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Research Article

INFLUENCE OF TEAK (*Tectona grandis*) AND BAMBOO (*Dendrocalamus strictus*) PLANTING SYSTEMS ON MICRONUTRIENT STATUS OF SOIL

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Abstract- A field study was conducted to study the soil dynamics in teak and bamboo stands planted to rehabilitate degraded soil in Futala farm, Dr. P.D. Krishi Vidhyapeeth, College of Agriculture, Nagpur, India. Soil samples were collected from a planting arrangement and age sequence of 0-, 8-, 14-, 17- and 19- year old plantations to assess the effects of trees stand on physic-chemical and micronutrient status of the soil. The tree stand altered the status of soil organic carbon (OC), Inorganic carbon (IOC), DTPA-Zn, Fe, Cu and Mn, decreased pH of the soil when referred to the cultivable land. The increment of micronutrients and decrement of pH in the soil was in the order of chrono-sequence and the nutrient index (NIV) for soil of teak and bamboo plantations was medium for iron, zinc and high for manganese and copper. These changes in the soil are hypothetical in agroforestion of degraded sites.

Keywords- Agroforestry, Bamboo, inorganic carbon (IOC), organic carbon (OC), Teak.

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Introduction

In last decades the production of profitable products was increased by high input agriculture [1]. Despite successes in terms of agricultural productivity on a global scale, these developments have been accompanied by soil degradation, declined biodiversity and environmental pollution, which led to rehabituation of farmers due to reduction in food security and farm incomes [2]. The dependence on external inputs for agricultural production is augmented by disrupted ecological interaction due to decline in biodiversity. In general the existence of trees in croplands was a general feature in the past, which were benefited for the system of productivity and assumed for additional income generation for farming community [3]. The introduction of trees into croplands and pasture lands has been increasing in recent years [4], the trees has numerous benefits on environmental aspects which generally associated with reduction in use of fertilizer, leaching of nutrients, soil conservation, increased carbon sequestration and biodiversity in respect to agroforestry systems [5]. Teak is one of the timber species, which has gained precious value around the world for its quality, and bamboo is a boon to poor man in contrast to domestic use in India.

The teak and bamboo are broadly managed in India- both as plantations [6] and in agroforestry [7, 8]. Agroforestry is quite useful system because this is not only utilizes water efficiently but meets the basic requirements of fodder, fuel, pulp and green manure for agricultural crops [9].

There are different ways, that tree can ameliorate soil conditions at a given site. Therefore, tree plantations are an important consideration for maintaining soil properties dependence on type and amount of organic matter produced after decomposition. The physical and chemical properties are soil are mainly regulated by the site characteristics Different forest trees species are known to extent verified influence on soil properties [10]. Keeping above facts in view, an investigation was carried out to compare and evaluate the physico-chemical properties and micronutrient status of the soil in teak, bamboo plantations of different aged and soil under the cultivable land was used as a reference.

Materials and methods

Site description

The study was undertaken at Futala farm, Dr. P.D. Krishi Vidhyapeeth, College of Agriculture, Nagpur from September 2011 to April 2012. The experimental site used in this study includes teak and bamboo plantations which were planted indifferent years with different spacing [Table-1]. The cultivable land was selected to provide reference of comparison for agroforestry plantations. The study sites had soil texture clay developed in the basaltic alluvium deposition and colour of soils were dark brown to very dark greyish brown and classified as vertisols. The teak and bamboo plantations were established by AICRP on Agroforestry initiative in 1992. Teak plantations were planted with native species at spacing of 3m × 3m, 8m × 2m, 8m × 4m, 12m × 2m and 12m × 4m. Bamboo plantations were planted with spacing of 6m × 8m, 5m × 5m and 8m × 8m, cleared of competing vegetation for 4 years. At the time of study plantations were 8, 14, 17 and 19 years old. The details of planting of two plantations were listed in [Table-1].

