Indian Journal of Agronomy **53**(2): 152–156 (June 2008)

Fodder and fuel-wood production through agroforestry in semi-arid Central India

J.V.N.S. PRASAD*[1], A.S. GILL, M.J. BAIG, D. BURMAN[2] AND S.K. GUPTA

Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh 284 225

Received: December, 2007

ABSTRACT

A study was conducted at Jhansi (Uttar Pradesh) during 1999ñ2002 to evaluate the production potential of tree-crop systems under rainfed situations. Four tree species, viz. *Azadirachta indica, Albizia lebbeck, Dalbergia sissoo* and *Acacia nilotica* were evaluated in sole stands and intercropped with chickpea (*Cicer arietinum L.*) in 6 x 12 m spacing. The intercrop had a positive effect on the growth of *Azadirachta indica* and *Albizia lebbeck* but not on *Acacia nilotica* and *D. sissoo. Acacia nilotica* and *D. sissoo* produced maximum growth, *Azadirachta indica* produced minimum growth and *Albizia lebbeck* intermediate growth. None of the tree species reduced the crop yield in agroforestry in the first 3 years of tree growth. In the fourth year (2001-02), 25 to 36% reduction in grain yield and 37 to 45% reduction in stalk yield across the four tree species was recorded. The highest reduction was observed nearer to the tree row and the negative effect decreased with distance from the tree. Forage and crude-protein yields were higher from *D. sissoo* and the fuel-wood yield was higher from *Acacia nilotica*. Benefit : cost ratio and the net present worth was the highest with *Acacia nilotica* system, followed by that of *D. sissoo*. Hence both these tree species can be grown in combination with crops in the semi-arid central India to produce fodder and fuelwood.

Key words: *Acacia nilotica, Albizia lebbeck, Azadirachta indica,* Biomass productivity, Canopy management, *Dalbergia sissoo,* Rainfed conditions

The supply of fodder and firewood is increasingly becoming critical for the rural households in many parts of Bundelkhand region. In the absence of adequate green fodder cattle are fed low quality crop residues leading to low productivity. Due to the growing human and cattle population there is an urgent need to increase the food, fodder and fuel-wood production from farm holdings as the forests cannot be put under more pressure (Anonymous, 2006). Traditional systems in semi-arid India have used native species such as *Azadirachta indica, Albizia lebbeck, Dalbergia sissoo* and *Acacia* spp. for many years but at low density (Singh and Roy, 1993). Multi-purpose tree species provide high-quality fodder and contribute to the sustainability of farming systems. Foliage of many fodder trees contains high levels of digestible protein, minerals and vitamins, and plays a major role in improving the ruminants' intake of roughage (Barnes, 1998). Integration of multi-purpose tree species (MPTS) into the arable cropping system reduces the pressure on forests and community lands for fodder and fuel wood production. However, it increases competition and reduces crop yields (Ong *et al.*, 2002). Though practices such as tree canopy management reduce the effect of shade on the intercrop, little information is available on the intercrop productivity and the profitability of such systems. Hence the present study was conducted to estimate the fodder and fuel-wood productivity of important MPTS of Bundelkhand region.

MATERIALS AND METHODS

The experiment was conducted over a 3-year period from 1999-00 to 2001-02 at Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh (25°27' N latitude, 78°35' E longitude and 270 m above mean sea level). The annual rainfall varies between 431 and 1467 mm (long-term annual average 908 mm). Maximum temperature varies from 17°C to 49° C and minimum temperature varies from 1°C to 32°C. About 93% of annual rainfall is received from July to first week of October. The amount of rainfall received during 1999-00, 2000-01 and 2001-02 were 1118, 712 and 1174 mm respectively in 52, 37 and

***Corresponding author** (Email: jasti2008@gmail.com)

Present address: [1]Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Andhra Pradesh 500 059; [2]Central Soil Salinity Research Institute, Regional Research Station, Canning Town, West Bengal 743 329

51 rainy days. The soils are black, fine loams at the surface and clayey at lower depths. The nutrient status of the 0–20 cm soil horizon was: organic C, 0.48%; pH, 6.5; inorganic N, 235 kg/ ha; available P, 13 kg/ha; and exchangeable K, 279 kg/ha.

