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Soil Properties Under Fresh and Replanted Poplar (*Populus deltoids* Bartr. ex Marsh.) Sites

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ABSTRACT

The change in soil properties under fresh and replanted poplar sites was carried out at the University Seed Farm, Ladhowal, Punjab Agricultural University, Ludhiana. Analysis of soil showed that K, P and pH was low in replanted site than the fresh site, whereas, EC, OC, N and total soil organic carbon was higher on replanted site as compare to the fresh site. Highest per cent OC and N were found in poplar + turmeric combination with added pruning material. With depth, soil pH, bulk density increased while other parameters such as EC, P, K, OC and N decreased with depth from surface layer (0-15) to sub-surface layer (15-30). Total carbon storage in soil was recorded more in the agroforestry combinations (poplar + turmeric) than in poplar plantations without inter-cultivation.

Key Words:

Agroforestry, Carbon storage, Poplar, Replanted site, Soil nutrients, Turmeric

INTRODUCTION

Punjab state with geographical area of 5.036 million hectare is predominantly an agrarian state having 84 per cent of its area under highly intensive, technical and mechanical agriculture, whereas, forests occupy only 3459sq km (forest and tree cover), which accounts only 0.012 hectare per capita (FSI 2017) against national average of 0.05 ha. Intensive cultivation of grain crops on irrigated and fertile lands has made a significant contribution to the 'Central Pool' of wheat and rice. But, very fast agricultural and industrial development as well as adoption of rice-wheat system over a very long period has deteriorated soil health, lowered the water-table and increased the environmental degradation. Furthermore, this mono-cultural and chemical-intensive agricultural practice will ultimately lead to barren soils and weakened genetic pool (Chhetri 2007). The forest and tree cover in the state is only 6.87 per cent of the total geographical area against the required 20 per cent as suggested in the National Forest Policy (1988) or reaching 15 per cent by 2047 (Anon. 2015). It is not possible to divert the fertile agriculture land to forests in view of prevailing socio-economic and agro-climatic conditions favourable for agriculture. The only option to increase area under tree cover is to integrate the compatible tree species with agricultural crops on farm lands. Agroforestry systems, there are both ecological and economic interactions between different components. There are wide variations in carbon sequestration under agroforestry systems (1.3–173 t C ha^{-1}) depending upon tree species, climatic conditions and age of plantations (Nair et al. 2009; Sharma et al. 2016). Agroforestry is believed to increase the soil organic matter (SOM) through the addition of above and belowground biomass to soil (Dhillon et al. 2012). SOM is an extremely important attribute of quality since it influences soil physical, chemical and biological properties and processes and therefore its content is now regarded as a key factor in the evaluation of the sustainability of an agroecosystem.

MATERIAL AND METHODS

The investigation for soil properties at two different poplar planting sites was carried out at the University Seed Farm, Ladhowal, Punjab Agricultural University, Ludhiana. The experimental site is located at an elevation of 731 ft above mean sea level and lies at 30° 58' latitude and 75° 45' longitude, which represents the central agro-climatic zone of the Punjab. Experimental site is only 1.5 km away from Sutlej river. The climate is sub-tropical with a long dry season from late September to early June and wet season from July to early September. May and June are the hottest months with intensive evapo-transpiration losses, whereas, December and January are the coldest months. The area receives an average rainfall of 732 mm per annum and 80 per cent of total rainfall is received during July to September with an average of 37 rainy days. It is characterized by hot and dry early summers, which are followed by a hot and humid monsoon period and cold winters. The topography of the study area is plain and characterized inceptisol soils (USDA classification). The soils are deep, well drained, sandy loam in texture with low humus content and soil pH of 8.0. The irrigation is by tube well.

Poplar clone, PL5 (G-48) of two years age raised at 4 x 4 m^2 spacing was intercropped with Turmeric var. Punjab Haldi 1 at two different environments i.e., fresh and replanted sites. Three different treatments (Poplar sole plantation, Inter-cultivation of turmeric on fresh and replanted sites with added pruning material (300 kg ha^{-1}) and sole turmeric crop) were assessed for different soil parameters iz. pH, electrical conductivity, bulk density, organic carbon (%), SOC, total nitrogen, available P and K. Equilibrium pH of 1:2 soils water suspension was determined with Elicho L1-10. Electrical conductivity of 1:2 soils: water supernatant (kept overnight) was estimated using solubridge. Bulk density (Mg m^{-3}) for 0-15 and 15-30 cm depth was determined by soil core sampler (Blake and Hartage 1986). Total organic carbon was estimated by Walkley and Black (1934) rapid titration method. The organic carbon concentration in the soil was converted to total SOC pool as per Gupta et al. (2009) and described below:

