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Editorial

The 48th volume of Tea Journal of Bangladesh contains six research articles.

The first article is on minimizing the use of inorganic fertilizer by increasing the use of organic fertilizer to sustain maximum yield of tea. Repeated applications of chemical fertilizers lead to the deterioration of soil properties and subsequently cause environmental damage. The application of organic manures has positive benefits over chemical fertilizers in improving soil fertility on the other hand application of organic manure & inorganic fertilizer in soil is a good agricultural practice for soil fertility and crop productivity. Application of both organic and inorganic fertilizers has optimized the yield of tea as well as minimize the inorganic fertilizer up to 15%.

The second article titled "Nutrient status of soil in the Tea Estates of Balisera Valley" is a study report on soil health condition and nutrient status of the tea estate's soils of Balisera Valley of Moulvibazar district. Tea is a perennial and monoculture crop. Every year for getting satisfactory yield and protect tea plants from pest and diseases enormous amount of chemical fertilizers and pesticides are using. It is the prime reason for the deterioration of the tea soil health and nutrient status. Therefore, it is utmost important to analyses the soils and evaluate the nutritional status of different tea estates to take necessary remedial measures to improve the soil fertility. This study reveals that nutritional value of most of the tea soils of Balisera Valley are quite lower than the critical value. These findings will be helpful for proper nutrient management practices to improve soil fertility & productivity.

Third article of this journal is on study for comparison of four mature and established tea clones which are released from BTRI and these are BT2, BT5, BT6 and BT8. Plantation year of these clones is 1995 in a field of BTRI and more than 20 years later yield and yield related parameters are being studied. Generally all of the clones perform well at the beginning of plantation however in this study yield related parameters were observed including casualty percentage of tea bushes at the completely mature and established condition. Among four clones, BT6 showed the highest yield which was similar to BT2 and the lowest was in BT5. Considering both yield related parameters and casualty percentage, BT2 was better than others.

The fourth article is related to the observations on spatio-temporal variation in soil moisture within the tea plantation. The efficient use of irrigation water and proper management of drainage system are dependent upon the availability of

reliable soil moisture data. Hence, there is a need to understand the soil moisture content and its distribution for an area with respect to both time and depth for proper planning of irrigation and drainage management. Again, among the many factors, soil moisture variation is also controlled by the type of vegetation. Therefore, soil moisture content at two tea plantation areas (BT2 & BT6) of Bangladesh Tea Research Institute (BTRI) were monitored at nine different depths almost every week in two consecutive years. The study was carried out using a sophisticated soil moisture gauge "Neutron Probe". From the study, it was noticed that soil moisture varies both spatially and temporally, but spatial variability is larger than the temporal variability. Types of vegetation exerts a great impact on the soil moisture content. Between the two tea clones compared, higher soil moisture content was noticed under BT2 plantation area compared to BT6 plantation area. The root system of both the BT2 and BT6 clones are mainly confined in between 15 cm to 105 cm soil depths and hereby water uptake is confined in between these depths.

The fifth article is about integrated nutrient management during poly bagging in secondary bed of VP nursery of tea. In this research work, combined effects of different nutrients (organic and inorganic) with different doses were evaluated. Considering all the factors, it is found that use of vermicompost @ 150 g per kg soil to fill polybags in VP nursery found most effective and at the same time use of Poultry manure in different doses showed detrimental effects on root growth of tea saplings in polybags.

The fourth article is about to determine the most economically viable and effective weed control approach in young tea plantation. About 4- 5% of the total cost of production of made tea is involved for weed control that is second to plucking and fertilizer application. Cost for weeding is very high as high cost of labor and increasing price of herbicides. Thus the strategies for controlling weeds in young tea plantations at minimum cost are of paramount importance for sustainable tea production. From this experiment, it is revealed that, treatment (Hand weeding + Glyphosate @ 3.7 Lha⁻¹) showed maximum reduction of weed density (62.05%) over the control after 45 days of spraying. Besides, it also significantly increases tea production (41.68%) over the control & highest marginal rate of return (770). Thereby the combination of (hand weeding + Glyphosate @ 3.7 Lha⁻¹) is recommended for economically cost effective, sustainable and effective weed control approach in young tea.

All these research articles would have direct impact on the technological thrust needed for the Bangladesh Tea Industry. The main objective of this journal is to

disseminate our new research findings to the tea industry for the improvement of tea culture, production and management. We sincerely express our heartiest gratitude to our respected Chairman and all the advisory members of Bangladesh Tea Board for providing all sorts of support to materialize this journal. I also express my heartfelt thanks to all the BTRI scientists who have worked so hard to make this journal possible by their valuable research findings.

(Dr. Mohammad Ali)
Chief Editor

RESPONSE OF ORGANIC AND INORGANIC SOURCES OF MANURE AND FERTILIZER ON SOIL PROPERTIES AND YIELD OF TEA

A. K. Saha^{1*}, A. Biswas², K. F. T. Zohora³, N. M. Ali⁴ and F. J. Chowdhury⁵

Abstract

Tea cannot be produced optimally without fertilizer application and external nutrient supply as it requires needs large amount of macro and micro nutrients for its growth. Chemical fertilizer application is the primary method used to maintain tea yield and quality, but has a negative environmental impact owing to its excessive use. Application of organic manure combined with or without inorganic fertilizer in soil is considered as a good management practice for sustainability of soil fertility and crop productivity. An experiment was conducted at Bilashcherra experimental farm of Bangladesh Tea Research Institute for minimizing the use of inorganic fertilizer by increasing the use of organic fertilizer to obtain the maximum yield of tea (*Camellia sinensis L.*). Different doses of organic manure along with the diverse rates of chemical fertilizers were applied in eight dissimilar treatments with three replications. The plucking data was recorded during harvesting season at seven days interval. The highest yield (1684 kg/ha) of made tea was recorded in the treatment T6 where 85% of the recommended dose of chemical fertilizer along with 6 t/ha organic manure were applied and the rate of increase over the control was 9.00%. The yield of tea was increased with the highest use of organic manure along with the reduced rate of chemical fertilizers from the recommended doses and the increase of yield due to different treatment was statistically significant at 1% level ($F = 23.99$). Treatment T6 treated plot showed maximum increase in pH (4.7), organic carbon (1.4%), total nitrogen (0.142%), available phosphorus

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(34.54 mg/kg), potassium (112.33 mg/kg), calcium (82.97 mg/kg) and magnesium (18.85 mg/kg) over its initial value among others.

Key words: Organic manure, chemical fertilizer, yield, tea.

Introduction

Tea is the most popular, inexpensive beverage throughout the world because of its characteristic aroma and flavour produced from the shoots of the commercially cultivated tea plants [*Camellia sinensis* (L.) O. Kuntze]. After water, it is the most widely consumed drink in the world. Tea is grown in more than 50 countries, mostly as plantation (Gebrewold, 2018). The principal categories of tea-green, black and oolong-originate from a single tea plant, a white-flowered evergreen tea. Tea shoots are plucked at regular intervals which remove various quantities of different elements from the plant-soil system. Therefore, certain major nutrients have to be supplemented through fertilizer application. Tea plant needs large amount of micro and macro nutrients for its growth. The deficiency of these nutrients could adversely affect the yield and quality.

Chemical fertilizer application is the primary method used to maintain tea yield and quality, but has a negative environmental impact owing to its excessive use (Wang *et al* 2020). Excessive use of inorganic fertilizers leads to deterioration of soil physical and chemical properties, air pollution through nitrous gas emission and excessive leaching leads to underground water pollution. The soil degradation causes loss of organic matter, nutrient imbalance, and reduced crop yield and finally, the soil becomes unsuitable for cropping.

Overwhelming uses of chemical fertilizer as such without conservation of soil fertility not only results in depletion of soil nutrient reserves but also it disrupts the biological eco balance of soil - plant system (Singh *et al*, 2011).

The world has been shifting to environmentally safe and economically viable alternatives for crop production. Hence, to meet the increasing demand of tea, crop production has to be increased per unit area of land. Manmade fertilizers containing nitrogen, phosphorus and potassium have increased the output of agricultural products. The use of organic manure is a very well-established sources of organic matter to supplement the nutritional requirement of any crop. Therefore, the strategy for improving agricultural production in developing countries should consider supplementing nutrition through organic

manuring processes (Gebrewold, 2018). Nutrients contained in organic manure are released slowly and are stored for a longer time in the soil, thereby ensuring a more prolonged residual effect and persistence of nutrient availability. On the other hand, for the improvement of soil condition and maintenance of soil health to ensure optimum production, there is a need to reduce the cost of fossil fuel based inorganic fertilizers which have significant adverse influence on the environment. A combined application of balanced inorganic fertilizer and supplementary dose of organic manure sustains crop productivity and maintains soil fertility (Singh *et al*, 2011).

The quality of tea is greatly influenced by both agro-climatic conditions and nutrient management. For a few decades the deleterious impact of the continuous use of chemical fertilizers alone in agriculture have been observed. Chemical fertilizers indeed boost up crop production initially and gradually it causes decrease in fertilizer use efficiency. Integrated plant nutrient supply not only sustains the soil and crop productivity but also ensures environmental and ecological security. Application of nutrients through organic sources stimulates the activity of soil microorganisms, improves the structure/texture of soil, plant nutrients holding capacity and increases the availability of plant nutrients (Singh *et al*, 2011). The appropriate combination of mineral fertilizers and organic manures varies according to the system of land use and ecological conditions. Results from systematic field experiments on integrated supply of organic and inorganic doses are still in dark. With this drop back, the present study focused on increase the use of organic manure and reduce use of chemical fertilizer in tea production.

Materials & methods

A five years long experiment was conducted at Bilashcherra Experimental Farm (BEF) to observe the performance of organic manure on different levels in reducing the chemical fertilizer use for maximizing yield of tea. The experiment was laid out in a Randomized Complete Block Design (RCBD) having eight treatments (Table 1) with three replications. Nitrogen (N), Phosphorus (P) and Potassium (K) nutrients were applied through urea, triple super phosphate (TSP) and muriate of potash (MOP) respectively. The unit plot size was 14.90 sq.m. Before fertilization, dolomite was applied in every experimental plot except control depending on soil pH and sufficient soil moisture. Every year chemical fertilizers were applied after a good shower of rain. Urea and MOP

fertilizer were applied in two splits. Cow-dung was applied as organic manure mixed with the soil by light forking in two split doses before 15 days of chemical fertilizer application. In every year, first dose of fertilizer was applied in the month of April & second dose was applied in the first week of August.

Table 1: Details of treatments

Symbol	Treatment details
T ₁	Control (No organic manure and chemical fertilizer)
T ₂	Recommended doses of chemical fertilizers (N ¹⁰⁰ , P ³⁰ , K ⁶⁰ kg/ha)
T ₃	Organic manure (2t/ha)
T ₄	Organic manure (6t/ha)
T ₅	85% of T ₂ + Organic manure (2t/ha)
T ₆	85% of T ₂ + Organic manure (6t/ha)
T ₇	70% of T ₂ + Organic manure (2t/ha)
T ₈	70% of T ₂ + Organic manure (6t/ha)

Yield of tea *i.e.* the weight of green leaves was recorded during harvesting season at seven days interval. Irrigation, pruning, pest control and other intercultural operations were done as and when necessary. Data on yield were recorded and analyzed statistically by Statistix 10.0.

Initial and post-harvest soil samples were collected from a depth of 0-9 inches to determine different soil physio-chemical properties viz. soil texture, pH, organic carbon (%), total nitrogen (%), available phosphorus (ppm), potassium (ppm), calcium (ppm) and magnesium (ppm). Soil texture was determined by hydrometer method. However, pH was determined by using pH meter (soil: distilled water = 1 : 2.5). Soil organic carbon was determined using wet oxidation method developed by Walkley and Balck. For determination of total nitrogen Micro Kjeldahl steam distillation method was applied (Imamul Huq and Alam, 2005). Colorimetric estimation of available phosphorus was done by ascorbic acid method. Available potassium, calcium and magnesium were extracted with 77% ammonium acetate solution. Available K was determined by flame photometer while calcium and magnesium were determined by AAS (atomic absorption spectrophotometer) and data were analyzed statistically. Physical and chemical analysis of organic manure (cow-dung) was done. The moisture % was calculated as a percentage for organic manure according to the method described by Page *et al.* (1982). The pH of organic manure was determined in compost-water suspension (1:10) according to Jodice *et al.*

(1982). Organic matter, total N, P and K content were determined in organic manure as reported by Jackson (1973).

Result and Discussion

Table 2 represented the analytical results of organic manure (cow-dung) which was applied during the experiment. The physico-chemical analysis of supplied organic manure reveals that, it is an excellent source of organic matter (43.06%) and it also contain organic carbon (25.04%), total N (1.98%), P (0.64%), and K (0.43%) respectively.

Table 2: Analytical results of organic manure

Parameters	Organic manure (Cow-dung)
pH	7.36
Moisture content (%)	59.92
Dry matter (%)	40.08
Organic matter (%)	43.06
Organic carbon (%)	25.04
Total Nitrogen (%)	1.98
Ash (%)	56.93
Total Phosphorus (%)	0.64
Total Potassium (%)	0.43

The effect of organic manure on the yield of tea is presented in Table 3 and result showed that, every treatment has increased yield over the control. Maximum made tea yield (1684 kg/ha) was found in treatment T6 which receiving 85% of recommended doses of chemical fertilizers and 6t/ha organic manure. The rate of increase over the control was 9.00% in case of treatment T6. Among the treatments, T5 is the second-best treatments where made tea yield was 1667 kg/ha and the rate of increase over the control was 7.90%. Made tea yield increase in the case of treatment T7 and T8 over the control was 6.92% and 7.18%. Made tea yield under combination with inorganic and organic manures gave better result, because of the improved physical condition of the soil, thereby improving the efficiency in utilization of native as well as applied nutrients which ultimately improved the yield attributing characters and yield. These results corroborate the finding of Bhandari *et al.* (1992) and Premi and Kalia (2003). Ipinmoroti *et al.* (2009) also reported that the use of the organic fertilizer in combination with inorganic fertilizers gave better yield.

Table 3: Effect of organic manure on the yield of tea

Treatment	Made tea yield (kg/ha)	% increase over control
T ₁	1545e
T ₂	1567de	1.42
T ₃	1595d	3.24
T ₄	1629c	5.44
T ₅	1667ab	7.90
T ₆	1684a	9.00
T ₇	1652bc	6.92
T ₈	1656abc	7.18

CV (%) = 1.09, SE = 0.0939

Figure 1 shows the effect of different treatments on the made tea yield. The made tea yield was gradually increased in the case of treatments T₃, T₄, T₅ and T₆ compare to T₁ and T₂. But the made tea yield due to treatments T₇ & T₈ was increased over the made tea yield due to treatments T₁ and T₂ while the yield of made tea was declined than made tea yield due to the treatments T₅ and T₆. The result also shows that there is no significant difference among treatment T₆, T₇ and T₈; T₄ and T₇; T₁, T₂ and T₃ (Table 3). But the increase of yield due to different treatments was statistically significant at 1% level (F= 23.99).

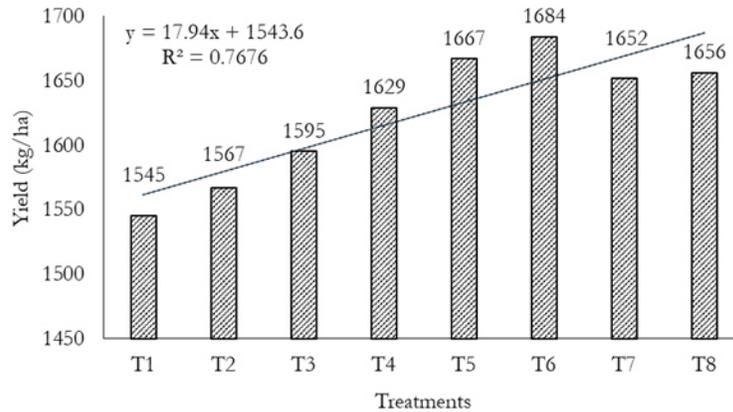


Fig 1. Effect of different treatments on the yield of tea

Tea may be grown on soils of diverse geological origins. In Bangladesh most soils are quaternary and recent alluvia. Tea soils are highly weathered,

extremely acidic and low of fertility status. Furthermore, these soils do not receive deposits of fertile silt by flooding; rather they suffer from erosion (Khan et al, 2013). Table 4 & 5 presented analytical results of the soil samples which were collected from the experimental plots before set up the experiment and after completion of the experiment.

