The Pharma Innovation Journal 2023; 12(1): 2109-2112

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(1): 2109-2112

www.thepharmajournal.com
Received: 22-10-2022
Accepted: 25-11-2022

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Impact of *Dendrocalamus stocksii* Munro based agroforestry system on soil fertility and yield of crops in Alfisol

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Abstract
A study was conducted during 2021-22 at the Research Farm of AICRP on Agroforestry, Dr. BSKKV, Dapoli, on "Impact of *Dendrocalamus stocksii* Munro based agroforestry system on soil fertility and yield of crops in Alfisol". Significantly maximum yield of Turmeric (25.25 t/ha), Ginger (16.72 t/ha), Alpinia (20.01 t/ha) and Finger millet (1.55 t/ha) were observed by turmeric + bamboo agroforestry system at 8 m x 8 m spacing than other. Similarly, maximum improvement in pH (5.87), EC (0.091 dSm^{-1}), OC (33.35 g kg^{-1}), avai. N (355.91 kg ha^{-1}), avai. P_2O_5 (24.76 kg ha^{-1}) and avai. K_2O (426.11 kg ha^{-1}) were noticed by under turmeric growing soil with 8 m x 8 m spacing under bamboo based agroforestry system than other. Among the agroforestry based land use systems, bamboo based turmeric agroforestry system growing at 8 x 8 m spacing may be used for getting higher yield of crops and overall development of soil fertility in Alfisols.

Keywords: Bamboo, turmeric, alpinia, ginger, agroforestry, soil properties

Introduction
Agricultural soils are a significant sink for carbon (C) through formation of SOM. Conversion of natural to agricultural ecosystems depleted the global soil organic carbon (SOC) pool by 50 to 100 Pg (billion tons) of C, and this trend is continuing by conversion of forests and savannas to agriculture in the tropics (Jarecki and Lal, 2003) [4]. Indian agriculture is facing diverse challenges and constraints due to growing demographic pressure, increasing food, feed and fodder needs, natural resource degradation and climate change. Therefore, diversification of landuse systems with agroforestry is a necessary strategy for providing variety of products for meeting requirements of the people, insurance against risks caused by weather aberrations controlling erosion hazards and ensuring sustainable production on a long-term basis, particularly in view of the effects of climate change. Crop production on red and laterite soil under rainfed condition is low and unstable. Bamboo based agroforestry system is mostly adopted by the Konkan Farmers of Maharashtra. Agroforestry is a collective name for land use systems and technologies where woody perennials (bamboos, trees, fruit trees, shrubs, etc.) are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry system, returns a substantial amount of nutrients to the soil, thereby minimizing the nutrient losses to a great extent and contributing to soil productivity. Particularly bamboo species fix atmospheric carbon and restore the land within 4 and 5 years. Bamboo is a one of the world's most productive and quickly expanding plants (Singh *et al*. 2004) [10]. *Dendrocalmous stocksii*, *Dendrocalamus strictus*, *Bambusa bamboo, Dendrocalamu vulgaris*, etc. bamboos species and based agroforestry are playing important role in enhancing crops productivity, sustainability, soil and environment resource conservation. Most of these species are indigenous from Konkan region of Maharashtra. The current farmers demand and doubling farmer's income concept mitigation and possibility only through adaptation of agroforestry systems. As per the urgent needs, adaptation of bamboo based agroforestry systems in healthy soils may be helps in future for development of economic status of the farmers by getting higher yield of sustainable crops in Konkan region of Maharashtra.

Materials and Methods
The experiment was conducted at the Research Farm of All India Co-ordinated Research