Sampling and soil chemical analysis

The soil sampling was carried out in a plantation after subdivision into three plots (replication). In each plot a composite samples were collected in 0-15 cm and 15-30 cm layer, which represented greater uniformity. The samples were air dried and sieved in a 2 mm sieve. Soil pH, OC, IOC and micronutrients were determined following the methods generally used. The soil pH was determined in H_2O with a soil water ratio of 1:2.5 [11]; OC was determined by chromic acid titration method by [12], IOC was analyzed by rapid titration method using phenolphthalein indicator [13] and the micronutrients like zinc, iron, copper and manganese were extracted using 0.005 DTPA, 0.01 M $CaCl_2$ + 0.1 N TEA at pH 7.3. The concentration of Zn, Fe, Cu and Mn were determined using atomic absorption spectrophometer as outlined by [14]. Nutrient index value for micronutrients was calculated as per the system give [15].

Table-1 *Details of different aged agroforestry plantations under taken for studying soil characteristics*

Name of the species	Botanical name	Year of plantation	Spacing	Latitude	longitude
1.Teak	***Tectona grandis***	1994	3 X 3m	21⁰09'23.04"	79⁰01'47.26"
		1992	8 X 2m	21⁰09'22.79"	79⁰01'48.05"
		1992	12 X 2m	21⁰09'23.55"	79⁰01'48.39"
		1992	8 X 4m	21⁰09'22.62"	79⁰01'50.33"
		1992	12 X 4m	21⁰09'23.16"	79⁰01'51.60"
		1997	3 X 3m	21⁰09'22.38"	79⁰01'53.07"
		2004	2 X 2m	21⁰09'69.82"	79⁰01'04.51"
2. Bamboo	***Dendrocalamus strictus***	1992	6 X 8m	21⁰09'26.16"	79⁰01'52.08"
		1994	5 X5m	21⁰09'27.76"	79⁰01'59.06"
		1997	8 X 8m	21⁰09'22.04"	79⁰01'03.20"
3. Cultivable land				21⁰09'22.79"	79⁰01'48.82"

Statistical analysis

The experimental design used was factorial randomized block, with eleven treatments (different plantings), two factors (soil depth and plantations) and three replicates. Means were compared with the T-test, at 5% of probability.

Results and Discussion

Soil chemical attribute

The soils chemical analysis in teak and bamboo over a range of 10-19 years old plantations comparison with cultivable land yielded significantly differed pH among the plantations [Table-2]. The pH of the cultivable land, teak and bamboo plantations were ranged from 6.53±0.22 to 7.97±0.17, the teak pH of the soils were in the order of Teak (1994, 3x3m) recorded lower values followed by teak (1992, 8x2m), teak (1992, 12x2m), bamboo (1992, 6x8m) and the highest values were recorded in cultivable land when compared with the teak and bamboo plating systems. The electrical conductivity was also determined and it ranged from 0.092±0.023 dSm^{-1} to 0.680±0.319 dSm^{-1} with an average of 0.353±0.19 dSm^{-1} surface soil and 0.224±0.1 dSm^{-1} subsurface soil where as electrical conductivity was differed significantly among the depth but the distribution of soluble salts showed non significant among the plantations. The decrement in pH among the plantations can be attributed to litter fall, which on decomposition are known to produce the organic acids [16,17]. The phenomenon of lowering pH might be related to several mechanics that release H^+ ions, such as cation uptake by biomass, decomposition of organic matter to organic acids and CO_2, root respiration and nitrification. The above ground biomass produced by the trees are accumulated on the soil which in turn helps for cation uptake by the tree component of agroforestry systems perhaps this is the causes for the decreased pH in the soil. The electrical conductivity ranged from 0.092±0.023 dSm^{-1} to 0.680±0.319 dSm^{-1} with an average of 0.353±0.19 dSm^{-1} in surface soil and 0.224±0.1 dSm^{-1} in subsurface soil. Further electrical conductivity differed significantly among the depth. However, the distribution of soluble salts showed non-significant among the plantations. The uptake of nutrients by agroforestry plantations may contribute to differential values of soil. The results pertaining to electrical conductivity corroborate the findings of [18]. The results pertaining to calcium carbonate ($CaCO_3$) in the soils of the cultivable land, teak and bamboo plantations represented in [Table-2] were found to be higher in the bamboo plantations and followed by teak and cultivable land. The $CaCO_3$ content in the experimental site was in the order of bamboo (1992, 6x8 m) 12.3±0.61 per cent followed by bamboo (1994, 5x5 m) 7.93±0.17 per cent, teak (2004, 3x3 m) 7.01 ±0.035 per cent further the lowest values was recorded in teak (1992, 8x2 m) 4.74±0.35 per cent among the agroforestry plantations where as the cultivable land yielded 6.17±0.47 percent compared with agroforestry plantations. In this investigation relative lesser $CaCO_3$ percent was found among the teak plantations and higher $CaCO_3$ percent in bamboo plantations this might be due to Ca content in the litter fall added to surfaces soil under the teak and bamboo cover.

