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RESEARCH PAPER

Influence of bamboo - soybean agroforestry system on soil chemical characteristics in northern transitional zone of Karnataka

*DIVYA SOMAN[1] AND RAJU L. CHAVAN[1]

[1]Department of Silviculture and Agroforestry, College of Forestry, Sirsi
University of Agricultural Sciences, Dharwad - 580 005, India
*E-mail: devusoman94@gmail.com

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Abstract: A prospective avenue for sustainable land management in India involves the utilization of a bamboo-centered agroforestry system. A scientific research was conducted during the *kharif* season of 2022 at the Main Agricultural Research Station in Dharwad to investigate the soil chemical characteristics within an agroforestry framework centered around bamboo and soybean. The composite samples were analyzed for several chemical attributes including pH, electrical conductivity (EC), soil organic carbon (SOC), available nitrogen, available phosphorus, and available potassium. The experiment featured five distinct treatments denoted as T1 (*Bambusa balcooa* + Soybean), T2 (*Dendrocalamus stocksii* + Soybean), T3 (*Dendrocalamus asper* + Soybean), T4 (*Bambusa vulgaris* + Soybean), and T5 (Sole soybean). Notably, the soil pH exhibited a decline under the bamboo-based agroforestry system when compared to the exclusive soybean cultivation. However, there was no statistically significant variance observed in soil electrical conductivity (EC) between the control and the agroforestry systems. Moreover, the levels of soil organic carbon (SOC), available nitrogen (N), phosphorus (P), and potassium (K) were notably higher in the bamboo-centric agroforestry system compared to the sole soybean cropping. Consequently, the sustained adoption of a bamboo-focused agroforestry system has the potential to enhance soil chemical attributes and enrich nutrient status over the long term.

Key words: Bamboo-soybean intercropping, Bamboo based agroforestry system, Macronutrients, Soil properties

Introduction

Soil degradation poses a significant threat to agricultural productivity, with nutrient loss being exacerbated by practices such as sole cropping, straw burning, and inadequate nutrient management. Implementing suitable agroforestry systems offers a long-term solution to nutrient decline. The perennial components of agroforestry systems wield a profound influence on soil nutrient pools due to their extensive and deep-rooted systems, extracting substantial nutrient quantities from below the crop root zone and transporting them to the surface soil through nutrient pumping and root turnover. Bamboos are key players in nutrient cycling, leveraging their dense, mat-like fine roots to function as a safeguard for crops, minimizing nutrient seepage into the deeper soil profile. The consistent addition of litter to the soil year-round, coupled with rapid root turnover, enhances the soil's nutritional status. Bamboo, recognized for its rapid growth and adaptability to various climates, soils, and environmental conditions, is predominantly found in the understory of natural forests. In the wild and in cultivation, there exist 124 indigenous bamboo species distributed across 23 genera.

The adoption of agroforestry practices can significantly enhance farm productivity and socioeconomic standing by revitalizing the fertility of depleted fields through organic matter supplementation and diversification. Agroforestry systems are widely acknowledged for their eco-friendliness and ability to enhance soil characteristics and nutrient levels. In the *kharif* season, soybean (Glycine max), a pivotal crop in Karnataka's Dharwad region, takes precedence. This annual legume, a member of the pea family Fabaceae, holds great global significance, providing essential vegetable protein to millions and serving as a key ingredient in numerous chemical products. Additionally, soybean is extensively used as an oilseed. Bamboo-centered agroforestry systems stand out for their profitability, sustainability, and economic viability compared to various other farming practices.

Material and methods

The experiment was carried out at the Main Agricultural Research Station (MARS) of the University of Agricultural Sciences, Dharwad. MARS is situated at 15.485738 latitude, 74.981644 longitude, and at an elevation of 678.45 meters above mean sea level. It is located in a transitional tract that represents the Northern transitional agro-climatic zone (zone 8) of Karnataka. Dharwad experiences a humid subtropical climate, characterized by mild and dry summers followed by a monsoon season. In the year 2017, four different bamboo species, namely *Bambusa balcooa*, *Dendrocalamus stocksii*, *Dendrocalamus asper*, and *Bambusa vulgaris*, were planted in randomized block design.

