POPLAR (*POPULUS DELTOIDES*) BASED AGROFORESTRY SYSTEMS FOR AN ALLUVIAL SOIL UNDER IRRIGATED CONDITION IN WESTERN UTTAR PRADESH

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Introduction

Traditional agroforestry systems mainly consist of slow growing indigenous tree species and have poor quality of produce which are not able to meet the requirements of locality/country. Thus, a search has to be made for fast growing valuable exotics. Poplar (*Populus deltoides* M.) with high productivity (upto 50 m^3 ha^{-1} yr^{-1}), in 6-12 years rotation is being preferred for various agroforestry systems in different parts of India (Tiwari, 1993). For boundary plantation, Poplar is now getting popularized with the farmers (Sharma and Dadhwal, 1996) and Wheat (*Triticum aestivum*) is one of the most important Rabi crops being grown with association of boundary plantation of Poplar. Being a deciduous tree, cultivation of Poplar under agroforestry system provides addition of organic matter through leaf fall. However, leaves may also add sufficient allelochemicals near the tree line to have a detrimental effect on crop growth. Modification in micro-climate due to the interception of solar radiation by the Poplar canopy may influence the growth of understorey (crop and weeds). Being a fast growing tree, Poplar needs more moisture and nutrients and poses competition to share the land resources with understorey vegetation. Thus, the system is not simply farming system where both trees and crops give useful products to the farmers, but system where tree and crop production interacts. Therefore, a quantitative approach is an important step in the quest for better understanding of the complex mechanisms of tree-crop interaction, which should offer scientific basis for designing productive and sustainable agroforestry systems. Hence, in Poplar-Wheat agroforestry system growing condition of wheat may modify due to the presence of tree and thus, response of wheat may differ than that of pure agricultural system. It is, therefore, essential to clearly understand the extent of Poplar impact on wheat crop. Keeping this in view, an experiment was planned to study the various interactions occurring at the tree line/crop interface of Poplar and Wheat grown on irrigated alluvial soils in Western U.P.

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Table 1

Summary statistics of growth characters of Poplar trees during study period

Growth Characters	3rd year			4th year		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Height (m)	9.3	11.6	10.3	11.5	14.5	12.9
DBH (cm)	9.1	16.0	12.1	10.5	21.6	17.1
Crown diameter (m)	4.8	5.8	5.1	5.5	6.9	6.1
MAI of DBH (cm)	3.0	5.3	4.0	2.6	5.7	4.3

DBH = Diameter at Breast Height; MAI = Mean Annual Increment

Material and Methods

A field study was conducted for two years (1994-95 and 1995-96) at the Research Farm of J.V. College, Baraut, U.P., India. Baraut is situated at a height of 230 m above mean sea level, intersected by 29°6'N latitude and 77°60'E longitude. The soil of the experimental area varied in texture from sandy clay loam to loam and was low in nitrogen and phosphorus with pH varying from 6.5 to 7.1. The average annual rainfall of the area is 652 mm out of which more than 84% is received during monsoon season (July to September). Summers are very hot and windy with maximum temperature during crop growth period varying from 37.7 to 17.0°C and minimum from 23.4 to 4.2°C.

Wheat (*Triticum aestivum*), variety HD-2285 was sown in agricultural field having a single row boundary plantation (60 m long) of three year old Poplar (*Populus deltoides*, clone 'G-3') trees, already existing (3.5 m tree to tree distance) and oriented in North-East and South-West direction. Summary statistics revealed that average tree height, dbh and crown diameter was 10.3 m and 12.9 m, 12.1 and 17.1 cm, 5.1 and 6.1 m, respectively, in 1994-95 (3 year old) and 1995-96 (4 year old), respectively (Table 1). The wheat seeds were drilled at the rate of 100 kg ha^{-1} in 22.5 cm wide rows. Half of the nitrogen (60 kg ha^{-1}), through urea and entire quantity of phosphorus (60 kg ha^{-1}) through single superphosphate and potash (40 kg ha^{-1}) through muriate of potash were applied at the sowing times as basal dose. The remaining half quantity of *nitrogen (60 kg ha^{-1}) was applied at first* irrigation in both years. The wheat field was flood irrigated five times during the growing season. The effect of trees on the wheat crop was estimated in terms of growth and yield parameters. To take the observations, 10 m wide and 15 m long strip (one replication) was divided into five segments. Each segment had 10 m (along the tree line) x 3 m (perpendicular to the tree line) area. Area beyond 15 m was treated as unaffected or control. Thus, there were six distances (0-3, 3-6, 6-9, 9-12, 12-15m and control, no effect) from where observations were recorded. Each distance was considered as an independent treatment. To avoid the variation, 10 m space (3 trees) on either side of the tree line (60 m long) was left as border and rest space (40 m) divided into 4 equal parts.

