International Journal of Tea Science
Vol. 9(1) 2013

Effect of organics and inorganics on soil nutrient status, nutrient uptake and yield in tea plantations of NW Himalayas

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ABSTRACT: The first tea garden in Himachal Pradesh was established in the year 1852 and it was a commercial success. The tea industry in the state flourished for next 50 years. During this period the teas from this region attained international fame and won several awards between 1886 and 1895 in London and Amsterdam. It was unfortunate that this flourishing industry was devastated by the great earthquake of 1905 and the plantations were abandoned. Thereafter due to continuous fragmentation, the size of the holdings became small and now tea in Himachal Pradesh is predominantly a small grower's crop. The recorded area under tea in the year 1951 was 4317 ha owned by 1,115 growers and the production was around 1.125 Mkg. Over the years, some of tea areas having been used for diverse use, the effective area had declined considerably and currently it is reported to be approx. 2,300 ha. This figure was derived on the basis of a survey conducted by the Tea Board way back in 1995 and now this data is quite outdated. The survey indicated that out of the total tea area of 2,300 ha, nearly 1,100 ha was lying neglected/abandoned and around 600 ha was owned by 23 big tea-growers and the balance 600 ha was owned by 720 small growers. Hence, it would be necessary to explore the potential of this neglected/abandoned area by applying the Integrated Nutrient Management Techniques and Organic Farming in a phased manner. In the State of H.P. there is sufficient availability of biomass *vis-a-vis Albizzia sinensis* and Tea Skiffing litter in the tea gardens itself. Presently some of the tea plantations are using chemical fertilizers, FYM and compost without proper guidance and package and practices. Some of the major challenges before the Indian tea industry are as follows: increase the production, improve the quality, ensure availability of tea at a price remunerative to the producers, get sufficient residue-free tea of good quality and meet the export requirements in order to retain and improve India's share in world market. Organic orthodox black tea produced in H.P. could fill-up the void in this aspect. To meet out this challenge, it has been contemplated that chemical fertilizer could be reduced up to some extent and integrated with compost for optimizing the productivity as well as the quality of tea. Research was, therefore, initiated to fill up the gap in our knowledge on nutrition of tea, and to develop an optimum integrated nutrient management recommendation for tea under North-West Indian condition.

KEYWORDS: *Hill and mountain agro ecosystem; Tea cultivation; Integrated nutrient management; Organic farming; Sustainable; Quality; Production*

Introduction

Kangra tea is unique in its quality and it could compete in international market only on the basis of its special flavour and not quantity as total tea-growing area of the region is very small. It was felt that for getting a premium price in international tea market, a road map be developed for Kangra tea marketing. Tea gardens are often not properly managed for yielding good quality tea, and constant advisory support in tea plantation management and tea processing has been the need of the hour. It has also been realized that as a general practice the load of chemical pesticides and fertilizers is not so heavy, and keeping in view the availability of biomass in the tea plantations, it would be easier for the region to become organic. However, before jumping to organic farming, some basic studies are required to be undertaken which could be one of the initial phases of conversion to organic. Therefore, a comparative efficacy trial was set up to study effects of some selected biomass compost on tea in terms of *yield, nutrient uptake, nutrient status* and *quality* of made tea. In addition to this, to ensure high economic productivity and to sustain the available nutrient status at the desired level, correct doses of manures and fertilizers must be applied by using reliable diagnostic tools designated to avoid nutrient shortages or excesses. For crops that grow continuously on the same field and are harvested periodically, the control and correction of their nutrient status can be accomplished by interpreting correctly their leaf analysis.

Though leaf analysis has been established to be the most precise way of mineral nutrition study, soil analysis is also being used in many laboratories all over the world to understand the changes taking place in the rhizosphere of the plant.[1] In the conventional way, it is primarily a

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ISSN: 0972-544X (print)

way of monitoring the fertilizer use and fertilizer efficiency and not of predicting an annual fertilizer requirement.

The present series of experiments were undertaken to look into some of the most important aspects of tea cultivation *viz.* the composting and the manuring programme (both inorganic and organic)—all seen through and connected to the perspective of mineral nutrition of tea. A comparative efficacy trial was, therefore, set up to study the effects of some selected biomass compost on tea in terms of yield, nutrient uptake, nutrient status and quality of made tea, to fill up the gap in our knowledge on integrated nutrient management and nutrition of tea and, if possible, to develop an optimum recommendation for it.

The effect of organics and inorganics on yield and quality parameters of made tea were found to be significant in most of the treatment combinations. The highest yields were obtained in T7 (integrated) treated plots which was comparable to T2 (chemical based treatment). In addition the yield was found to be high in the year 2009 when compared to 2007 in pure organics as well as integrated treatments. As far as the quality parameters were concerned, treatment T7 recorded the highest quality in respect of TR, TF, TC and Brightness during the final year of study. Treatment combination T7 consisting of 50% organics and 50% recommended doses of fertilizers could be inferred to be the best treatment as far as optimization of yield and quality parameters were concerned.

