harnessing Alocasia needs to be developed through biochemical extractions of various wild species of Alocasia.

Non target effects on soil organisms

Among the four different treatments, Alocasia showed the highest diversity of micro arthropod communities. The population densities of insects, collembolans, mites and myriapods changed with the type of soil amendment (Figure 2). During organic matter decomposition process, the important soil arthropod communities appeared to have activated and thus their numbers have increased significantly in tea soils. The increased micro arthropod densities showed a negative correlation with parasitic nematode

populations in soils which acted as natural enemies (Mohotti, 2002). This could also be possible during grass rehabilitation although not researched.

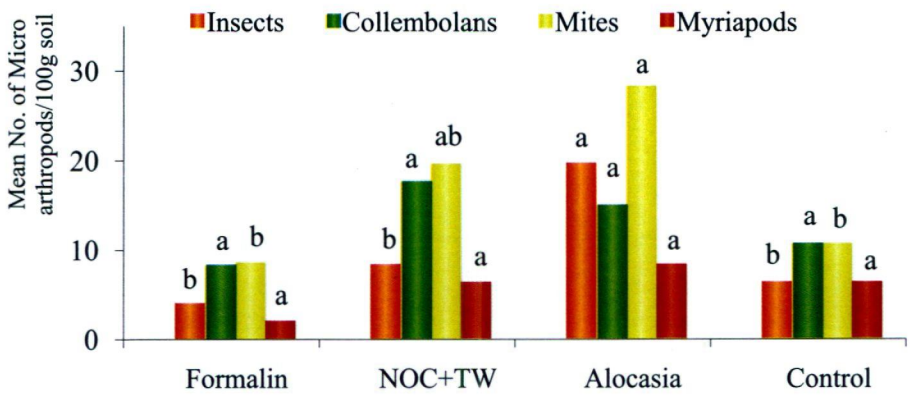

Figure 2. Micro arthropod communities in UCLWT infested soil six month after amendments with different organic materials

As shown in Table 1, the chemical treatment (Formalin) and untreated soil showed the lowest microarthropod densities compared to that of soils amended with organic materials (Neem oil cake + Tea waste and Alocasia). In contrast, lowered termite population densities were seen with soils treated with organic materials (Figure 1). Further, the analysis of results revealed an inverse correlation of 0.78 between micro arthropod densities and termite populations.

Table 1. Impact of incorporation of different organic amendments on non-target soil organisms in UCLWT infested soil after six months

Soil treatment	Soil microbial activity (mg CO_2 / 10 g soil / day)	Micro arthropod density (Number/100g soil)	Fungal growth (Million colonies / g soil)
Formalin	6.86 [b]	23.0 [b]	41.1 [a]
Neem oil cake + Tea waste	7.93 [a]	52.0 [ab]	56.9 [a]
Alocasia	8.48 [a]	71.0 [a]	56.4 [a]
Untreated	7.21 [b]	34.0 [b]	46.9 [a]

(Means with the same letter are not significantly different at p=0.05 level)

There were no significant differences in the fungal growth under different soil treatments. However, Neem oil cake + Tea waste and Alocasia treated soils showed higher fungal growth in comparison to both Formalin and untreated controls.

The soil microbial activity was significantly ($p = 0.002$) increased with incorporation of Alocasia and Neem oil cake + Tea waste as compared to untreated and formalin treated soils. Incorporation of organic matter irrespective of their pesticidal properties in Neem oil cake, Tea waste and Alocasia has facilitated the microbial biomass in tea soils. These results also corroborate findings of Mohotti *et al.* (1999). There was no significant difference among the microbial activity of tea soils amended with Neem oil cake + Tea waste and Alocasia. The highest microbial activity was reported from Alocasia as compared to Formalin treated and untreated soil.

Irrespective of the soil organic amendment incorporated, the densities of soil inhabiting organisms elevated would have certainly acted as limiting factors to UCLWT for space and other requirements. Resultantly, the pest populations of the UCLWT reaching tea roots for entry may have been lowered. As shown in Figure 1, in soil termite densities would have been minimized due to pesticidal properties of the organic amendments used.

Yield in termite infested tea field of the estate

Figure 3 presents the yield decline pattern of the Field No. 2B and the rainfall distribution in the estate during the period 1999 – 2003. Alarmingly, the average yield of the entire estate was also seen diminishing despite adopting of other good agronomic and cultural practices and rainfall distribution pattern. Amongst, the fields with severe UCLWT infestations inclusive of Field No. 2B of Cruden Division showed remarkably lower crop besides general crop and soil management practices in the estate.

The weekly plucking records of Field No. 2B of Cruden Division monitored for 33 weeks since application of soil treatments in order to study any growth compensation in tea plants in the UCLWT affected field are presented in Figure 4.

