International Journal of Silviculture and Agroforestry ISSN 1720-349X Vol. 1 (6), pp. 038-045, August, 2017. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

*Full Length Research Paper*

# Effect of spacing and fertility levels on growth and yield of wheat *(Triticum aestivum L.)*

***Rajesh Mishra, Salman Patel and Gangadhar Jagdish**

Department of Silviculture and Agroforestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni-173 230 (HP), India.

Accepted 17 July, 2017

**A field experiment was laid out at Pantnagar (Uttarakhand, India) in Mollisols during rabi season (2009-10) to study effect of spacing and fertility levels on growth and yield of wheat (*Triticum aestivum* L.) under different tree species in Terai region. The experiment was conducted in split-split plot design comprising four tree species in main plots, four spacing treatments in sub plots and four fertility levels in sub-sub plot with three replications. The wheat crop var. PBW-502 was sown on November 29, 2009 and harvested on April 21, 2010. Significant higher grain yield was recorded under Poplar (44.60 qha$^{-1}$); however, it was statistically at par with Melia (42.60 qha$^{-1}$) interface at 180-60-40 kg NPK ha$^{-1}$ fertility level. At 3 × 2.5 m, the wheat growth, yield attributes and yield (grain, straw and biological yield) under Poplar was significantly higher than closer spacing. Application of 180-60-40 kg NPK ha$^{-1}$ had significant effect on crop growth and grain yield than other levels of fertility. The correlation coefficient (r) studies exhibited that wheat growth and yield attributing characteristics are significantly ($p<0.05$) and positively correlated with each other.**

**Key words:** Tree species, spacing, fertility levels, wheat, growth, yield attributes, yield.

## INTRODUCTION

The pressure from increasing population and urbanization, coupled with land degradation and climate change are the major causes for food insufficiency in developing world. Among different approaches to combat this problem, woody perennial based production systems has the great potential. Historically, agroforestry in India involved two distinct pathways, viz., growing food crops in the forests and establishing tree-crop production systems on arable lands. Agroforestry systems not only arrest land degradation but also improve site productivity through interactions among trees, soil, crops, and livestock (Kumar, 2006). This is the most important way to practice agriculture without deteriorating agro-diseases and environmental degradation is highly appreciable (Garrity, 2004).

Wheat (*Triticum aestivum* L.) is the most important food crop under agroforestry system in North Indian states, which accounted 88.31 million tones production in 2011-

*Corresponding author. E-mail: mishra.rajesh@hotmail.com

12. In India, it is widely intercropped cereal crop during *rabi* season (November-April) with Poplar, Eucalyptus and other fast growing short rotation tree species in Uttarakhand, Punjab, Haryana, U.P and Bihar states in north-and-parts of central and eastern states of M.P, Chhatisgarh and W.B. The micro-climate under agroforestry is modified by trees, under such conditions;ecosystems. Its role in the light of combating hunger, the growth response of under story wheat crop may be different from sole cropping system. The wheat production technology in Indo-Gangetic plains is well established but it may require some refinement in technology in mixed land-use systems, like agroforestry particularly nutrient management aspect, where wheat is grown in association with trees. Agroforestry systems have more than two components, which makes it productive and complex in nature as well. The fundamental challenge is therefore to develop a farming system that will be adopted by the farmers. The dynamic nature of nutrient cycling is one of the obstacles in nutrient management in agroforestry systems. It dictates that soil nutrient capital useful for supplying nutrients for plant growth must be equated with short to medium-term, rolling capital (the monthly or annual salary), rather than long-term reserves (gold in the bank). The role of organics is varied and complex, the challenge is to use organics of differing quality in combination with inorganic fertilizers to optimize nutrient availability to plants. A systematic framework for investigating the use of inorganic nutrient sources includes assessment of the fertilizer equivalency value for determining optimal use of nutrient sources. The desired outcome is tools that can be used by researchers and farmers for assessing options of using scarce resource for maintaining soil fertility and improving crop yields.

Usually farmers grow multipurpose tree species on their farmlands to meet their requirements. But the selection of tree species, spacing and the fertility levels are very important to reduce negative tree-crop interactions. Reduction in the yield of annuals arises either due to selection of non-compatible agricultural crop or improper tree spacing. Since no proper spacing as yet has been standardized in different agroforestry systems to avoid the adverse effect of trees on growth and yield of intercrops, therefore, there is a need to determine proper tree spacing for intercropping in agroforestry systems.

## MATERIALS AND METHODS

The field experiment was conducted at Agroforestry research center, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29°N Latitude, 79° 30' E longitude and at an altitude of 243.84 masl) during 2009-2010. The plot comprised silty-clay-loam soil with 1.2% of organic carbon, 227, 23 and 230 kg $ha^{-1}$ available nitrogen, phosphorus and potassium, respectively. The site is characterized by a humid sub-tropical, cold and hot dry summers with 1400 mm mean annual rainfall, of which 80 to 90% is received between June and September. The remaining 10 to 20% rainfall is received during wheat-growing season (November to April). Soybean-wheat crop rotation was followed under short rotation fast growing tree species.

