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# EFFECT OF SPACING AND PLANT DENSITY ON THE GROWTH OF POPLAR (*Populus deltoides*) TREES UNDER AGRO-FORESTRY SYSTEM

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Poplar AY-48 was planted at a spacing of 3.7 x 6.1m, having the density of 455,305 and 230 trees per hectare under agro forestry system. Arable crops, wheat and fodder maize were sown alternately through out the study period of 8 years. Poplar trees put significantly greater diameter (dbh) growth under the spacing of 3.7 x 12.1 m. Increment in dbh was highest during 3rd year of planting and later on tapered down with the increase in age. There was no significant difference in height gain and clean bole formation under all the spacing and densities. Crown development was significantly better in lower density (230 trees/ ha.) Diameter growth increase with the increase in spacing, however at certain point it levels off and there is non linear relationship between diameter growth and spacing. Crown development has a linear relationship with tree spacing and increases with the increase in spacing. Wood production was higher under closer spacing of 3.7x 6.1m with a tree density of 455 trees/ha. While it was lower under wider spacing 3.7x 12.1m. It was observed that wood volume contribution per tree was 31.4% more in lower density of 230 trees/ha. (3.7x 12.1m.) as compared to higher density of 455 trees/ha. (3.7x 6.1m) while the difference was only 9.6% under 305 trees/ha. Density (3.7 x 9.1m.), indicating competition amongst trees for below ground resources (water and nutrients) at closer spacing. At the spacing of 3.7 x 12.1m. and density of 230 trees/ha. 72.2% trees were found in bigger dbh class of 30.6-35.5 cm while only 23.2% & 27.3% trees were able to touch this dbh class under higher density of 455% 305 trees/ha at a spacing of 3.7x12.1m. and 3.7x 9.1m. respectively.
**Keywords:** Poplar, agro-forestry, intercropping spacing

## INTRODUCTION

Poplar (*Populus deltoides*) tree is an exotic species in Pakistan and was introduced in the country during late fifties (Sheikh, 1988). It has gained much popularity as commercial timber tree, due to multifarious uses, market potential and fast rate of growth. Almost all poplar tree wood requirement of industry is being met from farm grown poplar trees and very small quantity of about 0.029 million $m^3$ is contributed by state owned irrigated plantations of the Punjab province (Laeeq, 1999). Its wood is of good quality with white colour, lack of smell, good workability, even grained, light weight and resistance to splintering. Its wood is used in preparation of packing cases, matches, plywood, particle board, pulp and paper, ice cream sticks tooth picks, sports goods, artificial limbs, furniture, ‘khas’ of desert coolers, shuttering material, fuel and fodder (Siddiqui et al., 1986; Sheikh, 1993). Under world trade organization (WTO) poplar wood has been recommended as packing material. After the implementation of WTO its wood demand and market potential will enhance manifolds.

Poplar (*Populus deltoides*) is deciduous, remains leafless during winter months and combines very well with most of the winter season agricultural crops (Jain et al., 1999). Owing to the higher market price that poplar wood fetches (about 3-4 times that of Eucalyptus wood) and certain other factors, the farmers cultivate poplar within agricultural fields with arable crops like wheat, sugarcane, turmeric, potatoes, tomatoes, vegetables, berseem, maize fodder, etc. It gives good returns in short rotation of 6-8 year (Sharma, 1996). Its fast rate of growth, ease of establishment, easy marketing, no fruiting and multifarious uses make poplar the most popular tree species for agroforestry systems.

Usually farmers grow poplar trees on their farmlands in linear or block fashion. In block form mostly intercropping is done for initial 2-3 years only. Afterwards crop yields start declining and farmers stop growing crops in poplar blocks (Hussain et al. 1999). Due to this inability of growing agricultural crops farmers feel that their land has become unproductive and they do not pay proper attention to their tree crop. As a result the tree-growth slows down, area becomes infested with weeds, wood quality reduces and trees take more time to gain required dimensions. This clematis arises either due to selection of non-compatible agricultural crop or improper tree spacing. Since no proper spacing has yet been decided to avoid the adverse effect of poplar trees on growth and yield of intercrops, therefore, there is a dire need to determine proper spacing for intercropping in agroforestry systems. This study was conducted to determine suitable spacing for intercropping poplar under wheat-fodder maize agroforestry system.

