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Dynamics of soil properties as influenced by rubber based agroforestry system in hilly zone of Karnataka

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ABSTRACT : The basic precept of agroforestry is its ability to maintain fertility of poor soil. Researchers always try to assess how different nutrients present in soil respond to the age levels and practices on tree and crop cultivation, and effect of application of different organic manures and biofertilizers to intercrops. Present study, aiming to assess the effect of different age levels and practices on rubber plant and nutrient management on bird's eye chilli (BEC) on soil fertility status, was carried out. The age of rubber plantation and practices followed on rubber significantly influenced soil parameters. The plots treated with combined application of FYM, *Azotobacter* and phosphate solubilizing bacteria (PSB) registered highest values in terms of soil physical and chemical properties. Interactions were non-significant for most of the soil parameters. Thus, combined use of FYM, *Azotobacter* and PSB on BEC under organic practice on rubber in two-years old rubber plantation proved better in improving soil fertility under agroforestry system.

Key words: Bird's eye chili, FYM, intercrop, nutrient management and soil fertility.

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1. INTRODUCTION

Agroforestry is an ideal scientific approach for restoration of degraded lands. The importance of tree based land-use system in restoring soil fertility and improving economy of farmers having small land holdings has been realized. Improvement in soil fertility under agroforestry systems occurs mainly through addition of plant biomass. Also fertility can be maintained by the addition of different organic and inorganic sources of nutrition to both trees and intercrops.

Rubber (*Hevea brasiliensis* Muell. Arg.), a fast growing perennial economic crop, is primary source of natural rubber in the world. Wood of rubber is utilized for making diverse products such as toys, furniture and packing material constituting an additional fixed carbon sink (Anonymous, 2016).

Bird's eye chilli (*Capsicum frutescens*. L), a perennial herb, is being cultivated as homestead crop in coastal areas of Kerala, Karnataka, Tamilnadu and North-Eastern states of India. Its fruits are small, highly pungent and used to extract oleoresin. It is also being used for curry powder, pickle, paste and hot sauces. Besides, it is a medicinal and natural insects repellent (Chatterjee *et al.*, 2012). Due to high pungency and medicinal values, its dry pod fetches Rs. 750 to 850 kg^{-1}.

In hilly zone of Karnataka (zone-9) where cultivable lands has been degraded by heavy rainfall and erosion hazard, agroforestry can restore and maintain soil fertility and increase agricultural production.

Rubber is one of the important components of agroforestry system in zone-9. Farmers are practicing intercrops during early stage of the rubber trees, and the interspaces can be utilized for growing neglected economic horticultural crops such as bird's eye chilli (BEC). Both trees and intercrops demand lots of nutrients from soil resulting in deterioration of soil quality which can be restored by addition of leaf litter from tree and external application of different organic manures and biofertilizers. With these ideas in view, present study was conducted with objective to evaluate the effect of organic manure on rubber trees, and different doses of organic manures and biofertilizers on BEC on physico-chemical properties of soil under two different aged rubber plantations.

2. MATERIALS AND METHODS

The field study was conducted in an existing one- and two-years old rubber plantation established in hilly zone (zone-9) of Karnataka at Harishi village of Sorab taluka, Shimogga district, which is located at 14° 37' N and 75° 09' E, with an elevation of 580 m above mean sea level. The average mean maximum temperature recorded was 29.6 °C and the mean minimum temperature was 17.0 °C. During 2017 and 2018, total of 1768.10 and 1942.60 mm of rainfall was recorded in 102 and 117 rainy days, respectively. Major proportion of the rainfall was received during month of June, July and August. Relative humidity was higher during July to October months. The soil of the experimental site was red sandy loam, grouped under the class of

Alfisol. Rubber plantation was planted at spacing of 5 × 5 m. In between the rows of rubber plants, BEC was planted as intercrop at spacing of 1 × 1 m. The experiment consisted of two main factors, two sub-factors and nine sub-sub factors, which are detailed below:

