Growth and Productivity of Soybean Under Five Promising Clones of *Populus deltoides* in Agrisilviculture System

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ABSTRACT

An experiment was conducted to investigate the growth and productivity of soybean under *Populus deltoides* based agrisilviculture system at Raipur (Chhattisgarh), India. The system comprised of five poplar clones (G3, G48, 65/27, D121 and S7C1) planted in a randomized block design with three replications. Soybean was intercropped under these clones during kharif 2002. The results revealed that shoot biomass, root biomass and nodules were highest in sole soybean (control). Grain yield was highest (14.5 q ha^{-1}) in sole crop and decreased under poplar clones. It reduced from 2.06 to 33.1% under different clones. The highest reduction was observed in soybean grown under clone G3 and lowest in clone S7C1. The grain yield reduction under different clones followed the order: S7C1 < D121 < 65/27 < G 48 < G3.

Key Words : *Leaf area index (LAI), nodulation, photo synthetically active radiation (PAR), shoot-root biomass, tree-crop competition.*

1. INTRODUCTION

Agroforestry is gaining importance as land use practice in different parts of India with emphasis on sustainable agriculture. Different kinds of agroforestry practices have been recognized in India (Puri and Nair, 2004). Agrisilviculture is one such system, where agricultural crops are grown in association with trees. The fast growing, multipurpose and remunerative trees which are compatible with crops and provide maximum benefits in quickest possible time are preferred under agroforestry practices.

Populus deltoides Bart. is one among the fast growing exotics widely adopted by farmers in agrisilviculture system in north India (Bhardwaj and Gupta, 1993). As compared to other forest species, *Populus* has many characteristics that make it compatible for agroforestry such as fast growth, adaptability and amenability with agricultural crops and ability to provide substantial production of biomass on short rotation. Poplar cultivation is now being successfully extended to central and eastern U.P., Bihar, parts of M.P., Chhattisgarh, Maharashtra and West Bengal (Singh et al., 2001). Poplars were introduced in Chhattisgarh during 1995 (Puri et al., 2002). As many as 125 clones were screened in nursery and field. Among them five promising clones *viz.* G3, G48, 65/27, D121 and S7C1 were suggested for introducing in agrisilviculture system. Limited efforts were made to understand the productivity of crops especially in young (below 4 yrs) poplar clones (Puri and Sharma, 2002). However, limited reports are available on crop productivity under mature clones in Chhattisgarh. Selection of suitable clones is important for minimizing competition and improving the crop yields in poplar based agrisilviculture system. The study was conducted to evaluate productivity of soybean under mature (6 yr-old) stands of five promising clones of *P. deltoides*.

2. MATERIALS AND METHODS

The study was conducted in Forestry Research Farm of Indira Gandhi Agricultural University, Raipur, Chhattisgarh (latitude 21° 12'; longitude 81° 36' E). The climate of study area is sub-humid tropical with an annual precipitation of 1200-1400 mm, of which 80% is received during July to October. Mean monthly minimum and maximum temperature ranges from 27°C and 13°C in December to 42°C and 28°C in May, respectively. The soil type of study site is *vertisol*, which is characterized by fine texture, sticky in nature and angular blocky structure with good water holding capacity. It is fairly rich in organic carbon (0.43 ± 0.1%) and low to medium in available nutrients (253 ± 11 kg ha^{-1} N; 10.8 ± 0.9 kg ha^{-1} P; 358.6 ± 28 kg ha^{-1} K) with a pH of 7.5 ± 0.2. An agrisilviculture system was established by planting five promising clones (G3, G48, 65/27, D121 and S7C1) of poplar at 4 x 5 m spacing in randomized block design with three replications in 1996. Further details on site preparation and cultural practices for establishment of plantations were described by Puri et

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Table 1. Growth attributes of soybean under five clones of *Populus deltoides* in agrisilviculture system

Clone	Plant population (m^{-2})	Shoot length (cm)	Root length (cm)	Shoot biomass (g $plant^{-1}$)	Root biomass (g $plant^{-1}$)	Total biomass (g $plant^{-1}$)
G3	40.33	46.56	16.20	9.12	0.71	9.83
G48	28.33	38.53	12.71	10.76	0.69	11.45
65/27	43.33	52.88	17.06	11.86	0.80	12.66
D121	27.66	54.23	17.21	13.22	0.66	13.88
S7C1	34.66	39.84	13.70	14.50	0.56	15.06
Sole crop	48.33	40.51	12.75	15.16	0.55	15.71
LSD ($P \leq 0.05$)	9.84	1.99	2.99	0.85	0.16	0.91

