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Assessment of yield, economics and soil health in organic cultivation of tea under Palam valley of Himachal Pradesh

Lachha Choudhary[1], Sanjay Kumar[2], Sandeep Manuja[3], Supriya[*4], Vipin Kumar[5] and Dilip Choudhary[6]

[1,2,3]Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, 176061, Himachal Pradesh, India

ABSTRACT

Field experiment was conducted during pre-monsoon (summer), monsoon (kharif) and post- monsoon season of 2021–22 at the experimental farm of Department Tea Husbandry & Technology, CSK HPKV, Palampur (H.P.) to study effect of different organic nutrient sources on soil health and tea yield [*Camellia sinensis* (L.) O. Kuntze]. The experiment was laid out in Randomized Block Design (RBD) with ten treatments and three replications. Among the organic treatments, application of different nitrogen sources viz. farmyard manure (FYM), vermicompost, jeevamrit and vermiwash. The experimental soil was acidic in reaction, silty clay loam in texture and low on N while it medium to P and K. A statistical analysis of the results revealed that incorporation of vermicompost @10 t/ha + jeevamrit @10% significantly increased available nitrogen (273.2 kg/ha), microbial count (179.2 µg/g) including bacteria, fungi and actinomycetes. Moreover, vermicompost applied @ 10 t/ha (split dosed) of which half was supplemented with added to P and K produced a significantly highest available phosphorus (20.74 kg/ha) and potassium (247.1 kg/ha) content at a depth of 0 - 22.5 cm by the end of the experiment compared to the control. Application of vermicompost @ 10 t/ha + jeevamrit @10% increased the yield (1022.4 kg/ha) and improves the soil health. This treatment also resulted in significantly higher gross returns (₹ 562320/ha) and net returns (₹ 321524.4/ha) compared to the control.

Key words: *Camellia sinensis,* farmyard manure, jeevamrit, vermiwash, vermicompost.

INTRODUCTION

In early India, the farmers followed the natural law which helps to maintain soil fertility over the period. As per the statistics for the financial year 2022, the net area under organic farming has increased by up to 2.45% over the last year (Keelery, 7). For sustainable crop production, a good soil fertility system is essential, which necessitates the constant use of organic fertilizer sources. Farmyard manure, vermicomposting, vermiwash, and other organic fertilizers can provide nutrients (Iqbal *et al*., 4). These organic sources not only replenish N, P, and K minerals to plants, but also convert inaccessible major nutrients, micronutrients, and decomposing plant residues into plant-available forms (Yadav *et al*., 18). Therefore, organic agriculture is considered as a holistic approach for agriculture which not only assure sustainable crop production but also helps to enhance agro-ecosystem and the resulting crops are more nutritious (Yadav *et al*., 19). Tea, a member of the Theaceae family, is one of the oldest and most widely consumed beverages globally (Juang and Chen, 6; Zhang *et al*., 20). In recent years, the adoption of chemical farming practices has notably impacted soil ecology, crop productivity, and quality in tea cultivation (Deka and Goswami., 1).

The use of chemical fertilizers and pesticides in conventional tea farming has endangered soil health, caused yield instability and decreased product quality throughout the years (Maitra *et al*., 9; Zhen *et al*., 20). The effects of chemical fertilizers on the intricate biogeochemical cycles essential for sustainable agricultural systems was extremely deteriorating (Sharma *et al*., 14). Comparatively to chemical fertilizers, organic fertilization of tea plantations may increase soil fertility and achieve carbon build-up, which was a crucial component of determining soil characteristics and production (Qui *et al*,, 13). Organic nutrient sources in tea production are inexpensive and readily available with no negative environmental impact. The use of organic fertilizers is an important practical measure for increasing soil fertility (Zhen *et al*., 20). Application of organic fertilizer boosts potential ecosystem function, changes the network structure, and increases soil microbial diversity. This study was carried out to compare the various organic inputs and their potential to release necessary nutrients into the soil while mitigating the burden on farmers' cultivation costs. The objective of the experiment

*Corresponding author's email: supriya.ndri5@gmail.com

[4,5]National Dairy Research Institute, Karnal 132001, Haryana, India

[6]Swami Keshwanand Rajasthan Agriculture University, Bikaner 334006, Rajasthan, India

was to study the effect of organic inputs on the different properties of soil.

