SHORT COMMUNICATION

Attribution of allelopathy in tea soils on bush debilitation and yield decline in old tea cultivar TRI 2026 grown in mid elevations of Sri Lanka

M.M.N. Damayanthi[a], K.G. Prematilake[b]*, M.G.S. Liyanage[a]

[a]Agronomy Division, Tea Research Institute, Talawakelle, 22 100, Sri Lanka
[b]Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Badulla, 90 000, Sri Lanka

Submitted: June 09, 2017; Revised: July 25, 2017; Accepted: December 05, 2017
*Correspondence: kapilagamini@yahoo.com

ABSTRACT

An experiment was conducted at Meddakanda Estate, Balangoda, Sri Lanka (Elevation: 1050 m amsl) during 2008 – 2010 to investigate the underline causes for bush debilitation and yield decline in tea (Camellia sinensis L.), of 36 yr old cultivar TRI 2026. The tea land was divided in to three categories as severely affected, moderately affected with above problem and unaffected and a 10 x 10 m land block was demarcated from each category. Soil samples were obtained beneath randomly selected 15 tea bushes, from each category at 3 depths (0 – 15, 15 – 30 and 30 – 45 cm) and in-vitro bio assays were performed by germinating Lettuce seeds (Lactuca sativa) (variety Grand rapids) directly on these soils. Furthermore, soils at 30 cm depth were extracted for allelochemicals using a neutral EDTA solution and in-vitro bio-assays were performed using Lettuce seeds treated with these extracts. Distilled water was used as control. Tea yield in severely affected block was zero but the moderately affected and unaffected tea blocks recorded 119 and 92 g made tea/bush, respectively, over 7-month period. The healthy seedling number of test plants was significantly (P>0.01) reduced with soils of all three depths from severely and moderately affected tea blocks compared to that of the unaffected tea block. Germination percentage was also significantly (P>0.01) reduced with soil extracts of severely and moderately affected blocks compared to that with extract of unaffected field and control. Hypocotyl length and radical length of Lettuce were lower and growth inhibition percentage of both were significantly (P>0.01) higher with soil extracts of severely and moderately affected fields compared to those of unaffected tea block. Allelochemicals exudates from old tea itself and residues of fertilizers, pesticides specially herbicides etc. added to the soil may have caused phytotoxicity in test plants when treated with soil extracts of affected tea fields and there in bush debilitation and yield decline in tea.

***Keywords**: Tea (Camellia sinensis L.), yield decline, bush debilitation, allelochemicals*

INTRODUCTION

A majority of tea (*Camellia sinensis* (L.) Kuntze) grown in all Up, Mid and Low elevations in Sri Lanka is within the age of 30 – 40 yr. Some gradual declining trend in crop productivity has been reported with ageing of tea. However, almost 19 – 40% yield decline is attributed to bush debilitation in all Up, Mid, Low and Uva regions reporting the highest in Galle, Matara and Nuwara Eliya districts (Sidhakaran and Nishanthi, 2011). Some sudden bush debilitation together with yield decline followed by die back of tea of this stage of growth reported from some of the tea plantations have also contributed to report such higher figures

(Sidhakaran and Nishanthi, 2011). Leaf discoloration, short spell of wilting followed by scorching and leaf senescence are the common symptoms of the problem. As a consequence, severely affected bushes were found only with primary, secondary and tertiary branches without leaves. The survivors have very low yield and recovery of affected bushes after pruning is also very poor and tended to die off. This problem was first reported in 1989 in three estates in Nuwara Eliya district later in Deniyayaand Balangoda area in 2005 (Mohotti *et al.*, 2017). Apart from above symptoms, in uprooted tea bushes it was observed that there were no feeder roots in the root system and some lenticels could be seen in some primary and secondary roots. Many incidences of this bush debilitation have been seen as a result of multiple factors mainly pest and disease problems and bad management practices such as regular use of nitrogen fertilizer and glyphosate herbicide (Ekanayake *et al.*, 2013) A majority of debilitated tea bushes in Deniyaya and Balangoda areas was infested with shot hole borer (*Xyloborus fornicates*) (Sidhakaran and Nishanthi, 2011). The average yield drop due to bush debilitation in Deniyaya region was estimated to be 12 – 13% (Ratnayake and Munasinghe, 2013). This is because such pest incident could occur as a secondary infestation since the insects could easily attack on such weak and debilitated tea bushes.