The experimental site featured medium-deep black soil. Soil samples were collected both before and after the harvest of the soybean crop from a depth of 0-30 cm. Prior to conducting chemical analyses, the soil samples underwent a series of preparations, including air drying, pulverization, and sieving through a two-mm sieve. The soil's pH was determined using a 1:2.5 soil-to-water ratio, with pH measurements carried out using a glass electrode on a microprocessor-based pH monitor. The measurements were taken after allowing the samples to equilibrate for half an hour, following the procedure described by Jackson (1973).

The electrical conductivity of the soil was measured in a 1:2.5 soil-to-water solution at 25°C, employing a digital microprocessor-based conductivity meter. The organic carbon content of the soil was determined using a modified approach based on the method developed by Walkley and Black (1934) as adapted by Jackson (1973). Available nitrogen in the soil was determined using the alkaline potassium permanganate method introduced by Subbiah and Asija (1956). The extraction of accessible phosphorus from the soil was performed using a sodium bicarbonate extractant (0.5 M NaHCO3) at pH 8.5, following the method outlined by Jackson (1973). For the estimation of available potassium, Jackson (1973) provided a method that utilized neutral ammonium acetate.

Results and discussion

Soil pH, electrical conductivity (EC), organic carbon (OC), available nitrogen, phosphorus, and potassium are pivotal soil fertility attributes influencing soybean growth and production. Table 1 presents the varying soil pH levels observed in both sole cropping and bamboo-based agroforestry systems during soybean cultivation. A notable decrease in soil pH is evident across all agroforestry combinations, both pre- and post-harvest, compared to the control plot (sole cropping). Initially measured soil pH ranged from 5.63 to 6.82. Post-harvest, a slight increase in pH values is observed across all treatment combinations compared to the initial readings. Sole cropping exhibited significantly higher soil pH (6.94), while other agroforestry treatments demonstrated comparable pH values. The decline in soil pH within bamboo-based agroforestry systems can be attributed to the substantial generation of leaf litter, which decomposes and forms weak acids (humic acid and fulvic acid), leading to pH reduction. Similar findings were reported by Akoto *et al*. (2020), Kaushal *et al*. (2020), and Garima *et al*. (2021). Soil EC values ranged from 0.21 to 0.22 ds/m and revealed no significant difference between the two farming practices in the 0-30 cm layer, likely due to the low concentration of soluble salts (Ghimire *et al*., 2015).

Table 2 presents the findings on soil organic carbon percentage, showcasing a distinction between open farming and bamboo-based agroforestry systems. Initially, organic carbon levels measured under agroforestry ranged from 0.63 to 0.69%. *D. asper* demonstrated significantly higher OC (0.69%), on par with *B. balcooa* (0.67%). Post-harvest, significantly elevated OC values were observed under *D. asper* (0.72%), comparable to values under *B. balcooa* (0.70%) and *D. stocksii* (0.70%). Lignified cells present in perennial components like litter, bark, tiny branches, and roots may contribute to the biochemical stabilization of organic carbon in the soil, resulting in enhanced soil organic carbon content under agroforestry systems as opposed to open farming or sole cropping (Singh *et al*., 2014). Gupta *et al*. (2009) also reported an increase in soil organic carbon under agroforestry compared to sole cropping. The data in Table 2 illustrates a substantial enhancement in soil available nitrogen values over the experimental period. Pre- and post-crop harvest, significantly higher soil nitrogen values are observed under the agroforestry system compared to the control plot. Initially, the T3 plot (*D. asper*) recorded the highest nitrogen value (165.67 kg/ha), statistically on par with T2 (163.95 kg/ha) under *D. stocksii*. The control plot registered the lowest nitrogen value (140.04 kg/ha) among the various treatments. Singh *et al*. (2014) found that poplar-based agroforestry systems promoted more nodule formation in soybean roots than open farming systems, indicating greater nitrogen accessibility. Kaushal *et al*. (2020) reported higher nitrogen levels in bamboos than in controls, with maximum values (243.4 kg/ha at 0-15 cm soil depth) in *D. hamiltonii*, comparable to *B. balcooa*.