MATERIALS AND METHODS

The experiment took place during the pre-monsoon (summer), monsoon (kharif), and post-monsoon (rabi) seasons of 2021-22 at the Research Farm of Tea Husbandry and Technology, [3]Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh (H.P.), Palampur, India. The experimental field is an organic established tea orchard since 2008 and organic certificate was issued in 2011. The research site is located at an altitude of 1291 meters above sea level , at a latitude of 32°61' N and a longitude of 76°3' E, nestled in the Palam Valley of H.P.. Agro-climatically, this experimental site represents sub humid temperate and mid hill zone of H.P., characterized by cool winters from November to February and moderate summers from March to June. Throughout the trial, 2332.6 mm of rain fall received. The average weekly maximum temperature fluctuated between 22.1°C and 31.1°C, while the average minimum temperature ranged from 9.3°C to 20.8°C. The average relative humidity remained between 48-97.6% during the experimental period. The mean sunshine hours for the experimental period remained between 1.3-9.6 hours. The experiment was conducted using a randomized block design, featuring ten different treatments, each replicated three times. The treatments included a control (T_1) where no external source of nutrients has been applied, FYM at 20 t/ha (T_2), vermicompost at 10 t/ha (T_3), split applications of FYM at 10 t/ha + 10 t/ha (T_4), split applications of vermicompost at 5 t/ha + 5 t/ha (T_5), FYM at 20 t/ha + jeevamrit at 10% (T_6), vermicompost at 10 t/ha + jeevamrit at 10% (T_7), FYM at 20 t/ha + vermiwash at 10% (T_8), vermicompost at 10 t/ha + vermiwash at 10% (T_9), and jeevamrit at 10% (T_{10}). The soil samples were collected from two depths i.e., 0-22.5 and 22.5- 45.0 cm. The soil samples collected before and after the treatment's application was dried, ground, passed through 2 mm sieve and used for analysis. These samples were processed and analyzed for pH, organic carbon, microbial count and microbial biomass carbon. Using Walkley and Black, 17 wet digestion method, the amount of organic carbon was measured. The approach outlined by Subbiah and Asija, 15 was used to calculate the available nitrogen content. Extraction of available phosphorus from the soil was conducted using a sodium bicarbonate extractant and the concentration of phosphorus in the extract was resolved using Olsen's method (Olsen *et al.*, 12). Lastly, the available potassium content was determined through the method outlined by Metson (10).

The standard serial dilution plate count method was used to count the total number of soil bacteria, fungus, and actinomycetes. Nutrient agar was used for bacteria, Rose Bengal agar for fungi, and crustose agar for actinomycetes. The plates were incubated at 28 ± 2°C, and colony counts were recorded on the seventh day. Microbial biomass carbon was determined using the fumigation-extraction method (Vance *et al.*, 16).

The two leaf and one bud from each plot were plucked manually. The total fresh weight of the pluck from each plot was taken. The green leaf yield obtained from each plot was converted to kg/ha. The cumulative green leaf yield was the sum total of all the plucking's taken during three seasons i.e., pre-monsoon (summer), monsoon (kharif), and post-monsoon (rabi) seasons. In each plot, a quadrate of 50 cm × 50 cm was placed randomly at three spots. Green leaves i.e., two leaves and one bud were plucked manually and their average fresh weight was measured and converted into weight per square meter by multiplying the value with factor 4. Green leaf yield was expressed in g m^{-2} taking an average of 25 % recovery of green leaf during the entire growing season. Made tea was prepared from the two leaves and a bud which were plucked from each plot and converted into kg/ha.

The cultivation cost, gross return and net return under varied treatments were calculated using the present market cost of various inputs. The gross monetary return is a total return on an investment before deducting expenses, which is worked out by considering price of tea during harvest. Net returns were determined by subtracting the cost of cultivation from the gross returns. Net returns (₹/ha) = gross returns (₹/ha) – total cost of cultivation (₹/ha). The benefit-cost ratio was calculated using the following formula:

$$\text{B: C ratio} = \frac{\text{Net return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

The data collected during the field experiment was analyzed using analysis of variance (ANOVA) as outlined by Gomez and Gomez, 3 in MS EXCEL. The statistical significance of the experimental data was assessed at the 5% level using the "F test." When the F value was found to be significant, the critical difference (p=0.05) was calculated.

