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Soil fertility status under long-term block plantations of different tree species in South-West Haryana

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ABSTRACT

The multipurpose tree species (MPTs) played a vital role in improvement of soil fertility by addition of tree biomass in terms of leaf, twigs, stem and roots to the soil. Plant species and soil type substantially affect the structure and function of microbial populations associated with the rhizosphere. By considering the role of multipurpose tree speciesin relation to soil fertility,the present study has been conducted to visualize the effect ofPongamia pinnata, Prosopis cineraria and Ailanthus excelsaon available nitrogen, phosphorus, potassium and DTPA-extractable micronutrients (Mn, Fe, Cu and Zn) content of soil in Regional Research Station, Bawal, Rewari (Haryana) as these species are easy to cultivate, require less management practices and are most commonly found under arid and semi-arid conditions of Haryana. For this, soil samples from 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm soil depths under 50 % tree canopies including site without plantations of these tree species (control) have been collected. The soil samples were analysed in laboratory using standard procedures. The available nitrogen, phosphorus, potassium and DTPA-extractable micronutrients (Mn, Fe, Cu and Zn) content were increased significantly under different plantations as compared to control site, while decreased with increase in soil depth due to addition of lower organic matterin lower depths. Among tree species, nutrient content was observed highest under Prosopis cineraria followed by Ailanthus excelsa and Pongamia pinnata.

Keywords: *Nutrients, block plantation, soil depth, multipurpose tree species (MPT's)*

INTRODUCTION

Soil fertility deterioration is an emerging concern now-a-days that is directly influencing agriculture production. Also, soils of semi-arid and arid regions are generally poor in fertility and have less nutrient retention capacity and water holding capacity due to which in these areas production of agronomic crops is less (Singh *et al.,* 2012). In these areas cultivation of multipurpose tree species results in a better way to improve production as well as soil health (Kumar *et al.,* 2017). Also practicing alternate land use system that is adoption of cultivation of multipurpose tree species, or traditional farming with agro-forestry under these circumstances will help to improve fertility status of soil and also reduce the production risk. In this regard, nutrient recycling is one of the important practices for amelioration of the soil health. Addition of organic matter in terms of leaves, twigs, roots, flowers help in increase in organic acid which in turn increases available macro- and micro-nutrients in soil. Release of nutrients depends upon decomposition rate of organic matter, which is primarily a function of the chemical quality, and prevailing weather conditions and which vary according to change in tree species and biomass (Kumar *et al.,* 1998*).* Mahaneem (*Ailanthus excel*sa) yields about 500-700 kg green leaves twice a year (Roy *et al.,* 2010). Addition of N, P and K content in soil through litter fall of *Ailanthus excelsa* were 185.80, 259.40 and 97.51 kg ha^{-1}, respectively (Desai *et al.,* 2014). Deep rooting system of trees also helps to improve quality of ground water as excess nutrients which are being leached down below rooting zone, in case of agronomic crops, are taken up by them (Patel *et al.,* 2018). Also, the deeper penetration of extensive deep root system of multipurpose tree species helps to improve soil properties and also physical interaction of rhizosphere, root growth and penetration, root-soil interface, microbial activity created heterogeneous soil matrix which in turn improve soil physical properties (Rex and Ganpathy, 2020). By considering different aspects, the present study was undertaken to quantify changes in soil fertility under block plantation of three MPTs viz. *Pongamia pinnata*, *Prosopis cineraria* and *Ailanthus excelsa* which were commonly found in arid and semi-arid conditions of Haryana.

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MATERIALS AND METHODS

The study was carried out on stands of tree species situated at Regional Research Station, Bawal. Geographically, the research station is located at 28º08′ N latitude, 76º58′ E longitude and 266 meters above mean sea level in Rewari district and forms South-Western zone of Haryana state. The station has area of about 100 hectares. The Research Station falls under semi-arid region of Rewari district and climate is characterized by hot dry windy summer, cold winter and humid-warm monsoon season. Annual average rainfall of district is about 569 mm. The minimum temperature is recorded as 5-6 °C in month of December-January and maximum temperature is recorded upto 47 ºC in month of May-June. Soil of the Research Station is Loamy-Sand which is light textured and poor in fertility and has low nutrient and water retention capacity. Soil samples were collected from each block plantations of selected tree species that is *Prosopis cineraria* (34 years old), *Ailanthus excelsa* (19 years old), *Pongamia pinnata* (14 years old) and also from adjoining area without plantation of these tree species (control). For this, randomly trees were selected in each block plantation and samples were taken (under 50% tree canopy) with help of an auger. The soil samples from 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150-180 cm depth were collected from each spot. In this way, three replicates from each site were taken. A representative soil sample was taken by properly mixing the soil for each spot and depth. Soil samples were air dried, ground and stored in poly bags for further analysis. The samples were analyzed for available nitrogen, phosphorus, potassium and DTPA-extractable micronutrients (Mn, Fe, Cu and Zn). The available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1951), available phosphorus by Olsen's method (Olsen, 1954) and available potassium was extracted using neutral ammonium acetate (NH_4OAc) solution and estimation was done using flame photometer (Jackson,1973). The DTPA-extractable micronutrients (Fe, Cu, Mn and Zn) were estimated using Atomic Absorption Spectrophotometer (AAS) following the method proposed by Lindsay and Norvell (1978).

