

## Comparative Growth and Yield of Multipurpose Trees in Semi-arid Natural Grassland

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**Abstract:** Studies on comparative growth and production of 12 multipurpose tree species (MPTS) from 1988 to 1995 under *Dichanthium annulatum*-dominated natural grassland revealed that 6 trees viz., *Albizia amara*, *A. lebbek*, *Acacia tortilis*, *Dichrostachys cinerea*, *Leucaena leucocephala* and *Pongamia pinnata* had better growth (leaf fodder and fuel wood) and production, as well as higher crude protein in leaf fodder under this agro-climatic region. Thus, the above six MPTS are suitable for introduction in such type of grassland for getting the higher and nutritious leaf fodder as well as fuel wood.

**Key words :** Natural grassland, semi-arid, multipurpose tree species, marginal lands, leaf fodder, fuel wood, livestock.

The fuel wood and fodder (green and dry) production from all the sources in the country is projected to be 201 and 1759 (1083 and 676) million tonnes, respectively, against the current availability of 115 and 913 (513 and 400) million tonnes (Anonymous, 1997; 1999). Further, it is estimated that at global level, leaf fodder from trees and shrubs constitutes about 25% of the annual diet of livestock in semi-arid regions (Shorrocks, 1981). The gap between demand and supply of fuel wood and fodder needs to be bridged by maximizing the wood and fodder production in space and time through integration of agroforestry systems in the marginal, sub-marginal, degraded and problem lands. Therefore, the present study was undertaken to find out the suitable tree species for introduction in the natural grassland under rainfed condition in order to obtain maximum fodder and fuel wood production on the same unit of land.

### Materials and Methods

The experiment was carried out at the National Research Center for Agroforestry, Jhansi (78°35'E longitude and 25°26'N latitude and about 275 m above mean sea level), from June, 1988 to December, 1995 in natural grassland under rainfed condition. The experimental site was dominated by natural vegetation comprising of *Dichanthium annulatum* and *Heteropogon contortus*, along with other species like *Iseilema laxum*, *Themeda quadrivalvis*, *Apluda mutica*, *Eulaliopsis binata* and *Cenchrus ciliaris*. The legumes present in the area were *Alyosia scarabaeoides*, *Rhynchoisa minima*, *Cassia indigofera*, etc., in addition to the shrub species viz., *Carissa spinerum*, *Lantana camara*, *Mimosa himalayana* and *Ziziphus numularia*. The soil was shallow in depth, medium black in color and neutral in reaction. The texture of the soil was sandy loam (62.0% sand,

23.6% silt and 11.2% clay). The organic carbon in the soil ranged from 0.50 to 0.65%. Average annual long term rainfall for the site is estimated to be 900 mm, occurring predominantly (80%) during July to mid-September. A long dry spell during the rainy season is also common. The total annual rainfall (mm) and the number of rainy days were 815 and 52 in 1988, 700.5 and 31 in 1989, 1092.9 and 51 in 1990, 957.7 and 35 in 1991, 786 and 43 in 1992, 788.3 and 40 in 1993, 551.0 and 41 in 1994 and 829.9 and 52 in 1995, respectively.

Unwanted shrubs like *Mimosa*, *Carissa*, *Lantana* etc., were removed and pits (30 x 30 x 30 cm) were prepared for planting of saplings. In the third week of July, 1988, 6 to 8-month-old nursery-raised saplings of 12 multipurpose tree species (MPTS) viz., *Azadirachta indica*, *Albizia amara*, *Albizia lebbek*, *Acacia tortilis*, *Anogeissus pendula*, *Ceiba pentandra*, *Dendrocalamus strictus*, *Dichrostachys cinerea*, *Pongamia pinnata*, *Leucaena leucocephala*, *Terminalia belerica* and *Ziziphus mauritiana* were planted at a spacing of 8 x 4 m in a randomized block design with 4 replications. During July, 1989, gap filling was done to obtain 100% population. During the onset of monsoon, 20 kg N + 20 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> was applied uniformly through broadcasting to increase the growth and production of natural vegetation and MPTS.