RESULTS AND DISCUSSION

The organic nutrient inputs significantly influenced the levels of available nitrogen (N), phosphorus (P), potassium (K), organic carbon, and microbial populations (bacteria, fungi, and actinomycetes), as well as microbial biomass carbon, in the soil at a depth of 0-22.5 cm. However, these inputs did not have a significant effect on these soil properties at a depth of 22.5-45 cm (Table 1).

The higher value of pH found at 22.5-45.0 cm compared to 0-22.5 cm might be due to the leaching of bases from surface to subsurface soil with high rainfall in Palampur region. However, no significant difference was noticed in soil pH after the addition of organic inputs. A positive impact of all the treatments except control was observed over available soil nitrogen. At 0-22.5cm depth, a significantly higher value of available nitrogen, phosphorus, and potassium was recorded with the application of vermicompost@10t ha^{-1}+ jeevamrit @10% (Table 1). However, the lower available nitrogen, phosphorus, and potassium were recorded without the use of any organic nutrient sources. The increase in the amount of these nutrients was due to enhanced biomass carbon which results in the mineralization process. Mineralization helps in the solubility of native phosphates these results are in accordance with Gogoi *et al*. (2).

The effect of organic nutrient sources on soil microbial properties was found to be significant at 0-22.5 cm of soil depth however, at 22.5-45cm it was not significant. This might be due to the application of all organic sources on the upper surface, better physical condition, comparatively higher root biomass, and the presence of a higher population of microbes on the upper surface of the soil. At 0-22.5cm depth, a significantly higher value of soil organic carbon (0.758%) was observed with the application of FYM @ 20 t ha^{-1} which was statistically similar to all other treatments except for the application of jeevamrit@10% and the use of any organic source. The percent increase in soil organic carbon was 7.65 % over control. The significantly higher values of microbial biomass carbon (179.2 µg/gram), bacterial ($31.1*10^{-6}$ cfu /g of soil), fungal ($34.3*10^{-3}$ cfu / g of soil) and actinomycetes ($11.1*10^{-3}$ cfu / g of soil) populations were obtained with the application of vermicompost @ 10t ha^{-1} + jeevamrit at 10% (Table 2). These results are in close conformity with Lin *et al*. (8), Qui *et al*. (13), Ji *et al*. (5) and Juang and Chen (6).

The influence of organic nutrient sources on black tea yield was significant during the pre-monsoon, monsoon, and post-monsoon seasons (Table 3). In the pre-monsoon season, the highest

Table 1. Effect of different organic nutrient sources on soil properties (pH, available N, P and K) at the end of experiment.

	Treatment details	pH		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
		0-22.5 cm	22.5-45 cm	0-22.5 cm	22.5-45 cm	0-22.5 cm	22.5-45 cm	0-22.5 cm	22.5-45 cm
T_1-	Control	5.19	5.32	233.5	195.6	18.51	14.38	226.3	178.8
T_2-	FYM at the rate 20 t/ha	5.25	5.33	246.4	197.2	19.90	14.79	246.3	183.4
T_3-	Vermicompost @ 10 t/ha	5.25	5.30	260.1	198.7	20.50	15.40	246.2	183.2
T_4-	FYM at the rate 10 t/ha (pre-monsoon season) + @ 10 t/ha (monsoon season)	5.20	5.31	243.0	196.7	19.70	14.89	244.9	183.5
T_5-	Vermicompost at the rate 5 t/ha (pre-monsoon season) + at the rate 5 t/ha (monsoon season)	5.21	5.30	262.4	199.1	22.10	15.45	247.7	184.2
T_6-	T_2 + Jeevamrit at the rate 10% within 2 days after plucking	5.20	5.33	248.6	197.2	19.91	14.91	246.6	183.2
T_7-	T_3 + Jeevamrit at the rate 10% within 2 days after plucking	5.26	5.34	273.2	198.7	20.74	15.43	247.1	183.5
T_8-	T_2 + Vermiwash at the rate 10% within 2 days after plucking	5.22	5.33	245.4	197.2	19.91	14.91	246.3	183.4
T_9-	T_3 + Vermiwash at the rate 10% within 2 days after plucking	5.25	5.33	263.6	198.7	20.70	15.43	247.1	184.2
T_{10}-	Jeevamrit at the rate 10% within 2 days after plucking	5.20	5.29	236.4	195.6	18.52	14.38	226.7	178.8
	Initial value	5.2	5.3	245.3	197.6	19.2	14.45	230.7	179.2
	SEm±	0.07	0.07	5.98	4.28	0.45	0.28	5.62	3.78
	CD (P= 0.05)	NS	NS	17.54	NS	1.31	NS	16.50	NS