Main factor (at 2 levels)	A_1- one year old plantation and
	A_2- two year old plantation
Sub-factor (at 2 levels)	P_1- organic practice on rubber (12 t/ha FYM - 1st year) and (24 t/ha FYM - 2nd year)
	P_2- inorganic practice on rubber (60:60:30 kg/ha NPK - 1st year) and (120:120:60 kg/ha NPK - 2nd year)
Sub-sub factor (at 9 levels)	T_1- Farm Yard Manure (FYM)
	T_2- Vermicompost (VC)
	T_3- Town Compost (TC),
	T_4- FYM + *Azotobacter*
	T_5- FYM + Phosphate Solubizing Bacteria (PSB)
	T_6- FYM + *Azotobacter* + PSB
	T_7- FYM + Mycorrhizae
	T_8- NPK
	T_9- Control

The experiment was laid out in split-split plot design with three replications. The inorganic fertilizers were applied to rubber in one split during June in the form of urea (N), rock phosphate (P) and muriate of potash (K). Different doses of organic manures, biofertilizers and inorganic fertilizers were applied to BEC plants after one month of transplanting (2017-18). Same was repeated in June during 2018-19.

Soil samples were collected from each representative sample plot in all replications from 0-45 cm depth after scraping away the litter before initiation (before intercropping) and at the end of experiment. The soil samples were air dried, powdered and allowed to pass through 2 mm sieve and analyzed for physical and chemical properties *viz*., bulk density (Black, 1965), soil moisture (Sankaram, 1966), soil pH (Piper, 1966), electrical conductivity (Jackson, 1973), organic carbon, available nitrogen, phosphorus and potassium (Jackson, 1973) and status of micronutrients such as iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) using standard procedures (Lindsay and Norvell, 1978). Analysis of FYM revealed that it contained 0.48% N, 0.25% P_2O_5 and 0.5% K_2O; VC contained 1.45% N, 0.46% P_2O_5, 0.55% K_2O, and TC contained 1.13% N, 0.21% P_2O_5 and 0.14% K_2O. The data collected on various parameters during investigation were statistically analyzed using OPSTAT data analysis software version (developed by CCS HAU, Hisar, Haryana).

3. RESULTS AND DISCUSSION

The initial soil tests indicated acidic soil reaction with pH: 5.35, organic carbon: 0.39%, EC: 0.27 dSm^{-1}, bulk density: 1.40 gm/cm^3, water holding capacity: 25.34% and available N, P and K: 187.0, 18.75 and 110 kg/ha, respectively. Also micronutrients such as available Cu (0.213 ppm), Fe (19.27 ppm), Mn (8.97 ppm) and Zn (0.094 ppm) showed that these soils were poor in nutrient status due to soil type and partly due to high rainfall experienced in the region.

The data pertaining to the soil parameters under different treatments are presented in Table 1. Age levels did not show significant effect on various studied soil parameters, except organic carbon which was recorded highest in soils of two-years old rubber plantation (0.58%). This might be due to addition of more leaf litter by two-years old rubber plantation compared to one-year old rubber plantation (0.57%).

Soil under organic practice on rubber recorded high water holding capacity (32.93%), pH (5.27), EC (0.20 dSm^{-1}) and organic carbon (0.59 %) when compared with the soil under inorganic practice on rubber (31.32% water holding capacity, 5.25 pH, 0.18 dSm^{-1} EC and 0.57% organic carbon).

Among different nutrient applied to BEC seedlings, bulk density (1.41), pH (5.42) and EC (0.31 dSm^{-1}) were more in plots treated with NPK fertilizers while water holding capacity (34.60 %) and organic carbon (0.75 %) were more in a plot receiving FYM + *Azotobacter* + PSB (T_6) which was significantly higher than remaining treatments. The decrease in bulk density is due to accumulation of high organic matter by the addition of diverse organic manures and due to incorporation of leaf litter of trees into soil. These results are in line with reports of Melis *et al*. (2008) who observed decrease in bulk density with increase in organic matter. The lower pH in organic manures treated plots may be due to the fact that during process of decomposition of organic manures, mineralization takes place and releases organic acids, due to which soil pH decreased. Addition of FYM along with biofertilizers helps in improvement of

Table 1. Soil parameters as influenced by age and practice on rubber and nutrient management on Bird's Eye Chili (BEC) under agroforestry system.

