RESEARCH ARTICLE

Performance of Poultry Litter Compost on Physiochemical Properties of Soil and Yield of Mature Tea

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Abstract

To evaluate the performance of poultry litter compost on the physiochemical properties of soil and yield of mature tea an experiment was carried out at the Bangladesh Tea Research Institute (BTRI) farm from January 2022 to December 2022. The effect of compost on the tea garden soil properties was also determined. This compost was applied at different rates (1.5, 3.0, 4.5 and 6.0 ton/ha) with 100% of the BTRI recommended fertilizer doses. Compost was applied in two splits in a year about 15 days before of inorganic fertilizer application. The yield of tea was recorded at seven days intervals during the harvesting season. Soil samples were collected before starting of the experiment as well as after completion of the experiment and analyzed accordingly. The highest yield (2354 kg made tea/ha) was recorded in the treatment T6 where 6.0 ton/ha poultry litter compost and 100% of BTRI recommended chemical fertilizer were applied. The increase of yield was 24.75% over the control which was statistically significant ($p < 0.05$). Though T6 gave a significantly higher yield the highest marginal rate of return (18.83%) was obtained from the treatment T4 where 3.0 ton/ha compost was applied along with 100% of BTRI recommended chemical fertilizer, which is the most economically acceptable doses of this fertilizer. The changes of the nutritional status of tea soil was statistically insignificant due to the application of compost.

Keywords: Compost, Poultry litter, Mature tea, Soil physiochemical properties, Economic analysis.

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INTRODUCTION

Tea is a popular beverage worldwide produced from the leaves of the evergreen shrub *Camellia sinensis L* (O Kuntze). Tea has enormous economic importance that can meet the domestic demand for Bangladesh's cheapest healthy beverage.[1] It is a perennial crop grown under monoculture on large contiguous areas that requires a lot of macro- and micronutrients to grow. Tea cannot be produced optimally without external nutrient addition as well as fertilizer application. Khan *et al.*[1] stated that fertilizer is one of the major agro-inputs contributing to the productivity in tea plantations. A well-balanced fertilization is necessary at certain intervals throughout the year for proper maintenance of the health of tea bushes as well as obtaining high yield.[1,2] Chemical fertilizer application is the primary method that is usually used to maintain tea yield as well as quality, though it has a negative environmental impact owing to its excessive use.[3] Enormous use of inorganic fertilizers leads to deterioration of soil physiochemical and biological properties that makes air pollution through nitrous oxide gas emission as well as excessive leaching, which leads to groundwater pollution by nitrate and heavy metals.[4] On the other hand the use of inorganic fertilizers has been observed to cause the destruction of soil texture and structure, which often leads to soil erosion acidity as a result of leaching effects of mineral nutrients, which reduced crop yields through soil degradation and nutrient imbalance.[5] The use of chemical fertilizers not only depletes soil nutrient reserves but also disrupts the biological eco-balance of the soil-plant system.[6]

For soil conservation and sustainable crop production, proper management of nutrient resources and maintenance of soil fertility through a combined application of inorganic and organic fertilizer is the primary and foremost need.[1] Nutrients in organic manure are released slowly and stored for a longer time in the soil, thereby ensuring a longer residual effect and persistence of nutrient availability.[6] Organic fertilizer is the storehouse of all nutrients. It can increase soil's water-holding capacity and make nutrients readily available to the plants when added to the soil.[1]

Poultry litter is a mixture of poultry excreta, spilled feed, feathers and materials used as bedding in poultry operations. Poultry litter has traditional uses as fertilizer. It contains high level of nutrients such as N, P and C.[7] According to Urra *et al.*[8] a direct application of raw poultry litter has harmful effects on soil health, as a result raw poultry litter needs to be composted before application in the agricultural field. Compost produced from poultry litter can supply substantial plant nutrients, contributing to sustainable crop yields.[9,10,11] The application of poultry manure in combination with chemical fertilizers will increase soil productivity and supplement all nutrients to crop.[12]

The present investigation was, therefore, undertaken to investigate not only the effect of poultry litter compost on the yield of mature tea but also improvement of soil condition and maintenance of soil physiochemical properties.

