# Effect of different spacings of poplar-based agroforestry system on soil chemical properties and nutrient status in Haryana, India

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**A field experiment was conducted during 2013–14 and 2014–15 to study the effect of different spacings, i.e. 5 × 4 m, 10 × 2 m and 18 × 2 × 2 m (paired row) of 7- and 8-yr-old poplar-based agroforestry system on soil chemical properties such as soil pH, electrical conductivity (EC), soil organic carbon (SOC) and available N, P and K. Poplar-based agroforestry system had better available nutrients status in comparison to sole wheat crop. The lowest value of soil pH (7.5) was recorded under 5 × 4 m spacing after harvesting of wheat crop during April 2015. The decrease in EC was maximum (67%) under 5 × 4 m spacing followed by 10 × 2 m and 18 × 2 × 2 m spacing with a reduction up to 63% and 61% respectively. SOC increased with the decrease in tree spacing and was maximum (0.74%) under 5 × 4 m spacing; it followed the order 5 × 4 m > 10 × 2 m > 18 × 2 × 2 m > control after harvesting of wheat crop during April 2015. The available soil N, P and K increased significantly under different spacings of poplar-based agroforestry system in all the treatments from their initial values. The highest available soil N (366.3 kg ha$^{-1}$), P (21.4 kg ha$^{-1}$) and K (355.3 kg ha$^{-1}$) were recorded under 5 × 4 m spacing compared to 10 × 2 m and 18 × 2 × 2 m and sole cropping after harvesting of wheat crop during April 2015.**

**Keywords:** Agroforestry, nutrient status, poplar, spacing, soil chemical properties.

SELF-RELIANCE in food production has been achieved by the Green Revolution in India. However, unremitting ecological degradation, especially of soil, plant life and water assets has resulted in Haryana due to over exploitation of natural indigenous resources. On the one hand, the level of soil organic substances is deteriorating whereas on the other, the use of chemical inputs is increasing. However, newly introduced crop varieties have been accountable to input, but this has necessitated both augmented fertilizer application and the use of irrigation resulting in water contamination by nitrate and phosphate; this has resulted in changes in the groundwater table. In Haryana, 82% of the geographic area is already under use for cultivation, scope for increased productivity lies in further intensification which is crucially dependent on more energy intensive-inputs[1]. On one hand, crop production has been limiting due to the various intangible factors like declining efficiency of nutrient-use, soil degradation – both physically and chemically, inadequate use of water, etc. whereas on the other, the use of monocultures, mechanization and extreme dependency on chemical plant protection have limited the diversity of flora and fauna. Around 60% of the geographical area will face soil degradation like waterlogging, salinity and alkalinity which threaten the food safety of the region in the future. The water table has increased more than 1 m/annum since 1985 and patches of salinity at the farm level are now visible. In high-rainfall areas, the condition is not better as waterlogging suddenly occurs after the rains. A high water table not only affects agricultural crops but also causes floods even following slight rains creates such situations because of the low water holding capacity of the soil. The use of fertilizers and pesticides is on the decrease by the farmers due to such environmental effects. The increasing deforestation for human habitation, developmental activities and intensive agriculture has resulted in ecological imbalance. As a result, 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[2]. It may be stated here that the diversifying land-use systems with agroforestry are an obligatory strategy for the availability of multiple products for fulfilling the requirements of the population such as food, fodder, fuel-wood, fertilizer, etc. They also provide insurance against risks factors that occur results through various natural calamities like weather aberrations and checking erosion hazard. In this way, they will ensure sustainable production on a long-term basis and must play an important role to achieve greater food security. It has been reported that many of the global challenges, including deforestation, indefensible cropping practices, loss of flora and fauna, amplified risk of weather alteration, as well as intensifying food shortage, poverty and undernourishment are being addressed through an alternative agroforestry land management system[3]. Appropriate selection of tree and crop species helps fulfil the demand for wood, increase crop yield, improve soil fertility, promote land sustainability

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and resource use efficiency[4]. Intercropping with high-density short-rotation tree species is the best option to meet increasing food and industrial raw material requirement through sustainable utilization of natural resources[5]. To check land degradation and achieve biological production on a sustainable basis, *Populus deltoides* is a promising species recognized as an important tree component in agroforestry system[6]. Due to its speedy augmentation, high price, less competition with allied crops and pruning tolerant nature this species has been widely grown by farmers of North India, especially in the states of Punjab, Haryana and Uttar Pradesh as boundary or block plantation along with agricultural crops. The soil is enriched through the addition of leaf litter in large quantities by this species, which ultimately improves the fertility in terms of soil organic carbon (SOC), available N, P and K and also provides alternate sources of revenue and employment to the rural population[7–10]. Nevertheless, because of their fast growth, poplar plantations deplete the physico-chemical properties of soil more than the slow-growing and long-rotation trees[11,12]. Being a winter deciduous tree, it produces a substantial quantity of litter fall in the winter season. The litter fall is an important input for replenishment of soil microbial substances and is one of the most imperative pathways for maintaining soil fertility of plantations[13,14]. The poplar tree provides enhanced availability of macro and micro nutrients in the soil by intensification of above- and below-ground organic matter inputs, nutrient cycling, checking soil erosion and fixing nitrogen. However, meagre information is available related to relationships between soil properties and poplar plantations. In this communication, we study the influence of poplar-based agroforestry system on soil chemical properties and nutrient status.

