International Journal of Sustainable Agricultural Research
2022 Vol. 9, No. 2, pp. 46-54.
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/ijsar.v9i2.2968

INSIGHTS INTO PHYSICOCHEMICAL ASSESSMENT OF SHADE TREE LITTER BIOMASS IN TEA PLANTATIONS OF TERAI REGION

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Article History
Received: 11 February 2022
Revised: 21 March 2022
Accepted: 4 April 2022
Published: 19 April 2022

Keywords
Shade tree
Biomass
Organic matter
Tea plantation
Organic carbon
Nitrogen.

ABSTRACT

Tea is a major plantation crop and the socioeconomic pillar of Terai region of West Bengal. Use of various inorganic fertilizers may have increased the crop production but affected the environment badly. Importance of biomass of different trees in accumulation of carbon had long been known but few studies on characterization of biomass accumulation are reported. So, selection of different species for getting the good amount of organic nutrients is important. In tea plantation, various leguminous trees are used as shade trees. This research, conducted in the tea plantation of University of North Bengal, has provided some approaches which could possibly reduce the application of inorganic fertilizers. Different tests on physicochemical parameters, micronutrients status, biomass etc. were conducted with the collected plant litters. The results of this comparative analysis suggested and validated the beneficial effects of each shade tree in organically maintaining nutrient profile of tea plantation soil.

Contribution/Originality: This study is a novel approach to find out the use of shade tree litters as an alternative to inorganic fertilizers in tea plantation. Results showed the beneficial effects of litters from each shade tree in organically maintaining nutrient profile of tea plantation soil.

1. INTRODUCTION

Increase in soil fertility resulting in maximum productivity in sustainable agriculture system or agroforestry is positively related with the quality of leaf litter, air, water, light, nutrient concentrations in fresh leaf tissue, decomposition rates of leaf litter, and the mineralization of nitrogen (Bohre, Chaubey, & Singhal, 2013). Decomposition rate of litters generally depends upon woody and non-woody tissues (Aerts, 1997). Litters also have its role in temperature moderation, water holding, erosion mitigation, plant establishment (Apolinário et al., 2014). Availability of high nutrients play an important role to control the osmotic pressure in leaves and make the plants able to withstand environmental stress (Wood, Lawrence, & Clark, 2006). Nitrogen (N), phosphorus (P), potassium (K) and organic carbon (OC) are the most essential elements to make soil nutrient rich matter (Osono & Takeda, 2004), as these essential elements directly help to perform various physiological activities like photosynthesis, growth and development of plants, reproduction etc (Maathuis, 2009). Protons present in soil would get cleared by the organic anions of plant material, in the time of decomposition (Noble, Zenneck, & Randall, 1996). In the tea plantation, especially in plains/tropical area, where the intensity of sun lights is high, besides providing shade, trees are planted to add humas content by shredding their leaf, twigs, seed, pod etc. (Ghosh, Majumder, Saha, & Bhattacharya, 2020). As, leguminous shade trees are deciduous, they shed huge amount of litter (leaf, pod, seed etc.) in the soil specially in winter and spring. Leaf litters also play a crucial role to balance the population of earthworms (Chen et al., 2020). Application of fertilizer may provide enough nutrients but some factors like nutrient leaching, storage in plants, high cost etc. create problem which may not be adequate to maintain the plantation (Sitienei, Home, Kamau, & Wanyoko, 2013). As plants are reservoir of many macronutrients as organic conjugate, so this study was conducted to determine the amount of nitrogen, potassium, phosphate, sulphate and organic carbon released from fallen parts of plant and their presence in available form in the soil.