The treatments evaluated were: sole stands of *Azadirachta indica, Albizia lebbeck, Dalbergia sissoo* and *Acacia nilotica*; these tree species intercropped with chickpea; and sole chickpea. The nine treatments were evaluated in randomized block design replicated three times. Tree seedlings at 6 months raised in polyethylene bags were transplanted in July 1998 at a spacing of 6 x 12 m (139 trees/ha). Basins were made at the base of tree seedlings and water was applied to the seedlings during the dry period in the first year. A uniform basal dose comprising 50 g P in the form of diammonium phosphate and 10 kg well-rotten FYM was applied per tree at the time of planting. Each plot had four trees. No crop was grown in the first year and chickpea (cv 'K 850') was grown from 1999 onward for 3 years. It was sown using a tractor-drawn seed-cum-fertilizer drill in October and harvested during February in all the three years. Spacing adopted was 25 cm between rows and 10 cm within the row, which gives a population of 400,000 plants/ha. The crop was fertilized with the recommended level of 20 kg N, 40 kg P and 20 kg K/ha at the time of sowing. It was harvested row-wise on the northern and southern sides of the tree row, and yields at different distances from tree row were computed by averaging the respective row yields on both sides of the row. Individual plot yields were computed by combining the row yields.

The trees were pruned once every year during April-May for fodder and fuel-wood to a height of 1.5 m and the branches were headed back. The dry period starting from March coincides with rising temperatures and non-availability of green fodder to the animals. Tree height, collar diameter and diameter at breast height (DBH) and also canopy diameter were recorded at 3-month intervals from July1998 to September 2002. Fresh weights of leaf biomass and fuel-wood were measured and a known quantity of these components was oven-dried for determining the dry biomass. Crude protein of the tree leaves was determined following the standard procedures. The financial analysis of different systems was based on the benefit-cost ratio (BCR), net present worth (NPW) and payback period, at 18% discount rate (Gittinger, 1982) and also on 12% discount rate. The streams of costs incurred and the benefits derived from each system were worked out. For agroforestry (trees + crop) the costs included are the initial expenditure for planting trees plus the cultivation costs such as land preparation, seed, fertilizers, interculture, harvesting and threshing for raising the intercrops. In agriculture (sole crop) the expenditure incurred for raising the crops was the same as for raising intercrops in the agroforestry practice. Prevailing market prices were adopted for calculation of direct benefits, i.e. fodder and fuel-wood from trees. The market prices of gram were Rs 10, 11 and 12/kg, which were equivalent to the support prices during 2000, 2001 and 2002, whereas the price of straw was Rs10,00/t. The rates of tree leaves and fuel-wood were taken as Rs 800/t and Rs 1,000/t, respectively. All the data were subjected to analysis of variance (ANOVA) and treatment differences were tested using the least significant test at 5% probability.

RESULTS AND DISCUSSION

Chickpea yields

Sole chickpea during the second and third years of tree growth (1999-00 and 2000-01) produced 1.00 to 1.10 t/ha grain respectively, and during the fourth year (2001-02) it produced the highest yield of 1.46 t/ha (Table 1). The lower chickpea yield in 2000-01 was mainly due to low total rainfall (712 mm) received in 37 rainy days, whereas higher yield in 2001-02 was due to higher rainfall (about 1174 mm) spread over 51 rainy days. Though the chickpea yields in sole and agroforestry were similar in the second year, there was 17 to 25% reduction in agroforestry in the third year of tree growth and 25 to 37% reduction in the fourth year (2001-02). The treatment differences between sole and agroforestry were however, not significant.