## Materials and methods

The present study was carried out in the research farm of the Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana (29°09′N and 75°43′E; an elevation 215 m amsl). The climate of the study area is semi-arid and mainly characterized by hot summer, a short rainy season and a cold winter. Maximum rainfall is received during June to September (monsoon season). The site received 447.9 mm rainfall during 2014–15. 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 investigation was conducted in already established 7- and 8-yr old poplar plantations at 5 × 4 m, 10 × 2 m and 18 × 2 × 2 m (paired row) spacing. The wheat crop was raised with the recommended cultural practices under different spacings of poplar during 2013–14 and 2014–15. Four soil samples were collected randomly under different spacings in three replicates from surface soil (0–15 cm). The soil samples were taken at two stages, i.e. before sowing of wheat crop (October) and after harvest of wheat (April) during both the years under different spacings of poplar and also from control field for the study of various soil chemical properties (pH, electrical conductivity (EC) and SOC) and available nutrients (nitrogen, phosphorus and potassium). The samples were air-dried, ground in a wooden mortar and pestle, passed through a 2 mm stainless steel sieve and stored for subsequent analysis. The soil pH and EC were determined in soil : distilled water suspension (1 : 2). The available N in the soil was determined by alkaline permanganate method[15], SOC by partial oxidation method[16], available P by sodium bicarbonate method[17] and available K by neutral normal ammonium acetate method[18].

## Results and discussion

### Soil pH and EC

The pH of soil decreased with increasing age of poplar in all the spacings. The magnitude of decline in soil pH was greater in the tree integrated with wheat plots than the sole wheat plots. The lowest pH value (7.5) was found in 5 × 4 m spacing, which was closely followed by 10 × 2 m (7.7) spacing after the harvesting of wheat crop during April 2015. Among different spacings, the highest pH (7.9) was recorded in 18 × 2 × 2 m (paired row) (Figure 1). The marginally lower pH under agroforestry system than sole cropping might be owing to considerable accumulation of organic substances beneath the trees and release of weak organic acids during litter decomposition, as has also been reported in the agrisilvicultural system[19–21]. Corroborative results were also reported with a six-month study on litter production under poplar[22].

The EC of soil decreased from 0.14 to 0.08 $dSm^{-1}$ under 5 × 4 m spacing of poplar and from 0.26 to 0.20 $dSm^{-1}$ in control during both the years of observation (Figure 2). The soil EC was lowest under 5 × 4 m spacing closely followed by 10 × 2 m, 18 × 2 × 2 m (paired row)

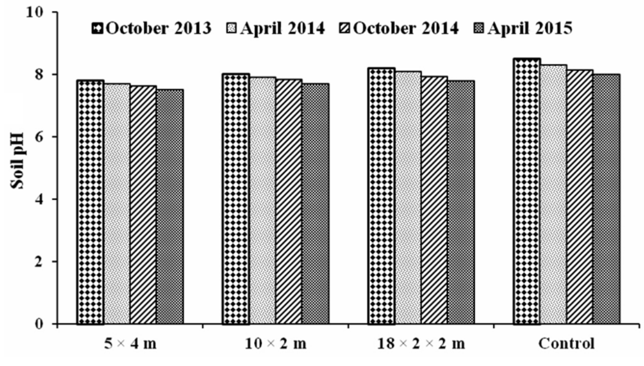


**Figure 1.** Effect of different poplar spacings on soil pH before sowing and after harvest of wheat crop during 2013–14 and 2014–15.

and control. The decrease in EC was maximum (67%) under 5 × 4 m spacing followed by 10 × 2 m and 18 × 2 × 2 m (paired row) with a reduction up to 63% and 61% respectively. Under sole crop, 46% reduction of EC was observed from its initial status before sowing of wheat crop during October 2013. The reduction of soil EC under the tree cover can be ascribed to addition and consequent disintegration of organic substances which release organic acids[23].