Table 4. Initial physico-chemical properties of the soil of experimental site

Soil Properties	Analytical Value	Critical Value (Khan <i>et al</i> , 2013)
Texture	Sandy Clay Loam (SCL)	Sandy Loam to Loam (SL-L)
pH	4.3	4.5 to 5.8
Organic Carbon (%)	1.03	1.0
Total Nitrogen (%)	0.106	0.1
Available Phosphorus (mg/kg)	5.12	10
Available Potassium (mg/kg)	52.4	80
Available Calcium (mg/kg)	43.2	90
Available Magnesium (mg/kg)	6.3	25

Table 5. Effect of organic manure on the physico-chemical properties of soil

Treatment	Texture	pH	O. C %	Total N %	Av. P mg/kg	Av. K mg/kg	Av. Ca mg/kg	Av. Mg mg/kg
T ₁	Sandy Clay Loam	4.2	0.98	0.099	10.88	50.97	58.41	8.25
T ₂	Sandy Clay Loam	4.3	1.01	0.102	21.41	51.57	66.78	10.96
T ₃	Sandy Clay Loam	4.3	1.25	0.127	21.63	51.79	68.25	11.62
T ₄	Sandy Clay Loam	4.4	1.32	0.135	22.59	59.00	73.90	15.20
T ₅	Sandy Clay Loam	4.6	1.29	0.131	31.22	77.83	81.52	16.46
T ₆	Sandy Clay Loam	4.7	1.40	0.142	34.54	112.33	82.97	18.85
T ₇	Sandy Clay Loam	4.5	1.22	0.125	28.07	63.37	77.80	15.92
T ₈	Sandy Clay Loam	4.6	1.26	0.129	29.51	74.25	80.95	16.27

Figure 2 shows the effect of different treatments on the changes in soil pH. The maximum increase in pH over its initial value was recorded in the plots receiving treatment T6 where 85% of recommended doses of chemical fertilizers and 6t/ha organic manure were applied.

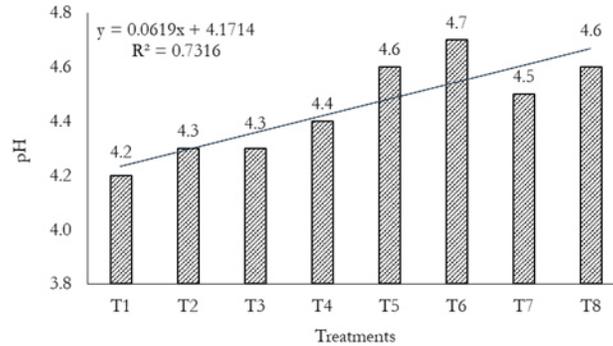


Fig 2: Effect of different treatment on the changes of soil pH

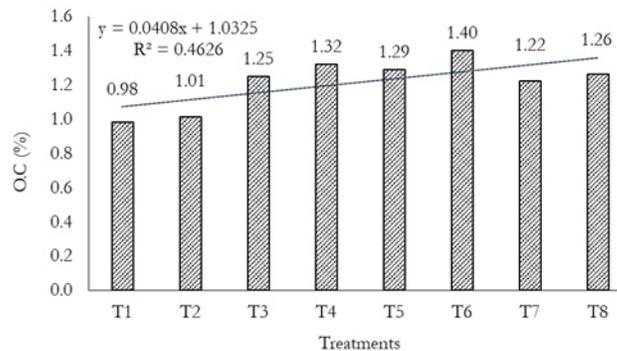


Fig 3: Effect of different treatment on the changes of soil organic carbon

However, a reduction in soil pH over its initial value was in the control plots. The increase in pH of the soil in the plots receiving organic manure and combined application of organic and inorganic fertilizers might be due to the application of dolomite every year.

It is clear from figure 3 that the application of chemical fertilizer alone had no effect on the increase in the organic carbon content of the soil over its initial value, while a higher build-up of organic carbon was observed in the treatments where organic manure was applied alone followed by combined application of

organic and inorganic fertilizers. The increased organic carbon content of the soil in the plots receiving organic manure might be due to the direct incorporation of organic matter through organic manure in the soil. In contrast, in the plots receiving the combined application of inorganic and organic fertilizers it was probably due to enhanced plant growth leading to more organic residues in the soil. These results are in close conformity with the finding of Hegde (1996). Raju and Reddy (2000) also reported that the application of green manure increased the organic carbon status of soil over its initial value.

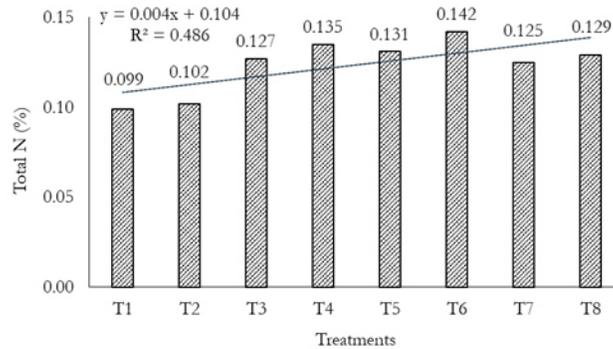


Fig 4: Effect of different treatment on the changes of total nitrogen

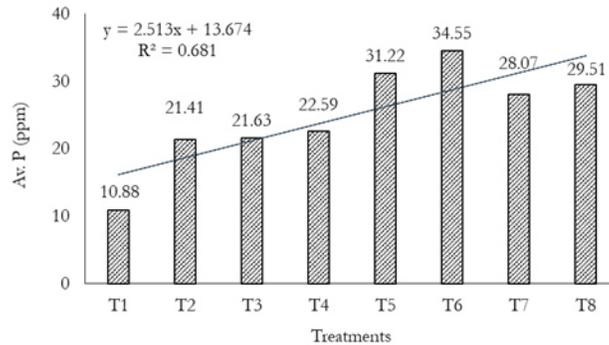


Fig 5: Effect of different treatment on the changes of available phosphorus

Figure 4 shows the effect of different treatment on the changes of total nitrogen in soil. The increase in the content of total N in soil under the treatments having organic manure alone and combination of chemical fertilizers and organic manure might be because of build-up of organic matter due to application of organic manure. Organic matter also reduced the losses of

nitrogen and thus the content of total N had increased. Similar observations were also made by Sharma and Ghosh (2000).

Figure 5 shows the effect of different treatment on the changes of available phosphorus in soil. The maximum available phosphorus (34.54 mg/kg) was observed under the treatment T6 receiving 85% of recommended doses of chemical fertilizers and 6t/ha organic manure. Chettri and Bandopadhyay (2005) also reported that the available phosphorus was improved with the application of 75% NPK + green manure.

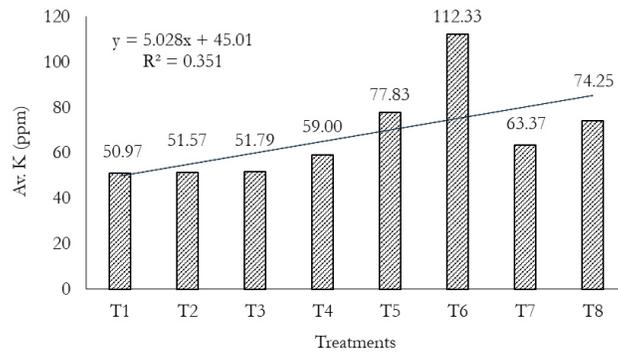


Fig 6: Effect of different treatment on the changes of available potassium

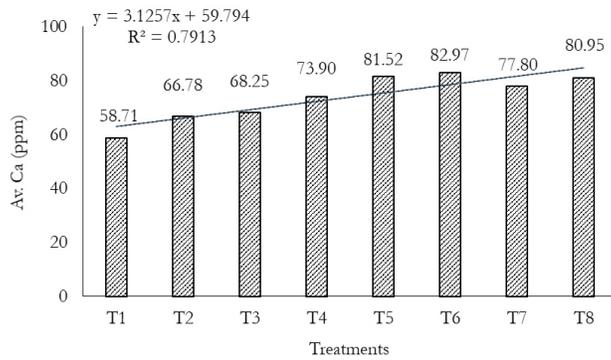


Fig 7: Effect of different treatment on the changes of available calcium

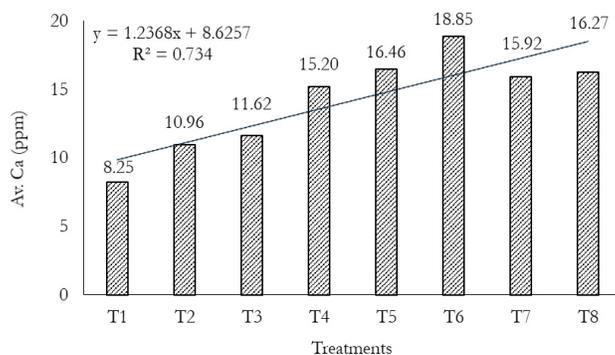


Fig 8: Effect of different treatment on the changes of available magnesium

Figure 6 shows the effect of different treatment on the changes of available potassium in soil. Maximum available potassium (112.33mg/kg) was measured in the plot receiving the treatment T₆. It might be due to direct addition of potassium to the available pool of the soil as well as the beneficial effects of organic manure on the available K might be ascribed to the reduction of fixation and release of K due to the interaction of organic matter with clay. Anand *et al*(2000) reported a marginal improvement of K status with 100 and 150% N, P, K treatments.

Figure 7 & 8 shows the effect of different treatment on the changes of available calcium and magnesium in soil. The maximum available calcium (82.97 mg/kg) and available magnesium (18.85 mg/kg) was also observed under the treatment T₆. The increase in the availability of calcium and magnesium in soil under the treatments having organic manure alone and combination of chemical fertilizers and organic manure might be because of application of dolomite every year as well as build-up of organic matter due to application of organic manure. However, Clark *et al.* (1998) and Bulluck *et al.* (2002) reported that these elements were higher in organic farming systems.

Conclusion

Tea is an aromatic beverage commonly prepared by pouring hot or boiling water over cured leaves of *Camellia sinensis*, an evergreen shrub (bush). Soil fertility has been described as the capacity of soils to make nutrients available to plants. Nutrient management in tea plantations is an important aspect, and nutrients are supplied mainly through chemical fertilizers. However, it is widely accepted that a balanced fertilizer application with efficient use of other inputs is the key to achieve higher crop production. Repeated and heavy applications of chemical mineral fertilizers lead to the deterioration of soil

properties and subsequently cause environmental damage. The application of organic manures could minimize these problems as they have positive benefits over chemical fertilizers in improving soil fertility. The findings revealed some valuable benefits of combined application of organic manure and chemical fertilizers over sole application of organic manure or chemical fertilizers in tea production.

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NUTRIENT STATUS OF SOIL IN THE TEA ESTATES OF BALISERA VALLEY

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Abstract

A study was carried out in the tea estates of Balisera valley to investigate the fertility status of soil. The results of the present study showed that soil textures of the study area were found to be Sandy loam, sandy clay loam, and clay loam in nature. The average soil pH was 4.42, and the pH value of 48.15% of the total collected soil samples was less than the critical value of 4.5. The average organic carbon and total nitrogen content of the soil samples were 0.93% and 0.094%, respectively. In addition, the organic carbon content of 55.6% of the total collected soil sample was less than the critical value of 1.0%, whereas nitrogen content of 51.9% of soil samples was less than the critical value of 0.1%. The average available phosphorus and available potassium content of the soil samples of Balisera valley were 39.83 mg/kg and 73.83 mg/kg, respectively. Moreover, 25.9% of the total collected soil sample's available phosphorus content was less than the critical value of 10 mg/kg, and 55.55% soil sample's available potassium content was less than the critical value 80 mg/kg. The average available calcium and available magnesium content of the soils was 74.46 mg/kg and 17.01 mg/kg, respectively. Moreover, 85.19% of the total collected soil sample's available calcium content were less than the critical value of 90 mg/kg, and 81.48% soil sample's available magnesium content was less than the critical value of 25 mg/kg. The soil pH was positively correlated with available calcium ($r = 0.8972^{**}$) and available magnesium ($r = 0.9374^{**}$). Soil organic carbon had a positive correlation with total nitrogen ($r = 0.9213^{**}$). The available phosphorus also had a positive correlation with available potassium content ($r = 0.5275^{**}$), while a significant positive correlation was also observed between available calcium and available magnesium ($r = 0.4401^*$) of the soil. The pH, organic carbon, total nitrogen, available phosphorus, available potassium, available calcium, and available

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magnesium contents of most of the collected soil samples were found to be quite lower than the critical value considered ideal for tea cultivation. Lime (dolomite) treatment and adequate inorganic fertilizers as per BTRI recommendations as well as organic based fertilizer for maintaining the active acidity level, proper nutrient management practices like retention of pruning litters, shade tree droppings, and weed mass are recommended to achieve sustainable productivity.

Key words: Fertility status, soil pH, organic carbon, tea estates, Balisera valley

Introduction:

Soil fertility status is the nutritional condition of the soil to grow better crops which are closely related to the success and failure of agriculture. It is necessary that all the needs of plants be met according to their requirements for healthy growth. A scarcity of nutrients can cause severe restrictions to crop growth as well as decrease the fertility of the soil. The main reason for the variation of soil properties is the difference in parent material of soil, climate, irrigation, and biological activity. Shortage of soil nutrient content and extensive fertilization create soil acidification problems which are more prominent (Liu J. *et. al.*, 2003; Xiao R.L.*et. al.*, 2004). It restricted the sustainable development of the tea production and the sustainable utilization of the tea plantations soil. Nutrient status of the tea soil is the conclusive factor for vigorous growth and the quality of tea (Liang Y. F. *et. al.*, 2003).

Tea (*Camellia sinensis* L.) is a perennial evergreen plant growing in many soil types derived from various parent materials in tropical, subtropical, and temperate climates. It is an important cash crop, which is considered a major agricultural commodity that sustains the economy of Bangladesh. Under marginal climatic conditions, Bangladesh Tea is also being grown in different soil types. Cultivation of tea for quite long years in a particular garden leads to the loss of the desired yield due to deterioration in soil quality.

Nutrient management has greater importance, particularly to sustain yield potential and improvement of soil health. In a given locality, however, soil characteristics and nutrient parameters play an important role for better tea production (Khanda *et al*, 2019). Tea soils are generally rich in aluminum ions (Al^{3+}) and those ions also indirectly cause soil acidity. A soil suitable for tea growing is moderately acidic with pH ranging from 4.5 to 5.5. Any significant deviation from this range could cause difficulties in the uptake of nutrients (Kavitha *et al*, 2016). Nutrient requirements for commercial tea production are particularly high because the harvestable portions of tea are succulent shoots,

which contain the largest percentage of nutrients in the plant. Thus, nutrient recycling and mineral balance are important factors affecting nutrient budgets in tea garden soil. Fertilization is known to balance nutrient cycling and improve plant growth and crop yield. Nitrogen, phosphorous and potassium are the three major nutrients of the soil which plants use in large amounts for their growth and survival (Haorongbam *et al*, 2014). Nitrogen (N) fertilizer is to improve tea yield and quality, especially for the synthesis of amino acids critical for producing high-quality green tea (Ruan *et. al*, 2010, Mudau *et. al*, 2007), and the metabolism of minerals and metabolite products is influenced by phosphate (P) uptake (Ding *et al*, 2017). Tea yield and the synthesis of amino acids and caffeine is greatly influenced by Potassium (K) (Sharma and Sharma, 1998), and application of K fertilizer can significantly increase water-extractable dry matter (Ruan *et. al*, 2013). Nutritional requirement of these tea plants is met by the inherent supplying capacity of soil as well as by the inorganic and organic fertilizers that are applied additionally.

Soil testing plays an important role in the use of fertilizers and other agricultural inputs. Soil test summaries are of vital necessity as reference materials for scientific management of soil. Different indicators and parameters such as soil texture, pH, soil organic matter (SOM), total nitrogen, available phosphorous, potassium, calcium, magnesium etc. are appropriate for describing soil quality and agricultural productivity (Baruah *et al*, 2013). The critical values in Bangladesh condition have been fixed at sandy loam to loam for soil textural class, 4.5 to 5.8 for pH, 0.1% for nitrogen, 1% for organic matter, 10 mg/kg for P, 80 mg/kg K, 25 mg/kg for Mg and 90 mg/kg for Ca (Khan *et al*, 2013). The need of the hour is to achieve substantially higher crop yield than the present yield levels from our limited land resources. Thus, the present study was undertaken to draw a general picture of fertility level of soils in and around tea gardens of Balisera valley of Moulvibazar district in order to strengthen the national and local soil quality database so that purpose-oriented soil assessments and predictions can be made in the area. This information will also help to adopt effective strategy on fertilizer management in the tea field.