Materials and Methods

Field Experimentation

Two experiments each with Tea Skiffings and Albizzia compost were conducted with the treatments mentioned in Table 1.

The experiment consist of China hybrid variety laid out with 12 treatments replicated thrice consisting total no. of 72 plots with a plot size (1.5 m × 1.5 m apart) covering 45 bushes (approx. plot size 45–60 m^2). Design was RBD and duration of experiment was 3 years.

Table 1: Treatment Combinations Applied in the Experimental Plots[a]

T1	Control
T2	Recommended N, P_2O_5, K_2O
T3	Tea skiff/ Albizzia compost @ 1.5 t/ha
T4	Tea skiff/ Albizzia compost @ 3.0 t/ha
T5	Tea skiff/ Albizzia compost @ 4.5 t/ha
T6	N- 75% from fertilizer + 25% from compost material + P&K recommended
T7	N- 50% from fertilizer + 50% from compost material + P&K recommended
T8	N- 25% from fertilizer + 75% from compost material + P&K recommended
T9	N- 25% from fertilizer + 75% from compost material + P&K- 25% from fertilizer
T10	N- 50% from fertilizer + 50% from compost material + P&K- 50% from fertilizer
T11	N- 75% from fertilizer + 25% from compost material + P&K- 75% from fertilizer
T12	Farmer's Practice- 25% of the recommended N + natural addition of shady plant litter
	CD ($P = 0.05$)

[a]Recommended N, P_2O_5 and K_2O @ 90, 45 and 60 kg ha^{-1}, respectively.
TSE = Tea Skiff Experiment and AE = Albizzia Experiment.

Prepartion of Compost

Method

Composts used in the field experiments were prepared by pit method (agro-waste collection, preparation of compost structure, maturing of compost) using Tea Skiffing litter and Albizzia litter. The detail of the method used to prepare compost is given below:

Collection of Organic Compost Samples

The compost samples were collected during each turning and were collected during the months of September–January every year. Collected samples were dried in hot air oven at 60–65°C for 48 hr.

Analysis of Organic Compost Samples

The organics compost of both type of experimental material (Tea Skiff litter compost and Albizzia litter compost) were analysed for total carbon, N, P and K.[6]

Field Observation

The observations recorded include the following:

- Annual green leaf yield/plot.
- Year-wise levels of pH, O, C, N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu in soil before and after fertilizer and manure applications.
- Levels of N, P, K, S and Zn in "third leaf" samples (mean of three seasons).

Sampling Procedure

Representative soil samples were drawn from a depth of 0–30 cm as top soil, generally one month before the manurial applications and after the end of a particular year of plucking. Yearly the soil samplings were done from the same borings at a particular spot of the treatment plot.

Soil samples were drawn by using screw auger of one inch diameter. Samples were bored fro at least six points and from all the plots under each treatment for the experiments I and II and at every location. Samples collected from each plot were taken in a polyethylene bag properly sealed and tagged with label indicating experiment number, plot number, treatment and replication number, trial site, date of collection and depth of sampling. Soil sampling was not done on rainy days. Field sampling was carried out early in the morning, and rainy days were avoided for sample collection. The plucked shoots or leaf samples were taken in paper bags properly labeled with experiment number, plot number, treatment and replication number, trial site and date of collection, which were immediately brought to the laboratory for subsequent works. The collected material was immediately shifted to the Research and Development Laboratory of UPASI and Department of Soil Science and Department of Tea Husbandry, CSKHPKV Palampur for laboratory analysis.

Sample Handling

The soil samples brought in from the field were exposed to simple air-drying separately under shade. The place for drying was well protected from sun, rains splash and any trespassing. Care was also taken to avoid any sort of contamination with foreign matter/particles, dirt and intermingling of samples. During drying, each of the samples was mixed well, a representative sample was drawn afterwards.

After proper drying, the samples were ground well using wooden mallet, which were then sieved by using 0.5 mm sieve and stored in clean airtight containers for analysis. For total N estimation these sieved samples were again sieved through 0.2 mm sieve and then stored for chemical analysis.

The plant samples, after transport from the field were temporarily kept at 5°C till they were washed and sorted out.

Some of the plucked shoot samples while in storage were subjected to quick hand sorting to remove the internodes and two and a bud and retain only the third leaf as the analytical sample. Fresh leaf samples were cleaned by giving a quick wash with dilute (0.2%) detergent solution, followed by a quick dip in N/10 HCL solution, distilled water and finally in double distilled water to remove any sort of contamination.

