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# Agro-techniques for increasing productivity of wheat (*Triticum oestivum*) under poplar (*Populus deltoides*) plantation

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## ABSTRACT

Field experiments were done to standardize the agronomic practices of wheat grown in association with poplar (*Populus deltoides* Bartr.) plantation at Ludhiana, Punjab. The study was conducted under block plantation of poplar (Clone G-48) grown at a spacing of 5 x 4 m, (accommodating 500 trees/ha) at the age of 2, 3 and 4 years in 2004, 2005 and 2006, respectively. The soil of the site was low in available N and medium in available P. Three seed rates (100, 125 and 150 kg/ha) and combinations of 3 N (125, 187.5 and 250 kg N/ha) and 2 P levels (27 and 40.5 kg P/ha) were evaluated to find out the optimum fertilizer and seed requirement of wheat (cv. PBW 343) intercropped with poplar. The height and diameter of trees increased from 10.4-15.1 m and 10.4 - 16.5 cm, respectively in the span of 2 years (2004-06). Wheat yield under poplar reduced with the increase in tree age. However, the crop under poplar responded positively to higher fertilizer and seed rates. The yield of sole wheat was significantly higher when compared with intercropped wheat. Among 3 seed rates, 25% additional seed rate (125 kg/ha) over recommended to sole wheat significantly increased (6%) the grain yield of wheat under poplar plantation. Among different fertilizer levels, grain yield of wheat was significantly higher (3.93 tonne/ha) at 50% additional N than recommended to sole wheat with recommended P *i.e.* at 187.5 kg N and 27 kg P/ha. N and P uptake by wheat was higher in sole wheat than under poplar. Additional application of seed and nutrients over the recommended levels significantly increased their uptake. The benefit cost ratio in poplar plantation were highest with the application of 150 kg/ha seed and 187.5 + 27 kg N + P/ha to wheat.

***Key words:*** Agro-silviculture systems, Nutrient uptake, Poplar, Profitability, Seed rate.

In Indo-Gangetic plains of India comprising mostly North-Western states *viz.,* Punjab, Haryana, Uttar Pradesh, Uttara Khand, lower parts of Himachal Pradesh and Jammu and Kashmir, poplar (*Populus deltoides* Bartr.) based agri-silviculture models have been adopted by farmers. The farmers grow poplar due its short duration, ease of regeneration, easy availability of quality planting material, good market demand and its compatibility with agricultural crops. In this region, productivity of poplar was achieved up to 50 $m^3$/ha/year through intensive management practices when compared with 1.0 $m^3$/ha/year of natural forests (Lal, 2007). Poplar plantations intercropped with agricultural crops have better growth than those without intercrops and the growth of trees is variable under different intercrops.

Wheat (*Triticum oestivum* L. emend. Fiori & Paol.) can be successfully grown under block plantation of poplar throughout its rotation of six years. Although there is yield reduction (10-46%) of wheat from 1-6 year of poplar plantation but this yield loss is often compensated by the sale of poplar wood at the end of rotation. The package of practices of growing sole wheat has been standardized for different agro-climatic zones of Punjab (Anonymous, 2004). However, there is need to refine the cultural practices to grow wheat under the block plantation of poplar. Recently attempt has been made to screen out partially shade tolerant wheat varieties that could be successfully grown under poplar. Moreover, the time of sowing wheat under poplar has also been standardized to minimize yield loss due to seed germination hindrance by leaf litter (Gill *et al.,* 2009). Yadav (2001) worked out the spacing and fertilizer requirement of lemon grass under 4 and 5 year old poplar plantations. Higher fertilizer doses ($N_{250}P_{100}K_{80}$) proved to be superior in respect of number of tillers, plant height, herbage yield and oil yield when compared with other treatments under poplar plantations. Thus to make the poplar-wheat based agroforestry system more remunerative there is need to standardize the cultural practices of wheat sown under poplar. Therefore the present study was undertaken to study the effect of additional seed rate and fertilizer dose over recommended rates to sole wheat, on performance of wheat grown with poplar under 2, 3

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and 4 year old plantation.