Thus, in all, there were 24 plots, each measuring 10x3 m area, in the experiment. Grain yield (q ha^{-1}) was *determined on the* net plot area (6 x 3 m) basis. Statistical analysis was done as per standard procedure (Gomez and Gomez, 1984).

Soil moisture content was determined thermo-gravimetrically from the soil samples drawn up to 120 cm depth by means of a locally fabricated post-hole auger. The first sampling was done at wheat sowing and subsequent samples were taken before and after each irrigation. Data obtained were utilized in computing water use (Dastane, 1972) and water use efficiency (Viets, 1962) at different distances from tree line.

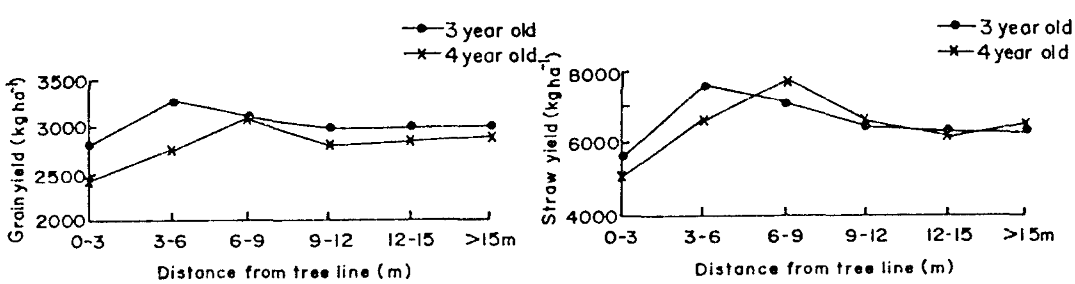
To measure leaf litter production ten quadrats of 1x1m size were laid down randomly in each segment (50 m along the tree line and 3m from trees base line of trees towards the centre of the field). Leaf litter was oven dried at 80°C and one composite sample was prepared and analysed for N, P, K, Ca and Mg using standard laboratory technique (Piper, 1950). In this manner, spatial and temporal distribution of leaf litter and quantity of nutrients return was estimated. The percentage distribution over distance from the tree line was estimated.

Population of individual weed species was worked out by quadrat method at 30 and 40 days after sowing (Mishra, 1968). Three quadrats of 0.5 x 0.5 m were selected randomly in each plot, total number of weed species and their respective numbers were counted and plants harvested for biomass estimations at the time of wheat harvest. To estimate the dry biomass of weeds samples were sun dried and then oven dried at 70°C to a constant weight.

