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Soil Chemical Properties and Nutrient Status as Influenced by Different Spacings of Poplar under Agroforestry in Semi-Arid Region

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Abstract: A field experiment was carried out during 2018–19 to study the effect of $2^{1/2}$ year old poplar based agroforestry system on soil chemical properties and nutrient dynamics. Present study was conducted in an already established two and half-year-old plantation of *Populus deltoides* with six different spacings *viz.,* 3×3 , 4×3 , 5×3, 6×3, 7×3 and 8×3m. During rainy season cowpea (var. RC-19) and sorghum (var. HC-171) were sown during first week of July and Oat (var. HJ-8) and Berseem (var. HB-1) were sown in interspaces of poplar spacing's as winter crops and sole crops of both rainy and winter seasons were sown in open condition (devoid of tree) as control. Intercropping of both winter and rainy season crops in poplar spacing's showed better available of macronutrients than sole cropping. Soil pH decreased considerably under different poplar spacing and maximum decrease of 13.60 percent was recorded in 3x3 m spacing over control. However, soil organic carbon (SOC) increased with the decrease in poplar spacing and maximum SOC (0.45%) was observed under 3×3m followed by 4×3m (0.42%), 5×3m (0.40%) and least under sole cropping (0.30 %) after harvesting of rainy season fodder crops. The available soil N, P and K increased significantly under different spacings of poplar based cropping system from initial values. The higher available nitrogen (158.5 kg/ha), phosphorous (16.8 kg/ha) and potassium (343.8 kg/ha) was recorded under 3×3 m spacing as compared to other spacings and sole cropping (open environment) after harvesting of both season fodder crops.

Keywords: Agroforestry, Nutrient status, Poplar, Spacing, Soil chemical properties

Trans Indo-Gangetic plain with deep fertile alluvium witnessed green revolution but now the productivity becomes stagnant. However, unremitting ecological degradation, especially of water, plant life and soil assets has resulted in loss of soil health due to over exploitation of natural indigenous resources. Ultimately crop production is decreasing due to the various intangible factors like declining efficiency of nutrient-use, soil degradation, inadequate availability of water, etc (Sirohi and Bangarwa 2017). The need has been realized for conservation of natural resources and protection of the deteriorating environment so that the required growth in agriculture is maintained with sustainability (Chauhan et al 2012). In agricultural lands, planting of trees improves the ecosystem services, enhances soil fertility through addition and decomposition of leaf litter on sustainable basis (Zhang et al 2013). For such scenario, agroforestry is considered as a natural resource conserving system (Shehnaz and Singh, 2014). Introduction of agroforestry systems improved the soil fertility and micro-environment (Giri et al 2019). Agroforestry systems help to reduce the use of chemical fertilizer, reduce surface run off, nutrient leaching and can maintain the nutrient requirement for the plant by nutrient recycling (Gliessmann 2007). Agroforestry systems are generally considered to be sustainable and to improve soil properties. Multifunctional agroforestry systems improve soil physical and chemical properties, maintain soil organic matter, and promote nutrient cycling (Bisht *et al*., 2018). Agroforestry affects nutrient status of soils via addition of leaf litter and also by plant uptake, and is considered an important option for C sequestration (Albrecht and Kandji 2003). Nutrient availability in soils is influenced by the addition of organics (Sui and Thompson, 2000, Singh et al 2010). In poplar based agroforestry system soil organic matter (SOM) increased significantly through the addition of above and below-ground biomass to soil (Dhillon et al 2020).

Populus deltoides Bartr. based agroforestry system is one of the realistic alternate land use system in semi-arid and dry sub-humid agro-ecosystem of North-Western states of India. Poplar has become most popular among the farmers as poplar based agroforestry systems are economically viable and more profitable than many of the other crop rotations. The information on the effect of addition of leaf and root biomass of poplar on SOC, soil chemical properties and available nutrients is known to lesser extent. Therefore, present study was conducted to investigate the effect of poplar based cropping system on soil chemical properties in semi-arid region.

MATERIAL AND METHODS

The present investigation was carried out at CCS Haryana Agricultural University, Hisar during 2018-19. Experimental site is situated at 29°09' N latitude and 75° 43' E longitude at an altitude of 215.2 m above the mean sea level situated in the semi-arid region of north-western India. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with mean maximum temperature ranging from 40 to 45 °C in May and June whereas December and January are the coldest months (lowest temperature reaches as low as 0 °C). However, Hisar region consists of plain land, 90% of its cultivated area is irrigated, whether under crop-growing or agroforestry systems, and the source of irrigation is good quality canal or tube-well water.