The samples after being washed were surface dried on blotting papers, and then placed in a forced hot air oven for drying. Drying was done to deactivate rapidly all plant enzymes, which was carried out at 70°C in a stainless steel lined forced hot air oven, allowing adequate circulation of air between samples.

The fully dried samples were finally ground completely using an agar mortar and pestle to a particle size of less than 1 mm, and mixed thoroughly before storing for analysis. The samples were stored in clearly labeled paper bags for a period prior to analysis, which were kept air tight in polycarbonate containers. The samples were again dried at 70°C for 12 hr immediately before analysis.

The nutrients were estimated in a 50 ml solution prepared after digesting 0.5 g of leaf sample in di-acid mixture.

Chemical Analysis

Standard and well established reproducible analytical procedures were followed for the analysis of the collected samples. Soil and plant samples were analyzed with sufficient control, and swere repeated whenever necessary.

Analytical methods were standardized in the laboratory for determination of the various nutrients in soil and plant samples using the standard methods of analysis as suggested by other workers *viz.*, Bray and Kurtz,[2] Barua and Ghosh[3] Black,[4] Chapman and Pratt,[5] Jackson,[6] and Lindsay and Norvell[7] as well.

The total N was estimated using the dry combustion technique in an automated nitrogen analyzer (NC-2500, CE Instruments, Italy), phosphate and sulphur colorimetrically using UV-visible spectrophotometer (Shimadzu, Japan), potassium flame photometrically while iron, manganese, zinc and copper were determined spectrophotometrically using an atomic absorption spectrophotometer (Shimadzu-6401 F, Shimadzu, Japan).

The total nitrogen estimation by the dry combustion principle was based on the technique of dry ashing or combusting the sample at very high temperature and separating the nitrogen gas through a gas chromatographic column and the quantity was detected through a detector and was recorded in a computer connected to the system (Literature , NC Analyzer, CE Instruments, Italy).

Results and Discussion

Effect on Yield of Made Tea

There were two sets of experiments one with Tea skiffing litter and other with Albizzia litter compost comprising of 12 treatments in RBD. Made tea yield for the 1st, 2nd, 3rd year (Table 2) has been expressed in kg ha^{-1}.

Tea Skiff Experiment

The yield of made tea was significantly influenced by the application of organics and inorganics during the experimental period (2007–2009) in both type of experiments (Table 1).

The yield of made tea due to chemical fertilizer application (T2) decreased during second year but showed improvement during the final year of experimentation in case of tea skiff experiment. Due to pure organics (T3–

Table 2: Integrated Effect of Chemical Fertilizers and Organics on Made Tea Yield (kg ha^{-1}) of Both Experiments During Experimental Period (2007–2009)*

Treatments	2007		2008		2009	
	TSE	AE	TSE	AE	TSE	AE
T1	1766	1798	1628	1760	1801	954
T2	2258	2264	2054	2190	2510	1171
T3	1910	1853	1757	1807	1953	1107
T4	1954	1895	1854	1914	1984	1122
T5	2003	2016	1890	2012	2444	1240
T6	2088	2184	1995	2175	2347	1271
T7	2118	2262	2131	2279	2564	1280
T8	2071	2002	1935	2061	2366	1214
T9	2046	1960	1917	1988	1961	1099
T10	2073	2234	2019	2214	2272	1187
T11	2050	2186	2012	2132	2189	1123
T12	1855	1899	1768	1903	1815	1075
CD ($P=0.05$)	90	110	99	138	361	168

*Recommended N, P_2O_5 and K_2O @ 90, 45 and 60 kg ha^{-1}, respectively.
TSE = Tea Skiff Experiment and AE = Albizzia Experiment

T5) in case of Tea Skiff experiment, the same trend as in case of chemical fertilizers was inferred. Integrated treatments (T6–T11) recorded mixed trend however the highest yielder (T7) recorded consistent increase during the years.

Contrary to these results several farmers and researchers have claimed that tea yield decreases drastically upon conversion to organic from conventional cultivation. During the transition from chemical based agriculture to natural system of farming, the yield levels definitely drop. It had been claimed that when commercial tea estates switched over to organic farming the normal tea fields lost 10% crop in the first year, 20%, 30% and 40% crop in second, third and fourth years respectively and stabilized to gain 20% in the fifth year as a consequence of recycling the organic matter.[9]

The experimental site of the tea skiff experiment was the most ideal site having optimum shade and good health of bushes. Consistent increase in yield during the years and treatment T7 attaining the highest yield levels may be due to so many factors like ideal competition for nutrients, sunlight and water. Moreover the input (tea skiff compost) used (Table 3) consisted the good quality (ideal C:N ratio and nutrient composition) material for supplying nutrition in a sustainable manner. These findings are in general agreement with those of Barbora *et al.*[10] who found superiority of concentrated forms of organic manures to bulky forms in promoting yield of tea. This is possibly due to better enrichment of the soil with organic manures, which also act as a soil conditioner. The tea skiff compost used in this experiment being rich in nutrients and quality, activates various microbial population in the rhizosphere of the bushes which, in turn, facilitates higher uptake of different soil macro-& micro-nutrients by the plant.