Results and Discussion

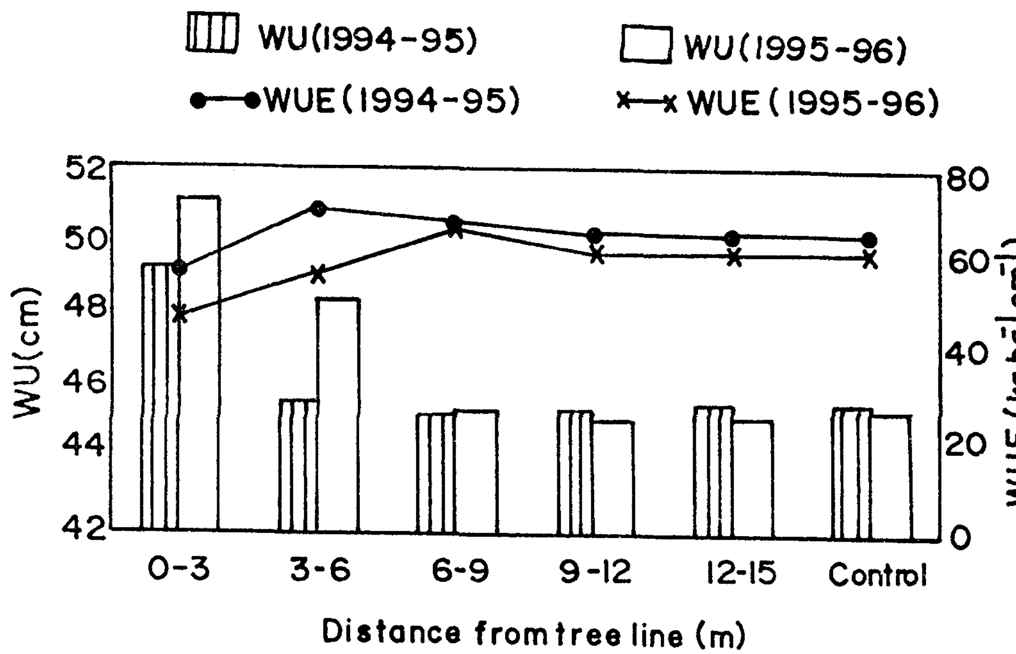
Yield of wheat : No significant adverse effect was noticed on wheat crop when grown with association of 3 year old boundary plantation of Poplar. However, significant decline of 15.5% was recorded up to a distance of 3 m from the tree base due to 4 year old plantation. Similarly, Ahmed (1989) found that in the first two years after plantation, the effect of trees on crop production was almost negligible, in the 3rd and 4th year loss was 8.2 per cent, it increased to 13.6 per cent in the 5th and 6th year and increased further to 26.4 per cent in the 7th and 8th years. Poplar offered

Fig. 1



Wheat grain and straw yield (kg/ha) at different distances from Poplar tree line

Fig. 2



Water Use (WU) of the system and Water Use Efficiency (WUE) of wheat at different distances from Poplar tree line

maximum competition near the tree line (0-3m) and reduced the grain and straw yield by 10.7 and 16.7 per cent, respectively. Poor crop performance near the tree line has also been reported by several workers (Kohli *et al.*, 1990; Puri and Bangarwa, 1992; Sharma and Singh, 1992). Highest reduction in the grain yield of wheat near the tree line as compared to control and improvement and increasing distance can be attributed to the severe competition by the tree roots which gets reduced with increase in distance from the tree line. However, synergetic effect was obtained between 3-9 m distance, on an average, 9 per cent increase over control was recorded in straw yield between 3-12 m distance from the tree line. It is evident from data that benefit was extended to grain yield also, though it was non-significant, and increase of 8.7 and 2.7 per cent at 3-6 and 6-9 m distance, respectively was reported over control in 1994-95 (Fig. 1). Thevathasan and Gordon (1995) stated that total above around biomass of barley produced in the Poplar-barley intercropping system was 14 per cent higher than in the mono-cropped system. Synergetic effect between 3-9 m distance can be attributed to the micro-site enrichment caused by favourable environment for wheat growth due to modification in micro-climate (Marshall, 1967; Rosenberg, 1974) and recycling of nutrients at tree and crop interface. Additional income from sale of poplars compensated for the losses caused by reduction in wheat production (Sharma and Singh, 1992).

Water use and water use efficiency : Water use was increased considerably, over control near the tree line (0-6 m distance) however, differences disappeared beyond 6 m distance (Fig. 2). It can be attributed to the presence of Poplar tree which is highly demanding in respect of water (Tiwari, 1993). Contrary to this, it was observed that water use efficiency was enhanced between 3-9 m distance in 1994-95. However, in 1995-96 increase was narrowed down between 6-9 m distance. Radke and Hagstrom (1976) reported that benefit to wheat caused by boundary plantation under irrigated condition is due to improvement in plant water relationship which resulted in increase of water use efficiency.