Project on Agroforestry, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra during 2021-2020. The experimental soil site is Alfisols, especially Kaolinitic, and hyperthermic family of *Typic Haplustalf* of characteristics. Initial status of pH is 5.43, EC of soil is 0.056 dSm^{-1}, organic carbon is 24.50%, Available N, P_2O_5 & K_2O of soil are 315.20, 12.50 & 360.72 kg ha^{-1} respectively. The present experiment was framed in Split Plot Design (SPD) with two levels, viz. spacing [S_1- 8 x 4 m^2 , S_2- 8 x 6 m^2 and S_3- 8 x 8 m^2]and crops level [C_1- Turmeric, C_2- Ginger, C_3- Alpinia and C_4- *Finger millet*] consisting twelve treatment combinations in three replications. The treatments combinations were: T_1 - S_1 + C_1 (8 m x 4 m + Turmeric), T_2 - S_1 + C_2 (8 m x 4 m + Ginger), T_3 - S_1 + C_3 (8 m x 4 m + Alpinia), T_4 - S_1 + C_4 (8 m x 4 m + Finger millet), T_5 - S_2 + C_1 (8 m x 6 m + Turmeric), T_6 - S_2 + C_2 (8 m x 6 m + Ginger), T_7 - S_2 + C_3 (8 m x 6 m + Alpinia), T_8 - S_2 + C_4 (8 m x 6 m + Finger millet), T_9 - S_3 + C_1 (8 m x 8 m + Turmeric), T_{10} - S_3 + C_2 (8 m x 8 m + Ginger), T_{11} - S_3 + C_3 (8 m x 8 m + Alpinia), T_{12} - S_3 + C_4 (8 m x 8 m + Finger millet). In order to determine the chemical properties of experimental soil, before start and after harvest of agroforestry crops of the experiment at 0 to 30 cm depth soil samples were collected from randomly selected spots covering the each experimental area. Composite samples from each treatment were prepared for chemical analytical purpose. The ½ of these samples were air dried and ground with the help of wooden mortar and pestle and sieved through < 2 mm sieve and also stored in polythene bags with well labelled for physicochemical analysis of soil in the laboratory. Electrical conductivity (EC), soil reaction (pH), organic carbon (OC) and available NPK were determined by Jackson (1973) [3]. The experimental data was subjected to analysis of variances (ANOVA) and treatment means were compared and significant differences were tested at 5% significance level as per Panse and Sukhatme (1985) [7].

Results and Discussion

Significantly soil pH with spacing was improved (5.06 and 5.76) in the S_3- 8 x 8 m^2 over before start and its initial status of soil (Table 1). While, the lowest values of soil pH (5.58 and 5.63) was noticed in S_1- 8 x 4 m^2 both years of bamboo based agroforestry system. Regarding the crops levels, C_1-Turmeric based agroforestry systems was observed maximum (5.76 and 5.87) improvement in soil pH over before start and its initial status of soil. Whereas, lowest soil pH (5.50 and 5.54) showed in crop level C_4- *Finger millet*. Interaction effects between spacing and crop levels were statistically non-significant in both initial and final years of bamboo based agroforestry system. However the maximum improvement in soil pH may be due to the phenomenon of phytoremediation through agroforestry system effect leads to increases the soil pH to neutralizing the levels acidity particularly in acid soil conditions. The improvement in soil pH might be due to several mechanisms that release soil-based cation and uptake by the plants after decomposition of readily organic matter produces all the nutrients (Meshram *et al.* 2020 and Mahadik, 2020) [6, 5]. However, EC of soil (0.071 and 0.078 dSm^{-1}) was significantly higher at spacing S_3-8 x 8 m^2 over before start and its initial status of soil under bamboo based agroforestry system. Regarding the crops level, C_1-Turmeric + bamboo agroforestry system was improved EC of soil (0.084 and 0.091 dSm^{-1}) over before start and its initial status of soil. The interaction effects between spacing and crop levels on EC of soil had statistically non-significant over before start and its initial status of soil. While, bamboo based turmeric agroforestry system only showed the significant effect on improvement of soil EC than other. It may be due to the contribution of organic matter can accumulation of soluble salts at the surface and helps to increases the neutralizing EC levels and releasing cations due to phytoremediaton in acid soils (Meshram *et al.* 2020 and Mahadik, 2020) [6, 5]. The highest soil organic carbon (28.03 and 29.91 g kg^{-1}) was received by S_3-8 x 8 m^2 in before start and final year at harvest of crops under bamboo based agroforestry system. In-case of crops level of C_1-Turmeric was significantly observed maximum soil organic carbon (29.89 and 33.35 g kg^{-1}) over it's before start and initial status of soil. While, the interaction effect between spacing and crop levels were statistically non-significant in the initial year, but it was statistically significant at final year of harvest stage under bamboo based agroforestry system. About the interaction effects of treatment combination like S_3- 8 x 8 m^2 + C_1- turmeric gave maximum soil organic carbon (34.67 g kg^{-1}) under bamboo based turmeric agroforestry system. The higher build-up of soil organic carbon may be attributed to reduction-oxidation of process of organic matter in soil by the action of higher microbial community, humus synthesis and soil enzyme assay owing to a prevailing optimum amount of moisture conservation through agroforestry litters and balancing temperature in Coastal areas of soil site (Meshram *et al.* 2020 and Mahadik, 2020) [6, 5].

