21. EVALUATION OF THE GROWTH POTENTIAL OF *PAULOWNIA FURTUNEI* IN GUILAN PROVINCE

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Paulownia furtunei is a fast-growing tree which under optimal conditions can produce useful timber in five to six years. The wood of this species has properties suited for a variety of applications. This species is highly adaptable with regard to planting site, and is widely distributed. Its natural distribution ranges from tropical through to temperate climates. *P. furtunei* is cultivated in many locations including in the Golestan Province of Northern Iran. To evaluate diameter and height growth potential of *P. furtunei* in Guilan in order to use this species in forest farming or cultivated forests with the purpose of rapid exploitation of timber in Guilan Province, an area of about 3000 m^2 was selected in Shanderman Nursery and was planted at a 4 m by 4 m spacing. The diameter at breast height (dbh) and total height were measured after planting and again in the second and third year to estimate diameter and height growth potential and some important characteristics were analyzed. Growth measurements will be continued for at least five or six years. The dbh and height annual increment of *P. fortunei* were 3.24 cm and 1.88 m in the second year and 4.87 cm and 3.23 m in the third year, respectively. The mean dbh and annual height increment were 4.12 cm and 2.61 m up to the third year. A paraboloid relationship between height and dbh was estimated. If the current growth rate continues, it seems that growth of *P. fortunei* in Guilan Province is suitable and comparable to its natural distribution areas.

INTRODUCTION

Population growth and daily requirement for using wood and wood products with regard to wood shortage is a highly important issue today. Production of short-rotation species is one solution to overcome wood shortage. Development of plantations and establishment of an exotic species in a new region can also cause an increase in species diversity in the region. Sometimes exotic species have high growth performance in a new location (Zobel *et al.* 1987). With improvement in wood production by fast growing species, the pressure exerted on natural forest regarding wood utilization will be subdued. This is the method that is adopted in many countries.

Paulownia furtunei is one of nine recognised species of the genus *Paulownia* (Jey 1998). Fast growth is an outstanding characteristic of these species (Zhu Zhao Hua *et al.* 1986). These species are similar in appearance and timber properties (Cheng Jueng Ching *et al.* 1983). *Paulownia furtunei* is a fast-growing tree and occurs naturally in China, Taiwan, Cambodia, Laos and Vietnam (Van de Hoef 2003). This species has been cultivated in China for at least 3000 years (Hu 1959), and 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). *P. furtunei* is currently being grown in plantations in Australian, and in fact has been widely promoted in Australia as a fast growing, short-rotation timber crop (Van de Hoef 2003). The Turkish Ministry of Forestry has been researching plantations production of *P. furtunei* since 1998 (Boydak 1999). This species has been cultivated in the Golestan Province in northern Iran and the growth in diameter and height has been at a satisfactory level (Abbasi 2000).

This species is highly adaptable and widely distributed (Zhu Zhao Hua 1981). Its natural distribution ranges from tropical through 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 2400 m. The growth of *P. furtunei* is strongly dependent on site conditions and trees may reach 40–50 m in height and have a diameter of greater than 2 m when mature, although trees of this size under cultivation are rare. In the first year of growth, trees may reach 4–6 m in height, growing another 2–3 m in the second year. *P. furtunei* growth on favourable sites in China and Japan may be 10 m in height with a clear bole of 5m and diameter of 22 cm at breast height in four years. 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 year old *P. furtunei* 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 an annual increment of about 0.37 m^3. As the Chinese say, 'It

looks like a pole in one year, an umbrella in three years and can be sawn into boards in five years', (Zhu Zhao Hua *et al.* 1986).

In China, *P. furtunei* adapts well both at low and high altitude. Diameter and height increments of five year old *P. furtunei* in Wu Guemy (Lat. N. 34º 26' Long. E 107º 42') are 2.9 cm and 1.9 m, respectively. *P. furtunei* can attain an annual average diameter increment of 3.4–4.2 cm on acid soil yet also grow well on soil with a pH of 8.8. At the Xiao Pu Forestry Farm, Chang Xing county, Checkiang Province, the trunk of 4-year old *P. furtunei* was 7 m in height and the dbh 21 cm. At an altitude of 600 m in En Shi County, Hupeh Province, 6-year old *P. furtunei* was 11 m height with a trunk height of 7 m and dbh of 22 cm (Zhu Zhao Hua *et al.* 1986). Other studies show that *P. furtunei* can be grown with succes in more than one region in Vietnam. The site conditions found to be suitable for its growth are: elevation ranging from 200 m to 1300 m above sea level; average annual temperature from 15.2 to 23.5 ºC; 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).