The data on survival, plant height, collar diameter (cd) and diameter at breast height (dbh) were recorded in December each year. Pruning once in a year (November-December) at 50 and 75% height was initiated during 4<sup>th</sup> year of establishment of trees. Representative samples of leaf

material and branches were collected separately for each species and oven-dried at 60±5°C for dry matter determination. Crude protein in tree leaves was estimated by the method given by AOAC (1984) during 1991, 1992 and 1993.

## Results and Discussion

### Survival

The survival percentage of MPTS (Fig. 1) differed significantly ( $P < 0.05$ ) in all the years except 1995 (8<sup>th</sup> year). Maximum survival percentage was recorded with *A. tortilis* (90), followed by *A. amara* (85), *D. cinerea* (75), *Z. mauritiana* (75) and *A. pendula* (65) (Fig. 1) upto 7<sup>th</sup> year of establishment. A very low survival of *A. tortilis*, *A. amara*, *D. cinerea* and *L. leucocephala* during 8<sup>th</sup> year, as compared to 7<sup>th</sup> year, was due to damage of some of the trees by fire incidence in April, 1995. The lowest survival (10%) was recorded with *T. belerica*, whereas none of the plants of *C. pentandra* survived after 1989. This showed non-adaptability of this species to dry region.

### Growth parameters

The growth in height, cd and dbh of MPTS showed significant differences in all the years (Tables 1-3). The plant height was significantly higher in *A. lebbek* (6.4 m), *A. tortilis* (6.3 m) and *L. leucocephala* (6.2) than *A. amara*, *A. indica*, *A. pendula*, *D. strictus*, *D. cinerea*, *P. pinnata*, *T. belerica* and *Z. mauritiana* after eight years of establishment. The increase in height of former three species may be attributed to fast growing nature of the species. Singh and Pathak (1990) also reported similar



Fig. 1. Survival (%) of MPTS introduced in natural grassland.

Table 1. Plant height (m) of MPTS introduced in natural grassland

Tree species	1988	1989	1990	1991	1992	1993	1994	1995
<i>A. indica</i>	0.53	0.68	1.38	1.89	2.9	3.1	3.6	4.2
<i>A. amara</i>	0.76	1.34	2.11	2.54	2.9	3.6	3.9	5.3
<i>A. lebbek</i>	0.53	0.61	1.21	1.83	3.6	4.4	4.8	6.4
<i>A. tortilis</i>	0.55	1.27	2.03	2.63	3.4	4.4	4.8	6.3
<i>A. pendula</i>	0.26	0.44	0.88	1.43	1.7	2.0	2.6	2.7
<i>C. pentandra</i>	0.87	0.76	–	–	–	–	–	–
<i>D. strictus</i>	0.36	0.72	1.61	1.83	2.9	3.2	2.7	3.7
<i>D. cinerea</i>	0.51	1.18	1.85	2.2	2.6	3.0	4.8	4.9
<i>L. leucocephala</i>	1.0	1.52	2.19	2.66	3.6	4.5	5.4	6.2
<i>T. belerica</i>	0.24	0.34	0.44	0.80	1.7	2.6	3.4	3.8
<i>Z. mauritiana</i>	0.40	0.80	1.31	1.57	2.3	2.7	2.9	3.5
SEm±	–	0.11	0.24	0.23	0.32	0.39	0.42	0.25
CD at 5%	–	0.31	0.69	0.66	0.92	1.13	1.21	0.72

findings with *A. tortilis* and *L. leucocephala*. *A. pendula* showed significantly lower plant height as compared to all other species. Rai *et al.*, (1995) observed slow growth after 5 years of establishment in case of *Madhuca latifolia* and *A. pendula* when compared to other 16 MPTS grown in degraded rangelands having red gravelly soils. Current annual increment (CAI) in plant height varied between MPTS in different years of growth (1989-1995), but the difference was significant ( $P < 0.05$ ) only among the different years of growth in plant height. No trend was observed in CAI of plant height from 1989 to 1995 among different MPTS. The annual current increment (m) was as low as 0.08 and as high as 1.77 in *A. lebbek* after 1<sup>st</sup> and 4<sup>th</sup> year of establishment, respectively, showing an increasing trend only up to 1992. The overall (1988-1995) increment (m) in plant height was non-significant among different MPTS, with a maximum in *A. lebbek* (5.87) and minimum in *A. pendula* (2.44).