al. (2002). Sixteen trees were maintained for a given clone in each replication in a 20 x 16 m plot. Soybean var. JS-335 was cultivated as intercrop and as sole crop in kharif (June-November) season in 2002. Before sowing, soybean seeds were inoculated with *Rhizobium* culture @ 0.75 kg ha^{-1} per 100 kg of seed. The seed rate of 100 kg ha^{-1} was applied by maintaining a distance of 25 cm between rows and 5 cm between two plants. Recommended doses of fertilizer nitrogen (urea) @ 20 kg ha^{-1}, phosphorus (SSP) @ 60 kg ha^{-1} and potassium (MOP) @ 20 kg ha^{-1} were applied as basal dose. Vegetative growth parameters *viz.* plant density, height, biomass and nodulation were recorded at 50 days after sowing and yield attributes (pods/plant, seeds per pod, test weight, grain and straw yields) at harvest of the crop. Morphological growth parameters *viz.* dbh, height, clean bole, crown width, number of branches and LAI were recorded after the harvest of soybean crop. DBH was measured using tree caliper and plant height by Abney's level. Number of major branches was counted, while mean branch length was recorded on three randomly selected branches. LAI of clones was measured using Plant Canopy Analyzer (LAI 2000, LI - COR, Lincoln, NE) in August. A single measurement of LAI was accomplished by taking the LAI 2000 unit outside the experimental plot (in the open) to record an " above canopy reading " of sky brightness and then sampling 10 random localities in the central region of each clone (beneath canopy readings). Care was taken to ensure that the unit was facing the same direction both outside and inside the stand. Measurements were taken between 1100 to 1300 hrs. A view restrictor 90^0 was used in all measurements to prevent direct sunlight from reaching the sensor and at the same time to the measuring person occluded from the area of view. The data on crop and tree parameters were analyzed in randomized block design. Least significant difference (LSD) test was used to separate the significant differences between treatment means (Gomez and Gomez, 1984).

3. RESULTS

Growth and biomass of soybean were significantly ($p \leq 0.05$) influenced by poplar clones in agrisilviculture system (Table 1). Crop density was highest in sole soybean compared to crop grown under different poplar clones, while shoot and root lengths were higher in crop under poplar clones. Among different clones, plant population was lowest

Table 2. Yield and yield attributes of soybean under five clones of *Populus deltoides* in agrisilviculture system

Clone	Pods $plant^{-1}$	Seed per pod	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
G3	23.60	2.3	10.50	9.7	12.1
G48	26.30	2.4	11.30	10.2	15.6
65/27	30.30	2.5	11.50	10.9	17.9
D121	34.30	2.6	11.70	13.2	18.4
S7C1	38.60	2.5	12.10	14.2	19.3
Sole crop	44.00	2.6	13.90	14.5	23.2
LSD ($P \leq 0.05$)	6.80	NS	1.41	1.1	3.3

