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

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ABSTRACT

A field experiment was conducted during pre-monsoon (summer), monsoon and post monsoon season of the year 2021-22 to monitor the effect of organic nutrient sources on soil properties and yield of Tea [*Camellia sinensis* (L.) O. Kuntze]. The experiment comprised of 10 treatments with the organic treatment include application of different nitrogen sources, *viz*. farmyard manure; vermicompost; *Jeevamrit* and vermiwash. The soil of experiment field was acidic in nature, silty clay loam in texture, low in nitrogen, medium in phosphorus and potassium. Results revealed that the significantly higher available nitrogen, microbial count and microbial biomass carbon was recorded with the application of vermicompost @ 10 t ha^{-1} + Jeevamrit @ 10%. Applying split dose of vermicompost @ 5t ha^{-1} + 5 t ha^{-1} recorded significantly higher phosphorus and potassium in soil at end of experiment as compared to the control at the depth of 0 - 22.5 cm. The growth, yield attributes and yield of tea increased with application of vermicompost @ 10t ha^{-1} + jeevamrit @ 10%. Treatment with vermicompost @ 10 t ha^{-1} + jeevamrit @ 10% showed significantly higher gross return, net return, and additional net return compared to 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 (Chandra and Chauhan, 1). 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*., 19). 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 belongs to family Theaceae is one of the world's oldest and most important beverages consumed worldwide (Jigisha *et al*., 6). In recent years, the use of chemical farming practices has significantly altered soil ecology, crop productivity, and quality within the tea farming system.

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. The effects of chemical fertilizers on the intricate biogeochemical cycles essential for sustainable agricultural systems was extremely deteriorating (Sharma *et al*., 13). 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 and Wang, 12). 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 (Sun *et al*., 15). 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 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

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Husbandry and Technology, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, India. 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 Himachal Pradesh. Agro-climatically, this experimental site represents sub humid temperate and mid hill zone of Himachal Pradesh, 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 with ten different treatments, each replicated three times. The treatments included a control (T1), FYM at 20 t/ha (T2), vermicompost at 10 t/ha (T3), split applications of FYM at 10 t/ha + 10 t/ha (T4), split applications of vermicompost at 5 t/ha + 5 t/ha (T5), FYM at 20 t/ha + Jeevamrit at 10% (T6), vermicompost at 10 t/ha + Jeevamrit at 10% (T7), FYM at 20 t/ha + vermiwash at 10% (T8), vermicompost at 10 t/ha + vermiwash at 10% (T9), and Jeevamrit at 10% (T10).

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 were 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's, 17 wet digestion method, the amount of organic carbon was measured. The approach outlined by Subbiah and Asija, 14 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, 11). Lastly, the available potassium content was determined through the method outlined by Metson, 9.

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 krustose agar for actinomycetes. The plates were incubated at 28 ± 2°C in an incubator, and colony counts were recorded on the seventh day of incubation. Microbial biomass carbon was measured 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. 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 fodder during harvest.

The net returns were calculated by deducting the cost of cultivation from the gross returns.

Net returns (₹/ha) = gross returns (₹/ha) – total cost of cultivation (₹/ha)

Benefit-cost ratio was calculated by using formula

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

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

RESULTS AND DISCUSSION

The impact of organic nutrient inputs on available nitrogen (N), phosphorus (P), potassium (K), organic carbon, and microbial populations (including bacteria, fungi, and actinomycetes), as well as microbial biomass carbon in the soil, was found to be significant at a depth of 0-22.5 cm. However, at a depth of 22.5-45 cm, these organic inputs did not show any significant effect on these soil properties.

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

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

T. N.	Treatment details	pH		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
		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 @ 20 t ha^{-1}	5.25	5.33	246.4	197.2	19.90	14.79	246.3	183.4
T_3	Vermicompost @ 10 t ha^{-1}	5.25	5.30	260.1	198.7	20.50	15.40	246.2	183.2
T_4	FYM @ 10 t ha-1 (pre-monsoon season) + @ 10 t ha^{-1} (monsoon season)	5.20	5.31	243.0	196.7	19.70	14.89	244.9	183.5
T_5	Vermicompost @ 5 t ha^{-1} (pre-monsoon season) + @ 5 t ha^{-1} (monsoon season)	5.21	5.30	262.4	199.1	22.10	15.45	247.7	184.2
T_6	T2 + *Jeevamrit* @ 10% within 2 day after plucking	5.20	5.33	248.6	197.2	19.91	14.91	246.6	183.2
T_7	T3 + *Jeevamrit* @ 10% within 2 day after plucking	5.26	5.34	273.2	198.7	20.74	15.43	247.1	183.5
T_8	T2 + Vermiwash @ 10% within 2 days after plucking	5.22	5.33	245.4	197.2	19.91	14.91	246.3	183.4
T_9	T3 + Vermiwash @ 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* @ 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