Methodology:

The soil samples that were sent from different tea gardens of Balisera valley to Bangladesh Tea Research Institute (BTRI) for routine physico-chemical analysis are taken into consideration in this investigation. Samples received from the tea gardens are Amrail Tea Estate (T.E.), Amtali T.E., Balisera T.E., Baraora T.E., Bilashcherra Experimental Farm (BEF) of BTRI, Clonal T.E., Daragaon T.E.,

Dauracherra T.E., Deanston T.E., Dinarpur T.E., Hamidia T.E., Horincherra T.E., Hooglicherra T.E., Hossainabad T.E., Moulvi T.E., Mazdehee T.E., Mirzapore T.E., Nahar T.E., Nurjahan T.E., Parkul T.E., Premnagar T.E., Rasidpur T.E., Rajghat T.E., Saif T.E., Sathgao T.E., Sreebari T.E. and Zareen T.E. Physical and chemical analyses of the collected soil samples were done by standard analytical procedure at the soil science laboratory of Bangladesh Tea Research Institute.

Soil samples were collected from a depth of 0-23 cm. Texture, pH, organic carbon (%), total nitrogen (%), available phosphorus (mg/kg), available potassium (mg/kg), available calcium (mg/kg) and available magnesium (mg/kg) of the soil samples were determined.

Table 1: The selected parameters and the methods of determination

Parameters	Method	References
Soil parameters (physical & chemical)		
Texture	Hydrometer method	Day, 1965
pH	Glass electrode pH meter (1:2.5 soil water ratio)	Imamul and Didar, 2005
OC	Walkley-Black potassium dichromate wet oxidation method	Walkley and Black, 1934
Total N	Micro-Kjeldahl method	Bremner and Mulvaney, 1982
Available P	Ascorbic acid blue color method	Murphy and Riley, 1962
Available K	Flame photometer	Imamul and Didar, 2005
Available Ca, Available Mg	Atomic absorption spectrophotometer (AAS)	Imamul and Didar, 2005

Data were analyzed statistically by using the software Statistix 10.0.

Result and Discussion:

Table 2 shows the nutrient status of soils of different tea estates of Balisera valley. The texture of the collected maximum soil samples varies from sandy loam to sandy clay loam. But the texture of the soil samples of Baraooora, Moulvi and Sreebari tea estates samples are clay loam. Soil texture may affect productivity in a variety of ways i.e. by affecting moisture availability, soil temperature, nutrient supply and the accessibility of soil organic matter to microbial decomposition.

Table 2: Physico-chemical properties of tea soils of Balisera valley

Name of T.E.	Depth (cm)	Texture	pH	OC (%)	TN (%)	Av. P (mg/kg)	Av. K (mg/kg)	Av. Ca (mg/kg)	Av. Mg (mg/kg)
Amrail	0-23	Sandy Loam	4.50	1.07	0.11	6.55	103.41	78.42	16.39
Amtali	0-23	Sandy Clay Loam	4.10	1.01	0.10	31.39	76.35	60.12	7.08
Balisera	0-23	Sandy Clay Loam	4.71	0.94	0.10	17.96	45.27	87.59	24.50
Baraoora	0-23	Clay Loam	4.20	0.41	0.05	67.35	78.44	65.84	8.56
BEF	0-23	Sandy Clay Loam	4.80	1.14	0.117	58.88	91.03	91.19	28.97
Clonal	0-23	Sandy Loam	4.40	1.05	0.093	2.35	24.54	46.14	7.34
Daragaon	0-23	Sandy Clay Loam	4.16	1.00	0.10	45.87	87.94	68.77	10.35
Dauracherra	0-23	Sandy Clay Loam	4.64	0.61	0.06	1.67	53.12	84.02	22.47
Deanston	0-23	Sandy Loam	3.89	0.86	0.09	16.89	80.83	51.32	6.49
Dinarpur	0-23	Sandy Clay Loam	4.78	1.04	0.10	46.86	95.00	84.86	20.93
Hamidia	0-23	Sandy Loam	4.60	1.00	0.104	2.73	58.67	84.69	23.01
Horincherra	0-23	Sandy Clay Loam	3.89	0.93	0.10	278.53	125.11	52.25	5.12
Hooglicherra	0-23	Sandy Clay Loam	3.87	0.79	0.08	12.27	97.63	51.48	7.07
Hossainabad	0-23	Sandy Loam	3.90	0.99	0.102	7.41	37.87	38.65	3.82
Moulvi	0-23	Clay Loam	3.98	1.05	0.08	30.37	55.02	55.56	4.65
Mazdehee	0-23	Sandy Clay Loam	4.61	0.87	0.09	22.40	42.82	92.35	24.25
Mirzapore	0-23	Sandy Clay Loam	4.51	0.84	0.09	46.13	55.65	84.38	22.64
Nahar	0-23	Sandy Clay Loam	5.50	0.82	0.085	39.55	68.72	105.82	37.86
Nurjahan	0-23	Sandy Loam	4.70	1.06	0.12	50.25	120.69	87.89	25.61
Parkul	0-23	Sandy Clay Loam	4.10	0.56	0.061	20.73	37.61	60.85	7.12
Premnagar	0-23	Sandy Clay Loam	4.53	1.32	0.11	6.57	62.96	77.47	15.75
Rasidpur	0-23	Sandy Clay Loam	4.18	0.90	0.09	87.05	87.87	60.30	10.22
Rajghat	0-23	Sandy Loam	4.33	1.21	0.12	12.13	109.88	72.77	112.15
Saif	0-23	Sandy Clay Loam	4.56	1.36	0.14	10.87	83.69	74.34	15.11
Sathgao	0-23	Sandy Clay Loam	4.50	0.68	0.070	89.09	96.77	78.89	15.12
Sreebari	0-23	Clay Loam	4.30	0.90	0.096	5.33	37.8	69.05	9.08
Zarreen	0-23	Sandy Clay Loam	5.20	0.76	0.080	58.36	78.82	103.31	37.08

Descriptive Statistical analysis of the soil nutrient status

Mean			4.42	0.93	0.094	39.83	73.83	74.46	17.01
SD			0.3976	0.2155	0.0199	54.145	27.053	17.461	9.7849
Minimum			3.87	0.41	0.05	1.67	24.54	38.65	3.82
Maximum			5.50	1.36	0.14	278.53	125.11	105.82	37.86

In the present findings, the soil textures of the study areas were found to be Sandy loam, sandy clay loam and clay loam in nature, which might have favoured tea plantation. The texture of soil cannot be changed easily in such a way that there is a preferential migration of finer soil particles to the lower layers due to the changes brought by organic matter and root activities of plants under the plantation (Haorongbam *et al*, 2014).

The critical value of soil pH for tea plantation is 4.5 to 5.8 (Khan *et al*, 2013). From the pH test of the collected samples, it is revealed that soil pH of Amtali, Baraoora, Clonal, Daragaon, Deanston, Horincherra, Hooglicherra,

Hossainabad, Moulvi, Parkul, Rasidpur, Rajghat and Sreebari tea estates are below the critical range while soil pH of the rest of the gardens are within the critical limit. The highest soil pH value 5.50 was found in the Nahar tea estate while the lowest soil pH value 3.87 was recorded in the Hooglicherra tea estates. The average soil pH value of Balisera valley was 4.42 (Table 2) and the pH value of 48.15% of the total collected soil samples was less than the critical value 4.5. The infiltration long-term rainfall, fertilization with excessive nitrogen fertilizer and the root metabolism of the tea tree itself may be the causes of acidification of tea garden soil (Zhang, 2018).

Khan *et al* (2013) stated that the critical values of organic carbon and total nitrogen in tea soil are 1% and 0.1%, respectively. From the soil analytical results (Table 2), it is revealed that soil organic carbon of Amrail, Amtali, BEF (Bilashcherra Experimental Farm), Clonal, Daragaon, Dinarpur, Hamidia, Moulvi, Nurjahan, Premnagar, Rajghat and Saif tea estates are above the critical limit while in case of rest of the gardens, soil organic carbon are below the critical limit and the higher content of organic carbon may be due to the continuous agronomic practices and decomposition of pruning materials and leaf litter. So, management practices, including fertilizer application, pruning of tea trees, and soil tillage, might also have a substantial impact on organic carbon content (Haorongbam *et al*, 2014).

Total nitrogen content of Amrail, Amtali, Balisera, BEF (Bilashcherra Experimental Farm), Daragaon, Dinarpur, Hamidia, Horincherra, Hossainabad, Nurjahan, Premnagar, Rajghat and Saif tea estates are above the critical limit and this might be due to the contribution of organic matter derived from tea plant litter (Haorongbam *et al*, 2014). Total nitrogen of soil in case of rest of the gardens are below the critical value. The total nitrogen content in soil was below the critical value may be due to less inputs of fertilizer nitrogen and or organic amendments (Ray and Mukhopadhyay, 2012). The highest organic carbon 1.36% and total nitrogen content 0.14% were found in the soils of Saif tea estate while the lowest organic carbon 0.41% and total nitrogen content 0.05% were recorded in the soils of Baraooora tea estates. The average organic carbon and total nitrogen content of the soils of Balisera valley was 0.93% and 0.094%, respectively (Table 2). In addition, organic carbon content of 55.55% of the total collected soil samples was less than the critical value 1.0% whereas total nitrogen content 51.85% of the samples were below the critical value (0.1%).

Khan *et al* (2013) stated that the critical value of available phosphorus in tea soil is 10 mg/kg. From the soil analytical results (Table 2), it is revealed that available phosphorus in soil of Amrail, Clonal, Dauracherra, Hamidia, Hossainabad, Premnagar and Sreebari tea estates are below the critical value while rest of the gardens available phosphorus in soil are above the critical value. Wide variation of available P in soil might be due to the fixation of P in soil as insoluble aluminum and iron phosphate (Ray and Mukhopadhyay, 2012). Moreover, the critical value of available potassium in tea soil is 80 mg/kg (Khan *et al*, 2013). Available potassium in soil of Amtali, Balisera, Baraora, Clonal, Dauracherra, Hamidia, Hossainabad, Moulvi, Nahar, Parkul, Premnagar, Sreebari and Zarreen tea estates are below the critical value while available potassium in the soil of rest of the gardens are above the critical value. These large variations in available K content might be due to the non-uniform application of K fertilizers (Ray and Mukhopadhyay, 2012). The highest available phosphorus 278.53 mg/kg and available potassium content 125.11 mg/kg were found in the soils of Horincherra tea estate and lowest available phosphorus content 1.67 mg/kg was recorded in the soils of Dauracherra tea estate. But the lowest available potassium content 24.54 mg/kg was recorded in the soils of Clonal tea estate. The average available phosphorus and available potassium content of the soils of Balisera valley was 39.83 mg/kg and 73.83 mg/kg, respectively (Table 2). Moreover, available phosphorus content of 25.93% of the total collected soil samples was less than the critical value 10 mg/kg whereas in case of potassium 55.55% soil samples was less than the critical value 80 mg/kg. Continuous use of fertilizers and intensive cropping had resulted in lowering the potassium status of soil indicating the need to apply the potassium to meet the crop requirement (Baruah *et al*, 2013).

Khan *et al* (2013) stated that the critical values of available calcium and available magnesium are 90 mg/kg and 25 mg/kg, respectively. From the soil analytical results (Table 2), it is revealed that available calcium in soil of BEF (Bilashcherra Experimental Farm), Mazdehee, Nahar and Zarreen tea estates are above the critical value while available calcium content in soil of maximum tea gardens are below the critical value. Besides, the available magnesium content in soil of BEF (Bilashcherra Experimental Farm), Nahar, Nurjahan and Zarreen tea estates are above the critical value while available magnesium in soil of most of the gardens are below the critical value. The available calcium and magnesium content were low, might be due the surface leaching of basic cations by the excessive rainfall, higher acidity and poor application of liming materials in soils (Ray and Mukhopadhyay, 2012). The highest available calcium 105.82

mg/kg and available magnesium content 37.86 mg/kg were found in the soils of Nahar tea estate while the lowest available calcium 38.65 mg/kg and available magnesium content 3.82 mg/kg were recorded in the soils of Hossainabad tea estate. The average available calcium and available magnesium content of the soils of Balisera valley was 74.46 mg/kg and 17.01 mg/kg, respectively (Table 2). Moreover, available calcium content of 85.19% of the total collected soil samples was less than the critical value 90 mg/kg whereas in case of magnesium 81.48% of the soil samples were below the critical level (25 mg/kg).

Table 3: Correlation matrix among soil chemical properties of Balisera valley

Soil properties	pH	Org. C	Total N	Av. P	Av. K	Av. Ca	Av. Mg
pH	1						
Org. C	NS	1					
Total N	NS	0.9213**	1				
Av. P	NS	NS	NS	1			
Av. K	NS	NS	NS	0.5275**	1		
Av. Ca	0.8972**	NS	NS	NS	NS	1	
Av. Mg	0.9374**	NS	NS	NS	NS	0.4401*	1

NS= Not Significant, *Significant at 5% level, **Significant at 1% level

Table 3 shows correlation matrix among soil chemical properties of Balisera valley. The soil pH was positively correlated with available calcium ($r = 0.8972^{**}$) and available magnesium ($r = 0.9374^{**}$) at 1% level of significance which indicated that availability of calcium and magnesium were dependent on soil acidity. Soil organic carbon had a positive correlation with total nitrogen ($r = 0.9213^{**}$) at 1% level of significance suggesting that soil organic carbon increased the nutrient content under tea growing soils. The available phosphorus had also a positive correlation with available potassium content ($r = 0.5275^{**}$) at 1% level of significance. The significant positive correlation was observed between available calcium and available magnesium ($r = 0.4401^*$) of the soil at 5% level.

Conclusion

The growth and quality of tea trees are closely related with soils condition. The soil nutrient status of the different tea estates of Balisera valley indicated different physicochemical characteristics of the soils (texture, soil pH, organic carbon content, total nitrogen, available phosphorus, available potassium, available calcium and available magnesium content of the soils). Therefore, this

would provide an appropriate measure on the problem of the tea soils of Balisera valley. However, application of more labile organic inputs, liming materials and suitable inorganic fertilizers (N-P-K) would be effective for sustainable management and improving fertility status of the soils under tea estates of Balisera valley. The use of recommended dose of chemical fertilizers over the years may impair the soil fertility on long-term basis. Now, it is utmost important to develop an integrated inorganic-organic soil fertilization programme for higher crop yield and improved soil health.

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A COMPARATIVE STUDY ON YIELD AND YIELD RELATED PARAMETERS OF SOME MATURE TEA CLONES (*Camellia sinensis* L.)

T. Ahmed^{1*}

Abstract

A comparative study was carried out among four different established tea clones e.g. BT2, BT5, BT6 and BT8 in a mature tea area at BTRI main farm of Bangladesh Tea Research Institute, Srimangal, Moulvibazar. All of the above mentioned clones were used as treatments – T₁, T₂, T₃ and T₄, respectively. Plantation year of these clones was 1995 and observation period of this study was from 2017 to 2019. As the age of these bushes passed 20 years, that's the right time to study about the performances in field in mature condition. Yield parameters and yield were studied. Shoot extension rate (mm/week), harvested fresh weight of 100 shoot (gm) and harvested shoot density (no./m²) were significantly different for treatments. Among the clones, maximum average yield of made tea observed in BT6 (2655 kg/ha) which was followed by BT2 (2643 kg/ha), BT8 (2538 kg/ha) and BT5 (2326 kg/ha), respectively. From the study, it is evident that the lowest yield was observed in BT5 and it is caused mainly due to the lower number of branches and consequently the harvested shoot density. Moreover, at the end of the experiment when the casualty percentage was observed in the field, greater number was found in BT5 clonal tea area (5%) which was followed by BT8 (4%), BT6 (3%) and BT2 (1%), respectively. From this study, it is evident that some clones have better and enhancing characters for giving higher yield than others. Similar types of study should be continued for other clones as well and the result will help to spread the elite clones among the tea growers for ensuring sustainable growth and yield of tea.