Four tree species of $T_1$: Poplar, S7C20 (*Populus deltoides*), $T_2$: Eucalyptus, K23 (*Eucalyptus camaeldulensis*), $T_3$: Leucaena, K636 (*Leucaena leucocephala* and $T_4$: Melia, Local (*Melia azedarach*) were planted in 2007 with four spacing treatments of $S_1$: 3 × 1.0 m, $S_2$: 3 × 1.5 m, $S_3$: 3 × 2 m and $S_4$: 3 × 2.5 m. The wheat (PBW - 502) was sown with a uniform row-to-row distance of 20 cm. At the time of sowing half dose of N (N doses are varied), 60 kg $P_2O_5$ $ha^{-1}$ and 40 kg $K_2O$ $ha^{-1}$ were applied. The remaining half nitrogen was applied before first irrigation (crown root initiation stage). Three irrigations were applied to the crop coinciding with crown root initiation (21 days after sowing), late jointing (65 DAS) and milking stage (105 DAS). The crop was fertilized with four treatments of $F_0$: No fertilizer, $F_1$: 120-60-40 kg $ha^{-1}$ NPK, $F_2$: 150-60-40 kg $ha^{-1}$ NPK and $F_3$: 180-60-40 kg $ha^{-1}$ NPK through urea, diammonium phosphate (DAP) and murate of potash, respectively. The experiment was designed as split-split-plot with tree species in main plots, spacing in sub-plots and fertility levels treatments in sub-sub-plots and treatments were replicated thrice. The area of the net plot was 3 $m^{-2}$ (3 × 1 m) for the wheat crop.

Leaf area was recorded at anthesis (90 DAS) by an area meter and converted to leaf area index (LAI) with dividing total leaf area by land area of the sample. The plant height and the dry matter accumulation were recorded at maturity stage (142 DAS). The number of spikes per meter row length, ear length, spikelets $spike^{-1}$, number of grains $spike^{-1}$ and 1000-seed weight was recorded at physiological maturity. The net plots were harvested to obtain grain/ seed, straw and biological yield. Harvest index was calculated as the ratio of grain to total biological yield.

Data obtained during the course of this investigation, was analyzed by using standard statistical procedure for split-split plot design with the help of computer for analysis of variance (ANOVA) technique (Snedecor and Cochran, 1967). Standard error of mean (SEm±) were computed in each case. The differences among treatments were compared by applying "F" test of significance at 5% probability. Correlation studies (Panse and Sukhatme, 1978) were also performed to study the inter-relationship between various parameters.

## RESULTS AND DISCUSSION

### Wheat growth

The wheat growth was significantly varied with respect to different tree species at different spacing and fertility levels (Table 1). The leaf area index (LAI) was significantly higher (3.36) under Poplar interface. The LAI increased significantly with widening spacing of all tree species. It was significantly higher (3.18) at 3 × 2.5 m spacing. LAI was significantly increased from 2.30 to 3. 38 and 4.45 as nitrogen dose increases from 120 to 150 and 180 kg $ha^{-1}$, respectively. The tallest crop individuals were recorded under Poplar (81.6 cm); however, it was statistically at par with Melia (80.4 cm) interface. The wider spacing (3 × 2.5 m) contributed to produce taller (81.9 cm) crop plants. The crop height was significantly higher at plots fertilized with 180-60-40 kg NPK $ha^{-1}$, whereas, it was statistically at par with 150-60-40 kg NPK $ha^{-1}$ fertilized plots. Dry matter accumulation followed same pattern of the plant height and LAI. The interaction between tree species and fertility level for LAI was also found to be significant, whereas, tree species and their spacing interaction were