## MATERIALS AND METHODS

The study was conducted in the research farm of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, Punjab for 3 successive years 2004-05, 2005-06 and 2006-07. It is situated at $30^0$54' N, $78^0$48' E and 247 m above mean sea level. Total rainfall during the crop season varied considerably (55.2 mm in 2005-06; 184.8 and 191.7 mm in 2004-05 and 2006-07, respectively). The region is covered by Indo-Gangetic alluvium. The experimental soil (0-15 cm depth) was loamy sand in texture with a pH of 8.21, EC 0.30 dS/m, organic carbon 0.24%, available N 147 kg/ha, available P 12.7 kg/ha and available K 207 kg/ha. Experiments were carried out under poplar block plantation during 2, 3 and 4 year of its growth. The tree to tree spacing of 5 m was kept in East-West direction and 4 m in North–South direction to facilitate the movement of tractor in both directions for cultivation and to maintain a sufficient tree population (500 trees/ha) for good returns. Thick and vertical branches competing with main stem were pruned during leafless period in third year of planting.

The growth parameters viz. tree height, clear bole height and girth of total 61 trees in experiment were measured in February during 2005, 2006 and 2007 and average values were calculated. Height of trees (m) was recorded from base of the tree to growing tip with the help of Ravi's multimeter. The clear bole height was also measured with Ravi's multimeter from ground level to the point where crown branches started. To calculate crown length, clear bole height was subtracted from the total tree height. Girth at breast height (GBH) was measured by measuring tape at 1.37 m from ground level. The value of GBH, measured from plantations, was converted to diameter at breast height (DBH) using the formula DBH = GBH/p. The crown diameter was measured using a non-elastic tape, stretched along an axis from one edge of the crown to its opposite edge passing through the centre of the crown.

'PBW 343' wheat was sown in early November (2004, 2005 and 2006) prior to leaf fall from poplar. The recommended seed rate and fertilizers for the sole wheat in Punjab are 100 kg seed/ha and 125-27 kg N-P/ha (Anonymous, 2004). For determining the seed and fertilizer requirement of wheat intercropped in poplar, 3 seed rates *i.e.* recommended ($S_1$, 100 kg/ha), 25% more ($S_2$, 125 kg/ha) and 50% more than recommended ($S_3$, 150 kg/ha) to pure wheat along with 5 fertilizer levels (kg N-P/ha) consisting of $F_1$, 125-27 *i.e.* recommended NP fertilizer to pure wheat ; $F_2$, 187.5-27 *i.e.* 50% more than recommended N along with recommended P; $F_3$, 187.5-40.5 *i.e.* 50% more than recommended both N and P; $F_4$, 250-27 *i.e.* 100% more than recommended N along with recommended P and $F_5$, 250-40.5 *i.e.* 100% more than recommended N and 50% more than recommended P to pure wheat were evaluated. The plot size was co-terminus with trees planted at 5 m x 4 m spacing and buffers of 75 cm were provided breadth wise and length-wise between the contiguous plots. The wheat crop was also grown as control adjacent to compact poplar plantation under open conditions as sole crop with 3 seed rates and 5 fertilizer treatments every year. The experiment was sown in split plot design with randomization of seed rates in the main plots and fertilizer levels in sub plots with three replications both under poplar as well as in open conditions. Seed was placed 4-6 cm deep with and a spacing of 22 cm between the rows. The planting was done with seed drill to ensure uniform placement of seed at proper depth throughout the field. Full amount of P and ½ N were applied at the time of sowing, ¼ N immediately after first irrigation and remaining ¼ N after second irrigation. The source of N and P fertilizers were urea and diammonium phosphate. Total 4 - 5 irrigations were given during the crop growth. After heavy pre-sowing irrigation, first irrigation was applied at crown root initiation stage of wheat *i.e.* 4 weeks after sowing; second and third irrigation at 5-6 weeks after previous irrigation and last irrigation was applied in mid-March. But during 2005-06 (having unusually low rainfall) due to sudden rise in temperature at grain filling/formation, the crop was irrigated immediately. The harvesting of wheat intercropped in poplar and sole crop was done in April each year. The crop growth parameters were recorded during 3 and 4 year of poplar plantation.

