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Role of poplar (*Populus deltoides*) based agroforestry system for soil moisture conservation in semi-arid region of Haryana

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Abstract
The study was undertaken to assess the soil moisture content, when wheat crop was grown in association with different spacings of poplar (5 × 4 m, 10 × 2 m and 18 × 2 × 2 m) during 2013-14 and 2014-15 Among all the spacings of poplar based agroforestry system, the maximum moisture content (13.3%) was found in 5 × 4 m spacing at a soil depth of 15-30 cm which was closely followed by 10 × 2 m (12.4%) before 1st irrigation (pooled data). The moisture content was higher under different spacings of poplar as compared to control during both the year of study. However, in all the spacings of poplar, the moisture content was found to be significantly lesser from 1st irrigation to 5th irrigation during both the years of observations. The control plot resulted in less moisture content (8.1%) than planting of poplar at 18 × 2 × 2 m (8.9%), 10 × 2 m (9.7%) and 5 × 4 m (10.4%) spacing at a soil depth of 0-15 cm before 5th irrigation.

Keywords: Moisture content, irrigation, *Populus deltoides*, spacing

Introduction
Sustainable development through scientific agroforestry interventions has a huge potential in meeting the various demands of fuel wood, fodder and timber in conjunction with agricultural crops on non-forests land apart from providing economic and environmental security. However, competition for water between crops and trees in agroforestry systems is one of the main challenges encountered in arid and semi-arid regions (Ong and Kho, 2015) [10]. This competition varies in all three spatial dimensions, as well as with time, depending on tree phenology and age (Teixera *et al.*, 2003) [13]. Many tree root systems can access water from deeper soil horizons than herbaceous or annual plants. Much of the competitive pressure from trees on soil water comes during the crop growing season, when trees and crops compete for water.

However, in some farming systems where stored moisture is important for crop yield, water use by trees prior to crop sowing is a major cause of yield loss. Extraction of soil water prior to sowing can also cause extensive crop germination failure. Trees can dry the soil during fallow periods resulting in less stored moisture for crop growth and sometimes insufficient soil moisture for seeds to germinate. Agroforestry may improve water use efficiency by reducing the unproductive components of the water balance, such as run-off, soil evaporation and drainage (Bayala and Wallace, 2015) [2]. The high proportions of potentially available water, which are lost to biological production, might be captured by incorporating trees into land use systems, although effects on groundwater recharge may also need to be considered (Ong *et al.*, 2006) [11]. In addition, many trees in agroforestry systems capture water resources that would not be put to productive use in the absence of trees, mainly from deep soil layers beyond the reach of annual crops. Crop roots in drier surface soil may benefit from hydraulic lift of water by trees from wetter soil at depth (Burgess *et al.*, 1998) [4], either at night when transpiration is low (Hultine *et al.*, 2003) [8] or during the day along water potential gradients driven by variation in soil salinity (Hao *et al.*, 2009) [7].

To accomplish these objectives, poplar (*Populus deltoides* Bartr. Ex Marsh.,) based agroforestry system is prime important and will provide the numerous direct and indirect output. It is usually managed in 6-8 year rotation cycle under agroforestry system. Due to its fast growth, high price, less competition with associated crops and pruning tolerant nature this species has been grown by farmers in Punjab, Haryana and Uttar Pradesh, as boundary or block plantation along with agricultural crops on 2.7 lakh hectare. Boundary plantation of poplar is very popular in Northern India as they are providing extra income to famers with minimum interference with various agricultural operation and crop.

Moreover, the small farmers cannot afford to raise block plantation at the cost of agricultural crop yield because the yield reduction ranges from 30-50 % in block plantation whereas 15-20 % in boundary plantation. Wheat is one of the most important winter crops being grown in association with boundary or block plantations of poplar and which considered as most appropriate agroforestry systems of North India. This is due to the ability of poplar to adapt to the wheat competition by distorting its root architecture that improves complementarity between trees and crops.