## MATERIALS AND METHODS

This study was conducted at the research garden, Punjab Forestry Research Institute, Faisalabad. The site is well-drained, alluvial and fine loamy soil. It is located in arid moisture regime with 300mm precipitation having Longitude 73.11°E, Latitude 31.28°N and elevation 183m from sea level.

The experimental site was prepared by ploughing 4-5 times with tractor mounted cultivator, followed by planking and leveling. Poplar (*Populus deltoides* clone AY-48) was planted at a spacing of 3.7 x 6.1m, 3.7 x 9.1m and 3.7 x 12.1m, having the density of 455, 305 and 230 trees/ha, by digging 75cm deep and 30cm wide pits during first week of February, 1994. Planting was done using one year old, bare rooted entire nursery plants of uniform size. Good compaction and ramming of the plants was done after planting. First irrigation with canal water was given immediately after planting. After 24 hours of irrigation the leaning and wind fallen plants were straightened by adding and compacting more soil. Average height and diameter of plants was 4.5m and 5cm respectively at the time of planting. There were 3 rows of poplar under each spacing treatment with an array of 8 x 3 = 24 plants per plot. The orientation of rows was south-east to north-west. The study was laid out using RCB design and replicated three times. Poplar tree data on the growth parameters of diameter at breast height (cm), plant height (m), clean bole (m) and crown width (m) were recorded each year upto rotation age of 8 years.

Agricultural crops namely, wheat (*Triticum aestivum*) variety Inqalab-91 and fodder maize (*Zea mays*) variety Neelum were sown alternately during ‘Rabi’ and ‘kharif’ seasons each year throughout the entire study period in poplar plots. Wheat was sown during third week of November through broad cast method using 125kg seed per hectare each year. Fertilizers (Urea, Di-ammonium phosphate (DAP) and Sulphate of potash (SOP)) were applied at the rate of 125kg/ha. DAP and SOP was applied at the time of sowing while urea was applied at the time of first and third irrigation in equal doses. Similarly fodder maize was sown during third week of July through broad cast method using 100kg seed per hectare. Fertilizer (urea) was applied at the rate of 125kg/ha at the time of first and fourth irrigation.

The data regarding tree diameter (dbh), mean annual increment in dbh, tree height, clean bole, crown development and tree basal area/ha were recorded in the month of May during the year 2001, at the age of 8 years. The total volume of wood was calculated using the volume table of poplar on farmlands in irrigated areas of Punjab (Cheema et al., 1998).

## RESULTS AND DISCUSSION

Tree growth is function of age, spacing and site quality (Nissen et al., 2001). The growth of poplar tree is reflection of many factors, viz. genotype, climate, soil conditions, care of trees, use of fertilizers, frequency of cultural operations and irrigation schedule.

The data presented in Table 1 reveals that various plant densities at various spacing significantly affected the diameter (dbh) growth and crown width. However, plant height and clean bole was not significantly affected under the various poplar spacing.

**Table 1. Poplar trees mean diameter, height, clean bole, crown width, basal area and wood volume as influenced by different tree spacings/densities under agroforestry system**

| Poplar trees spacing | Poplar trees density | DBH (cm) | Ht. (m) | C.B (m) | C.W (m) | Basal area ($m^2$/ha) | Wood volume ($m^3$/ha) | Wood Vol. Contribution/ tree ($m^3$) |
|---|---|---|---|---|---|---|---|---|
| D1(3.7x6.1m) | 455 trees/ha | 25.16b | 13.50a | 5.60ab | 6.10b | 22.61 | 110.2 | 0.24 |
| D2(3.7x9.1m) | 305 trees/ha | 27.57ab | 13.93a | 5.90ab | 6.62b | 18.20 | 97.7 | 0.32 |
| D3(3.7x12.1m) | 230 trees/ha | 29.28a | 13.87a | 5.03b | 8.21a | 15.48 | 80.5 | 0.35 |
| lsd 0.05 | | 2.966 | 0.640 | 1.042 | 0.652 | | | |