Nutrient uptake (N and P) by wheat crop was determined by following standard procedures. The uptake of these nutrients was estimated from concentration of nutrients and yield of crop. The net returns in respect of wheat (grain and straw yield) with varying seed and fertilizer levels in open as well as under 3-and 4-year-old poplar plantations were worked out considering 3 years (2004 to 06) average material cost, labour cost, interest on working capital, depreciation cost and output prices. The returns from poplar trees were calculated at the age of four years including cost of cultivation and total returns.

## RESULTS AND DISCUSSION

### *Tree growth*

The poplar diameter at breast height (DBH) on an average increased from 10.36 cm to 16.48 cm in a span of 2 years (Table 1). The mean height of the poplar trees was recorded to be 10.37 m after 2 years of growth. The subsequent gain in height of the trees was 9.74% in third year and 31.33% in fourth year. Consequently, the mean values

of clear bole increased from 7.20 m to 12.13 m with increase in age and height of poplar. The mean clear bole length increased with increase in age of poplar from 2 to 3 years as pruning had been practiced during third year in December. Generally poplar is harvested after 6 - 7 years of plantation, thus pruning is done to provide more light to understorey crops and for better quality of timber. The average crown diameter was recorded to be 2.44 m in 2-year old and 4.25 m in 4-year old plantation.

### *Crop growth performance*

Plant height of wheat was significantly more in sole than the intercropping with poplar (Table 2). The plant height of wheat reduced with progressive increase in age of poplar. Similarly all other crop growth parameters *viz.,* tiller number, spike length, 100-grain weight and straw yield were maximum under open conditions when compared with wheat grown under poplar plantation. The significant difference between intercropped wheat and sole wheat in respect of all parameters suggests that shade effect of poplar trees might have reduced germination and seedling growth of intercrop. All these growth parameters showed inverse relationship with the age of plantation. The number of tillers, spike length and 100-grain weight decreased under higher aged plantation. Although the differences in number of tillers under 3 to 4 year old poplar were non significant, whereas the rest of growth parameters were significantly more under 3-year old than 4-year old poplar plantation. It might be due to effect of tree-crop competition, which extended with age of trees. There was non-significant difference with respect to wheat plant height under different seed rates during all the 3 years (Table 2). However, the number of effective tillers varied significantly under different seed rates. The effective tillers increased with increase in seed rate from 100 to 150 kg/ha. This increase in number of tillers with increasing seed rate may be due to more number of seedlings/m on account of higher seed rates. Besides, higher seed rate compensates the loss of seed and seedlings damaged due to birds under trees. The production of more leaf litter in higher aged plantation is among one of the primary factors that adversely affects the crop. Singh *et al.* (2007) observed that leaf litter increased with age of poplar and litterfall was significantly higher during November (1.72 tonne/ha) and

**Table 1.** Performance of different age groups of poplar at Ludhiana, Punjab

| Parameter | 2005 | 2006 | 2007 |
|---|---|---|---|
| Poplar age | 2 years | 3 years | 4 years |
| Diameter at breast height (cm) | 10.36 | 12.68 | 16.48 |
| Height (m) | 10.37 | 11.38 | 15.15 |
| Clear bole (m) | 7.20 | 7.45 | 12.13 |
| Crown length (m) | 3.17 | 3.93 | 3.02 |
| Crown diameter (m) | 2.44 | 3.14 | 4.25 |