Treatments	Bulk density (gm/cm^3)	Water holding capacity (%)	pH	Electrical conductivity (dSm^{-1})	Organic carbon (%)
Age levels (A)					
A_1	1.28	31.46	5.27	0.19	0.57
A_2	1.28	32.79	5.26	0.19	0.58
S.Em.±	0.001	0.321	0.003	0.003	0.003
$LSD_{0.05}$	NS	NS	NS	NS	0.008
Practices (P)					
P_1	1.28	32.93	5.27	0.20	0.59
P_2	1.28	31.32	5.25	0.18	0.57
S.Em.±	0.003	0.136	0.003	0.003	0.003
$LSD_{0.05}$	NS	0.409	0.010	0.011	0.008
Nutrient Management (NM) on BEC					
T_1	1.24	34.55	5.23	0.16	0.63
T_2	1.24	33.94	5.24	0.17	0.65
T_3	1.23	30.48	5.23	0.16	0.51
T_4	1.23	32.56	5.23	0.15	0.63
T_5	1.27	33.41	5.23	0.16	0.66
T_6	1.24	34.60	5.19	0.17	0.75
T_7	1.25	33.54	5.23	0.18	0.63
T_8	1.41	28.37	5.42	0.31	0.35
T_9	1.40	27.68	5.37	0.27	0.40
S.Em.±	0.004	0.235	0.005	0.005	0.005
$LSD_{0.05}$	0.013	0.704	0.013	0.014	0.015
Interaction- A × P					
A_1P_1	1.28	32.12	5.27	0.19	0.58
A_1P_2	1.28	30.80	5.26	0.18	0.57
A_2P_1	1.27	33.74	5.27	0.20	0.60
A_2P_2	1.28	31.84	5.25	0.18	0.57
S.Em.±	0.005	0.148	0.003	0.004	0.004
$LSD_{0.05}$	NS	NS	NS	NS	0.011
Interaction- A × NM					
A_1T_1	1.23	33.51	5.22	0.15	0.62
A_1T_2	1.24	32.98	5.25	0.18	0.64
A_1T_3	1.24	29.46	5.22	0.15	0.51
A_1T_4	1.24	31.79	5.24	0.14	0.62
A_1T_5	1.28	33.20	5.24	0.16	0.65
A_1T_6	1.23	34.09	5.19	0.16	0.75
A_1T_7	1.26	32.88	5.24	0.18	0.62
A_1T_8	1.42	28.13	5.42	0.31	0.35
A_1T_9	1.40	27.09	5.37	0.28	0.40
A_2T_1	1.25	35.60	5.23	0.17	0.63

Treatments	Bulk density (gm/cm^3)	Water holding capacity (%)	pH	Electrical conductivity (dSm^{-1})	Organic carbon (%)
A_2T_2	1.24	34.90	5.23	0.16	0.66
A_2T_3	1.22	31.51	5.24	0.17	0.51
A_2T_4	1.23	33.33	5.22	0.15	0.64
A_2T_5	1.26	33.62	5.21	0.16	0.67
A_2T_6	1.25	35.11	5.19	0.17	0.75
A_2T_7	1.25	34.20	5.23	0.18	0.64
A_2T_8	1.41	28.62	5.41	0.31	0.35
A_2T_9	1.40	28.27	5.36	0.27	0.41
S.Em.±	0.006	0.352	0.007	0.007	0.008
$LSD_{0.05}$	0.018	NS	0.020	NS	NS
Interaction- P × NM					
P_1T_1	1.23	35.31	5.25	0.16	0.64
P_1T_2	1.23	34.87	5.26	0.19	0.66
P_1T_3	1.23	31.82	5.24	0.17	0.53
P_1T_4	1.22	33.30	5.25	0.16	0.64
P_1T_5	1.28	33.98	5.24	0.18	0.67
P_1T_6	1.23	35.65	5.20	0.18	0.77
P_1T_7	1.26	34.05	5.26	0.20	0.64
P_1T_8	1.41	28.98	5.40	0.29	0.35
P_1T_9	1.41	28.42	5.36	0.27	0.41
P_2T_1	1.25	33.80	5.21	0.15	0.62
P_2T_2	1.25	33.00	5.22	0.15	0.64
P_2T_3	1.23	29.16	5.22	0.15	0.49
P_2T_4	1.24	31.82	5.21	0.14	0.62
P_2T_5	1.26	32.84	5.22	0.15	0.65
P_2T_6	1.25	33.55	5.18	0.15	0.73
P_2T_7	1.25	33.03	5.21	0.16	0.62
P_2T_8	1.42	27.77	5.44	0.33	0.35
P_2T_9	1.40	26.94	5.37	0.27	0.40
S.Em.±	0.006	0.352	0.007	0.007	0.008
$LSD_{0.05}$	0.02	NS	0.02	0.02	NS
Interaction- A × P × NM					
$A_1P_1T_1$	1.22	34.14	5.24	0.15	0.62
P_1T_2	1.23	33.84	5.28	0.19	0.65
P_1T_3	1.24	30.37	5.23	0.16	0.52
P_1T_4	1.23	32.39	5.26	0.15	0.63
P_1T_5	1.30	33.67	5.25	0.17	0.66
P_1T_6	1.21	34.81	5.19	0.17	0.76
P_1T_7	1.27	33.64	5.25	0.18	0.62
P_1T_8	1.42	28.55	5.41	0.30	0.34
P_1T_9	1.41	27.62	5.36	0.28	0.40