**Table 1.** Effect of tree species, spacing and fertility levels on wheat growth and yield.

| Treatments | Growth | | | Yield attributes | | | | | Yield (q ha$^{-1}$) | | | Harvest Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LAI | Plant height (cm) | Dry matter accumulation (g) | Ear bearing shoots m$^{-2}$ | Spike length (cm) | Spikelets spike$^{-1}$ | Grain number spike$^{-1}$ | 1000-grain weight (g) | Grain | Straw | Biological | |
| T1 | 3.36 | 81.6 | 739.4 | 406.5 | 8.2 | 16.9 | 43.7 | 36.4 | 25.6 | 45.6 | 71.2 | 0.34 |
| T2 | 2.50 | 72.8 | 697.8 | 380.0 | 5.6 | 13.4 | 29.7 | 33.7 | 18.7 | 38.1 | 56.8 | 0.31 |
| T3 | 2.55 | 77.8 | 713.9 | 383.4 | 5.9 | 14.7 | 34.8 | 34.6 | 21.1 | 40.7 | 61.8 | 0.32 |
| T4 | 2.77 | 80.4 | 722.9 | 392.3 | 6.1 | 15.2 | 36.9 | 35.6 | 23.4 | 43.2 | 66.6 | 0.33 |
| SEm± | 0.030 | 0.73 | 4.2 | 5.0 | 0.04 | 0.30 | 0.78 | 0.16 | 0.48 | 0.38 | 0.83 | 0.004 |
| CD $_{0.05}$ | 0.10 | 2.5 | 14.5 | 17.4 | 0.2 | 1.0 | 2.7 | 0.55 | 1.66 | 1.30 | 2.86 | 0.015 |
| CV (%) | 7.4 | 6.5 | 4.1 | 8.9 | 5.0 | 13.5 | 14.8 | 3.1 | 14.9 | 6.2 | 8.9 | 9.4 |
| S1 | 2.35 | 76.1 | 675.4 | 377.4 | 5.7 | 13.8 | 29.4 | 32.7 | 18.0 | 37.7 | 55.7 | 0.30 |
| S2 | 2.71 | 76.2 | 718.9 | 383.3 | 6.3 | 14.7 | 35.5 | 34.1 | 20.2 | 39.9 | 60.2 | 0.32 |
| S3 | 2.93 | 78.3 | 726.9 | 392.1 | 6.7 | 15.1 | 37.4 | 35.6 | 23.3 | 43.0 | 66.2 | 0.33 |
| S4 | 3.18 | 81.9 | 753.0 | 409.4 | 7.1 | 16.8 | 42.8 | 37.9 | 27.3 | 47.0 | 74.4 | 0.35 |
| SEm± | 0.029 | 0.69 | 4.9 | 3.6 | 0.04 | 0.27 | 0.73 | 0.089 | 0.42 | 0.42 | 0.83 | 0.003 |
| CD $_{0.05}$ | 0.08 | 1.9 | 13.9 | 10.2 | 0.12 | 0.75 | 2.1 | 0.25 | 1.17 | 1.17 | 2.34 | 0.008 |
| CV (%) | 7.1 | 6.1 | 4.8 | 6.4 | 4.7 | 12.3 | 14.0 | 1.8 | 13.0 | 6.9 | 9.0 | 6.2 |
| F0 | 1.04 | 55.9 | 545.5 | 350.3 | 4.1 | 9.4 | 13.4 | 27.4 | 9.2 | 28.9 | 38.0 | 0.23 |
| F1 | 2.30 | 83.5 | 719.6 | 391.5 | 5.4 | 15.6 | 37.9 | 35.0 | 17.4 | 37.1 | 54.4 | 0.31 |
| F2 | 3.38 | 85.8 | 773.5 | 401.8 | 7.2 | 17.0 | 42.5 | 37.6 | 24.0 | 43.7 | 67.6 | 0.35 |
| F3 | 4.45 | 87.3 | 835.5 | 418.6 | 9.0 | 18.4 | 51.2 | 40.3 | 38.4 | 58.1 | 96.4 | 0.39 |
| SEm± | 0.03 | 0.60 | 4.3 | 3.5 | 0.04 | 0.30 | 0.86 | 0.14 | 0.45 | 0.45 | 0.90 | 0.004 |
| CD $_{0.05}$ | 0.09 | 1.7 | 12.6 | 10.0 | 0.13 | 0.88 | 2.5 | 0.42 | 1.32 | 1.32 | 2.64 | 0.012 |
| CV (%) | 7.7 | 5.3 | 4.2 | 6.1 | 4.9 | 13.9 | 16.4 | 2.8 | 14.1 | 7.5 | 9.8 | 8.9 |

found to be non-significant. The LAI was significantly higher (5.22) under Poplar with 180-60-40 kg NPK ha$^{-1}$ fertility level (Figure 1). The interaction among factors was non-significant for plant height and dry matter production.

The crop growth is mainly affected by light and nutrient availability. Leaf litter inputs from agro-forestry trees could provide sufficient nutrients and organic matter to sustain crop growth (Lehmann et al., 2002; Bhardwaj et al., 2005). However, concentrations of foliar nutrients and organic constituents show considerable variation from different tree species. The leucaena added valuable nutritive leaf litter and improved soil properties, which help to improve crop growth. As poplar tree species shed their leaves before sowing of wheat crop, improves soil physic-chemical properties and nullified the negative tree-crop interaction for light. Corroborative findings have also been reported by Bhardwaj et al. (2005), Teklay (2004), Patil et al. (2002); Pant (1993) and Sidhu and Hans (1988). The poor wheat growth showed under eucalyptus due to inhibitory effects of allelochemicals. Similar findings were recorded by Fikreyesus et al. (2011) in the case of tomato; Ahmed et al. (2008); Kaushik and Singh (2001) for agricultural rabi crops. Negative tree-crop interactions for light, moisture and nutrients at closer spacing reduces crop growth rate. At closer spacing tree species

