Journal of Environmental Biology **July 2006,** 27(3) 499-504 (2006)

Growth variation of *Paulownia* Sieb. and Zucc. species and origins at the nursery stage in Kastamonu-Turkey

S. Ayan,[1] A. Sivacioglu[1] and N. Bilir[2]
[1]Gazi University, Kastamonu Forestry Faculty, 37200 Kastamonu, Turkey
[2] Suleyman Demirel Universty, Forestry Faculty, Isparta, Turkey

(Received: 24 June, 2005 ; Accepted: 10 December, 2005)

Abstract: *The present study was carried out on Paulownia tomentosa (6), Paulownia elongate (4), Paulownia fortunei (5) and Paulownia fortunei x tomentosa (1) origins at Kastamonu Forest Nursery. The seedling height growth (SH), root collar diameter (RCD), dry root percentage (DRP) and seedling percentage (SP) of one-year old seedlings of the origins were studied for comparing growth performance of the species and origins and discussing for guidance to field stage based on nursery stage. As a result, P. tomentosa x fortunei hybrid has the highest SH (72.62 cm) among the used species. Significant difference was determined among the origins as to the SH and DRP .The maximum SH were determined for P. tomentosa Beijing-Daxin (81.32 cm) and P. elongata Beijing-Daxin (80.76 cm) origins. The maximum DRP were determined for P. tomentosa Anhui-Tongling (77 %) origin. There were no significant differences based on RCD and SP among the species and the origins. Among the parents, there were important diversities for SH and RCD. As a final remark, observations and evaluations of the Paulownia studies should be included with the clonal variation for further studies because of the observed growth variations within the population.*

Key words: *Paulownia, Origin, Adaptation, Nursery stage, Kastamonu.*

Introduction

It is estimated that the gap between supply and demand of industrial wood in Turkey will become 6.7 million cubic meters in 2010 (Anonymous, 1988).Therefore the emphasis has been given to the establishment of industrial plantations with fast growing species in order to meet the increasing shortage of wood and fiber. Accordingly, Turkish forestry has been establishing plantation of the different fast growing species since 1950. However, the plantation of *Eucalyptus* sp. and *Pinus pinaster* Ait as a fast growing species had been started earlier than 1950. Turkey did not find the expected result to meet the wood and fiber shortages by the fast growing species plantation eventhough, having more than 50 years of experience. *Eucalyptus* sp., *Robinia pseudoacacia* L., *Ailanthus altissima* (Mill.) Swingle., *Pinus pinaster* Ait., *P. radiata* D. Don. and *Pseudotsuga menziesii* (Mirb.) Franco. have been used mostly as the fast growing species. On the other hand, *Paulownia* Sieb.& Zucc. as a fast growing species has been used by Turkish forester after 1990.

The genus *Paulownia* (Scrophulariaceae) includes nine species of fast-growing trees, indigenous to China and East Asia. These are *Paulownia fortunei, P. tomentosa, P. fagesii, P. australi, P. elongata, P. taiwaniana, P. albiphloea, P. catalpifolia and P. kawakamii*. These trees were also introduced to North America, Australia, Europe and Japan for different purposes (Kumar *et al.,* 1999; Anonymous, 2002). *Paulownia* wood is widely used for house construction, pulp and paper, furniture, farm implements, music instrument and handcrafts. Other than its wood uses, *Paulownia* has been planted for medicinal, seed oils, fodder, manure, charcoal, mined land reclamation purposes (Turner *et al.*, 1988).