Addition of organic manures to soil generally leads to increase in soil organic carbon, humus carbon, fulvic acid carbon and the residual carbon—all bear a positive correlation with the yield Phukan *et al.*[12] The abundance, nature and composition of humic substances and increase of microbial activity might be positively influenced by tea skiff compost, which had been reflected on the yield of tea.

Albizzia Litter Experiment

Albizzia experiment showed drastic decline in yield during final year of experimentation for all the treatments. This may be because of the moderate health of bushes and below standard site location of Albizzia experiment. The site of Albizzia experiment showed overshade with thick parasitic creepers on the Albizzia sinensis shade trees. One of the reason for drastic reduction in low yields has been the thick shade which leads to hampering of good sunlight due to which the photosynthesis decreases and simultaneously the effect on yield. The shade trees and parasite creepers compete for nutrients, sunlight and water due to which the drastic yield reduction has been observed.

The input (Albizzia compost) for organics used in case of Albizzia experiment, was also not of good quality (Table 3) due to which the nutrient build-up (Table 6) and nutrient uptake (Table 8) hampered. All these factors in totality lead to yield reduction in case of Albizzia experiment.

It can be suggested from the study that the integrated nutrient management can be adopted as a first phase before converting to organic farming. Simultaneously

Table 3: Nutrient Dynamics in the Composting Process During 2007–2009

Duration after	N%	P%	K%	C%	C:N	pH
	Tea Skiffing litter					
Fresh material	3.35–3.52	0.12–0.16	0.52–0.61	45.00–52.93	13–16:1	–
1st month	3.21–3.50	0.13–0.18	0.51–0.61	42.50–50.15	12–16:1	6.8–7.2
2nd Month	3.32–3.70	0.15–0.19	0.54–0.63	32.00–42.13	9–13:1	5.8–7.2
3rd Month	3.15–3.90	0.17–0.25	0.57–0.62	29.00–32.50	8–10:1	5.2–6.2
4th Month	3.10–3.82	0.16–0.27	0.59–0.70	22.80–25.15	6–8:1	6.3–6.9
	Albizzia litter					
Fresh material	1.71–2.15	0.14–0.16	0.57–0.59	43.68–48.24	22–27:1	–
1st month	1.65–1.92	0.10–0.16	0.61–0.66	38.90–45.30	22–26:1	7.2–7.3
2nd Month	1.67–2.30	0.14–0.17	0.64–0.68	32.10–37.22	14–22:1	6.8–7.1
3rd Month	1.82–2.35	0.15–0.19	0.68–0.70	20.00–29.30	08–16:1	6.3–6.5
4th Month	2.20–2.48	0.16–0.21	0.59–0.68	13.33–25.20	05–11:1	6.4–6.9

Table 4: Integrated Effect of Chemical Fertilizers and Organics on pH and Organic Carbon of Both Experiments in 2007 and 2009

Treatments	2007				2009			
	Tea skiff field		Albizzia field		Tea skiff field		Albizzia field	
	pH	O.C%	pH	O.C%	pH	O.C%	pH	O.C%
T1	5.10	0.91	4.80	0.96	5.17	0.99	5.07	0.97
T2	4.97	0.98	5.00	0.97	4.90	1.06	4.90	1.03
T3	5.10	0.92	5.13	0.98	5.23	1.06	5.20	0.99
T4	5.03	0.97	5.17	1.04	5.17	1.08	5.13	1.08
T5	5.13	0.98	5.10	1.09	5.27	1.07	5.17	1.18
T6	5.07	1.05	4.80	1.06	5.07	1.09	5.07	1.09
T7	5.20	1.10	5.00	1.01	5.23	1.18	5.10	1.09
T8	5.23	1.05	5.07	1.00	5.23	1.08	5.13	1.06
T9	5.30	1.04	4.97	1.01	5.20	1.09	4.97	1.10
T10	4.97	1.07	4.97	1.04	4.97	1.12	5.03	1.05
T11	5.10	1.02	5.00	1.00	5.00	1.08	4.90	1.06
T12	5.23	0.89	5.10	0.99	5.13	1.07	5.07	1.06
CD ($P=0.05$)	NS	0.11	0.20	NS	NS	NS	NS	0.09

Table 5: Integrated Effects of Chemical Fertilizers and Organics on Primary Nutrient Status (% N, P, K) of Tea Skiff Experiment in 2007–2009

