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Impact of Organic Mulches on Soil Carbon, Microbial Properties and Yield in High-grown Tea

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ABSTRACT

Organic matter transformation and nutrient recycling in soil mainly depend on the activity of soil micro-organisms. Deterioration of soil fertility lowers the biological activity, and it leads to lower productivity. In the absence of adequate organic matter, the process of conversion of nutrients to available forms and their retention is very low. To enhance the activity of soil organisms, high quality organic matter addition is very important. Even though there are plenty of organic materials available in tea lands, there is inadequate information on their suitability and influence on biological properties of soil. Therefore, two trials were conducted to study the suitability of the commonly available mulching materials with varying C/N ratios and their influence on soil micro-organisms on young/ immature tea and mature tea after pruning in the field.

Soil microbial biomass carbon, soil respiration, organic carbon and pH, were measured one year after application of mulch. The materials tested were refuse tea (25 tonnes ha^{-1} $year^{-1}$), mana grass (*Cymbopogon confertiflora* -35 tonnes fresh weight ha^{-1} $year^{-1}$), and dadap legume (*Erythrina lithosperma* - 35 tonnes fresh weight ha^{-1} $year^{-1}$). For young/ immature and mature tea, mana and dadap were applied three times and refuse tea two times during the first year after planting and after pruning respectively. The results indicated that refuse tea and dadap mulches enhanced soil pH, organic carbon, microbial biomass carbon, and soil respiration and also showed suppression of gram negative bacteria which are mostly pathogenic, one year after the application of treatments.

The suitable mulching materials to accelerate the microbial activity are those with C/N ratios below 20, and low in lignin and unoxidisable polyphenols. Therefore, Dadap and refuse tea, which improve the microbial properties of the tea soil, are suitable organic mulches for tea.

Key words: Microbial biomass carbon (MBC), soil respiration, tea soils

INTRODUCTION

Organic matter turnover and soil structure are regulated by micro organisms (bacteria, fungi, actinomycetes) and macro organisms (earthworms, arthropods) and, in order to achieve sustainable land use for agriculture, it is essential to stimulate biological activity of soils (Alexander, 1977; Gupta and Roper, 1994; Killham, 1994). Crop residue retention

(Doran, 1980; Roper, 1983; Powlson *et al.*, 1987; Dalal *et al.*, 1995; Amir and Pineau, 1998) and soil amendments by liming *etc.* (Ishaque and Cornfield, 1976; Sandanam *et al.*, 1978; Carter, 1986; Shah *et al.*, 1990) have been shown to maintain or improve soil organic matter levels, soil structure and crop productivity. But the associated changes in biological processes under different soil amendments are poorly understood (Sivapalan *et al.*, 1985; Gupta and Roper, 1994). Application of mulch is an important cultural practice in new clearings (Anandacoomaraswamy *et al.*, 2003). Though it enhances the soil physical, chemical and biological characters, there is a lack of information on its effect on soil biological processes especially related to soil microbial activity.

Nutrients such as carbon, nitrogen, sulphur, and phosphorus are important in the life cycle of plants, animals, and micro-organisms, and are cycled in the soil between organic matter residues and the available plant nutrient pool. The death and microbiologically-mediated decay of organisms result in release of inorganic ions which can be readily taken up by plants (Paul and Clark, 1989; Killham, 1994). Thus, decomposing organic matter acts as a slow release fertilizer. The objective of this study is to examine the effects of mulching materials available *in situ* on soil biological properties and its relation on growth and yield of tea.

MATERIALS AND METHODS

Field studies with young / immature tea and pruned mature tea

The study was undertaken in the young/immature and pruned tea fields. The rate of application of the mulching materials was based on the requirement of mulching materials for the young tea fields. The cultivars TRI 4071 and TRI 2025 were used for immature (2 years old) and mature tea (20 years old), respectively. Both trials were carried out at St. Coombs Estate, Tea Research Institute of Sri Lanka, Talawakelle (Latitude 6°55' N, longitude 80° 40' E, altitude 1382 m amsl).

For both experiments, refuse tea (25 MT ha^{-1}), mana - *Cymbopogon confertiflorus* (35 MT fresh weight ha^{-1}) and dadap - *Erythrina lithosperma* (35 MT fresh weight ha^{-1}) were used as mulches and compared with no treatment (Control). In the control plots, only fallen tea leaves were available. Fertilizer was applied for young /immature tea at three-month intervals using the T 200 fertilizer mixture (10.3% N, 6.9% P_2O_5, 7.5% K_2O, 3.0% MgO) at the rate of 15g per plant for young tea and T750 for immature tea (13.7% N, 3.7% P_2O_5, 8.0% K_2O, 1.6% MgO) at the rate of 60g per plant and VP/UM 910 fertilizer mixture (29.7% N, 3.9% P_2O_5 and 13.2% K_2O) for mature tea. Other management practices were carried out according to the TRI recommendations and no pesticide application was done during the study period. Randomized Complete Block Design (RCBD) was used with four replicates including 20 plants per plot. Data were analyzed using SAS computer software.

