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Effect of different bamboo species on soil properties grown on Entisol of semi-arid climate

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Abstract
A long-term field experiment initiated in the year 2018-19 at National Agricultural Research Project, Dryland Sub-Centre (Agroforestry), M. P. K. V., Rahuri, Maharashtra, was selected for conduct of present study during the year 2020-21. Soil profile samples collected under different bamboo species were analysed in order to estimate the effect of different bamboo species on soil properties *viz.*, soil pH, EC, $CaCO_3$ content, bulk density, organic carbon and available N, P and K content after 2nd year of bamboo plantation grown on Entisol of semi-arid climate. The soil under tested bamboo species had shown significant reduction in soil pH (0.75 to 7.5%) and EC (4.76 to 28.57%) as compared to its initial soil level. Whereas, these bamboo species have shown non-significant change *i.e.* 1.10 to 8.60% increase in $CaCO_3$ content over its initial soil level. The soil under *Bambusa nutans* recorded significantly highest organic carbon content (8.07 g kg^{-1}) over rest of tested bamboo species as well as its initial soil level. As compared to control plot, slight reduction (0.66 to 2.72%) in bulk density was recorded in the soil under the influence of different bamboo species. The soil under the treatment of *Bambusa tulda* recorded significantly highest soil available nitrogen, phosphorus and potassium content (191.83, 8.37 and 410.33 kg ha^{-1}, respectively) as compared to other tested bamboo species and its initial soil level. Bamboo species showed a enriched soil nutrient status and organic carbon, indicating that they might be used for soil restoration, onsite nutrient conservation and nutrient cycling. The results revealed that all the tested bamboo species treatments showed varying effects on soil properties grown on Entisol of semi-arid climate.

Keywords: Available nitrogen, phosphorus, potassium, Bamboo, Bulk density, *Bambusa balcooa*, *bamboos*, *nutans*, *tulda*, Calcium carbonate, *Dendrocalamus asper*, *brandisii*, *strictus*, Entisol, Electrical Conductivity, pH, Semi-arid, Soil organic carbon

1. Introduction

Bamboo a sturdy growing, adaptable tall woody grass, is classified as a member of the Poaceae family and sub-family Bambusoideae. Bamboo, sometimes known as 'the grass of hope' (PIA, 2008) [14], is a wonder plant with over 1500 recorded uses (Ranjan, 2001) [17]. This 'green gold' often known as "poor man's timber" (Ram *et al*., 2010) [16], introduces itself as a valuable and abundant resource that may be used to fulfill a range of livelihood demands while also delivering multiple ecological services to rural communities. According to Ohrnberger (1999) [12] the sub-family Bambusoideae comprises 1575 species of woody and herbaceous bamboo from 87 genera. Bamboo has a unique rhizomal growth feature by which culms (stem) in the clump (cluster of culms) are interconnected and reproduce asexually to produce new culms every year. This characteristic distinguishes bamboo from the majority of other woody plants. Additionally, bamboo is crucial for maintaining and boosting the soil's nutrient content (Kleinhenz *et al.* 2001) [7]. Bamboo species have been reported to grow well in degraded regions under conditions of inadequate soil nutrients and water stress (Tripathi and Singh, 1994) [23], as well as make efficient use of available nutrients and build up relatively fertile soil surrounding the clumps (Singh and Singh, 1999) [18]. Bamboos, with its rapid growth and widespread root system, enhances the physical, chemical and biological properties of soil, limits soil erosion and is ideal for the rapid rehabilitation of degraded lands (Sujatha *et al.*, 2008) [20]. Bamboos tendency of producing new culms annually from underground rhizomes allows sustainable annual harvesting without disturbing the soil (Zhou *et al.*, 2005). Bamboo litter and fine roots add a significant quantity of carbon and nutrients to degraded soils, which aids in improving soil health (Christanty *et al.*, 1996) [4]. Bamboos that grow in wild play a crucial role in nutrient build-up and soil fertility management. Nutrient cycling in bamboo forests attributed to its vigorous growth and litter production, had shown improvement in soil fertility.

However, the cultivated one, which has been managed by Indian farmers for their livelihood, has received little research in terms of its role in soil nutrient status and change in soil properties. In this context, the present study was conducted in order to estimate the effect of different bamboo species on soil properties within which the different bamboo species grown on Entisol under semi-arid climate, this might ultimately help in the identification of bamboo species which are suitable for maintaining soil fertility status in the region.