### *Soil organic carbon (SOC)*

SOC was considerably influenced by tree spacing and it also increased from its initial status (before sowing of wheat crop, October 2013) under different spacings of poplar-based agroforestry system and control (Figure 3). SOC increased with the decrease in tree spacing and was maximum (0.74%) under 5 × 4 m of poplar spacing; it followed the order 5 × 4 m >10 × 2 m >18 × 2 × 2 m > control after the harvesting of wheat crop during April 2015. Sole cropping exhibited significantly lowest SOC (0.38%) before sowing of wheat crop during October 2013.

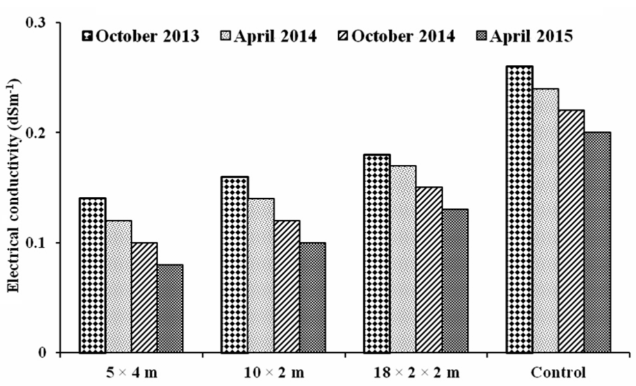


**Figure 2.** Effect of different poplar spacings on electrical conductivity (dS $m^{-1}$) before sowing and after harvest of wheat crop during 2013–14 and 2014–15.

The low SOC content under the sole cropping system may be ascribed to inadequate vegetation and unremitting cropping with consequent elimination of plant residues. The average SOC contents in 5 × 4 m, 10 × 2 m, 18 × 2 × 2 m (paired row) spacing was higher by 37%, 32% and 28% respectively, over sole crop after harvesting of wheat crop during April 2015. Hence, one of the reasons for the lower concentration of SOC under sole crop (without tree) is lack of lignified cells in agricultural residues. The large-scale tillage and cultural operations may be another cause for reduced SOC under sole cropping with full exposure to sun light. High organic matter in the intercropping treatment could be ascribed to leaf fall before and during crop sowing period, which is incorporated into the soil through tillage practices; its partial decomposition adds to the soil organic matter. These outcomes are in line with the findings of Das *et al.*[24] and Antonio and Gama-Rodrigues[25]. The enrichment in SOC under tree-based systems could be due to several factors such as addition of litter, annual fine root biomass recycling, and root exudates and their reduced oxidation of organic matter under tree shade[26]. Physico-chemical properties of soil are major destabilizing forces in agroforestry systems, particularly during the phase following disturbances, i.e. ploughing, weeding and other cultural practices. During this period, referred as the restructuring phase of environmental development, the agro ecosystem increase total biomass and nutrients[27,28].

### *Available N, P and K*

Figure 4 shows the effect of different spacings of poplar-based agroforestry system and sole crop on available nitrogen. Available soil nitrogen increased significantly under different space of poplar-based agroforestry system and sole crop from its initial values (before sowing of wheat crop, October 2013). Like SOC, available nitrogen was significantly influenced by tree spacing because the amount of N depends upon organic matter. Available N

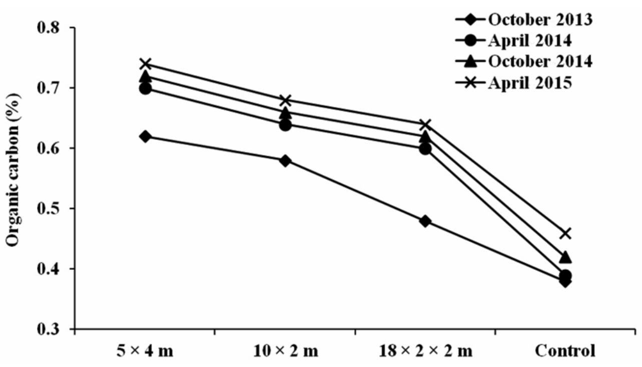


**Figure 3.** Effect of different poplar spacings on soil organic carbon (%) before sowing and after harvest of wheat crop during 2013–14 and 2014–15.

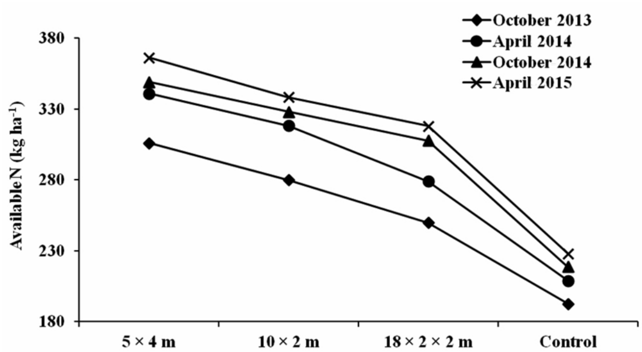


**Figure 4.** Effect of different poplar spacings on available N (kg $ha^{-1}$) before sowing and after harvest of wheat crop during 2013–14 and 2014–15.