Another possible scenario that could attribute to the above problem is the development of phytotoxicity in soil. Tea being a perennial mono crop has a great potential for accumulation of various chemical compounds in the surrounding soil, which can possibly bring about phytotoxic effects (Owuor, 1996). Many allelochemicals have been identified in tea plants such as alkaloids, tannins, polyphenols, catechins, and phenolic compounds (benzoic acid, caffeic acid, chlorogenic acid, ferulic acid, p-cumaric acid, vanillic acid) etc. Three phenolic acids, p-coumaric, ferulic and vanillic acid, which are found in tea plants were reported to severely inhibit photosynthesis and protein synthesis (Rezaeinodehi, 2006). Tea normally contains a high amount of flavanoids. Allelochemicals are usually not toxic to the donor plants. However, in some instances they may be toxic to the host plants or plants of the same species, which is referred as 'autotoxicity'. Autotoxicity is known to limit yield of many perennial and annual crops in continuous monoculture (Hedge and Miller 1990).

In previous studies, it was evident that yield decline or die back of tea plants were attributed to some phytotoxic effects (Mohotti, 2008). These chemicals involved in the toxicity were identified as allelochemicals. All kinds of such soil contaminants can typically alter plant metabolism, most commonly to reduce crop yields. Therefore, this study was conducted to identify any attribution of allelochemicals to the issue of bush debilitation and yield decline in Meddakande estate.

MATERIALS AND METHODS

An experiment was conducted at Meddakanda Estate, Rassagala, Balangoda, Sri Lanka (elevation: 1050 m amsl) to investigate the underlying causes for bush debilitation and yield decline in tea, cultivar TRI 2026, which is 36 yr old. Tea land blocks were grouped in to three categories as severely affected, moderately affected and unaffected (healthy) with the above problem and 10 x 10 m area was demarcated from each category for the study. Soil samples were obtained 10 cm away from the base of each of the 15 tea bushes, which were selected randomly, at 3 depths *i.e.* 0 – 15, 15 – 30 and 30 – 45 cm from each field category and then five composite samples were prepared. *In vitro* bio assays were performed by germinating Lettuce seeds (*Lactuca sativa*) (variety *Grand rapids*) @ 10 seeds/dish directly on these soils. Experiment was laid out in a Complete Randomized Design (CRD) with five replicates.

Furthermore, soil was collected at 30 cm depth from 15 randomly selected tea bushes from each category and seven composite samples were prepared to extract allelochemicals using a neutral EDTA solution (Kaminsky and Muller, 1976). *In vitro* bioassays were performed by germinating lettuce seeds (10 seeds/dish) treated with these soil extracts. Distilled water was also used as the Control. Experiment was laid out in a CRD with seven replicates.

The responses were evaluated through visual observation on seed germination. Growth assessments were undertaken for 96 h of bio-assay where, hypocotyl length and radical length were measured separately. The percentage inhibition of growth was calculated using following equation and the data were subjected to square root transformation before statistical analysis.

$$\text{Inhibition \% of radical elongation} = \frac{\text{Radical lengthin control} - \text{Radical length inaffected soil}}{\text{Radical length in control}}$$

The same equation was used to calculate the percentage inhibition of hypocotyl elongation.

All data were subjected to ANOVA and the mean comparisons were done following Duncan's Multiplied Range Test of General Linear Model with the help of SAS statistical software.

RESULTS AND DISCUSSION

Healthy and moderately affected tea blocks recorded 119 and 92 g made tea/bush, respectively, over seven-month period. The mean casualty percentage of tea was 30 in moderately affected block compared to that of the unaffected, healthy tea block. In the preliminary trial, the germination percentage of lettuce seeds was significantly lower (P<0.01) in soils obtained at 15 – 30 cm depth from both severely and moderately affected blocks compared to that of the unaffected block (Figure 1): 60 and 65% in severely affected and moderately affected, respectively. Further, viable seedling number of Lettuce were also significantly reduced (*P*<0.01) with soils at all three depths collated from severely and moderately affected tea blocks compared to that of the unaffected tea block (Figure 2). With these results, it can be inferred that there may be some unfavourable conditions for seed germination in soils of affected tea blocks compared to the unaffected tea blocks.