The cd significantly varied in all the species over the years. *A. lebbek* showed significantly higher (17.0 cm) growth in cd as compared to all other species (*A. amara*, *A. indica*, *A. pendula*, *A. tortilis*, *D. cinerea*, *L. leucocephala*, *P. pinnata*, *T. belerica* and *Z. mauritiana*) during 1995. *A. pendula* gave significantly lower (4.0 cm) cd than all other species except *Z. mauritiana* (5.2 cm). Significant ( $P < 0.05$ ) difference in current annual increment of cd was observed between MPTS and among the different years of growth (1989-1995). No trend was observed in CAI of cd from 1989 to 1995 among different MPTS except *A. lebbek*, where an increasing trend was observed from 1989 to 1994. The annual current increment was as low as 0.16 cm and as high as 3.90 cm, respectively, in *A. pendula* and *A. lebbek* after 3<sup>rd</sup> and 6<sup>th</sup> year of establishment. The overall (1988-1995) increment (cm) in cd varied significantly ( $P < 0.05$ ) among different MPTS, with a maximum in *A. lebbek* (16.30) and minimum in *A. pendula* (3.72).

Table 2. Collar diameter (cm) of MPTS introduced in natural grassland

Tree species	1988	1989	1990	1991	1992	1993	1994	1995
<i>A. indica</i>	0.66	1.14	2.83	2.74	5.5	6.9	8.9	9.1
<i>A. amara</i>	0.99	1.87	3.28	4.71	5.7	8.3	9.7	12.3
<i>A. lebbek</i>	0.70	1.11	2.55	3.93	6.3	9.4	13.3	17.0
<i>A. tortilis</i>	0.84	1.98	2.95	4.67	5.12	7.9	8.8	10.4
<i>A. pendula</i>	0.28	0.83	1.63	1.79	2.1	2.9	3.4	4.0
<i>C. pentandra</i>	1.61	0.80	—	—	—	—	—	—
<i>D. strictus</i>	0.41	0.75	2.07	5.08	—	—	—	—
<i>D. cinerea</i>	0.96	2.22	3.93	4.31	5.9	7.7	9.5	11.4
<i>P. pinnata</i>	0.75	1.38	2.83	4.28	7.5	7.9	9.8	10.7
<i>L. leucocephala</i>	0.93	1.48	3.31	4.10	6.6	9.2	10.2	12.9
<i>T. belerica</i>	0.36	1.05	2.23	2.77	4.8	6.0	7.2	8.8
<i>Z. mauritiana</i>	0.46	1.14	2.01	3.08	4.4	4.7	4.9	5.2
SEm±	—	0.20	0.37	0.58	0.79	0.9	0.82	1.32
CD at 5%	—	0.6	1.07	1.68	2.29	2.61	2.38	3.77

The growth in dbh showed significant difference in all the MPTS from 1991 to 1995. None of the species attained the dbh height (1.37 m) during second year of establishment, while during the third year also only 5 species viz., *A. indica*, *A. amara*, *A. tortilis*, *D. cinerea* and *L. leucocephala* attained the dbh height. During 4<sup>th</sup> year, all the species attained the dbh height except *T. belerica*. This indicates that, *T. belerica*

has very slow growth in early stage under semi-arid condition. *A. lebbek* showed significantly higher dbh (12.8 cm) than *A. indica*, *A. pendula*, *A. tortilis*, *L. leucocephala*, *T. belerica* and *Z. mauritiana* during 8<sup>th</sup> year of establishment of trees, whereas significantly lower dbh was noted with *A. pendula* (2.8 cm) as compared to other species, except *Z. mauritiana* (4.4 cm). A non-significant difference was found in

Table 3. Diameter (cm) at breast height of MPTS introduced in natural grassland

Tree species	1990	1991	1992	1993	1994	1995
<i>A. indica</i>	1.63	1.88	4.7	6.5	8.1	8.7
<i>A. amara</i>	3.24	3.52	5.2	8.2	9.3	11.2
<i>A. lebbek</i>	—	1.79	4.8	7.7	9.4	12.8
<i>A. tortilis</i>	2.34	3.60	4.6	7.1	8.3	9.3
<i>A. pendula</i>	—	0.13	0.9	1.5	2.5	2.8
<i>D. cinerea</i>	2.54	2.70	5.7	7.5	9.0	10.1
<i>P. pinnata</i>	—	2.98	6.8	7.5	9.3	10.0
<i>L. leucocephala</i>	2.18	2.49	2.8	7.1	8.7	9.6
<i>T. belerica</i>	—	—	1.2	2.4	3.7	7.6
<i>Z. mauritiana</i>	—	0.60	2.0	2.7	4.0	4.4
SEm±	—	0.62	0.66	0.87	1.07	0.98
CD at 5%	—	1.81	1.89	2.52	3.11	2.84