2. Material and Methods

2.1 Experimental Site

A long term field experiment entitled, "Performance of different bamboo species on growth and yield of bamboo" was initiated in the year 2018-19 at National Agricultural Research Project, Dryland Sub-Centre (Agroforestry), M. P. K. V., Rahuri, Dist. Ahmednagar (M.S.). The same field experiment was selected for conduct of present study in order to estimate the effect of different bamboo species on soil properties grown on Entisol of semi-arid climate during the year 2020-21. The geographical location of experimental site is N 19º 31′ 996″ to N 19º 32′ 073″ latitude and E 74º 63′ 920″ to E 74º 64′ 042″ longitude, at the altitude of 608.4 to 616.1 meter above mean sea level. During crop growth period of different bamboo species for the year 2020-21, the total rainfall received was 1345.8 mm in 66 rainy days (15 months).

2.2 Soil of Experimental Site

The soil of experimental site is grouped under Entisol order. Particle size distribution revealed that the soil contains 67% sand, 10% silt and 23% clay, and belongs to sandy clay texture. The initial soil of experimental field was slightly alkaline in reaction (pH 8.01), had low EC (0.21 dSm^{-1}) and $CaCO_3$ content (3.37%), was medium in organic carbon (6.70 g kg^{-1}), low in available nitrogen (178.70 kg ha^{-1}), very low in available phosphorus (6.10 kg ha^{-1}) and very high in available potassium (403.20 kg ha^{-1}) content. The average depth of experimental soil is upto 45 cm. The control plot next to the experimental field free from the effect of different bamboo species had a bulk density of 1.51 Mg m^{-3}.

2.3 Experimental Setup

The field experiment was laid out in Randomized Block Design comprising 3 replications and 7 treatments of different bamboo species *viz.*, T_1: *Dendrocalamus brandisii*, T_2: *Bambusa nutans*, T_3: *Bambusa balcooa*, T_4: *Dendrocalamus strictus*, T_5: *Bambusa tulda*, T_6: *Bambusa bamboos*, T_7: *Dendrocalamus asper*. Bamboo seedlings of uniform size and age were planted during October, 2018 in the pits of 45 cm × 45 cm × 45 cm. The gross plot size for the field experiment was 20 m × 15 m, and the net plot size was 12 m x 09 m. The optimum spacing adopted was 4 m x 3 m so as to accommodate 833 clumps per ha. The recommended dose of chemical fertilizers, 160:40:200 kg N, P_2O_5 and K_2O ha^{-1} $year^{-1}$ was applied as split dose through commercial grade urea, single superphosphate and muriate of potash, respectively. Well decomposed farm yard manure was added @ 25 kg $clump^{-1}$ as a source of organic manure.

2.4 Collection and Preparation of Soil Sample

Representative composite soil sample was collected from the experimental field upto 0-45 cm soil depth at the time of bamboo seedling plantation during October, 2018 for determining the initial soil properties. The composite soil profile samples under selected bamboo species were collected from the experimental field upto 0-45 cm soil depth in the year 2020-21 during the active growing season. The collected soil samples were air-dried, grinded with wooden mortar and pestle to pass through 2 mm sieve and stored in cloth bag for further laboratory analysis. Soil profile samples collected under selected bamboo species were analysed for soil chemical and physical properties. The observations on soil chemical properties (*viz.*, pH, EC, $CaCO_3$ and available N, P, K content) recorded in the present study (2020-21) were compared with the initial soil test values (2018) to get more reliable results. Whereas, soil bulk density were compared with senile soil sample (*i.e.*, soil free from the effect of different bamboo species). The initial and senile soil samples were used as control for monitoring change in soil properties as influenced by different bamboo species grown on Entisol of semi-arid climate. The soil chemical and physical properties were analysed by adopting standard methods, are presented in Table 1.