Total SOC pool = (OC/100) × (Bd × 1500)

Where, total SOC pool is weight of soil organic carbon (Mg ha^{-1}), OC- soil organic carbon (%), Bd- soil bulk density of 0-15 cm layer (Mg m^{-3}) and 1500 is the volume (m^3) of 1 hectare furrow slice (15cm)

Nitrogen was estimated from OC. First OC is converted to OM (%) and converted to N % as on an average OM contain 5% N. The available phosphorous was determined by extracting the soil samples with 0.03 NH_4F + 0.025N HCL (Bray and Kurtz 1945) and measuring the P content in the extract by calorimetric method using a spectrophotometer at 760 nm wavelength using ascorbic acid method. Available potassium content was estimated by extraction with neutral normal ammonium acetate and determined on flame photometer (Mervwin and Peech 1950).

RESULTS AND DISCUSSION

Poplar plantation had significant effect on soil pH, which decreased significantly on replanted site as compared to fresh site (Table 1). Also significant differences were recorded among different treatments. Soil under poplar plantation had significantly higher pH as compared to all other treatments, which though were statistically at par with each other. pH also varied significantly along the depth. Soil pH increased with increase in depth (0-15 cm to 15-30 cm) which may be attributed to excess removal of sodium which may have been beneficial to bring down the high pH on replanted site than on fresh site (Singh 1998).

Table 1. Effect of poplar tree plantation on soil pH, EC (dSm^{-1}) and bulk density in fresh and poplar replanted sites

Planting site	pH	EC (dSm^{-1})	Bulk density (Mgm^{-3})
Fresh site	8.31	0.262	1.324
Replanted site	8.13	0.278	1.325
CD (p=0.05)	0.078	0.001	NS
Treatment			
Control	8.17	0.273	1.329
Poplar	8.30	0.269	1.327
Poplar + pruning material	8.20	0.273	1.318
Poplar + turmeric	8.23	0.240	1.319
Poplar + turmeric + pruning material	8.21	0.294	1.328
CD (p=0.05)	0.061	0.006	NS
Depth (cm)			
0-15	8.18	0.281	1.298
15-30	8.27	0.258	1.350
CD (p=0.05)	0.030	0.006	0.043

The decrease in basicity of the replanted sites may be due to the reason that with time more litter fall was added to replanted site as compare to the fresh site. As addition of the litter fall take place only on surface layer thus, pH value decreased on the surface layer as compared to the sub-surface layer. Moreover, accumulation of more salts on the sub-surface layer increased its pH or did not reduce the pH in comparison to surface layer, where the OC supports the formation of carbonic acids, which decreased the pH. Mclntosh and Allen (1993) also recorded negative relationship of pH and OC.

The estimated values of EC of soils presented in Table 1 show the same reverse trend as in pH *i.e.* there were significant variation in environment, treatments and depth. All other interactions recorded non-significant effect on EC. Replanted environment recorded higher EC as compared to fresh site. Data shows that EC also varied significantly between treatments and depths, it ranged from 0.240 to 0.294 dSm^{-1} among different treatments. Along depth, EC of the soil decreased as we move from surface to sub surface layer i.e., 0.281 to 0.258 dSm^{-1} at 0-15 and 15-30 cm depth, respectively.

Not much variation existed in bulk density of the fresh and replanted sites (Table 1). The interaction effect among treatments was non-significant. Bulk density increased with increase in soil depth, meanwhile all other interactions were found non-significant. Pingale et al. (2014) also recorded inconsistent trend with depth but reduction in bulk density with increase in tree density.

Fresh and replanted sites were statistically at par with each other with respect to total N (Table 2). But numerically, 0.042 per cent N was recorded on replanted site and 0.033 on fresh site. Per cent of N differences were non-significant for all the treatments. It's value ranged from 0.036 to 0.039 per cent. N varied significantly along the depth. Higher percentage was recorded in 0-15 cm layer as compare to 15-30 cm layer. Environment and soil depth interaction effect was also significant. It is clear from the Table 3 that per cent N was statistically at par in 0-15 cm layer and 15-30 cm layer at fresh site (0.035 and 0.032 per cent, respectively). However on replanted site, N was significantly higher in 0-15 cm layer than in 15-30 cm. In both the layers higher percentage was recorded in replanted site. These findings are in line with the study conducted by Sharma et al. (2015). They reported that total N content increased sequentially with the number of cutting cycles and on surface layer (0–15 cm), an increase of 33.0, 35.6 and 127.9 % was observed in subsequent cycles. The soil N concentration has been reported to be highly correlated to soil carbon concentration and the same was observed in our study also where a continuous increase in SOC was observed with increase in number of cutting cycles. Mohsin et al. (1996) also reported decrease in N, P and K with soil depth. The decrease in N at lower depth was probably due to uptake by the fast growing trees, which is required to be supplemented externally to maintain the status for sustainable yield. Singh (1998) had also recorded loss in nutrients with removal of poplar biomass. Poplar being a fast growing tree, harvested at short relation demands heavy resources from soil for its growth.