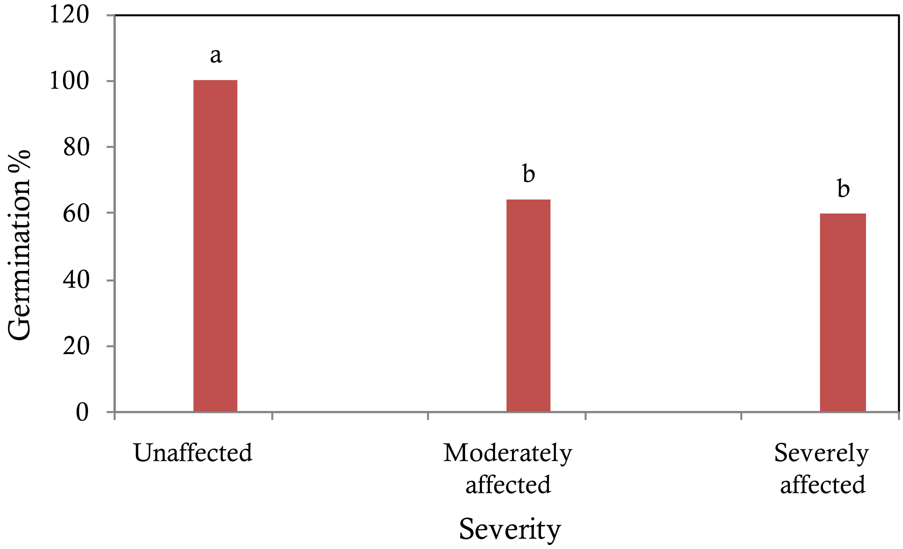

Figure 1: Germination percentage of lettuce seeds as affected by the soils of tea blocks affected at different levels.

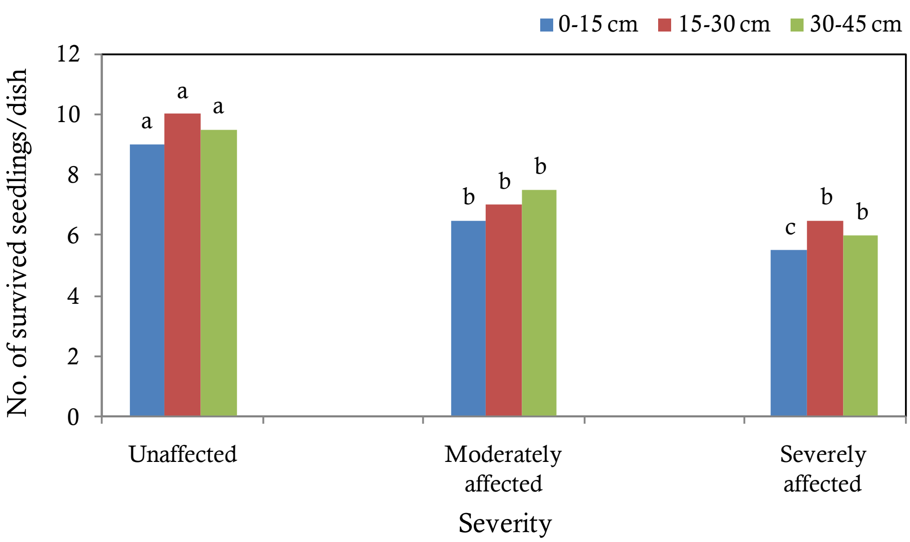

Figure 2: Number of survival seedlings after planting Lettuce seeds on soil samples collated from affected and unaffected tea blocks.

Germination percentage of lettuce seeds at 96 h after seeding was significantly ($P<0.01$) reduced when seeds were treated with soil extracts of severely and moderately affected blocks compared to that of extracts of unaffected field and the control (Figure 3).