Table 1: Standard methods used for analysis of soil chemical and physical properties

Sr. No.	Parameter	Method adopted	Reference
1.	pH (1: 2.5)	Potentiometry	Jackson (1973) [5]
2.	EC (1: 2.5) (dSm^{-1})	Conductometry	Jackson (1973) [5]
3.	$CaCO_3$ (%)	Acid neutralization method	Allison and Moodie (1965) [1]
4.	Organic Carbon (g kg^{-1})	Wet oxidation method	Nelson and Sommers (1982) [10]
5.	Available N (kg ha^{-1})	Alkaline potassium permanganate	Subbiah and Asija (1956) [19]
6.	Available P (kg ha^{-1})	0.5 *M* $NaHCO_3$ method (pH 8.5)	Watanabe and Olsen (1965) [25]
7.	Available K (kg ha^{-1})	Neutral *N* NH_4OAc (pH 7.0)	Knudsen *et al.* (1982) [8]
8.	Bulk Density (Mg m^{-3})	Core sampler method	Blake and Hartage (1986) [3]
9.	Soil Texture	International pipette method	Black (1965) [2]

2.5 Statistical Analysis

The experimental data generated from present study were analysed statistically by applying the technique of "Analysis of variance" *i.e.* ANOVA table as described by Panse and Sukhatme (1985) [13].

3. Results and Discussion

3.1 Effect of Different Bamboo Species on Soil Physico-Chemical Properties

3.1.1 Soil pH: The pH of soil under all the tested bamboo species varies in the range of 7.45 to 7.95 (Table 2 and Fig. 1) which was significantly lower as compare to its initial pH level (8.01). The reduction in soil pH was observed in the range of 0.75 to 7.5% over its initial soil level after 2nd year of bamboo plantation. Among the tested bamboo species, the highest reduction in soil pH was observed under the treatment of *Bambusa nutans* (7.45) which was found statistically at par with the treatment of *Bambusa tulda* (7.46). The reduction in pH under the influence of tested bamboo species might be due to rapid and continuous decomposition of organic matter, which may have produced some organic acids as well as the root exudation of organic anions from bamboo plant such as malate, citrate and oxalate resulted in reduction of soil pH. Mandal *et al.* (2010) [9] also reported reduction in soil pH due to continuous decomposition of organic matter under natural woodlands.

3.1.2 Soil Electrical Conductivity (EC)

Perusal of Table 2 and Fig. 2, it is observed that, the soil under *Bambusa nutans* and *Bambusa tulda* recorded lowest EC (0.15 dSm^{-1}), which was statistically at par with the treatment of *Dendrocalamus brandisii*, *Dendrocalamus asper*, *Dendrocalamus strictus* and *Bambusa balcooa* (0.16, 0.17, 0.18 and 0.19 dSm^{-1}, respectively). EC under all the tested bamboo species varies in the range of 0.15 to 0.21 dSm^{-1} which were 4.76 to 28.57% low as compare to its initial soil level after 2nd year of bamboo plantation. Kim *et al.* (2018) [6] also reported reduction in soil EC under the influence of different bamboo species. The reduction in EC under tested bamboo species might be due to leaching of soluble salts from rhizosphere, which may be attributed to increase in infiltration rate as well as the growth of bamboo species is very fast, hence, there may be very high uptake of soluble salts of calcium, magnesium and potassium from rhizosphere which results in reduction of soil EC.

3.1.3 Soil Calcium Carbonate ($CaCO_3$) Content

The calcium carbonate content did not show any significant changes under different bamboo species, though slight increase *i.e.* 1.10 to 8.60% in $CaCO_3$ content (Table 2 and Fig. 3) was recorded under tested bamboo species as compared to its initial soil level. $CaCO_3$ content under different bamboo species were found at par with each other as well as its initial soil level after 2nd year of bamboo plantation grown on Entisol of semi-arid climate.

3.1.4 Soil Organic Carbon (OC) Content

The soil under the treatment of *Bambusa nutans* recorded significantly highest organic carbon content (8.07 g kg^{-1}) over rest of bamboo species as depicted in Table 2 and Fig. 4. However, organic carbon content under all tested bamboo species were statistically at par with each other after 2nd year of plantation. All the tested bamboo species recorded higher OC content as compare to its initial soil level (6.70 g kg^{-1}). Similar findings regarding increase in organic carbon content over initial soil levels were reported by Venkatesh *et al*. (2005) [24]. The increase in organic carbon content under tested bamboo species was ranged from 16.41 to 20.44% over its initial soil level. This increase in soil organic carbon content under the influence of bamboo species may be owed to the ability of bamboos to retain soil organic matter through sufficient production and decomposition of leaf-litter and below ground biomass (*i.e.*, rhizodeposition), which may have helped in slight build-up of organic carbon in soil under different bamboo species (Noble and Randall, 1998) [11]. Whereas, variation in the OC content under different bamboo species might be due to addition of varying amounts of leaf litter and root residues to the soil.