The past three decades have witnessed the rapid increase in poplar based agroforestry as an alternate land use practice in north-western states of India. The deciduous phenology of poplar minimizes the evapo-transpiration, which contributes considerably to its low water impact on water use rather improves water productivity with a dormancy period that corresponds with the peak growth of winter crops (Zomer *et al.*, 2007) [14]. 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 organic matter. It is one of the most important pathways for maintaining the soil fertility and moisture under agroforestry system. Increased above and below ground organic matter inputs, nutrient cycling, protection of soil from erosion and nitrogen fixation by the poplar tree results in enhanced soil fertility. It has also been observed that air as well as soil temperature is low while the humidity remains higher under poplar tree canopy, which itself has generated the interest for future research for adaptation to changing climate (Rani *et al.*, 2011; Dhillon *et al.*, 2012; Chauhan *et al.*, 2012) [12, 6, 5]. Keeping in view the ever increasing demand of poplar wood and the interest of farmers in poplar culture, the present study was conducted to evaluate the soil moisture content under different spacings (5 × 4 m, 10 × 2 m and 18 × 2 × 2 m) of poplar in semi-arid region.

Materials and Methods

Experimental site

The present study was conducted during 2013-14 and 2014-15 under already established 7 and 8 years poplar plantation spaced at 5 × 4 m, 10 × 2 m and 18 × 2 × 2 m at research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar, Haryana (29^0 09' N latitude and 75^0 43' E longitude at an elevation of 215 m above mean sea level), situated in the 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 maximum temperature ranging from 40 to 45 ºC in May and June whereas, December and January are the coldest months (lowest January temperature as low as 0 °C).

Soil moisture studies

Soil moisture content (per cent on dry weight basis) was determined by gravimetric method by drawing soil samples at before each irrigation in both the experiments in which Wheat crop was grown under during two consecutive *Rabi* seasons of 7 and 8 years poplar plantation spaced at (5 × 4 m, 10 × 2 m and 18 × 2 × 2 m) and in control field. Soil samples were taken in both the experiments at different spacings of poplar (5 × 4 m, 10 × 2 m and 18 × 2 × 2 m) at different soil depth viz., 0-15 and 15-30 cm with the help of locally fabricated post hole augar. Soil moisture per cent was determined by drying the soil samples in oven at 105°C till a constant weight was attained. The loss in soil moisture was expressed as per cent on dry weight basis. The moisture per cent was worked out as follows:

$$\text{Moisture per cent} = \frac{\text{Weight of moist soil (g)} - \text{weight of oven dry soil (g)}}{\text{Weight of oven dry soil (g)}}$$

Results and Discussion

Moisture studies under different spacings of poplar

Moisture content was higher in poplar (5 × 4 m, 10 × 2 m and 18 × 2 × 2 m) based agroforestry system as compared to control at all the soil depths during both the years of observations (Figure 1). The differences in moisture content in agroforestry system compared to control were clearly visible before first to fifth irrigation during both the years. The moisture content increased with increasing the soil depth in both the systems. It is evident from the data presented in Figure 1 among all the spacings of poplar based agroforestry system, the maximum moisture content (13.3%) was found in 5 × 4 m spacing at a soil depth of 15-30 cm which was closely followed by 10 × 2 m (12.4%) before 1st irrigation (pooled data). Among different spacings, paired row planting (18 × 2 × 2 m) showed significantly lesser moisture content (11.0, 10.4, 9.9, 9.4 and 8.9%) from 1st irrigation to 5th irrigation on a surface soil (0-15 cm) under this study. However, in all the spacings of poplar, the moisture content was found to be significantly lesser from 1st irrigation to 5th irrigation during both the years of observations. The control plot resulted in less moisture content (8.1%) than planting of poplar at 18 × 2 × 2 m (8.9%), 10 × 2 m (9.7%) and 5 × 4 m (10.4%) spacing at a soil depth of 0-15 cm before 5th irrigation. The results revealed that the interaction between spacing and soil depth were not found significant. It was based on the fact that there is direct relationship between soil moisture and shade due to tree canopy. Zomer *et al.* (2007) [14] reported that the deciduous phenology of poplar minimizes the evapo-transpiration, which contributes considerably to its low water impact on water use rather improves water productivity with a dormancy period that corresponds with the peak growth of winter crops. Burgess *et al.* (1996) [3] also reported little competition for moisture between poplar and wheat crop.