Treatments	Bulk density (gm/cm^3)	Water holding capacity (%)	pH	Electrical conductivity (dSm^{-1})	Organic carbon (%)
$A_1P_2T_1$	1.24	32.87	5.21	0.14	0.62
P_2T_2	1.25	32.11	5.23	0.16	0.63
P_2T_3	1.23	28.55	5.21	0.15	0.50
P_2T_4	1.24	31.19	5.22	0.13	0.62
P_2T_5	1.27	32.73	5.24	0.15	0.63
P_2T_6	1.24	33.38	5.18	0.15	0.73
P_2T_7	1.24	32.13	5.22	0.17	0.62
P_2T_8	1.42	27.71	5.43	0.32	0.35
P_2T_9	1.39	26.57	5.38	0.27	0.40
$A_2P_1T_1$	1.23	36.47	5.26	0.17	0.65
P_1T_2	1.23	35.91	5.25	0.18	0.67
P_1T_3	1.21	33.26	5.25	0.18	0.53
P_1T_4	1.22	34.20	5.23	0.17	0.65
P_1T_5	1.27	34.29	5.23	0.18	0.67
P_1T_6	1.24	36.49	5.21	0.19	0.78
P_1T_7	1.25	34.45	5.26	0.21	0.66
P_1T_8	1.39	29.40	5.39	0.28	0.35
P_1T_9	1.40	29.23	5.35	0.26	0.41
$A_2P_2T_1$	1.26	34.73	5.21	0.16	0.61
P_2T_2	1.25	33.89	5.21	0.14	0.64
P_2T_3	1.23	29.76	5.23	0.15	0.49
P_2T_4	1.24	32.45	5.20	0.14	0.62
P_2T_5	1.25	32.95	5.20	0.15	0.66
P_2T_6	1.25	33.73	5.18	0.15	0.72
P_2T_7	1.25	33.94	5.20	0.15	0.62
P_2T_8	1.42	27.83	5.44	0.35	0.35
P_2T_9	1.40	27.32	5.37	0.27	0.40
S.Em.±	0.009	0.498	0.009	0.010	0.011
$LSD_{0.05}$	NS	NS	NS	NS	NS

A_1– One year old rubber, A_2– Two year old rubber; P_1– Organic practice on rubber, P_2– Inorganic practice on rubber; T_1– Farm Yard Manure (FYM), T_2– Vermicompost (VC), T_3– Town Compost (TC), T_4– FYM + *Azotobacter,* T_5– FYM + Phosphate Solubizing Bacteria (PSB), T_6– FYM + *Azotobacter* + PSB, T_7– FYM + Mycorrhizae, T_8– NPK, T_9– Control

soil organic carbon content, which usually contains complex compounds and provides wide variety of nutrient resources. These results are in line with findings of Bade *et al*. (2017) who reported maximum organic carbon content (2.27%) in treatment where FYM, *Azotobacter* and phosphotika were applied simultaneously.