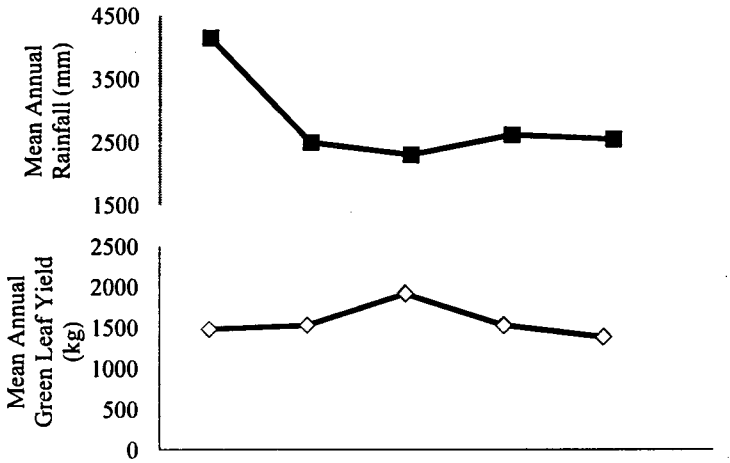

Figure 3. Green leaf yield of Field No. 2 B of Cruden Division and mean total rainfall of Gouravilla estate from 1999 to 2003

Alocasia and Neem oil cake + Tea waste treatments resulted in significantly (p= 0.4464) higher yields. While showing termicidal effects, such organic amendments have made recovery of damage in tea due to UCLWT even within the shorter exposure period for the soil treatments tested. Alocasia and Neem oil cake + Tea waste treatments were capable in increasing the yield by 57.66 and 42.30 kg made tea/ha/year respectively. As demonstrated by Mohotti *et al.* (1999), organic amendments induce plant vigor and tolerance against pests in tea. Overall results therefore, elucidated the evidence of altering the pest potential of UCLWT on tea through augmenting the ecology of native soil organisms and behavior of the termites as described by Stoll (1986). Crop sustenance due to soil treatments has also been proven.

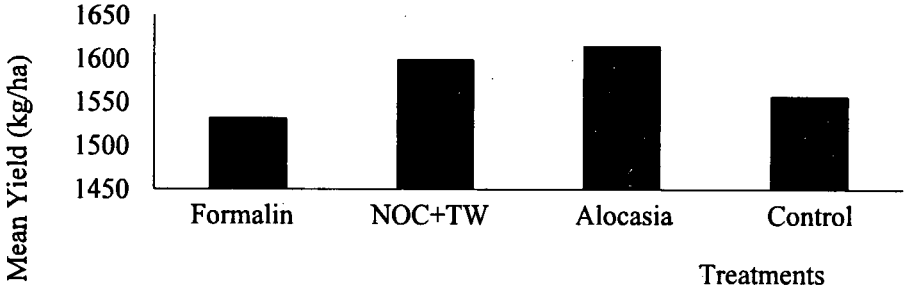

Figure 4. Response on yield of tea (kg/ha) in UCLWT infested tea field following different soil treatments

Hence, the organic matter incorporation in mature tea was proven not only as an agronomic practice but also in pest and disease management strategy with appreciable benefits. Therefore, selection of organic matter that contains pesticidal properties for use would undoubtedly contribute towards the sustainable pest and disease management in tea.

Economic analysis of soil treatments

In the present UCLWT management schedule, uprooting of affected tea bushes along with a concentric circle of neighboring unaffected bushes and burning are recommended. The vacant area needs to be rehabilitated with Mana grass for 4 - 5 years in view of eliminating UCLWT densities posing threat to tea. An average annual expenditure of Rs. 157,200 per hectare is envisaged for the adoption of this practice; the loss on uprooted tea bushes is additional.

In the present study, incorporation of feasible soil organic amendments with termicidal properties was compared with untreated control. The grass rehabilitation was not included owing to long treatment period. It was revealed according to the results of the present study, that Neem oil cake + Tea waste and Alocasia applications have recovered the tea fields through managing UCLWT populations as well as compensated the growth. The yields due to respective soil treatments have resulted in an income of Rs. 16,800 (2.7% increase

compared to untreated control) and Rs. 23,200 (3.7% increase compared to untreated control) respectively (Table 2). The additional expenditure incurred on Neem oil cake + Tea waste and Alocasia applications have been Rs. 177,000 and Rs. 50,000 inclusive of material, transport and application cost respectively. As extended grass rehabilitation was not included to the untreated control, cost component was not accountable in the analysis.

Table 2. Cost benefit analysis of the different soil organic amendments in managing UCLWT

Treatments	Income through yield (Rs.)	Additional expenditure (Rs.)	Income through yield compensation (Rs.)
Neem oil cake + Tea waste	639,200	177,000	16,800
Alocasia	645,600	50,000	23,200
Untreated control	622,400	Nil	Nil

Therefore, use of Neem oil cake, Tea waste and Alocasia has shown its economic befits in terms of damage compensation. Tea waste is freely available in tea plantations. Their long term benefits on biological, chemical and physical improvements and overall productivity of soil are undoubtedly accepted (Mohotti *et al.*, 1999).

CONCLUSIONS

The results of the present study validated the bioefficacy of indigenous methods used in the control of termites using three locally available organic amendments. Use of soil organic amendments showed potentials for the management of UCLWT. This is particularly so, as early detection of the UCLWT damage in tea is difficult and the existing recommendation on control by uprooting affected bushes and extending the period of grass rehabilitation are not practically feasible owing to longer period and higher costs.

Amongst the tested materials, Neem oil cake, Tea waste and Alocasia lowered UCLWT populations in soil and the damage to tea by recovering tea from the pest attack appreciably.

The incorporation of above organic amendments bring a beneficial option for tea planters in UCLWT prone areas where there is no other remedy for management other than uprooting affected tea and rehabilitation for a long period. The cost benefit of incorporating soil organic amendments is also attractive and the pest management approach is purely a non chemical, environmentally sound and user friendly method appropriate for both conventional and organic tea growers.

The present study exhibited best practices in harnessing indigenous knowledge and also potential of materials and invasive plant species for managing pest and diseases. It is an example of natural resource management options to solve a pest problem in a perennial crop like tea.

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