Comparison of growth and wood production of *Populus deltoides* and *Paulownia fortunei* in Guilan province (Iran)

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Abstract

An area about 3000 m^2 located in Shanderman nursary (Guilan province, North Iran) was selected in order to compare increment and wood production of *Paulownia fortunei* and *Populus deltoides* (collected from clone no. 69.77), These species were planted at a 4 m by 4 m spacing in the form of complete randomize block design. After planting, they were measured in terms of diameter of the bright height (dbh) and total height. The given parameters were also measured in the second, third and fourth years for determining increment of whole species.

The obtained results revealed that after four years, the increment condition of *Paulownia fortunei* was better than *Populus deltoids*. The mean annual increment of the both species has increased in comparison with last year and this increment was significant at the 0.01 confidence interval. Mean annual diameter and height increment for *Populus deltoides* were 2.65 and 201.84 cm, respectively and for *Paulownia fortune,* it was obtained 5.23 and 298.03 cm, respectively. Mean annual basal area increment of *Paulownia fortunei* and *Populus deltoides* was 7.66 and 27 cm^2 and there were significant differences between mean dbh, height and basal area increment of *Paulownia fortunei* and *Populus deltoides* at the 0.01 confidence interval in this area. Plantation of both *Paulownia fortunei* and *Populus deltoides* as pure plantation or mix plantation together did not show a significant difference on mean dbh and height increment of these species at this study area.

Keywords: Fast-growing, Increment, Guilan province, *Populus deltoids, Paulownia fortunei*

1. Introduction

Increment of wood production in the short rotation with planting fast growing species can lead to wood shortage. Using the exotic tree species also may be suitable because sometimes exotic species show very good potential in a new location (Zobel, B. J. et al, 1987). Plantation fast growing species and improvement in wood production also can reduce the pressure exerted on natural forest regarding wood utilization.

Populus deltoids is one of the successful exotic species in Iran that some of its clones have been planted in northern Iran as a fast growing, short-rotation timber crop, especially in Guilan and Gorgan (Hassanzad Navroodi., 2005). Poplars occur naturally throughout the U.S. and Canada (Shortle. 1979 & Stout, and Schreiner. 1933). Poplars were initially developed for conventional pulpwood (Stout, A. B., R. H. McKee, and E. J. Schreiner. 1927). The rapid growth of poplars and their usefulness as a source of fiber, energy, and solid-wood products has encouraged an expanding plantation culture worldwide, but especially in North America (Ranney *et al*., 1987; Abelson, 1991; Zsuffa *et al*., 1996). A suitable species for this purpose is *P. deltoides* from the central and eastern US (Hinckley *et al*., 1989) so is widely planted in commercial plantations (Zsuffa *et al*., 1996). Poplars are used to stabilize soils on hillsides, along streams and rivers, landfills, and borrow pits. They are also planted as fence rows to reduce air speed in agricultural areas where soil is transported by the wind.

In general, poplars grow best on humid and micro thermal regions with adequate moisture throughout the year. They are rarely found in regions where temperatures reach to -46° C or exceed 38° C for more than a week. Poplars grow best where soils are at least 1 m in depth to interrupted bedrock. The water table and porous or gravel layers should also be at least 1 m below the soil surface. Optimum pH ranges from 6.0 to 7.0, though some hybrids tolerate high or low pH conditions. They grow well on upland and bottomland soils if the soils have good moisture-holding capacities and are of medium texture. Hybrids show extreme variation in tolerance of adverse climate conditions. They grow best on soils of the orders Entisols, Inceptisols, Mollisols, Spodosols, and Ultisols (Roller, K. J., D. H. Thibault, and V. Hildahl. 1972).

Poplars grow best on fertile soils, and early height growth can average 1.2 to 1.8 m per year (Demeritt, Maurice E., Jr. 1979 & Demeritt, Maurice E., Jr. 1981). On many sites in the northeastern United States (Dickmann, Donald I., and Katherine W. Stuart. 1983), the first-year height growth is 0.9 to 2.4m. Mean annual height growth after 10 to 20 years is 0.9 to 1.4m; mean annual diameter growth after 10 to 20 years is 1.0 to 1.5 cm; mean annual volume increment after 10 to 20 years is 7.0 to 24.5 m^3/ha; and mean annual biomass increment after 5 to 20 years is 4.5 to 20.2 tons/ha. A study in New Orleans showed that mean annual diameter increment of *Populus deltoides* that have planted

on medium-textured soil was 1.3 to 1.7 cm (Krinard, Roger M.; Johnson, Robert L. 1984). This species in Washington (at 12 km east of Olympia) averaged nearly 15 cm in diameter and 19 m in height at age 7 (Dean S. DeBell, Gary W. Clendenen, Constance A. Harrington, and John C. Zasada). It means that mean annul diameter and height growth of this species is 2.14 cm and 2.71 m in this area, respectively.