Key words: Tea clone, Shoot weight, Shoot extension rate, Shoot density, Yield

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Introduction

Tea (*Camellia sinensis* L.) is a perennial tree which is cultivated as a shrub with a flat canopy, artificially maintained from 0.6 to 1.2 m above ground level. Tender shoots with apical leaves are harvested ('plucked') at regular intervals above from the plucking table. Tea requires a particular type of soil and climate and so the cultivation of tea is limited only in few selected areas in Bangladesh. As a result, there is a very little scope of increasing tea by expanding production area. Use of high yielding tea clones and improved cultural practices would be the way to increase tea yield and production. Before the liberation period (1971), average yield of tea in Bangladesh was about 800 kg/ha only which was gradually increasing and in 2019 that was 1768 kg/ha (PDU, 2020). One of the principal factors for increasing productivity of tea is the use of high yielding and better quality vegetative clones in the new areas (Boonerjee, 2016).

Though the yield is in increasing trend, the present average yield of our country is below than other major tea growing countries of the world like India (2153 kg/ha), Sri Lanka (2088) etc. (ITC, 2017). Hence, it should be mandatory for tea growers to plant elite clones as planting materials in their new area for extension, uprooted area for replantation and vacancy infilling. Elite clone has the superior characteristics e.g. high yielding capacity, better quality or both in a consistent way for many years. At the same time, tea planters need to give emphasis on the improved cultivars as per the requirement of tea industry (Palni *et al.*, 1999).

Yield of tea is quantified in terms of the weight of made tea per unit land area per year. Yield is heavily influenced by the bush density which is determined at the time of planting (Wijeratne, 2001). If the casualty percentage in a tea area is more, yield will be reduced. Hence, percentage of casualty should be estimated and compared in different clonal tea areas after few years of plantation. Yield components of tea are mainly the harvested shoot per unit land area (shoot density) and the mean weight per shoot. Of these two components, shoot density is the major factor that determines tea yield (Wijeratne, 2001). Harvested shoot density and weight of shoots at harvesting are greatly influenced by the rate of shoot growth. Number of harvested shoots per unit land area is determined by the rate of shoot initiation whereas harvested shoot weight is determined by the rate of shoot extension (De Costa *et al.*, 2007). Apart from genetic make-up, yield parameters and yield are largely dependent on some environmental factors e.g. rainfall, temperature, solar radiation etc. (Zoysa, 2008) which were similar for treatments of this experiment. Therefore,

this study was undertaken to compare among four established tea clones to observe yield related parameters and yield without considering environmental factors.

Materials and Methods

Bangladesh Tea Research Institute (BTRI) was established in 1957 and till to date it has developed and released more than 20 tea clones with high yield potential and better quality. Among those clones, only four established tea clones were selected in this experiment to carry out a comparative study on their yield and yield related parameters. The study continued from the beginning of 2017 to the end of 2019 and the experimental site was in A-2 section of BTRI main farm, Bangladesh Tea Research Institute, Srimangal which geographically located near about 23°98' north latitude and 91°50' east longitude and the elevation about 30 meter above from sea level. During the experimental period, soil characteristics of the site were observed (texture: sandy clay loam, pH: 5.1, % organic carbon: 1.24, % total nitrogen: 0.127, available phosphorus: 117.4 ppm and available potassium: 66.22 ppm). Meteorological data during the experimental period were collected from Weather Station which located adjacent to BTRI, Srimangal (average rainfall per annum: 2690.67 mm, maximum and minimum average day temperature: 31.12°C and 19.85°C respectively, average sunshine hour per day: 5.8).

Four established tea clones which used as treatments in the study were BT2 (T₁), BT5 (T₂), BT6 (T₃) and BT8 (T₄). General characteristics during the release of these clones were cited as, BT2 was with very high drought tolerant capacity and average yield 3627 kg/ha, BT5 was with moderate to high drought tolerant capacity and average yield 2811 kg/ha, BT6 was with moderate drought tolerant capacity and average yield 2916 kg/ha and BT8 was with high drought tolerant capacity and average yield 3316 kg/ha. Plantation year of the section was 1995 *i.e.* it was completely a mature and established tea field to study on yield and yield related different characteristics. The topography of the area is flat and there was no significant variation among treatments for soil, environmental and intercultural factors. The experiment was laid out as Randomized Complete Block Design having four replications. Spacing of the plantation was 105 cm × 60cm and in each plot there were 20 mature tea bushes. Harvested green leaf yield from each plot was collected regularly following a general plucking round during the peak cropping season in each of three years. During the plucking, harvested shoot density were counted by

using a wooden frame (30cm × 30cm) and then it was used to extrapolate as no./m². Finally, collected data were compiled and statistically analyzed.

Data on yield related parameters e.g. shoot extension rate (mm/week), fresh weight of 100 shoot (g) and shoot density (no./m²) were collected when it was required, particularly during the peak cropping season. Girth diameter of the main stem (mm) measured by using the slide calipers after the end of pruning and at the same time number of productive branches were also counted from bushes. As the experimental site located in a flat area, there was a tendency of water logging during the heavy rains. Hence, at the end of experiment the casualty percentage counted from all over the section for each clone which mainly caused due to outbreak of many diseases e.g. root rot, collar rot, black rot etc. for water logging condition.

Results and Discussion

Shoot extension rate (mm/week) and harvested fresh shoot weight (g) were significantly different for treatments. Shoot extension rate was maximum in BT8 clone and minimum was in BT2. The phenomenon also affected on weight of harvested 100 fresh shoot. Maximum weight was found in BT8 which was statistically similar with BT6 and BT5 but significantly different from BT2, presented in Table 1. The variation of shoot extension rate and shoot weight of different clones may be due to the inherited different characteristics of shoot internodes and leaf size which was also supported by Wickramaratne (1981).

Table 1. Variation of shoot extension rate and shoot fresh weight in different clones

Clones	Shoot extension rate (mm/week)	Fresh weight of 100 shoot (g)
BT2	17.75 ^b	57.00 ^b
BT5	19.50 ^{ab}	63.25 ^{ab}
BT6	21.50 ^{ab}	65.00 ^a
BT8	22.75 ^a	65.75 ^a
Mean	20.38	62.75
Level of significance	0.05	
LSD	3.91	7.33
CV (%)	12	8

After pruning, branches were counted and it was observed that average number of branches per bush were significantly different for treatments. Maximum number of branches per bush observed in BT2 clone which was statistically similar with BT6 and BT8 but significantly different from BT5. Similarly

during the plucking season it was observed that harvested shoot density (no./m²) was significantly different for treatments. Highest number of shoots harvested in BT2 clone which was similar with BT6 and BT8 but significantly different from BT5 as presented in Table 2. Similar findings were reported by Stephen and Carr (1994) who observed that shoot population density of tea plants almost depended on their genetic make-up.

Table 2. Variation of number of branches and harvested shoot density in different clones

Clones	Branches after pruning (no. of branches/bush)	Harvested shoot density (no./m ²)
BT2	93 ^a	200 ^a
BT5	72 ^b	182 ^b
BT6	89 ^a	196 ^a
BT8	86 ^a	194 ^a
Mean	85	193
Level of significance	0.05	
LSD	10.24	8.57
CV (%)	8	8

All of the above yield related parameters affected yield. From the analysis, average yield of made tea was found maximum in BT6 clone (2655 kg/ha) which was followed by BT2 (2643 kg/ha), BT8 (2538 kg/ha) and BT5 (2326 kg/ha) as shown in Figure 1.

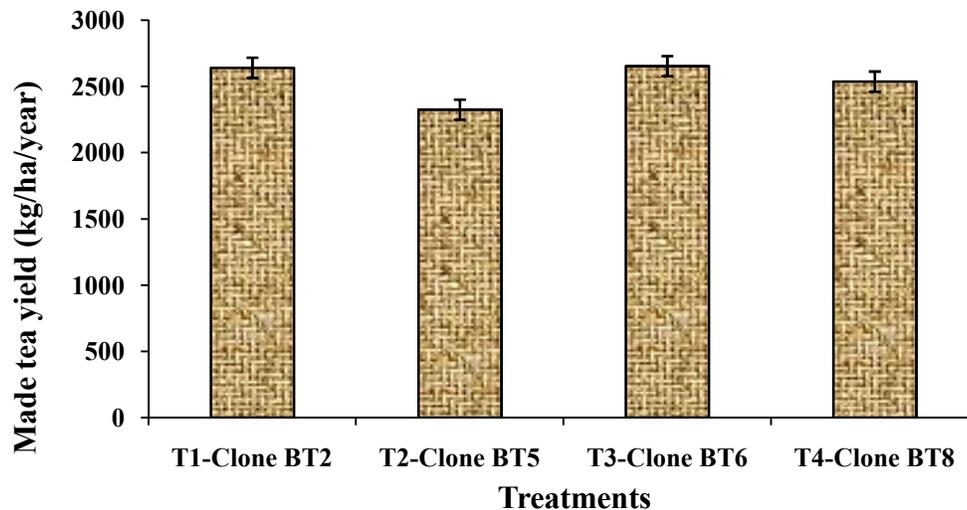


Figure 1. Variation of made tea yield among different clones

Result of the present study on shoot fresh weight and shoot density are supported by Rahman (1988) who stated that there is inverse relationship between number and weight of shoots in a tea bush. Although shoot density was higher in BT2 but due to less weight of shoot, maximum yield was found for BT6 clone in which both of the yield related parameters were higher. The findings clearly indicate that these two yield components need to be maximized for obtaining higher yield and the observation is supported by Wijeratne (2001).

After the pruning, stem girth of tea bushes were measured and it was observed that there was no significant variation among treatments. Maximum mean of stem girth was observed in BT6 tea bushes (63.50 mm) which was followed by BT8 (61.55 mm), BT5 (56.20 mm) and BT2 (47.85 mm), respectively.

At the final stage of the experiment, casualty percentage of tea bushes were counted and after analyzing data significant variation among treatments was found. Greater casualty of tea bushes was observed in BT5 tea clone (5%) which was similar with BT8 (4%) but different from BT6 (3%) and BT2 (1%) respectively as shown in Figure 2.

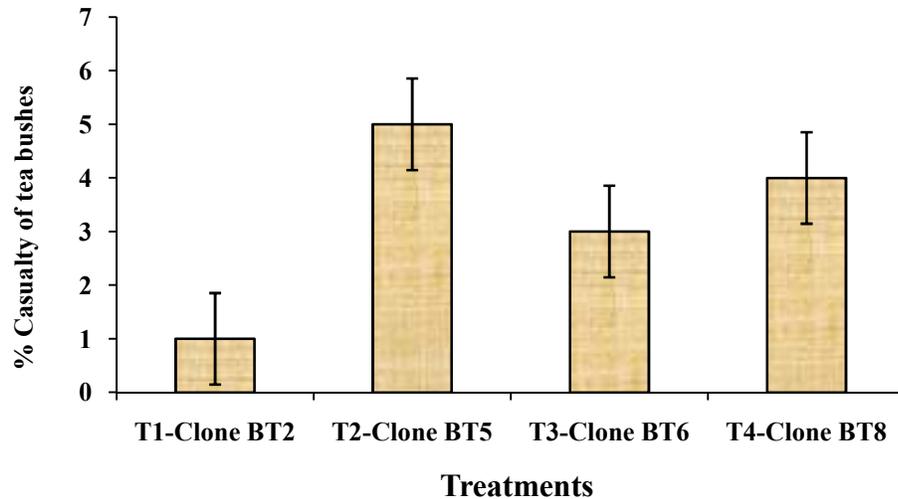


Figure 2. Casualty percentage of tea bushes in different treatments

Conclusion

During the last 60 years, Bangladesh Tea Research Institute (BTRI) has developed and released more than 20 tea clones for the betterment of its tea industry. Now, it is the time to observe the actual field performances of the

released tea clones which have reached at full mature condition. A clone is released after getting its better performances of quantity, quality and sometimes the both. Many of the major tea producing countries like India and Sri Lanka have withdrawn some of their released tea clones when they showed unsatisfactory performances in practical field. In that sense, BTRI is luckier that still there is no such incident of withdrawing any clone from the field. However, from the present study it is evident that the performances of some clones on established condition are significantly better than others. Such type of study will help to find out elite clones which are actually performing well in established and mature condition. During the last few years, planters are using mainly clonal tea plants in newly extension and uprooted tea area to increase the production. If planting materials collected from elite tea clones like BT2, BT6 rather than BT5, the yield and production will be increased in a sustainable way and gradually the industry will reach to its desired goal.

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SPATIO-TEMPORAL VARIATION IN SOIL MOISTURE AT TWO TEA PLANTATION AREAS OF BANGLADESH TEA RESEARCH INSTITUTE

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Abstract

The soil moisture contents at two tea plantation areas of Bangladesh Tea Research Institute (BTRI) were monitored almost every week in two consecutive years using the soil moisture gauge “neutron probe” for better understanding of some important hydrological processes and proper planning of irrigation and drainage in tea plantation. The moisture contents (% vol) were measured from the soil surface to 120 cm depth maintaining a vertical interval of 15 cm. Therefore, moisture data were taken at 0, 15, 30, 45, 60, 75, 90, 105 and 120 cm soil depths. Two different tea plantations were BT2 and BT6; and were selected based on their differences in drought tolerance and yield. From the results it was noticed that the trends of soil moisture contents in both the years was very similar starting with a dry period (from January to May) and ends up with a dry period (from October to December) and a wet period in the middle (from June to September) of the year. The trend was mostly correlated with the rainfall pattern of the year and also somewhat affected by the type of the tea plantation. The lowest moisture contents were always observed in the surface soil. On the other hand, the highest moisture contents were observed at different depths and were mainly in between 90-120 cm soil depths. Soil moisture contents at BT2 plantation area at all the selected depths were higher than the BT6 plantation area suggesting that phenotypic traits of the tea clones may affect the soil moisture content.

Keywords: Soil moisture, tea, spatial, temporal, neutron probe.

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Introduction

Soil water, as a type of water resource, plays an important role in agricultural production and food security. Soil water monitoring and simulation technologies can provide a good foundation for the efficient use and management of soil water resources in rain-fed agriculture (Gao *et al.*, 2016). Tea is grown primarily as a rain fed plantation crop and its yield is greatly influenced by weather. Among the weather elements, rainfall is the vital one that can affect the tea yield significantly. Uncharacteristic heavy rainfall patterns can lead to negative effects on tea production (Jayasinghe *et al.*, 2019). Therefore, a good drainage system is important in tea plantation. Deka *et al.* (2006) reported that proper drainage systems can increase tea yield around 30–35%. On the other hand, though the monsoonal rains bring sufficient amount of rainfall to recharge the soil, uneven distribution within a year also causes drought stress on tea plants resulting in a considerable loss of crop and increased casualties (Karunaratne *et al.*, 1999). Cheruiyot *et al.* (2008) reported that drought is responsible for a 14-20% reduction in yield and 6-19% mortality of tea plants. In order to overcome these problems, water-saving irrigation techniques are used in many tea plantations (Jia *et al.*, 2019). However, there is a lack of scientific irrigation schemes. When and how much water is applied is generally determined by experience based on weather conditions, and there is a large blindness. Therefore, in order to ensure the stable yield, tea plantations need appropriate irrigation and drainage. Through proper planning, the amount of irrigation water can also be controlled, which not only improve the utilization rate of water but also help to increase production, save resources, and improve labor productivity (Yu *et al.*, 2013).

Soil moisture is highly variable in both space and time, and knowledge of its spatial and temporal variation is very important for better crop production. The soil must contain adequate moisture at the root zone to maintain plant growth, avoid yield reduction and facilitate nutrient uptake. Nutrient uptake and crop yield can be maximized when the moisture content is known and well-characterized across a field and used to inform irrigation scheduling (El-Naggar *et al.*, 2021). The soil water pattern in the topsoil may not match that of the subsoil and this spatial variability in soil water patterns down the soil profile as well as across the landscape needs to be determined. Generally, it is assumed that the roots of the mature clonal tea plants remains confined within the top 90 cm of soil profile. Therefore, it is important to have sufficient moisture content within this soil profile during drought, and to drain out excess water during monsoon period as tea also cannot withstand stagnant

water. Hence, there is a need to understand the soil moisture content and its distribution for an area with respect to both time and depth for proper planning of irrigation and drainage management. Again, among the many factors, soil moisture variation is also controlled by vegetation.