3.1.5 Soil Bulk Density (BD)

Bulk density did not reveal any significant differences, however a slight reduction (0.66 to 2.72%) was observed as compared to control under different bamboo species (Table 2 and Fig. 5). The bulk density under different bamboo species varies between 1.47 and 1.50 Mg m^{-3} as compared to its control (1.51 Mg m^{-3}). The soil under the treatments of *Bambusa nutans* and *Bambusa tulda* showed significantly lower bulk density (1.47 Mg m^{-3}) which was at par with *Bambusa bamboos* (1.48 Mg m^{-3}). Bulk density represents the soil's ability to sustain structure, convey water and solutes, and aerate the soil. High bulk density indicates soil compaction and low soil porosity, both of which restrict root growth and impair air and water mobility. The slight reduction in BD may be attributed to an increase in soil carbon content as a result of leaf litter deposition as well as a more extensive fine root system, both of which enhance pore space. Reduction in bulk density and soil compaction under trees was also reported by Mandal *et al.* (2010) [9].

3.1.6 Soil Available Nutrients Content

3.1.6.1 Soil Available Nitrogen

Perusal of Table 2 and Fig. 6, it is observed that, the soil under the treatment of *Bambusa tulda* recorded significantly highest soil available nitrogen content (191.83 kg ha^{-1}), which was statistically at par with all the tested bamboo species treatments. The soil available nitrogen content in all the tested bamboo species varies in the range of 187.47 to 191.83 kg ha^{-1} which was significantly higher as compared to its initial soil available nitrogen content (178.70 kg ha^{-1}). The increase in soil available nitrogen content under tested bamboo species varies from 4.90 to 7.34% over its initial soil level after 2nd year of plantation. Increase in nitrogen mineralization under bamboo species was also reported by Raghubanshi (1994) [15]. This increase in soil available nitrogen content may be due to application of manure and fertilizer nutrients to bamboo, thereby increasing the soil carbon content which improves cation exchange capacity of soil and reduces leaching losses.

3.1.6.2 Soil Available Phosphorus

The soil under the treatment of *Bambusa tulda* recorded significantly highest soil available phosphorus content (8.37 kg ha^{-1}) as depicted in Table 2 and Fig. 7, which was statistically at par with all the tested bamboo species treatments. The soil available phosphorus content in all the tested bamboo species varies in the range of 8.17 to 8.37 kg ha^{-1}, which was significantly higher as compared to its initial soil available phosphorus content (6.10 kg ha^{-1}). The increase in soil available phosphorus content under tested bamboo species varies from 33.93 to 37.21% over its initial level after 2nd year of plantation. Similar findings were also reported by Tariyal *et al.* (2013) [21]. The increase in soil available phosphorus content may be due to application of manure and fertilizer nutrients to bamboo as well as slight reduction in soil pH and higher rooting intensity in bamboo helps in dissolution of inorganic phosphorus.

3.1.6.3 Soil Available Potassium

Table 2 and Fig. 8 depicts that, soil under the treatment of *Bambusa tulda* recorded significantly highest soil available potassium content (410.33 kg ha^{-1}), which was statistically at par with all the tested bamboo species treatments. The soil available potassium content in all the tested bamboo species varies in the range of 409.33 to 410.33 kg ha^{-1} which was significantly higher as compared to its initial soil available potassium content (403.20 kg ha^{-1}). The increase in soil available potassium content under the tested bamboo species varies from 1.52 to 1.76% over its initial level after 2nd year of plantation. Bamboo plays a significant role in conservation of potassium due to its ability for rapid uptake and accumulation of K in the living biomass, thereby its deposition in soil through leaf litter shedding (Toky and Ramakrishnan, 1982) [22].