Paulownia fortunei is also another exotic species that it has planted in northern Iran. Plantation of this species may solve majority of wood requirements. The reports on plantation of this species in the Golestan province are promising (Abbasi, 2000). This species is native species in China and has been cultivated in China for at least 3000 years (Hu, 1959). Some reports show that fast growth is an outstanding characteristic of *Paulownia fortune*i (Zhu Zhao Hua et al., 1986); that is a fast-growing tree and occurs naturally in China, Taiwan, Cambodia, Laos and Vietnam and as a fast growing, short-rotation timber crop and it has been widely promoted in Australia (Van de Hoef, 2003).

In natural sites of Vietnam, the average diameter growth of *Paulownia* at dbh has been reported 3-7 cm and height 2.39-2.43 m (Tran Quang Viöt, 2001). The growth in diameter and height of this species has been in satisfactory level in the Golestan province - Iran (Abasi, 2000). *Paulownia fortunei* is suitable for agro forestry systems and is planted in large scale in agro forestry systems in China. This species used in polyculture with coffee on granite soils reveals more favorable results (Tran Quang Viöt, 2001). *Paulownia fortunei* occurs naturally in China, Taiwan, Cambodia, Laos and Vietnam. It was introduced into Japan and Korea over 1000 years ago (Van de Hoef, 2003) and into the United States in the 1800s (El-Showk and El-showk, 2003). That is currently being grown in plantations in Australian (van de Hoef, 2003) and Turky (Boydak, 1999).

This species is highly adaptable and widely distributed (Zhu Zhao Hua, 1981). Its natural distribution areas range from tropical to moderate climates, on sites with average annual rainfall ranging from 500 mm to over 2000 mm. It occurs from just above sea level up to an altitude of 2400m. The growth of *P. fortunei* is strongly dependant on site conditions and trees may reach to 40-50m in height and have a diameter of greater than 2m when mature. In the first year of growth, trees may reach to 4-6m in height, growing another 2-3 m in the second year. *P. fortunei* growing on favorable sites in China and Japan may be 10 m in height with a clear bole of 5m and diameter of 22cm at breast height in 4 year. At these sites it is usual for trees to have a diameter of 45-50cm at 10 years of age, with production of 12 m^3/ha/year (Van de Hoef, 2003). In Yingang county, Szechuan province of China, an 18 years old *P. fortunei* tree averages about 21.7 m height, has a dbh of 100.5 cm, and volume of 6.65 m^3 of timber, thereby having annual increment of about 0.37 m^3 (Zhu Zhao Hua et al., 1986). The suitable site conditions for its growth is elevation ranging from 200 m to 1300 m above sea level, average annual temperature from 15.2 to 23.5^{o}C; annual precipitation from 1391 to 2833 mm, and moist soils not severely degraded. Under these conditions, the species can yield a diameter growth of 3.0 – 4.5 cm annually and a height growth of 2.5 – 3.0 m a year (Tran Quang Viet, 2001). The growth in diameter and height of this species has been in satisfactory level in the Golestan province in Iran (Abasi, 2000). Climatic and edaphically conditions in Guilan is similar to the distributions region of *Paulownia* and *Populus* in the world.

P. fortunei can withstand -5^{o}C to 10^{o}C temperature. The optimal temperature for growth is about 24-29^{o}C as a daily mean. Sufficient moisture is important for growth. *P. fortunei* is found mostly on light clay sandy. Soil pH is 5.0-8.0 is most suitable for *P. fortunei. P. fortunei* provides suitable wood for the manufacture of furniture, plywood and musical instruments and many other uses (Zhu Zhao Hua et al.,1986).

Populus deltoides and *Paulownia fortunei* both have shown very good results and received attention of people interested in planting fast growing. Considering that these species have been planted in northern Iran as fast growing species and primary studies showed that *Paulownia fortunei* is faster growing than *Populus deltoides* and shows better results under culture condition in planting sites as compared to *Populus deltoides* (Hassanzad Navroodi I., 2005), thus comparison the increment and wood production of these species is considered. *Paulownia* like *Populus* prefers fertile, deep and well-drained soils. It is assumed that there will be significant differences between increment and wood production of *Populus deltoids* and *Paulownia fortunei* in Guilan province. The objective of this study is to compare the increment and wood production of fast-growing species of *Populus deltoids* and *Paulownia fortunei* in Guilan province in order to know which species can produce high wooden biomass in this area.