**Table 2.** Performance of intercropped wheat as affected by age of poplar plantation, seed rates and fertilizer levels at Ludhiana, Punjab

| Treatment | Plant height (cm) | Tiller no./m row length | Spike length (cm) | 100-grain weight (g) | Grain yield* (tonne/ha) | Straw yield (tonne/ha) |
|---|---|---|---|---|---|---|
| *Age of poplar (years)* | | | | | | |
| Open | 87.2 | 100.1 | 10.6 | 4.61 | 4.53 | 6.22 |
| 3 | 84.3 | 92.3 | 9.4 | 4.18 | 3.88 | 5.74 |
| 4 | 82.5 | 89.2 | 8.7 | 3.20 | 3.30 | 5.63 |
| SEm± | 0.6 | 0.9 | 0.02 | 0.01 | 0.03 | 0.05 |
| CD (P=0.05) | 3.3 | 5.6 | 0.13 | 0.05 | 0.19 | 0.31 |
| *Seed rate (kg/ha)* | | | | | | |
| $S_1$ (100) | 85.4 | 90.1 | 9.58 | 3.98 | 3.76 | 5.67 |
| $S_2$ (125) | 85.0 | 94.7 | 9.54 | 4.05 | 3.98 | 5.89 |
| $S_3$ (150 ) | 83.7 | 96.8 | 9.62 | 3.96 | 4.11 | 6.03 |
| SEm± | 0.9 | 0.7 | 0.02 | 0.01 | 0.02 | 0.05 |
| CD (P=0.05) | NS | 4.3 | NS | 0.04 | 0.13 | NS |
| *Fertilizer level (kg N-P/ha)* | | | | | | |
| $F_1$ (125-27) | 78.8 | 89.9 | 9.47 | 3.98 | 3.73 | 5.32 |
| $F_2$ (187.5-27) | 84.7 | 94.2 | 9.81 | 4.07 | 3.93 | 5.85 |
| $F_3$ (187.5-40.5) | 86.0 | 94.6 | 9.37 | 3.95 | 4.02 | 6.08 |
| $F_4$ (250-27) | 86.6 | 94.6 | 9.64 | 3.96 | 4.01 | 5.82 |
| $F_5$ (250-40.5) | 87.2 | 96.0 | 9.62 | 4.02 | 4.06 | 6.24 |
| SEm± | 0.8 | 1.0 | 0.12 | 0.01 | 0.04 | 0.05 |
| CD (P=0.05) | 3.1 | 4.1 | NS | 0.05 | 0.15 | 0.20 |

*Grain yield under 2-year-old poplar=4.09 tonne/ha

December (1.77 tonne/ha) than other months in five-year-old poplar plantation, thus inhibiting the seed germination and tillering of wheat. However, there was no significant difference in tiller number between 125 and 150 kg/ha seed rate under different age of plantation. The seed rates did not affect spike length significantly. The 100-grain weight significantly increased with increase in seed rate upto 125 kg/ha. But further increase in seed rate to 150 kg/ha decreased the grain weight. Higher plant population on account of increased tiller number might be the reason for lower 100-grain weight at higher seed rate. The straw yield also increased with increasing seed rates. This production of more straw at higher seed rates might be attributed to the fact that straw yield is additive and complementary effect of growth parameters *viz.* tiller height, number of total tillers and spike length. Srivastava *et al.* (1996) also reported higher grain and straw yield of wheat in response to higher seed rate.