Table 2: Effect of different bamboo species on soil physico-chemical properties after 2nd year of bamboo plantation grown on Entisol of semi-arid climate

Tr. No.	Treatment (Bamboo species)	pH	EC (dSm^{-1})	$CaCO_3$ content (%)	Organic Carbon ($g\ kg^{-1}$)	Bulk Density ($Mg\ m^{-3}$)	Soil Available Nutrients ($kg\ ha^{-1}$)		
							N	P	K
T_1	*Dendrocalamus brandisii*	7.50	0.16	3.60	7.93	1.50	187.47	8.17	409.60
T_2	*Bambusa nutans*	7.45	0.15	3.56	8.07	1.47	189.73	8.33	410.07
T_3	*Bambusa balcooa*	7.70	0.19	3.60	7.80	1.50	187.47	8.17	409.67
T_4	*Dendrocalamus strictus*	7.65	0.18	3.66	7.87	1.50	189.73	8.17	409.73
T_5	*Bambusa tulda*	7.46	0.15	3.60	8.03	1.47	191.83	8.37	410.33
T_6	*Bambusa bamboos*	7.95	0.20	3.41	7.80	1.48	187.83	8.27	409.33
T_7	*Dendrocalamus asper*	7.60	0.17	3.48	7.83	1.50	189.13	8.30	409.67
	General Mean	7.62	0.17	3.56	7.90	1.49	189.03	8.25	409.77
	Initial / Control*	8.01	0.21	3.37	6.70	1.51*	178.70	6.10	403.20
	S.Em +	0.01	0.01	0.10	0.13	0.002	2.35	0.22	1.23
	CD at 5%	0.04	0.04	NS	0.41	0.007	7.19	0.68	3.78

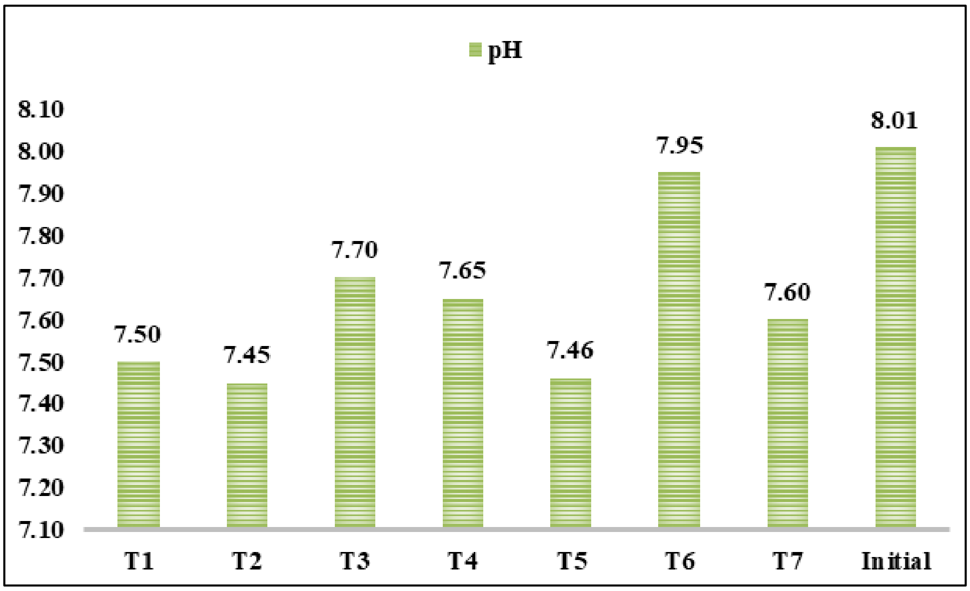

Fig 1: Effect of different bamboo species on soil reaction (soil pH)

