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Soil chemical properties under bamboo-soybean agroforestry system in northern transitional zone, Karnataka

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Abstract
In India, a bamboo-based agroforestry system is a viable choice for sustainable land management. The experiment was conducted out in the Main Agricultural Research Station, Dharwad, during the *kharif* season of 2021, with the goal of determining soil chemical characteristics under a bamboo - soybean based agroforestry system. The chemical characteristics of the composite samples were determined (pH, EC, organic carbon (OC), available nitrogen, available phosphorus, and available potassium).The treatments i.e., T_1- *Bambusa balcooa* + Soybean, T_2- *Dendrocalamus stocksii* + Soybean, T_3- *Dendrocalamus asper* + Soybean, T_4- *bambusa vulgaris* + Soybean and T_5 is control. A drop in soil pH was registered under bamboo based agroforestry system compared to open farming system. The difference in soil electrical conductivity (EC) between the control and agroforestry systems was not statistically significant. Soil organic carbon (SOC), accessible nitrogen (N), phosphorus (P), and potassium (K) levels were higher in the bamboo-based agroforestry system than in the open agricultural system. As a result, long-term adoption of bamboo-based agroforestry systems aids in improving soil chemical characteristics as well as nutrient status.

Keywords: Soil properties, bamboo based agroforestry system, macronutrients, bamboo- soybean intercropping, safety net

Introduction

Soil degradation poses a significant danger to agricultural productivity. Sole cropping, straw burning, and poor nutrient management practices hasten nutrient depletion. Adoption of appropriate agroforestry systems is a sustainable solution to address such nutrient declines, because perennial components of agroforestry systems have a profound impact on soil nutrient pools, as deep and extensive root systems enable them to extract significant quantities of nutrients below the crop root zone and move them to the surface soil via nutrient pumping and root turn over. Bamboos are important in nutrient cycling. Bamboos have dense mat-like fine roots that restrict nutrient leakage into the deeper soil profile and act as a safety net for crops. The continuous input of litter to the soil throughout the year, as well as faster root turn over, improves the soil's nutrient condition. Bamboo, as one of the plants with the quickest growth rates, can withstand a wide range of climatic, edaphic, and environmental conditions. It is generally found in the understory of natural forests. There are 124 endemic species found in the wild and in cultivation, organized into 23 genera.

By restoring the fertility of degraded fields through organic matter addition and diversification, agroforestry practices can enhance farm productivity and socioeconomic position. Agroforestry systems are frequently seen as sustainable, capable of improving soil properties and nutrient status. Soybean (*Glycine max*) is the most important crop in Karnataka's Dharwad region during the kharif season. Soybean (*Glycine max*), often known as Soja bean or Soya bean, is a pea family Fabaceae annual legume. The soybean is the most significant bean in the world, giving vegetable protein to millions of people and ingredients for hundreds of chemical goods, as well as being widely utilized as an oil seed. Bamboo has grown in popularity among farmers because bamboo-based agroforestry systems are more profitable and economically viable than many other crop rotation options.

Materials and Methods

Experimental Site

The experiment was carried out in the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, which is located at 15° 26 North latitude, 75° 0 East longitude, and 678 m above mean sea level. It is located in a transitional tract that represents Karnataka's Northern transitional agro-climatic zone (zone 8). Dharwad has a humid subtropical climate. Summers are moderate and dry, with a monsoon season following.

Experiment details

Four different species of bamboo (*Bambusa balcooa*, *Dendrocalamus stocksii*, *Dendrocalamus asper*, *bambusa vulgaris*) were planted in the year 2017. Performance of these different species of bamboos under agroforestry system is studied with agricultural crop soybean in kharif season of 2021.

Soil and its characteristics

The experimental area was medium deep black soil in nature. The composite soil sample was collected from 0-30 cm soil depth before and after the harvest of soybean crop. The soil samples were air dried, powdered, and passed through a two-mm sieve before being tested for chemical characteristics. Nutrient return added to the soil through litterfall by several thornless bamboo species was collected and examined to correlate the soil chemical property values. The pH of the soil was measured in a 1:2.5 soil:water ratio, and after half an hour of equilibrium, the pH was measured using a glass electrode on a microprocessor-based pH metre (Jackson 1973) [4]. The electrical conductivity of the soil was measured using a digital microprocessor-based conductivity metre in a 1:2.5 soil: water solution at 25 °C. The organic carbon content of soil was determined using Jackson's (1973) [4] modified Walkley and Black (1934) [10] technique. The alkaline potassium permanganate method was used to determine available nitrogen in soil (Subbiah and Asija 1956) [9]. According to Jackson (1973) [4], available phosphorus was extracted using a sodium bi-carbonate extractant (0.5 M NaHCO3) set to pH 8.5. Jackson (1973) [4] described a neutral ammonium acetate method for determining available potassium. The nutritional status of bamboo litter was determined using the same approach as described previously.