P. furtunei can withstand −5 ºC to 10 ºC temperature. The optimal temperature for growth is about 24–29 ºC as a daily mean. In China, maximum, minimum and mean temperatures for growth are 40, −10 and 15–23 ºC, respectively. Sufficient moisture is important for growth. The annual precipitation of extensive areas is 1200–2500 mm. *P. furtunei* is found mostly on light clay, sandy soils. *P. furtunei* grows on soils with 16.3–23.5% clay while the other *Paulownia* species are found on soils with less than 10% clay. On excessively clay soils, *P. furtunei* can grow well. A soil pH of 5.0–8.0 is most suitable for *P. furtunei.* It is tolerant of poor soil, but grows much better on fertile soils (Zhu Zhao Hua *et al.* 1986). Application of NPK fetilizer increases the growth rate (Jey 1998).

Considering that this species has many uses and is very fast-growing, adaptable and widely distributed, it seems well-suited to forest farming or short-rotation plantations in Guilan Province. It is hypothesised that diameter and height growth of *P. fortunei* in Guilan will be similar to that in other locations, including China and Vietnam. Growth trials have been established to test this hypothesis.

P. furtunei provides suitable wood for the manufacture of furniture, plywood and musical instruments. *Paulownia* timber was exported from China to Japan, where it was used to produce handicrafts. The wood is easily worked, suitable for carving, and has excellent insulation properties. This species is an exceptionally well-suited for intercropping, and can also be used in polyculture with other species. The leaves and flowers are rich in nitrogen and therefore serve as good fertilizer and fodder. They also have many medicinal uses, and the flowers of *P. furtunei* are a good resource for attracting honey bees (Zhu Zhao Hua *et al.*1986).

The objectives of this study are to evaluate diameter and height growth potential in *P. fortunei* in the study area in comparison with its other natural distribution locations. Climatic and edaphic conditions in Guilan are similar to the distribution region of *P. fortunei* elsewhere in the world. Growth performance will be monitored in the coming years. If *P. fortunei* shows a suitable growth potential in Guilan, it could be cultivated as an alternative for sustainable forestry in cultivated forests or forest farming.

RESEARCH METHOD

The project was carried out in a nursary in the Shanderman district in western Guilan. The annual mean percipitation is 1958 mm, and the annual maximum, minimum and mean temperatures are 38.5, −11 and 15.6 ºC, respectively (Hassanzad 2000). In March 2003, *P. fortunei* seedlings collected from Gorgan in the Golestan Province (North Iran) were planted in an area of 3000 m^2. The dbh and height of all seedlings were measured immediately after planting, and again in the following March, when the survival rate was also determined. In the second and third years, the diameter and height growth and also percentage of survival of seedlings were again determined. The t-test was used to compare mean diameter and height growth in *Paulownia fortunei* between years and with other locations.

RESULTS

Diameter and Height Increment of *Paulownia fortunei*

P. fortunei sapling diameter and height, and the mean increment of dbh and height growth, in Guilan Province are shown in Figures 1 to 3. About 14% of saplings died during the first three years after out-planting.