	2007			2008			2009		
	N	P	K	N	P	K	N	P	K
T1	0.017	11	62	0.014	9	51	0.015	10	59
T2	0.019	15	87	0.017	14	73	0.022	13	101
T3	0.017	11	72	0.017	10	60	0.019	10	82
T4	0.020	12	78	0.017	12	68	0.021	13	83
T5	0.020	14	79	0.019	14	73	0.024	14	87
T6	0.022	15	84	0.018	13	76	0.022	13	86
T7	0.018	17	81	0.019	14	84	0.022	14	99
T8	0.021	14	74	0.019	14	83	0.022	13	102
T9	0.020	13	66	0.018	11	65	0.019	13	72
T10	0.020	15	74	0.019	13	74	0.021	13	83
T11	0.020	13	78	0.019	13	80	0.021	14	86
T12	0.016	11	71	0.017	12	65	0.017	12	76
CD ($P=0.05$)	0.025	NS	8	0.002	2	8	0.003	2	10

Table 6: Integrated Effects of Chemical Fertilizers and Organics on Primary Nutrient Status (% N, P, K) of Albizzia Litter Experiment in 2007–2009*

	2007			2008			2009		
	N	P	K	N	P	K	N	P	K
T1	0.014	10	73	0.016	9	64	0.017	12	71
T2	0.024	18	89	0.024	15	83	0.022	19	95
T3	0.017	13	77	0.015	11	72	0.016	12	71
T4	0.017	14	80	0.018	13	68	0.020	13	77
T5	0.021	15	79	0.022	13	76	0.023	15	79
T6	0.021	18	86	0.021	14	82	0.021	16	89
T7	0.024	19	91	0.022	14	88	0.020	17	88
T8	0.022	18	85	0.022	15	82	0.021	16	77
T9	0.019	12	64	0.020	13	66	0.022	14	70
T10	0.020	16	77	0.017	14	72	0.018	16	74
T11	0.020	16	87	0.020	14	72	0.019	14	82
T12	0.018	13	68	0.016	12	67	0.021	14	68
CD ($P=0.05$)	0.003	2	11	0.002	2	8	0.004	2	9

*Recommended N, P_2O_5 and K_2O @ 90, 45 and 60 kg ha^{-1}, respectively.

and during the course of years the integrated nutrient management would be easily shifted to to organic farming without any jerk of drastic yield reduction.

Effect on Physico-chemical Properties of Soil

Summarily results conclude that organics and inorganics addition has effect on pH and O.C. in the experimental soils (Table 4).

Tea Skiff experiment recorded the pH values ranging from 4.97 to 5.30 and the corresponding values in Albizzia experiment ranges from 4.80 to 5.20 for all the years under study. The lesser pH range in Albizzia experiment may be attributed to the inherent basic physico-chemical properties of soil and the quality of compost (Table 3) and chemical fertilizers supplied.

The results further infer that among the organics compost experiment, tea skiff litter based experiment exhibited higher values of O.C (1.10–1.18%) compared to Albizzia experiment(0.96–1.18%). The treatment T7 exhibited highest O.C in soil, which may be attributed to the succulence and low C:N ratio (12:1) of tea skiff leaves compared to Albizzia leaves which contains wider C:N ratio. It can be inferred from the results that integrated chemical and organic supply will lead to good O.C. build-up in soil.

To achieve economical production, soil fertility has to be maintained and gradually improved. Improvement and maintenance of organic matter of the soil is important in organic tea production, as this would increase physical parameters of soil, improve soil structure and enhance nutrient supply.[9] Since huge quantities of compost are generally not available to meet nutrient requirements of the tea crop, a combination of chemical and organics should preferably be used.

In case of Albizzia experiment, the data in Table 4 revealed that the values of O.C. content under different treatments varied significantly. Maximum O.C. (1.18%) recorded in T5 (organics) was at par with T9 (1.10%).

pH was found to be non-significant in case of Albizzia experiment during final year (2009) and the lowest values of 4.90 were recorded in treatment T2 and T11, respectively.

Effect on Available NPK in Soil during 2009

Tea Skiffing Experiment

Initially the effects of organic manures were not appreciable, which however, became quite pronounced in the subsequent years indicating requirement of some time gap for manifestation of manurial effects.

Results of Tables 5 and 6 clearly show that organics and inorganics in combination has effect on the available NPK build-up in the experimental soil, both in Tea Skiff and Albizzia compost treated soils.

The P availability continued to increase with the gradual increase in the organic dose from T3 to T5 and integrated dose from T6–T11.However, the changes were not always in conformity with the changes in organic and inorganic doses. On most occasions maximum P-availability was noticed under T7.

It is evident from data in Table 5 that the available soil-K level though not always consistent with the treatments, appeared to increase gradually with the increase in the organic and inorganic doses (from control to recommended and higher doses like T2, T6, T7 and T5). Maximum K level (87 ppm) was recorded under T2 (chemical fertilizer dose). T6 and T7 recorded P values (15% and 17%) which were significant and at par with T2.