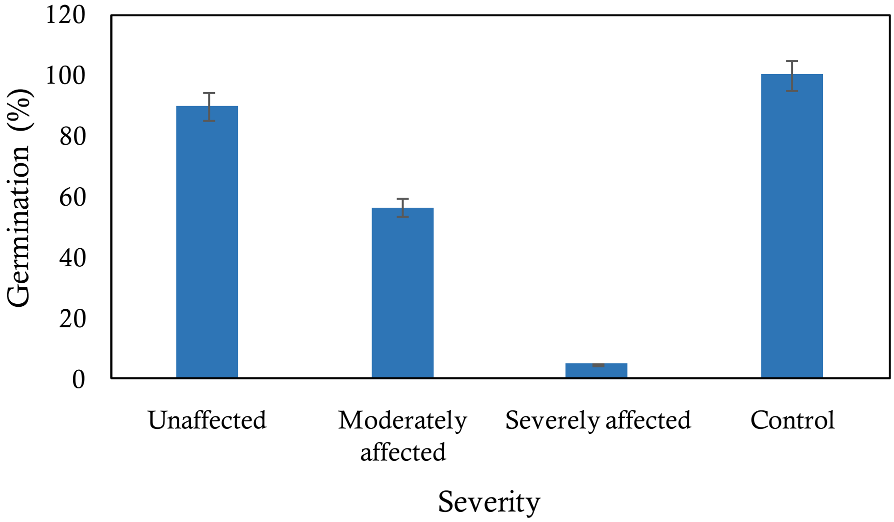

Figure 3: Germination percentage at 96 h after seeding of lettuce seeds as affected by soil extracts of severely and moderately affected blocks compared to that with soil extract of unaffected block and Control.

Hypocotyl length and radical length of lettuce seeds treated with soil extracts of severely and moderately affected were significantly ($P<0.01$) lower than those of seeds treated with soil extract in unaffected tea blocks (Figure 4). Furthermore, percentage inhibitions of elongation of hypocotyl, radical and root of seeds treated with soil extracts of affected tea blocks were significantly higher ($P<0.01$) compared to the control (Table 1).

Table 1: Percentage inhibition of seedling growth of lettuce by soil extracts of severely and moderately affected tea blocks in comparison to the seedling growth in the Control.

Severity of the debilitation	Inhibition of radicle elongation (%)	Inhibition of hypocotyl elongation (%)	Inhibition of root elongation (%)
Severely affected	95.76 a	97.39 a	88.02 a
Moderately affected	51.79 b	71.35 b	47.92 b
Untreated Control	0	0	0

These results further confirm the percentage of some inhibitory effects in soils of affected tea blocks on germination of Lettuce seeds. This may be attributed to the phytotoxicity in soils. Some allelochemicals exudates from old tea roots may thus be present in the rhizosphere in affected tea blocks. In addition, accumulation of residues of fertilizers, herbicides etc. and secondary metebolites released from pest and disease affected parts of old tea may also be present in the rhizosphere. Hence, the presence of all such chemicals substances may have caused to hinder the growth of old tea and in turn to debilitate the bush.

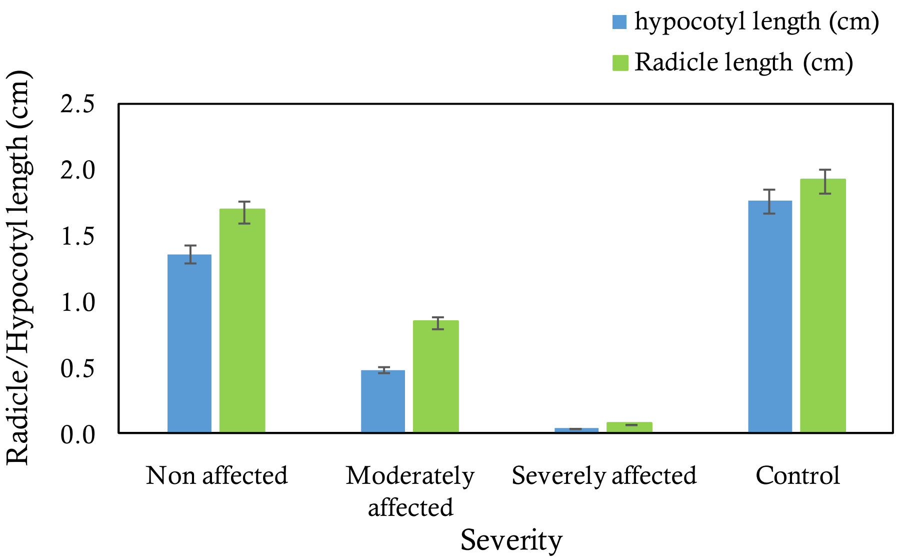

Figure 4: Radical length and hypocotyl length of lettuce as affected by soil extracts of severely and moderately affected blocks as compared to that with soil extract of unaffected block and control.