Weed Biomass : Influence on natural vegetation was observed in terms of shift in weed flora, reduction in plant density and dry matter accumulation near the tree line. *Vicia sativa* was the most abundant weed species near the tree line, whereas *Chenopodium album* heavily infested the area between 6-9 m distance. It was observed that species of Leguminoseae family (*Melilotus* sp.) was less abundant where leaf litter fell on the ground. Maximum reduction in plant population of *Phalaris minor* (narrow leaf) and *Anagallies arvensis* (broad leaf) was observed near the tree line and increased as the distance increase from tree line. Less population of weeds resulted in minimum accumulation of dry matter and nutrient uptake near the tree line and increased as move away from tree line (Table 2).

Table 2

Dry weight produced (kg ha^{-1}) by weeds at harvest at different from Poplar tree line

Distance from tree line (m)	Dry weight (kg ha^{-1})		
	3rd year	4th year	Mean
0-3	395.2	302.8	349.0
3-6	572.4	485.6	529.0
6-9	612.4	534.0	573.2
9-12	995.6	972.0	983.8
12-15	1023.6	1012.0	1017.8
Control*	1058.4	1049.2	1053.8
LSD (P=0.05)	112.6	160.5	

*Recorded 15m away from tree line

Nutrient recycling : It was estimated that total amount of 913.8 kg ha^{-1} (520.9, 283.3 and 109.7 kg ha^{-1} between 0-3, 3-6 and 6-9m distance from tree line, respectively) and 1291.8 kg ha^{-1} (593,9, 451.9 and 245.3 kg ha^{-1} between 0-3, 3-6 and 6-9 m distance from tree line, respectively) leaf litter was added in the soil through 3 and 4 year old plantation.

Considerable amount of nutrients was recycled to the soil through leaf fall. The analytical results of leaf litter showed that the quantity of nutrients added into the soil decreased in the order of Ca > N > Mg > K > P. The nutrients return to the soil through litter fall followed the same trend that of amount of litter fall at different distances. Moreover, the maximum addition/return of nutrient was estimated near the tree line, where maximum quantity of litter fall was observed (Table 3). It was estimated that on an average 11.9 kg ha^{-1} nitrogen (6.1, 3.9 and 1.9 kg ha^{-1} between 0-3, 3-6 and 6-9 m distance from tree line, respectively), 2.5 kg ha^{-1} phosphorus (1.3, 0.8 and 0.4 kg ha^{-1} between 0-3, 3-6 and 6-9 m distance from tree line, respectively), 7.9 kg ha^{-1} potassium (4.0, 2.6 and 1.3 kg ha^{-1} between 0-3, 3-6 and 6-9 m distance from tree line, respectively), 21.3 kg ha^{-1}

Table 3

Nutrients recycled (kg ha^{-1}) to soil through leaf litter by Poplar tree line at different distance from tree line

Distance from tree line (m)	Nutrients (kg ha^{-1})														
	Nitrogen			Phosphorus			Potassium			Calcium			Magnesium		
	3rd year	4th year	Mean	3rd year	4th year	Mean	3rd year	4th year	Mean	3rd year	4th year	Mean	3rd year	4th year	Mean
0-3	6.4	5.8	6.1	1.4	1.2	1.3	3.9	4.1	4.0	10.4	11.2	10.8	4.4	4.6	4.5
3-6	3.5	4.4	3.9	0.8	0.9	0.8	2.1	3.1	2.6	5.7	8.5	7.1	2.4	3.5	3.0
6-9	1.4	2.4	1.9	0.3	0.5	0.4	0.8	1.7	1.3	2.2	4.6	3.4	0.9	1.9	1.4
Total	11.3	12.6	11.9	2.5	2.6	2.5	6.8	8.9	7.9	18.3	24.3	21.3	7.7	10.0	8.9