Albizzia Experiment

Data in Table 6 indicate that organics, inorganics and integrated treatments had significant effect on available nutrients (NPK) build up in the experimental soil. The highest N-level (0.024%) was observed under treatment T2 and the same level (0.024%) was recorded under integrated treatment T7 followed by T8, T6 and T5, respectively.

The results of Table 6 observed the highest P(19%)

Table 7: Integrated Effect of Chemical Fertilizers and Organics on Nutrients (N, P, K) Uptake (Removal) by Tea Leaves (kg ha^{-1}) in Case of Tea Skiff Experiment During 2007–2009

	2007			2008			2009		
	N	P	K	N	P	K	N	P	K
T1	56.4	4.9	15.3	54.3	5.0	14.5	60.6	5.6	18.7
T2	89.5	7.8	22.5	84.9	8.6	22.1	109.9	10.6	29.7
T3	71.7	6.0	15.3	71.1	5.4	14.5	80.5	6.1	20.1
T4	72.3	5.8	15.9	75.8	6.1	15.6	83.1	7.2	21.0
T5	75.9	6.5	15.3	78.5	6.7	16.2	103.5	9.8	26.6
T6	70.3	6.8	16.4	76.8	7.4	18.4	91.8	9.3	31.1
T7	84.1	7.3	20.0	95.9	8.8	23.9	60.6	5.6	18.7
T8	79.3	7.1	16.8	80.5	7.6	17.9	109.9	10.6	29.7
T9	74.6	7.1	16.7	77.7	7.5	17.1	80.5	6.1	20.1
T10	78.6	6.6	17.6	80.7	7.5	18.5	83.1	7.2	21.0
T11	70.2	6.6	15.2	71.1	7.1	17.4	103.5	9.8	26.6
T12	59.2	5.3	13.8	59.3	5.9	13.8	91.8	9.3	31.1
CD ($P = 0.05$)	9.7	0.8	2.4	4.2	0.6	1.4	60.6	5.6	18.7

and K(90%) status under treatment T7 (integrated) followed by treatment T2. The organics (T3, T4, T5) also exhibited significant increase, which were at par with integrated and inorganics treatment.

Results of Table 6 recorded significant effects of organics and inorganics on the available NPK content of T.S. Experiment during second year of study.

Various treatments *vis-à-vis* T2 to T12 observed available N, P and K status values ranging from 0.017% to 0.019%; 11% to 14% and 65% to 84%, respectively. It may be recorded that all the organics resulted in significant increase in available NPK level of the soil over control values (Table 6). However, maximum available N content (0.019%) were observed with treatments (T5, T7, T8, T10 and T11 incorporation.

In case of Phosphorus, the maximum available content (14%) was recorded in T2, T5, T7 and T8, respectively. The maximum K-content of 84% (Table 10) was recorded in case of T7 (integrated) followed by T8 and T11, respectively.

Albizzia experiment also recorded significant effect of organics and chemical fertilizers on the available NPK of soil during 2008. Treatments *vis-à-vis* T2–T12 recorded available N, P and K status ranging 0.016–0.024%, 9–15% and 64–88%, respectively. It may be inferred that all the organics resulted in significant increase in available NPK level of the soil over control (Table 10). However, maximum available N-content (0.024%), P-content (15%) and K-content (88%) were observed with respective treatments T2, T2 and T7. Critical examination of data showed that the T7 and T2 had N and P content values at par with each other.

Effect on Available NPK in Soil during 2009

Tea Skiffing Experiment

The treatment effects showed highly significant variation in NPK - content and are presented in Table 5. Maximum N-content (0.024%) was observed in treatment T-5 followed by treatments T2, T6, T7 and T8 having N-content at par with T5.

The perusal of Table 5 revealed that the P-content varied from 10% to 14% with maximum (14%) recorded in treatments T5, T7 and T11, respectively. K-content was found to be maximum (102%) in treatment T8 followed by T2 (101%) respectively.

Albizzia Experiment

From Table 6, it is evident that N-status of soil was highest (0.023%) in case of treatment T5. The N-status seemed to reach the peak in treatments supplying higher doses of N (*e.g.* T2, T5, T9). The P availability continued to increase with the gradual increase in the organic dose from T3 to T5 (13% to 16%). The maximum P (19%) was noticed in T2 and no definite trend recorded in case of integrated treatments (T6–T11). However maximum P-content of 17% was noticed in case of T7 respectively. K- content was noticed highest, *i.e.* 95% for the treatment T2 followed by T6 (89%) and T7 (88%), respectively.