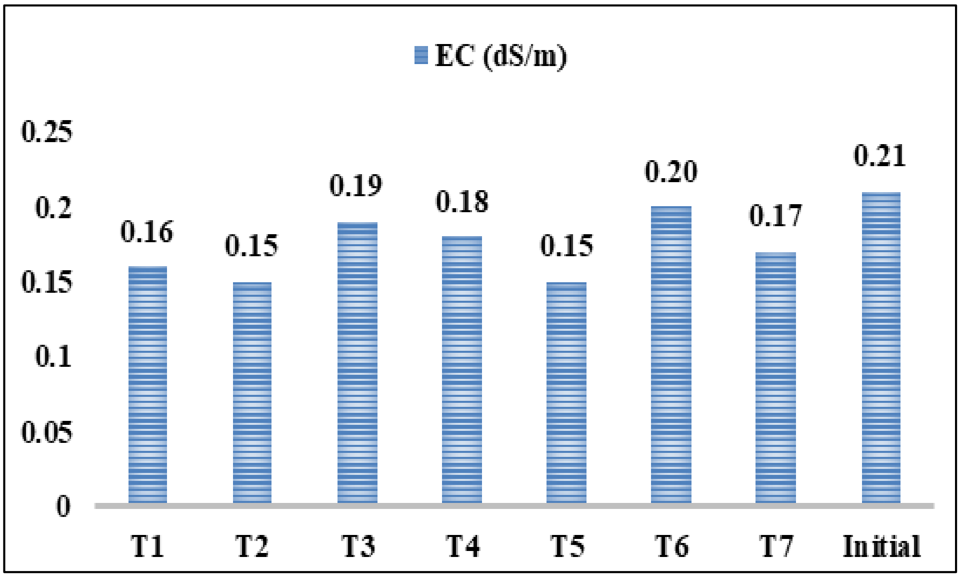

Fig 2: Effect of different bamboo species on soil electrical conductivity

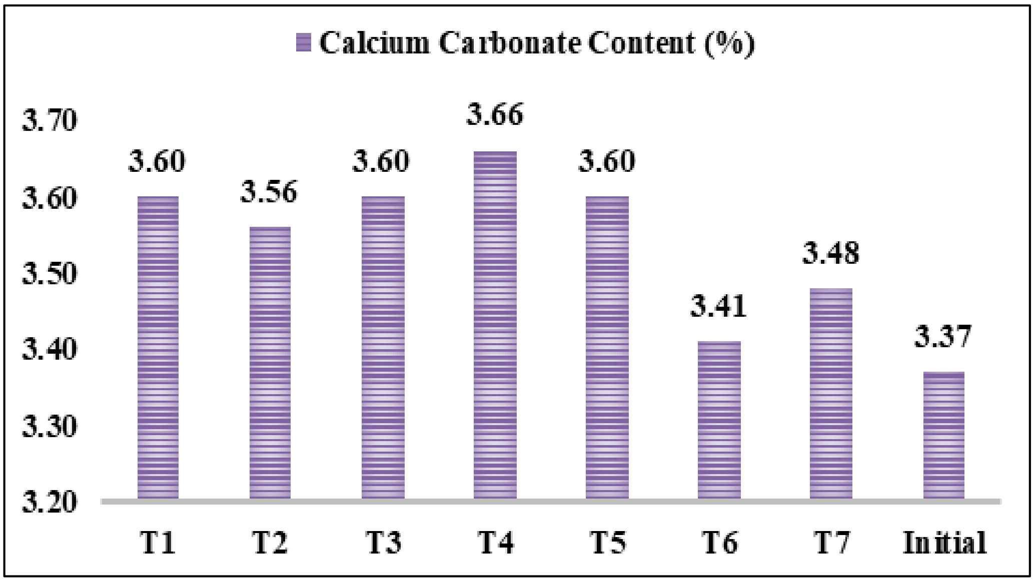

Fig 3: Effect of different bamboo species on soil calcium carbonate content

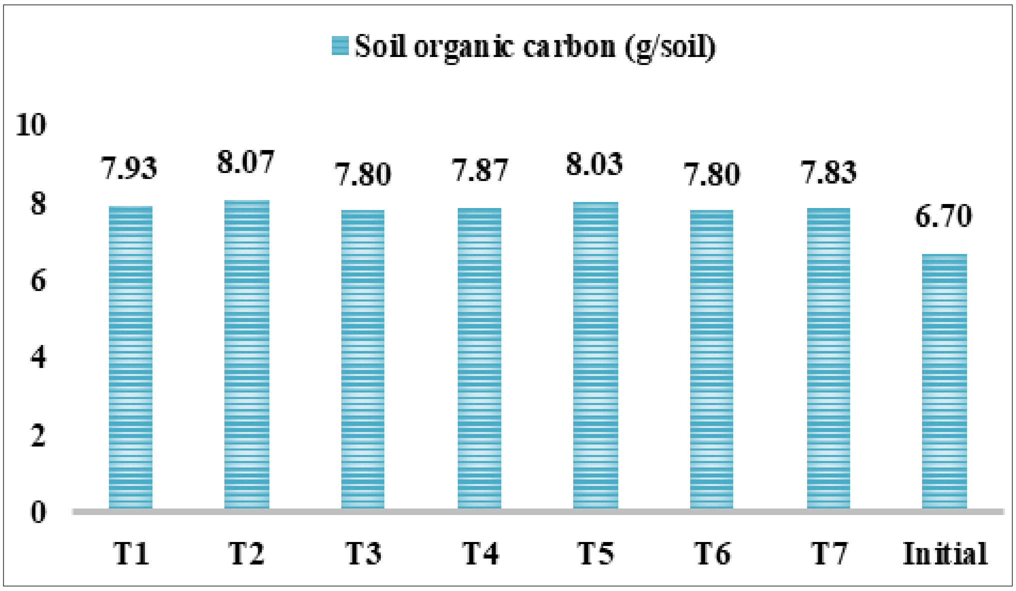

Fig 4: Effect of different bamboo species on soil organic carbon content

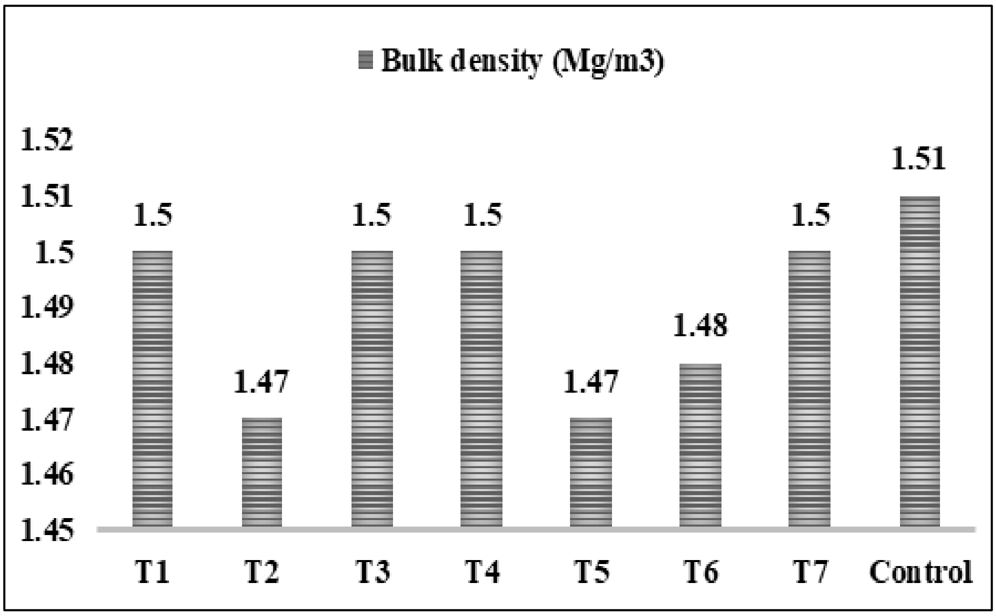

Fig 5: Effect of different bamboo species on soil bulk density

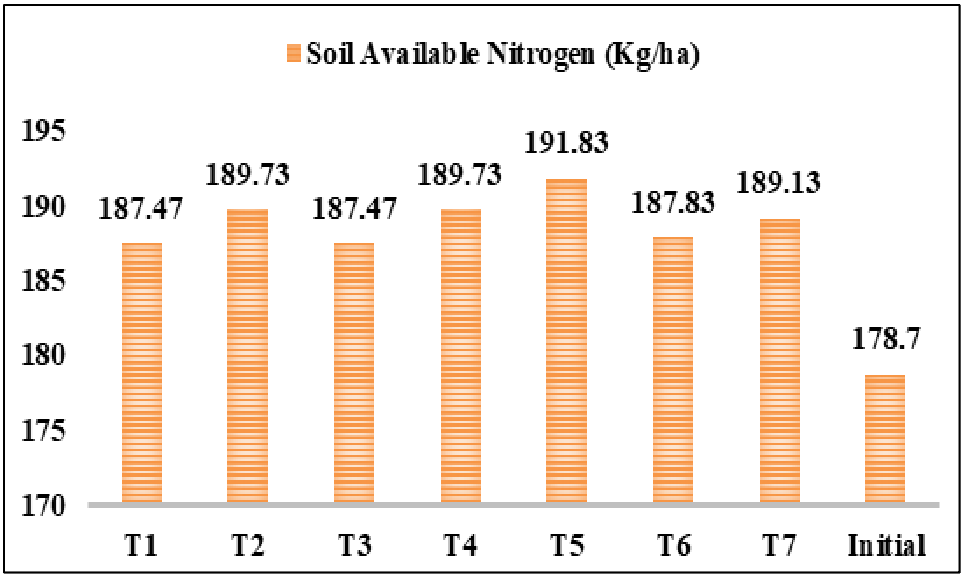

Fig 6: Effect of different bamboo species on soil available nitrogen content

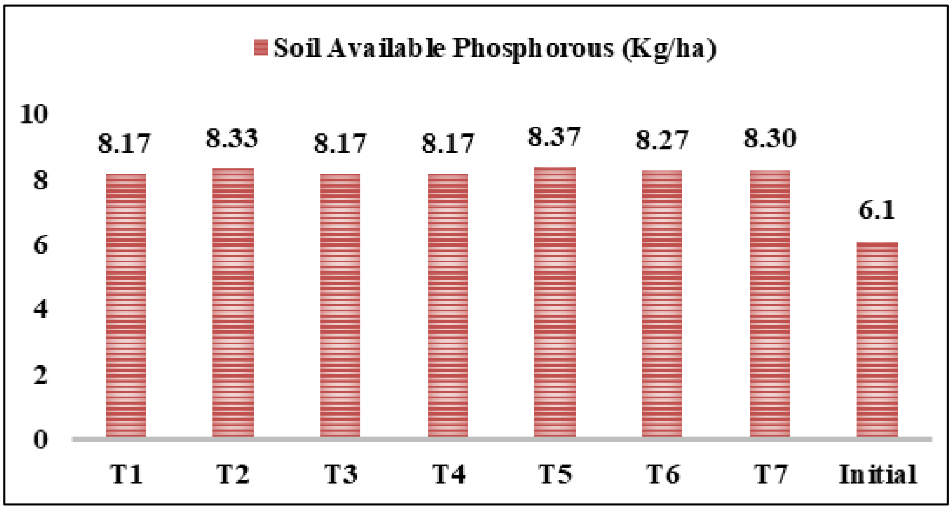

Fig 7: Effect of different bamboo species on soil available phosphorus content