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MATERIALS & METHODS

Treatment Details and Fertilizer Application

An experiment was conducted at BTRI farm (24° 17′39.7″ N and 91° 44′50.5″ E) from January 2022 to December 2022 to evaluate the

Table 1: Details of treatments

Symbol of Treatment	*Treatment details*
T_1	Control
T_2	100% of BTRI recommended chemical fertilizer (Urea = 233 kg/ha, TSP = 68 kg/ha and MOP = 126 kg/ha)
T_3	1.5 ton/ha (Poultry litter Compost) + T_2
T_4	3.0 ton/ha (Poultry litter Compost) + T_2
T_5	4.5 ton/ha (Poultry litter Compost) + T_2
T_6	6.0 ton/ha (Poultry litter Compost) + T_2

performance of poultry litter compost on the yield & soil properties of mature tea in a randomized block design with six treatments and three replications as shown in Table 1. The unit plot size was 17.07 m^2.

Nitrogen, phosphorus and potassium nutrients were applied through urea, triple superphosphate (TSP), and muriate of potash (MOP) on the basis of 5 years average yield of the experimental plot. Urea and Muriate of Potash fertilizer were applied in two splits where TSP was applied during the 1st split of fertilizer application. The first dose of fertilizer was applied in April when soil contained sufficient moisture & the second dose was applied in the first week of August 2022. Poultry litter compost was applied and mixed with the soil by light forking in two split doses before 15 days of chemical fertilizer application around the year. Depending on soil pH and sufficient soil moisture, dolomite was applied in every experimental plot except control before fertilization.

METHOD

Soil Sample Collection and Analysis Method

Surface soil (0–23 cm) from all the experimental plots were collected before and after the experiment was completed. The tea yield, i.e., green leaves' weight, was recorded at seven days intervals. Irrigation, pruning, pest control and other intercultural operations were done when necessary. Soil 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. Soil texture was determined by the hydrometer method. However, pH was determined by using pH meter (InoLab pH 7110) (soil: distilled water = 1: 2.5). Total nitrogen was determined by Micro kjeldahl steam distillation method.[13] Walkley and black[14] wet oxidation method was applied for soil organic carbon determination.[13] Colorimetric estimation of available phosphorus was done by Bray-II ascorbic acid (Blue Color) method.[13] Organic carbon and available phosphorus was determined by spectrophotometer (JENWAY 6300). Available potassium, calcium and magnesium were extracted with 77% ammonium acetate solution. Available potassium was determined by a flame photometer (BUCK- Scientific PEP7) while calcium and magnesium was determined by AAS (atomic absorption spectrophotometer) (Analytikjena. Model: novAA 400P).

Compost Analysis Method

The moisture content (%) of poultry litter compost was determined by using a moisture analyzer (KERN. Model: DBS60-3). The Organic Matter (%) and Organic carbon (%) of the compost fertilizer was determined by using Muffle Furnace (JISICO. Model: J-FM-28) at 550°C.[15] The pH of the compost samples was measured using a pH meter (InoLab pH 7110). Distilled water was used to make the compost suspension at a compost: water ratio of 1:10.[16] Total nitrogen (N) was determined by Micro Kjeldahl steam method.[13] Total P was determined by the colorimetric method (Blue color method) using a spectrophotometer (JENWAY 6300).[17] For determination total potassium (K), total calcium (Ca), total magnesium (Mg), total zinc (Zn) and total Copper (Cu) of the compost sample was digested by the nitric acid - -perchloric acid digestion method[13] and determined using the Atomic Absorption Spectrophotometer (AAS) (Analytikjena. Model: novAA 400P).

Statistical and Economic Analysis

All the data were recorded and analyzed statistically by using Microsoft excel, IBM SPSS 20 and Minitab 17 software. The data were analyzed using one-way ANOVA the Analysis of Variance of Simple Classification and box plot analysis. Treatments that were significant were analyzed with Tukey's post hoc test at 5% level. Microsoft excel determined scatter plot to find out economical viable treatments. After that, Marginal rate of return were calculated by subtraction of marginal net return and marginal total variable cost to find out the most cost-effective doses of the poultry litter compost.