The data were subjected to statistical analysis using ANOVA technique in randomized block design (RBD) taking different tree species as treatments. The mean difference was compared using critical difference (CD) test at 5% level of significance (Panse and Sukhatme, 1985). The analysis was performed using OPSTAT software developed by CCS Haryana Agricultural University, Hisar.

RESULTS AND DISCUSSION

Available nitrogen

When compared with control (adjoining area without plantation of these tree species), significant increase in N content was observedunder tree plantations (Table 1.1). Available N content of soilvaried from 106 to 34.8, 180 to 85.2, 222 to 94.5 and 229 to100 kgha^{-1}(from upper to lower soil layer) under control, *P. pinnata*, *A. excelsa* and *P. cineraria*, respectively. The increase in N content (from 64.1 to 164 kg ha^{-1}) may be due to the fact that there is higher accumulation of leaf litter and its decomposition due to higher microbial activity and also favorable soil condition specially temperature and moisture under tree cover as compared to open/ control site.The available nitrogen content decreased significantly from upper soil depth (0-15 cm) to lower soil depth (150-180 cm). The decrease in available N content with depth might be due to the fact that in upper soil layer accumulation of leaf litter and decomposition rate was more as compared to lower soil depth where microbes are not active due to which nutrient accumulation is very less in lower depths (Rahi *et al.,* 2012). Also there is regular addition of organic matter in upper soil layers that helps in improvement of soil porosity (Desai *et al.,* 2014) and thus better water movement that will help in release of fixed nitrogen in soil solution (Kaushik *et al.,* 2015) and thus there will be more accumulation of available nitrogen. It was observed that available nitrogen had positive and highly significant relationship with organic carbon as organic carbon helps in mineralization and helps in build up of available nitrogen content. Sharma (2015) also reported higher content of available N under *Prosopis cineraria*.

Table 1.1: Available nitrogen content (kg ha^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	106.8	180.2	222.7	229.5
15 – 30	84.06	157.7	199.0	208.2
30 – 60	67.5	154.5	176.0	175.0
60 – 90	56.7	142.9	166.0	167.0
90 – 120	48.8	132.1	144.2	148.5
120 – 150	45.1	106.6	116.4	120.0
150 – 180	34.8	85.2	94.53	100.6
Mean	63.4	137.0	159.8	164.1
C.D. (at 5%)	Tree species = 0.122*		Depth =0.162*	
S.E. (m)±	Tree species =0.043		Depth = 0.057	

*Significant

Available phosphorus

Increase in available P content was observed under tree plantations as compared to control (Table 1.2). The content under control varied significantly from 12.4 kg ha^{-1}at upper soil layer (0-15 cm) to 1.31 kg ha^{-1} at lower soil layer (150-180 cm). Among tree species, the phosphorus content was observed highest under *P.cineraria* (21.0 to 7.87 kg ha^{-1}), followed by *A. excelsa* (20.0 to 7.01kg ha^{-1}) and *P. pinnata* (18.1 to 5.23 kg ha^{-1}).The increase may be due to solubilization of phosphorus in considerable amount through organic acids which is produced during decomposition of leaf litter under tree canopies (Singh *et al.,* 2012 and Laik *et al.,* 2009). Available Pcontent significantly decreased with increasing depth and decreased from0-15 cm soil depth to150-180 cm soil depth. This might be due to the lower microbial activity and less organic matter in deeper layers as compared to upper soil layers (Singh *et al.,* 2012).High pH results in the formation of insoluble calcium phosphate and thus decreases its availability in the soil solution. The decomposition of organic matter decreases the soil pH by release of organic acids that will influence the transformation of phosphorus (Baloda *et al.,* 2014) and thus improves its availability.