Table 2. Effect of different organic nutrient sources on soil properties at the end of experiment.

	Treatment details	Organic Carbon (%)		Microbial count (µg/g)		Bacteria ($*10^{-6}$ cfu/g of soil)		Fungi ($*10^{-3}$ cfu/g of soil)		Actinomycetes ($*10^{-3}$ cfu/g of soil)	
		0- 22.5 cm	22.5-45 cm	0- 22.5 cm	22.5-45 cm	0-22.5 cm	22.5-45.0 cm	0-22.5 cm	22.5-45.0 cm	0-22.5 cm	22.5-45.0 cm
T_1-	Control	0.700	0.520	164.6	104.6	24.2	15.9	31.2	21.2	8.7	5.7
T_2-	FYM @ 20 t/ha	0.758	0.538	172.2	105.8	28.0	16.0	32.7	22.0	10.5	6.0
T_3-	Vermicompost @ 10 t/ha	0.722	0.541	174.8	106.3	28.9	16.5	33.0	22.6	10.8	6.6
T_4-	FYM @ 10 t/ha (early season) + @10 t/ha (monsoon season)	0.750	0.538	171.1	107.2	28.3	16.0	32.9	22.0	10.3	6.0
T_5-	Vermicompost @ 5 t/ha (early season) + @ 5 t/ha (monsoon season)	0.745	0.540	172.6	107.9	29.9	16.5	33.6	22.7	10.8	6.7
T_6-	T_2 + Jeevamrit @ 10% within 2 days after plucking	0.721	0.539	173.1	108.0	29.7	16.0	33.0	22.0	10.8	6.0
T_7-	T_3 + Jeevamrit @ 10% within 2 days after plucking	0.721	0.541	179.2	108.1	31.1	16.8	34.3	22.7	11.1	6.6
T_8-	T_2 + Vermiwash @ 10% within 2 days after plucking	0.755	0.539	172.9	108.0	29.7	16.0	33.0	21.9	10.8	6.0
T_9-	T_3+Vermiwash @ 10% within 2 days after plucking	0.753	0.540	178.6	108.0	31.0	16.6	34.0	22.6	11.0	6.6
T_{10}-	Jeevamrit@10% within 2 days after plucking	0.713	0.523	165.5	105.5	25.0	15.9	32.0	21.2	8.9	5.7
	Initial value	0.701	0.52	163.2	103.2	23.5	14.78	30.6	20.89	8.53	5.53
	SEm±	0.008	0.005	3.42	1.87	0.77	0.33	0.85	0.48	0.26	0.26
	CD (P= 0.05)	0.024	NS	10.04	NS	2.26	NS	2.48	NS	0.76	NS

Table 3. Effect of different organic nutrient sources on made black tea yield.