The maximum available nitrogen in soil (330.67 and 341.42 kg ha^{-1}) was received by the spacing S_3-8 x 8 m^2 over it's before start and initial status of soil under bamboo based agroforestry system (Table 2). Regarding the crops levels, the maximum available nitrogen in soil (341.44 and 355.91 kg ha^{-1}) by C_1-Termeric + bamboo agroforestry system than other. However, less improvement of available nitrogen of soil was recorded in overall results by the treatment combination like S_1-8 x 4 m^2 + C_4- *Finger millet* + bamboo agroforestry system comparably to other. Interaction effects between spacing and crop level on nitrogen availability in soil was statistically non-significant over before start and final year at harvest stage of crops under bamboo based agroforestry system. It may be attributed that due to the available N status although showed increased under the organic matter, it has not been increased much due to the prevailing climatic condition accelerating oxidation of organic matter as well as the nature of nitrogen forms in the soil in the form of its losses through volatilization and leaching. In this view, the results of present investigation suggest that the maintenance of soil available N levels is more challenging. This necessitates the regular addition of organics through agroforestry system for maintenance of soil fertility in the soils of Konkan Coastal Zone (Meshram *et al.* 2020 and Mahadik 2020) [6, 5]. Singh and Singh (1999) [9] studied biomass production and impact of bamboo plantation on soil redevelopment in India and reported that the considerable amount of nitrogen was found to be immobilized in soil microbial biomass which may be attributed to higher amount of leaf-litter fall in bamboo plantation as well as the immensity of immobilization was found to be increased with the increasing age of bamboo plantation. Significantly maximum available phosphorus in soil (18.52 and 22.15 kg ha^{-1}) was received by the spacing S_3-8 x 8 m^2 than other under bamboo based agroforestry system. In-case of the crops levels, significantly higher available phosphorus (20.16 and 24.76 kg ha^{-1}) in soil was recorded by C_1-Termeric + bamboo agroforestry system than other. The interaction effect of spacing along with crop level was found statistically non-significant in before start and final year at harvest stage of crops under bamboo based agroforestry system, but overall increased phosphorus availability in soil was noted by the treatment combination like S_3-8 x 8 m^2 + C_1- turmeric + bamboo based agroforestry system than other. This might have solubilized the native phosphorus in the soil through the release of various organic acids which had the chelating effect that reduced phosphorus fixation (Meshram *et al*. 2020, Mahadik 2020 and Prasad *et al*. 2021) [6, 5, 8] noted that availability of phosphorus was increased due to addition of organic matter along with giving optimum dose of fertilizers under agroforestry system. In case of level of spacing's, the maximum availability of potassium in soil (393.75 and 404.00 kg ha^{-1}) was observed by the spacing S_3- 8 x 8 m^2 under bamboo based agroforestry system (Table 2). Whereas the crops levels, maximum availability of potassium (410.22 and 426.11 kg ha^{-1}) were noticed by C_1- Turmeric + bamboo based agroforestry system than other. Significantly lowest availability of potassium of soil showed (376.56 and 379.56 kg ha^{-1}) in crop level C_4- *Finger millet* + bamboo based agroforestry system as compared to other. The interaction effects between the spacing and crop levels on potassium availability of soil had statistically non-significant in both initial and final year at harvest stage of crops under bamboo based agroforestry system. Overall, higher influenced of available potassium in soil by T_9-C_1- Turmeric + bamboo and lower by T_4- S_1 + C_4 (8 m x 4 m + Finger millet) + bamboo based agroforestry system. The maximum availability of potassium in soils may be due to greater degree of weathering of potash minerals in soil and higher amount of nitrogen content in the plant leaves, litters, rhizomes, etc. which leads to synergistic effect through plant and root biomass contribution in soil or apply decomposition which increased the potassium content in soil (Meshram *et al*. 2020) [6]. Similarly, Prasad *et al*. (2021) [8] noted that potassium contributed in soil through optimum fertilizers and organic matter under agroforestry system.

Table 1: Chemical properties of soil under bamboo based agroforestry system.

Treatment	pH		EC (d Sm^{-1})		OC (g kg^{-1})	
	2021	2022	2021	2022	2021	2022
Spacing						
S_1- 8 x 4 m^2	5.58	5.63	0.067	0.071	26.10	28.50
S_2- 8 x 6 m^2	5.63	5.67	0.070	0.074	27.17	29.17
S_3- 8 x 8 m^2	5.66	5.76	0.071	0.078	28.03	29.91
F- test	Sig	Sig	NS	Sig	NS	Sig
SE(m)±	0.014	0.023	0.002	0.0005	0.50	0.14
CD at 5%	0.042	0.070	-	0.0015	-	0.49
Crops						
C_1- Turmeric	5.76	5.87	0.084	0.091	29.89	33.35
C_2- Ginger	5.57	5.65	0.063	0.067	25.47	27.44
C_3- Alpinia	5.65	5.70	0.075	0.081	27.71	29.43
C_4- *Finger millet*	5.50	5.54	0.055	0.059	25.33	26.53
F-test	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)±	0.010	0.03	0.002	0.001	0.61	0.17
CD at 5%	0.029	0.08	0.006	0.003	1.80	0.49
Interactions (Spacing x Crops)						
F-test	NS	NS	NS	NS	NS	Sig
SE(m)±	0.01	0.04	0.003	0.0020	1.05	0.29
CD at 5%	-	-	-	-	-	0.86

Table 2: Chemical properties of soil under bamboo based agroforestry system.