The fertilizer doses had significant impact on all crop growth parameters like plant height, tiller number, 100-grain weight and straw yield. Nitrogen being an essential constituent of chlorophyll, protoplasm and enzymes is well known to promote the growth of plants. An increase in N level from 125 to 187.5 kg/ha significantly increased the plant height (Table 2). The height of tillers continued to increase with increase in the fertilizer doses from $F_1$ to $F_5$. The increased supply of N accelerates synthesis of chlorophyll and amino acids resulting in higher vegetative growth. Maximum plant height was observed where 250 kg N and 40.5 kg P/ha were applied. However, the effect of fertilizers on plant height was found to be significant upto $F_2$ only. Similar trend was observed in tiller number where number of tillers increased significantly from 125 kg N/ha ($F_1$) to 187.5 kg N/ha ($F_2$) along with 27 kg recommended P. Subsequent increase in dose of nitrogen and phosphorus also marginally enhanced the number of tillers and treatments were statistically at par with each other. The spikes of wheat crop were observed slightly longer under 187.5 kg N along with 27 kg P/ha. However, the differences were non-significant. Higher dose of fertilizers significantly increased the 100 grain weight. The grain weight was maximum under $F_2$ and further increase in N and P levels failed to appreciate grain weight. This beneficial effect of N and P was owing to well developed root system, facilitating better nutrition of tillers and flower primordial which directly produced well developed spike with more assimilating area to fill the storage tissue with photosynthates (Nerson *et al*., 1990). Straw yield of wheat was highest under $F_5$ (250 kg N and 27 kg P/ha). It may be attributed to the cumulative effect of more plant height, tiller number and spike length.

### *Crop productivity*

In general, the quantum of wheat yield was observed to be low under higher age plantation. It was in the order of 4.09>3.88>3.30 t/ha (Table 2) when averaged over seed rates and fertilizer levels during 2, 3 and 4 year of poplar growth. This indicates that the tree-crop competitive interactions increase with increase in age of poplar trees that might be due to different level of competition for light and soil resources under different aged plantations. Poplars at early age cause less adverse effects on understorey crops but at later stages reduce the crop stand due to more production of leaf litter.

The grain yield of wheat was significantly higher under additional seed rates (Table 2). Highest response was obtained at seed rate of 50% more than recommended (150 kg/ha) in 2, 3 as well as 4-year old plantations but it was statistically at par with the seed rate of 25% more than recommended dose under all the fertilizer levels (Table 3). At this rate (125 kg/ha) there was 10%, 12% and 12.7% increase in seed yield over recommended dose in 2, 3 and 4-year old poplars, respectively. Kohli *et al*. (1997) reported that allelopathic effect of poplar trees played a vital role in growth suppression of associated crops or understorey vegetation. Higher seed rate has significantly increased the effective tillers/m, which was due to more number of mother shoots. Besides, the 100-grain weight was enhanced significantly with the increase in seed rate, consequently, grain yield was higher under higher seed rate in poplar.

The grain yield of wheat increased significantly with increase in the fertilizer dose in poplar plantation (Table

**Table 3.** Wheat grain yield (t/ha) under open and different aged poplar as affected by seed rates and fertilizer levels

| Age of poplar | Seed rate (kg/ha) | | |
|---|---|---|---|
| | $S_1$(100) | $S_2$ (125) | $S_3$ (150) |
| Open | 4.69 | 4.39 | 4.52 |
| 2 | 3.80 | 4.18 | 4.28 |
| 3 | 3.55 | 3.98 | 4.13 |
| 4 | 3.00 | 3.38 | 3.51 |
| SEm ± | | 0.07 | |
| CD (P=0.05) | | 0.25 | |

| | *Fertilizer level (kg N-P/ha)* | | | | |
|---|---|---|---|---|---|
| | $F_1$ (125-27) | $F_2$ (187.5-27) | $F_3$ (187.5-40.5) | $F_4$ (250-27) | $F_5$ (250-40.5) |
| Open | 4.24 | 4.63 | 4.60 | 4.66 | 4.54 |
| 2 | 3.74 | 4.14 | 4.18 | 4.19 | 4.19 |
| 3 | 3.58 | 3.88 | 3.98 | 3.91 | 4.07 |
| 4 | 2.95 | 3.63 | 3.32 | 3.29 | 3.46 |
| SEm ± | | | 0.10 | | |
| CD (P=0.05) | | | 0.29 | | |