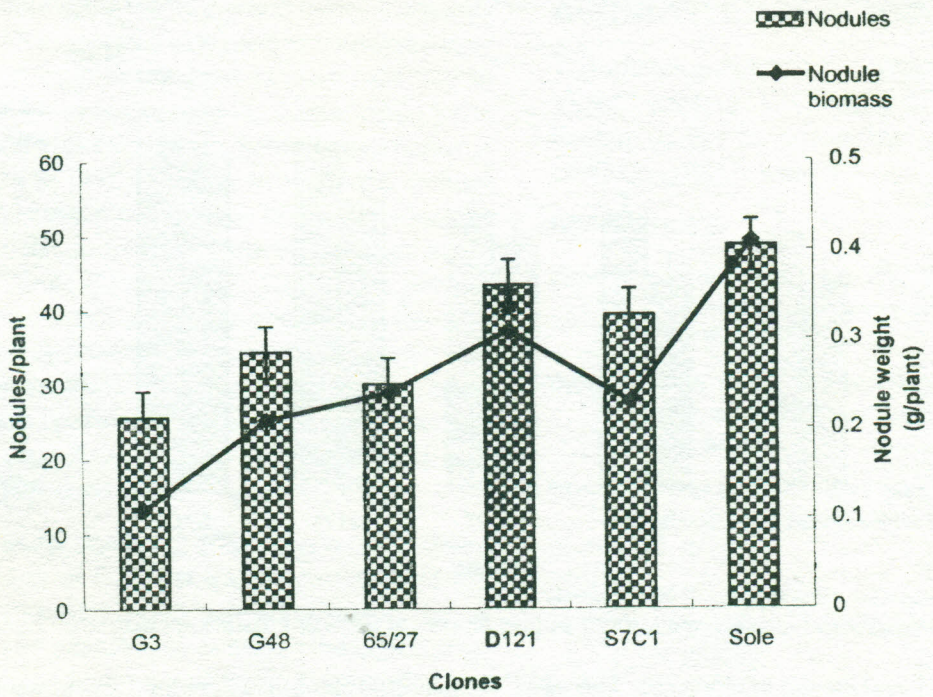

Fig. 1. Effect of poplar clones on number and dry biomass of nodules in soybean

under clone D121 followed by clone G48. It was reduced by 43% under clone D121 compared to sole crop. The shoot and root lengths of soybean were significantly higher under clone D121 and lowest with clone G48. Shoot length varied from 38.5 to 54.2 cm, while root length from 12.7 to 17.2 cm. In contrary to shoot and root lengths, their biomass was significantly higher in sole soybean and lower under different poplar clones. It was lowest under clone G3. Shoot and root biomass were 1.66 and 1.73 times higher in sole compared to intercropped soybean under clone G3. Nodulation in soybean was also significantly influenced by poplar clones (Fig. 1). Number of nodules and its biomass were higher in sole soybean and lowest in crop grown under clone G3. Nodules decreased almost by half and their biomass by 1/3 rd under this clone compared to sole soybean.

Except seeds per pod, all yield attributes *viz.* pods plant^{-1}, test weight, grain and straw yields of soybean were significantly ($p \leq 0.05$) influenced by poplar clones in agrisilviculture system (Table 2). Pods per plant varied from 23.6 to 44. Grain and straw yields were significantly higher in sole soybean and lower under poplar clones. Grain yield ranged from 9.7 to 14.5 q ha^{-1}, while straw yield varied from 12.1 to 23.2 q ha^{-1}. Grain yield reduced from 2.06 to 33.1% under different clones. The highest reduction was observed in crop grown under clone G3 and lowest under clone S7C1. Straw yield also showed similar trend. It was

Table 3. Morphological growth variations in five clones of *Populus deltoides* under agrisilviculture system

Clone	DBH (cm)	Total height (m)	Clean bole (m)	Crown length (m)	Crown diameter (m)	No. of branches	Branch length (m)	LAI
G3	19.3	13.6	5.0	7.3	2.6	21	3.1	4.5
G48	19.7	14.5	5.3	8.2	2.8	25	3.3	4.1
65/27	21.6	14.3	5.6	9.4	6.3	28	3.2	4.2
D121	20.1	13.0	3.8	7.4	3.4	16	3.1	2.0
S7C1	13.3	11.16	3.9	8.2	2.5	18	2.9	2.5
LSD ($P \leq 0.05$)	3.57	1.85	1.03	0.84	1.3	3.5	NS	0.5

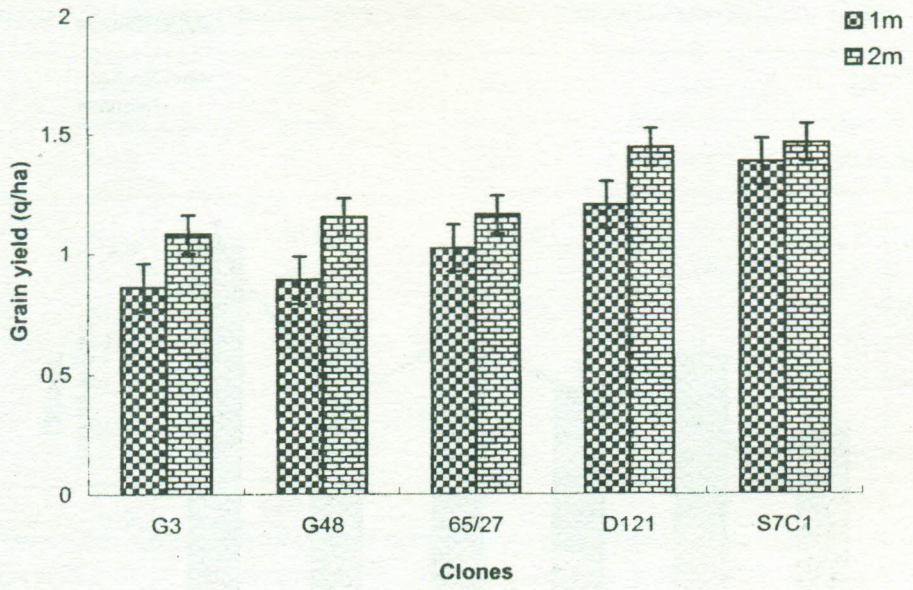

Fig. 2. Grain yield of soybean under poplar clones at different distances from tree base.

highest in clone S7C1 and lowest in clone G3. The yield reduction under clones was in the order: G3 > G48 > 65/27 > D121 > S7C1. Grain yield significantly varied from tree bases in different clones (Fig. 2). It increased with an increase in distance from tree base. Grain yield reduced from 5.5% to 22.6% at 1m distance when compared to crop grown at 2 m distance from tree base. The reduction was lowest in clone S7C1 and highest in clone G48.