*Means followed by different letters are significantly different at 0.05 P

### Bole diameter at brest hight growth

The most significant dbh growth was observed in spacing of 3.7x12.1m treatment (D3) (Table 1). However, this treatment did not differ significantly from D2 (3.7x9.1m) treatment. Similarly dbh growth in D2 treatment did not differ significantly from D1 (3.7x6.1m) treatment, while D3 treatment differed significantly from D1 treatment. These results indicated that there was no root competition amongst poplar trees under wider spacing while in closer spacing treatments root competition took place amongst trees, resulting in lesser diameter growth. This increased dbh growth may also be attributed to greater plant spacing, cultural operations and availability of additional nutrients applied for arable crops. These results are in line with the findings of Sheikh (1988), Chaturvedi (1992), Hafeez and Hafeezullah (1993), Misra et al. (1996), Bisaria et al. (1999) and Nissen et al. (2001).

These results showed that dbh improved at a swift pace in lower density of 230 and 305 as compared to higher density of 455 trees/ha. This trend was well exhibited from the initial year to the 8th year (Figure1). Maximum dbh was registered in trees having a density of 230 trees/ha followed by 305 trees/ha and 455 trees per hectare treatment. The dbh growth declined with increase in age of *P. deltoides* but the pace of dbh growth decline in D3 and D2 treatments were slower as compared to D1 treatment (Figure 1). From Figure 2 it is clear that dbh increment was maximum during the year 3 and with the increase in age dbh increment decreased. These results are in agreement with Ralhen et al., 1992. The relationship between dbh and tree spacing is non-linear exhibiting a second order polynomial trend (Figure 3). It is clear from the Figure 3 that with increase in tree spacing the dbh increases but after a limit this increase level off.

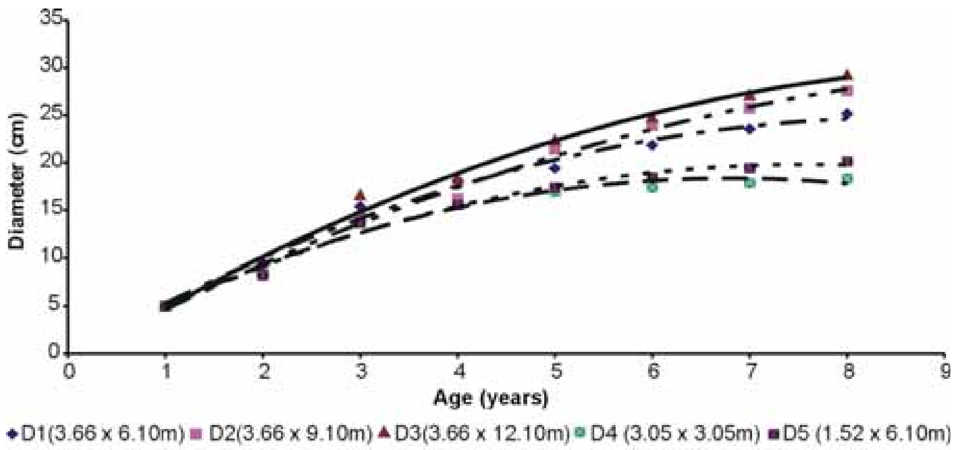


Figure 1. Relationship between age and diameter growth of poplar trees at various densities as influenced by wheat-fodder maize intercropping