During 1999-2000 season there was no noticeable effect of trees on chickpea stalk yield. In the fourth year (2001-02) all the four tree species reduced the stalk yield significantly by 36 to 45% (Table 1). Chickpea yields in northern and southern sides of the tree rows were similar (data not presented). The yields at different distances from the tree row were similar during the second year of tree growth. During 2000-01 season the crop rows nearer to the tree row recorded relatively lower yields (rainfall 712 mm). The negative effect of trees was, however, confined to the first 1 m from the tree in the case of *Albizia lebbeck* and *Azadirachta indica* and 2 m in *Acacia nilotica* and *D. sissoo* (Table 2). Relatively higher moisture content was found at 20-40 cm soil depth and the differences in soil-moisture contents at 1-4 m away from trees were not substantial at the time of harvest of gram during 2000-01, when the amount of rainfall received was lowest (Table 3). Puri and Bangarwa (1992) reported reduction in yield with multi-purpose tree species such as *D. sissoo*. Tree-crop competition normally exists for moisture in the rainfed areas (Rao *et al.*, 1991). The competition for water in the present study might have decreased due to repeated tillage towards the land preparation and sowing of intercrop, resulting in the disturbance of tree roots in the topsoil, where the crop roots are generally present.

Significant reduction in intercrop yields in the present study was not observed till 4 years after planting of trees. This could be due to severe pruning of trees for fodder and fuel-wood, thus reducing shade to the intercrop (Semwal *et al.*, 2002). However, pruning in the present study might not have eliminated competition for light, as the trees after pruning had 6 months of active growth during the rainy season from April-May to October, when chickpea was sown. A second pruning at the start of the post-rainy season may have to be considered to minimize above-ground competition. Green fodder is generally available for some period during the post-rainy season, so the fodder harvested at this stage may have limited value, and in such situations it needs to be preserved until the dry season either in dry form or silage.

Tree growth and biomass yield

Both *Albizia lebbeck* and *Azadirachta indica* grew slightly better in agroforestry than in sole system, particularly in terms of height (Table 4). *D. sissoo* and *Acacia nilotica* grew similarly and faster with thicker stems than *Albizia lebbeck* and *Azadirachta indica* in both sole and agroforestry. In 2001-02 all other species, except *Azadirachta indica* attained more than 6 m height. *Acacia nilotica* had significantly greater DBH in all the 3 years than all other species, followed by *D. sissoo* which also recorded significantly higher DBH than *Albizia lebbeck* and *Azadirachta indica*.

In the second year of tree growth, fodder and fuel-wood yields from all the tree species were very low but the yields increased to a reasonable level in the subsequent 2 years (Table 5). *D. sissoo* and *Acacia nilotica* gave significantly higher yields than *Azadirachta indica* and *Albizia lebbeck* in all the 3 years Average fodder yield from *D. sissoo* increased from 216 kg/ha in the second year to 406 kg in the third year and to 503 kg/ha in the fourth year. Its fuel-wood yield increased from 345 kg/ha in the second

Table 1. Chickpea grain and stalk yields in agroforestry and sole system during 3-year period

System	Grain yield (t/ha)			Stalk yield (t/ha)		
	1999-2000	2000-2001	2001-2002	1999-2000	2000-2001	2001-2002
Agroforestry						
Albizia lebbeck	1.09	1.15	0.94	2.47	1.79	1.44
Azadirachta indica	1.15	0.92	0.98	2.56	1.50	1.31
Dalbergia sissoo	1.17	0.82	1.09	2.68	1.42	1.49
Acacia nilotica	1.17	1.12	0.93	2.67	2.22	1.25
Sole crop	1.01	1.10	1.46	2.20	2.14	2.26
SEm+	0.08	0.18	0.20	0.20	0.28	0.12
CD (P=0.05)			0.38			

Table 2. Mean chickpea grain and stalk yields at different distances from tree row during 2000-01

Tree species	Grain yield (g/m row)				Stalk yield (g/m row)			
	1 m	2 m	3 m	4 m	1 m	2 m	3 m	4 m
Albizia lebbeck	26.1	29.8	29.7	29.6	40.6	44.3	46.2	47.7
Azadirachta indica	21.6	22.6	22.8	25.3	35.8	33.7	36.6	43.6
Dalbergia sissoo	19.8	18.7	20.1	23.8	33.0	35.0	34.2	39.3
Acacia nilotica	24.4	25.6	30.5	31.4	52.5	48.7	56.3	64.4
SEm+	1.12	1.96						
CD (P=0.05)	3.11	5.44						