Available P was significantly higher in fresh site as compared to the replanted site (Table 2). Amount of P ranged from 6.231 kg ha^{-1} to 8.447 kg ha^{-1} among treatments. Maximum amount of P was recorded in control and minimum was recorded in poplar + turmeric + pruning material. Statistically poplar + turmeric and poplar + turmeric + pruning material was at par with each other for available P. Poplar and poplar + added pruning material were statistically at par with each other. Along the depth, P decreased with increase in soil depth i.e. upper layer (0-15 cm) had significantly higher amount of P as compared to lower layer (15-30 cm). Planting site and soil depth interaction effect was also recorded significant (Table 3). Available P decreased as we moved from surface layer to sub-surface layer. Higher amount of P in fresh site may be due to the reason that with time P harvested from the soil in the form of pruned biomass and total tree biomass of poplar was more than the P returned to the soil through litter fall. Durai et al. (2009) stated that amount of P harvested from soil in poplar plantation in the form of pruned and total tree biomass of poplar was 82.76 kg ha^{-1} as compare to the annual returned 8.19 kg ha^{-1} in four year poplar plantations.

K also followed the same trend as followed by P under both the environments i.e. fresh and replanted poplar sites (Table 3). Amount of K was significantly higher in fresh as compared to the replanted sites. It is evident from the data that available K also varied significantly between the treatments. For control, K was found significantly higher as compared to other treatments, which were statistically at par with each other. Amount of K varied significantly along the soil depth (129.10 to 111.23 kg ha^{-1}). More amount of K was found in surface layer as compared to the sub-surface layer. Interaction effect between environment and soil depth was also significant (Table 4). Amount of K decreased significantly with increase in depth i.e. 150.00 kg ha^{-1} in 0-15 cm layer to 121.93 kg ha^{-1} in 15-30 cm layer on fresh site. The same trend was followed on replanted site i.e., 107.79 and 100.5 kg ha^{-1}, respectively. Higher amount of the K on fresh site as compared to the replanted site may be due to the reason that the amount of K removal exceeded natural inputs during the entire rotation on replanted site. Durai et al. (2009) calculated that 739.77 kg K ha^{-1} was removed from soil in the form of tree biomass meanwhile, only 20.06 kg ha^{-1} was added through litter fall in 4 year old poplar plantations. Though Punjab soils are rich in K, therefore in short term it would not affect much in terms of K removal from the system but other nutrients lead to deficiency and need external addition.

Table 2. Effect of poplar tree plantation on soil total N, Av P, Av. K and OC (%) in fresh and poplar replanted sites

Planting site	N (%)	P (kg ha^{-1})	K (kg ha^{-1})	OC (%)
Fresh site	0.333	8.492	136.166	0.394
Replanted site	0.042	5.890	104.166	0.488
CD (p=0.05)	0.064	1.990	12.883	0.072
Treatment				
Control	0.036	8.447	126.583	0.419
Poplar	0.037	7.277	118.750	0.431
Poplar + pruning material	0.038	7.683	120.333	0.448
Poplar + turmeric	0.038	6.317	118.250	0.443
Poplar + turmeric + pruning material	0.039	6.231	116.916	0.462
CD (p=0.05)	NS	0.799	5.794	NS
Depth (cm)				
0-15	0.043	8.138	129.100	0.499
15-30	0.032	6.244	111.23	0.382
CD (p=0.05)	0.002	0.626	3.208	0.032

In contrast to P and K, organic carbon was significantly higher on replanted site as compared to the fresh sites (Table 2). However, per cent of OC was found non-significant among the various treatments. Numerically its value ranged from 0.419 to 0.462 per cent and higher values were recorded where turmeric was inter-cultivated than without the crop. Comparatively higher values of OC were observed in treatments where pruning material was incorporated though at par with other treatments. Agroforestry is believed to increase the soil organic carbon through litter fall and root turnover (Young 1989; Thevathasan and Gordon 2004; Yadav et al. 2014; Pal and Panwar 2013). Kohli et al. (2007) also empathized that tree litter and pruning improve the soil fertility through addition of organic carbon, which however, varies with quantity, quality, decomposition rate, soil type, climatic conditions, microorganism activity, etc. (Lee and Jose 2003). Similar observations of better response of poplar + turmeric and poplar + ginger were reported by Singh (1998) and Kaushal et al. (2006), than alone tree plantation.