Treatment	Avai. N (kg ha^{-1})		Avai. P_2O_5 (kg ha^{-1})		Avai. K_2O (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022
Spacing						
S_1- 8 x 4 m^2	324.33	335.75	16.92	20.95	387.92	393.33
S_2- 8 x 6 m^2	328.17	339.85	17.73	21.40	390.00	394.75
S_3- 8 x 8 m^2	330.67	341.42	18.52	22.15	393.75	404.00
F- test	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)±	0.65	1.07	0.26	0.22	0.51	1.36
CD at 5%	2.54	4.19	1.01	0.87	2.00	5.34
Crops						
C_1- Turmeric	341.44	355.91	20.16	24.76	410.22	426.11
C_2- Ginger	320.22	333.67	17.33	20.36	383.78	388.33
C_3- Alpinia	331.22	340.33	17.89	22.20	391.67	395.44
C_4- *Finger millet*	318.00	326.11	15.50	18.67	376.56	379.56
F-test	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)±	1.21	1.46	0.47	0.37	1.27	2.59
CD at 5%	3.58	4.33	1.40	1.11	3.78	7.68
Interactions (Spacing x Crops)						
F-test	NS	NS	NS	NS	NS	NS
SE(m)±	2.09	2.52	0.81	0.65	2.2	4.48
CD at 5%	-	-	-	-	-	-

Table 3: Yield of turmeric, ginger, alpinia and *Finger millet* under bamboo based agroforestry system.

Treatment	Yield (t ha^{-1})	
	2021	2022
Spacing		
S_1- 8 x 4 m^2	13.52	14.91
S_2- 8 x 6 m^2	14.20	15.68
S_3- 8 x 8 m^2	15.04	17.05
F- test	Sig	Sig
SE(m)$\pm$	0.24	0.17
CD at 5%	0.89	0.62
Crops		
C_1- Turmeric	21.14	25.25
C_2- Ginger	15.70	16.72
C_3- Alpinia	18.59	20.01
C_4- *Finger millet*	1.58	1.55
F-test	Sig	Sig
SE(m)$\pm$	0.24	0.18
CD at 5%	0.71	0.54
Interactions (Spacing x Crops)		
F-test	NS	Sig
SE(m)$\pm$	0.41	0.31
CD at 5%	-	0.93

Significantly gained the maximum yield of turmeric (15.04 and 17.05 t ha $^{-1}$) was observed under bamboo based agroforestry system at 8 x 4 m^2 spacing in initial and final year and in initial (Table 3). In subplot treatments, highest yield of crops were achieved by turmeric (21.14 and 25.25 t ha^{-1}) in initial and final year after harvest of crops than other intercrops under bamboo based agroforestry system. While, the interaction effect reflected, it was found statistically non-significant in initial year, but it was significant in final year which resulted maximum yield of turmeric (27.00 t ha^{-1}) gained by S_3- 8 x 8 m^2 + C_1-Turmeric + bamboo and showed significantly superior over all treatments under bamboo based agroforestry system. The lowest yield was recorded by C_4-*Finger millet* (1.58 and 1.55 t ha^{-1}) in both initial and final year under bamboo based agroforestry system. Bhol and Nayak (2014) [2] recorded bamboo based agroforestry system in two varying spacings (12 x 10 m and 10x10 m), the growth of bamboo clumps and root intensity were significantly higher in intercropping as compared to sole bamboo. The results indicated that all the intercrops performed better in the wider spacings (12 x 10 m) as compared to closer spacing (10x10 m). While, Vikram and Hegde (2014) [11] and Ali *et al*. (2006) [1] noted that bamboo based turmeric, ginger, finger millet, Dinathus grass achieved high yield under agroforestry systems than sole cropping.

It can be concluded that significantly achieved higher soil fertility and yields of crops by the treatment combination (T_9) S_3-8 x 8 m^2 + C_1-Turmeric + bamboo based agroforestry system than other system. However, the maximum gained yield of crops were recorded by wider spacing of bamboo 8 x 8 m^2 may be due to optimum photosynthesis and less crop competition helps for higher productions.

Acknowledgement

All the facilities are provided by CAFRI-AICRP on Agroforestry, Dr. BSKKV, Dapoli under ICAR, New Delhi for carrying out the field experiment is duly acknowledged.

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