Maintaining the amount of soil organic carbon (SOC) in the Agroecosystems is desirable for maintenance or rehabilitation of soil fertility. The soil organic carbon of the experimental site was differed significantly among the cultivable land, teak and bamboo plantations and depth of the soil [Table-2]. The SOC among the plantations and cultivable land ranged from 3.3±0.03 g kg^{-1} to 10.7 ±0.089 g kg^{-1}. The mean organic carbon content (0-30 cm) of the experimental site took the order of bamboo (1992, 6x8 m) 9.7± 0.07 g kg^{-1}, bamboo (1994, 5x5 m) 8.9± 0.04g kg^{-1}, teak (1994, 3x3 m) 8.6 ± 0.04 g kg^{-1} and at lastly the cultivable land recorded lowest SOC (3.9±0.03 g kg^{-1}) when compared with teak and bamboo panting systems [Table-2]. Increase in soil organic carbon was due to litter fall and magnitude of build up. The organic carbon varied among the teak and bamboo plantations varied with the biomass production. The SOC recorded increasing trend with increasing in the biomass production and litter fall. The organic carbon content in soil accounted that rate and quantity of litter fall and their rate of decomposition were reported by [19]. Variations in organic carbon content in soils under various tree sp. is attributed to the age of plantation and amount of litter fall and their biochemical composition [20], [21] reported higher organic carbon content in bamboo plantation soil. Even though comparison was made only between the two plantation soils, it could be seen that due to disturbances and subsequent plantation activities, soils exhibited wide variability in their properties within each plantation [22].

Micronutrient status

The DTPA extractable micronutrients were determined under different aged plantations and planting systems are represented in the [Table-3]. The DTPA extractable micronutrients differed among the treatments and decreased with the increase in depth this might be due to the decrease in organic carbon content in the soil at lower depths. The mean DTPA extractable Fe and Mn content (0-30 cm) in an experimental site was differed significantly and ranged from 4.42±0.06 to 2.01±0.29 mg kg^{-1} and 13.71±0.35 to 6.45±0.10 mg kg^{-1} respectively [Table-3]. The highest rank was recorded by bamboo (1992, 6 x 8m) 4.42 ± 0.06 mg kg^{-1} and 13.71± 0.35 mg kg^{-1} respectively which took the order Teak (1994, 3 x 3m) 4.27 mg kg^{-1} and 13.31 ± 0.43 mg kg^{-1} however, the lowest rank among the plantations was recorded by teak (2004, 3 x 3m). The DTPA Fe and Mn was less in cultivable land/crop land when compared with teak and bamboo plantations this may be differential performance of the element by the tree sp as represented by [23]. The soils of Teak (1994, 3 x 3m) showed higher DTPA Zn 0.91 ± 0.03 mg kg^{-1} which was followed by Bamboo plantations, where as the lower values was recorded under teak (2004, 3 x 3 m) plantations and it was higher when compared with the cultivable land. The Copper content in experimental site was differed significantly among the plantations mean values were ranged from 3.57 ± 0.05 mg kg^{-1} to 1.08 ± 0.04 mg kg^{-1} and took the order bamboo (1992, 6 x 8m) followed by bamboo (1994, 5 x 5m) however the 4^{th} position was occupied by teak (1994, 3 x 3m) and it fallows. The changes in nutrient concentration in different aged plantations might be attributed to the composition of leaf litter and their rate of mineralization in soils under canopy cover while that nutrient accumulation is as result of the relatively long term biotic influence of trees on the soil. The differentiated nutrient concentration in planting arrangement and aged plantation was mainly to the fact that build up of nutrients in the top soil was due to the accumulation of soil organic matter which is the store and source of important nutrients [24 & 25].