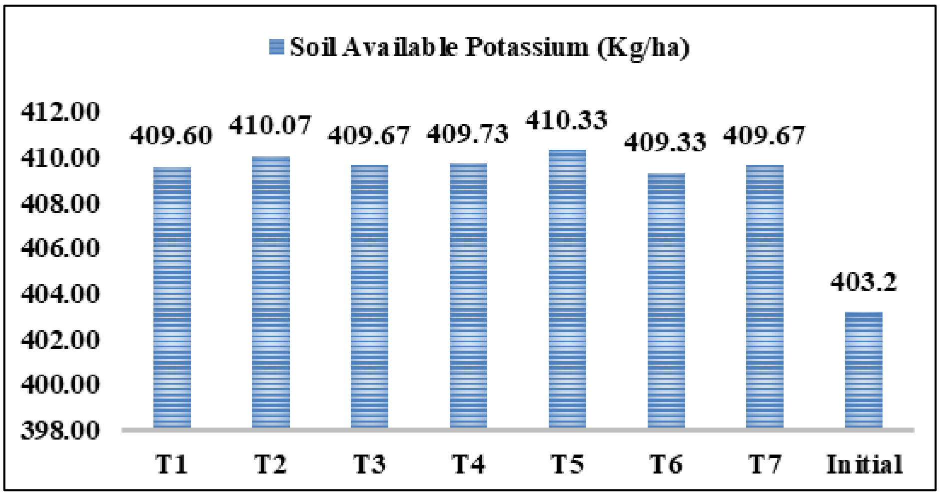

Fig 8: Effect of different bamboo species on soil available potassium content

4. Conclusion

The significant reduction in soil pH was observed under all the tested bamboo species as compared to its initial soil status. In contrast to its initial level, the EC of the soil in all of the tested bamboo species was 4.76 to 28.57% lower. The $CaCO_3$ content under different bamboo species were found at par with each other. All the tested bamboo species recorded higher soil OC content as compare to its initial level (6.70 g kg^{-1}). As compared to control plot a slight reduction in soil BD was observed under different bamboo species. The increase in soil available nitrogen, phosphorus and potassium content under tested bamboo species varies from 4.90 to

7.34%, 33.93 to 37.21% and 1.52 to 1.76% respectively, over to its initial level. Bamboo species showed a enriched soil nutrient status and organic carbon, indicating that they might be used for soil restoration, onsite nutrient conservation and nutrient cycling. Among different species of bamboo, *Bambusa nutan* and *Bambusa tulda* displayed better nutrient cycling in Entisol under semi-arid climate after 2nd year of bamboo plantation.

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