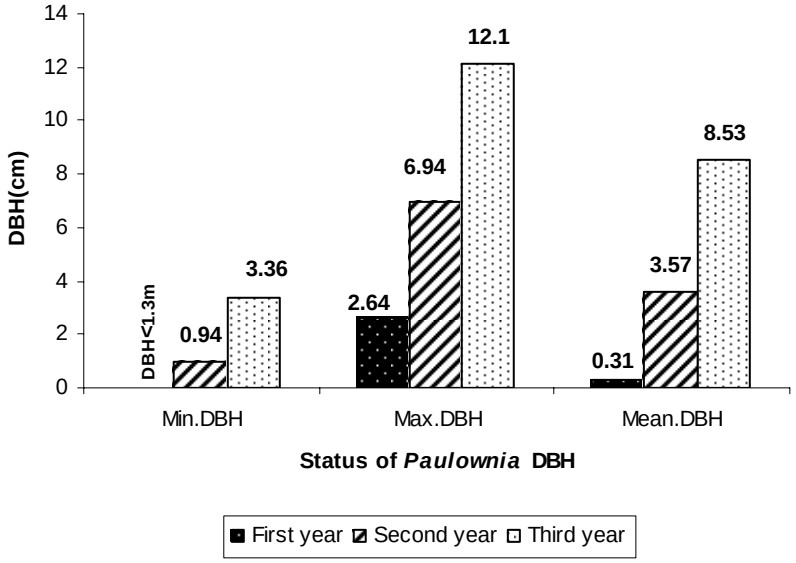

Figure 1. Status of *Paulownia* sapling DBH.

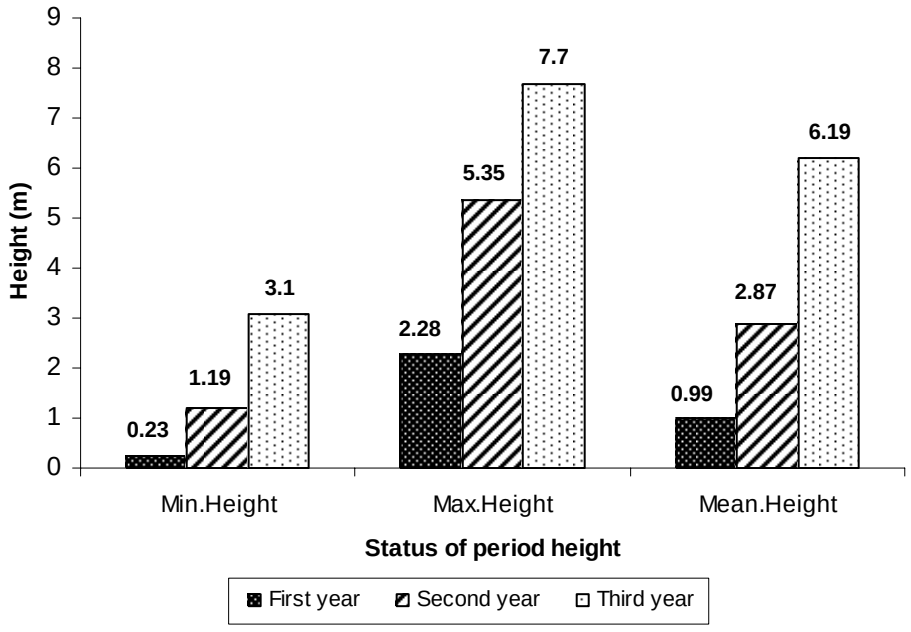

Figure 2. Status of *Paulownia* sapling height

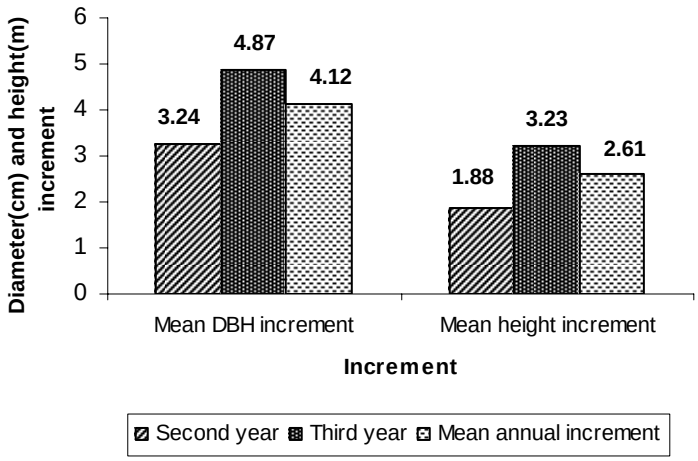

Figure 3. Status of diameter and height growth of *Paulownia fortunei* saplings.