Table 3. Soil moisture content in the 0-40 cm depth at the time of harvest of gram during 2001-02

Tree species	Soil moisture content (%)							
	0-20 cm depth				20-40 cm depth			
	1 m	2 m	3 m	4 m	1 m	2 m	3 m	4 m
Albizia lebbeck	5.13	5.20	5.86	5.28	11.21	8.98	9.18	10.11
Azadirachta indica	5.60	5.46	6.21	6.62	11.62	9.87	8.67	9.65
Dalbergia sissoo	6.34	6.95	8.14	7.81	13.84	8.93	9.21	10.89
Acacia nilotica	5.94	6.21	7.78	5.21	12.98	10.21	8.12	11.86

year to 1108 kg/ha in the fourth year. Although *Acacia nilotica* produced similar fodder yield similar to that of *D. sissoo* in all the years, it gave significantly greater fuel-wood at 860 kg/ha in the second year and 1809 kg/ha in the fourth year. Fodder yields from *Albizia lebbeck* and *Azadirachta indica* on an average were only 40 to 49%, and fuel-wood yields were 32 to 36% of the yields of *D. sissoo* even in the fourth year. There was no significant difference in the performance of trees between sole and agroforestry systems. Protein yields closely reflected the dry fodder yields. *D. sissoo* and *Acacia nilotica* produced significantly higher protein yield than *Albizia lebbeck* and *Azadirachta indica* in the second year (Table 5). Although protein yields of *A. lebbeck* and *A. indica* increased in the later years, those from *D. sissoo* and *Acacia nilotica* were still substantially higher. The superior performance of *Acacia nilotica* and *D. sissoo* at the present site could be attributed to their adaptation, rapid growth and biological nitrogen fixation. The better early growth of trees in agroforestry could be attributed to the application of fertilizers and regular weeding to the intercrop. Low fodder (<0.5 t/ha) and fuel-wood (1.1 to 1.8 t/ha) yields even from the best species in this study were probably because of low density of trees used in the study. An increase in tree density would increase the production from trees, but this may reduce the crop yield and may not be acceptable to farmers. An alternative strategy that needs to be explored is higher tree density in combination with pruning of trees twice a year.

Economic analysis

In agroforestry systems the highest benefit : cost ratio was observed in case of *Acacia nilotica* followed by *D. sissoo,* and the lowest in *Azadirachta indica* (Table 6). In the trees alone, *Acacia nilotica* was the most remunerative system, followed by *Dalbergia sissoo* and the lowest was *Azadirachta indica*. The value of net present worth was also positive in all the cases, which varied from Rs 4,530

Table 4. Growth of tree species in terms of height and diameter at breast height (DBH) in sole and agroforestry during 3-year period

Treatment	Height (m)			DBH (cm)		
	1999-2000	2000-01	2001-02	1999-2000	2000-01	2001-02
Agroforestry						
A. lebbeck + chickpea	4.62	4.10	7.37	1.61	2.02	3.19
A. indica + chickpea	3.32	3.77	5.42	1.56	1.93	3.33
D. sissoo + chickpea	4.41	4.97	6.44	2.02	2.44	3.73
A. nilotica + chickpea	4.43	5.00	6.29	2.39	2.98	4.25
Sole trees						
Albizia lebbeck	3.97	3.03	5.86	1.53	1.89	3.09
Azadirachta indica	2.97	3.50	4.92	1.23	1.74	2.71
Dalbergia sissoo	4.77	5.27	6.95	1.99	2.56	3.74
Acacia nilotica	4.16	4.70	6.20	2.22	3.06	4.19
SEm±	0.19	0.39	0.33	0.17	0.28	0.19
CD (P=0.05)	0.56	1.14	1.03	0.50	0.82	0.58

Table 5. Fodder, fuel-wood and protein yields of tree species in sole and agroforestry systems during different years