Table 1.2: Available phosphorus (P) content (kg ha^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	12.4	18.15	20.08	21.03
15 – 30	11.79	15.79	18.66	19.46
30 – 60	10.93	14.88	16.09	17.22
60 – 90	7.42	12.13	12.22	13.39
90 – 120	7.42	9.89	10.55	11.37
120 – 150	6.11	8.36	10.37	11.34
150 – 180	1.31	5.23	7.01	7.87
Mean	8.20	12.06	13.57	14.52
C.D. (at 5%)	Tree species = 0.031*		Depth = 0.041*	
S.E. (m)±	Tree species = 0.011*		Depth = 0.015*	

*Significant

Available potassium

The available Kcontent (as shown in Table 1.3) increased significantly (at 5 % level of significance) under different tree plantations as compared to open field. Highest available K content was recorded under *P. cineraria* (264.6 to 157.6 kg ha^{-1}) followed by *A. excelsa* (260.9 to 153.8 kg ha^{-1}) and *P. pinnata* (215 to 124.1 kg ha^{-1}) while lowest was recorded under control

(184.29 to 80.7 kg ha^{-1}).Significant reduction in available Kcontent was observed with increasing soil depth. Higher availability of K at upper soil layers might be due to continuous addition of organic matter at upper layers which helps in mineralization and transformation of various plant available nutrients as compared to deeper layers. Similar findings were also recorded by Singh *et al*. (2011). Organic matter has positive and significant correlation with available potassium content. The composition and nature of leaf litter of different plant species is also responsible for varying rate of decomposition (Baloda *et al.,* 2014; Da Silva Cerozi and Fitzsimmons, 2016) and thus the variation in accumulation of available nutrient content under different tree species is also reported. Increased biological activities in rhizosphere zone by addition of organic matter leads to higher content of available N, P and K (Singh *et al.,* 2019) under plantation of tree species than natural fallow.

Table 1.3: Available potassium (K) content (kg ha^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	184.2	215.0	260.9	264.6
15 – 30	110.7	199.4	244.7	251.3
30 – 60	104.9	188.8	229.9	235.5
60 – 90	100.0	164.4	210.0	215.0
90 – 120	98.3	150.0	197.1	200.1
120 – 150	84.8	137.1	179.1	182.1
150 – 180	80.7	124.1	153.8	157.6
Mean	109.13	168.4	210.8	215.1
C.D. (at 5%)	Tree species = 0.356*		Depth = 0.471*	
S.E. (m)±	Tree species = 0.125		Depth = 0.166	

**Significant*

DTPA-extractable micronutrients (Mn, Fe, Zn and Cu)

Available manganese

There was significant reduction in available Mn content with increasing soil depth both in control as well as under tree plantations as shown in Table 2.1. Available Mn content varied from 0.83 to 0.28, 2.40 to 0.64, 2.36 to 0.59, 2.18 to 0.46 mg kg^{-1} under control, *P. cineraria*, A. *excelsa* and *P. pinnata*, respectively. Maximum available Mn content was observed under plantation of *P. cineraria* (1.51 mg kg^{-1}) followed by *A. excelsa* (1.40 mg kg^{-1}) and *P. pinnata* (1.24 mg kg^{-1}) while minimum was recorded under control (0.50 mg kg^{-1}). The higher accumulation under *P. cineraria*was due to more number of branches and high litter biomass as compared to other tree species (Singh *et al.,* 2019). Pareek *et al.,* 2015 and Kumar *et al.,* 2017.

Table 2.1: Available Mn content (mg kg^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	0.83	2.18	2.36	2.40
15 – 30	0.77	1.91	2.00	2.11
30 – 60	0.54	1.56	1.72	1.86
60 – 90	0.42	1.22	1.41	1.50
90 – 120	0.38	0.86	1.16	1.28
120 – 150	0.30	0.52	0.62	0.78
150 – 180	0.28	0.46	0.59	0.64
Mean	0.50	1.24	1.40	1.51
C.D. (at 5%)	Tree species = 0.021*		Depth= 0.028*	
S.E. (m)±	Tree species = 0.007		Depth= 0.01	

**Significant*

Available Iron

Available Fe content (Table 2.2) significantly varied from 0.81 to 0.32, 1.78 to 0.39, 2.20 to 0.59 and 2.52 to 0.70mg kg^{-1}(from upper to lower soil layer) under control, *P. pinnata*, *A. excelsa* and *P. cineraria*, respectively. Available Fe content of soil increased with tree plantations as compared to control. Highest available Fe content was observed under plantation of *P. cineraria* (1.47 mg kg^{-1}) followed by *A. excelsa* (1.19 mg kg^{-1}) and *P. pinnata* (1.01 mg kg^{-1}) while it was lowest under control (0.55 mg kg^{-1}).The iron content decreased significantly with increasing soil depth viz. highest at 0-15 cm soil depth and lowest at 150-180 cm soil depth. The increase in iron content under tree plantations was might be due to addition of organic matter and formation of chelates of micronutrient cations with organic molecules produced due to decomposition of organic matter which enhanced the availability of these cations in the soil. The results are in conformity with findings of Pareek *et al.* (2015).