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*@10% (Table 2). These results are in close conformity with Lin *et al*. (8); Qui *et al*. (12) and Ji *et al*. (5).

The influence of organic nutrient sources on black tea yield was significant during the pre-monsoon, monsoon, and post-monsoon seasons. In the pre-monsoon season, the highest 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 Negi *et al*., (10) (Table 3).

The application of vermicompost @ 10t ha^{-1} + *jeevamrit* @ 10% recorded the highest gross return of Rs 562320/ha, which was followed by vermicompost @ 10t ha^{-1} + vermiwash @ 10%. 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 (Rs 562320/ha) and additional net return (Rs 119288/ha) follow the same trend (Table 4).

Table 2: Effect of organic nutrient source on soil properties (organic carbon, microbial biomass carbon, population of bacteria, fungi and actinomycetes) at the end of experiment.

T. N.	Treatment details	Organic carbon (%)		MBC (µg/ gram)		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^{-1}	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^{-1}	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^{-1} (early season) + @10 t ha^{-1} (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^{-1} (early season) + @ 5 t ha^{-1} (monsoon season)	0.745	0.540	172.6	107.9	29.9	16.5	33.6	22.7	10.8	6.7
T_6	T2 + *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	T3 + *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	T2 + 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	T3+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 finished black tea yield.

T. N.	Treatment details	Finished tea (kg ha^{-1})			
		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^{-1}	306.7	318.6	236.8	862.1
T_3	Vermicompost @ 10 t ha^{-1}	356.0	348.0	257.6	961.6
T_4	FYM @ 10 t ha^{-1} (pre-monsoon season) + @ 10 t ha^{-1} (monsoon season)	286.7	320.0	240.0	846.7
T_5	Vermicompost @ 5 t ha^{-1} (pre-monsoon season) + @ 5 t ha^{-1} (monsoon season)	333.3	360.0	259.2	952.5
T_6	T2 + *Jeevamrit* @ 10% within 2 days after plucking	318.8	344.0	248.0	910.8
T_7	T3 + *Jeevamrit* @ 10% within 2 days after plucking	370.7	373.3	278.4	1022.4
T_8	T2 + Vermiwash @ 10% within 2 days after plucking	313.5	334.6	246.4	894.6
T_9	T3 + 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 organic nutrient sources on economics (Rs) of finished black tea.

T. N.	Treatment details	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Net return per rupee invested
T_1	Control	151817.8	354053.3	202235.6	1.33
T_2	FYM @ 20 t ha^{-1}	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^{-1} (early season) + @ 10 t ha^{-1} (monsoon season)	203509.5	465661.8	262152.3	1.29
T_5	Vermicompost @ 5 t ha^{-1}(early season) + @ 5 t ha^{-1} (monsoon season)	226675.6	523893.3	297217.8	1.31
T_6	T2 + Jeevamrit @ 10% within 2 day after plucking	217129.7	500964.7	283835	1.31
T_7	T3 + Jeevamrit @ 10% within 2 day after plucking	240795.6	562320	321524.4	1.34
T_8	T2 + Vermiwash @ 10% within 2 days after plucking	209395.9	492009.8	282613.9	1.35
T_9	T3 +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

AUTHORS' CONTRIBUTION

Conceptualization (L.C., S.K., S.M.), Methodology (L.C., S.M., S.K.), Investigation (S.K., S.M.), Data curation and formal analysis (L.C., S.M.), Writing original draft (L.C.), Resources, Software, Validation (S.K., S.M.), Writing, review and editing (L.C., S.M., S., A.B.).

DECLARATION

The authors declare that they have no conflicts of interest.

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