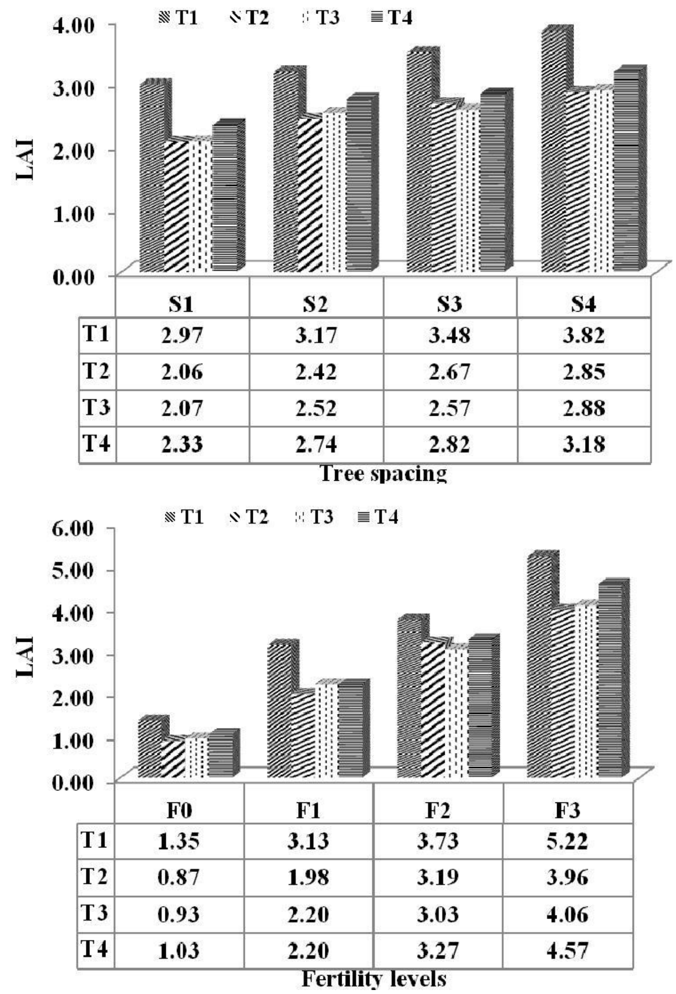



**Figure 1.** Wheat growth influenced by tree species, spacing and fertility levels.

utilize more resources for their growth and development. Sharma et al. (2000) also reported that close spacing increased amount of leaf litter, which inhibited the crop growth. Corroborative results were reported by Khan and Ehrenerich (1994). Additional supply of inorganic nutrients reduces tree-crop competition for nutrients resulting increase in crop growth. Corroborative results were reported by Ahmed et al. (2002) and Smithson and Giller (2002).