Table 4. Biomass production under two pruning managements in some MPTS

Tree species	50% pruning				75% pruning			
	Leaf fodder yield		Fuel wood yield		Leaf fodder yield		Fuel wood yield	
	1994 <sup>a</sup>	Average*	1994 <sup>a</sup>	Average*	1994 <sup>a</sup>	Average*	1994 <sup>a</sup>	Average*
<i>A. indica</i>	0.04	0.06	0.15	0.09	0.05	0.11	0.16	0.20
<i>A. amara</i>	0.98	0.60	4.45	2.25	1.21	1.01	4.86	3.02
<i>A. lebbek</i>	0.55	0.34	1.58	0.67	6.40	2.16	13.1	4.12
<i>A. tortilis</i>	0.80	0.46	4.98	2.83	0.93	0.56	5.21	3.55
<i>A. pendula</i>	0.05	0.03	0.08	0.06	0.16	0.09	0.26	0.23
<i>D. strictus</i>	0.26	0.29	0.55	0.69	0.79	0.56	1.54	1.01
<i>D. cinerea</i>	0.22	0.36	1.58	1.82	0.40	0.47	4.31	3.14
<i>P. pinnata</i>	0.33	0.31	0.23	0.29	1.89	1.02	2.08	0.94
<i>L. leucocephala</i>	1.16	0.66	2.60	1.37	1.80	1.11	3.00	1.52
<i>T. belerica</i>	0.33	0.18	0.19	0.13	0.35	0.19	0.23	0.12
<i>Z. mauritiana</i>	0.09	0.12	0.15	0.28	0.17	0.20	0.26	0.40
SEm ±	0.20	0.06	0.55	0.29	1.41	0.19	2.73	0.45
CD at 5%	0.63	NS	1.74	NS	NS	NS	NS	NS

<sup>a</sup> Values are current year yield (1994); \* Values are average of four year (1991-94).

the current annual increment of dbh among different MPTS and among the different years of growth (1989-1995). No trend was observed in CAI of dbh from 1989 to 1995 among different MPTS except *T. belerica*, where an increasing trend was observed from 1993 to 1995. The annual current increment (cm) was as low as 0.16 cm and as high as 4.30 cm, respectively, in *D. cinerea* and *L. leucocephala* after 4<sup>th</sup> and 5<sup>th</sup> year of establishment. The overall (1990-1995) increment in dbh varied significantly

( $P < 0.05$ ) among different MPTS, with a maximum in *A. lebbek* (11.01) and minimum in *A. pendula* (2.67).

#### Biomass production

Biomass production during the year 1994, with pruning upto 50% height, showed a maximum ( $P < 0.05$ ) leaf fodder of 1.16 kg tree<sup>-1</sup> with *L. leucocephala*, followed by *A. amara* and *A. tortilis* (Table 4), and was the lowest in *A. indica* (0.04). A similar trend was observed in 4-years (1991-1994)

Table 5. Correlation coefficient values among growth parameters and biomass yield (n=55)

Growth parameters	CD	DBH	F-50	F-75	L-50	L-75
Height	0.761**	0.763**	0.557**	0.499**	0.736**	0.713**
CD		0.934**	0.306*	0.349*	0.605**	0.597**
DBH			0.491**	0.555**	0.631**	0.620**

\* Significant ( $P < 0.05$ ); \*\* Significant ( $P < 0.01$ )

CD = Collar diameter, DBH = Diameter at breast height, F-50 = Fuel wood (pruned up to 50% height), L-50 = Leaf fodder (pruned up to 50% height), F-75 = Fuel wood (pruned up to 75% height), L-75 = Leaf fodder (pruned up to 75% height).