None of the interaction between age levels and practices on rubber (A × P) significantly differed for soil parameters except organic carbon, where interaction having two-years old organic practice on rubber (A_2P_1) recorded maximum organic carbon (0.60%). While interaction having NPK treated plot both in one and two-years old rubber (A_1T_8 and A_2T_8) recorded highest bulk density (1.41 to 1.42%) and pH (5.41 to 5.42). The maximum bulk density (1.42%), pH (5.44) and EC (0.33 dSm^{-1}) were observed in interaction having inorganic practice (NPK) on rubber and BEC (P_2T_8). Interaction between age levels, practices on rubber and nutrient management on BEC (A × P × NM) found non-significant.

The perusal of data (Table 2) indicates that soil macro- and micro-nutrients significantly differed among age levels and practices on rubber and nutrient could be due management on BEC and their interactions. Nutrients such as available N (284.04 kg ha^{-1}), P_2O_5 (24.52 kg ha^{-1}), K_2O (139.67 kg ha^{-1}), Fe (40.55 ppm) and Mn (17.90 ppm) were significantly higher under two-years old rubber plantation compared to one-year old plantation. The increasing trend of the nutrients observed, could be due to addition of organic matter in form of litter with advancement in age and subsequent decomposition resulting in release of nutrients to soil. Above result was substantiated with Njar *et al*. (2011) on rubber plantation at Nigeria. The increase in N with the age of trees could be due to increase in vegetation cover and tree size. Since, mature rubber tree has large biomass which not only affords adequate ground cover, but also acts as a huge reservoir of nutrients, thereby preventing them from being leached away from the plantation. Both aged plantations were non-significant for available Cu and Zn.

Addition of FYM as organic source to rubber gave significantly higher available N (280.37 kg ha^{-1}), P_2O_5 (23.39 kg ha^{-1}), K_2O (139.49 kg ha^{-1}), Cu (0.613 ppm), Fe (39.74 ppm), Mn (18.01 ppm) and Zn (0.335 ppm), while significantly lower values for all nutrients were found in rubber plants applied with NPK fertilizers. Higher available N content under organic manure might have contributed for favourable microbial activity and enhanced decomposition of applied organic manures. Increased soil available N due to incorporation of organic manure was also reported by Gaur (1986) and Seth and Balyan (1989).

Increased soil available P_2O_5 with addition of FYM based manure treatment may be due to lesser fixations of P, Al and Fe, which are likely to form organic compounds, thereby preventing P absorption by these compounds. Yadav and Chhipa (2007) and Sharma *et al*. (2009) also observed increase in soil available P_2O_5 with addition of organics. The significant improvement in soil K status might be due to retention of more K by FYM because of greater capacity of organic colloids to hold the cation in the exchangeable form. Yadav and Chhipa (2007) also reported increased available K in FYM treatment than in potassic fertilizer.

Among nutrient management treatments, BEC plants treated with combination of FYM + *Azotobacter* + PSB (T_6) recorded highest available N (322.03 kg/ha), K_2O (157.50 kg/ha), Cu (1.045 ppm), Fe (65.73 ppm), Mn (24.75 ppm) and Zn (0.458 ppm), while BEC plants treated with combination of FYM + PSB (T_5) recorded highest available P_2O_5 (31.92 kg/ha). Poor performance in all macro- and micro-nutrients was observed in BEC plants treated without manures (control). Good performance in T_6 was due to the fact that addition of FYM which results in slow and continuous supply of nutrients and *Azotobacter* converts atmospheric N into ammonical form which is made available to plants. Bade *et al*. (2017) noticed higher available N and K_2O in soil after chilli harvest in treatment having poultry manure, *Azotobacter* and phosphotika. Similar trend in increase of available N by dual inoculation of *Azotobacter* and PSB in strawberry was reported by Singh *et al*. (2010). Higher values of available P_2O_5 in T_5 was due to presence of PSB which solubilizes fixed P in soil and makes it available to the plants.