The measurement of field soil moisture content can be performed through a range of methods, and most of them require soil sample to be collected from the site. When the soil sample is taken to the laboratory, the moisture content can be estimated with a high degree of precision and accuracy. However, it is not easy to ensure the collected samples are really representing the soil at the desired depth due to variability of soil and sampling procedures. The major disadvantage of the classical sampling methods (i.e. auguring) is their destructive features, where the soil profile is severely damaged by every sampling event. Soil variability is another problem as collecting soil sample at the “same” depth for each sampling event requires another location to be sampled. Therefore, using a simple, reliable, cost-effective and non-destructive technique is very important to carry out this type of research work for a longer period of time. In the 1950’s the soil moisture neutron probe (SMNP) was introduced and quickly became a widely accepted non-destructive method of soil profile water content measurement (Evet, 2001). The neutron probe technology has advantages over classical soil moisture measurement method because it is non-destructive, capable of frequent measurements and measurement for over large study areas (Chan *et al.*, 2010).

The aim of this study was to monitor the soil moisture content variation both spatially and temporally on a monthly basis using the instrument neutron probe to improve our understanding on some important hydrologic processes for proper planning of the related cultural practices including irrigation and drainage in tea plantation.

Materials and Methods

Site

The experiment was set in the A2 area (latitude 24° 18’N, longitude 91° 43’E, altitude 18 m) of Bangladesh Tea Research Institute, Srimangal, Moulvibazar. The annual rainfall of the locality ranges from 1800 to 3800 mm, with most rainfall in between May to July. Pan evaporation rate ranges from approximately 2.0-5.5 mm/d and usually higher during March to May. The soil is well-drained sandy clay loam and acidic (pH: 5.0).

Tea plantation

Existing 12 years old BT2 and BT6 clone plantations were selected for the measurement of soil moisture content. These two plantations were selected because of (i) their differences in drought tolerance and yield, and (ii) they were located in the same area and were under the same management practices. Clone BT2 is well known for its high drought tolerance and its yield is categorized as above average. It is an intermediate to small leaved bush with a loose bush frame. On the other hand, clone BT6 is moderately drought tolerant and its yield is categorized as average. Clone BT6 possess intermediate leaf size with fairly compact bush. Both the tea plantations were in the flat land located in the A2 area of BTRI and were adjacent to each other. The plantations had a good drainage system with standard main, lateral and sub-lateral drains.

Soil moisture data collection

Soil moisture content was measured with the instrument neutron probe (TROXLER, Model: 4300, USA) according to the methods defined by Hignett and Evett (2002) and calibrated to the experimental site soil. The basic procedure of installation of the neutron probe is shown in the Figure 1. In brief, the instrument neutron probe consist of a probe and an electronic counting scale which are connected together by an electric cable. Measurements with depth are made by lowering the probe down into the access tube and taking the moisture reading. In this study, two meter long aluminum access tubes were used and installed within the tea plantations. During soil moisture data collection, the instrument was placed on the access tube. Then the probe was lowered down at different depths into the access tube and respective moisture data were taken. Soil moisture data were collected almost every week starting from January 2007 to December 2008. The moisture contents (% vol) were measured from the soil surface to 120 cm depth maintaining a vertical interval of 15 cm. Just below the soil surface was considered as soil surface and was denoted as 0 cm depth. Therefore, moisture data were taken at 0, 15, 30, 45, 60, 75, 90, 105 and 120 cm soil depths. In each depth, soil moisture data were taken in triplicate. The collected data were then compiled and averages were made in a monthly basis.

Meteorological data collection

The rainfall and other related meteorological data of the locality during the study period were collected from the 1st Class Meteorological Observatory cum Agromet office of the Bangladesh Meteorological Department located within the BTRI campus.

Treatments

There were three sets of treatments for the study: a) Different months: January, February, March, April, May, June, July, August, September, October, November, and December; b) Different depths: 0, 15, 30, 45, 60, 75, 90, 105 and 120 cm; c) Different tea plantations: BT2 and BT6.

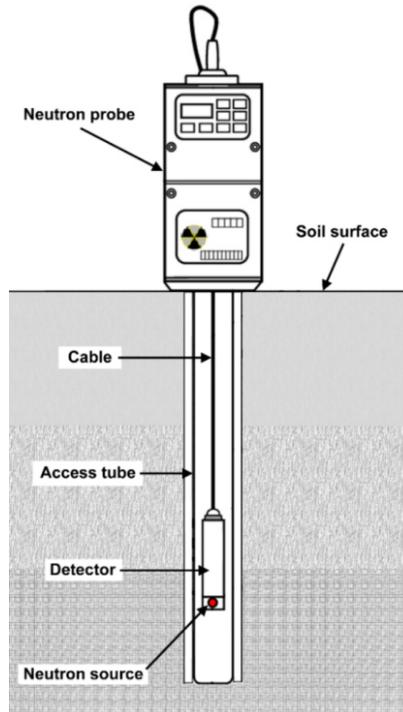


Figure 1. Schematic diagram of Neutron probe in operation (Kodikara *et al.*, 2013)

Statistical analysis

Data were statistically analyzed using the software SPSS (SPSS, Inc., Chicago, IL, USA). One-way ANOVA was used for the comparison of means. Significant differences were tested using DMRT at 5% level of probability.

Results and discussion

It is observed that there was a great variation in soil moisture content among different depths of soil (Table 1-4). The general trend noticed was that the soil moisture content progressively increased with increasing depths; but it was not always the case. In many cases it was noticed that at different depths, the upper soil horizon had the higher moisture content than the lower horizon (Table 1-4). This could be due to the differences in the properties of the soil at different depths. Hedley and Yule (2009) reported that spatial variability of moisture

content is attributed to the influence of varying soil properties such as texture, structure and drainage characteristics, as well as topography. Rout and Arulmozhiselvan (2019) also reported a significant variability in moisture content and moisture retention pattern among the soils of variable texture. They stated that this was because, the infiltration rate and water holding capacity of soil depends on the texture of the soil. For instance, loamy sand will have less water holding capacity and allow more water to percolate to the lower horizon than the sandy clay loam soil. From the data it was noticed that changes of every 15 cm depth from 15 cm to 120 cm did not change the soils moisture content as sharply as was noticed from 0 cm (near surface) to 15 cm soil depths (Table 1-4). This is most probably due to the high evaporation of soil moisture from the near surface soil.

Table 1: Soil moisture content (% v/v) at different depths under BT2 plantation area in 2007

Month	Soil depth								
	0 cm	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
Jan	4.60 g	9.43 f	14.16 e	15.24 d	16.17 c	18.58 b	18.58 b	18.55 b	20.89 a
Feb	9.68 f	12.08 e	16.40 cd	15.79 d	16.19 d	17.25 c	18.37 b	22.38 a	23.11 a
Mar	6.93 f	14.22 e	16.69 c	15.93 d	16.41 c	16.70 c	20.33 b	20.33 b	21.49 a
Apr	6.24 f	13.77 e	17.33 d	19.00 c	19.32 bc	18.99 c	19.98 b	21.78 a	21.33 a
May	5.90 g	14.29 f	14.87 e	19.77 b	17.84 d	18.90 c	20.30 a	20.62 a	20.57 a
Jun	8.03 g	15.17 f	16.90 e	26.70 b	24.33 c	19.73 d	29.30 a	20.47 d	20.40 d
Jul	7.97 f	26.77 d	27.80 c	28.80 b	28.90 b	29.67 a	20.03 e	28.23 c	28.73 b
Aug	8.57 f	15.87 e	17.17 d	17.40 d	29.23 c	29.97 a	30.13 a	29.63 b	29.50 bc
Sep	12.23 g	18.33 f	23.31 e	24.68 c	28.27 b	28.19 b	24.00 d	29.40 a	28.60 b
Oct	7.52 i	14.00 h	15.95 g	17.57 f	22.45 a	19.20 e	20.53 b	20.20 c	19.92 d
Nov	7.96 f	14.97 e	17.47 d	20.14 c	20.60 c	24.01 a	22.73 b	24.46 a	23.23 b
Dec	8.21 i	12.60 h	18.51 g	20.48 f	21.06 e	22.18 d	23.52 c	25.83 b	28.09 a

(Values bearing different letters within a row are significantly different at 5% level of probability).

In the year 2007, lowest moisture contents were noticed in the month of January at 0 cm (near surface) soil depth for both the plantations (Table 1-2). The lowest moisture contents (% v/v) were 4.60 % and 5.54 % for the BT2 and BT6 plantation areas respectively. In the same year, highest moisture contents were noticed in the month of August. The highest moisture content for BT2 plantation area was 30.13 %(v/v) at 90 cm soil depth (Table 1) and for BT6 plantation area was 29.03 %(v/v) at 105 cm soil depth (Table 2). Therefore, from the highest and lowest soil moisture content data no notable variation was observed between the two plantations. However, from the data it can be

assumed that perhaps there was no or less rainfall in January and more rainfall in August in 2007, as rainfall is the principal source of ground water recharge. Xu *et al.* (2011) also stated from their study that soil water content in all soil layers significantly increased with rainfall intensity.

Table 2: Soil moisture content (% v/v) at different depths under BT6 plantation area in 2007

Month	Soil depth								
	0 cm	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
Jan	5.54 g	9.37 d	9.28 d	7.33 e	5.80 f	5.67 fg	9.88 c	17.87 b	18.90 a
Feb	8.56 g	9.92 e	11.45 c	9.28 f	7.59 h	7.75 h	10.57 d	19.53 b	21.03 a
Mar	6.25 g	9.83 d	9.39 e	7.42 f	5.90 h	5.86 h	10.72 c	18.05 b	19.01 a
Apr	7.14 h	12.51 d	12.87 c	11.32 e	10.26 g	10.73 f	16.79 b	19.16 a	19.13 a
May	6.62 g	12.80 e	14.36 d	12.77 e	11.61 f	11.33 f	16.28 c	19.72 a	19.18 b
Jun	7.90 h	13.67 g	15.17 f	15.00 f	15.83 e	17.40 d	18.63 c	20.37 a	19.67 b
Jul	8.70 f	14.17 e	14.33 e	14.03 e	16.73 d	18.30 c	20.07 a	20.23 a	18.93 b
Aug	9.87 h	15.77 g	25.17 d	24.93 d	17.53 f	19.10 e	27.80 c	29.03 a	28.50 b
Sep	11.12 h	19.82 g	20.68 ef	21.21 e	22.83 d	27.02 a	24.33 c	20.37 fg	25.26 b
Oct	7.23 i	13.95 h	14.77 f	14.42 g	15.57 e	17.35 d	18.90 c	20.22 a	19.67 b
Nov	8.41 h	18.24 e	17.03 f	18.74 d	16.44 g	21.83 c	23.32 b	24.20 a	21.61 c
Dec	11.27 g	15.29 f	16.38 d	15.11 f	15.47 ef	15.78 e	22.34 c	24.59 b	27.45 a

(Values bearing different letters within a row are significantly different at 5% level of probability).

Table 3: Soil moisture content (% v/v) at different depths under BT2 plantation area in 2008

Month	Soil depth								
	0 cm	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
Jan	7.78 f	15.39 d	14.20 e	15.03 d	17.12 c	24.87 a	24.01 b	25.08 a	25.27 a
Feb	7.41 g	14.33 f	17.08 e	17.02 e	20.23 d	20.83 d	23.85 b	25.06 a	22.39 c
Mar	8.50 i	15.29 h	18.19 g	19.24 f	20.67 e	21.46 d	24.97 a	22.38 c	23.27 b
Apr	6.81 g	10.96 f	13.13 e	17.87 c	14.81 d	21.22 b	23.67 a	21.62 b	23.13 a
May	11.57 g	16.42 f	22.04 d	22.18 d	19.94 e	19.30 e	24.22 c	25.42 b	27.80 a
Jun	7.63 g	15.13 f	17.35 e	20.62 b	18.78 d	20.16 c	20.48 b	22.30 a	20.40 bc
Jul	10.96 f	19.28 e	20.18 d	23.04 b	21.34 c	21.93 c	21.64 c	22.90 b	24.23 a
Aug	12.18 h	17.19 g	21.35 f	25.98 de	26.42 d	25.68 e	29.80 a	27.20 c	28.92 b
Sep	13.75 g	18.13 f	19.47 e	22.13 d	21.89 d	22.92 c	27.35 a	24.49 b	27.00 a
Oct	14.33 e	18.76 d	20.43 c	23.96 ab	24.54 ab	23.68 b	25.11 a	24.31 ab	25.04 a
Nov	12.99 i	17.03 h	16.15 g	23.09 e	22.63 f	25.33 d	28.26 a	25.68 c	26.18 b
Dec	13.13 h	13.91 g	17.16 f	21.64 d	19.33 e	19.86 e	26.73 b	24.29 c	27.56 a

(Values bearing different letters within a row are significantly different at 5% level of probability).

Similarly, in 2008, lowest soil moisture contents (6.81%, 5.76%) were noticed at 0 cm (near surface) soil depths (Table 3-4). However, unlike previous year, the lowest moisture contents in this year were recorded in the months of March-April. This is probably correlated with the rainfall pattern of the year. From the meteorological data it was observed that there was no rainfall in January 2007, whereas there was 34 mm rainfall in January 2008 (Table 5-6). This is why the lowest moisture content was recorded in January in 2007. However, a total of 463 mm rainfall and 424 mm pan evaporation occurred from January to April in 2007. In contrast, 434 mm rainfall and 493 mm pan evaporation occurred during the same period in 2008. This indicates that during the period from January to April less rainfall and higher evaporation resulted the higher moisture deficit in April in 2008 compared to 2007. Conversely, the highest moisture contents in 2008 were noticed in the month of August which was similar with 2007. The highest moisture content for BT2 plantation area was 29.80 % (v/v) at 90 cm soil depth (Table 3) and for BT6 plantation area it was 28.40 % (v/v) at 120 cm soil depth (Table 4). From these data it can be said that within 120 cm soil depth, spatial variability of soil moisture is larger than the temporal variability.

Table 4: Soil moisture content (% v/v) at different depths under BT6 plantation area in 2008

Month	Soil depth								
	0 cm	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
Jan	11.09 f	15.72 d	17.06 c	15.63 d	13.47 e	11.54 f	15.35 d	23.65 b	25.31 a
Feb	7.63 f	12.94 c	14.70 b	11.59 d	9.23 e	7.58 f	12.82 c	19.70 a	19.76 a
Mar	5.76 f	12.83 de	13.17 d	13.17 d	12.76 de	12.06 e	17.44 c	20.10 b	25.11 a
Apr	7.08 ef	9.08 de	10.97 c	7.47 f	7.82 f	9.29 d	14.58 b	20.71 a	21.56 a
May	8.61 f	10.39 d	11.02 c	10.61 cd	8.94 ef	5.80 g	9.49 e	20.04 b	21.72 a
Jun	9.88 i	15.63 h	16.68 f	16.11 g	17.06 e	18.01 d	19.74 c	21.77 a	21.37 b
Jul	9.01 h	17.91 g	19.48 f	21.67 e	24.69 b	24.91 b	26.93 a	22.83 d	23.62 c
Aug	15.78 g	20.63 e	19.06 f	20.34 e	24.15 d	27.14 b	26.58 b	25.08 c	28.40 a
Sep	10.08 h	17.92 g	20.72 d	19.30 e	18.40 f	23.66 c	25.27 b	25.14 b	27.78 a
Oct	13.06 f	20.89 e	21.84 de	22.86 cd	22.46 d	23.86 bc	24.82 ab	24.58 ab	25.07 a
Nov	14.78 g	18.48 f	19.23 e	21.40 c	19.95 d	21.71 c	25.08 b	24.79 b	27.11 a
Dec	9.45 g	15.76 e	17.03 d	16.77 d	16.66 d	12.94 f	20.83 c	26.74 a	26.28 b

(Values bearing different letters within a row are significantly different at 5% level of probability).