RESULT AND DISCUSSION

Analysis of Poultry Litter Compost

In Table 2 the physicochemical analysis of compost was shown. The supplied compost contained organic matter (40.40%), organic carbon (23.35%), and total nitrogen (2.59%), C: N ration (9:1), total phosphorus (2.83%), total potassium (2.61%), total calcium (3.64%), total magnesium (1.38%), total zinc (0.06%) and total copper (0.02%). The compost analytical results revealed that most of the nutrient content and other properties of the supplied samples are within the critical limits set by the Bangladesh government.[18]

Changes of Soil Physiochemical Properties

Analytical results of the soil samples which were collected from the experimental plots before set up the experiment and after completion of the experiment, are presented in both Table 3 and 4. The textural class of the soils of the experimental plots were sandy clay loam. All the properties, including the nutrient contents except available calcium, was above the critical limit in the soil samples collected initially from the experimental site as shown in Table 3.

Table 2: Composition of poultry litter compost

Parameter	*Analytical results*	*Government Approved Critical Limits.*[18]
Color	Gray	Dark Grey to Black
Odor	Absence of foul odor	Absence of foul odor
Physical Condition	Non granular	Non granular
Moisture%	22.05	10–20
pH	7.3	6.0–8.5
Organic Matter %	40.40	-
Organic Carbon %	23.35	10–25
Total Nitrogen %	2.59	0.5–4.0
C:N	9:1	20:1(max)
Total Phosphorous %	2.83	0.5–3.0
Total Potassium %	2.61	0.5–3.0
Total Calcium %	3.64	-
Total Magnesium %	1.38	-
Total Zinc %	0.06	(0.1 max)
Total Cu%	0.02	0.05

Table 3: Initial physiochemical properties of the soil of the experimental site

Soil properties	*Analytical value*	*Critical value[1]*
Texture	SCL	Sandy Loam to Loam (SL-L)
pH	5.31	4.5-5.8
OC%	1.55	1.0
Total N%	0.150	0.1
Available Phosphorous mg/Kg	36.12	10
Available Potassium mg/Kg	39.78	80
Available Calcium mg/Kg	181.66	90
Available Magnesium mg/Kg	40.59	25

According to Table 4 after the experiment's completion, there were no changes in the textural class of the soil. Highest pH (5.83) was recorded in treatment T_2 and the lowest pH (4.90) was found in the treatment T_4 and T_5 respectively. Box plots showing the variability of soil pH in the surface soils (0–23 cm) of the plots of different treatments as shown in Figure 1. Wider variability of soil pH was found in the case of treatments T_4 and T_6. The differences of soil pH among the different treatment was statistically insignificant.

The highest OC (2.04) was found in Treatment T_4 and the lowest OC (1.66) was found in case of treatment $T_{1,}$ which is presented in Table 4. It is clear that the application of chemical fertilizer alone had no effect on the increase of soil organic carbon content where the box plot shows (Figure 1) that Only T_2 have wide variability and T_5 has a symmetric distribution with small variation. Tough the differences of OC were statistically insignificant but 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 findings of Hegde.[19]

Due to the application of poultry litter compost and the combination of chemical fertilizers under the treatments, organic matter has buildup which increases in the content of total N in soil[20]; the author also stated that organic matter also reduced the losses of nitrogen and thus the content of total N had increased. In (Table 4) total N content is higher (0.20%) in case of T_4 the lowest total N (0.170%) was found in case of treatment T_1. Box plots showing the variability of total N in the surface soils (0-23 cm) of the plots of different treatment (Figure 1). Wider variability of total N was found in the case of treatment T_2 and where T_6 shows small variability due to loss of nitrogen by evaporation and leaching loss of Urea.[20] The differences of total N among the different treatment was statistically insignificant.