No significant variation was found for interaction between age levels and practices on rubber (A × P) for all macro- and micro-nutrients, except available Mn, where interaction consisting of two-years old rubber having FYM as organic practice recorded highest available Mn (18.40 ppm).

Among interaction between age levels of rubber and nutrient management of BEC (A × NM), treatment combination consisting of two-years old rubber plantation and combined application of FYM + *Azotobacter* + PSB (A_2T_6) recorded maximum available N (326.78 kg/ha), K_2O (159.80 kg/ha) and Fe (69.53 ppm), followed by A_1T_6. Lowest values of nutrients were observed for interaction consisting of one-year old rubber plantation and BEC plants without manures (A_1T_9).

Among treatments under two-way interaction, between the practices on rubber and nutrient management on BEC (P × NM), treatment combination consisting of organic practice on rubber with combined application of FYM + *Azotobacter* + PSB (P_1T_6) observed maximum available Fe (67.07 ppm), followed by interaction consisting of inorganic practice on rubber with combined application of FYM + *Azotobacter* + PSB (P_2T_6). Poor performance was observed in BEC plants applied with NPK fertilizer, irrespective of age of the rubber plantation (P_1T_8 and P_2T_8). Rest of the macro- and micro-nutrients were at par with each other.

No statistical differences were found for three-level interaction between age levels, practices on rubber and nutrient management on BEC (A × P × NM). However, higher values in above mentioned parameters were found in plots applied with FYM, *Azotobacter* and PSB grown under two-years old rubber plantation having organic practice ($A_2P_1T_6$).

Table 2. Soil macro- and micro-nutrients as influenced by age and practice on rubber and nutrient management on Bird's Eye Chili (BEC) under agroforestry system.

Treatments	Macro-nutrients (kg/ha)			Micro-nutrients (ppm)			
	Nitrogen	Phosphorus	Potassium	Copper	Iron	Manganese	Zinc
Age levels (A)							
A_1	271.33	21.28	132.64	0.581	35.60	16.78	0.317
A_2	284.04	24.52	139.67	0.603	40.55	17.90	0.338
S.Em.±	1.802	0.139	1.698	0.007	0.546	0.253	0.004
$LSD_{0.05}$	5.41	0.42	5.09	NS	1.64	0.76	NS
Practices (P)							
P_1	280.37	23.39	139.49	0.613	39.74	18.01	0.335
P_2	275.00	22.41	132.82	0.571	36.42	16.68	0.320
S.Em.±	1.646	0.260	0.616	0.005	0.373	0.101	0.004
$LSD_{0.05}$	4.94	0.78	1.85	0.01	1.12	0.30	0.011
Nutrient Management (NM) on BEC							
T_1	299.98	21.90	134.12	0.573	35.15	16.65	0.333
T_2	302.68	25.12	147.22	0.713	40.56	19.00	0.398
T_3	275.60	19.57	121.43	0.470	27.94	15.52	0.288
T_4	314.27	26.98	143.96	0.689	42.64	19.70	0.415
T_5	313.28	31.92	152.74	0.766	47.88	22.39	0.441
T_6	322.03	29.90	157.50	1.045	65.73	24.75	0.458
T_7	300.72	23.69	147.05	0.682	43.76	19.26	0.417
T_8	190.06	14.71	118.77	0.151	16.08	8.79	0.088
T_9	180.56	12.32	102.59	0.240	22.93	10.02	0.112
S.Em.±	1.682	0.476	1.213	0.015	0.673	0.328	0.006
$LSD_{0.05}$	4.75	1.35	3.43	0.04	1.90	0.93	0.018
Interaction- A × P							
A_1P_1	274.14	21.78	135.36	0.607	37.11	17.61	0.326
A_1P_2	268.52	20.78	129.92	0.556	34.10	15.96	0.309
A_2P_1	286.60	25.01	143.61	0.619	42.37	18.40	0.345
A_2P_2	281.48	24.03	135.72	0.587	38.74	17.40	0.331
S.Em.±	1.788	0.283	0.670	0.005	0.405	0.142	0.004
$LSD_{0.05}$	NS	NS	NS	NS	NS	0.43	NS
Interaction- A × NM							
A_1T_1	291.29	19.60	131.35	0.547	32.93	15.46	0.300
A_1T_2	296.30	22.69	142.19	0.698	37.62	18.34	0.372
A_1T_3	271.85	16.41	116.85	0.440	25.89	14.66	0.271
A_1T_4	308.33	26.03	141.39	0.710	40.28	18.50	0.414
A_1T_5	303.73	31.02	148.39	0.747	44.45	22.00	0.440
A_1T_6	317.29	28.98	155.15	1.022	61.93	24.57	0.447
A_1T_7	290.49	21.53	140.23	0.686	43.43	18.93	0.416
A_1T_8	187.40	13.96	116.89	0.151	13.04	8.65	0.086
A_1T_9	175.32	11.31	101.36	0.232	20.84	9.94	0.108