The NPK content was found to be higher in case of TS compost compared to Albizzia compost during the three years of study (Tables 5 and 6). The N content increases during third and fourth turning respectively. This may be due to the decomposition, mineralization and finally availability of nutrients during the final turning of compost.

An important process parameter in composting is the nutrient content available to the micro-organisms for growth which is generally measured by the carbon to nitrogen ratio within the compost litters. The rate at which organic matter decomposes is determined principally by their relative amounts of carbon and nitrogen ratio (Table 3). In living organisms, the C:N ratio is about 30:1 and as composting proceeds, the microflora use the carbon for energy, and the nitrogen for cell building. The C:N ratio becomes smaller with time, since the nitrogen remains in the system while the C is released as CO_2. This process of microbial regeneration of nitrogen is extremely slow and will greatly increase the time required for digestion. The Albizzia litter reveals wide C:N ratio (25:1) material compared to tea skiff litter (16:1) as observed in this study. So it can be concluded that tea skiff litter is the ideal material for preparing compost.

pH is also one of the important factors identified for analysing quality compost. Decomposition will occur most readily in a neutral pH because most micro-organisms grow best under neutral conditions. Under anaerobic conditions an initially neutral material will experience a decrease in pH during the start of composting. The drop is a consequence of the activity of acid-forming bacteria, which breakdown complex carbonaceous material and it is followed by an increase in pH which will result in a final stage as slightly alkaline. But contrary to these standard facts, during the course of this study the pH values show slight acidic or decline in pH at the end of composting.

Effect on Nutrient Uptake in Both the Experiments

Effect on Nutrient Uptake (NPK kg ha^{-1}) during 2007–2009

Initially the effects of organic manures were not appreciable, which however, became quite pronounced in the subsequent years indicating requirement of some time gap for manifestation of manurial effects.

Results of Tables 5 and 6 clearly show that organics and inorganics in combination has effect on the available NPK build-up in the experimental soil, both in TS and Albizzia compost treated soils. This may be attributed to the high value of NPK removal by the tea leaves, as indicated by the data given in Tables 7 and 8 for nutrients uptake.

The results infer that among the organic materials incorporated in the soil, tea skiff litter treatment exhibited higher values of NPK build up which may be due to the succulency, and higher nutrient content of TS litter compost. This may also be attributed to the high values of NPK removal by the tea leaves, as indicated by the data given in Table for NPK uptake.

Tables 5–8 further reveal that T7 treatment recorded the highest primary nutrient status and nutrient uptake. This may be attributed to the balanced nutrition supplied by the 50% N through organics and 50% through chemical fertilizers. In 1989, Owuor[14] also observed similar increase in nutrient uptake in tea shoot by the application of enriched cattle manure. Significant improvement in the uptake of nutrients owing to N-fertilizer applied in conjunction with organic manures under different soil-crop conditions was reported by many workers.[15]

During 2007–2008, the NPK values in Albizzia experiment were on higher side compared to TS Experiment. Contrary to this, during 2009 the TS experimental values showed increasing trend compared to Albizzia experiment. The treatment T7 and T2 recorded high values of NPK in TS experiment while in case of Albizzia experiment only T2 recorded the highest NPK values.

This may be attributed to the high values of NPK uptake by the tea leaves as confirmed by the data given

Table 8: Integrated Effect of Chemical Fertilizers and Organics on Nutrients (N, P, K) Uptake (Removal) by Tea Leaves (kg ha^{-1}) in Case of Albizzia Experiment During 2007–2009^a

	2007			2008			2009		
	N	P	K	N	P	K	N	P	K
T1	60.0	6.5	15.6	63.0	6.2	17.2	31.4	2.6	7.4
T2	95.9	8.6	21.8	87.3	8.5	26.4	48.9	4.3	14.0
T3	74.0	7.4	18.5	73.6	6.7	18.1	43.0	3.1	8.7
T4	78.8	7.0	16.6	73.6	6.8	17.7	42.5	3.3	8.9
T5	84.4	7.4	17.7	79.1	7.3	17.6	47.6	3.9	9.8
T6	86.5	9.2	21.2	86.0	8.5	20.3	48.5	4.4	11.8
T7	94.4	9.3	24.2	93.9	9.6	24.0	54.6	4.9	14.4
T8	85.4	7.9	21.6	86.0	7.9	21.9	49.3	4.2	11.1
T9	81.2	7.8	20.0	80.5	8.3	20.2	41.9	3.9	9.7
T10	89.6	8.7	23.0	87.5	8.0	22.4	45.4	4.0	10.9
T11	82.9	7.9	20.6	79.5	8.1	19.7	39.1	3.7	9.1
T12	69.5	6.4	16.9	68.6	6.7	16.0	37.9	3.4	7.5
CD (P = 0.05)	6.1	1.5	4.9	8.0	1.0	2.8	6.5	0.7	1.8