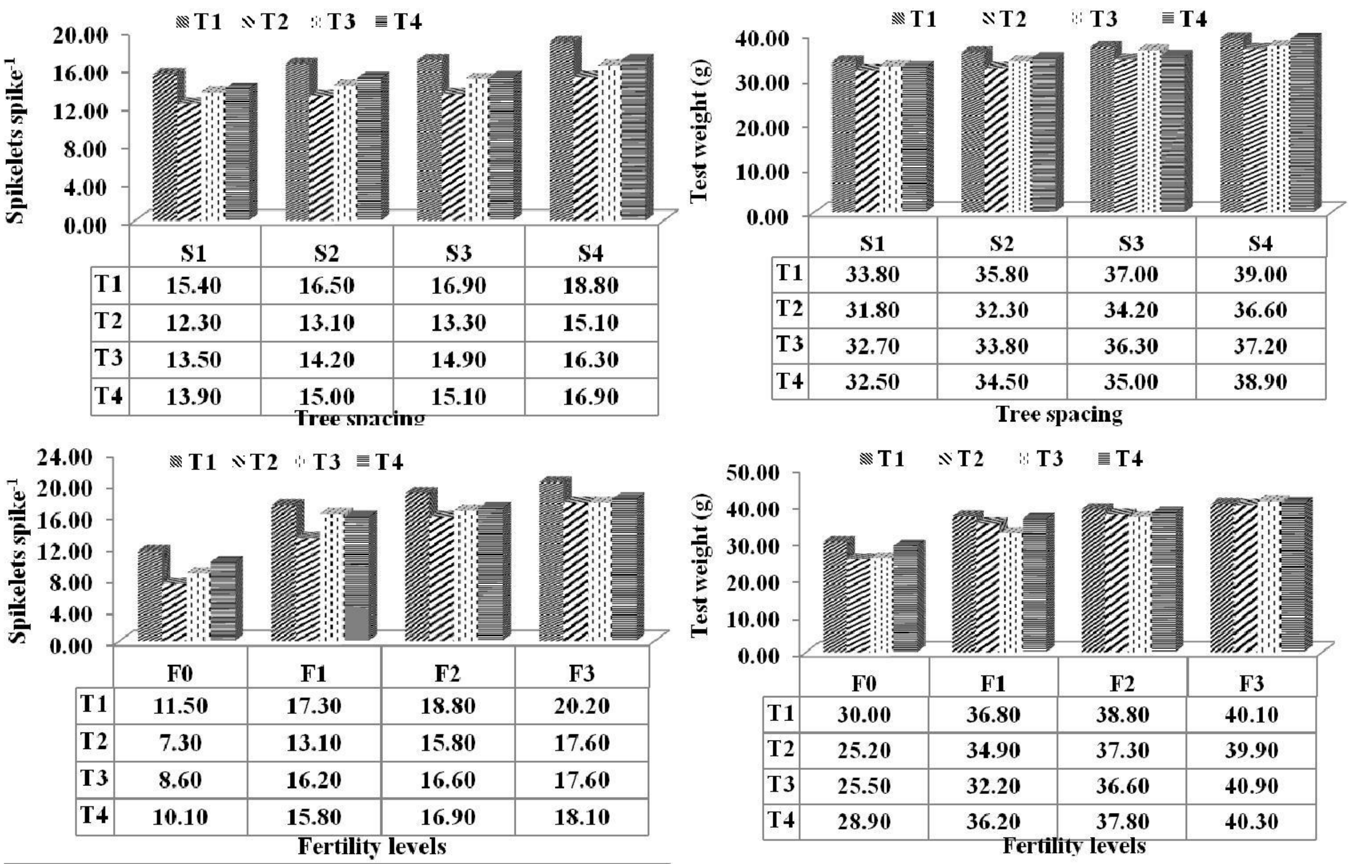
### Yield attributes

Ear bearing shoots m$^{-2}$, spike length, spikelets spike$^{-1}$, grain number spike$^{-1}$ and 1000-grain weight (test weight) was significantly affected by tree species, spacing and fertility levels (Table 1). The ear bearing shoots m$^{-2}$ were highest under Poplar (406.5) followed by Melia (392.3), Leucaena (383.4) and Eucalyptus (380.0) interface. Wider spacing (3 m×2.5 m) and 180-60-40 kg NPK ha$^{-1}$ fertility level recorded higher ear bearing shoots m$^{-2}$. The spike length was significantly higher under Poplar (8.2 cm) interface at wider spacing (7.1 cm) with 180-60-40 kg NPK ha$^{-1}$ fertility levels (9.0 cm).

The spikelets spike$^{-1}$ was followed the same pattern of spike length. The Poplar (43.7) interface at wider spacing (42.8) with 180-60-40 kg NPK ha$^{-1}$ fertility levels (51.2) recorded significantly higher grain numbers spike$^{-1}$.

Test weight was significantly higher under Poplar (36.4 g) at wider (37.9 g) spacing with 180-60-40 kg NPK ha$^{-1}$ fertility levels (40.3 g). Poplar with 3 × 2.5 m spacing recorded highest test weight (39.0 g), whereas, statistically at par with Melia with 3 × 2.5 m spacing (38.9g). Leucaena interface recorded highest (40.9 g) test weight, whereas; statistically at par with Melia (40.3 g) and Poplar (40.1 g) at 180-60-40 kg NPK ha$^{-1}$ fertility level (Figure 2).

The yield attributes are mainly depends on the crop growth and significantly affected by tree species, spacing and fertility levels as they affect wheat growth. Similar results were reported by Kaushik and Singh (2001), Sharma




| | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| T1 | 15.40 | 16.50 | 16.90 | 18.80 |
| T2 | 12.30 | 13.10 | 13.30 | 15.10 |
| T3 | 13.50 | 14.20 | 14.90 | 16.30 |
| T4 | 13.90 | 15.00 | 15.10 | 16.90 |

| | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| T1 | 33.80 | 35.80 | 37.00 | 39.00 |
| T2 | 31.80 | 32.30 | 34.20 | 36.60 |
| T3 | 32.70 | 33.80 | 36.30 | 37.20 |
| T4 | 32.50 | 34.50 | 35.00 | 38.90 |

| | F0 | F1 | F2 | F3 |
|---|---|---|---|---|
| T1 | 11.50 | 17.30 | 18.80 | 20.20 |
| T2 | 7.30 | 13.10 | 15.80 | 17.60 |
| T3 | 8.60 | 16.20 | 16.60 | 17.60 |
| T4 | 10.10 | 15.80 | 16.90 | 18.10 |

| | F0 | F1 | F2 | F3 |
|---|---|---|---|---|
| T1 | 30.00 | 36.80 | 38.80 | 40.10 |
| T2 | 25.20 | 34.90 | 37.30 | 39.90 |
| T3 | 25.50 | 32.20 | 36.60 | 40.90 |
| T4 | 28.90 | 36.20 | 37.80 | 40.30 |

**Figure 2.** Wheat yield attributes influenced by tree species, spacing and fertility levels.

et al. (2000), Ahmed et al. (2002), Kumar and Rajput (2003) and Smithson and Giller (2002).

## Yield

The reduction in grain, straw and biological yield was significantly higher under Eucalyptus interface at closer (3 × 1 m) spacing and without fertilizer applications (Table 1). The grain (25.6 qha$^{-1}$), straw (45.6 qha$^{-1}$) and biological (71.2 qha$^{-1}$) yield were significantly higher under poplar interface. The wider (3 × 2.5 m) tree species recorded higher grain (27.3 qha$^{-1}$), straw (47.0 qha$^{-1}$) and biological (74.4 qha$^{-1}$) yield as compared to closer spacing (3 × 1 m). The response crop to the fertility levels significantly affected grain, straw and biological yield. The crop grain (38.4 qha$^{-1}$), straw (58.1 qha$^{-1}$) and biological (96.4 qha$^{-1}$) yield at 180-60-40 kg NPK ha$^{-1}$ were highest as compared to other fertility levels. Harvest index was significantly higher under poplar (0.34), however it was significantly lower under Eucalyptus (0.31) interface. Wider spacing (3 × 2.5 m) had significantly effect on harvest index (0.35) as compared to 3 × 1 m spacing (0.30). Significant highest (0.39) harvest index was recorded under the plot fertilized by 180-60-40 kg NPK ha$^{-1}$. Interaction among the factors was significant for crop grain yield. It was significantly higher under Poplar at 3 × 2.5 m (31.10 qha$^{-1}$) followed by Melia at 3 × 2.5 m (29.40 qha$^{-1}$) spacing. At Poplar with 180-60-40 kg NPK ha$^{-1}$ fertility levels, grain yield (44.60 qha$^{-1}$) was significantly higher, followed by Melia with fertilized by 180-60-40 kg NPK ha$^{-1}$ (42.60 qha$^{-1}$). Highest HI was recorded under poplar with 3 × 2.5 m spacing (0.36) and Poplar inter-phases fertilized with 180-60-40 kg NPK ha$^{-1}$ (0.41) fertility treatment (Figure 3).