2. MATERIALS AND METHOD

2.1. Collection of Samples

The present study was conducted in the tea plantation of University of North Bengal, Siliguri, West Bengal (26°42′47.1″N 88°20′54.2″ E) during 2020-21. Litter of nine shade trees viz. *Albizia odoratissima* (AO), *Albizia chinensis* (AC), *Albizia lebbeck* (AL), *Dalbergia sissoo* (DS), *Derris robusta* (DR), *Cassia siamea* (CS), *Leucaena leucocephala* (LL), *Acacia lenticularis* (ALn) and *Melia azedarach* (MA) were collected on the month of December and January. Quadrates (1 m × 1 m) were placed under each of those shade trees to collect the litters like pods, leaves and twigs. Collected samples were kept in hot air oven at 80°C. All results have been described on the basis of dry weight.

2.2. Estimation of Biomass

Girth at breast height (GBH), diameter at breast height (DBH), basal area (BA) and volume of those trees were determined by the following protocol (Toppo, Oraon, Singh, and Kumar (2021) as given below;

- At 1.37 m height from the base of the tree, GBH was measured. And DBH was calculated by dividing GBH with 3.14.
- BA of those 9 trees was calculated with the formula; BA = $\pi d^2/4$. where d is the diameter.

To calculate volume of the tree, this formula is followed given by Toppo et al. (2021).

Volume (m3) = Basal area (m^2) × height (m).

2.3. Estimation of pH and EC

To find out the pH value in shade tree litter (STL), samples were taken in a ratio of 1:8 (5 g STL and 40 ml distilled water) followed by constant shaking for half an hour. Finally, the pH and EC was determined by a previously calibrated pH and EC meter respectively.

2.4. Estimation of Crude Fiber

Percentage of crude fiber was determined by acid and alkali digestion. 2g of STL (W1) was boiled in 200 ml of sulfuric acid for 30minutes. The boiled matters were filtered and washed several times with distilled water until the pH of fibrous residue became neutral. The residue was again boiled in 200 ml of sodium hydroxide solution for 30minutes and then filtered washed with distilled water. The residue was washed with 25 ml of boiling 1.25% H_2SO_4, 50 ml distilled water and 25 ml of ethanol one after another. The rest part was taken in a crucible and kept at 130±2 °C in a hot air oven for 2hours. The crucibles were cooled down at room temperature and their weight (W2) were recorded. Crude fiber% =(W2/W1) x100.

2.5. Estimation of Ash

To determine the ash content, STL (5g) were taken in crucibles and kept in a muffle furnace at 600°C for 6hours. Percentage of ash content was calculated by the following formula: - Ash (%) = (weight of residue/ weight of sample) x100.

2.6. Determination of Organic Carbon (OC) and Organic Matter (OM)

Quantification of organic carbon was determined by following the protocol of Mukherjee, Sarkar, Saha, and Bhattacharya (2018), with slight modification. 0.1 g of dried litter samples of different trees was taken in a conical flask and 10 ml of 1 N Potassium dichromate ($K_2Cr_2O_7$) solution was added and shaking it continuously for proper mixing. Then 20 ml of conc. H_2SO_4 was added and the flask was swirled for 2 minutes. The conical flask was then kept 30 minutes for incubation. To dilute the mixture, 170 ml of water was added to the flask. Then back titration process was followed with 0.5 N ferrous ammonium sulphate, by adding 0.2 g of Sodium fluoride (NaF) and 1 ml of diphenylamine as an indicator, until the colour changed to bright green. The volume of the ferrous ammonium sulphate was observed. One control (without sample) titration was done also. Percentage of organic Carbon in the litter samples was calculated by following formula.

Organic carbon (%) = {0.1 x (B-S) x N x 0.003 x (100/W)}

Organic matter (%) = % of organic carbon x 1.72

Where; B= blank reading, S= sample reading, N= represents the normality of solution, W=weight of litter taken.

2.7. Determination of Total Nitrogen, Available Phosphorus, Potassium and Sulphur

Preparation of sample for estimation of available phosphorus as phosphate, available potassium as potash and available sulphur as sulphate requires di-acid digestion, where 70% nitric acid (HNO_3) and perchloric acid ($HClO_4$) was used at a ratio of 3:1. Sample (0.1 g) was taken for di-acid digestion and make up the final volume to 100 ml in a volumetric flask.