Table 5: Meteorological data for the year 2007

Months	Rainy days	Rainfall (mm)	Evaporation (mm)	Temperature (°C)		Dew point (°C)	Sunshine hrs.	R.H.
				Max.	Min.			
January	00	00	59.90	24.54	08.26	10.75	4.49	69.98
February	06	81	85.50	26.91	13.29	13.59	6.21	64.30
March	02	99	135.50	30.75	15.10	13.73	7.69	56.92
April	17	283	143.10	31.53	21.20	21.27	6.82	71.77
May	16	214	157.50	33.26	23.80	23.90	7.11	74.46
June	19	564	114.00	31.40	24.55	24.80	3.44	82.76
July	22	424	130.50	31.53	25.19	25.31	3.74	82.82
August	23	413	131.60	32.43	25.03	25.64	4.89	82.02
September	18	316	109.10	31.65	25.10	24.72	3.89	81.13
October	14	152	106.70	31.39	22.07	23.19	6.23	78.91
November	03	143	97.20	29.03	18.00	20.34	6.81	78.97
December	01	01	62.50	25.83	11.51	14.86	6.47	74.48
Average =	11.75	224.17	111.09	30.02	19.43	20.18	5.65	74.88
Total =	141	2690	1333.10	-	-	-	-	-

Table 6: Meteorological data for the year 2008

Months	Rainy days	Rainfall (mm)	Evaporation (mm)	Temperature (°C)		Dew point (°C)	Sunshine hrs.	R.H.
				Max.	Min.			
January	05	34	75.60	24.38	11.19	13.70	4.91	73.64
February	02	53	97.70	26.07	11.15	11.61	6.73	61.87
March	05	150	136.60	30.92	18.72	18.62	6.34	65.61
April	04	197	183.00	34.29	21.28	19.80	9.00	59.64
May	20	298	161.50	33.37	23.08	22.91	6.39	69.99
June	23	373	134.40	31.64	24.75	24.57	3.84	80.12
July	23	334	113.80	31.90	25.54	24.81	3.60	80.65
August	18	299	97.60	32.54	25.15	25.20	5.08	80.79
September	15	158	135.10	32.84	24.88	24.98	6.35	78.18
October	12	273	108.09	30.79	21.65	23.14	6.30	81.10
November	00	00	110.00	29.74	15.12	17.88	8.81	72.12
December	00	00	36.80	26.50	14.18	16.82	5.30	75.35
Average =	10.58	180.75	115.85	30.42	19.72	20.34	6.05	73.26
Total =	127	2169	1390.19	-	-	-	-	-

From the meteorological and soil moisture data, a general trend noticed was that soil moisture contents were higher during the period of heaviest rainfall months. However, rainfall was not the only factor that directly affected the soil moisture content. It was observed that in both the years (2007 and 2008), the

highest rainfall was recorded in the month of June (Table 5-6). Whereas, the highest average soil moisture content from 0-120 cm depth was not recorded in June; rather it varied and was recorded in July for BT2 plantation area and in August for BT6 plantation area in the year of 2007 (Figure 2). In 2008, the highest average soil moisture content was recorded in August for BT2 plantation area and in October for BT6 plantation area (Figure 3). These observations suggested that soil moisture content is not only associated with the rainfall pattern of the year but some other factors are also involved. The amount and distribution of rainfall, soil texture, infiltration rate, drainage system, evapotranspiration and types of vegetation could be the factors that can affect the soil moisture content. If a soil is already reached to its water holding capacity, no more water will be absorbed whether there is any rainfall or not. Again, depletion of soil moisture from a soil that is at field capacity will depend on the rate of evapotranspiration which is predominantly determined by the type of vegetation. Weekley *et al.* (2007) also reported that soil moisture availability is governed by rainfall, hydraulic properties of the soil, evaporation and transpiration.

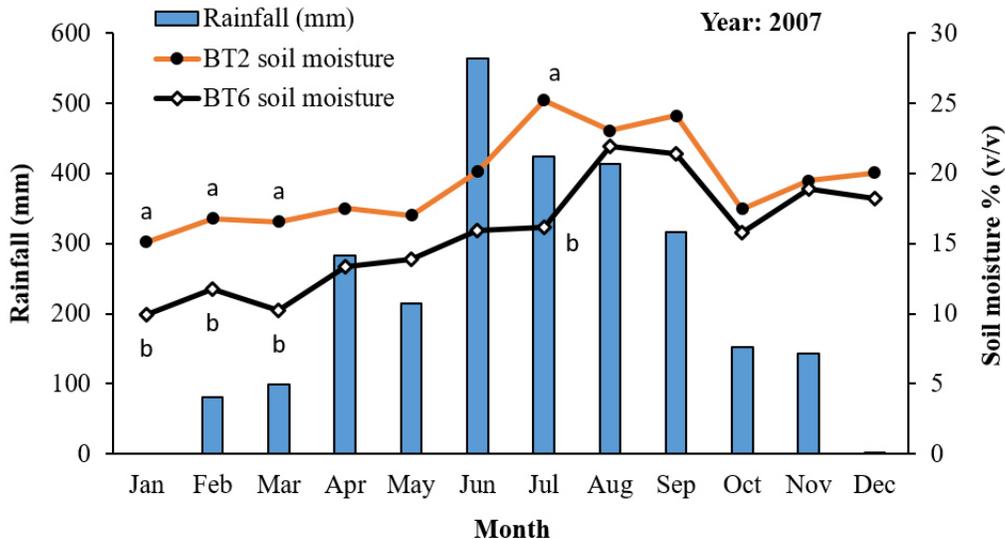


Figure 2. Temporal variation of soil moisture in the BT2 and BT6 plantation areas in relation to rainfall in 2007. BT2 and BT6 soil moisture indicates the average soil moisture contents (% vol) of nine different depths from 0-120 cm. Means in any of the month that bears different letters are significantly different ($p > 0.05$).

Another observation noticed was that an increasing trend of average soil moisture content was observed from October to December in 2007, though the rainfall was in declining trend (Figure 2). This could be due to the fact that the tea bushes progressively goes to the dormant stage during this period due to low temperature and short day length, demanding less water for physiological processes. In addition, there could be a capillary rise of water from the lower soil horizon that might have increased the soil moisture content over time.

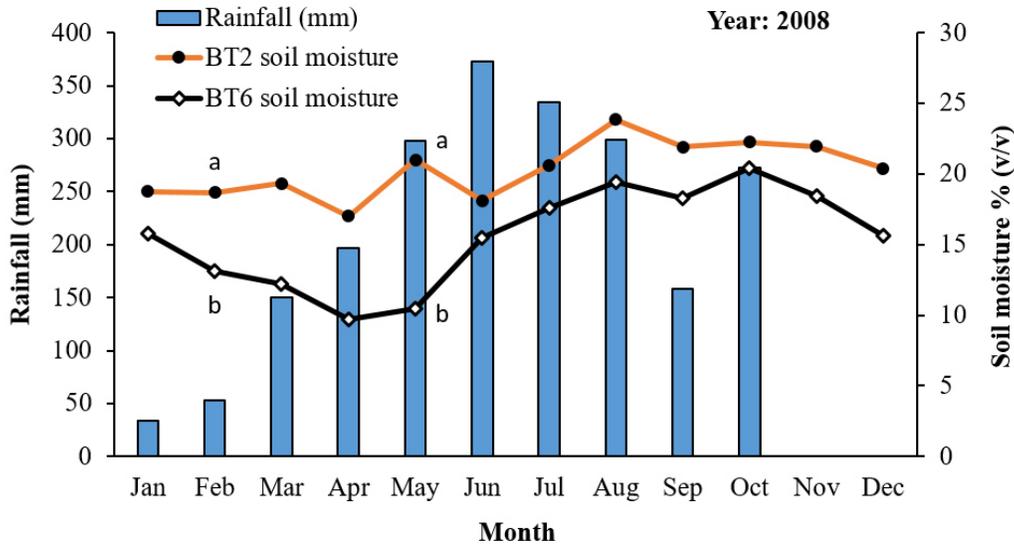


Figure 3. Temporal variation of soil moisture in the BT2 and BT6 plantation areas in relation to rainfall in 2008. BT2 and BT6 soil moisture indicates the average soil moisture contents (% vol) of nine different depths from 0-120 cm. Means in any of the month that bears different letters are significantly different ($p > 0.05$).

Results of this study demonstrated that temporal variation of soil moisture in a particular type of soil can be affected by the vegetation type. In this study, the selected plantations were the two different varieties of the same species. Yet, a great variation was noticed between the soil moisture contents of the two plantations. In both the years of 2007 and 2008, the average soil moisture contents throughout the year were always higher in the BT2 plantation area than the BT6 plantation area and in some of the months the variations were statistically significant (Figure 2-3). Wang and Singh (2017) also reported temporal variability of soil water content under different crops. This might be due to the variation in phenotype and transpiration rate between the two tea clones. The tea clone BT2 is an intermediate to small leaved bush with a loose

bush frame; whereas the BT6 possess intermediate leaf size with fairly compact bush. Thus it can be assumed that compared to BT2 clone, more leaf area of the BT6 clone requires more water from the soil to meet up the transpiration demand. The clone BT2 is also well known for its high drought tolerance. The finding of this study suggests that one of the reason of this drought tolerance could be the clone BT2 uptakes or depletes less water from the soil.

Considering the spatial variation of soil moisture content between the two plantations, it was noticed that there was no such variation from 0 cm (near surface) to 15 cm and from 105 cm to 120 cm soil depths (Figure 4-5). Variation was higher in between 15 cm to 105 cm soil depths and in some of the depths the variations were statistically significant (i.e. at 45, 60 and 75 cm depths in 2007 and at 45, 60, 75 and 90 cm depths in 2008) between the two plantations. Wang and Singh (2017) also reported spatial variability of soil water content under different crops. The finding of the present study indicating that the roots of both the tea clones are mainly confined in between 15 cm to 105 cm soil depths and hereby water uptake is also confined in between these depths. As, their water requirement is different, the soil moisture content varied only in between these depths for these two plantations. On the basis of this finding, it can be said that the depth of sub-lateral drains for BT2 and BT6 plantation areas can be fixed at 105 cm to remove excess water from the root zone during the rainy season for better drainage.

From the figures (Figure 4-5), it also can be assumed that the root system of BT2 clone is well distributed between 15 cm to 90 cm soil depth as the moisture content is progressively increased within this depth. On the contrary, for BT6 clone, the moisture content started declining from 30 cm soil depth and continued up to 60-75 cm depths and then increased thereafter (Figure 4-5). This suggests that majority of the root system of the BT6 clone are mostly confined in between 30 cm to 75 cm soil depth, as the depletion of soil moisture is higher in between these depths. Further study by destructive root sampling would be helpful to confirm this finding.

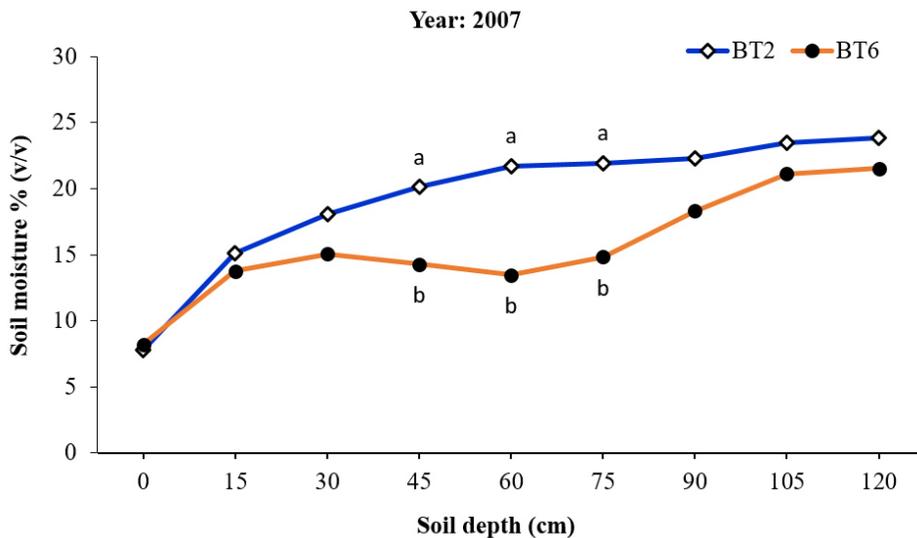


Figure 4. Spatial variation of soil moisture in the BT2 and BT6 plantation areas in 2007. Means in any of the depth that bears different letters are significantly different ($p > 0.05$).

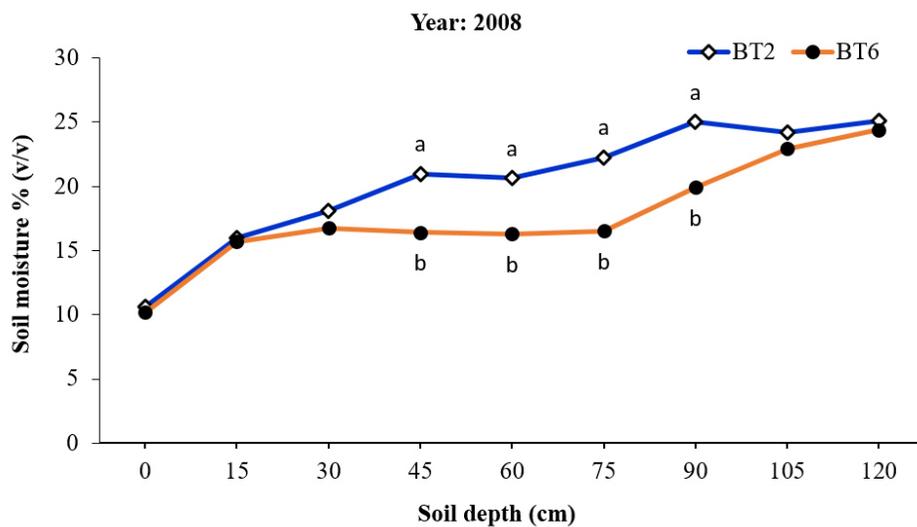


Figure 5. Spatial variation of soil moisture in the BT2 and BT6 plantation areas in 2008. Means in any of the depth that bears different letters are significantly different ($p > 0.05$).

Conclusion

In a tea plantation, soil moisture varies both spatially and temporally; and findings of this study showed that spatial variability is larger than the temporal variability. In case of spatial variability, variation is larger between surface to 15 cm soil depths; and afterwards, the variation is minimum with increasing depths. Temporal variation of soil moisture is somewhat linked with the rainfall pattern of the year. Along with rainfall, some other factors also affects the soil moisture content spatially and temporally; and these may include soil texture, drainage, vegetation type etc. Types of vegetation exerted a great impact on the soil moisture content. Between the two tea clones compared, higher soil moisture content was noticed at BT2 plantation area compared to BT6 plantation area. The root system of both the BT2 and BT6 clones are mainly confined in between 15 cm to 105 cm soil depths and hereby water uptake is confined in between these depths.

Future research direction

This study was carried out on flat land. Future studies can be carried out on tillah tops and tillah slopes to understand the spatial and temporal variation of soil moisture at those particular locations.

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INTEGRATED NUTRIENT MANAGEMENT FOR RAISING CLONAL TEA SAPLINGS IN POLYTBAGS IN SECONDARY BED

S.M.M. Islam^{1*}, M.M. Rana² and T. Ahmed³

Abstract

An experiment was conducted at Vegetative Propagation (VP) Nursery of Bangladesh Tea Research Institute, Srimangal during the period November, 2018 to January, 2020 to observe the effect of cowdung (CD), poultry manure (PM) and vermicompost (VC) on secondary bed and to standardize their ratios with soil in filling the polybags using BT 2 clone. The experiment comprised ten treatments of CD, PM and VC with control where different doses (50 g, 100 g and 150 g) of CD, PM and VC were mixed with 1 kg of soil to fill the polybags. The highest shoot length (50.083 cm) and leaf number (14.26) were found in 150 g VC per kg of soil, whereas lowest shoot length (45.217 cm) and leaf number (13.377) were found in 50 g CD per kg of soil. The highest root length (18.233 cm) and maximum base diameter (7.380 mm) was found in 50 g VC per kg of soil. The use of PM in different doses showed detrimental effects on root growth of tea saplings in polybags. Considering all the growth parameters, using VC @ 150 g per kg soil to fill polybags in VP nursery found most effective.

Key words: Tea, sapling growth, polybags, cowdung, poultry manure, vermicompost, vegetative propagation.

Introduction

Tea [*Camellia sinensis* (L.)] is the most widely consumed beverage in the world, ranked second after water as the most consumed drink worldwide (Zhen 2002, Ho *et al.* 2009).

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Besides being a traditional beverage, tea has a more significant role as a health drink. Tea is a unique crop and, identically, a very interesting and attractive one. The tea bush, its cultivation and harvesting do not fit into any typical cropping pattern (Willson and Clifford, 1992). Tea has been cultivated in Bangladesh since 1857.