3). Minimum grain yield under different aged poplar and in open conditions was observed with the application of recommended fertilizers ($F_1$) and a significantly higher yield was obtained at $F_2$. Further increase in the fertilizer doses did not increase the yields significantly. But the data revealed that yield was statistically at par between $F_2$ and $F_4$. Thus the additional dose of N with recommended P increased the yield significantly under poplar plantations. Increase in yield due to increase in fertilizer levels of N and P has been reported earlier (Singh *et al.,* 1996). The significant response of wheat to additional nitrogen in poplar and in open may be due to requirement of poplar trees for this essential element and the soil of the site was very low in available N (147 kg/ha). The root system of the crop is usually confined to soil strata that are also available to the tree root system, but the tree can also exploit soil layers beyond the reach of associated crop. The roots of poplar absorb this nutrient from the cropped area across the tree, thus lowering the quantity of the element in the soil, which ultimately lead to reduction in crop yield, where lower dose of nitrogen has been applied. This competition for nutrients increases with increase in tree height, girth and crown spread with age of trees. As both poplar and wheat crop depend on the same soil reserves for meeting their needs with respect to moisture and nutrients. Therefore, additional dose of nitrogen is required for meeting the demand of wheat under poplar. Besides, a very high C:N ratio (38.7:1, C-48.8% and N-1.26%) of poplar leaf litter might have lead to initial immobilization of N during decomposition of litter mass. Initial immobilization of N by micro-organisms while decomposing the litter of tree species has been observed (Maharudrappa *et al.,* 2000). Maximum grain yield of wheat in poplar spaced at 5 m × 3 m was reported at 150% of the recommended dose of nitrogen by Sharma *et al.* (1998). A declining trend has been observed with respect to grain and straw yield from 2 to 4-year-old plantation which might be due to increase in below and above ground competition. Besides this, increase in root development and shade of trees also adversely affects the yield of associated crops. The interaction effect of S x F and A x S x F were non-significant.

### *Nutrient uptake*

The treatment main effects indicated a significant effect of poplar age, seed rates and fertilizers on N and P uptake by wheat (Table 4). The average uptake of N and P by wheat was the highest in open conditions, which decreased significantly (except N uptake by wheat straw) under poplar. Higher uptake of nutrients in open conditions than under poplar might be due to higher grain as well straw yield in open than under the trees. Higher uptake of N, P and K by wheat in open condition than under 6 year old poplar has been observed by Gill *et al.* (2009) in Punjab. Lower removal of N and P by wheat grain and straw was observed under different tree species when compared with wheat in open conditions (Yadav *et al.*, 2005).

The uptake of nutrients increased significantly with

**Table 4.** Uptake (kg/ha) of N and P by wheat grain and straw as affected by age of poplar, seed rates and fertilizers at Ludhiana, Punjab

| Treatment | Grain | | Straw | | Total uptake | |
|---|---|---|---|---|---|---|
| | N | P | N | P | N | P |
| *Age of poplar (years)* | | | | | | |
| Open | 76.5 | 20.53 | 44.0 | 15.35 | 120.5 | 35.87 |
| 3 | 69.4 | 18.10 | 43.3 | 14.34 | 112.7 | 32.44 |
| 4 | 59.5 | 15.61 | 43.1 | 14.20 | 102.6 | 29.81 |
| SEm± | 0.6 | 0.31 | 0.5 | 0.14 | 1.3 | 0.18 |
| CD (P=0.05) | 3.6 | 1.89 | NS | 0.84 | 7.6 | 1.12 |
| *Seed rate (kg/ha)* | | | | | | |
| $S_1$ (100) | 65.6 | 17.34 | 41.2 | 14.18 | 106.8 | 31.52 |
| $S_2$ (125) | 68.7 | 18.20 | 43.8 | 14.79 | 112.5 | 32.98 |
| $S_3$ (150) | 71.2 | 18.69 | 45.4 | 14.93 | 116.6 | 33.62 |
| SEm± | 0.3 | 0.09 | 0.3 | 0.07 | 1.1 | 0.17 |
| CD (P=0.05) | 1.6 | 0.57 | 1.5 | 0.43 | 6.8 | 1.02 |
| *Fertilizer level (kg N-P/ha)* | | | | | | |
| $F_1$ (125-27) | 62.9 | 15.62 | 37.0 | 11.35 | 99.9 | 26.98 |
| $F_2$ (187.5-27) | 66.9 | 17.00 | 42.4 | 13.44 | 109.3 | 30.43 |
| $F_3$ (187.5-40.5) | 69.4 | 19.32 | 45.3 | 16.70 | 114.7 | 36.03 |
| $F_4$ (250-27) | 71.1 | 17.95 | 44.8 | 13.84 | 115.9 | 31.77 |
| $F_5$ (250-40.5) | 72.2 | 20.50 | 47.8 | 17.82 | 119.9 | 38.33 |
| SEm± | 0.4 | 0.22 | 0.4 | 0.18 | 1.9 | 0.32 |
| CD (P=0.05) | 1.7 | 0.86 | 1.4 | 0.71 | 7.4 | 1.27 |