Table 2.2: Available Fe content (mg kg^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	0.81	1.78	2.20	2.52
15 – 30	0.74	1.59	1.86	2.14
30 – 60	0.61	1.29	1.40	1.86
60 – 90	0.56	0.82	0.96	1.39
90 – 120	0.44	0.70	0.74	0.95
120 – 150	0.40	0.52	0.60	0.76
150 – 180	0.32	0.39	0.59	0.70
Mean	0.55	1.01	1.19	1.47
C.D. (at 5%)	Tree species = 0.040*		Depth= 0.053*	
S.E. (m)±	Tree species = 0.014		Depth= 0.019	

**Significant*

Available zinc

Available Zn content (Table 2.3)increased significantly under tree plantations when compared with control. The available Zn content under control varied from 0.50 to 0.10 mg kg^{-1} , while under tree species it varied from 0.76 to 0.18, 0.85 to 0.19 and 0.96 to 0.28 mg kg^{-1} under *P. pinnata*, *A. excelsa* and *P. cineraria*, respectively. Highest available Zn content was observed under plantation of *P. cineraria* (0.57 mg kg^{-1}) followed by *A. excelsa* (0.44 mg kg^{-1}) and *P. pinnata* (0.39 mg kg^{-1}) while it was lowest under control (0.27 mg kg^{-1}).

Table 2.3: Available Zn content (mg kg^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	0.50	0.76	0.85	0.96
15 – 30	0.42	0.66	0.70	0.82
30 – 60	0.39	0.48	0.54	0.68
60 – 90	0.24	0.30	0.34	0.45
90 – 120	0.16	0.21	0.26	0.45
120 – 150	0.10	0.20	0.21	0.36
150 – 180	0.10	0.18	0.19	0.28
Mean	0.27	0.39	0.44	0.57
C.D. (at 5%)	Tree species = 0.009*		Depth= 0.012*	
S.E. (m)±	Tree species = 0.003*		Depth= 0.004*	

**Significant*

At upper soil layer (0-15 cm), maximum Zn content was recorded, while lowest was recorded at 150-180 cm soil depth. Release of organic acids during decomposition of organic matter leads to reduction in soil pH which results in higher accumulation of available mirco-nutrients in soil (Singh *et al.,* 2019). The decrease in availability of micro-nutrients with depth was less due to less organic matter addition in lower depths (Singh and Singh, 2017).

Available copper

Significantly highest available Cu content (Table 2.4) was recorded under *P. cineraria* (0.19 mg kg^{-1}) followed by *A. excelsa* (0.15 mg kg^{-1}) and *P. pinnata* (0.13 mg kg^{-1}) while Cu content under control was 0.09 mg kg^{-1} which was lowest among all treatments. The addition of organic matter in terms of litter fall resulted in enhancement of various nutrients including copper under tree plantations as compared to open site. Decreasing trend in available Cu content was observed with increasing soil depth. Available Cu content varied from 0.20 to 0.04, 0.23 to 0.06, 0.26 to 0.07 and 0.29 to 0.10 mg kg^{-1} under control, *P. pinnata*, *A. excelsa* and *P. cineraria*, respectively. The decay of plant litter at upper soil layers will result in release of various plant available nutrients and thus availability of more nutrients at upper layers as compared to lower soil depths. The findings are similar to that of Singh and Mishra (2012) and Kaushik *et al.* (2015.

Table 2.4: Available Cu content (mg kg^{-1}) of soil as influenced by tree species (T) and soil depth (D) at 5 % level of significance (p=0.05)

Depth of Soil (cm)	Tree species			
	Control	*Pongamiapinnata*	*Ailanthusexcelsa*	*Prosopis cineraria*
0 – 15	0.20	0.23	0.26	0.29
15 – 30	0.14	0.20	0.22	0.26
30 – 60	0.11	0.15	0.17	0.21
60 – 90	0.08	0.12	0.15	0.20
90 – 120	0.05	0.09	0.12	0.18
120 – 150	0.05	0.07	0.10	0.14
150 – 180	0.04	0.06	0.07	0.10
Mean	0.09	0.13	0.15	0.19
C.D. (at 5%)	Tree species = 0.009*		Depth= 0.012*	
S.E. (m)±	Tree species = 0.003*		Depth= 0.004*	

**Significant*

Conclusion

The macro- and micro-nutrient content of soil was recorded higher under plantation of different tree species as compared to site without plantation of these tree species (control). Among tree species, significantly highest nutrient content was observed under*Prosopis cineraria*, followed by *Ailanthus excelsa* and *Pongamia pinnata*. The variation within tree species might be due to the difference in type of plant litter produced, varying rate of decomposition and quantity of litter fall produced. In general, the plantation of MPTs tree species positively influenced the available nutrient content of soil and thus improved the soil fertility.

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