The present study was conducted in an already established two and half-year-old plantation of *Populus deltoides* with six different spacings of 3×3 , 4×3 , 5×3m, 6×3, 7×3 and 8×3m. During rainy season cowpea (var. RC-19) and sorghum var. (HC-171) were sown during first week of July and oat (var. HJ-8) and berseem (var. HB-1) were sown during first fortnight of November under different poplar spacings under study and also in open (control) with the recommended cultural practices of the university. The soil samples were taken before sowing and after harvesting of fodder crops of both rainy and winter seasons under different spacings of poplar and also from control field under study for the analysis of various soil chemical properties (pH, electrical conductivity (EC) and soil organic carbon (SOC)) and available nutrients content (nitrogen, phosphorus and potassium). Four soil samples were collected randomly at different depths (0-15 and 15-30 cm) from the experimental field in three replications from different spacing of poplar. The soil samples were first air-dried, ground in a wooden pestle with mortar, passed through a 2 mm stainless steel sieve and stored for subsequent analysis. The soil pH and electrical conductivity were determined in soil: distilled water suspension (1:2). The soil pH was determined using glass electrode pH meter (Jackson 1973), electrical conductivity (dS m^{-1}) was determined using conductivity meter (Jackson, 1973) and soil organic carbon content (%) was determined using partial oxidation method (Walkley and Black 1934). The available nitrogen (kg ha^{-1}) was determined by alkaline permanganate distillation method (Subbiah and Asija1956), phosphorus (kg ha^{-1}) by sodium bicarbonate method (Olsen et al 1954) and potassium (kg ha^{-1}) by neutral normal ammonium acetate method (Jackson 1973).

RESULTS AND DISCUSSION

Soil pH: Soil pH decreased slightly under different spacings of poplar as well as in control (sole crop) from July 2018-April 2019. The magnitude of decline in soil pH was greater under different poplar spacings than control. However, the soil pH increased with increase spacing and depth of soil profile. The maximum soil pH of 7.94 and 7.98 at 0-15 and 15-30 cm soil depth, respectively were recorded in 8×3m spacing followed by 7×3 m spacing (Fig. 2) while, the minimum pH of 7.75 and

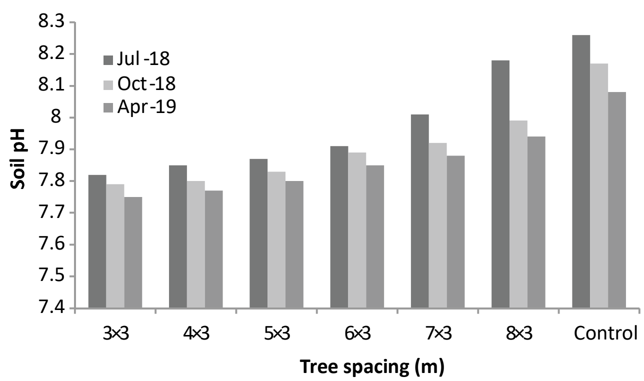

Fig. 2. Effect of different spacings of poplar on soil pH before sowing and after harvest of *Kharif* and *Rabi* crops (2018-19)

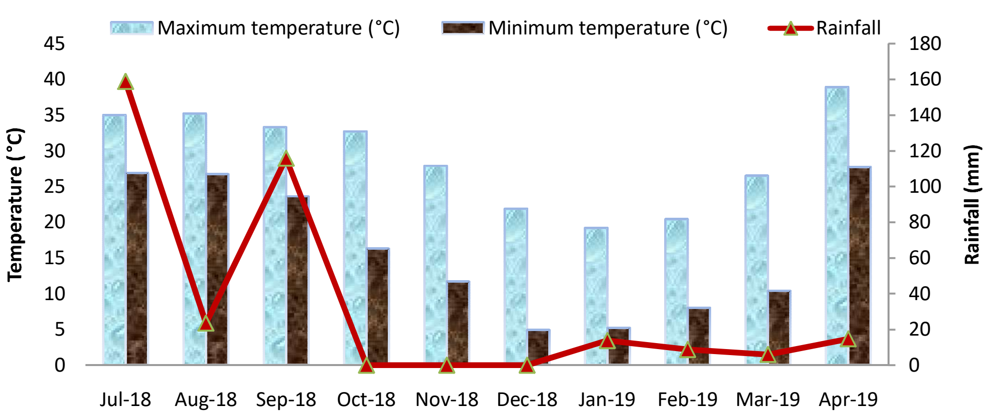

Fig. 1. The monthly mean meteorological data of the experimental site from July, 2018 to April, 2019