Table 4

Physico-chemical properties of soil as influenced by Poplar tree line at different distances from tree line

Distance from tree line (m)	Bulk density (g cm^{-3})		Total Nitrogen (%)		Available Phosphorus (kg ha^{-1})		Available Potassium (kg ha^{-1})		Exchangeable Ca^{++} (%)		Exchangeable Mg^{++} (%)	
	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year	3rd year	4th year
0-3	1.45	1.45	0.041	0.040	11.1	11.9	124	141	0.18	0.21	0.124	0.01
3-6	1.48	1.47	0.042	0.043	22.4	20.3	133	128	0.17	0.22	0.124	0.076
6-9	1.49	1.49	0.042	0.042	22.1	23.5	131	121	0.14	0.18	0.160	0.088
9-12	1.48	1.48	0.041	0.041	21.3	21.8	124	115	0.12	0.25	0.144	0.077
12-15	1.49	1.49	0.040	0.041	21.9	21.7	123	115	0.10	0.25	0.141	0.078
Control*	1.49	1.49	0.040	0.041	21.7	21.8	123	115	0.10	0.25	0.140	0.078

*Recorded 15 m away from tree line

calcium (10.8, 7.1 and 3.4 kg ha^{-1} between 0-3, 3-6 and 6-9 m distance from tree line, respectively) and 8.9 kg ha^{-1} magnesium (4.5, 3.0 and 1.4 kg ha^{-1} between 0-3, 3-6 and 6-9 m distance from tree line, respectively) was added into the soil through litter fall. Addition of leaf litter and nutrients through Poplar has also been estimated by number of workers (Raizada, 1988; Ralhan *et al.*, *1996*; Tandon *et al.*, 1991).

Influence on physico-chemical properties of soil : Poplar tree plantation had a minor influence on the physico-chemical properties of the soil. The bulk density (BD) of surface soil (0-30 cm) decreased near the tree line (0-6 m distance). Results of de Jong and Kowalchuk (1995) and Kumar *et al.* (1993) showed that tree plantation decreased the bulk density and increased the field capacity of 0-15 cm soil layer. Decrease in bulk density was a result of introduction of trees in the systems (Kumar *et al.*, 1993). The favourable effects of tree planting on some of the physical properties has also been reported by Jha and Pandey (1984).

Chemical analysis of soil (Table 4) showed that boundary plantation extracted the soil profile near the tree line (0-3 m and 0-6 m with 3 and 4 year old plantation, respectively). Low concentration of phosphorus and potassium in the soil was recorded near the tree line (zone of high concentration of root), whereas, zone of low concentration of nitrogen exceeded beyond the area of high concentration of roots. More extensive soil depletion of nitrogen as compared to other nutrients may be due to its high rate of movement than other nutrients (Young, 1989). However, micro-site enrichment was also caused by tree plantation at the interface of tree and crops which was limited mostly in the surface soil (0-15 cm). Increased status of nutrients as compared to control, was recorded at those sites where nutrients were being added continuously through leaf letter and probably negligible amount of nutrients was removed through tree roots. High concentration of phosphorus on these sites was analysed only at surface soil (0-15 cm) whereas, in case of K, Ca and Mg it was recorded relatively to deeper layers. Minimum buildup of nutrients near the tree line may be due to their more removal as compared to addition through leaf fall by Poplar trees (Tandon *et al.*, 1991). Effect was more pronounced with increase in age of trees which may be due to more area occupied by the roots and increasing root density with advancement of age (Mathur and Sharma, 1983).