	Treatment details	Made tea (kg/ha)			
		Pre-monsoon season	Monsoon season	Post monsoon season	Total
T_1-	Control	213.3	240.0	190.4	643.7
T_2-	FYM @ 20 t/ha	306.7	318.6	236.8	862.1
T_3-	Vermicompost @ 10 t/ha	356.0	348.0	257.6	961.6
T_4-	FYM @ 10 t/ha (pre-monsoon season) + @ 10 t/ha (monsoon season)	286.7	320.0	240.0	846.7
T_5-	Vermicompost @ 5 t/ha (pre-monsoon season) + @ 5 t/ha (monsoon season)	333.3	360.0	259.2	952.5
T_6-	T_2 + *Jeevamrit* @ 10% within 2 days after plucking	318.8	344.0	248.0	910.8
T_7-	T_3 + *Jeevamrit* @ 10% within 2 days after plucking	370.7	373.3	278.4	1022.4
T_8-	T_2 + Vermiwash @ 10% within 2 days after plucking	313.5	334.6	246.4	894.6
T_9-	T_3 + Vermiwash @ 10% within 2 days after plucking	360.0	361.3	265.6	986.9
T_{10}-	*Jeevamrit* @ 10% within 2 days after plucking	231.7	262.7	196.8	691.2
	SEm±	16.6	16.1	11.8	
	CD (P= 0.05)	53.1	51.5	37.8	

Table 4. Effect of different organic nutrient sources on economics (₹) of made black tea.

	Treatment details	Cost of cultivation (₹/ha)	Gross return (₹/ ha)	Net return (₹/ha)	Net return per rupee invested
T_1-	Control	151817.8	354053.3	202235.6	1.33
T_2-	FYM @ 20 t/ha	206653.5	474160.4	267506.9	1.29
T_3-	Vermicompost @ 10 t/ha	228582.2	528880	300297.8	1.31
T_4-	FYM @ 10 t/ha (early season) + @ 10 t/ha (monsoon season)	203509.5	465661.8	262152.3	1.29
T_5-	Vermicompost @ 5 t/ha (early season) + @ 5 t/ha (monsoon season)	226675.6	523893.3	297217.8	1.31
T_6-	T_2 + Jeevamrit @ 10% within 2 days after plucking	217129.7	500964.7	283835	1.31
T_7-	T_3 + Jeevamrit @ 10% within 2 days after plucking	240795.6	562320	321524.4	1.34
T_8-	T_2 + Vermiwash @ 10% within 2 days after plucking	209395.9	492009.8	282613.9	1.35
T_9-	T_3 +Vermiwash @ 10% within 2 days after plucking	233788.9	542813.3	309024.4	1.32
T_{10}-	Jeevamrit @ 10% within 2 days after plucking	162024.4	380160	218135.6	1.35

black tea yield was recorded with the application of vermicompost at 10 t/ha + jeevamrit at 10% (370.7 kg/ha), which was statistically similar to the yield achieved with vermicompost at 10 t/ha + vermiwash at 10% (360 kg/ha). The lowest made black tea yield was recorded in absolute control. Similar trends were also followed in monsoon and post monsoon season.

These effects might be due to the fulfilment of nutritional requirements for tea, the better availability of nutrients throughout the year that ultimately improved growth and yield attributing characteristics (to a higher number of actively growing shoots per square meter, improved leaf growth and higher shoot biomass per square meter) of tea, which resulted in a higher yield. These results are in close conformity with Maitra *et al*. (9), Negi and Bisht (11).

The application of vermicompost @ 10 t ha^{-1} + jeevamrit @ 10% recorded the highest gross return of ₹ 562320/ha, which was followed by vermicompost @ 10 t ha^{-1} + vermiwash @ 10% (Table 4). The lowest gross return was recorded in absolute control. The significant difference in gross return was mainly because of the difference in made tea yield due to the treatment effect. Similarly, higher net return (₹ 562320/ha) and additional net return (₹ 119288/ha) follow the same trend. The finding was similar to (Deka and Goswami, 1; Zhen *et al*., 20).

It is evident form the study that the that yield, monetary returns and physical, chemical and biological properties of soil was recorded highest with application of vermicompost @10t/ha+ @10% in pre-monsoon, monsoon and post monsoon. Therefore, the applications of organic inputs showed significantly improved results in comparison to the conventional methods and can be recommended to the farmers.

AUTHORS' CONTRIBUTION

Conceptualization (LC, SK, SM), Methodology (LC, SM, SK), Investigation (SK, SM), Data curation and Formal analysis (LC, SM), Writing original draft (LC, S), Resources, Software, Validation (SK, SM), Review and editing (SM, S, VK, DC).

DECLARATION

The authors declare that they have no conflicts of interest to disclose regarding the research presented in this article.

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