With the depth, the per cent OC also varied significantly. On surface layer (0-15 cm), the per cent OC content was 0.499 as compare to 0.382 on sub-surface layer (15-30 cm). Higher per cent OC was recorded on replanted site in both the layer as compared to fresh site (Table 3). OC was recorded statistically at par between both the layers at fresh site, whereas, significant differences were recorded on replanted site between both the layer. Even values at two sites on top layer varied significantly. These results are consistent with the findings of Chauhan et al. (2010, 2011, 2012); Arora et al. (2014) in poplar based system as well, however, non significant treatment effects may be due to low biomass addition and slow decomposition at initial years of growth. Soil amelioration is a slow process and enrichment through biomass addition or other biological activities would be low as well at initial stage or plantation development. Complete decomposition of *P. deltoides* leaves takes nearly 20 months (Kaushal et al. 2006) and probably more for woody pruned material. Thevathasan and Gordon (1997) also recorded that two years of addition or removal of litter unlikely affect the total SOC pool in poplar.

Table 3: Environment and soil depth interaction in OC (%) and N (%)

Planting site	Fresh site		Replanted site	
Depth	OC (%)	N (%)	OC (%)	N (%)
0-15 cm	0.400	0.035	0.582	0.050
15-30 cm	0.376	0.032	0.388	0.030
CD (p=0.05)	OC = 0.040			
	N = 0.030			

The temporal effects of poplar based agroforestry system on dynamics of carbon and nitrogen pools was studied by Sharma et al. (2015). The soil organic carbon (SOC) content increased from 0.434 in one cutting cycle to 0.902 % in four cutting cycles in the surface soil layer. The SOC, total organic carbon and total carbon (TC) stock increased significantly from one to four cutting cycles of poplar. Higher percentage of OC on surface layer was due to more addition of litter fall on surface layer of standing trees and harvested residue but values decreased with depth. Ramesh et al. (2015) recorded 52 per cent higher total organic carbon in surface soil (0-15 cm) in comparison with subsurface soil layer (15-75 cm). Pingale et al. (2014) reported 54 per cent increase in OC with increase in density from 200 to 1000 poplar trees ha^{-1}. Also top layer (0-15 cm) after 8 years had 174 per cent more OC than sub surface layer (30-45 cm). Gupta et al.(2009) also reported higher soil OC in top layer (0-30 cm) under poplar trees, however, Singh (1998) indicated that low leaf biomass addition in the system does not appear to have substantial change in carbon level.

Table 4. Environment and soil depth interaction in P (kg ha^{-1}) and K (kg ha^{-1})

Planting site	Fresh site		Replanted site	
Depth	P (kg ha^{-1})	K (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
0-15 cm	9.82	150.00	6.44	107.79
15-30 cm	7.15	121.93	5.33	100.5
CD (p=0.05)	P = 0.88			
	K = 4.53			

Data in Table 5 show that SOC varied significantly between fresh and replanted sites. Amount of SOC was recorded higher in replanted site (11.43 Mg ha^{-1}) as compare to fresh site (7.98 Mg ha^{-1}).

Table 5. Total soil organic carbon pool (Mg ha^{-1}) in 0-15 cm soil depth

Planting site	Treatments					Mean
	Control	Poplar	Poplar+ pruning material	Poplar + turmeric	Poplar + turmeric + pruning material	
Fresh site	7.57	7.73	7.77	7.70	9.17	7.98
Replanted site	10.34	10.94	12.14	11.69	12.04	11.43
Mean	8.95	9.33	9.95	9.69	10.60	
CD (p=0.05)	A=1.17	B=NS	AB=NS			

All the treatments recorded non-significant effect on SOC. Gupta et al. (2009) also recorded SOC in the same range *i.e.*, 6.07 t ha^{-1} in poplar based agroforestry system. Panwar et al. 2017 also reported initial soil C pools of 7.8 Mg ha^{-1} in Ludhiana. The initial differences in soil properties at both sites including addition of the residue results in significant changes. However, the quantity of residue and period of observations are important factors in such studies. Robertson and Morgan (1995) discussed the importance of quality of carbon and nitrogen source in decomposition process. The continued field would provide better inference about the loss in nutrients under agroforestry and substituting the same through the residue in the system itself.

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