Relationship between Height and Diameter of *P. fortunei*

The parabolic formula ($H = -0.025^* DBH^2 + 0.9154^* DBH + 0.1435$) was estimated between height and diameter of planted *P. fortunei* in the study area, with $R^2 = 0.93$ (Figure 4).

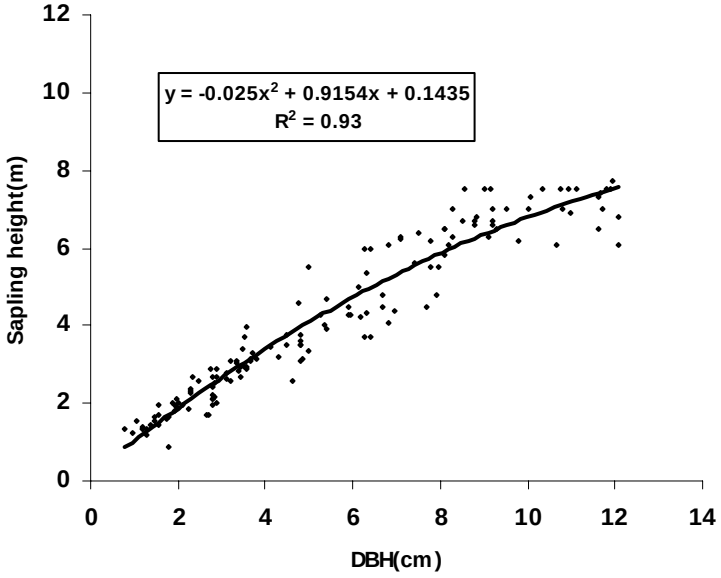

Figure 4. Height versus DBH curve of *P. fortunei* in the study area

Paired samples t-test was used to study the relationship between diameter and height increment of *P. fortunei* between second and third years (Tables 1 and 2). One-sample t-tests were used to compare mean diameter and height growth of P. fortunei in Guilan with other locations. The results are reported in Tables 3 and 4.

Table 1. Paired samples test for study the status of diameter increment of *P. fortunei* between second and third years.

Paired samples test	Paired differences					t	df	Sig. 2-tailed
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Pair 1 DBH incr. in 2nd Yr-DBH incr. in 3rd yr	1.4998	1.8254	.2318	1.0363	1.9634	6.470	61	.000

Table 2. Paired samples test for study the status of height increment of *P. fortunei* between second and third years.

Paired samples test	Paired differences					t	df	Sig. 2-tailed
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Pair 1 Hi incr. in 2nd Yr-Hi incr. in 3rd Yr	-123.854	101.985	12.952	-149.754	-97.955	-9.563	61	.000

Table 3. One-sample test for comparing mean diameter increment of *P. fortunei* in the study area with its natural distribution areas.

One-sample test	Test value = 3.75					
	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Mean diameter increment	2.618	61	.011	.3707	8.753E-02	.6539

Table 4. One-samples test comparing mean height increment of *P. fortunei* in the study area and its natural distribution areas.

One-sample test	Test value = 275					
	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Mean height increment	-1.893	61	.063	-13.6855	-28.1414	.7704

DISCUSSION AND CONCLUSION

Analysis of data show that there are significant differences at the 1% level between diameter and height increment of *P. fortunei* in the second and third years after out-planting. The level of diameter increment of *P. fortunei* in the second year is greater than that of the third year and the level of height increment of *P. fortunei* in the second year is less than in the third year (Tables 1 and 2). There are no significant differences at 1% level between diameter and height growth of *P.*

fortunei in the study area with its natural distribution areas in other location of world. But between diameter growth of *P. fortunei* in the study area with its natural distribution areas in other location of world, there are differences at 5% significance level (Tables 3 and 4). The level of dbh and height increment of *P. fortune*i in the study area is slightly more than in its natural distribution areas.

The average diameter increments of this species were 3.24 and 4.87 cm in the second and third years respectively, and its dbh annual increment averaged 4.12 cm. The mean height increments were 1.88 and 3.23 m in the second and third years respectively, and the annual height increment averaged 2.61m.