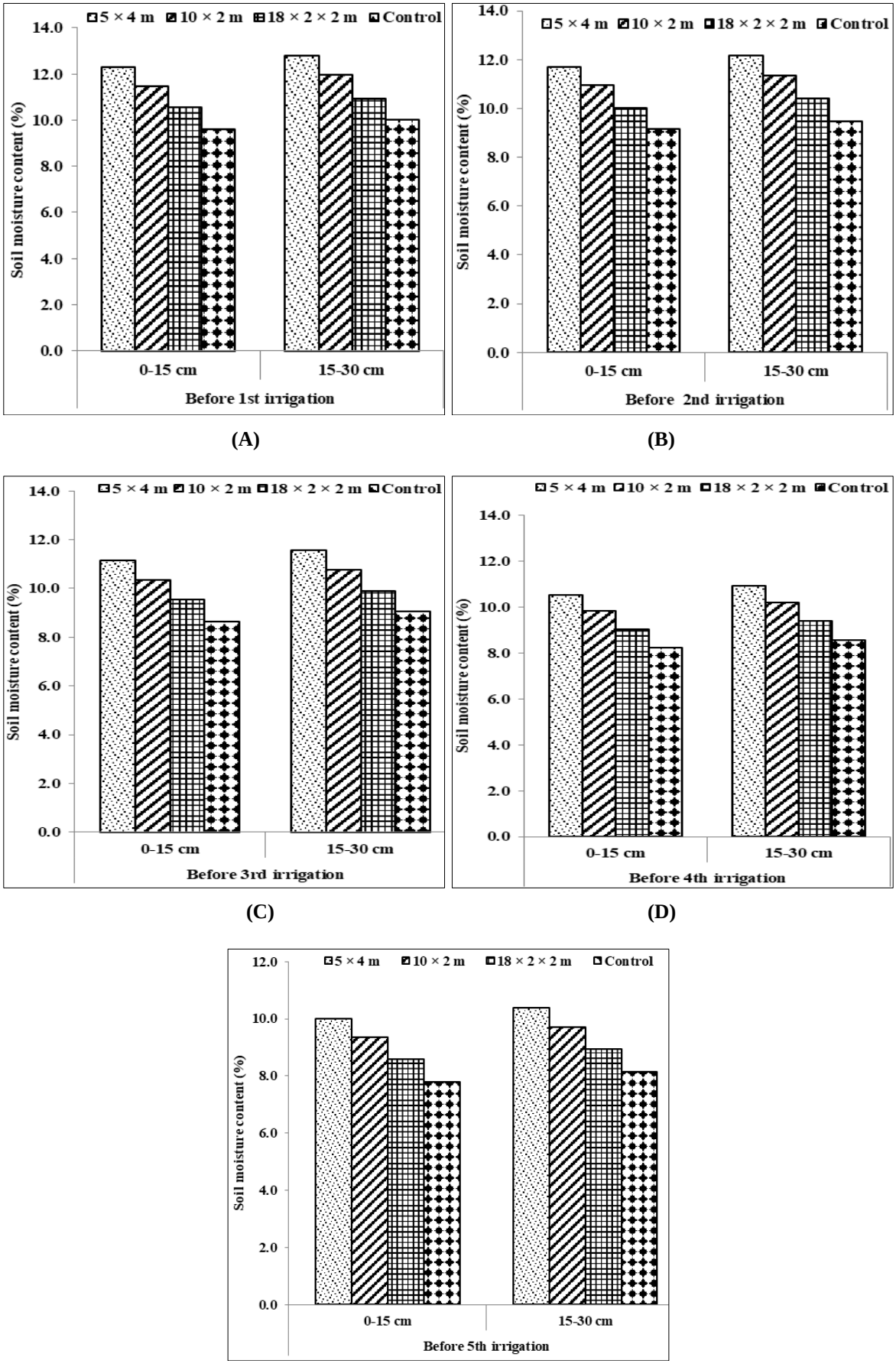

Fig 1: Effect of different spacings of poplar on moisture content (%) of various soil depths (cm) (A, B, C, D & E) during wheat growing season (pooled data, 2013-14 and 2014-15)

Bayala and Wallace (2015) [2] revealed that agroforestry may improve water use efficiency by reducing the unproductive components of the water balance, such as run-off, soil evaporation and drainage. Many tree root systems can access

water from deeper soil horizons than herbaceous or annual plants. Positive effects on crops may also arise through improved water relations (Bayala *et al.,* 2008) [1] and microclimate (Muthuri *et al.,* 2014) [9].

Conclusion

Based on the experimental findings, among all the different spatial arrangements of poplar based agroforestry system, 5 × 4 m spacing was found best for the maximum moisture content in both the soil depths (cm) for all the irrigations during both the consecutive years. In control plot (devoid of poplar tree) the moisture content was low during all the irrigations as well as all the soil depths due to the presence of maximum sunlight which is mainly responsible for low moisture content in semi- arid region of India.

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