^{a}Recommended N, P_2O_5 and K_2O @ 90, 45 and 60 kg ha^{-1}, respectively.

in Tables 7 and 8 for NPK uptake. Further the results revealed that among the organics, Albizzia incorporation resulted in higher values of available NPK build-up in the soil during Ist and IInd year while during IIIrd year TS compost resulted in slight improvement in NPK build-up and hence uptake . This may be attributed to the succulency and low C:N ratio (Table 3) of TS compost. Also NPK content was maximum in TS in comparison to Albizzzia organic compost. During initial years, the inherent soil physico-chemical properties and nutrient availability yielded good results for 1st and 2nd year but the sustainable nutrient supply leads to consistent build-up and increase in nutrients supply, uptake and high yields during third year of experimentation.

Thus, the impact of organic manures was little in improving the NPK status of soil during final year of experimentation in case of Albizzia experiment. However in case of tea skiff experiment, the NK build up improved during the final year of experimentation. It is well known that nitrogenous fertilizers undergo rapid transformations through hydrolysis and nitrification leading to losses of soluble nitrogen and thereby resulting in N deficiency and low fertilizer use efficiency by the crops. Regulating the N supply by reducing the rate of hydrolysis or nitrification would be a means of higher N use efficiency.

The effect of organic and inorganic manures on the availability of soil-P was less pronounced during the initial years of investigation. However, with time the P-availability seems to decline. This may be because of the fact that the recommended dose of P_2O_5 @ 45 kg seems to be lower and also the P content in both type of composts is low. Moreover, the tea soils of Palampur are fixed by Fe and Al sesquioxides which hamper the release of P.[16] Hence to improve the P build-up, the recommendation needs slight improvement and compost should also be enriched with additives like Rock Phosphate.

Sharma and Jain stated that organic manures on decomposition release organic acids which help in the release of P from Al–P and Fe–P fractions of soil, thereby increasing its availability.[17]

Like N or P, soil K also did not show any appreciable change as a result of application of organic manures initially, but with time the effect of organic manures in conjunction with chemical fertilizers on K status became apparent. The maximum soil K was recorded in plots receiving T2 and T7 on most occasions for both the experiments.

In a perennial crop like tea, yield is built over years by sound cultural and manurial practices. If fertilizers are withdrawn wholly or partially, the yield declines and takes several years of heavy and steady applications to bring the plants back to original yield level.[9] In organic tea fields, the absorption of nutrients through the application of compost and oil cakes is rather slow. This is the main reason for the decline in crop. In view of this, the concept of integrated nutrient management holds good in maintaining the fertility of soil and supply of nutrients.

The effect of organics and inorganics on the NPK uptake of tea leaves are presented in Tables 7 and 8. The perusal of data in Tables 7 and 8 indicates the significant effect of organics and inorganics on NPK uptake. Maximum N P and K uptake of 109.90, 10.6 and 29.7 kg ha^{-1} were recorded with the application of recommended NPK (T2) and integrated (T7) during 2009 in case of Tea Skiff Experiment. However, in case of Albizzia experiment the quantum of uptake was less compared to Tea Skiff Experiment. The highest uptake was recorded in case of treatment T2 during 2007, and subsequently during 2008 and 2009 the quantum of uptake declined in case of all the treatments.

It can be concluded that on the basis of nutrient status, uptake, C:N ratio and pH values of resource material studied for composting, the skiffing litter is the best source for preparing quality compost.

Secondly on the basis of the nutrient status, nutrient uptake and quality parameters studied, the treatment T7 of Tea Skiff Experiment (50% N was supplied through organics and 50% through inorganics with recommended P and K) owing to high yield recovery, highest uptake and good nutrient status may be recommended to the tea plantations for attaining the prime objective of optimum productivity and high quality laid-out in this study. One of the studies[12] conducted at TRA showed that the recommended dose of chemical fertilizers to tea can be reduced to 33–50% by integration with organics without compromising the soil fertility maintenance under under the experimental conditions laid out. The use of organics in conjunction with inorganic fertilizers improved soil physical, physico-chemical and chemical properties of soil. Organics and fertilizers are not only complementary but also synergistic since organic inputs have beneficial effects on physical properties beyond their nutritional components.

Acknowledgements

This work was supported by the Indian Council of Agricultural Research, New Delhi. Authors Dr. K.L. Sharma and Gagnesh Sharma are thankful to ICAR for the financial support. Our sincere gratitude is extended to Director

United Planters Association of South India for the support provided for analysis of soil and leaf samples. The authors are thankful to Department of Applied Plant Science, School of BioSciences and Biotechnology, Baba Saheb BhimRao Ambedkar University—A Central University Lucknow for enrolment in PhD and considering the work for the award of degree including administrative and research support.

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