Clones showed significant ($p \leq 0.05$) variation in all growth parameters except branch length (Table 3). After 6 years of planting, dbh varied from 13.3 cm to 21.6 cm and total tree height from 11.2 to 14.5 m in different clones. Among five clones, clone 65/27 attained maximum dbh and greater height, while clone S7C1 showed lowest growth. Dbh and height were 38.4% and 27.8% higher in clone 65/27 compared to clone S7C1. Clones D121, G48 and G3 however did not show any significant variation in dbh, height and clean bole when compared to clone 65/27. Crown diameter was 1.7 times higher in clone 65/27 compared to clone S7C1. LAI was lowest in clone D121 and it was 2.25 times higher in clone G3. Clones G3, G48 and 65/27 did not show any variation in LAI. In rank order of growth the best five clones were : 65/27 > G48 > G3 > D121 > S7C1.

4. DISCUSSION

The productivity of soybean decreased under poplar clones in agrisilviculture system. Reduction was higher in clone G3 and lowest in clone S7C1. The competition for light and soil nutrients could affect the productivity of soybean under poplar clones. The shade effect may be positive on crop yields under semi arid climate but could be negative in humid climate, where light and temperature are limiting factors under trees. These findings are in agreement with Sharma and Chauhan (2003), where they demonstrated poor performance of soybean under trees. The study showed that poplar clones attained full site occupancy / crown closure at 6 years age which caused severe competition with crop for sharing resources and drastically reduced the productivity of soybean. It is also evident from the results of the present study that soybean plants were tall and weak (low biomass) due to light competition especially under clones G3, 65/27 and D121. The clones G3 and 65/27 attained two times higher LAI that might had prevented sufficient amount of PAR by these clones to the under storey, soybean compared to clone S7C1. This is in agreement with findings of Swamy et al. (2003), where it was observed 20-35% of less photosynthetically active radiation (PAR) under high LAI stands (i.e. stands in 2 x 2 m) of *G. arborea*, which was responsible for 28% reduction in soybean yield. The study also showed that higher root biomass and consequently high root-shoot ratios were observed in soybean grown under poplar clones. The higher root shoot ratios in soybean were found in clones 65/27, G3 and G48. The increase in ratio in the crop seems to increase below ground competition for soil resources, although the present studies only infer competition and do not attempt to prove it. Implicit in this inference is that roots of soybean crop competed with roots of poplar trees and the consequent stress results in more allocation of carbon (biomass) to roots (Nambiar, 1990). Puri et al. (1994) in their earlier studies with distribution of *P. deltoides* roots demonstrated that bulk of coarse roots were distributed in the top 30 cm of soil, whereas fine roots

were concentrated in the top 15 cm and hence there may be root competition between trees and agricultural crops. Overall, the reduction in the yield of intercrops due to presence of trees may be attributed to differential patterns of canopy spread in clones (crown diameter was higher in clones 65/27 and G3) resulting in variation in light interception and severe competition of the tree roots for nutrients and moisture as well shade effects (Puri et al., 1994; Dupraz, 1999; Swamy et al., 2003). The present study also showed that yield of soybean was lower in proximity to the tree base and increased with an increase in distance from the trunk. Soybean yield at 2 m distance was higher than at 1m distance under all the clones studied. This reduced yield near the tree may be due to root competition between resources.

Large and statistically significant differences were observed among the clones of *P. deltoides*, which indicated the presence of considerable genetic variation in growth. These differences can be exploited by selecting the best clones and using these in future plantations. Among different clones, tested clone 65/27 showed higher growth followed by clones D121, G3, G48 and S7C1 in Chhattisgarh. Clones D121 and G3 also proved as best clones in other sites of northern India, while clones G48 and S7C1 are suitable in Punjab and Haryana. This confirms the potential of adaptability of clones. Differential performance of genetic entities (clones) grown under different environment is due to result of genotype x environment interaction and it is quiet evident in poplars (Puri et al., 2002; Singh et al., 2001).

5. CONCLUSION

The study concludes that clones *viz.* 65/27, D121, G3 and G48 were comparatively showed better growth than clone S7C1. However, the yield losses of soybean were higher under these clones due to competition. Therefore, it is suggested to minimize competition employing appropriate management practices such as pruning of branches, hoeing and root pruning during crop growing season.

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