Nutrient index

The results of the soil nutrient index value [Table-4] suggests a shift of increasing fertility in both surface and subsurface soils from the cultivable land, with the teak and bamboo planting have high to medium fertility classes. The nutrient index [Table-4] for soil of teak ad bamboo plantations was medium for iron, zinc and high for manganese and copper respectively. Although these results are only an indication of one decade of growth, the increased soil fertility, especially in the teak plantation is a resource that could be utilized by implementing understory crops.

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Table-2 *Mean (±S.D.) of some chemical and nutrient properties in the 0-15 and 15-30 cm soil layers under teak, bamboo planting systems and cultivable land*

Soil properties	Depth (cm)	Cultivable land	Teak (1992, 8x2m)	Teak (1992, 12x2m)	Teak (1992, 8x4m)	Teak (1992, 12x4m)	Teak (1994, 3x3m)	Teak (1997, 3x3m)	Teak (2004, 3x3m)	Bamboo(1992, 6x8m)	Bamboo (1994, 5x5)	Bamboo (1997, 8x8m)	Mean	Interaction	SEm ±	CD 5%
pH	0-15	7.71±0.09	6.81±0.07	7.04±0.22	7.07±0.22	7.16±0.35	6.53±0.22	7.04±0.46	7.35±0.12	7.03±0.02	7.09±0.03	7.54±0.12	7.13±0.18	**Crop (C)**	0.041	0.116
	15-30	7.97±0.17	7.15±0.52	7.28±0.35	7.39±0.25	7.41±0.16	7.28±0.09	7.48±0.37	7.67±0.14	7.31±0.17	7.66±0.04	7.82±0.15	7.49±0.22	**Depth (D)**	0.007	0.021
	Mean	7.84±0.12	6.98±0.29	7.16±0.28	7.23±0.23	7.28±0.25	6.90±0.15	7.26±0.41	7.51±0.13	7.17±0.09	7.38±0.03	7.68±0.13	-	**C×D**	0.081	NS
EC (dS m^{-1})	0-15	0.300± 0.01	0.092±0.02	0.68±0.32	0.458±0.31	0.457±0.41	0.498±0.31	0.168±0.06	0.513±0.32	0.273±0.08	0.146±0.04	0.302±0.26	0.353±0.2	**Crop (C)**	0.0323	NS
	15-30	0.176±0.06	0.100±0.01	0.143±0.07	0.136±0.08	0.105±0.03	0.376±0.36	0.242±0.11	0.281±0.02	0.465±0.22	0.226±0.08	0.215±0.12	0.224±0.1	**Depth (D)**	0.0059	0.017
	Mean	0.24±0.03	0.10±0.01	0.41±0.20	0.30±0.19	0.28±0.22	0.44±0.33	0.21±0.08	0.40±0.17	0.37±0.15	0.19±0.06	0.26±0.19	-	**C×D**	0.0647	NS
$CaCo_3$ (%)	0-15	5.99±0.58	3.57±0.39	5.96±0.61	5.61±0.45	6.16±0.19	6.24±0.55	6.63±0.65	6.51±0.37	11.66±1.00	6.49±0.12	6.18±0.57	6.45±0.50	**Crop (C)**	0.084	0.239
	15-30	6.35±0.36	5.91±0.30	6.85±0.40	6.36±0.21	6.48±0.27	6.71±0.91	6.75±0.87	7.50±0.33	13.00±0.22	9.37±0.21	6.82±0.25	7.46±0.39	**Depth (D)**	0.015	0.044
	Mean	6.17±0.47	4.74±0.35	6.40±0.51	5.98±0.33	6.32±0.23	6.47±0.73	6.69±0.76	7.01±0.35	12.33±0.61	7.93±0.17	6.50±0.41	-	**C×D**	0.168	0.479
Soil C (g kg^{-1})	0-15	0.45±0.03	0.86±0.04	0.81±0.06	0.82±0.05	0.75±0.04	0.94±0.05	0.81±0.03	0.58±0.04	1.07±0.08	0.96±0.05	0.87±0.03	0.81±0.05	**Crop (C)**	0.0072	0.021
	15-30	0.33±0.03	0.60±0.02	0.56±0.02	0.55±0.01	0.51±0.04	0.78±0.04	0.62±0.04	0.49±0.04	0.86±0.05	0.81±0.03	0.71±0.06	0.62±0.04	**Depth (D)**	0.0013	0.004
	Mean	0.39±0.03	0.73±0.03	0.68±0.04	0.68±0.03	0.63±0.04	0.86±0.04	0.72±0.04	0.54±0.04	0.97±0.07	0.89±0.04	0.79±0.05	-	**C×D**	0.0145	0.041