Tea bushes can be raised from seed, cuttings or tissue culture. Propagation from seed is rare, while vegetative propagation is common because it is high-yielding, fast and cheap, and leads to the development of uniform stands. Until the middle of the 19th century, tea was propagated from seeds from various sources (Mainaak, 2017). The first attempt for vegetative propagation of tea was done in Indonesia by budding as well as grafting. However, due to sluggishness, neither of them could serve the purpose. Faster propagation by single-leaf internode cutting was developed simultaneously in India, Sri Lanka, and Indonesia (Mondal, 2011).

Tea nursery is the first stage of tea cultivation. In other words, it can be considered as plant producing factory. The entire development program in any Tea Estate depends on the success of the nursery. With the advancement of technology, different types of tea nursery have been adopted. Vegetative Propagation (VP) nursery is the latest and widely practiced methods in tea cultivation and there are some limitations too. VP nursery requires special cares to establish and they are too much sensitive to changes of soil and climate between localities than a seed population.

According to purpose, VP nursery is categorized into two units, viz. primary and secondary bed, the first tea cuttings are planted for the purpose of rooting/callusing the cutting to grow the rooted new sapling. The rooted plants are then transferred to the polythene sleeves which are kept in the secondary bed till the planting out in the field (Sana, 1989). Soil and sand are used as the rooting medium for vegetative propagation in primary bed in the nursery. Polythene sleeve-planting is made with a single nodal-leaf-cutting or with the callused/ rooted cutting in the secondary nursery bed (Sana, 1989). Hence, intensive care and fertile soil are needed to grow the rooted cutting in secondary bed as the utmost target to establish a VP nursery to raise healthy, vigorous and uniform plants of appropriate species in the shortest possible time with a minimum cost.

The soil fertility status of Bangladesh is gradually declining day by day. Most of the soils of Bangladesh have organic matter less than 1.5% and in many cases it

is less than 1 % (BARC, 2012). Improper soil management practices and long time intensive use of chemical fertilizers create some fertility problems through soil exhaustion as well as through interactions with other elements causing micronutrients deficiency (Rahman and Mian, 1997). In addition, favorable climatic condition for microbial activities throughout the year may be responsible for this.

Integrated nutrient management (INM) is the maintenance and adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner (Gebrewold, 2018). The concept of INM aims to increase the efficiency of use of all nutrient sources, be they soil resources, mineral fertilizers, organic manures, recyclable wastes or bio-fertilizers. They enhance certain biological processes by which nutritionally important elements are made available to the plants (Lianet *et al.*, 2002). Tea is a non-leguminous crop that hosts colonizing asymbiotic nitrogen fixers and phosphate-solubilizing bacteria in its rhizosphere (Katznelson, 1965). The increased uptake of nutrients from soil due to the application of chemical nutrients and biofertilizers might have produced enough carbohydrate in leaves for translocation to the sink for maximum productivity.

Manure is an age-old source of nutrients. It provides all the necessary macronutrients and many micronutrients while increasing organic matter. Cowdung, poultry manure and vermicompost may play a vital role in soil fertility management as well as supplying primary, secondary and micronutrients for crop production. Cowdung contains 0.5-1.5%N, 0.4-0.8%P, 0.5-1.9%K and other nutrients in small quantity while the poultry manure contains high amount of secondary and micronutrients in addition to 1.6%N, 1.5%P and 0.85%K (Aktar *et al.*, 2020). Whereas, vermicompost is rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, beneficial soil microbes and also contain 'plant growth hormones & enzymes' (Sinha *et al.*, 2009). It is scientifically proving as 'miracle growth promoter & also plant protector' from pests and diseases. Vermicompost retains nutrients for long time and while the conventional compost fails to deliver the required amount of macro and micronutrients including the vital NKP to plants in shorter time, the vermicompost does (Sinha *et al.*, 2009). Recently use of vermicompost in tea plantation and in VP nursery has become popular and the users getting their expected outcomes.

Cowdung is used at the ratio of 4:1 (Soil : Cowdung) (Alam, 2003) for polybag filling in secondary bed of VP nursery to raise tea sapling. But nowadays, vermicompost and poultry manure become more available than cowdung and their nutrient status is more than cowdung. Therefore, need to evaluate their effectiveness and find out proper ratio for preparing polybag soil for rooted cutting in secondary bed.

Materials and Methods

An experiment was conducted at VP Nursery of Bangladesh Tea Research Institute (BTRI), Srimangal during the period 2018-2020 to observe the effect of cowdung, poultry manure and vermicompost on secondary bed of VP nursery and to standardize their ratios with soil in filling the polybags in VP nursery using BT2 clone. The experiment comprised ten treatments of cowdung (CD), poultry manure (PM) and vermicompost (VC) with control viz. Control (Recommended dose of cowdung, 4:1 = Soil : Cowdung) (Alam, 2003) and chemical fertilizers (300 g TSP and 150 g Dolomite per cubic meter soil) (Ahmed, 2016), 50 g CD per kg of soil, 100 g CD per kg of soil, 150 g CD per kg of soil, 50 g PM per kg of soil, 100 g PM per kg of soil, 150 g PM per kg of soil, 50 g VC per kg of soil, 100 g VC per kg of soil and 150 g VC per kg of soil. The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replications. 100 polybags were taken under each treatment and total 3000 nos. (100 polybags × 10 treatments × three replications) polybags were taken to observe the effects of different manures. Before using the soil for filling the polybags soil sample was tested in Soil Science and Entomology Division of BTRI to know the soil status and the amount of nematode present in the soil. According to the soil analysis the used soil was Silt-loam type having pH 5.5. The soil was treated with Furadan 5G (Carbofuran) @ 165 g/ m³ of soil to remove the nematodes. The CD, PM and VC were mixed with the treated soil according to the treatment. The polybags were filled 3 weeks before planting the rooted cuttings to settle down the soil in polybags. 150 days old cuttings of BT2 clone from primary bed were transplanted in polybags. Before planting the rooted cuttings from primary bed root length (cm), shoot length (cm), leaf number (nos.) and base diameter (mm) were recorded. 10 polybags were marked by bamboo stick excluding border rows to collect data on shoot length (cm), leaf number (nos.) and base diameter (mm). Three cuttings were destructed every sampling dates for recording root length (cm). Data on different parameters were collected at different dates after transplanting to observe the growth trend. Mortality percentage of rooted

cuttings also recorded till 45 days after transplanting. Other agronomic practices like watering, weed and pest control were done as and when needed. The collected data were analyzed as a completely randomized block design (RCBD) using ANOVA and mean separation was done with LSD at 0.05 level using the statistix10 software.

Results and Discussion

The final growth data were analyzed for comparison and statistical significance. All the growth characteristics were found statistically significant due to the treatments (Table 1). The highest shoot length (50.083 cm) and leaf number (14.26) were found in T10. Sinha *et al.* (2009) reported that, vermicompost has been found to influence on all yield parameters such as-improved seed germination, enhanced rate of seedling growth, flowering and fruiting of major crops like wheat, paddy, corn, sugarcane, tomato, potato, brinjal, okra, spinach, grape and strawberry as well as of flowering plants like petunias, marigolds, sunflowers, chrysanthemums and poinsettias. Whereas, lowest shoot length (45.217 cm) and leaf number (13.377) were found in T2. On the other hand, the highest root length (18.233 cm) was found in T8 which is statistically similar with all the treatments except T6 and T7. Siminis *et al.* (1998) and Datar *et al.* (1997) reported that, vermicompost supply balanced nutrients to plant roots and stimulate growth; increase organic matter content of the soil including the 'humic substances' that affect nutrient accumulation and promote root growth. Similarly, maximum base diameter (7.380 mm) was found in T8, which is statistically similar with all the treatments except T5, T6 and T7.

Growth trend of different parameters

After transplanting the rooted cuttings from primary bed to secondary bed, data on shoot length (cm), root length (cm), base diameter (mm) and leaf numbers were collected nine times. From the growth trend it is found that shoot length, root length and leaf number increased slowly upto the month of March, 2019 it may be due to the dry weather condition of winter season and after that (June, 2019 to January, 2020) the growth rate of all the growth parameters increased steeply and that may be due to the favorable environment of rainy season (Figure 1, 2 and 3). According to Laycock (1964), good growing season for tea is one having worm days, long sunshine hours, high humidity and adequate rainfall, preferably in overnight showers.

Table 1. Growth characteristics of tea saplings under different INMs

Treatments	Shoot length (cm)	Root length (cm)	Root : Shoot ratio	Base diameter (mm)	Leaf number (Nos.)
T1	50.050 a	16.780 a	2.9827 bc	7.2067 abc	14.106 a
T2	45.217 e	17.007 a	2.6630 e	7.3533 a	13.377 b
T3	48.343 b	16.867 a	2.8680 d	7.3033 ab	13.448 b
T4	49.033 b	17.060 a	2.8767 cd	7.2833 ab	13.595 b
T5	46.380 d	17.000 a	2.7283 e	6.9967 bc	13.384 b
T6	49.037 b	15.740 b	3.1153 a	6.9833 bc	13.603 b
T7	49.913 a	15.727 b	3.1743 a	6.8667 c	13.648 b
T8	47.207 c	17.047 a	2.7687 de	7.3800 a	13.413 b
T9	50.033 a	16.783 a	2.9817 bc	7.0567 abc	14.090 a
T10	50.083 a	16.747 a	2.9903 b	7.1333 abc	14.260 a
CV	0.84	2.25	2.16	1.35	2.88
LSD (0.05)	0.6998	0.6426	0.1080	0.3166	0.3535

Throughout the period (November, 2018 to January, 2020) it is seen that the growth rate of root lengths under poultry manure treatments (T5, T6 and T7) is slower than the other treatments and this growth is found slower with the increase of PM dose (Figure 2). Studies of poultry manure application to cropland have not always resulted in improved soil health indicators (Clark *et al.*, 2017), partially because of difficulties in assessing soil health in short-term studies due to the complex and dynamic nature of soil N and organic matter (Hoover *et al.*, 2019). The growth trend of base diameter found almost similar under different treatment of CD, PM and VC (Figure 4).

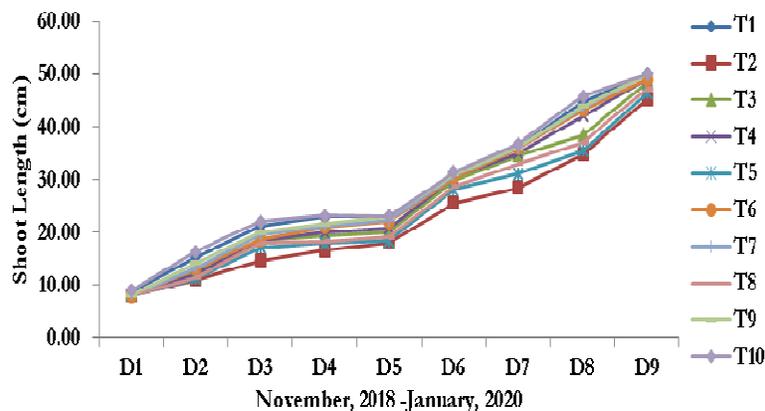


Figure 1. Shoot length at different dates

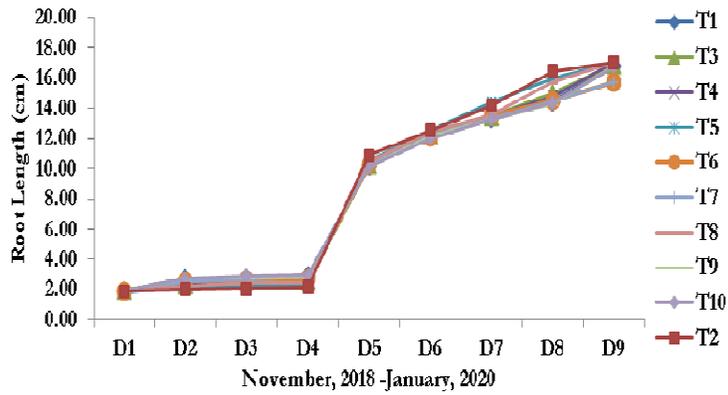


Figure 2. Root length at different dates

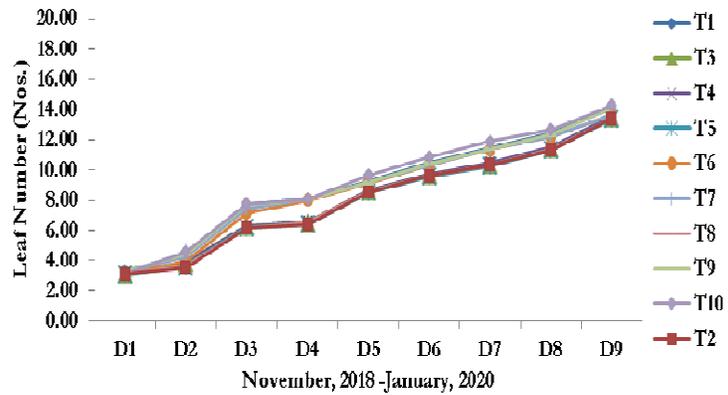


Figure 3. Leaf numbers at different dates

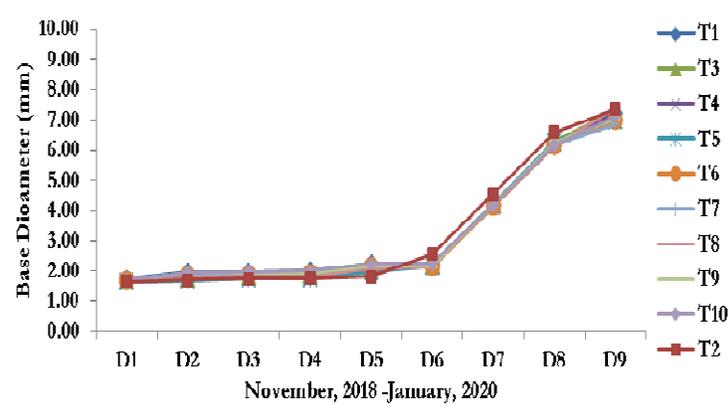


Figure 4. Base diameter at different dates

Mortality Rate of cuttings in Secondary Bed

After transplanting the rooted cuttings from primary bed to secondary bed (Polytube) mortality percentage was recorded upto 45 days after transplanting. Highest mortality percentages (Ranges from 18.67% to 21.33%) were found in PM treatments (T5, T6 and T7) the rate increases with the increase of PM dose. Magdy (2017) reported that poultry manure is responsible for transferring both of biological and chemical hazards to soil and agriculture environment, which may cause maximum mortality rate of tea sapling in secondary bed. On the other hand whereas, lowest mortality rate (Ranges from 8.33% to 11.67%) were found in VC treatments (T8, T9 & T10) (Figure 5). Whereas, the mortality percentage under crowding treatments ranges from 13.33% to 14.67% and this rate found 11.67% in control.

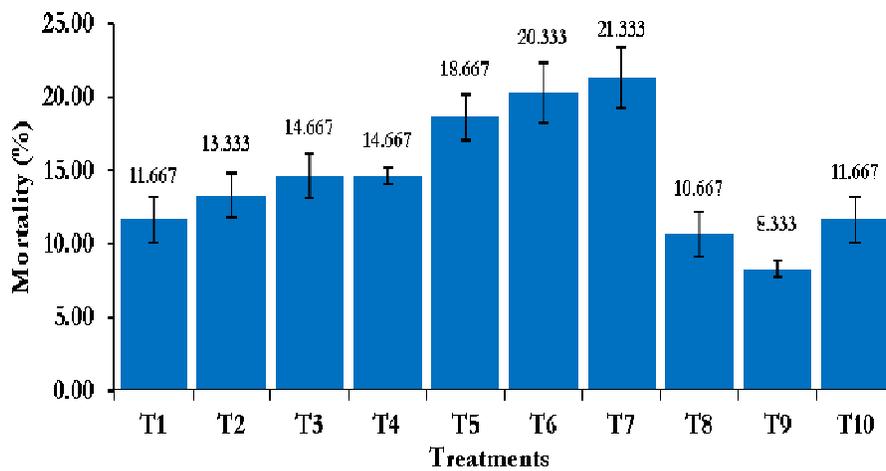


Figure 5. Mortality rate of rooted cuttings

Conclusion

From the study it is found that all the growth parameters were maximum when VC was mixed with the soil @ 150 g/kg of soil to prepare the secondary bed (polybag); whereas the recommended dose of CD and 150 g PM per kg of soil also showed similar performance statistically. However, more mortality percentage of the rooted cuttings were noted in the treatments consisting PM. Besides, the root lengths were also found smaller with the increase of PM dose. Therefore, to prepare the soil of the secondary bed, VC @ 150 g/kg of soil or CD at recommended dose can be mixed for better growth of the tea sapling in the nursery; and use of PM should be avoided as it exerted detrimental effect on root growth and increased the mortality percentage of the rooted cuttings.