In addition, *Paulownia* genus has also an unique biological character. Because its root system grows in deep into the soil and its crown develops in loose structure, which enable it suitable to be intercropped with other crops or mixed planting of other shade-tolerant trees. Thus, *Paulownia* can be considered as a suitable tree for the agroforestry practices (Zhao-Hua *et al.*, 1986; Lu and Xong, 1986; Dhiman, 1997). Among these, various types of *Paulownia* intercropping practised in Woyang Country, Anhui Province, a flat agricultural region in the lower Huang and Huai River Valley are the successful examples (Jiang *et al.*, 1994). Along with its high tolerance to natural conditions, appropriate trees for agroforestry systems and reclamation of degraded lands, valuable woods, having medicinal and aromatic value are likely to make it attractive to other countries (Wang and Shogren, 1992).

Ürgenç (1982) suggested that origin trials should be examined in two different stages. These are the nursery stage and the field stage. Field stage takes very long time to get the results as compared to the nursery stage. Therefore, field stage needs more man-power, time and money. On the other hand, nursery stage takes not more than five years of trial. As results, the nursery trials of species and origins are preferable for most of the researchers. The objective of present study is to determine suitable *Paulownia* species and their origins based on growth performance of nursery stage in Kastamonu.

Materials and Methods

In this study, one-year old seedlings, which were propagated from seeds of 16 origins of *P. tomentosa* (6), *P. elongata* (4) , *P. fortunei* (5) and *P. fortunei* x *tomentosa* (1) obtained from China (Anonymous 1998), were used. Some

Table – 1: *Paulownia* species and their origins.

No	Species	Provenance	Altitude (m)	Mean annual precip. (mm)	Mean annual temp. (C°)	Lowest temp. (C°)
1	*P. tomentosa*	Shannxi-Xi'an	1200	470	9.3	-15
2	*P. tomentosa*	Henan-Luoyang	100	640	14.2	-10
3	*P. tomentosa*	Shannxi-Taiyuan	750	604	13.3	-10
4	*P. tomentosa*	Shangdong-Chenwu	40	672	14.2	-10
5	*P. tomentosa*	Beijing-Daxin	50	682	11.6	-18
6	*P. tomentosa*	Anhui-Tongling	120	1000	15.7	-7
7	*P. elongata*	Henan-Shanggiu	50	640	14.2	-10
8	*P. elongata*	Shannxi-Xi'an	750	604	13.3	-10
9	*P. elongata*	Anhui-Tongling	120	1000	15.7	-7
10	*P. elongata*	Beijing-Daxin	50	682	11.6	-18
11	*P. fortunei*	Guangxi-Guilin	560	1873	18.8	-2
12	*P. fortunei*	GuiZhaou-Xinren	1100	1200	15.3	-2
13	*P. fortunei*	Zhejiang-Lin'an	650	1200	16.1	-6
14	*P. fortunei*	Hubei-Hunan	20	1260	16.3	-7
15	*P. fortunei*	Anhui-Tongling	120	1000	15.7	-7
16	*P. fortunei* x *tomentosa*	Shen xIhnan				

Table – 2: The physical and chemical characteristics of germination and growth media.

Medium	Specific gravity g/cm^3	Porosity % Vol.	Air capacity %Vol.	Water capacity %Vol.	pH	Organic matter %	Total N %	Cation exchange capacity me/100gr	Electrical condactivite 1/2.5 Volume mS/cm
50% peat + 25 % stream sand + 25% forest soil *	2.42	57	7	50	6.9	6.90	0.34	22.95	1.07
60% forest soil+ 20% barn manure+ 20% stream sand**	2.45	58	8	50	7.6	9.35	0.46	38.62	0.60

* Germination medium **Growth medium

Table – 3: Climatical data from Kastamonu Meteorology Station.