Table 4: Effect of Poultry litter based compost on the physiochemical properties of soil

Treatment	*Texture*	*pH*	*OC (%)*	*Total N (%)*	*Av.P (mg/kg)*	*Av.K (mg/kg)*	*Av.Ca (mg/kg)*	*Av.Mg (mg/kg)*
T1	SCL	5.50	1.66	0.170	45.00	40.63	284.93	57.97
T2	SCL	5.83	1.80	0.180	58.58	51.57	290.27	52.28
T3	SCL	5.23	1.77	0.180	37.36	48.61	262.35	41.31
T4	SCL	4.90	2.04	0.200	50.42	48.17	215.61	41.41
T5	SCL	4.90	1.77	0.180	56.45	68.77	232.73	45.20
T6	SCL	5.20	1.88	0.190	39.29	56.51	229.17	60.21

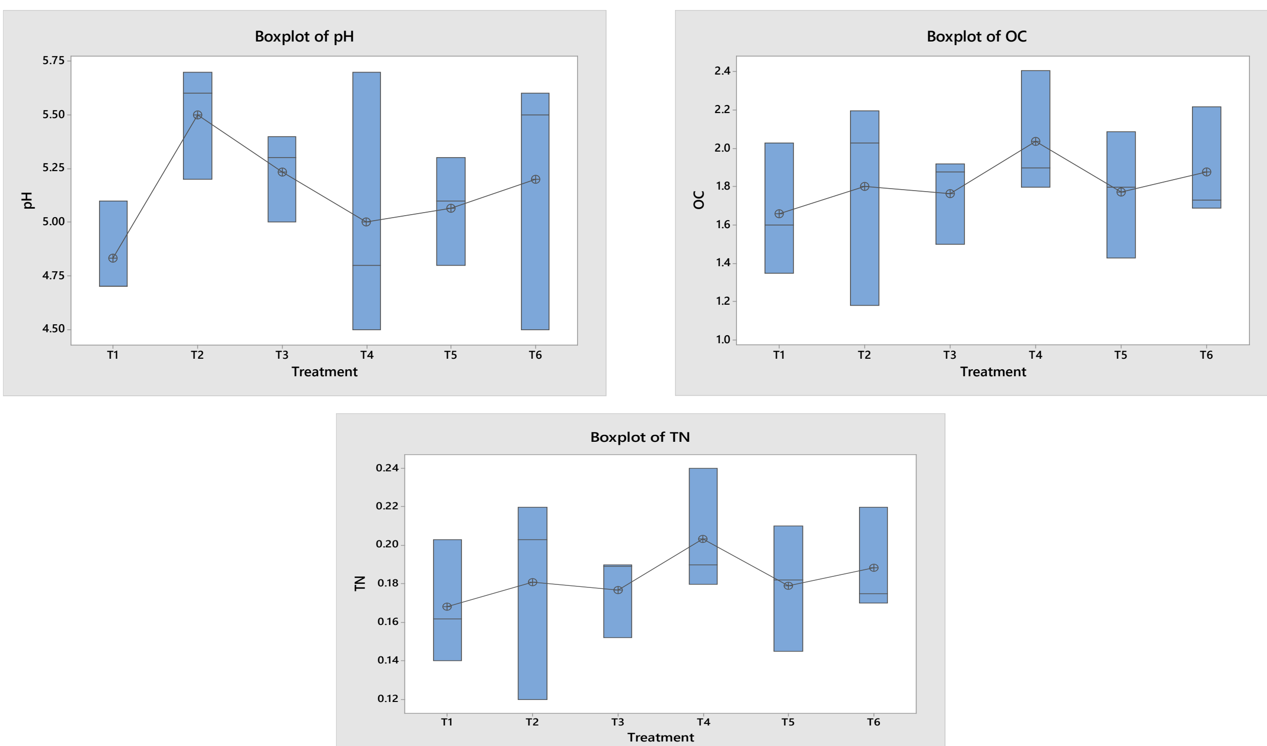

Figure 1: Box plots showing the variability of soil pH, organic carbon (%) and total nitrogen (%) content in the surface soils (0–23 cm depth) of the plots of different treatment