Treatments	Macro-nutrients (kg/ha)			Micro-nutrients (ppm)			
	Nitrogen	Phosphorus	Potassium	Copper	Iron	Manganese	Zinc
A_2T_1	308.67	24.21	136.89	0.599	37.37	17.85	0.365
A_2T_2	309.06	27.56	152.25	0.728	43.51	19.67	0.424
A_2T_3	279.35	22.73	126.00	0.500	29.99	16.38	0.305
A_2T_4	320.22	27.92	146.54	0.669	45.00	20.89	0.417
A_2T_5	322.83	32.81	157.09	0.785	51.31	22.78	0.441
A_2T_6	326.78	30.82	159.86	1.068	69.53	24.92	0.469
A_2T_7	310.95	25.86	153.87	0.678	44.10	19.60	0.418
A_2T_8	192.72	15.47	120.66	0.152	19.11	8.94	0.090
A_2T_9	185.79	13.33	103.83	0.248	25.03	10.10	0.117
S.Em.±	2.379	0.673	1.716	0.021	0.897	0.110	0.009
$LSD_{0.05}$	6.72	NS	4.85	NS	2.69	NS	NS
Interaction- P × NM							
P_1T_1	302.21	22.73	137.09	0.596	37.62	17.51	0.347
P_1T_2	306.86	26.20	151.20	0.729	42.96	19.52	0.406
P_1T_3	275.16	19.03	122.14	0.479	27.81	16.08	0.297
P_1T_4	316.35	27.56	147.97	0.709	45.57	20.94	0.420
P_1T_5	317.46	32.66	156.10	0.792	50.08	22.97	0.455
P_1T_6	325.61	30.23	162.52	1.094	67.07	25.57	0.462
P_1T_7	303.84	24.32	150.59	0.713	46.33	20.13	0.422
P_1T_8	192.80	14.95	122.58	0.161	16.15	8.99	0.091
P_1T_9	183.07	12.87	105.19	0.243	24.04	10.34	0.118
P_2T_1	297.75	21.08	131.15	0.550	32.68	15.80	0.319
P_2T_2	298.50	24.04	143.24	0.697	38.16	18.49	0.390
P_2T_3	276.05	20.12	120.71	0.461	28.07	14.96	0.279
P_2T_4	312.19	26.39	139.96	0.670	39.71	18.45	0.410
P_2T_5	309.10	31.17	149.38	0.739	45.68	21.81	0.426
P_2T_6	318.46	29.56	152.49	0.996	64.40	23.92	0.454
P_2T_7	297.59	23.06	143.52	0.651	41.20	18.40	0.411
P_2T_8	187.31	14.48	114.97	0.141	16.01	8.60	0.085
P_2T_9	178.05	11.77	100.00	0.238	21.83	9.70	0.107
S.Em.±	2.379	0.673	1.716	0.021	0.899	0.110	0.009
$LSD_{0.05}$	NS	NS	NS	NS	2.69	NS	NS
Interaction- A × P × NM							
$A_1P_1T_1$	293.37	20.33	133.30	0.581	34.42	16.59	0.306
P_1T_2	302.80	23.25	144.52	0.720	40.32	19.10	0.385
P_1T_3	268.29	15.67	118.37	0.450	26.16	15.44	0.285
P_1T_4	309.93	26.73	144.96	0.741	42.34	20.16	0.420
P_1T_5	308.09	32.18	150.75	0.779	46.02	22.71	0.455
P_1T_6	321.56	29.51	159.10	1.072	63.63	25.47	0.447
P_1T_7	294.28	22.29	143.39	0.713	45.28	19.91	0.422
P_1T_8	191.70	14.36	120.11	0.161	13.52	8.91	0.091