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2002	Total precipitation (mm)											
	41.6	5.3	21.0	68.4	13.4	62.4	73.8	46.5	133.4	54.1	26.6	17.8
	Minimum temperature (ºC)											
	-15.5	-9.1	-6.2	-5.1	0.8	5.1	10.9	5.8	4.0	-3.0	-4.0	-18.2
	Average temperature (ºC)											
	-3.8	3.1	6.6	9.0	14.1	18.4	22.2	19.2	15.8	11.3	5.4	-3.2
	Maximum temperature (ºC)											
	13.0	18.2	25.0	23.2	31.9	35.9	35.1	34.8	30.2	26.0	20.7	12.2

details of the origins are given in Table 1. The seedlings were grown in non-warming greenhouse and outdoors condition at 800 m elevation in Kastamonu, Turkey in 2002. The seed sowing was carried out in germination medium in the greenhouse at the beginning of May, 2002. After germination phase, when the seedlings reached to 5-10 cm height, the seedlings were uprooted from sowing boxes, and transplanted in polyethylene tubes, filled with growth medium on 17-21st

Table – 4: The average performance values of *Paulownia* species and origins.

No	Species	Origin	Average values SH (cm) (min-max)	RCD (mm) (min-max)	DRP (%)	SP (%)
1	P. tomentosa	Shannxi-Xi'an	58.61 (41-72)	8.14 (6-10)	73	**85.71**
2	*P. tomentosa*	Henan-Luoyang	71.95 (39-103)	8.65 (4-13)	52	87.14
3	*P. tomentosa*	Shannxi-Taiyuan	59.43 (24-78)	8.98 (6-11)	62	83.78
4	*P. tomentosa*	Shangdong-Chenwu	59.16 (29-79)	7.52 (5-11)	74	84.84
5	*P. tomentosa*	Beijing-Daxin	81.32 (40-100)	8.99 (5-14)	70	75.71
6	*P. tomentosa*	Anhui-Tongling	50.20 (12-68.5)	6.89 (3-11)	77	86.56
P. tomentosa			**63.44**	**8.19**	**68**	**83.95**
7	*P. elongata*	Henan-Shanggiu	62.96 (22-81)	8.90 (5-12)	76	81.15
8	*P. elongata*	Shannxi-Xi'an	54.72 (30-86)	8.87 (72-11)	74	82.60
9	*P. elongata*	Anhui-Tongling	77.81 (18-105)	9.14 (4-14)	66	81.69
10	*P. elongata*	Beijing-Daxin	80.76 (41-108)	9.26 (5-15)	51	83.56
P. elongata			**69.06**	**9.04**	**66.75**	**82.25**
11	*P. fortunei*	Guangxi-Guilin	-	-	-	-
12	*P. fortunei*	Guizhaou-Xinren	36.66 (18-54)	9.24 (5-12)	64	82.85
13	*P. fortunei*	Zhejiang-Lin'an	47.56 (14-76)	9.43 (5-13)	61	79.16
14	*P. fortunei*	Hubei-Hunan	55.55 (17-93)	8.56 (5-17)	70	76.05
15	*P. fortunei*	Anhui-Tongling	52.58 (28-75)	7.60 (4-12)	62	89.39
P. fortunei			**48.09**	**8.71**	**64.25**	**81.86**
16	*P. fortunei* x *tomentosa*	Shen x Ihnan	72.62 (36-95)	9.16 (5-15)	58	82.60
P. fortunei x tomentosa			72.62	9.16	63	82.60
General mean			63.30	8.77	65.92	82.66

June, 2002. The physical and chemical characteristics of the germination and growth media are given in Table 2. The seedlings were kept in the greenhouse during 2-2.5 months of the first growth period. During this time, the seeds germinated and the seedlings completed the succulent phase. After that, the seedlings were carried out to outdoor condition in the rest of the growth period. The related climatically data of the outdoor condition is given in Table 3.

Experimental design and data analysis: Experiment was arranged in a completely randomized plot design with three replications. The data were collected from thirty seedlings of each sampling time.

Analysis of variance was applied to the data obtained from seedling height (SH) root collar diameter (RCD), dry root percentage [(DRP= dry root weight (DRW) / dry seedling weight (DSW)] and seedling percentage (SP). Newman Keuls's Multiple Range Test (NKMT) was used for the grouping of the species and the origins in case of significant difference appeared between the species and the origins. For the variance analysis, after arc-sin transformation on SP and DRP parameters, TARIST Statistical Packet Programme Model 7 was used (Anonymous, 1994).