Table 6. Average (1991-93) crude protein content (%) and production (kg ha<sup>-1</sup>) in some MPTS

Tree species	CP (%)	CP production (kg ha <sup>-1</sup> )	
		50% pruning	75% pruning
<i>A. indica</i>	15.77	130.08	354.75
<i>A. amara</i>	16.83	3143.63	6602.88
<i>A. lebbek</i>	15.83	1828.75	5248.75
<i>A. tortilis</i>	15.70	1589.63	2131.28
<i>A. pendula</i>	12.30	92.25	322.88
<i>D. strictus</i>	11.77	811.9	1623.8
<i>D. cinerea</i>	13.07	1097.6	1479.8
<i>P. pinnata</i>	15.73	2029.6	4861.6
<i>L. leucocephala</i>	19.10	4096.95	7420.35
<i>T. belerica</i>	7.56	374.55	419.95
<i>Z. mauritiana</i>	11.3	245.78	525.45
SEm±	±0.71	±558.59	±1525.93
CD at 5%	1.46	1759.78	4807.29

average leaf fodder production, with lowest in *A. pendula* (0.03), indicating non-significant difference over the period among the different MPTS. Fuel wood production during 1994 (kg tree<sup>-1</sup>), with pruning upto 50%, was maximum (P<0.05) with *A. tortilis* (4.98), followed by *A. amara* and *L. leucocephala*, and was the lowest in *A. pendula* (0.08). A similar trend was observed in 4-years (1991-1994) average fuel wood production, except *L. leucocephala*, with lowest in *A. pendula* (0.06), indicating a non-significant difference over the period among the different MPTS. Pruning upto 75% gave maximum leaf fodder of 6.40 kg tree<sup>-1</sup> with *A. lebbek*, followed by *P. pinnata* and *L. leucocephala* during the year 1994, and was the lowest in *A. indica*. *A. lebbek* gave maximum leaf fodder of 2.16 kg tree<sup>-1</sup> year<sup>-1</sup> over a period of 4 years with pruning upto 75% height, followed by *L. leucocephala* and *P. pinnata*, with the lowest in *A. pendula* (0.09 kg tree<sup>-1</sup>). However, the differences were not significant

among the different MPTS. The fuel wood production with pruning upto 75% was also maximum in *A. lebbek* (13.1 kg tree<sup>-1</sup>) during the year 1994, followed by *A. tortilis* and *A. amara*, with the lowest in *A. indica* (0.16 kg tree<sup>-1</sup>). A similar trend was observed in 4-years (1991-1994) average fuel wood production except *A. amara*, with the lowest in *T. belerica* (0.12 kg tree<sup>-1</sup>), indicating non-significant difference over the period among the different MPTS.

The growth parameters like height and dbh in all the MPTS were highly correlated (Table 5) with biomass yield like fuel wood at 50% pruning (0.557 and 0.491), fuel wood at 75% pruning (0.499 and 0.620), leaf fodder at 50% pruning (0.736 and 0.631) and leaf fodder at 75% pruning (0.713 and 0.620), respectively, indicating positive relation between growth of MPTS and biomass yield.

#### Crude protein content and production

Average crude protein (CP) content was highest in *L. leucocephala* (19.1%), followed

by *A. amara* (16.9%). The CP content in *A. lebbek*, *A. indica*, *A. tortilis* and *P. pinnata* were at par (Table 4), whereas the lowest was recorded in *T. belerica* (7.6%). This showed that the leaf fodder from *L. leucocephala* was more nutritious than other species and leaf fodder from *T. belerica* was less nutritious than other MPTS. The CP content in various MPTS observed in the present agro-climatic condition was in the similar range as reported by Singh (1982).

Average CP yield was higher with 75% pruning than 50% due to higher leaf fodder yield. Significantly higher CP production ( $\text{kg ha}^{-1}$ ) was observed in *L. leucocephala* (4096.95 and 7420.35) with both 50 and 75% pruning. A very low CP production ( $\text{kg ha}^{-1}$ ) was recorded ( $P < 0.01$ ) in *A. pendula* (92.25 and 322.88), *A. indica* (130.08 and 354.75), *T. belerica* (374.55 and 419.95) and *Z. mauritiana* (245.78 and 525.45) than in other MPTS with both 50 and 75% pruning.

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