The soil physico-chemical properties improvement and lower down the tree-crop competition for resources resulted that an increases in crop growth and yield. Similar findings were reported by Singh and Sharma (2007). During wheat crop maturity (March–April) poplar start sprouting and shade the crop which decreases light intensity and it becomes one of the limiting factors for reduction in wheat grain yield under poplar interspaces as compared to sole crop (Gill et al., 2009). Apart from nutrient and moisture, light is a major limiting factor for crop growth and yield under tree species. Being an evergreen tree species, eucalyptus reduces light availability and decreased crop yield. Corroborative results were reported by Tripathi et al. (2006), Kumar and Rajput (2003), Kaushik and Singh (2001), Fikreyesus et al. (2011), Willey and Holliday (1971) and Ahmed et al. (2008). Sharma et al. (2001) and Khan and Ehrenerich

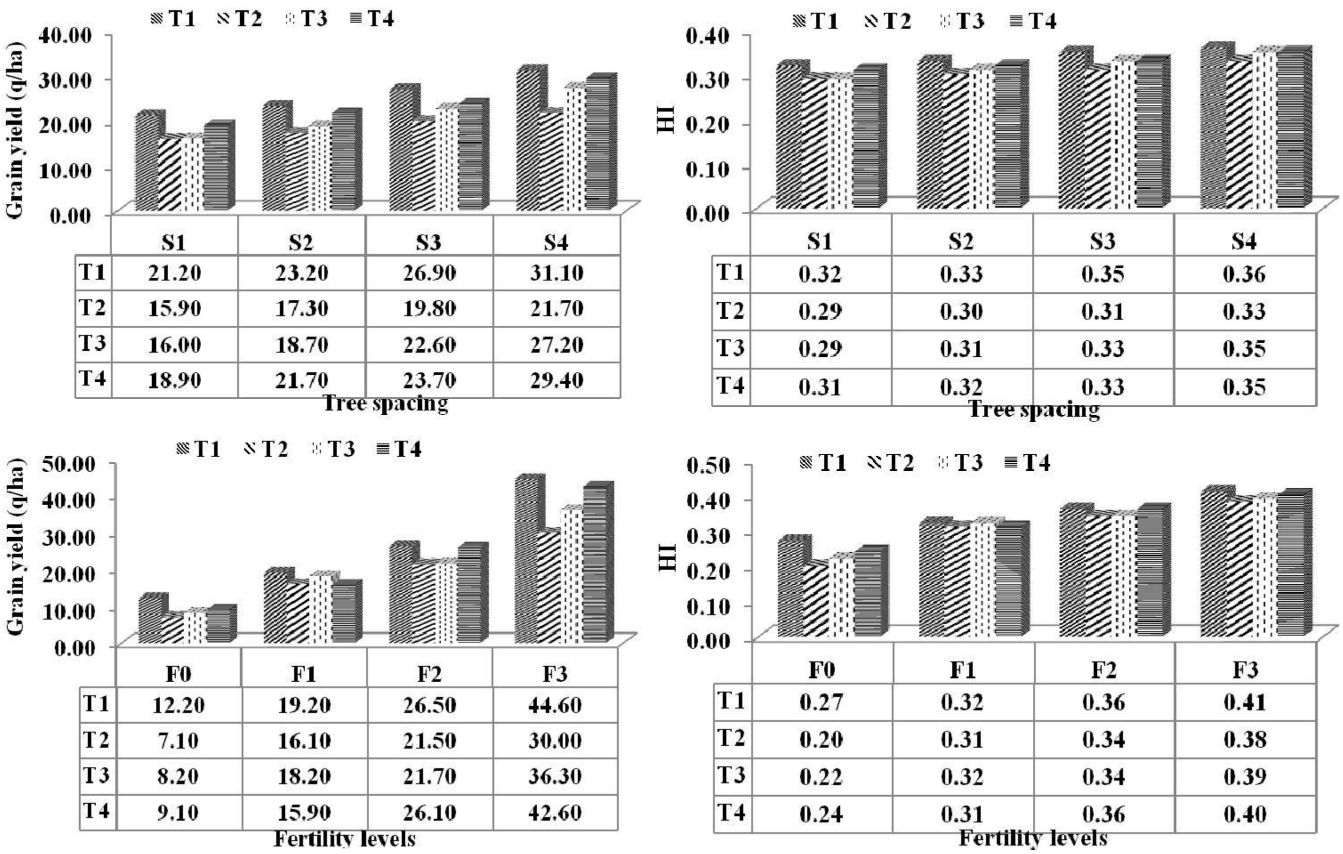



**Figure 3.** Wheat yield influenced by tree species, spacing and fertility levels.

**Table 2.** Correlation growth, yields attributes and yield of wheat under agroforestry system.

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.856** (0.000) | 0.960** (0.000) | 0.943** (0.000) | 0.964** (0.000) | 0.937** (0.000) | 0.949** (0.000) | 0.956** (0.000) | 0.972** (0.000) | 0.972** (0.000) | 0.972** (0.000) | 0.851** (0.000) |
| 2 | | 0.945** (0.000) | 0.914** (0.000) | 0.763** (0.004) | 0.966** (0.000) | 0.949** (0.000) | 0.937** (0.000) | 0.785** (0.002) | 0.786** (0.002) | 0.786** (0.002) | 0.826** (0.001) |
| 3 | | | 0.947** (0.000) | 0.874** (0.000) | 0.970** (0.000) | 0.976** (0.000) | 0.985** (0.000) | 0.915** (0.000) | 0.914** (0.000) | 0.915** (0.000) | 0.880** (0.000) |
| 4 | | | | 0.916** (0.000) | 0.981** (0.000) | 0.983** (0.000) | 0.981** (0.000) | 0.919** (0.000) | 0.921** (0.000) | 0.920** (0.000) | 0.864** (0.000) |
| 5 | | | | | 0.891** (0.000) | 0.908** (0.000) | 0.887** (0.000) | 0.939** (0.000) | 0.943** (0.000) | 0.941** (0.000) | 0.757** (0.004) |
| 6 | | | | | | 0.995** (0.000) | 0.980** (0.000) | 0.886** (0.000) | 0.888** (0.000) | 0.887** (0.000) | 0.864** (0.000) |
| 7 | | | | | | | 0.983** (0.000) | 0.911** (0.000) | 0.913** (0.000) | 0.912** (0.000) | 0.844** (0.001) |
| 8 | | | | | | | | 0.930** (0.000) | 0.929** (0.000) | 0.929** (0.000) | 0.902** (0.000) |

**Table 2.** Contd.

| | | | |
|---|---|---|---|
| **9** | 1.000** (0.000) | 1.000** (0.000) | 0.816** (0.001) |
| 10 | | 1.000** (0.000) | 0.812** (0.001) |
| 11 | | | 0.814** (0.001) |