Results and Discussion

The average and maximum-minimum values for three replications of SH, RCD, SP and DRP for each origin and species are given in Table 4.

As seen in Table 4, there were large differences among the origins within the species for SH. Also, within the origins, there were remarkable differences for RCD and SH. For instance, SH ranged from 50.20 cm to 81.32 cm while RCD ranged 6.89 mm to 8.99 mm for *P. tomentosa* for the species base. Besides, SH ranged from 18 cm to 105 cm while RCD ranged 4 mm to 14 mm for *P. elongata* Anhui-Tongling for the origin base.

According to variance analysis, there were significant differences ($p<0.05$) among SH measurements for the species and the origins (Table 5). For the DRP values, there were no significant differences among the species. However, there was a highly significant difference among the origins.

As a result of NKMT, the best SH was determined for P. *fortunei* x *tomentosa* (72.62 cm) hybrid, *P. elongata* (69.06 cm) and *P. tomentosa* (63.44 cm) species, respectively (Table 6). On the other hand, there were no significant differences among DRP, RCD and SP for the species base.

According to the evaluations for each origin in Kastamonu condition, the highest SH was determined for *P. tomentosa* Beijing-Daxin (81.32 cm) and *P. elongata* Beijing-Daxin (80.767 cm) origins, respectively. However, the lowest SH was determined for *P. fortunei* Guizhaou-Xinren (36.663 cm) origin (Table 7).

DRP values of origins ranged from 51% to 77%. *P. tomentosa* Anhui-Tongling (77%) showed the maximum DRP

Table – 5: Analysis of variance of growth responses of the *Paulownia* species and origins.

Character	Source of variation	df	Sum of squares	Mean of squares	F
SH	Species	3	1055,121	351,707	18,023 **
	Error	6	117,085	19,514	
	Total	11	1337,261	121,569	
RCD	Species	3	1,703	0,568	0,408 ns
	Error	6	8,337	1,390	
	Total	11	10,430	0,948	
DRP	Species	3	0,019	0,006	2,031 ns
	Error	6	0,019	0,003	
	Total	11	0,040	0,004	
SP	Species	3	11,008	3,669	0,071 ns
	Error	6	310,396	51,733	
	Total	11	497,644	45,240	
SH	Origin	14	7149,425	510,673	8,310***
	Error	28	1720,759	61,456	
	Total	44	9676,965	219,931	
RCD	Origin	14	23,865	1,692	1,946 ns
	Error	28	24,345	0,869	
	Total	44	48,988	1,113	
DRP	Origin	14	0,294	0,021	4,106***
	Error	28	0,143	0,005	
	Total	44	0,440	0,010	
SH	Origin	14	720,283	51,449	0,479 ns
	Error	28	3009,3	107,475	
	Total	44	3896,806	88,564	

***: significant at $p < 0.001$; **: significant at $p < 0.01$; *: significant at $p < 0,05$; ns: none significant

Table – 6: Grouping the species according to SH average values by NKMT.

Species	Homogeneous groups for morphologic parameters*			
	SH** (cm)	RCD (mm)	DRP (%)	SP (%)
P. tomentosa	63.44 a	8.2 a	68.00 a	84 a
P. elongate	69.06 a	9.1 a	66.75 a	82 a
P. fortunei	48.08 b	8.7 a	64.25 a	82 a
P. fortunei x tomentosa	72.62 a	9.2 a	58.00 a	84 a

* The same letter shows the same group at 0.05 significant level, **; mean values

while *P. elongata* Beijing-Daxin (51%) origin showed minimum DRP.