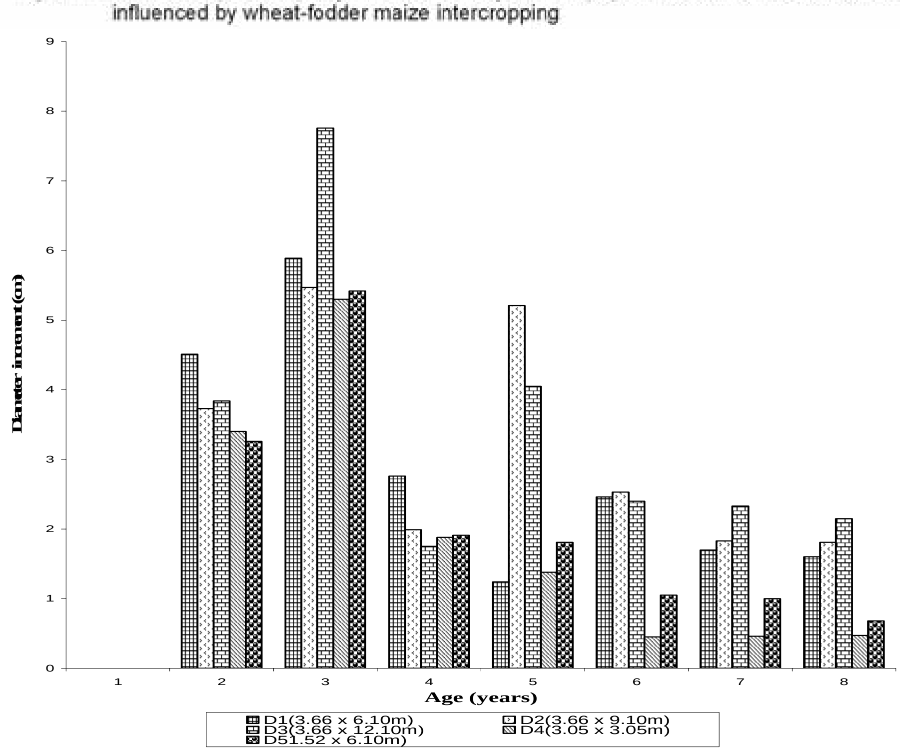


Figure 2. Year wise diameter (dbh) increment in poplar trees at various densities

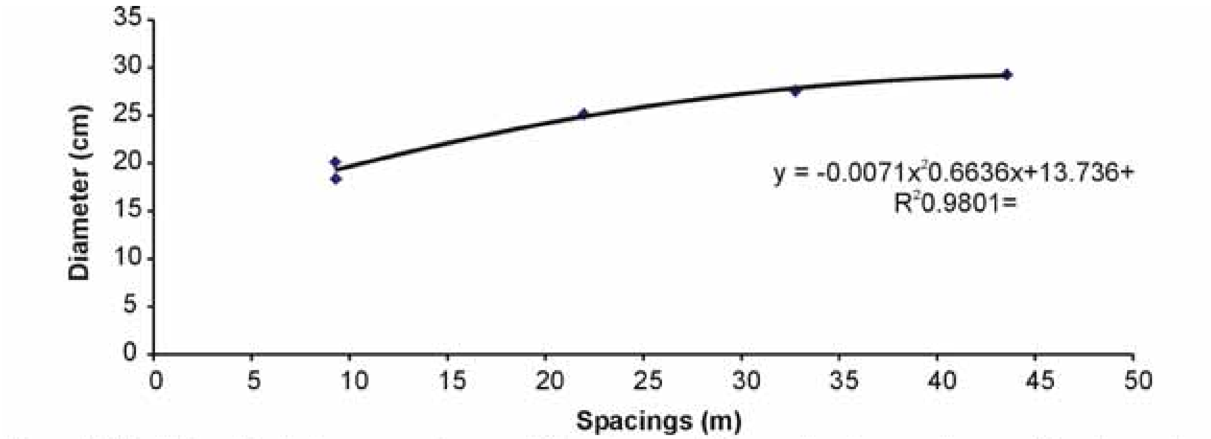


Figure 3. Rrelationship between spacing and diameter growth in poplar trees under agroforestry system