2.7.1. Estimation of Nitrogen

In our study, Nitrogen content was estimated by kjeldahl method (Mukherjee et al., 2018). 0.1 g of litter sample was mixed with K_2SO_4: $CuSO_4$ (5:1) and then add 20 ml of concentrated H_2SO_4; followed by heating at 420°C in a kjeldahl digestion tube. Then the blue-coloured mixture was taken in a 100 ml volumetric flask and makeup the flask with distilled water. From 100 ml mixture digested solution, 20 ml solution was taken in kjeldahl distillation tube and then add 40% NaOH (20 ml) and 10 ml of distilled water. After releasing ammonia, it was absorbed in 2% boric acid solution in a flask. Until the change of colour from purple to green distillation was done. Then the titration of that ammonia in flask was done against 0.05N H_2SO_4.

% Of total nitrogen= 0.014 x S x V x 100

Where, S = Strength of, V = Volume of H_2SO_4 required

2.7.2. Estimation of Phosphorus

Available phosphorus as phosphate (P_2O_5) was determined by following the protocol of Bray and Kurtz (1945). Digested litter sample (10 ml) was taken and 10 ml ammonium molybdate with 2 ml stannous chloride were added. Stannous chloride was used to decrease the molybdenum-phosphate complex and finally add water to make 50 ml. And there after phosphate content was measured in 660 nm transmittance at spectrophotometer. Quantification of phosphate (ppm) was calculated by following equation.

Quantification of phosphate = Concentration in (ppm)

2.7.3. Estimation of Potassium

Available potassium in the digested sample solution in form of potash(K_2O) was conducted by following the protocol of Chapman and Pratt (1961). 20 ml of digested sample was taken in a beaker and add 2 drops of butyl alcohol. Potash was determined (ppm) with pre standardized flame photometer.

Quantification of potash= Flame photometer reading (ppm)

2.7.4 Estimation of Sulphur

To determine the available sulphur as sulphate($SO4^{2-}$) of the STL we have followed the protocol of (Mukherjee et al., 2018). 10 ml of digested extracts was taken in a beaker and add four drops of 6N HCl and 0.4 g of $BaCl_2$. After few minutes, transmittance was taken in spectrophotometer at 420 nm.

Quantification of Sulphate = Concentration in (ppm)

3. RESULTS

3.1. Biomass Estimation

Shade tree litters contribute considerable amount of organic matter from aerial parts of plant that add organic matter to soil. Microbial degradation releases useful nutrients back to soil. In our observation the quantity of STL from individual plant species were highly variable. Table 1 has been provided to express the result. Maximum quantity of litters was dropped by AO (564.8 g/m^2) and minimum by AL (96 g/m^2). But, GBH, DBH, basal and volume were found highest in CS, followed by AL and lowest were found in MA, LL and ALn respectively. So, the ratio of STL was not related to the GBH and DBH, but related to leaf size, leaf density etc. In a work by Samanta, Chakraborty, Mukherjee, and Bhattacharya (2021) on weed biomass on the same area average fresh and dry weight recorded was 563.46 g/m^2, 256.88 g/m^2 respectively. A positive correlation was observed among GBH, DBH and BA, whereas negative correlation was found between litters amount with each of GBH, DBH and BA. Results have been shown in Table 2.

3.2. pH and EC of STL

Maintaining the alkalinity or acidity of soil is very crucial for any plantation, where tea plantation is not an exception. pH of those nine samples showed different results ranging from 5.3 to 6.51. EC or electrical conductivity used to quantify the charge particles present in particular sample was also found to change with plant species. The maximum EC (1124 μS/cm) was found in the leaf litter under the CS and lowest EC (211 μS/cm) was detected in the litter of AC. Results have been provided in Table 1.