There is no significant difference among the origins with respect to the RCD and SP parameters at the end of the first growing season. The highest RCD value was determined for *P. fortunei x tomentosa* Shen x Ihnan (9.1 mm), and the lowest for *P. tomentosa* (8.2 mm) for the species base (Table 6). Similar results for RCD were obtained for the same species and the origins by Ayan *et al.* (2002) at Of-Trabzon Forest Nursery.

According to the evaluations of third year of *Paulownia* field trials at the different elevations of Eastern Black Sea Region, any insect and fungus damage were not recorded. However, all seedlings were died because of winter frost of 1999 in the Gölköy-Ordu experiment area (at 1400 m elevation) (Ulu *et al.*, 2002). Ata and Demirci (1992) stated that; early frost damages on exotic tree species generally without killing in Turkey. In this study, biotic harms as insect or fungus were not observed, too. But, the early frost (-0.8 ºC) occurred at night of 2 nd November 2002 damaged to the top sprouts of all origins. This can be explained that the fast height growth do not give enough time to the lignification of a plant caused to severe early frost damages.

It was determined that among the species, used in this study, *P. tomentosa x fortunei* hybrid had the highest (72.62 cm) SH. Both P. *tomentosa* Beijing -Daxin (81.32 cm) and *P.*

Table – 7: Grouping the origins according to SH and DRP average values by NKMT

Origin No	Origin	Homogeneous groups for morphologic parameters*			
		SH** (cm)	RCD (mm)	DRP (%)	SP (%)
1	*P. tomentosa* Shannxi-Xi'an	58,617 bcde	8.14 a	73 ab	85.71 a
2	*P. tomentosa* Henan-Luoyang	71,967 abc	8.65 a	52 bc	87.14 a
3	*P. tomentosa* Shannxi-Taiyuan	59,433 abcde	8.98 a	62 abc	83.78 a
4	*P. tomentosa* Shangdong-Chenwu	59,167 bcde	7.52 a	74 a	84.84 a
5	*P. tomentosa* Beijing-Daxin	81,32 a	8.99 a	70 abc	75.71 a
6	*P. tomentosa* Anhui-Tongling	50,207 de	6.89 a	77 a	86.56 a
7	*P. elongata* Henan-Shanggiu	62,967 abcd	8.90 a	76 a	81.15 a
8	*P. elongata* Shannxi-Xi'an	54,72 de	8.87 a	74 ab	82.60 a
9	*P. elongata* Anhui-Tongling	77,817 ab	9.14 a	66 abc	81.69 a
10	*P. elongata* Beijing-Daxin	80,767 a	9.26 a	51 c	83.56 a
12	*P. fortunei* Guizhaou-Xinren	36,663 e	9.24 a	64 abc	82.85 a
13	*P. fortunei* Zhejiang-Lin'an	47,567 de	9.43 a	61 abc	79.16 a
14	*P. fortunei* Hubei-Hunan	55,55 de	8.56 a	70 abc	76.05 a
15	*P. fortunei* Anhui-Tongling	52,587 de	7.60 a	62 abc	89.39 a
16	*P. fortunei* x *tomentosa* Shen x Ihnan	72,627 abc	9.16 a	58 abc	82.60 a

* The same letter shows the same group at 0.05 significant level, **; mean values

elongata Beijing-Daxin (80.767 cm) origins showed the best height growth on the origin base. As a result, Beijing-Daxin provenance should be considered for Kastamonu region because of climatical similarities between regions. However, SH values is rather small when compared with the height value (3-4 m) denoted by Zhao-Hua (1986) for one-year old seedlings. Therefore, in Kastamonu ecological conditions, it can be stated that *Paulownia* can not make height growth as well as natural distribution areas. According to RCD and SP values, significant difference was not determined in Kastamonu ecological conditions.

The P*aulownia* plantations could be damaged by early frost at the interior part of Kastamonu region. So, the temperature must be evaluated as an effective factor on the success of the future plantations of these species and their origins.