Treatments	Macro-nutrients (kg/ha)			Micro-nutrients (ppm)			
	Nitrogen	Phosphorus	Potassium	Copper	Iron	Manganese	Zinc
P_1T_9	177.25	11.68	103.76	0.243	22.27	10.19	0.118
$A_1P_2T_1$	289.20	18.87	129.41	0.513	31.45	14.34	0.295
P_2T_2	289.80	22.13	139.87	0.677	34.91	17.58	0.359
P_2T_3	275.41	17.15	115.33	0.430	25.62	13.88	0.257
P_2T_4	306.73	25.34	137.82	0.680	38.21	16.85	0.407
P_2T_5	299.38	29.86	146.02	0.714	42.88	21.30	0.425
P_2T_6	313.01	28.44	151.19	0.972	60.24	23.68	0.447
P_2T_7	286.69	20.76	137.08	0.659	41.58	17.95	0.409
P_2T_8	183.10	13.57	113.66	0.140	12.57	8.39	0.081
P_2T_9	173.40	10.94	98.95	0.221	19.40	9.68	0.098
$A_2P_1T_1$	311.05	25.13	140.89	0.611	40.82	18.42	0.388
P_1T_2	310.93	29.16	157.89	0.738	45.61	19.94	0.426
P_1T_3	282.02	22.38	125.91	0.508	29.46	16.71	0.309
P_1T_4	322.77	28.40	150.97	0.678	48.81	21.73	0.420
P_1T_5	326.83	33.14	161.44	0.805	54.14	23.24	0.455
P_1T_6	329.65	30.95	165.93	1.116	70.50	25.68	0.477
P_1T_7	313.41	26.35	157.78	0.713	47.37	20.35	0.422
P_1T_8	193.91	15.54	125.05	0.161	18.77	9.07	0.091
P_1T_9	188.88	14.07	106.62	0.243	25.80	10.49	0.118
$A_2P_2T_1$	306.29	23.29	132.89	0.586	33.91	17.27	0.343
P_2T_2	307.20	25.96	146.62	0.717	41.41	19.40	0.421
P_2T_3	276.69	23.08	126.09	0.491	30.52	16.04	0.300
P_2T_4	317.66	27.45	142.10	0.659	41.20	20.06	0.413
P_2T_5	318.82	32.48	152.75	0.764	48.48	22.32	0.426
P_2T_6	323.92	30.68	153.79	1.021	68.57	24.15	0.461
P_2T_7	308.48	25.36	149.95	0.644	40.82	18.84	0.413
P_2T_8	191.53	15.39	116.28	0.142	19.45	8.81	0.088
P_2T_9	182.69	12.59	101.04	0.254	24.25	9.72	0.115
S.Em.±	3.364	0.952	2.427	0.030	1.347	0.656	0.013
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS

A_1– One year old rubber, A_2– Two year old rubber; P_1– Organic practice on rubber, P_2– Inorganic practice on rubber; T_1– Farm Yard Manure (FYM), T_2– Vermicompost (VC), T_3– Town Compost (TC), T_4– FYM + *Azotobacter,* T_5– FYM + Phosphate Solubizing Bacteria (PSB), T_6– FYM + *Azotobacter* + PSB, T_7– FYM + Mycorrhizae, T_8– NPK, T_9– Control

4. CONCLUSION

It can be concluded that integrated application of diverse source of nutrients not only increased the uptake of plant nutrients but also improved the post harvest soil fertility and subsequently helped for achieving the much desired crop production with sustainable soil health. These findings are of great value and will have long-term practical implications in choosing best sources of nutrient management for agroforestry systems in general and for hilly zone region, in particular.

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