Indian Journal of Plant Sciences ISSN: 2319-3824 (Online)
An Online International Journal Available at http://www.cibtech.org/jps.htm
2013 Vol. 2 (4) October-December, pp.118-123/Arvind Singh
Research Article

EVALUATION OF THE GROWTH PERFORMANCE OF PLANTED TREE SPECIES ON COAL MINE SPOIL IN SINGRAULI COALFIELDS, INDIA

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ABSTRACT
A study was conducted to evaluate the growth performance of eight native tropical trees planted on coal mine spoil in Singrauli coalfields, India. Of the evaluated eight tree species *Acacia catechu, Albizia lebbeck, Dalbergia sissoo* and *Pongamia pinnata* were represented by the leguminous tree species while *Azadirachta indica, Gmelina arborea, Tectona grandis* and *Terminalia bellerica* were represented by non-leguminous tree species. Among all the evaluated species the leguminous *A. lebbeck* was the best performing tree species while the non-leguminous *Terminalia bellerica* was poorest performing tree species on coal mine spoil. The overall performance of leguminous species was greater than non-leguminous species. *Gmelina arborea* and *Azadirachta indica* were the best performing tree species among the non-leguminous species.

Key Words: *Coal Mine Spoil, Diameter Growth Rate, Growth Performance, Height Growth Rate, Singrauli Coalfields, Volume Growth Rate*

INTRODUCTION
Mine spoils are drastically disturbed and physically, nutritionally and microbiologically impoverished habitats (Wali, 1975; Singh and Jha, 1993). It needs to be stabilized to prevent erosion and contamination of rivers and adjoining agricultural lands from harmful leachates. Natural revegetation of mine spoils is a slow process (Jha and Singh, 1991, 1992; Singh, 2012a) but it can be accelerated by planting suitable tree species. Therefore, evaluation of tree performance is crucial in selection of suitable species for revegetation of mine spoils for their prompt recovery. Several studies have been conducted in India and abroad to evaluate the performance of trees on mine spoils (Jha and Singh, 1993; Bending and Moffat, 1999; Singh and Singh, 2001; Singh, 2006, 2007, 2012b). The main aim of the present investigation was to evaluate the performance of eight native tropical tree species planted on coal mine spoil. The questions addressed were:

(i) Which tree species are the best performers on coal mine spoil among all the evaluated species?
(ii) Does any potential difference exist in terms of growth performance between leguminous and non-leguminous tree species?

MATERIALS AND METHODS
Site Description
The study was conducted at the Jayant coal mine in the Singrauli coalfields, Madhya Pradesh, India (Figure 1). The Singrauli coalfields cover an area of about 2200 km^2 ($23^o47'$-$24^o12'$ N, $81^o48'$-$82^o52'$ E and elevations of 280-519 m above mean sea level), of which 80 km^2 lies in Uttar Pradesh and the rest in Madhya Pradesh. The climate is tropical monsoonal with temperature reaching up to 42^oC during June and lowering to down to 5^oC in January. Rainfall varies from 90-100 cm confined during monsoon months from June to September. Winter rains are negligible. The potential natural vegetation is a Tropical Dry Deciduous Forest (Champion and Seth, 1968).

Experimental Design and Methods
Nursery-raised 1-year-old individuals of eight native tropical tree species namely *Acacia catechu* Willd., *Albizia lebbeck* (L.) Benth., *Azadirachta indica* A. Juss., *Dalbergia sissoo* Roxb., *Gmelina arborea*

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Roxb., *Pongamia pinnata* (L.) Pierre, *Tectona* grandis L. and *Terminalia bellerica* Roxb. were planted on fresh flat coal mine spoil in July 1993. The seedlings were planted in 20 m x 20 m plots with a spacing of 2 m x 4 m. The within row spacing distance was 2 m whereas the between row spacing distance was 4 m.