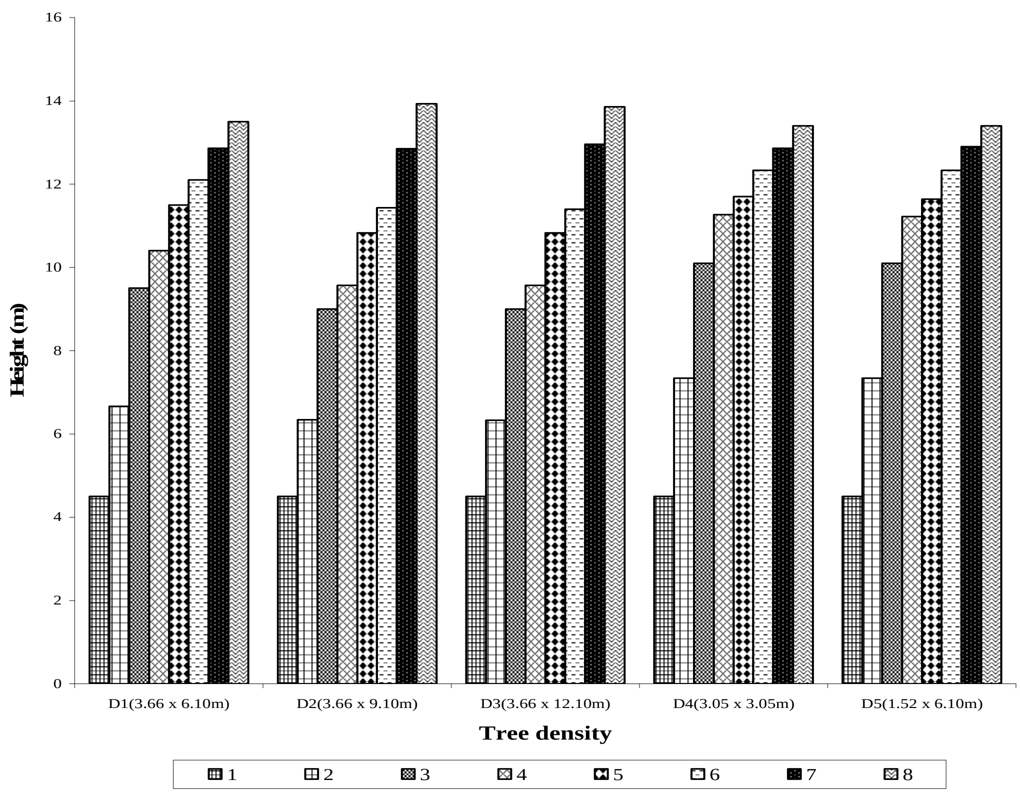


Figure 4. Year wise increment in height (m) of poplar trees at various densities under agroforestry system

**Tree Hight**

There was no significant difference in height gain in poplar trees under all tree densities (Table 1). Tree densities did not affect the rate of increase in height of the trees. Considering the effect of densities on rate of increase of height, it is clear from the figure 4 that the height increased at a bit faster pace in D1 treatment for 6 years and in later years height increment was more in D2 and D3 treatments. At the age of 8 years height gain in all treatments was non-significant. These results are in line with the findings of Mohsin et al., 1996; Bisaria et al., 1999.

**Clean Bole**

There was no significant difference in clean bole of poplar trees under all tree densities. However, lowest clean bole (5.03m) was in lowest tree density of 230 trees/ha and highest clean bole (5.90m) was in tree density 305 trees/ha (Table 1). The pace of increase in clean bole of the trees was more in treatment having density 305 trees/ha as compared to treatment with 455 and 230 trees/ha. Considering the effect of densities on rate of gain of clean bole it is clear from figure 5 that the clean bole contribution is more in higher density as compared to lower density (230 trees/ha). The result of study revealed that clear bole formation was governed by tree density. Closer the tree density more will be the clean bole and vise versa.

**Growth With**

There was significant difference in crown width (Table 1) under various tree densities. Crown width was maximum (8.21m) in lowest tree density (230 trees/ha) treatment (D3) and minimum (6.1m) was observed in highest tree density (455 trees/ha) treatment (D1). Crown width was significantly better in widest spacing (D3) as compared to tree densities D1 and D2. However D1 and D2 spacings (455 trees/ha and 305 trees/ha) were not significantly different from each other. The results of study revealed that crown development is affected by plant density. The figure 6 showed that there was linear relationship between poplar tree densities and crown width. From the figure it is clear that with the increase in tree spacing crown width increased and vice versa. However, tree canopy management is very important in agroforestry practices to reduce negative tree effects on arable crops. According to Samsuzzamam, et al. (2002) proper tree crop spacing and pruning management help reduce