3.3. Percentage of Ash and Crude Fiber

The average percentage of crude fiber of the litter of nine shade trees were found to 23.13% Table 1. Litters of four shade trees viz. AL; LL; ALn; MA have shown crude fiber above the average. Highest crude fiber was detected in the litter of LL (27.41%) and lowest was found in AC (17.30%). Ash content of nine STL is found to be from 1.66% to 9.33%; where minimum percentage was found in the litter of MA and maximum percentage was found in AC. In a previous work the deviation of data from the previous work is because in the present work total shade tree litter was considered rather than the leaflets. A negative correlation was observed between ash and crude fiber percentage in our study.

Table 1. Estimation of physical and physicochemical content.

Physical and physicochemical parameters	AO	AC	AL	DS	DR	CS	LL	ALn	MA
Litter (g/m²)	564.8±14.02	293.92±12.41	96.04±6.12	253.17±9.77	337.28±32.16	464.006±36.97	447.68±40.38	334.366±32.96	387.362±30.98
GBH (m)	1.108±0.10	1.172±0.10	1.46±0.07	0.91±0.07	1.062±0.05	1.624±0.09	0.808±0.06	0.81±0.03	0.794±0.13
DBH(m)	0.35±0.03	0.37±0.03	0.47±0.01	0.28±0.02	0.33±0.03	0.51±0.03	0.25±0.02	0.25±0.01	0.25±0.04
BA (m²)	0.096±0.015	0.107±0.019	0.166±0.014	0.061±0.009	0.085±0.008	0.204±0.022	0.049±0.007	0.049±0.004	0.049±0.018
pH	5.3±0.2	6.11±0.2	5.26±0.1	6.44±0.1	6.26±0.1	5.5±0.1	6.23±0.1	6.12±0.2	6.51±0.1
EC (µS/cm)	308±7.07	211±8.72	1068±16.78	864±12.83	281±10.56	1124±9.41	822±9.54	708±5.24	966±6.89
Crude fiber%	20.05±0.78	17.30±0.75	23.61±0.79	22.90±0.40	23.05±0.44	22.60±0.73	27.41±0.47	24.06±0.30	27.21±0.56
Ash%	5±0.07	9.33±0.03	3.66±0.04	4.33±0.04	6.66±0.04	6.33±0.06	4.66±0.05	4.66±0.03	1.66±0.05

Table 2. Correlation between Litter, GBH, DBH and BA

Physical and physicochemical parameters	Litter (g/m²)	GBH (m)	DBH(m)	BA (m²)
Litter (g/m²)	1			
GBH (m)	-0.163	1		
DBH(m)	-0.149	0.999	1	
BA (m²)	-0.135	0.994	0.994	1