Results and Discussion

Soil pH, electrical conductivity (EC), organic carbon (OC), available nitrogen, phosphorus, and potassium are essential soil fertility characteristics that influence soybean growth and production.

Table 1 shows how soil pH varied in open farming (single cropping) and bamboo-based agroforestry systems where soybean crops were cultivated. Soil pH was lowered in all agroforestry combinations before and after crop harvesting when compared to the control plot (single cropping). *D. asper* had the greatest reduction in soil pH when compared to the control (6.42 and 6.72), with values of 5.51 and 5.62 before sowing and after harvesting, respectively. Soil pH drop in bamboo-based agroforestry systems may be due to significant leaf litter generation, which decomposes to form weak acids (humic acid and fulvic acid), causing pH lowering. Akoto *et al*. (2020) [1], Kaushal *et al*. (2020) [6], all reported similar impressions. For both seasons, soil EC indicated no significant difference between two farming practises in the 0-30 cm layer. The non-significant value of EC could be attributed to the low concentration of soluble salts (Ghimire *et al*., 2015) [2].

Table 1: Effect of open farming and bamboo based agroforestry systems on soil pH and EC (dS/m) at 0 30 cm depth of soil before and after harvesting of Soybean crop

Treatment	pH		EC (ds/m)	
	Before sowing	After harvesting	Before sowing	After harvesting
B. balcooa	5.73	5.74	0.20	0.20
D. stocksii	5.65	5.66	0.20	0.20
D. asper	5.51	5.62	0.20	0.20
B. vulgaris	5.67	5.68	0.20	0.20
Control	6.42	6.72	0.20	0.20
CD @ 5%	0.26	0.05	NS	NS
S.Em ±	0.09	0.02	0.003	0.004

The findings in Table 2 on soil organic carbon percent showed a difference between open farming and bamboo-based agroforestry systems. Organic carbon measured in an agroforestry system ranged from 0.62 to 0.66% before crop sowing and 0.66 to 0.71% after crop harvesting. There were considerable changes in organic carbon percent under bamboos after crop harvest in an agroforestry system. Organic carbon percent was much greater in *D. asper* (0.71), followed by *D. stocksii* (0.69), which remained on level with *B. balcooa* (0.68), and lowest in *B. vulgaris* (0.66). Lignified cells in perennial components such as litter, bark, tiny branches, and roots may cause biochemical stabilization of organic carbon in the soil. Hence, it leads to improved soil organic carbon content under agroforestry system as compared to open farming system or sole crop (Singh *et al*., 2014) [8]. Gupta *et al*., (2009) [3] registered an increase of soil organic carbon under agroforestry compared to sole cropping.