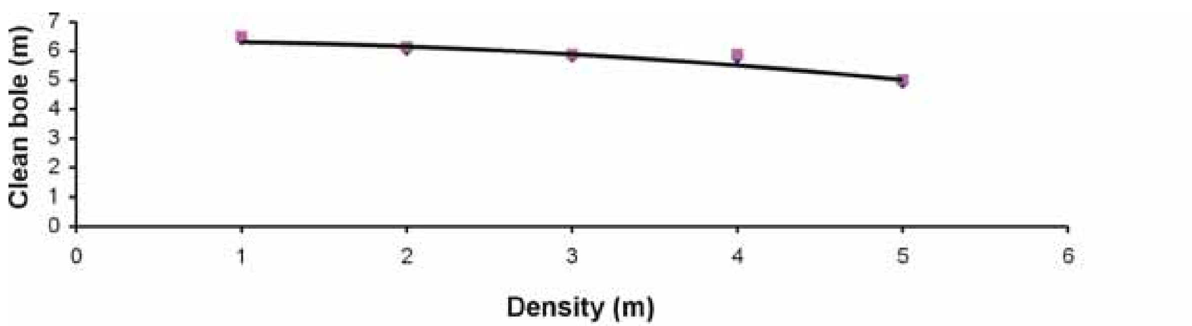


Figure 5. Relationship between poplar tree density and clean bole under agroforestry system

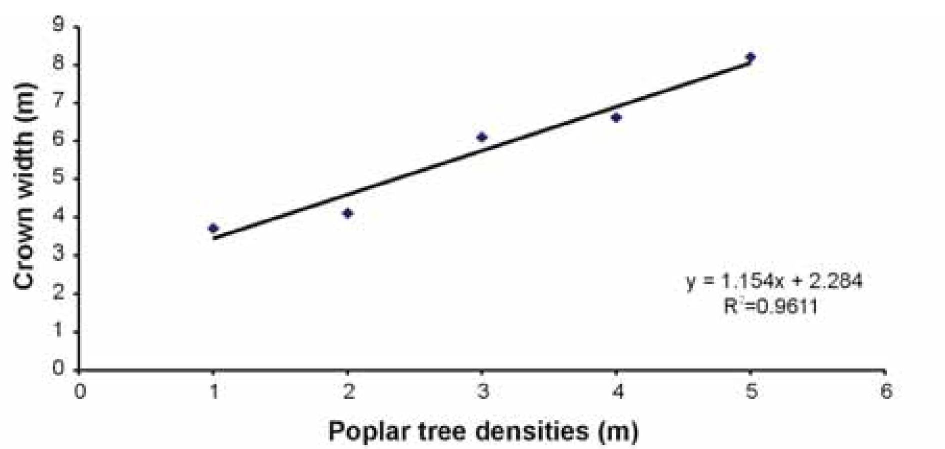


Figure 6. Relationship between poplar tree density and crown width under agroforestry system

negative tree crop interaction and thereby greatly influence the component productivity. It indicated that there is more crown expansion in trees having wider spacing and lesser crown expansion in trees having closer spacing. Chaudhry, et al. (2003) reported 11% more crown development in intercropped stand as compared to sole tree stand at similar spacing.

In this study wood volume produced was calculated at the age of 8 years (year 2001). Site quality, climatic conditions and cultural and silvicultural operations were same for all the spacing treatments. The only difference was of tree spacings. The Table 1 reveals that tree densities have contributed in poplar tree wood yield significantly. These results are in line with the findings of Misra et al. (1996). According to Misra et al. (1996) the increased tree growth with low density plantations might be due to the more availability of light, water and nutrients resulting in increase in crown size, leaf area and synthesis of carbohydrates and hormonal growth regulators. These changes might increase the downward transport of carbohydrates and hormonal growth regulators in the stem resulting eventual increase in cambial growth and redistribution of wood production along the tree stem. Chaudhry, et al. (2003) reported 29.4% higher wood yield in intercropped stand as compared to sole tree stand at same tree density.

The total volume of wood per hectare was highest (110.2 $m^3$/ha) at the spacing of 3.7 x 6.1m (D1) followed by the spacing of 3.7 x 9.1m (D2) treatment (97.7 $m^3$/ha) and the lowest volume was in widest spacing of 3.7x12.1m treatment (80.5 $m^3$/ha). It was due to more number of trees per hectare in these spacings. These results are in agreement with findings of Singh et al., 1988. However per tree contribution in wood volume production was 31.4% more in tree density 3.7x12.1m compared to3.7x6.1m density. Chaudhry, et al. (2003) reported a positive impact of intercropping wheat-fodder maize crops on poplar trees wood production compared to pure tree stand. This may be ascribed to better utilization of moisture, fertilizers and nutrients beyond the reach of arable crops with additional benefit of wider spacing and of cultural operations for arable crops.