content was maximum (366.3 kg ha$^{-1}$) under 5 × 4 m spacing and it decreased with increase in the spacings after harvesting of wheat crop during April 2015. The increase in available N was highest under 5 × 4 m spacing and lowest in control. Under 10 × 2 m and 18 × 2 × 2 m (paired row) spacing, the increase was significantly less compared to 5 × 4 m spacing during both cropping seasons. The increase in N content of soil under poplar-based agroforestry system is attributed to accumulation of organic substances in the soil in the form of litter fall and fine root biomass. The mineralization of organic matter releases nutrients into the soil[29,30]. It has also been reported that non-nitrogen-fixing trees can also improve the physical, chemical and biological properties of the soil by addition of considerable amount of organic substances, and releasing and recycling of nutrients in agroforestry system[31]. Available phosphorus in the soil also exhibited similar trend like soil nitrogen. Available phosphorus in sole crop was 13.5 kg ha$^{-1}$, while it ranged from 15.6 to 21.4 kg ha$^{-1}$ under different poplar spacing treatments (Figure 5). Among the different tree spacings, the highest available soil P (21.4 kg ha$^{-1}$) was recorded under 5 × 4 m of poplar, while it was lowest under control (13.5 kg ha$^{-1}$) after harvesting of wheat crop during April 2015. The available phosphorus in the soil increased substantially and it was more than two times both under poplar-based agroforestry system and control after eight years of poplar plantation.

In case of available potassium content of the soil, an increase was observed up to 52%, 49%, 46% and 36% under 5 × 4 m, 10 × 2 m, 18 × 2 × 2 m (paired row) and control respectively, over its initial values (before sowing of wheat crop during October 2013) (Figure 6). The higher nutrient status under closer spacing might be due to the accumulation of leaf litter. The higher decomposition of leaf litter favours higher nutrient status of the soil. The higher available nutrient content in poplar-based agroforestry system over the agriculture system may be attributed to litter fall from poplar trees as well as addition of root residues of crops and trees. On account of recycling of organic substances, higher SOC and available N, P and K were found in the soil under intercropped poplar plantations than sole agriculture, and the contents varied depending upon the intercrops[32,33]. The impact of agroforestry systems on soil fertility in terms of elevated organic matter content, total nitrogen, available phosphorus and potash in the topsoil has been reported by Rizvi *et al.*[34] and Mishra *et al.*[35] in wheat as intercrop with poplar.

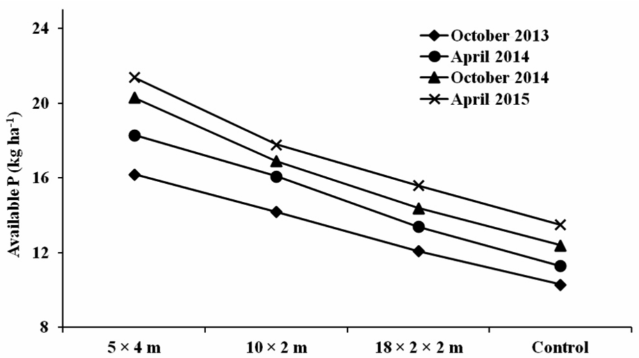


**Figure 5.** Effect of different spacings on available P (kg ha$^{-1}$) before sowing and after harvest of wheat crop during 2013–14 and 2014–15.

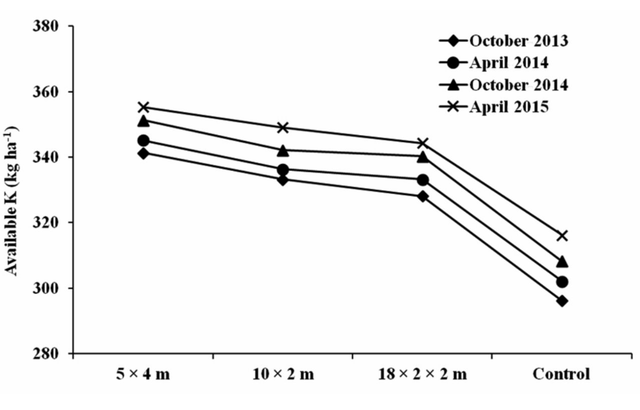


**Figure 6.** Effect of different poplar spacings on available K (kg ha$^{-1}$) before sowing and after harvest of wheat crop during 2013–14 and 2014–15.

## Conclusion

After eight years of poplar plantation, physico-chemical properties of soil (pH, EC, SOC, N, P and K) had improved under different spacings of poplar-based agroforestry system. The effect was more pronounced under 5 × 4 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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