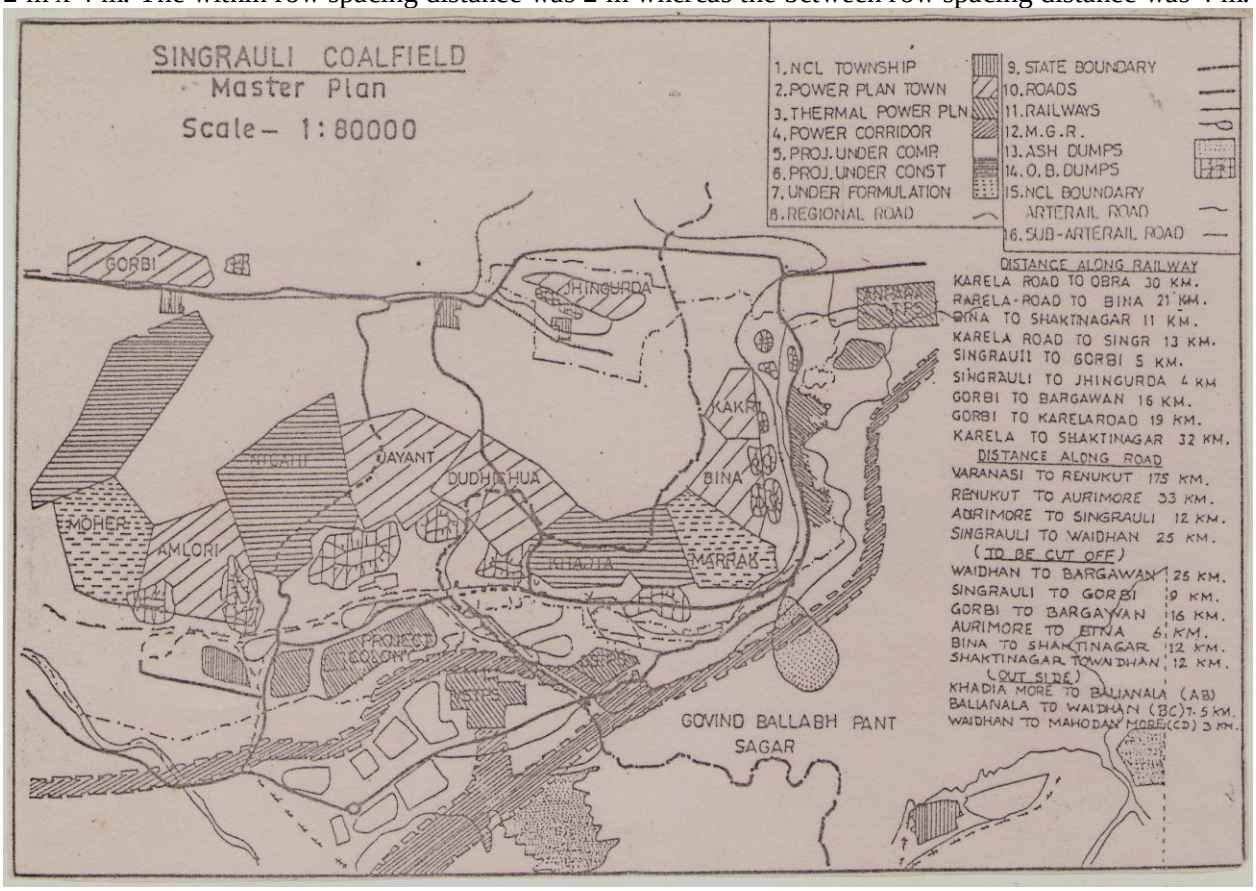

Figure 1: Singrauli Coalfields

Three replicate plots were maintained for each species. The texture of the spoil material was 80% sand, 10% silt, and 10% clay, with a pH of 7.4, total N 0.018% and total P 0.010% (Singh, 1999). Soil cores to a depth of 10 cm consisted for 75% of particles greater than 2 mm in diameter. A total of 9 individuals for each tree species, distributed equally between the three replicate plots selected at random were used for growth measurements. Height and diameter measurements were done in April 1996 (33 months after plantation) and in December 1997 (53 months after plantation). Since tree species were young hence diameter (*d*) was measured at 20 cm above the ground surface. Height (*h*) was measured using a scaled bamboo stick. Volumes of the trees (*V*) were calculated as a cone ($V = d^2h$). Annual height, diameter and volume growth rates were estimate as increments in height, diameter and volume from the values measured in April 1996 and December 1997.

RESULTS AND DISCUSSION

The data on height diameter and volume of the tree species for both the years are depicted in Table 1, while the data for annual height, diameter and volume growth rates are depicted in Table 2. The height, diameter and volume of 2-years and 9 months-old tree species ranged between 1.59 to 4.25 m, 4.41 to 9.29 cm and 3503 to 36238 cm^3, respectively. Similarly the height, diameter and volume of 4-years and 5-months-old trees varied between 2.09 to 6.72 m, 6.40 to 13.93 cm and 9645 to 129727 cm^3.

Table 1: Height, diameter and volume of planted tree species at two different age on coal mine spoil in Singrauli coalfields (Mean ± 1S E)

S.No.	Tree species (Family)	33 months after plantation			53 months after plantation		
		Height (m)	Diameter (cm)	Tree volume (d^2 h) cm^3	Height (m)	Diameter (cm)	Tree volume (d^2 h) cm^3
1.	*Acacia catechu* Willd. (Fabaceae)	2.84 ± 0.16	6.06 ± 0.60	12055 ± 3198	4.44 ± 0.23	8.52 ± 0.82	36814 ± 9176
2.	*Albizia lebbeck* (L.) Benth. (Fabaceae)	3.90 ± 0.37	9.12 ± 0.63	35357 ± 6642	6.14 ± 0.53	13.93 ± 0.92	129727 ± 25354
3.	*Azadirachta indica* A. Juss. (Meliaceae)	2.65 ± 0.18	5.92 ± 0.31	9714 ± 1250	4.09 ± 0.28	9.82 ± 0.52	41198 ± 5287
4.	*Dalbergia sissoo* Roxb. (Fabaceae)	4.25 ± 0.36	8.24 ± 0.53	24994 ± 5414	6.72 ± 0.57	11.94 ± 0.77	102372 ± 17274
5.	*Gmelina arborea* Roxb. (Verbenaceae)	3.66 ± 0.31	9.29 ± 0.85	36238 ± 6865	5.10 ± 0.43	12.04 ± 1.03	83491 ± 15518
6.	*Pongamia pinnata* (L.) Pierre (Fabaceae)	3.06 ± 0.11	5.88 ± 0.33	10993 ± 1458	4.35 ± 0.15	7.60 ± 0.40	26166 ± 3471
7.	*Tectona grandis* L. (Verbenaceae)	2.45 ± 0.17	5.37 ± 0.31	7714 ± 1611	3.07 ± 0.21	7.26 ± 0.42	17624 ± 3629
8.	*Terminalia bellerica* Roxb. (Combretaceae)	1.59 ± 0.14	4.41 ± 0.30	3503 ± 704	2.09 ± 0.17	6.40 ± 0.44	9645 ± 1904