2. Materials and Methods

The present project was carried out in a nursery in the Shanderman with a total area of 3000 m². The Shanderman nursery is located in western Guilan (west north Iran). The annual mean precipitation is 1958 mm and the annual maximum, minimum and mean temperatures are 38.5, -11 and 15.6 °c, respectively (Hassanzad, 2000). In March 2003, the *Populus deltoides* seedlings were collected from clone no. 69.77 of the Shanderman nursery and the *Paulownia fortunei* from Gorgan in the Golestan Province (east north Iran) were planted at a 4 m by 4 m spacing in the form of complete randomize block design with three replications. The dbh and height of all *Populus* and *Paulownia* seedlings were measured immediately after planting, and again in the following March, when the survival rate was also determined. In the second, third and forth years, the dbh and height increment and also percentage of survival of seedlings were again determined. ANOVA was used to compare increment and wood production fast-growing species of *Populus deltoides* and *Paulownia fortu-*

nei in the study area.

3. Results

Results showed that there were significant differences between mean annual dbh and basal area increment of *Paulownia fortunei* and *Populus deltoides* at the 0.01 confidence level in this area (Tables 1 through 4).

Table 1. Analysis of variance and test of the significance differences between mean annual dbh increment of P. fortunei and P. deltoides in the Guilan province

ANOVA (dbh increment)	Sum of Squares	df	Mean Square	F	Sig.
BetweenGroups	435.254	2	217.627	38.203	0.000
Within Groups	2187.476	384	5.697		
Total	2622.730	386			

Table 2. *Duncan's test for comparison groups of mean annual dbh increment of P. fortunei and P. deltoides in the Guilan province*

Species	N	Subset for alpha = 0.01		
		1	2	3
Populus deltoides	129	2.6542		
P.fortunei+P.deltoides(Mix)	129		3.7589	
Paulownia fortunei	129			5.2299
Sig.		1.000	1.000	1.000

Table 3. *Analysis of variance and test of the significance differences between mean annual basal area increment of P. fortunei and P. deltoides in the Guilan province*

ANOVA (Basal area increment)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	24403.020	2	12201.510	22.546	.000
Within Groups	207816.938	384	541.190		
Total	232219.957	386			

Table 4. *Duncan's test for comparison groups of mean annual basal area increment of P. fortunei and P. deltoides in the Guilan province*

Species	N	Subset for alpha = .01		
		1	2	3
Populus deltoides	132	7.6598		
P. fortunei+P.deltoides(Mix)	126		16.8333	
Paulownia fortunei	129			26.9951
Sig.		1.000	1.000	1.000

Results also showed that there were significant differences between mean annual height increment of *P. fortunei* and *P. deltoides* at the 0.01 confidence level in this area (Tables 5 and 6).

Table 5. *Analysis of variance and test of the significance differences between mean annual height increment of P. fortunei and P. deltoides in the Guilan province*

ANOVA (Height increment)	Sumof Squares	df	Mean Square	F	Sig.
Between Groups	603731.415	2	301865.708	30.142	.000
Within Groups	3845615.003	384	10014.622		
Total	4449346.419	386			

Table 6. *Duncan's test for comparison groups of mean annual height increment of P. fortunei and P. deltoides in the Guilan province*

Species	N	Subset for alpha = .01		
		1	2	3
Populus deltoides	132	201.8409		
P. fortunei+P.deltoides(Mix)	126		250.3730	
Paulownia fortunei	129			298.0310
Sig.		1.000	1.000	1.000

In Tables 1 through 6, mean annual dbh and height increment of *P. deltoides* are 2.65 and 201.84 cm, respectively and *P. fortunei* 5.23 and 298.03 cm, respectively. Mean annual basal area increment of *P. deltoides* and *P. fortunei* are 7.66 and 27 cm^2 in this area. Plantation of both *P. fortunei* and *P. deltoides* (as pure plantation or mix plantation together) did not show a significant difference on mean dbh and height increment of these species at this study area (Tables 7 through 10).