From the study it is found that, to prepare the polybag soil in secondary bed of VP nursery VC @ 150 g/kg of soil showed the best result among the treatments which was maximum dose of VC in the performed study. In future, we could perform the experiment taking higher dose of VC to find its effect to raise sapling in VP nursery. Beside this, any toxic effects in the physiology of tea sapling due to use of poultry manure were not analyzed and it might be done in future study.

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ECONOMICS AND INTEGRATED MANAGEMENT OF WEEDS IN YOUNG TEA

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Abstract

An experiment was conducted at the Bilashcherra Experimental Farm of Bangladesh Tea Research Institute during 2007- 2010 to determine the most economically viable and effective weed management combinations to control weeds in young tea plantation. The experiment was laid out with RCBD having six treatments replicated thrice. Data were collected on weekly harvesting of green leaves and weed density meter⁻² at fortnight intervals. All the treatments showed more or less significant increase of yield of made tea and reduction of weed density compared to control. The treatment (Hand weeding + Glyphosate @ 3.7 Lha⁻¹) showed maximum reduction of weed density (62.05%) over the control after 45 days of spraying. Glyphosate @ 3.7 Lha⁻¹ and (Hand weeding + Paraquat @ 2.8 Lha⁻¹) gave reduction of weed density 56.91% and 54.01% respectively over the control after 45 days of spraying. Accordingly, (Hand weeding + Glyphosate @ 3.7 Lha⁻¹) showed a significant increase of yield (41.68%) comparing with the control. On the other hand, (Hand weeding + Paraquat @ 2.8 Lha⁻¹) and Glyphosate @ 3.7 Lha⁻¹ revealed 25.57% and 24.25% increase of yield over the control. The highest marginal rate of return (770%) was obtained from Hand weeding + Glyphosate 3.7 L/Ha and it was found to be the most economical among the treatments used. Considering all the parameter, it is recommended that Hand weeding + Glyphosate @ 3.7 Lha⁻¹ is the most economic combinations for controlling weeds in young tea plantations.

Keywords: Young tea, Weed, Management, Yield, Economics.

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Introduction:

Weeds are unwanted plants in cultivated crops but to define it is difficult as one species in a particular place may be unwanted while it may have importance in another place. The term weed is applied to all those plants for which man has found no use and which in their evolution have developed such power of aggression, persistence or reproduction to make them a menace to the best possible development of crop. Weeds are probably most noxious and act as a vital antagonistic force to low productivity of tea. Young tea plants are more susceptible to weed competition than mature teas. Prematilake *et. al.* (1999) reported that the critical period of weed competition in young tea was 8-12 weeks after planting and weed infestation for more than 12 weeks adversely affect the growth of tea. It hampers frame formation in young tea and thereby affects its long term productivity. Weeds are responsible for the uptake and transpiration of appreciable amounts of water and this loss is particularly significant during drought. Weeds affect tea by competing with it for space, moisture, nutrient and light resulting reduced plant growth and yield of tea. Like other agricultural and horticultural crops, tea needs an adequate agronomic care for a high and sustained yield. Uncontrolled weed growth in tea cultivation can cause a loss of production to the extent of 10- 50% (Rajkhowa *et. al.*, 2005; Deka & Barua, 2015). Venketaramani (1964) observed that 6-12% crop was lost due to weed competition. Cramer (1967), Rahman (1975) and Sana (1989) also estimated the loss of crop to be 9%, 6-12% and 9% in Srilanka, South India and Bangladesh respectively. The annual crop loss in the world tea due to weed infestation has been estimated to be 146 million kilogram or approximately 14-15% of the total crop (Islam *et. al.* 2012). Worldwide weeds cause enormous losses to crops even more than that of other pests.

Weeds are generally vigorous plants and their demands for mineral nutrients are great. The weeds may remove up to 252 kg of soil nutrients per hectare annually in young tea (Chakravartee and Barbora, 1995). The weeds are not only affect the tea plants by competing with them for necessary requirements but also act as alternate host for various pathogens and pests. It is therefore of paramount importance to control weeds in tea crop fields (Ali & Islam, 2011).

The weed flora in Bangladesh tea is diversified in nature and composed of a wide spectrum of various monocot and dicot weeds. As many as 36 weed species have so far been recorded (Sana, 1989) in Bangladesh tea fields. The weed density is more prevalent in young tea than in mature tea. Most of the

weeds generally sprout after first rain during March-April, having a peak density in July- August (Ali & Islam, 2011). Under the tropical climatic conditions, the weed grows profusely during rainy season at the time of heavy flushing of tea. Thus employing workers on manual weeding at this phase is difficult; when most of the labors are fully engaged in plucking and other important intercultural operations. Normally, the practice of weeding has been done manually (sickling, cheeling, hoeing) or chemically (with herbicides). However, it is not always possible to keep such areas weed free by manual methods or by a single herbicide spray. It requires spraying for numbers of round and man- days at frequent intervals. Besides, the cost of weeding is in the range of 10-14% of the total cost of field operations. It is also accounted for 4-5% of the total cost of production of made tea and it is second only to plucking and fertilizer application (Prematilake, 2003). Cost of weeding is very high as a result of high cost of labor and escalating price of herbicides. Thus strategies for managing weeds in young tea plantations at minimum cost are of paramount importance for sustainable productivity of tea. It is therefore essential to evaluate the efficacy of combined effect of weed management measures in young tea and find out the most economically viable one. Thus the study was undertaken to find out the most economically viable integration of weed management practices for controlling weeds in young tea.

Materials and Methods:

The experiment was conducted at Bilashcherra Experimental Farm (BEF) of Bangladesh Tea Research Institute (BTRI) during 2007- 2010 in young tea plot where mixed stand of weeds were present. The experiment was laid out with Randomized Completely Block Design (RCBD) having six treatments and three replications. The plot size was $6.09 \times 4.87 \text{ m}^2$. Treatments are: T_0 = Control; T_1 = Hand weeding, T_2 = Hand weeding + Spraying with Paraquat @ 2.8 Lha^{-1} ; T_3 = Hand Weeding + Spraying with Glyphosate @ 3.7 Lha^{-1} ; T_4 = Spraying with Paraquat @ 2.80 Lha^{-1} and T_5 = Spraying with Glyphosate @ 3.7 Lha^{-1} . Hand weeding denotes the manually sickling of hard wooded broad leaved and more than 10 inches long weeds. Herbicide treatments were applied two times using knapsack sprayer when there was a fully ground covers of weeds and before they start flowering. Data were collected on the weekly weight of green leaves and following converted to made tea in kgha^{-1} . Weed density meter^{-2} was also recorded following quadrant method by Mahajan & Fatima (2017). All collected data have been compiled and analyzed statistically by using MSTATC program. Economic analysis was done as per Ali *et. al.* (2003).

Results and Discussion:

During the experiment, followings predominant weeds of monocotyledonous and dicotyledonous were recorded in untreated plots (Table 1) to be alive and growth was vigorous.

Table 1: List of observed monocotyledonous and dicotyledonous predominant weeds

Monocot weeds		Dicot weeds	
1	<i>Cyperus rotundus</i>	1	<i>Borreria hispida</i>
2	<i>Cynodon dactylon</i>	2	<i>Mimosa Pudica</i>
3	<i>Eleusine indica</i>	3	<i>Ageratum conyzoides</i>
4	<i>Digitaria sanguinalis</i>	4	<i>Mikania scandens</i>
5	<i>Axonopus compressus</i>	5	<i>Lucas aspera</i>
		6	<i>Peperomia pellucida</i>
		7	<i>Scoparia dulcis</i>
		8	<i>Euphorbia hirta</i>

Table 2: Showing the effect of different weeding methods and combinations on the yield of made tea (kg ha⁻¹) during the experimental periods.

Treatments	2007	2008	2009	2010	Average
T ₀ = Control	1960.45 d	1382.54 e	1433.12 f	1129.66 f	1476.44 c
T ₁ = Hand weeding	2025.45 d	1578.60 d	1488.68 e	1174.26 e	1566.74 c
T ₂ = T ₁ + Paraquat @ 2.8 Lha ⁻¹	2237.83 bc	2245.52 b	1578.15 c	1354.11 c	1853.90 ab
T ₃ = T ₁ + Glyphosate @ 3.7 Lha ⁻¹	2688.51 a	2495.46 a	1692.23 a	1490.86 a	2091.76 a
T ₄ = Paraquat @ 2.8 Lha ⁻¹	2097.45 cd	1710.69 d	1533.32 d	1261.95d	1650.85 bc
T ₅ = Glyphosate @ 3.7 Lha ⁻¹	2639.93 b	1889.40 c	1636.90 b	1441.81 b	1834.51 b

Same letter (s) against the value are statistically (p= 0.05) similar to each others.

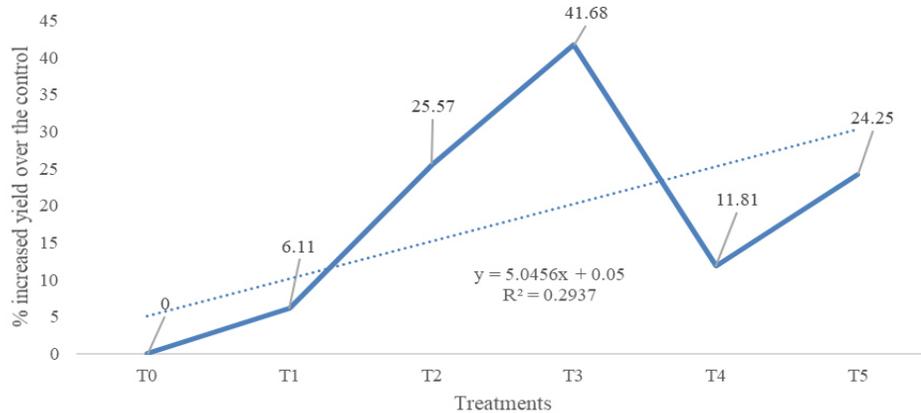


Fig 1: Showing the % increased yield over the control

All treatments regarding with weed control measures showed more or less significant increase of yield of made tea and reduction of weed density compared to control where no weed control operation was taken. Table 2 and figure 1 showed that in treatment T₃ there was maximum yield (2091.76 kg ha⁻¹) obtained by 41.68% more over the control followed by T₂ and T₅ by 25.57% and 24.25% increased yield respectively over the control. The least effective treatment were T₁ and T₄ which gave only 6.11% and 11.81% increase in yield of made tea over the control. Glyphosate is a slow acting and systemic herbicide which can penetrate to the root of weeds. It can completely kill the weeds where weeds are normally less than 9 inches and keep the sections weed free for a long time. If Glyphosate is applied after manual weeding, regrowth of weeds usually take a long period of time rather than application of any contact herbicides. As a result, In case of T₃, persistence of weed free condition for a long period of time helps increase the yield of tea rather than other treatments.

Table 3: Showing the effect of different weeding methods and combinations on the weed density meter⁻² during the experimental periods.

Treatments	2007	2008	2009	2010	Average
T ₀ = Control	80 a	78 a	81 a	72 a	77.75 a
T ₁ = Hand weeding	52 b	54 b	53 b	52 b	52.75 b
T ₂ = T ₁ + Paraquat @ 2.8 Lha ⁻¹	35 d	36 d	37 d	35 d	35.75 d
T ₃ = T ₁ + Glyphosate @ 3.7 Lha ⁻¹	31 e	30 f	28 f	29 f	29.50 e
T ₄ = Paraquat @ 2.8 Lha ⁻¹	40 c	39 c	39 c	40 c	39.50 c
T ₅ = Glyphosate @ 3.7 Lha ⁻¹	36 d	34 e	32 e	32 e	33.50 d

Same letter (s) against the value are statistically (p= 0.05) similar to each others.

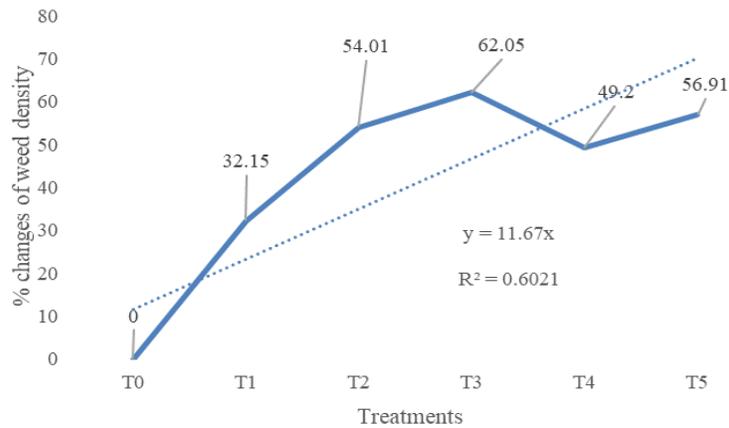


Fig 2: Showing the % changes of weed density yield over the control.

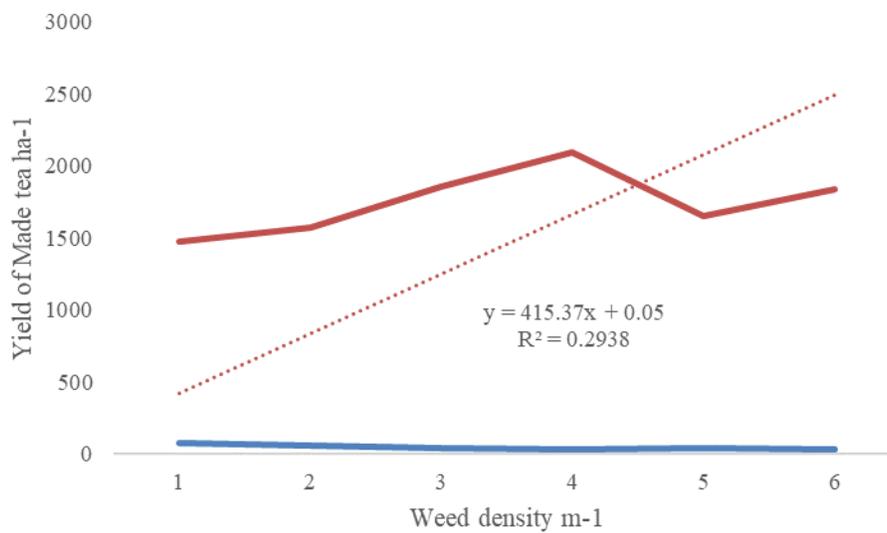


Fig 3: Relationship between weed density and yield of made tea

In case of weed density, significantly highest density (77.75) was observed in T₀ followed by T₁ and T₄. Among the treatments the significantly highest reduction in weed density was obtained with T₃ over the control, which is

followed by T₅, T₂ and T₄. They caused 62.05, 56.91, 54.01 and 49.20% reduction respectively over the control (Fig 2).

The yield of made tea ha⁻¹ was linearly and inversely correlated with weed density meter⁻¹. There relation could be expressed by the regression equation $Y=415.37X + 0.005$, where Y represented yield of tea and X represented slope of equation (Fig 3). The R² value indicated that their intensity of relationship may be expressed by 10.21%.

Table 4: Marginal analysis of different herbicides used for controlling weeds

Treatments	Gross margin	Variable cost	Marginal gross margin	Margin variable cost	Margin rate of return
T ₃	370591.00	5927.60	45641.00	5927.60	770
T ₀	265759.20	00	-	00	

From the economic analysis, it can be estimated that the treatment T₃ received the highest marginal rate of return (770%). It means that if the planter has spent an additional 100 taka they can get an extra income of taka 770 over the control (Table 4). Similar types of finding was revealed by Prematilake (2003) where he prescribed use of effective herbicides with proper dosages along with integrated weed management techniques for most cost-effective weed management as well as for healthy tea production also.

Conclusion:

Considering yield of made tea and economic analysis viewpoint it can be concluded that, the cost effective combination and rate of herbicides for controlling weeds in young tea is hand weeding + Glyphosate @ 3.7 Lha⁻¹ which to be done twice in nine month cropping season. Further research may be conducted with the combinations of IWM components and new molecule of herbicides to find out the better result.

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