The annual height, diameter and volume growth rates ranged between 0.30 to 1.48 m yr^{-1} $tree^{-1}$, 1.03 to 2.89 cm $year^{-1}$ $tree^{-1}$ and 3685 to 56622 cm^3 $year^{-1}$ $tree^{-1}$, respectively. Thus the result indicates that *T. bellerica* was the poorest performing tree species while the *A. lebbeck* was the best performing tree species among all the eight tree species growing on coal mine spoil. The *D. sissoo*, *G. arborea* and *A. indica* were the other good performing tree species on mine spoil of the four leguminous species *A. lebbeck* was the best performing tree species in terms of diameter and volume growth rates while *D. sissoo* was the best performing tree species in terms of height growth rate. The *Acacia catechu* was the another leguminous species which has shown average growth performance on mine spoil while *P. pinnata* was the poorest performer on coal mine spoil among the leguminous species.

Table 2: Annual height, diameter and volume growth rates (yr^{-1} $tree^{-1}$) in planted tree species on coal mine spoil in Singrauli coalfields (Mean ± 1S E)

S. No.	Tree species (Family)	Height growth rate ($m\ yr^{-1}$)	Diameter growth rate ($cm\ yr^{-1}$)	Volume growth rate ($cm^3\ yr^{-1}$)
1.	*Acacia catechu* Willd. (Fabaceae)	0.95 ± 0.05	1.47 ± 0.15	14860 ± 3645
2.	*Albizia lebbeck* (L.) Benth. (Fabaceae)	1.35 ± 0.12	2.89 ± 0.19	56622 ± 10627
3.	*Azadirachta indica* A. Juss. (Meliaceae)	0.86 ± 0.06	2.34 ± 0.12	18890 ± 2423
4.	*Dalbergia sissoo* Roxb. (Fabaceae)	1.48 ± 0.13	2.24 ± 0.15	42925 ± 7252
5.	*Gmelina arborea* Roxb. (Verbenaceae)	0.86 ± 0.07	1.64 ± 0.12	28352 ± 5194
6.	*Pongamia pinnata* (L.) Pierre (Fabaceae)	0.78 ± 0.03	1.03 ± 0.05	9104 ± 1208
7.	*Tectona grandis* L. (Verbenaceae)	0.37 ± 0.02	1.15 ± 0.07	5946 ± 1212
8.	*Terminalia bellerica* Roxb. (Combretaceae)	0.30 ± 0.02	1.19 ± 0.08	3685 ± 721

Comparative growth study between leguminous and non-leguminous species reveals that the average annual height, diameter, and volume growth rates for leguminous tree species were 1.14 m, 1.90 cm and 30878 cm^3, respectively whereas the same for non-leguminous tree species were 0.59 m, 1.58 cm and 14218 cm^3.

Thus the leguminous species have a greater annual height, diameter and volume growth rates than non-leguminous tree species. This clearly indicates that the leguminous tree species have exhibited better growth performance than non-leguminous species on coal mine spoil.

This may be owing to the nitrogen fixing attribute of the leguminous species. Nitrogen is one of the major limiting nutrients in mine spoils (Mays and Bengston, 1978; Jha and Singh, 1993). Compared to the result of the present study, Singh (2012b) recorded greater volume growth rate in non-leguminous tree species than leguminous tree species planted for revegetation of coal mine spoil in a tropical dry environment.

The study reveals a large degree of variation in tree volume (d^2h). The latter frequently figures as a proxy variable for biomass (Zavitkovski and Stevens, 1972; DeBell *et al.,* 1989). The variability in tree volume was greater among non-leguminous tree species than leguminous tree species.

Contrary to the present finding, other studies reports greater volume variability among leguminous tree species than non-leguminous tree species planted on coal mine spoil (Singh *et al.,* 2000; Singh and Singh, 2001).

Conclusion

The study has enabled to reach the conclusion that non-leguminous *G. arborea,* and *A. indica* and leguminous *A. lebbeck* and *D.sissoo* are the potential tree species for revegetation of coal mine spoils for their quick recovery in a tropical dry environment.

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