The indicates that if the spacing between tree rows is wider, more trees fall in bigger diameter classes over a period of time. The percentage of trees declined from 1.4 to 0% in case of smaller diameter class of 10.6 to 15.5 cm and increased from 0 to 58.3% in case of higher diameter class of 30.6-35.5 cm as the spacing increased during the year 2001. Even 13.9% trees moved into next higher diameter class of 35.6cm and above in widest spacing. This indicated that for getting better size trees in shorter period of time spacing should be wider.

The Table 2 reveals that in closest spacing treatment (D1) only 23.2% trees could move to 30.6- 35.5cm diameter class while maximum percentage of trees (42.0%) were in 25.6-30.5cm diameter class followed by 20.6-25.5 cm diameter class (24.6%). In widest spacing 58.3% trees moved into thicker diameter size class of 30.6-35.5 cm and even 13.6% trees moved to next higher diameter class while no tree remained in smaller size diameter classes of 5.6-10.5 cm, 10.6-15.5 cm and 15.6- 20.5cm. In D2 treatment 27.3% trees shifted to thicker diameter size class of 30.6-35.5 cm and 3.0% were moved into next higher diameter class. This is indicative of the fact that tree density plays an important role in the diameter growth of poplar trees. This point is also elucidated in figure-1. Here it is concluded that intercropping of poplar (*Populus deltoides*) with arable crops is the best option for getting more and better quality wood in short period of time at wider spacing. These results are in general agreement with the findings of Chaudhry and Ghauri (1995) and Chaudhry (1996) that reported significant effect of wider spacing on diameter growth and wood production per hectare. Hussain and Sheikh (1986) reported that a very strong linear relationship existed between dbh and total biomass production in poplar trees. Sharma and Singh (1992) reported that at the age of 6 years nearly 75% poplar trees were in higher diameter class (29cm and above). This is a pointer to the fact that poplar growth was faster under agroforestry practices. Similar results have been inferred from this study.

The better growth of trees observed in the agroforestry system could be attributed to the application of fertilizers and soil working for crops in these plots.

**Table 2. Frequency distribution percentage for trees under various diameter classes at the age of 8 years (2001)**

| Poplar tree density | Poplar tree density | No. of tree measured | Diameter classes (cm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 5.6-10.5 | 10.6-15.5 | 15.6-20.5 | 20.6-25.5 | 25.6-30.5 | 30.6-35.5 | 35.6 & above |
| D1(3.7x6.1m) | 455 trees/ha | 69 | 0.0 | 1.4 | 8.7 | 24.6 | 42.0 | 23.2 | 0.0 |
| D2(3.7x9.1m) | 305 trees/ha | 66 | 0.0 | 0.0 | 7.6 | 21.2 | 40.9 | 27.3 | 3.0 |
| D3(3.7x12.1m) | 230 trees/ha | 72 | 0.0 | 0.0 | 0.0 | 6.9 | 20.8 | 58.3 | 13.9 |

Thus trees seem to be benefited by exploiting the fertilizers etc. meant for crops. There are two possible explanations. (i) Uptake by trees of a proportion supplied primarily for the crops may result in a decrease in the crop yield. (ii) Utilization of nutrients by trees may help in their conservation in the system, that would have been lost through infiltration or run-off, as the nutrient use efficiency of the arable crops would not be 100%. Use of fertilizers and ameliorative effect in the agroforestry system also provided congenial soil environment for optimum soil microbial activity, which in turn might have caused rapid mineralization of organic matter thus facilitating the uptake of nutrients by trees. Beneficial effects on tree growth of growing crops in tree plantations have also been reported by several workers under different soil and climatic conditions (Yamoah et al, 1986; Atta-Krah, 1990; Kass et al., 1992; Chaudhry and Ghauri, 1995; Chaudhry, 1996; Singh et al., 1997).

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