Table-3 Showing *Mean (±S.D.) of micronutrient properties in the 0-15 and 15-30 cm soil layers under teak, bamboo planting systems and cultivable land*

Soil properties	Depth (cm)	Cultivable land	Teak (1992, 8x2m)	Teak (1992, 12x2m)	Teak (1992, 8x4m)	Teak (1992, 12x4m)	Teak (1994, 3x3m)	Teak (1997, 3x3m)	Teak (2004, 3x3m)	Bamboo(1992, 6x8m)	Bamboo (1994, 5x5)	Bamboo (1997, 8x8m)	Mean	Interaction	SEm ±	CD 5%
Iron (mg kg^{-1})	0-15	2.37±0.03	4.24±0.03	4.16±0.04	4.20±0.02	3.93±0.08	4.93±0.08	4.43±0.19	2.98±0.03	5.30±0.06	4.97±0.30	4.45±0.07	4.18±0.08	**Crop (C)**	0.0256	0.073
	15-30	1.65±0.55	3.34±0.03	3.24±0.03	3.28±0.03	3.18±0.03	3.62±0.04	3.33±0.05	2.74±0.03	3.54±0.06	3.52±0.04	3.24±0.18	3.15±0.10	**Depth (D)**	0.0047	0.013
	Mean	2.01±0.29	3.79±0.03	3.70±0.04	3.74±0.03	3.55±0.05	4.27±0.06	3.88±0.12	2.86±0.03	4.42±0.06	4.25±0.17	3.85±0.12	-	**C×D**	0.0512	0.146
Zinc (mg kg^{-1})	0-15	0.35±0.03	0.84±0.01	0.85±0.01	0.83±0.01	0.83±0.02	0.94±0.02	0.86±0.03	0.58±0.06	0.90±0.02	0.88±0.02	0.88±0.02	0.80±0.02	**Crop (C)**	0.005	0.016
	15-30	0.27±0.03	0.65±0.04	0.64±0.02	0.63±0.02	0.68±0.06	0.87±0.05	0.63±0.06	0.47±0.04	0.86±0.02	0.80±0.06	0.80±0.05	0.66±0.04	**Depth (D)**	0.001	0.002
	Mean	0.31±0.03	0.75±0.02	0.74±0.01	0.73±0.01	0.76±0.04	0.91±0.03	0.75±0.04	0.53±0.05	0.88±0.02	0.84±0.02	0.84±0.03	-	**C×D**	0.0112	0.032
Copper (mg kg^{-1})	0-15	1.13±0.02	2.84±0.07	2.61±0.03	2.64±0.03	2.44±0.06	3.24±0.08	2.91±0.07	1.34±0.04	3.90±0.07	3.55±0.06	3.37±0.05	2.73±0.05	**Crop (C)**	0.007	0.021
	15-30	1.03±0.06	2.32±0.07	2.24±0.04	2.31±0.04	2.29±0.04	2.54±0.07	2.55±0.03	1.17±0.07	3.24±0.02	3.12±0.02	3.01±0.06	2.35±0.05	**Depth (D)**	0.001	0.003
	Mean	1.08±0.04	2.58±0.07	2.43±0.04	2.48±0.04	2.37±0.05	2.89±0.08	2.73±0.05	1.26±0.05	3.57±0.05	3.34±0.04	3.19±0.05	-	**C×D**	0.015	0.043
Manganese (mg kg^{-1})	0-15	7.89±0.08	14.32±0.45	12.66±0.32	13.39±0.29	11.59±0.38	16.31±0.44	13.11±0.13	10.51±0.49	18.41±0.16	17.21±0.60	15.21±0.22	13.69±0.32	**Crop (C)**	0.070	0.20
	15-30	5.00±0.12	9.01±0.58	8.09±0.51	9.08±0.21	7.21±0.29	10.32±0.42	8.17±0.52	7.75±0.52	9.01±0.54	8.87±0.60	6.01±0.58	8.05±0.45	**Depth (D)**	0.012	0.036
	Mean	6.45±0.10	11.66±0.52	10.38±0.42	11.23±0.25	9.40±0.33	13.31±0.43	10.64±0.32	9.13±0.50	13.71±0.35	13.04±0.60	10.61±0.40	-	**C×D**	0.012	0.403