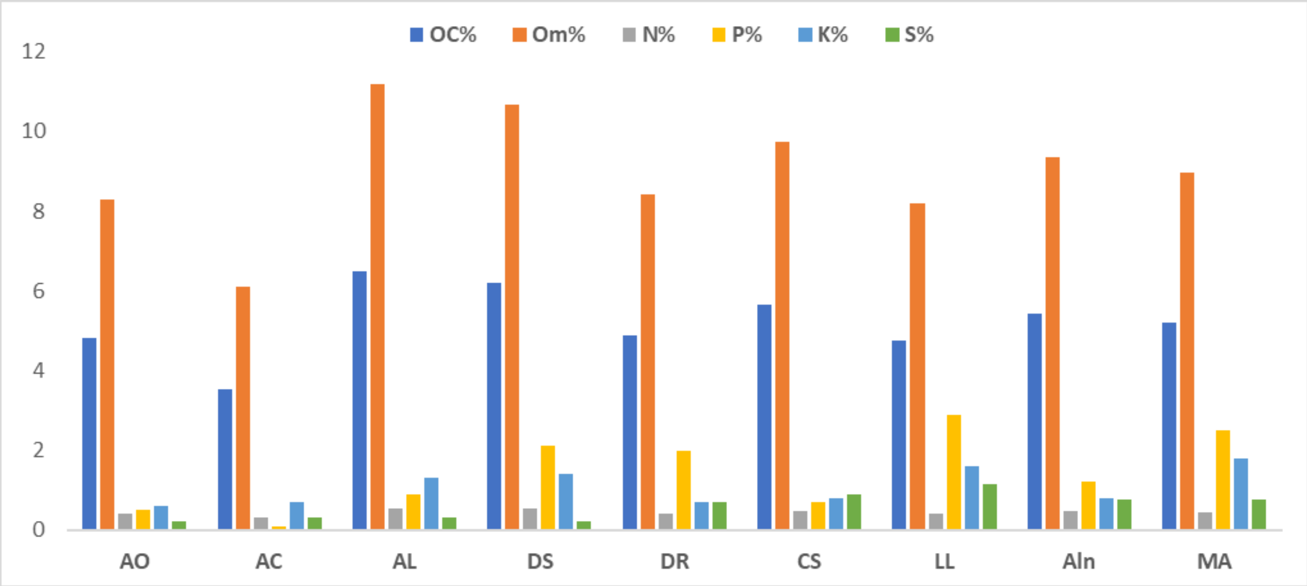

Figure 1. Graphical representation of comparison between percentage of OC, OM, N, P, K and S.

Table 3. Estimation of Organic carbon, organic matter, total nitrogen, phosphate, potash, and sulphate.

Nutrient	AO	AC	AL	DS	DR	CS	LL	ALn	MA
OC%	4.82±0.031	3.54±0.0167	6.50±0.353	6.21±0.296	4.89±0.468	5.66±0.365	4.76±0.304	5.44±0.355	5.21±0.241
OM%	8.30±0.270	6.09±0.3289	11.18±0.613	10.68±0.482	8.41±0.437	9.74±0.346	8.19±0.195	9.35±0.300	8.97±0.237
N%	0.407±0.003	0.311±0.0104	0.553±0.035	0.538±0.027	0.417±0.014	0.482±0.007	0.402±0.006	0.470±0.011	0.445±0.025
P%	0.5±0.081	0.1±0.0187	0.9±0.063	2.1±0.316	2±0.273	0.7±0.158	2.9±0.223	1.2±0.223	2.5±0.291
K%	0.6±0.158	0.7±0.158	1.3±0.255	1.4±0.255	0.7±0.255	0.8±0.187	1.6±0.273	0.8±0.223	1.8±0.255
S%	0.21±0.018	0.33±0.021	0.33±0.021	0.21±0.027	0.71±0.089	0.9±0.063	1.15±0.071	0.77±0.039	0.77±0.038

3.4. Determination of Organic Carbon, Organic Matter, Total Nitrogen, Phosphate, Potash and Sulphate

Organic carbon as well as organic matter are very important to maintain soil fertility, soil structure, nutrient cycling, biological, chemical and physical health (Chan, 2008). In this study, litters under AL have showed highest with both OC (6.50%) and OM (11.18%), followed by DS (6.21% OC;10.68% OM) and CS (5.66% OC;9.74% OM) and litters under AC possessed lowest OC (3.54%) and OM (6.09%). Nitrogen being a major essential and macronutrients directly helps in photosynthesis of plants as it is the main and major component of chlorophyll also it is the basic components of DNA protein, nucleotide, phosphatides etc. In our study we have found various results of nitrogen content where, lowest nitrogen content was found in the sample of AC and highest Nitrogen was found in the AL (0.553%) and DS (0.538%) and rest of the sample showed the nitrogen content from 0.402% to 0.470%. Phosphorus is one of the most important macronutrients, it helps in the growth and development of plants. Our study showed very high amount of phosphorus, varied from 0.1% to 2.9%; where litters of LL showed highest amount of phosphorus and AC showed lowest amount of phosphorus. Potassium is also very essential elements for plants for their phyto-growth, reproductivity, physiological activities. In our results, potassium content was found to be highest in the sample of MA (1.8%), LL (1.6%), DS (1.4%) respectively and lowest was found in AO (0.6%). Sulphur is very crucial element for plant growth as cysteine and methionine are the sulphur containing amino acid, which ultimately build plant body. Percentage of sulphur was found to be highest in the sample of LL (1.15%) followed by CS (0.9%) and lowest percentage was 0.21% found in both the sample of AO and DS. All the data have been given in Table 3 and Figure 1 illustrates the percentage of nutrient comparison. In a similar work done by Samanta et al. (2021) the absorption of nitrogen from soil per hectare of tea plantation compared to the absorption quantity of phosphate and potash, and the absorption amount of nitrogen, phosphate and potash in one hectare of plantation area were 280.8Kg, 1.3Kg and 21.3Kg respectively.