7.76 at 0-15 and 15-30 cm soil depth, respectively was recorded in closer (3×3m) spacing. However, in control, the soil pH at 0-15 cm and 15-30 cm was 8.08 and 8.12, respectively. The lesser value of soil pH under different spacings of poplar than sole cropping may be due to the acidic nature of litter humus of poplar after decomposition which decreased the soil pH. Similar results were reported by Pandey et al (2000) under *Acacia nilotica* based agroforestry system, Yadav et al (2011) under *Prosopis cineraria* (L.), *Dalbergia sissoo* (Roxb.) ex DC, *Acacia leucophloea* (Roxb.) and *Acacia nilotica* (L.) Del. based agroforestry system and Bisht et al (2018) under poplar based agroforestry system.

Soil electrical conductivity: The electrical conductivity of soil decreased from 0.22 to 0.19 dS/m under 3×3 m spacing of poplar and from 0.34 dS/m to 0.33 dS/m in control during the course of investigation (Table 1). The decrease in EC was maximum (13.60%) under 3×3 m spacing followed by 4×3 , 5×3 , 6×3 , 7×3 and 8×3 m spacing with a reduction of 13.04, 12, 7.69, 7.14 and 6.89% respectively. The rate of decrease in electrical conductivity was comparatively more under poplar based cropping system than control (2.94%) and may be due to substantial addition of organic matter under trees and release of weak organic acids during litter decomposition (Kumar et al (2020) under *Eucalyptus* based agroforestry system.

Soil organic carbon (SOC): The soil organic carbon was significantly influenced by tree spacing and it also increased from its initial status under different spacings of poplar and control as well (Fig. 3). The organic carbon in soil increased with the decrease in tree spacing and was recorded maximum (0.47 %) under 3×3 m spacing and followed by 4×3 m, 5×3 , 6×3 , 7×3 and 8×3 m after the harvesting of winter season fodder cops at 0-15 cm soil depth during 2019-20. High organic matter content in the intercropping treatment could be ascribed to the fact that heavy leaf fall in poplar occurs during winter and easily decomposed in soil. In control, continuous cropping with subsequent removal of plant residues leads to less accumulation of organic content in soil. Secondly may be due to lack of lignified cells in agricultural residues. Soil organic carbon under sole cropping may be reduced due to full exposure to the sun and thereby burning of organic carbon. Gill and Burman (2002) reported that the soil enrichment in organic carbon content under tree based systems could be due to several factors such as addition of litter, annual fine root biomass recycled and root exudates and its reduced oxidation of organic matter under tree shades. Agroforestry system recorded higher increase in soil organic carbon than open farming due to total leaf fall of poplar trees in winter season and leaves are easily decomposed in the soil. Addition of litter fall and fine-root in the soil turnover increased soil organic matter content. The changes in pH, EC and soil organic carbon of soil under the intercropping system could be due to the adequate plant

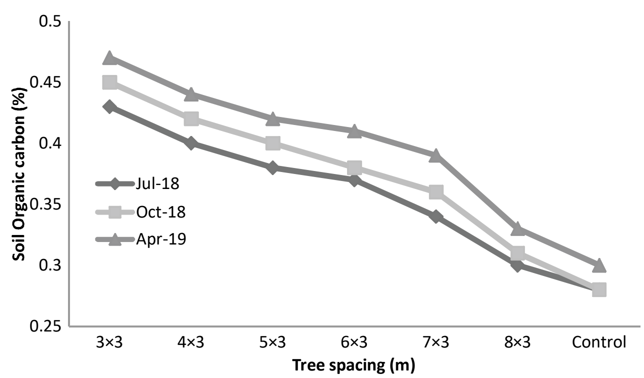

Fig. 3. Effect of different spacings of poplar on soil organic carbon content before sowing and after harvest of *kharif* and *rabi* crop

Table 1. Soil electrical conductivity (dsm^{-1}) under different spacings of poplar before sowing and after harvesting of cowpea, sorghum berseem and oat

Spacings (m)	EC (dsm^{-1})					
	Before sowing of fodder crops		After harvesting of cowpea and sorghum		After harvesting of berseem and oat	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
3×3	0.22	0.24	0.20	0.22	0.19	0.20
4×3	0.23	0.25	0.21	0.23	0.20	0.21
5×3	0.25	0.27	0.23	0.25	0.22	0.24
6×3	0.26	0.28	0.25	0.26	0.24	0.25
7×3	0.28	0.29	0.27	0.28	0.26	0.27
8×3	0.29	0.31	0.28	0.30	0.27	0.29
Control	0.34	0.34	0.34	0.33	0.33	0.32
CD (p=0.05)	0.017	0.019	0.020	0.021	0.014	0.020

cover on the soil which helped in the least crust formation, increased porosity and reduced bulk density. Dhillon et al (2018) and Dollinger and Jose (2018) also reported that the incorporation of trees in agroforestry system enhances the soil organic matter by adding litter both above and belowground. The results are in conformity with work of earlier researchers (Raj et al 2016, Kumar et al 2019, Bisht et al 2018, Dhillon et al 2020).