Table 7. *Analysis of variance and test of the significance differences between mean annual dbh increment of P. deltoides as pure plantation and mix plantation with P. fortunei in the Guilan province*

ANOVA (dbh increment)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.418	1	7.418	3.141	0.078
Within Groups	469.925	199	2.361		
Total	477.343	200			

Table 8. *Analysis of variance and test of the significance differences between mean annual height increment of P. deltoides as pure plantation and mix plantation with P. fortunei in the Guilan province*

ANOVA (Height increment)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1743.292	1	1743.292	0.224	0.636
Within Groups	1546434.529	199	7771.028		
Total	1548177.821	200			

Table 9. *Analysis of variance and test of the significance differences between mean annual dbh increment of P. fortunei (as pure plantation and mix plantation with P. deltoides) in the Guilan province*

ANOVA (dbh increment)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.011	1	5.011	0.673	0.413
Within Groups	1370.087	184	7.446		
Total	1375.098	185			

Table 10. *Analysis of variance and test of the significance differences between mean annual height increment of P. fortunei as pure plantation and mix plantation with P. deltoides in the Guilan province*

ANOVA (Height increment)	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	507.518	1	507.518	0.046	0.830
Within Groups	2025885.385	184	11010.247		
Total	2026392.903	185			

From the results of Table 10, one can conclude that increment and wood production of *P. fortunei* is better than *P. deltoides* in the study area.

4. Discussion and Conclusion

The results showed that mean annual dbh and height increment of *P. deltoides* are 2.65 and 201.84 cm, respectively and for the *P. fortunei* 5.23 and 298.03 cm in Guilan province. Mean annual dbh and height increment of *P. fortunei* is 3.75 and 275 cm in natural distribution area of world (Zhu Zhao Hua *et al.* 1986 & Tran Quang Viet 2001). A study in Washington (at 12 km east of Olympia) showed that mean annual increment of *P. deltoides* averaged nearly 2.14 cm in dbh and 2.71 m in height (Dean S. DeBell, Gary W. Clendenen, Constance A. Harrington, and John C. Zasada). Another study in New Orleans showed that mean annual diameter increment of *P. deltoides* that have planted on medium-textured soil was 1.3 to 1.7 cm (Krinard, Roger M.; Johnson, Robert L. 1984). This demonstrates that level of increment and wood production of *P. deltoides* in the study area is suitable and it is almost as the same as other natural distribution areas of *P. deltoides* in the world.

Mean annual basal area increment of *P. deltoides* and *P. fortunei* are 7.66 and 27 cm^2 in this area. There were significant differences between mean annual dbh, basal area and height increment and wood production fast-growing species of *P. deltoides* and *P. fortunei* at the 0.01 confidence level in Guilan province (Tables 1 through 6). Plantation of both *P. fortunei* and *P. deltoides* as pure plantation or mix plantation together did not show a significant difference on mean dbh and height increment of these species at this study area (Tables 7 through 10). These results also showed that increment and wood production of *P. fortunei* is better than *P. deltoides* in the study area. Previous results of *P. fortunei* and *P. deltoides* increment in the first year in the syudy area showed suitable growth of *P. fortunei* as compared to *P. deltoides* (Hassanzad Navroodi I., 2005). In the study area, it was assumed that there would be significant differences between increment and wood production of *P. fortunei* and *P. deltoides* in Guilan province and this hypothesis approved.

The site conditions of *P. deltoides* and *P. fortunei* showed that *P. fortunei* is highly adaptable and widely distributed (Zhu Zhao Hua 1981) and *P. fortunei* can be grown on sites that it is suitable for the growth of *P. deltoides* as the same as study area. However, some sites that *P. fortunei* can be grown well upon; it may be not suitable for growth of *P. deltoides*. Of course, the study area has an optimal temperature for growth of both species *P. deltoides* and *P. fortunei*.

P. fortunei has many uses (Zhu Zhao Hua *et al.*1986) and one of the most important objectives of this study is the production of high wooden biomass for wood industrials. The increment of *P. fortunei* in the study area was better than its natural distributions areas of the world (Hassanzad Navroodi I., 2007) and increment of *P. deltoides* in this area. Therefore, it is suggested to use *P. fortunei* in forest farming or cultivated forests with the purpose of wood production in the short rotation, as a suitable enterprise in Guilan province. the reason is that this species has an excellent increment in the study area in comparison to *P. deltoids*, although *P. deltoids* also has a suitable growth. *P. fortunei* is also a suitable alternative for sustainable forestry in cultivated forests (El-Showk and El-showk, 2003) or forest farming in the study area.

Although, *P. fortunei* is a very fast-growing species and it has an excellent increment and highly adaptable and it is widely distributed and also may be a suitable species to produce very high wooden biomass in the short rotation, but kind of application, people demand, economic value, market demand and others of these species should also be evaluated. The reason is that cultivation of this species may not have economic values in all conditions. It may not be significant demand for wood of this species. So this study has been done only on the diameter and height growth and increase of its wood volume. To decide about its planting should be conducted a comprehensive investigation. While, consumer demand for poplar wood is remarkable in the study area.

5. References

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