4. DISCUSSION

Being deciduous, shade trees shed huge amount of leaf, pod, twigs etc. as litter, which remain unutilized in the field or are used as mulching material in tea plantation. Biomass is an important parameter that can be considered to assess the atmospheric carbon harvested by green plants (Kale, Singh, Roy, Deosthali, & Ghole, 2004; Samanta et al., 2021). pH is an important determinant to maintain soil quality. Changes of pH is one of the main reasons for microbial growth and decrease of enzymatic properties, which ultimately resist the release of nutrients to the soil (Mukherjee et al., 2018). These shade tree litter on decomposition provide organic forms of carbon, nitrogen, phosphate, potassium, sulphate etc. to soil, that can be utilized by tea and other plants. With increase in demand for organic cultivation, source of cost-effective organic matter becomes an important issue. Besides nutrient supply, organic matter neutralizes pH by working as a buffer in aqueous solution. pH value of all the shade tree litters were below 7 in pH scale due to presence of organic acids like humic acid, fulvic acid etc. Tea plantation needed to maintain soil pH between 4.5-5.5, so shade tree litters have much beneficial role in maintaining the soil pH as pH value of AO, AL and CS were found to be very close to tea plantation soil. In tea plantations huge amount of NPK fertilizers are applied for increasing production, and in many cases fertilizer misuse has been recorded. According to our test reports huge quantity of NPK are added to soil by shade tree litter. Nitrogen content was very good in all the samples, varied from 0.311% to 0.553 %, where highest nitrogen percentage was delivered by STL of AL and lowest but very good amount has been found in the STL of AC. In case of available phosphorus, potassium highest percentages were found in the STL of LL (2.9%) and MA (1.8%) the lowest percentages were found in the STL of AC (0.1%) and AO (0.6%) respectively. But the STL of LL (1.15%) has shown highest percentage of available sulphur and lowest percentages were shown in STL of AO (0.21%) and DS (0.21%). Proper utilization of shade tree litter can reduce the use of inorganic inputs and providing a clean organic environment to the tea plantations.

5. CONCLUSION

Shade trees are inseparable part of tea plantation. They withdraw a considerable amount of nutrients from soil but at the same time they return back huge quantities of organic matter essential for retaining soil moisture and microbial activity. This research pointed out how much nutrients are returned back to soil and pH, EC, soil moisture etc. are regulated by shade trees. Proper utilization of shade trees like *Albizia lebbeck*; *Leucaena leucocephala*; *Melia azedarach; Derris robusta*; *Dalbergia sissoo* can help in reducing application of inorganic nutrients and maintaining a clean environment in tea plantation.

LIST OF ABBREVIATION:

STL: Shade tree litter; NPK: Nitrogen, phosphorus and potassium; OC: Organic carbon; OM: Organic matter; EC: Electrical conductivity; GBH: Girth at breast height; DBH: Diameter at breast height; BA: Basal area; AO: Albizia odoratissima; AC: Albizia chinensis; AL: Albizia lebbeck; DS: Dalbergia sissoo; DR: Derris robusta; CS: Cassia siamea; LL: Leucaena leucocephala; ALn: Acacia lenticularis; MA: Melia azedarach.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

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