Available N, P and K: The available soil nitrogen increased significantly under different spacings of poplar from its initial values (Fig. 4). Like organic carbon, available nitrogen was also considerably influenced by different spacing because availability of nitrogen in soil depends upon organic matter. In present study, that available N content was maximum (158.5 kg/ha) under 3×3 m spacing and it decreased with the increase in the poplar spacings and minimum (142.5 kg/ha) under 8×3 m after harvesting of winter season fodder crops. The magnitude of increase in available N was highest under 3×3 m spacing and lowest in control. The increase in N content of soil under poplar based agroforestry systems may be due to addition of organic matter in soil in the form of litter fall and fine root biomass and availability of adequate moisture level associated with more moderate temperature in shade may result in a faster rate of mineralization, breakdown of litter, and turnover of N than occurs in open. The mineralization of organic matter releases nutrient into the soil (Osman et al 2001). Non N- fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of organic matter and releasing and recycling of nutrients in agroforestry systems (Yadav et al 200, Antonio and Gama-Rodrigues 2011**).** Similar findings of improvement in the nutrient status of soil due to intercropping in an agroforestry have been reported by Pardon et al (2017), Bisht et al (2018), Kumar et al (2019) and Dhillon et al (2020).

Similarly, available phosphorus in soil also exhibited similar trend as of soil nitrogen (Table 2). Available phosphorus in sole crop was 12.3 kg/ha while, it ranged from 15.5 to 16.8 kg/ha in different spacings of poplar. Among different spacings of poplar, the highest available soil P (16.8 kg/ha) was in 3×3 m spacing. Maximum (343.8 kg/ha) available potassium was under 3×3 m and minimum (332.9 kg/ha) under 8×3 m spacing after culmination of the experiment (after harvesting of winter season fodder crop) at 0-15 cm soil depth. However the least (330.3 kg/ha) available potassium was found under control /sole cropping (Fig. 5).

There was improvement in the available phosphorus and potassium content in the soil may be due to the increase in the humus content of soil after decomposition of litter fall of poplar. Similar findings were also reported by Githae et al (2011) in an Acacia-based agroforestry system. Similar findings of improvement in the nutrient status of soil due to intercropping in an agroforestry have been reported by Chen et al (2017) under rubber based agroforestry system and

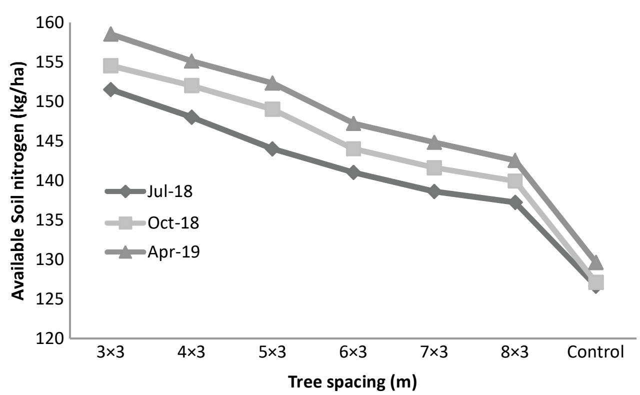

Fig. 4. Nitrogen content in the soil under different spacings of poplar before sowing and after harvesting of cowpea, sorghum berseem and oat

Table 2. Effect of different spacings of poplar on available soil phosphorus content before sowing and after harvest of *kharif* and *rabi* season crops

Spacings (m)	Available phosphorus (kg/ha)					
	Before sowing of fodder crops		After harvesting of cowpea and sorghum		After harvesting of berseem and oat	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
3×3	13.6	11.2	14.9	12.4	16.8	14.8
4×3	13.4	11.5	14.7	12.3	16.5	14.4
5×3	13.1	11.0	14.4	12.0	16.2	14.2
6×3	13.0	10.9	14.1	11.8	16.0	14.0
7×3	12.8	10.6	14.0	11.5	15.9	13.7
8×3	12.5	10.3	13.8	11.1	15.5	13.2
Control	11.3	9.7	12.0	10.2	12.3	11.8
CD (p=0.05)	0.75	0.67	0.92	1.22	0.73	0.99

Kumar et al (2019) under *Eucalyptus* based agroforestry system.