**Table 5.** Cost of cultivation, net returns (Rs x $10^3$/ha) and benefit: cost ratio (on net returns basis) of various treatments under different aged poplars.

| Treatment | Cost of Cultivation | Age of poplar | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sole wheat | | 3 years | | 4 years | |
| | | Net returns | BCR | Net returns | BCR | Net returns | BCR |
| $S_1F_1$ | 16.29 | 22.97 | 1.41 | 13.49 | 0.83 | 9.55 | 0.59 |
| $F_2$ | 16.81 | 28.15 | 1.67 | 17.12 | 1.02 | 14.35 | 0.85 |
| $F_3$ | 17.21 | 26.95 | 1.57 | 17.49 | 1.02 | 12.23 | 0.71 |
| $F_4$ | 17.35 | 29.04 | 1.67 | 16.37 | 0.94 | 12.06 | 0.70 |
| $F_5$ | 17.75 | 29.84 | 1.68 | 18.16 | 1.02 | 13.78 | 0.78 |
| $S_2F_1$ | 16.64 | 24.13 | 1.45 | 17.24 | 1.04 | 11.76 | 0.71 |
| $F_2$ | 17.16 | 24.83 | 1.45 | 19.97 | 1.16 | 16.98 | 0.99 |
| $F_3$ | 17.57 | 25.75 | 1.47 | 20.44 | 1.16 | 15.40 | 0.88 |
| $F_4$ | 17.70 | 23.54 | 1.33 | 21.42 | 1.21 | 16.60 | 0.94 |
| $F_5$ | 18.11 | 21.12 | 1.17 | 22.34 | 1.23 | 18.17 | 1.00 |
| $S_3F_1$ | 17.01 | 25.89 | 1.52 | 18.95 | 1.11 | 14.13 | 0.83 |
| $F_2$ | 17.51 | 24.08 | 1.37 | 22.55 | 1.29 | 18.67 | 1.07 |
| $F_3$ | 17.93 | 24.41 | 1.36 | 23.16 | 1.29 | 18.71 | 1.04 |
| $F_4$ | 18.05 | 21.06 | 1.17 | 21.97 | 1.22 | 17.08 | 0.95 |
| $F_5$ | 18.47 | 23.08 | 1.25 | 22.28 | 1.21 | 16.79 | 0.91 |

Prices (average of 3 years) of inputs and outputs (Rs/kg): seed: 11.45; seed treatment: 3.0, urea: 3.95; Diammonium phosphate: 7.75; wheat grain: 7.3 and wheat straw: 1.5.
For poplar: Total costs of cultivation: Rs 30,500; Net returns after 4 years: Rs 1, 97,500

increase in seed rate, which is attributed to higher grain as well as straw yield at higher seed rate than the lower rate. Singh *et al*., (1993) observed that increasing seed rate of wheat from 100 to 150 kg/ha increased grain and straw yields significantly which ultimately would have lead to higher uptake of nutrients at higher seed rate. Similar trend was noticed with total uptake by grain and straw.