Analysis of soil samples

One year after application of mulch material, soil samples (0 - 15 cm depth) from both trials were analyzed for pH, organic carbon, microbial biomass carbon, and soil respiration using the methods indicated below. Functional groups of micro-organisms were analyzed by FAME (Fatty Acid Methyl Ester) method at CSIRO Division of Land and Water, Adelaide, Australia (Vestal and White, 1989).

Yield was recorded at weekly intervals and made tea per hectare, per year was calculated. Soil pH (1: 2.5 soil water ratio), organic carbon by the modified Walkley and Black method (Rayment and Higginson, 1992), soil MBC by the chloroform fumigation extraction method (Sparling *et al.*, 1990) and soil respiration by the field method (Black, 1968) were used. Half lives of mulch material were tested using litter-bag technique (De Costa and Atapattu, 2001).

Trial 1. Field studies with young/immature tea

In this trial mana and dadap were applied three times and refuse tea two times per year for the year after planting. The decomposition rates of the mulching materials were determined by litter bag technique where predetermined weights of the mulching materials were enclosed in a litter bag (2 mm mesh size nylon bag) and kept in a young tea field. The weight of the entire litter bag was recorded at weekly intervals for about 50 weeks. Using the above values, half lives of the mulching materials were determined. The half life is the time taken for 100g of the dry materials to become 50 g.

Trial 2. Field study with pruned/mature tea

The only difference between this experiment and immature tea trial was that pruned mature tea covered the soil surface earlier than young/immature tea. For mature tea, mana and dadap were applied three times and refuse tea two times during the first year after pruning. The materials were applied based on the cover of soil surface.

RESULTS AND DISCUSSION

The C/N, lignin/N, (polyphenol + lignin)/N ratios and total lignin of Dadap, and refuse tea were lower than those of tea mulch (control) and mana. The C/N ratio of mana was the highest. Though the tea leaves and refuse tea have almost similar C/N ratios, tea leaves have unoxidised polyphenol which couldn't be easily decomposed and it is reflected by half life of tea leaves (Table 1). From the above, it could be concluded that the suitable leaf characteristics for selection of a good mulching material would be the total lignin and (lignin + polyphenol)/nitrogen ratio in addition to the C/N ratio. The Table 1 shows that the half lives of dadap is the lowest followed by mana and refuse tea. The tea mulch had the highest half life due to unoxidised polyphenol.

Table 1. C/N, lignin/N, (lignin + polyphenol)/N and half life of materials used in field trial

Mulch	C (%)	N (%)	C/N	L (%)	PP (%)	L/N	(L+PP)/N	Half life (weeks)
Control*	42	4.13	10	19	11.1	4.6	7.3	47
Refuse tea	34	3.15	11	9.5	22.5	3.0	10.2	30
Mana	40	1.40	28	29.7	1.0	21.2	21.9	10
Dadap	38	4.55	8	13.6	3.0	3.0	3.6	7

L: Lignin; PP: Polyphenol; control*: tea leaves

Litter decomposition mostly depends on fungi and actinomycetes (Lynch, 1983). Rate of decomposition of organic material depends on their C/N, lignin/N, (lignin + polyphenol)/N ratios (Muller *et al.*, 1988). The decomposition rate is expressed by half life. The rate of decomposition and nutrient release from added materials are determined by climatic factors such as rainfall and temperature and by litter quality as determined by its lignin, polyphenol and nitrogen contents (Palm and Sanchez, 1991). Depending on the lignin, polyphenol/N, the variation of decomposition rates was confirmed by De Costa and Atapattu (2001). This study was carried out with hedgerow species in tea plantation and it showed that *Calliandra* and *Flemingia* leaves decomposed at a slower rate than *Gliricidia*, *Tithonia* and *Eupatorium*.

One year after the application of the treatments, refuse tea and dadap increased the organic carbon, microbial biomass carbon and soil respiration and it was reflected through the yield of tea during the 1st year (Table 2). The higher yield response showed in refuse tea and dadap could be due to higher microbial activities. However, these parameters with mana were not significantly different to that of control.

The average yield under refuse tea (19%) and dadap (16%) were higher than that of the control (Table 2). Yield under mana was not significantly different from that of control.