When compared to open farming, agroforestry systems had the highest nitrogen content. Prior to crop sowing, the most nitrogen availability was in T_2 plot, i.e., under *Dendrocalamus stocksii* (163.50 kg/ha), which was comparable to T_3 plot, i.e., under *Dendrocalamus asper* (162.00 kg/ha), and the lowest in (T_5 plot) control (142.00 kg/ha). After harvesting the field crop, accessible nitrogen in *Dendrocalamus asper* was much higher (185.50). The remaining treatments in the bamboo-based agroforestry system had on par values of available nitrogen, whereas the open farming system had much lower nitrogen content (149.16 kg/ha). The continual input of litter, root exudates, and fine root turn over boosts the microbial population in a bamboo-based agroforestry system, which improves the soil's C:N ratio. Singh *et al*., (2014) [8] discovered that poplar-based agroforestry systems had more nodule formation in the root of soybean than open farming systems, implying that poplar-based agroforestry systems had more accessible nitrogen. Kaushal *et al*., (2020) [6] found that nitrogen was higher in bamboos than in controls, with maximum values (243.4 kg/ha at 0-15 cm soil depth) in *D. hamiltonii*, which was comparable to *B. balcooa*. At 0-30 cm, there was a considerable difference in available phosphorus between open and agroforestry cropping systems. Before and after crop harvest, all agroforestry treatments differed significantly from open agricultural systems. Initially, the highest available phosphorus concentration was found in the T_1 plot, which was planted with *Bambusa balcooa* (10.17 kg/ha). After harvesting the field crop, *Bambusa balcooa* had significantly higher phosphorus availability (14.97 kg/ha), followed by *Dendrocalamus stocksii* (14.26 kg/ha). The remaining two plots under *D. asper* and *B. vulgaris* had comparable available phosphorus values (13.69 and 13.41kg/ha). The open agricultural system has a significantly lower available Phosphorus value (9.45 kg/ha). Bamboo litter with high silica content decomposes slowly and contributes significant amounts of phosphorus to the soil (Shanmughavel *et al*. 2000) [7]. The difference in phosphorus concentration between species may be related to differences in decomposition rate and litter fall. The nutrient analysis of different bamboo species (Table 3) revealed that *B. balcooa* had the highest phosphorus concentration (0.09%), followed by 0.06% in *D. stocksii* and *D. asper*, while the lowest P was found in *B. vulgaris* (0.04%). The maximum available potassium was available (Table 2) before and after crop harvesting in an agroforestry system compared to an open farming system. T_2 plot (72.17 kg/ha) had the highest potassium level, followed by T_1 plot (69.90 kg/ha), which was comparable to T_3 plot (68.17). The control plot had the lowest potassium concentration (59.55kg/ha). Potassium availability ranged from 62.33 kg/ha in the control (T5) plots to 79.75 kg/ha in the T2 plot. *D. stocksii* had much more accessible potassium (79.75 kg/ha). Significantly lower potassium content was present in open farming system (62.33 kg/ha). The various effects of bamboo litter on soil available potassium are most likely due to variances in potassium intake by different bamboo species as well as changes in potassium concentration and decomposition rate of leaf litter. Because of its ability to rapidly absorb and accumulate potassium in its biomass, bamboo plays an important role in potassium conservation. Maximum soil potassium values were recorded by Kaushal *et al*., (2020) [6] under *D. hamiltonii* (247.5 kg/ha at 0-15 cm soil depth), which was comparable to *B. balcooa*.

Table 2: Effect of open farming and bamboo based agroforestry systems on soil organic carbon (%), available nitrogen (kg/ha), available phosphorus (kg/ha), available potassium (kg/ha) before and after harvesting of Soybean crop.

Treatment	OC (%)		N (kg/ha)		P (kg/ha)		K (kg/ha)	
	BS	AH	BS	AH	BS	AH	BS	AH
B. balcooa	0.64	0.68	155.67	178.67	10.17	14.97	69.90	78.11
D. stocksii	0.66	0.69	163.50	180.50	8.75	14.26	72.17	79.75
D. asper	0.66	0.71	162.00	185.50	8.74	13.69	68.17	77.07
B. vulgaris	0.62	0.66	151.66	177.67	8.70	13.41	67.45	75.58
Control	0.52	0.55	142.00	149.16	7.42	9.45	59.55	62.33
CD @ 5%	0.03	0.01	2.49	3.41	0.19	0.39	1.86	1.36
S.Em ±	0.01	0.01	0.84	1.15	0.06	0.13	1.63	0.46

*BS- before sowing, AH- after harvesting

The nutritional profile of bamboo litter (Table 3) demonstrated that *D. stocksii* and *D. asper* had higher nitrogen content. The phosphorus concentration of *B. balcooa* was higher. *D. stocksii* had the highest potassium content, and *B. balcooa* had the highest organic carbon content.

Table 3: Nutrient (N, P, K, OC) added to the soil through litterfall by different thorn less bamboo specie

Litter Sample	N (%)	P (%)	K (%)	OC (%)
Bambusa balcooa	0.84	0.09	0.51	13.14
Dendrocalamus stocksii	0.98	0.06	0.89	13.11
Dendrocalamus asper	0.98	0.06	0.34	13.21
Bambusa vulgaris	0.56	0.04	0.32	12.89

Conclusion
A noticeable improvement in soil chemical properties (SOC, N, P and K) was observed under bamboo-based agroforestry system over control (Sole crop). It is due to the continuous addition of organic matter from bamboo species and faster fine roots turn over. The soil pH decreased under agroforestry system than control. Soil organic carbon, available nitrogen, phosphorous and potassium increased significantly under bamboo agroforestry system than sole cropping at 0 to 30 cm, therefore it is more advisable for improving soil fertility.

Conflict of Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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