Yield of fodder crops : Among different spacings of poplar, significantly higher fodder yield of both rainy season (cowpea and sorghum) and winter season (berseem and oat) fodder crops was observed in wider spacing (8×3 m) as compared closer spacing (3×3 m) in poplar based agroforestry system and it follows increasing trend with increasing interspaces (Fig. 6). The maximum fresh fodder yield of both rainy and winter season fodder crops was recorded in control (crop devoid of trees) and it varied significantly under different spacings of poplar. The reduced yield of fodder crops under poplar plantation in present study may be ascribed to competition between tree and fodder crops for light, moisture and nutrients in a poplar based agroforestry system. Competition for light has a large influence in intercropping system than either moisture or nutrients and fodder production bears an almost linear relationship with the quantum of intercepted energy. Photosynthetic efficiency of crops increased due to more light intensity in control, resulting in better growth. The lesser availability of solar radiation and higher competition for growth resources in the silvi-pastoral system (poplar + fodder crops) may be responsible for lesser biomass production by fodder crops over control (fodder crops in open). Thus, competition for utilization of growth resources adversely affected the fodder yield of rainy (cowpea and sorghum) and winter (berseem and oat) season fodder crops under different spacings of poplar. Bhati et al (2004) revealed the similar result of fodder yield of cowpea and other fodder crops under the canopy of different agroforestry trees of arid regions of Rajasthan. Earlier researchers also reported reduction in grain yield of cowpea due to higher shade under *Eucalyptus tereticornis* based agroforestry system over open condition (Prasad et al 2010, Chesney et al 2010, Ratan et al 2015, Ranjan et al 2016). Sharma et al (2000) also reported that crop growth of wheat was inhibited under closer spacing of poplar.

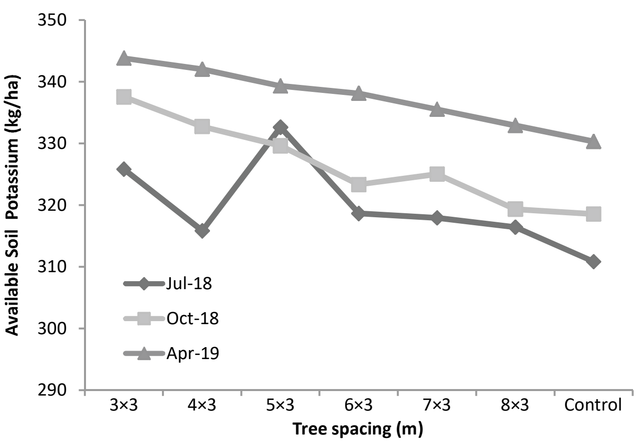

Fig. 5. Effect of different spacings of poplar on available soil potassium content before sowing and after harvest of *kharif* and *rabi* crops

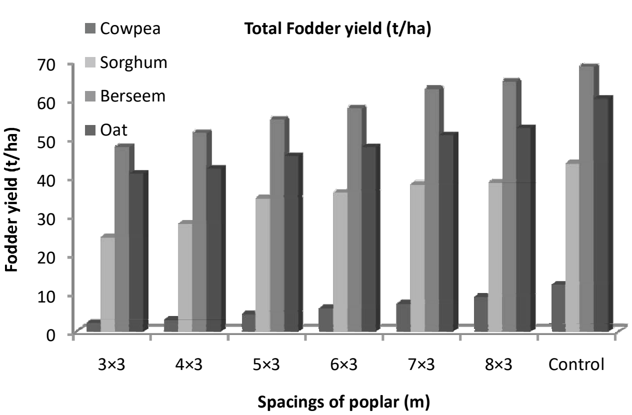

Fig. 6. Effect of different spacings of poplar on total fodder production of both rainy (cowpea and sorghum) and winter (berseem and oat) season

CONCLUSION

A considerable improvement in soil chemical properties (pH, EC, SOC, N, P and K) was observed under different spacings of poplar-based agroforestry system over control (sole crop). The soil pH and EC decreased more under different spacings of poplar than control (sole crop). The soil organic carbon and available soil N, P and K increased significantly under poplar spacings than control (sole crop) both at 0-15 and 15-30 cm soil depths. The effect was more pronounced under 3×3 m spacing, therefore this is more suitable for improving soil fertility by the accumulation of leaf litter with the advancement of tree age.

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