Table 4 also shows that the effect of different treatments on the changes in soil Av.P and Av.K. The highest soil Av.P (58.58 mg/Kg) found in T_2, the second highest T_5 (56.45 mg/Kg) where T_3 shows the lowest value (37.36 mg/Kg).In Boxplot (Figure 2) all treatments indicate that there was wide variability on Av.P distribution. The differences of Av.P were statistically insignificant. Saha *et al.*[20] stated that Av. P's content can be improved due to the combination of organic fertilizer and NPK fertilizer.In box plot (Figure 2), analysis available K shown small variability with symmetric distribution where T_5 shows the highest value (68.77 mg/Kg) (Table 4). Because direct addition of potassium on the pool of soil as well as the beneficial effects of organic fertilizer 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.[20]

Table 5: Effect of poultry litter Compost on the yield of mature tea.

Treatment	*Made tea kg/ ha*	*Rate % of increase over control*
T1	1887 ± 0.50 $^{(d)}$	0.00
T2	1970 ± 1.00$^{(cd)}$	4.40
T3	2069 ± 0.35 $^{(bcd)}$	9.64
T4	2170 ± 0.20 $^{(abc)}$	15.00
T5	2264 ± 0.18 $^{(ab)}$	19.98
T6	2354 ± 0.58 $^{(a)}$	24.75

Box plot analysis (Figure 2) shows the changes in soil Av.Ca and Av.Mg due to the effect of different treatments. All treatments indicate that there was wide variability on Av,Mg. Only treatment T_2 in case of Av.Ca and T_2, T_3 and T_4 in case of Av.Mg represents symmetric distribution with small variability where they are statistically insignificant. (Table: 4) shows that T_2 gives the highest Av.Ca (290.27 mg/Kg) and the lowest value (215.61 mg/Kg) in T_4. On the other hand T_6 gives the highest Av. Mg (60.21 mg/Kg) was the lowest value (41.31 mg/Kg) in case of T_3.

Table 6: Net Return rate of percentage from yield of different Treatments

Treatment	*Yield kg/plot*	*Yield kg/ ha*	*Made tea kg/ ha*	*Total Variable cost (USD/ha)*	*Average Sell price (USD)*	*Gross Return (USD/ha)*	*Net Return (USD/ha)*	*Rate % of increase over control*
T_1	14.007	8205.624	1887	0.00	1.53	2878.50	2878.50	0.00
T_2	14.585	8544.230	1965	120.88	1.53	3006.71	2885.83	0.25
T_3	15.3	8963.093	2062	256.20	1.53	3154.11	2897.92	0.67
T_4	16.08	9420.035	2167	391.51	1.53	3314.91	2923.40	1.56
T_5	16.81	9847.686	2265	526.83	1.53	3465.40	2938.57	2.09
T_6	17.47	10234.329	2354	662.14	1.53	3601.46	2939.32	2.11