### *Economics*

The benefit cost ratio (B: C ratio) *i.e.* 1.68 and net returns (Rs 29,840/ha) of sole wheat were maximum at recommended seed and $F_5$ fertilizer level (Table 5). In 3- and 4-year-old poplars, 150 kg/ha seed ($S_3$) along with $F_2$ gave highest B:C rato *i.e.* 1.29 and 1.07 respectively whereas, the net returns were maximum at $S_3F_3$ *i.e.* Rs. 23,160 and Rs 18,710/ha under 3- and 4-year-old plantation, respectively, which were about 72% and 96% higher than at recommended practice of 100 kg/ha seed rate ($S_1$) and 150-27 kg N-P/ha ($F_1$) under poplar. The total costs of cultivation of poplar were Rs 30,500 and net returns from poplar at the age of 4 years were Rs 1, 97,500.

Thus, the adverse effect of increasing poplar age can be reduced by use of higher seed (125 kg/ha) and nutrients (187.5 - 27 kg N-P/ha) to intercropped wheat. This will increase wheat productivity and economic returns in addition to better growth of the poplar trees.

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## REFERENCES

Anonymous. 2004. Package of practices for crops of Punjab, *rabi* 2004-05. Punjab Agricultural University, Ludhiana.

Gill, R.I.S., Singh, B. and Kaur, N. 2009. Productivity and nutrient uptake of newly released wheat varieties at different sowing times under poplar plantation in north-western India. *Agroforestry Systems* **76**: 579–590.

Kohli, R.K., Singh, H.P. and Batish, D.R. 1997. Phytotoxic potential of *Populus deltoides* Bartr. Ex Marsh. I. Comparative contribution of different parts. *Indian Journal of Forestry* **20**: 300–304.

Lal, P. 2007. Productivity of clonal plantations in northern India. *Indian Forester* **133**: 1014–1019.

Maharudrappa, A., Srinivasamurthy, C.A., Nagaraja, M.S., Siddaramappa, R. and Anand, H.S. 2000. Decomposition rates of litter and nutrient release pattern in a tropical soil. *Journal of the Indian Society of Soil Science* **48**: 92–97.

Nerson, H., Bhan, S. and Uttam, S.K.1990. Effect of N and P nutrition on spike development in spring wheat. *Plant and Soil* **124**: 33–37.

Sharma, S.K., Chauhan, S.K. and Handa, A.K.1998. Wheat based agroforestry system under rainfed ecosystem. *Range Management and Agroforestry* **19**: 43–48.

Singh, G., Singh, O.P., Yadava, R.A. and Singh, R.S. 1993. Re-

sponse of wheat (*Triticum aestivum*) to planting method, seed rate and fertility in late sown conditions. *Indian Journal of Agronomy* **38**: 195–199.

Singh, G., Singh, R. and Kumar, P .1996. Response of wheat (*Triticum aestivum*) to nitrogen, phosphorus and potassium fertilization. *Indian Journal of Agronomy* **41**: 157–159.

Singh, B., Gill, R.I.S. and Kaur, N. 2007. Litterfall and nutrients return in poplar plantation varying in row direction and spacings. *Indian Journal of Agroforestry* **9**: 33–37.

Srivastava, U.S.L., Paltoo, R. and Prakash, O. 1996. Response of wheat (*Triticum aestivum*) to row spacing, seed rate and fertilizer. *Indian Journal of Agronomy* **41**: 558–561.

Yadav, A.K.2001.Cultivation of lemon grass (*Cymbopogon flexuosus*, 'CKP-25') under poplar based agroforestry system. *Indian Forester* **127**: 213–223.

Yadav, R.S., Yadav, B.L., Chhipa, B.R. and Keshwa, G.L. 2005. Nutrient removal and yield of wheat (*Triticum aestivum* Linn.) as influenced by different tree species in agroforestry under semi-arid condition of Rajasthan. *Indian Journal of Agroforestry* **7**: 21–24.