Table 2. Soil parameters in immature tea after one year application of treatments

Mulch materials	Soil pH	Organic carbon (%)	MB-C ($\mu g\ g^{-1}$)	Soil respiration (C MT $ha^{-1}yr^{-1}$)	1st year yield (made tea kg $ha^{-1}\ yr^{-1}$)
Control*	4.42 b	3.0 b	119.9 b	3.2 b	1750 b
Refuse tea	4.75 a	3.7 a	263.6 a	4.1 a	2089 a
Mana	4.64 a	2.8 b	191.4 b	3.1 b	1785 b
Dadap	4.59 a	3.2 ab	288.4 a	3.7 ab	2030 a
LSD ($p < 0.05$)	0.13	0.2	74.2	0.6	180
CV %	6.4	4.7	5.9	1.7	9.7

Control* : fallen tea leaves

Values followed by the same letter are not statistically significant at 5% probability level

The ratio of gram +ve/gram-ve bacteria and fungal population were the highest under dadap (Figure 1). This may be due to rapid decomposition rate of dadap, which enhance the microbial activity.

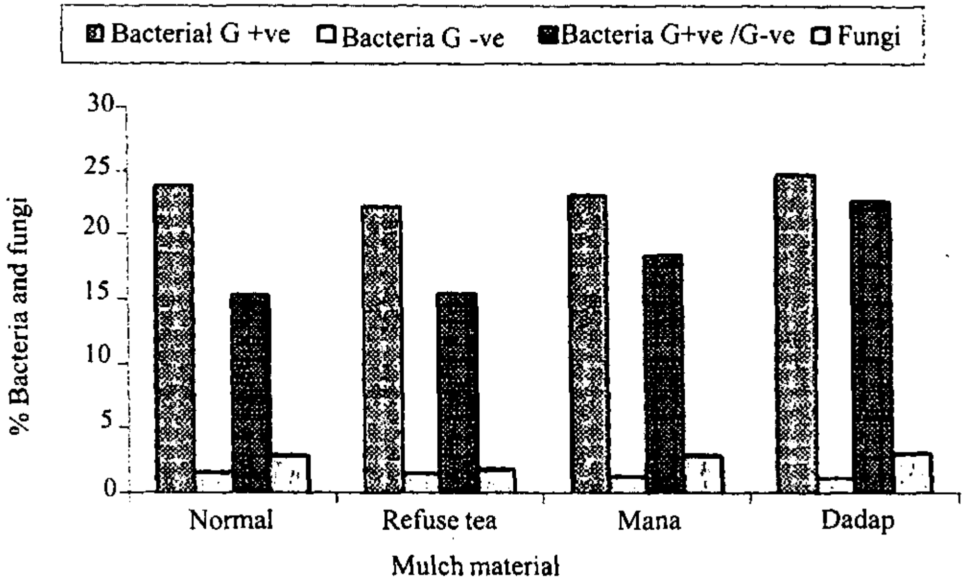

Figure 1. Ratios of gram +ve and –ve bacteria and fungi in immature tea soils, one year after application of treatments.

Soil microbial biomass and soil respiration significantly increased with refuse tea and dadap treatments in mature tea (Table 3). The highest yield was given by refuse tea (19%) and dadap (14 %) compared to the mana and the control. There is an improvement in soil microbial activity by application of refuse tea and dadap in terms of soil microbial biomass carbon and soil respiration. This improvement appeared to have reflected in the yield of tea. Therefore, the sustainability of soil fertility could be retained in long term basis by improving soil microbial activity.

Table 3. Soil biological parameters and yield after 12 months of harvesting in mature tea

Mulch materials	Soil pH	Organic carbon (%)	MB-C ($\mu g\ g^{-1}$)	Soil respiration (C MT $ha^{-1}yr^{-1}$)	Yield (made tea kg $ha^{-1}yr^{-1}$)
Control*	4.40 b	2.6 b	139 b	3.8 b	3604 b
Refuse tea	4.73 a	3.2 a	279 a	6.9 a	4110 a
Mana	4.51 ab	2.7 b	230 b	4.0 b	3640 b
Dadap	4.79 a	3.2 a	300 a	6.6 a	4105 a
LSD (P<0.05)	0.11	0.2	117	1.7	397
CV%	4.4	14.2	10.9	16.8	13.7

Control* : fallen tea leaves

Values followed by the same letter are not statistically significant at 5% probability level

CONCLUSIONS

Microbial activity of refuse tea and dadap treated plots is significantly higher in comparison to control plots where foliage of prunings remained on soil surface, despite the fact that the refuse tea contain higher (L + PP) / N ratio. Increase of microbial activity contributed to significant yield increments observed from both refuse tea and dadap treated plots.

Therefore, it is evident that the oxidized polyphenol predominantly present in refuse tea did not adversely affect the soil microbial activity.

Ratio of Gram+ve/Gram–ve bacteria increased by mulch materials, which leads to improvement in soil health.

Application of refuse tea and dadap as mulch increased soil pH, organic carbon, soil microbial biomass carbon, soil respiration and yield of tea in high grown areas.

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