** Correlation is significant at the 0.01% level (2-tailed); parenthesis values: Sig. (2-tailed); 1, LAI; 2, plant height; 3, dry matter accumulation; 4, ear bearing shoots per m-2; 5, spike length; 6, spikelets per spike; 7, grains per spike; 8, test weight; 9, grain yield; 10, straw yield; 11, biological yield; 12, HI.

(1994) reported that water use of the system increased up to a distance of 6 m from tree line, causes moisture stress to the crop. The tree and crop components compete for nutrients in simultaneous systems, but competition for growth resources is absent or minimal in sequential systems. Inorganic nutrients application may reduce tree-crop competition for nutrients. Corroborative results were reported by Yajun et al. (2009), Johannes et al. (2002), Pant (1993) and Steiner et al. (2007).

## Correlation study

Correlations between growth, yield components and grain yield under four tree species, spacing and fertility treatments were evaluated for the present study (Table 2). The grain yield was positively significant correlated with crop growth parameters and yield attributes.

Straw, biological yield and HI were positively significant correlated with LAI, plant height, dry matter accumulation, ear bearing shoots $m^{-2}$, spike length, spikelets per spike and grains per spike. Subhani and Chowdhry (2000) and Attarbashi et al. (2002) reported similar data on these lines. Singh et al. (1995), Rana and Sharma (1997) and Deswal et al. (1996) in wheat also supported these findings.

It may be concluded that the nitrogen fixing deciduous tree species with wider spacing improves growth, yield attributes and yield of wheat. Poplar tree species reduces competition for light with crop by shedding their leaves during crop sowing period which may helps to improve soil properties.

The application of inorganic fertilizers also helps to minimize tree-crop competition for nutrients as added nutrients also utilized by fast growing tree species.

## ACKNOWLEDGEMENT

The authors wish to thanks the Head, Agroforestry Section, Department of Agronomy, G. B. Pant University of Agriculture and Technology, Pantnagar, for providing facilities and support for this research activity.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

## REFERENCES

Ahmed R, Rafiqul Hoque ATM, Hossain MK (2008). Allelopathic effects of leaf litters of *Eucalyptus camaldulensis* on some forest and agricultural crops. J. Forestry Res. 19(1):19-24.

Ahmed SI, Abbasi MK, Rasool G (2002). Integrated plant nutrition system (IPNS) in wheat under rainfed conditions of Rawalakot Azad Jammu and Kashmir. Pak. J. Soil Sci. 21(122):79-86.

Attarbashi MR, Galeshi S, Soltni A, Zinali E (2002). Relationship of phenology and physiological traits with grain yield in wheat under rain-fed conditions. Iranian J. Agric. Sci. 33:21–28.