SUMMARY

Poplar with high productivity in 6-12 years rotation is being preferred, particularly as boundary plantations, in various agroforestry systems in northern part of India. A quantitative approach is an important step in the quest for a better understanding of the complex mechanisms of tree-crop interaction, which should offer scientific basis for designing more productive and sustainable agroforestry systems. This paper reports on the quantitative estimations of various interactions occurring at the tree line/crop interface of Poplar and wheat grown on irrigated alluvial soil in Western U.P. No significant adverse effect was noticed on wheat crop when grown with association of 3 year old boundary plantation of Poplar. However, a significant decline of 15.5 per cent was recorded only up to a distance of 3 m from the tree base due to 4 year old plantation. Water use of the system increased upto 6 m from the tree line which caused moisture stress to the wheat crop. At the same time boundary plantation of Poplar had favourable effect on the micro-climate which improved the status of soil moisture between 6-9 m distance and increased the water use efficiency. Competition for natural resources was reduced between weeds and wheat due to reduction in weed population and biomass in the system. Litter production averaged 1103 kg ha^{-1} in 3 and 4 year old plantation and this returned 12, 2.5, 8, 21.3 and 8.6 kg ha^{-1} of N, P, K, Ca and Mg to the soil. Addition of leaf litter near the tree line tended to change the physico-chemical properties of the soil.

पश्चिमी उत्तर प्रदेश की सिंचित दशाओं की जलोढ़ मृदाओं के लिए पोपलर (*पोपुलस डेल्टायडिस*) आधारित कृषिवानिकी प्रणालियां

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सारांश

भारत के उत्तरी भागों की विभिन्न कृषिवानिकी प्रणालियों में, विशेषत: सीमा बनाते रोपवनों के लिए 6 - 12 वर्ष के आवर्तनों में अधिक उत्पादकता दिखाने वाले पोपलर ज्यादा पसन्द किए जाते हैं । वृक्ष - फसल की अन्तर्क्रिया की अच्छी समझ की खोज में मात्रात्मक दृष्टि अपनाना महत्वपूर्ण कदम होता है जिससे लम्बे समय तक चल सकने वाली और अधिक उत्पादक प्रणालियां आकल्पित करने के लिए वैज्ञानिक आधार सुलभ हो जाना चाहिए । प्रस्तुत अभिपत्र पश्चिमी उत्तर प्रदेश की सिंचित जलोढ़ मृदाओं में उगाए जा रहे पोपलर और गेहूं में वृक्ष रेखा/फसल स्तर पर पाई जाने वाली विविध अन्तर्क्रियाओं के मात्रात्मक अनुमानों को सूचित करता है । पोपलर के 3 वर्षीय सीमावर्ती रोपवन के साहचर्य में गेंहू की फसल उगाई जाने पर उस पर कोई सार्थक कुप्रभाव पड़ता देखने में नहीं आया । तथापि, 4 वर्षीय रोपवन के कारण वृक्षों के आधार से केवल 3 मी॰ दूरी तक की फसल में 15.5 प्रतिशत कमी पड़ती आलेखित की गई । वृक्ष रेखा से 6 मी॰ दूरी तक प्रणाली द्वारा जल उपयोग में वृद्धि हुई जिसके परिणामस्वरूप गेहूं की फसल पर आर्द्रतापरक दबाव पड़ा । उसके साथ पोपलर के सीमावर्ती रोपवन का अणुजलवायु पर अनुकूल प्रभाव पड़ा जिससे 6 - 9 मी॰ की दूरी वाले क्षेत्र की मृदा नमी स्थिति में सुधार हुआ और उससे जल उपयोग की कार्यदक्षता में वृद्धि हुई । प्रणाली में खरपतवारों की संख्या और उनके जैवपुंज में कमी हो जाने से खरपतवारों और गेंहू के दरम्यान प्राकृतिक संसाधनों के लिए प्रतिस्पर्धा में कमी आई । 3 और 4 वर्षीय रोपवन में पर्णास्तरण उत्पादन का औसत 1103 किग्रा प्रति हेक्टे॰ रहा और उससे मृदा में क्रमश: 12, 2.5, 8, 21.3 और 8.6 किग्रा प्रति हेक्टे॰ नाइट्रोजन, फास्फोरस, पोटाशियम, कैलशियम और मैगनीशियम की वापसी हुई । वृक्ष रेखा के निकट पर्णास्तरण जमा होने से मृदा की भौत - रसायनिक विशेषताओं में बदलाव आने की प्रवृति बढ़ी ।

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