1Tk (BDT) = 0.0093 USD dollar

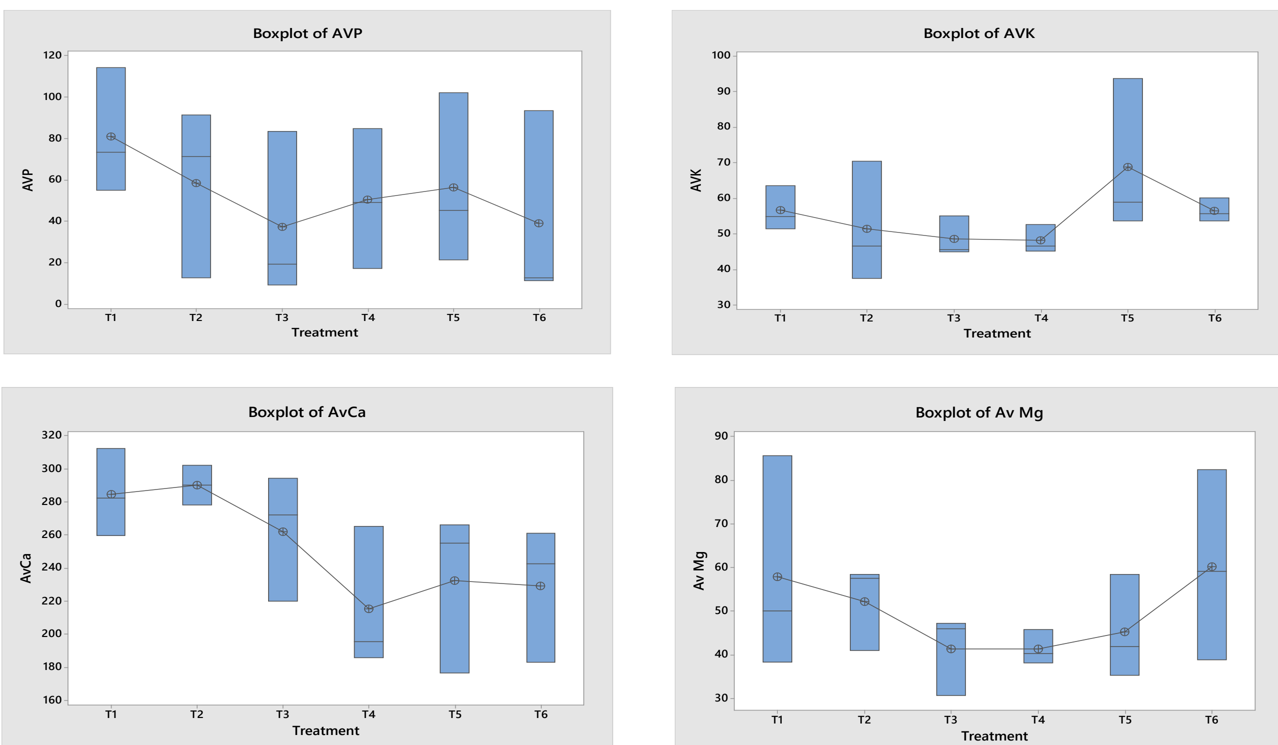

Figure 2: Box plots showing variability of available phosphorus, potassium, calcium and magnesium concentration (mg/kg) in the surface soils (0-23 cm depth) of the plots of different treatment.

Table 7: Partial budget of different dose of Poultry litter based compost applied in mature tea

Treatment	*Net Return (USD)*	*Marginal Net Return (USD) (a)*	*Total Variable Cost (USD)*	*Marginal Total Variable Cost (USD) (b)*	*Marginal Rate of Return (%)*
T_5	2938.57	15.17	526.83	135.32	11.21
T_4	2923.4	25.48	391.51	135.31	18.83
T_3	2897.92	12.09	256.2	135.32	8.93
T_2	2885.83	7.33	120.88	120.88	6.06
T_1	2878.5	0	0	0	0

Analysis of Tea Yield

The effect of poultry litter compost on the yield of tea is presented in Table 5. In the case of every treatment yield has increased over the control. The maximum yield of made tea (2354 kg/ha) was found in treatment T_6, which was 6 ton/ha compost with 100% recommended chemical fertilizers. The rate of increase over the control was 24.75% in the case of treatment T_6. Treatment T_5 is the second-best treatment, where yield of made tea was 2264 kg/ha and the rate of increase over the control was 19.98%. The yield of made tea was increased 4.40% over the control in the case of treatment T_2 where only 100% recommended doses of chemical fertilizers were used. A statistically significant ($^{ANOVA}F = 18.52$, $p < 0.05$) difference was found in the yield of tea among all treatments. Ipinmoroti *et al.*[21] reported that the use of organic fertilizer in combination with inorganic fertilizers gave better yield.

Economic analysis

The yield of tea also increased significantly in all the treated plots in comparison with the control plot. The identical yield from 1887 kg/ha to 2354 kg/ha was produced in the compost treated plot. The net return rate % of increase according to yield over Control due to various treatments ranged from 0.25% (Low in T_2) to 2.11% (High in T_6) (Table 6).