Bhardwaj BB, Gupta SR, Saini R, Sodhi JS Singh A (2005). Nutrient dynamics in a populus deltoides agroforestry system at Kurukshetra. Bulletin of the National Institute of Ecology 15:99-108.

Deswal RK, Grakh SS, Berwal KK (1996). Genetic variability and characters association between grain yield and its components in wheat. Ann Biol. (Ludhiana) 12:221–224.

Fikreyesus S, Kebebew Z, Nebiyu A, Zeleke N, Bogale S (2011). Allelopathic effects of *Eucalyptus camaldulensis* Dehnh. on germination and growth of tomato. American-Eurasian J. Agric. Environ. Sci.11(5):600-608.

Garrity DP (2004). Agroforestry and the achievement of the millennium development goals. Agroforestry Systems 61:5-17.

Gill RIS, Singh B, 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.

Johannes L, Gerhard G, Wolfgang Z (2002). Nitrogen cycling assessment in a hedgerow intercropping system using $^{15}N$ enrichment. Nutrient Cycling in Agroecosystems 62:1-9.

Kaushik N, Singh (2001). Performance of pearl millet- wheat in Poplar based agri-silvicultural system in sandy soils of southern Haryana. Indian J. Agroforestry 3(1):51-54.

Khan GS, Ehrenerich JH (1994). Effect of increasing distance from *Acacia nilotica* trees on wheat yield. Agroforestry systems 25(1):23-29.

Kumar BM (2006). Agroforestry: the new old paradigm for Asian food security. Journal of Tropical Agriculture 44(1-2):1- 14.

Kumar V, Rajput PR (2003). Studies on yield and yield components of wheat varieties in open and under poplar (*Populus deltoides* Bartr. Ex. Marsh) based agro-silviculture system. Plant Archives 3(2):183-189.

Lehmann J, Gebauer G and Zech W (2002). Nitrogen cycling assessment in a hedgerow intercropping system using $^{15}N$ enrichment. Nutrient Cycling in Agroecosystems 62:1-9.

Panse VG, Sukhatme PV (1978). Statistical methods for Agricultural Workers. 2$^{nd}$ ed. ICAR Publication, New Delhi. 381 pages.

Pant AK (1993). Effect of variable soil fertility on wheat productivity and

nutrient dynamics in an agri-silvicultural system. Pantnagar, Uttarakhand. P. 240.
Patil RH, Hunshal CS, Itnal CJ (2002). Influence of bund planted Eucalyptus trees row on winter wheat. Allelopathy J. 10(1):21-28.
Rana VK, Sharma SC (1997). Correlation among some morphophy siological characters associated with drought tolerance in wheat. Crop Improvement 24:194–198.
Sharma NK, Singh HP, Dadhwal KS (2000). Effect of poplar (*Populus deltoides*) on wheat growth at an early stage. Indian J Soil Cons. 28:221–225.
Sharma NK, Samra JS, Singh HP (2001). Poplar (*Populus deltoides*) based agroforestry systems for an alluvial soil under irrigated condition in western Uttar Pradesh. Indian For. 127:61–69.
Sidhu DS, Hans AS (1988). Preliminary studies on the effect of eucalyptus leaf litter on accumulation of biomass in wheat. J. Tropical Forestry 4(4):328-333.
Singh B, Sharma KN (2007). Nutrition and growth of wheat–sorghum rotation in soils amended with leaf litter of trees before planting of wheat. Agroforestry Systems 71:25–34.
Singh KN, Singh SP, Singh GS (1995). Relationship of physiological attributes with yield components in hread wheat (*Triticum aestivum* L.) under rain-fed condition. Agric. Sci. Digest (Karnal) India 15:11–14.
Smithson PC, Giller KE (2002). Appropriate farm management practices for alleviating N and P deficiencies in low-nutrient soils of the tropics. Plant and Soil. 245:169–180.
Snedecor GW, Cochran GW (1967). Statistical methods. 6$^{th}$ ed. Oxford and IBH Publishing company, Calcutta, P. 310.
Steiner C, Teixeira WG, Lehmann J, Nehls T, Vasconcelos de Macedo JL, Winfried EHB, Zech W (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant and Soil 291:275–290.
Subhani GM, Chowdhry MA (2000). Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions. Pakistan J. Biol. Sci. 3:72–77.
Teklay T (2004). Seasonal dynamics in the concentrations of macronutrients and organic constituents in green and senesced leaves of three agroforestry species in southern Ethiopia. Plant and Soil 267:297–307.
Tripathi MK, Saini BC, Chaturvedi S (2006). Growth and yield of intercropped wheat under *Salix- Dalbergia* agroforestry system. Annals of Bio. Of Agric. and Tech., Pantnagar, Uttarakhand, India.
Yajun G, Yun L, Jianchang Z, Wenguo L, Zhanping D, Weixian C, Qin Q (2009). Effects of mulch, N fertilizer, and plant density on wheat yield, wheat nitrogen uptake, and residual soil nitrate in a dry land area of China. Nutrient Cycling in Agroecosystems 85:109–121.
Willey R W, Holliday, R (1971). Plant population, shading and thining studies in wheat. J. Agric. Sci. Camb. 77:543–561.