Table 1. Effect of sole Soybean cropping and bamboo based agroforestry systems on soil pH and EC at 0-30 cm depth of soil.

TREATMENT	pH		EC (ds/m)	
	Before sowing	After harvesting	Before sowing	After harvesting
B.balcooa	5.72	5.73	0.20	0.21
D. stocksii	5.65	5.68	0.21	0.21
D. asper	5.66	5.76	0.20	0.21
B. vulgaris	5.63	5.66	0.20	0.20
Control (Sole soybean)	6.82	6.94	0.21	0.21
C.D (0.05)	0.05	0.22	NS	NS
S.Em ±	0.02	0.08	0.005	0.006

Table 2. Effect of sole Soybean cropping and bamboo based agroforestry systems on soil organic carbon, available nitrogen, available phosphorus, available potassium at 0-30 cm depth of soil.

TREATMENT	OC (%)		N (kg/ha)		P (kg/ha)		K (kg/ha)	
	BS	AH	BS	AH	BS	AH	BS	AH
B.balcooa	0.67	0.70	160.45	179.25	11.23	17.07	73.61	82.95
D. stocksii	0.66	0.70	163.95	182.94	9.63	16.48	75.82	84.91
D. asper	0.69	0.72	165.67	189.85	9.62	16.43	71.01	80.83
B. vulgaris	0.63	0.67	158.26	178.82	9.10	15.89	70.10	79.58
Control (Sole soybean)	0.54	0.57	140.04	148.26	7.45	9.00	62.76	64.26
CD (0.05)	0.03	0.03	2.05	2.07	0.44	0.27	0.63	0.92
S Em ±	0.01	0.01	0.69	0.70	0.15	0.09	0.21	0.31

*BS- before sowing, AH- after harvesting

Substantial disparities in available phosphorus are observed between open farming and agroforestry systems at 0-30 cm. The T1 plot under *Bambusa balcooa* (11.23 kg/ha) recorded significantly higher available phosphorus value among all treatments, followed by T2 (*D. stocksii*) plot (9.63 kg/ha), on par with T3 (*D. asper*) 9.62 kg/ha. Post-harvest, significantly higher phosphorus availability is observed under *Bambusa balcooa* (17.07 kg/ha), followed by *Dendrocalamus stocksii* (16.48 kg/ha), on par with T3 (16.43kg/ha) under *D. asper*. The slow decomposition of bamboo litter, rich in silica content, contributes substantial amounts of phosphorus to the soil (Shanmughavel *et al*., 2000).

Table 2 presents the data on available soil potassium (kg/ha) values, demonstrating notable variation between sole cropping and bamboo-based agroforestry systems. Pre-sowing and post-crop harvest, the agroforestry system consistently exhibits higher available potassium compared to open farming. Initially, the T2 plot under *D. stocksii* (75.82 kg/ha) demonstrated the maximum potassium content. T1 (*B. balcooa*) recorded a potassium value of 73.61 kg/ha. Post-harvest, significantly elevated potassium values are observed under *D. stocksii* (84.91 kg/ha), followed by T1 plot (82.95 kg/ha), T3 plot (80.83 kg/ha), and T4 plot (79.58 kg/ha). The control plot exhibited significantly lower available potassium values compared to all treatments (64.26 kg/ha). These variations in soil available potassium are likely due to differences in potassium absorption by different bamboo species and variations in potassium concentration and decomposition rates of leaf litter. Kaushal *et al*. (2020) reported maximum soil potassium values under *D. hamiltonii* (247.5 kg/ha at 0-15 cm soil depth), comparable to *B. balcooa*."

Conclusion

In the bamboo-based agroforestry system, a significant enhancement in soil chemical properties (including SOC, N, P, and K) was observed over the control (sole soybean crop). This improvement can be attributed to the consistent infusion of organic matter from bamboo species and the accelerated turnover of fine roots. Notably, the pH of the soil was comparatively lower in the agroforestry system than in the control. Furthermore, the levels of soil organic carbon, accessible nitrogen, phosphorus, and potassium substantially increased in the bamboo agroforestry system as compared to the sole cropping system, particularly within the 0 to 30 cm depth. This enhancement renders the bamboo agroforestry system more suitable for augmenting soil fertility.

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