Allelopathy can be effective only when plants are under stress resulting from various other mechanisms, for example, when there is a lack of water or competition for nutrients or light is strong; allelochemicals production has been shown to increase (Rezaeinodehi, 2006). Heavy infestation of tea bushes with shot hole borer and with termite attack at Meddakanda estate may also have caused to increase the formation of allelochemicals. On the other hand, it is argued that when the tea bush is weak some pest and disease organisms can easily attack the bush make further damages. Autotoxicity is another phenomenon whereby mature plants inhibit the growth of their own seedlings through the release of autotoxic chemicals. Tea plants also have been grown as a monoculture for a long period of time so there is a high possibility to accumulate allelochemicals and to show some autotoxicity and this may also lead to bush debilitation.

Present study thus confirms the presence of allelochemicals in the affected blocks in Meddakanda estate. Yield decline problem has earlier been reported elsewhere such as High Forest estate, Nuwaraeliya, and the association of allelochemicals with such bush debilitation and yield decline problem has been reported (Mohotti, 2008).

CONCLUSIONS

With the present study, it is apparent that some allelochemicals are present in soils of affected tea blocks in Meddakanda estate and these may have attributed to the tea bush debilitation apart from the damages occurred to tea bushes by shot hole borer and live wood termites. Bad management practices such as regular use of glyphosate herbicide and artificial fertilizers in the estate may also have contributed to have such allelochemicals. All these kinds of allelochemicals and aforementioned external factors may have attributed to the bush debilitation along with damage of feeder roots and finally to the yield decline in tea.

REFERENCES

Ekanayake, P.B., Prematilake, K.G. and Jayasekara, A. (2013). The effect of long term use of selected herbicides on soil organisms, growth and yield of tea (*Camelia sinensis.* L) in the Mid Country, Sri Lanka. J. Tea. Sci., 78, 13–28.

Hedge, R.S. and Miller, D.A. (1990). Allelopathy and autotoxicity in Alfalfa: characterization and effects of preceding crops and residue incorporation. Crop Sci., 30, 1255–1259.

Kaminsky, R. and Muller, W.H. (1976). The extraction of soil phytotoxins using a neutral EDTA solution. Soil Science, 124, (4), 205–210.

Mohotti, A.J. (2008). Evidence of allelopathy in tea (*Camellia sinensis* L.) soils of Sri Lanka. Proceedings of the Second Symposium on Plantation Crops Research, held on 17-18 October, 2008, Colombo. pp 212–223.

Mohotti, K.M., Prematunga, A.K., Amarasena, P.G.D., Nawaratne S.N. and Herath, U.B. (2017). Attribution of nematode infestation to bush debilitation, unusual yield decline and death of tea in Low-grown areas. Proceedings of 234th Experiments and Extension Forum of the Tea Research Institute, held in Colombo on 28th July 2017, pp 1–7.

Owuor, P.O. (1996). Problems of replanting tea or other crops on old tea lands: possible role of allelochemicals: A review. Tea 17 (1), 34–40.

Ratnayake, S.P. and Munasinghe, C.E. (2013). Possible causes affecting tea bush debilitation in Deniyaya region. Tea Bulletin, 22 (1 & 2), 1–20.

Rezaeinodehi, A., Khangholi, M. and Kazemi, H. (2006). Allelopathy potential of tea (*Camellia sinensis* L.) on germination and growth of *Amaranthus retroflexus* L. and *Setaria glauca* (L.) Beauv, J. Plant Dis. Protect., 20, 447–454.

Sidhakaran, V.S. and Nishanthi, H. (2011). Factors contributing to productivity decline in the Corporate tea sector, Proceedings of 222nd Experiments and Extension Forum of the Tea Research Institute, held in Talawakelle on 28th January 2011, pp 9–16.