In addition, Ayan *et al.* (2002) stated that there is important diversities among the parents within origins in respect to the SH and RCD. Similar results were obtained in this study. Therefore, the further *Paulownia* studies should include clonal variation in addition to the species and origins.

Acknowledgments

We thank to Prof. Dr. Hasan VURDU, Dean of Forestry Faculty for valuable comments on the manuscript. Financial support was provided by the Gazi University, Scientific Research Projects Fund.

References

Anonymous: Main plan of forestry (1990-2009 periods), Publication of Forest General Directorate, Num: 3, Ankara, Turkey, (1988).

Anonymous: TARIST statistical program of the Aegean University of Agricultural Research, Izmir, Turkey, (1994).

Anonymous: Research project on introduction and adaptation of *Paulownia* sp. in Turkey, The Ministry of Forestry, No: 15.10102, Izmir, Turkey, (1998).

Anonymous: *Paulownia* Water Requirements for Western Australia, Water and Rivers Commission, ISBN - 0-7309-7573-8, Western Australia, (2002).

Ata, C. and A. Demirci: Basic principles of silviculture (Silviculture I). Blacksea Technical University, Forestry Faculty, Textbook Num.42, Trabzon, (1992).

Ayan, S., V. Gerçek and A. Sahin: Performation of nursery stage of *Paulownia* Sieb.& Zucc. species and origins, Review of Faculty of Forestry University of Suleyman Demirel. *Seri.A,* **2**, 41-56, Isparta, (2002).

Dhiman, R. C.: An eco-friendly multi-purpose species: *Paulownia, MFP-News,* **7 (4)**, 14-16 (1997).

Jiang, Z., L. Gao, Y. Fang and X. Sun: Analysis of *Paulownia* intercropping types and their benefits in Woyang County of Anhui Province. *Forest Ecol. Manage.,* **67(1-3),** 329-337 (1994).

Lu, X. and Y. Xong: Chinese *Paulownia*, A marvellous tree species, The Chinese Academy of Forestry, Research Institute of Forestry, Beijing, China, (1986).

Kumar P. P., C. Dimps Rao, G. Rajaseger and A. N. Rao: Seed surface architecture and random amplified polymorphic DNA Profiles of *Paulownia fortunei, P. tomentosa* and their Hybrid. *Annals of Botany,* **83,** 103-107 (1999).

Turner, G. D., R. R. Lau and D. R. Young: Effect of acidity on germination seedling growth of *Paulownia tomentosa*, *J. Appl. Ecol.,* **25**: 561-567, (1988).

Ulu, F., S. Çetiner, N. Eren and S. Ayan: Results of the field stage in third year of species and provenances trials of P*aulownia* Sieb.& Zucc. in Eastern Black Sea Region. Proceedings IUFRO Meeting management of fast growing plantations (*Ed:* A. Diner *et al.*), DIV.4.04.06, 11th-13th September 2002, Izmit, Turkey. pp. 174-182, (2002).

Ürgenç, S.: Orman Ağaçları Islahı. İstanbul Üni. Yayın No. 2836, Orman Fak. Yayın No.293, İstanbul, (1982).

Wang, Q. and J. F. Shogren: Characteristics of the crop-*Paulownia* system in China. Agriculture, *Ecosy. Environ.,* **39 (3-4),** 145-152 (1992).

Zhao-Hua, Z., C. Ching-Ju, L. Xin-Yu and X. Yao Gao: *Paulownia* in China: Cultivation and utilization by Chinese Academy of Forestry Staff, Asian Network for Biological Sciences and International Development Research Centre, ISBN 9971-84-546-6, Beijing, China, (1986).

Correspondence to:
Dr. Sezgin Ayan
Kastamonu Orman Fakultesi, 37200, Kastamonu, Turkey
Email: sezginay@gazi.edu.tr
Tel.:+90 366 - 214 95 25;
Fax:+90 366 214 82 45