The average diameter of *P. fortunei* in the first year was 0.33 cm while this diameter reached 3.57 cm in the second year and 8.53 cm in the third year, representing an 11-fold increase in the second year and a further 2.5-fold increase in the third year. The average height of *Paulownia* in the first year was 0.96 m and reached 2.87 m in the second year, a 3-fold increase . The average height of saplings in the third year reached 6.19 m, a 2-fold increase relative to the second year.

These observations demonstrate that growth increments of *P. fortunei* are satisfactory in the second and third years. Considering that the increment level of this species was suitable at the end of third year and it can produce useful timber within five to six years, it seems that the growth of *P. fortunei* in Guilan Province is succesful at least until the third year. The studies also show that this species is highly adaptable and widely distributed. Its natural distribution ranges from tropical through moderate climates, on sites with average annual rainfal ranging from 500 mm to over 2000 mm. It occurs from just above sea level up to an altitude of 2400 m. *P. furtunei* can withstand −5 ºC to 10 ºC temperatures.

The studies show that site conditions of *P. fortunei* in the study area are similar to its natural distribution areas in other parts of the world. In the study area, the annual maximum, minimum and mean temperature are 38.5, −11 and 15.6 ºC, respectively, the mean annual precipitation is 1200–2500 mm and the soil pH is 6.0–7.0. In the natural sites of *P. fortunei* in China, maximum, minimum and mean temperature for growth are 40, −10 and 15–23 ºC, respectively and the suitable pH of the soil is 5.0–8.0.

Paulownia furtunei is one of nine recognised species of the genus *Paulownia* and fast growth is an outstanding characteristic of these species. This species also has high growth potential in the study area and shows no significant differences in its natural distribution. It seems that because the conditions of the study area are similar to that of the natural distribution areas of *P. furtunei*, satisfactory results will be obtained over the next few years. Evidence of this is the fact that this species has been cultivated in the Golestan Province in northern Iran and the growth in diameter and height has been of a satisfactory level.

This species has been widely promoted in Australia as a fast growing, short-rotation timber crop and could therefore also be regarded as a suitable alternative for sustainable forestry in cultivated forests in the Guilan Province for the rapid exploitation of timber and decreasing the pressure on natural forests.

REFERENCES

Abbasi, N. (2000), *Growth and adaptability of Paulownia fortunei*, Book of abstracts of the National Conference on Management of Northern Forest on Sustainable Development, 5–7 September 2000, Ramsar, Iran.

Boydak, M. (1999), 'Can *Paulownia* become a miracle species?', *Turkish Journal of Forestry Engineering,* 9, p. 4–9, Ankara.

Cheng Jueng Ching, (1983), 'Research on the wood properties and utilization of the genus *Paulownia', Forestry Science in China,* 19, No. 1–3.

El-Showk, S. and El-showk, N. (2003), The *Paulownia* tree; An alternative for sustainable forestry, Crop Development, Morocco, pp. 1–8.

Hassanzad Navroodi, I. (2000), A Survey on Quantity and Quality of Growing Stock Changes of Natural Forest Stand of Asalem Beech, PhD thesis, Tehran University of Natural Resources.

Hu, S.Y. (1959), A Monograph of the Genus *Paulownia,* Taiwan Musem XII, No. 1 and 2.

Jey, A. (1998), '*Paulownia* plantation experiences and profitable timber production', Australian Forest Growers Conference Proceedings, 1998, Lismore, pp. 199–214.

Tran Quang Viet (2001), Technology and Practice Development Research for the Cultivation of *Paulownia fortunei*: Forest Science and Technology Research Results, 1996–2000.

Van de Hoef, L. (2003), *Paulownia, Agriculture Notes* (AGO778), ISSN 1329-8062, A site in north east Victoria state, Department of Primary Industries, Box Hill, Melbourne, Australia, pp. 1–3.

Zhu Zhao Hua (1981), 'Exploration on the distribution centre and flora structure of the genus *Paulownia* plant', *Academy of Forestry*, Beijing, China, pp. 221-280.
Zhu Zhao Hua, Chao Ching-Ju, Lu Xin-Yu, Xiaong Yao Gao (1986), *Cultivation and Utilization, Academy of Forestry*, ANFBS and IDRC, Beijing, China.
Zobel B. *et al.* (1987), *Growing Exotic Forests*, John Wiley and Sons, New York, p. 508.