Average Cost of Poultry litter based compost = 0.074 USD/kg. Urea= 204.60 USD/ton, T.S.P= 186.00 USD/ton and M.O.P = 120.90 USD/ton. Average Auction price of made tea (BTRI) in 2022 approximately 1.53 USD/kg.

- Gross return = Yield x price of a particular product;
- Net return = Gross return - Variable cost.

Dominance test

According to CIMMYT.[22] a treatment is said to be dominated when at least one option offers a lower net return at an equal or higher cost and a treatment is undominated when no other options offer a greater net return at an equal or lesser cost. The treatments T_6 with 100% Recommended Chemical fertilizer with variable cost of Tk. 662.14 USD/ha were cost-dominated due to its higher cost compared to a relatively lower net return (2939.32 USD) than other treatment as shown in Figure 3. So this treatment was eliminated for further analysis.

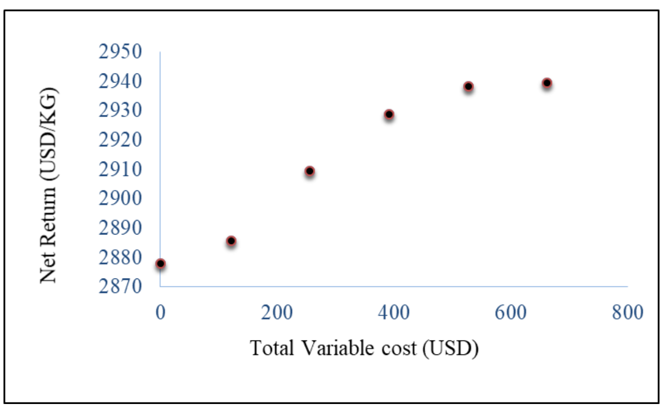

Figure 3: Dominance analysis of different doses of compost used in mature tea

Partial budget analysis

Though according to effectiveness and tea yield T_6 (6 ton/ha poultry litter compost+ 100% RFD) was significantly higher. But From the economic point of view, T_4 (3 ton/ha poultry litter compost+ 100% RFD) showed the highest marginal rate of return (18.83%) and T_2 (100% RFD) showed the lowest marginal rate of return (6.06%) compared to all other treatment (Table 7). So, T_4 (3 ton/ha poultry litter compost+ 100% RFD) is the most economically acceptable doses of poultry litter compost for application in mature tea plantation.

- Marginal Net Return: A farm's revenue increase caused by increasing one extra unit of inputs.
- Marginal Variable Cost: The increase in the variable cost of farm caused by increased output by one extra unit
- Marginal Rate of Return % : (a/b*100)
- RFD= Recommended chemical fertilizer dose.

CONCLUSION

Tea *Camellia sinensis* as an evergreen shrub (bush) is an aromatic beverage all over the world. Soil fertility has been described as the capacity of soils to make nutrients available to plants. In tea plantations Nutrient management is an important aspect which supplies nutrients mainly through chemical fertilizers. However, both organic and inorganic fertilization are essential for increasing tea yield and improving tea's soil properties. According to the present study, it could be suggested that the yield of tea can increase at the highest percentage (24.75%) with T_6 (6 ton/ha poultry litter compost +100% Recommended chemical fertilizer) that revealed to get the highest yield of tea 2354 kg/ha; as well as at the same time from economic analysis the highest marginal rate of return (18.83%) was obtained by T_4 (3.0 ton/ha Poultry litter compost + 100% of BTRI recommended chemical fertilizer) over control compared to other treatments. Tea planters could use NPK fertilizers with poultry litter compost in two splits at 15-day interval to reduce the enormous loss of inorganic fertilizers and their damaging effects on the soil. This experiment clearly indicated that the production of tea can be enhanced by the application of poultry litter compost along with chemical fertilizer. It may be recommended as an organic fertilizer for improving the physiochemical properties of soil as well as the production of mature tea. A long-term experiment on integrated nutrient management in combinations of poultry litter compost and reduced doses of NPK could also be undertaken to support general fertilizer application.

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