Table-4 *Category wise classification of soils of teak and bamboo planting systems for organic carbon and micronutrients*

Soil properties	Cultivable land	Teak (1992, 8x2m)	Teak (1992, 12x2m)	Teak (1992, 8x4m)	Teak (1992, 12x4m)	Teak (1994, 3x3m)	Teak (1997, 3x3m)	Teak (2004, 3x3m)	Bamboo(1992, 6x8m)	Bamboo (1994, 5x5)	Bamboo (1997, 8x8m)
Organic carbon g kg^{-1}	3.90	7.30	6.80	6.80	6.30	8.60	7.20	5.40	9.70	8.90	7.90
Iron (mg kg^{-1})	2.01	3.79	3.7	3.74	3.55	4.27	3.88	2.86	4.42	4.25	3.85
Zinc (mg kg^{-1})	0.31	0.75	0.74	0.73	0.76	0.91	0.75	0.53	0.88	0.84	0.84
Copper (mg kg^{-1})	1.08	2.58	2.43	2.48	2.37	2.89	2.73	1.26	3.57	3.34	3.19
Manganese (mg kg^{-1})	6.45	11.66	10.38	11.23	9.4	13.31	10.64	9.13	13.71	13.04	10.61
Boron (mg kg^{-1})	0.13	0.42	0.4	0.37	0.35	0.44	0.43	0.21	0.43	0.39	0.31
Soil fertility rating											
Organic carbon g kg^{-1}	L	MH	MH	MH	MH	H	MH	M	H	H	MH
Iron (mg kg^{-1})	L	M	M	M	M	M	M	M	M	M	M
Zinc (mg kg^{-1})	L	M	M	M	M	M	M	M	M	M	M
Copper (mg kg^{-1})	H	H	H	H	H	H	H	H	H	H	H
Manganese (mg kg^{-1})	H	H	H	H	H	H	H	H	H	H	H
Boron (mg kg^{-1})	L	M	M	M	M	M	M	M	M	M	M

Conclusion

This study has shown that the differences in soil chemical properties under different arrangements and aged plantations of teak and bamboo were significant. This implies that the various planting arrangements and age have different impacts on the soil chemical properties. Furthermore, the results show that of all the planting arrangements, that in which the teak and bamboo stand is close appears to be the most beneficial to the soil. It is suggested that the probable cause of this phenomenon is the synergistic interactions among the litter components of teak and bamboo, which increased constituents of nutrients in the soil. The increased soil fertility in both plantations, especially teak plantations would be beneficial for agricultural crops or agroforestry systems that can co-exist with the plantation. Further soil analysis would have to occur to determine if the increased fertility remains after the full rotation of the plantation, especially if agricultural crops will follow timber harvest. Thus, plantations with carefully evaluated agroforestry sp could be employed as productive soil ameliorations in humid, sub-humid, arid and semiarid soil of India.

Conflict of Interest: None declared

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