Treatment	Fodder (dry weight, kg/ha)			Fuel-wood (dry weight, kg/ha)			Crude protein (kg/ha)		
	1999-2000	2000-01	2001-02	1999-2000	2000-01	2001-02	1999-2000	2000-01	2001-02
Agroforestry									
A. lebbeck + chickpea	21	159	158	17	213	324	5.0	30.0	28.2
A. indica+ chickpea	32	299	310	47	361	428	5.4	39.5	52.0
D. sissoo + chickpea	242	358	446	377	743	1104	41.6	54.8	69.0
A. nilotica + chickpea	241	302	423	1,044	1,361	1724	35.9	39.9	70.3
Sole trees									
Albizia lebbeck	31	203	249	47	109	487	7.1	40.6	44.8
Azadirachta indica	46	198	185	104	255	298	7.4	25.7	31.0
Dalbergia sissoo	191	455	559	313	942	1,112	33.6	68.3	86.5
Acacia nilotica	139	390	494	676	1,761	1,894	20.3	50.7	80.6
SEm±	25	58	78	71	140	166	4.5	8.9	12.5
CD (P=0.05)	74	171	244	207	410	516	13.1	26.2	36.3

Table 6. Benefit : cost ratio, net present worth (NPV) and pay-back period (PBP) of various systems

Treatment	At 12% discount rate			At 18% discount rate		
	NPV (x 10^3 Rs)	B : C ratio	PBP (years)	NPV (x 10^3 Rs)	B : C ratio	PBP (years)
Agroforestry						
Albizia lebbeck	27.24	1.42	1	20.34	1.40	1
Azadirachta indica	26.46	1.40	1	19.48	1.38	1
Dalbergia sissoo	35.40	1.55	1	25.86	1.50	1
Acacia nilotica	37.34	1.58	1	28.38	1.55	1
Sole crop	48.68	1.99		36.88	1.95	
Sole trees						
Albizia lebbeck	4.62	1.46	7	1.68	1.20	10
Azadirachta indica	4.53	1.38	8	1.27	1.12	10
Dalbergia sissoo	15.62	2.31	6	9.28	1.92	6
Acacia nilotica	23.43	3.17	5	15.17	2.81	5

to Rs 37,343. The pay back period showed that the entire cost of the systems can be recovered within 1 year in agroforestry and up to 10 years in sole trees. The lower pay-back period in case of agroforestry is because of inter-crop yield, which was quite high during the initial years. The pay-back criterion also showed that agroforestry is more profitable and economically viable than planting trees alone. One of the reasons for higher benefit : cost ratio of sole crop could be non-inclusion of returns from the animal component in case of agroforestry and sole trees. Though the net present worth and benefit : cost ratio are higher with arable cropping, agroforestry systems yield fodder and fuel-wood, which reduces the burden of collection of fuel-wood and also the pressure on forests and common property lands substantially.

It was concluded that integration of trees with arable crops increased the biomass productivity of the existing cropping systems in the semi-arid Bundelkhand region of central India. Trees such as *Acacia nilotica* and *D. sissoo* are better suited than *Albizia lebbeck* and *Azadirachta indica.* Fodder and fuel-wood production from the trees compensate the reduction in crop yield greatly, and result in higher biomass production in agroforestry over sole cropping.

REFERENCES

Anonymous. 2006. *Report of the National Forest Commission,* pp.64-82., Ministry of Environment and Forests, Government of India, New Delhi.

Barnes, P. 1998. Fodder production of some shrubs and trees under two harvest intervals in subhumid southern Ghana. *Agroforestry Systems* **42:** 139–147.

Gettinger, J.P. 1982. *Economic Analysis of Agricultural Projects.* John Hopkins University Press, Baltimore, MD, USA.

Ong, C.K., Wilson, J., Deans, J.D., Mulayta, J., Raussen, T. and Wajja-Musukwe. 2002. Tree-crop interactions: manipulation of water use and root function. *Agricultural Water Management* 53: 171–186.

Puri, S. and Bangarwa, K.S. 1992. Effects of trees on the wheat crop in semi arid regions. *Agroforestry Systems* **20:** 229–241.

Rao, M.R., Ong, C.K., Pathak, P. and Sharma, M.M. 1991. Productivity of annual cropping and agroforestry systems on a shallow Alfisol in semi arid India. *Agroforestry Systems* **15**: 51–63.

Semwal, R.L., Maikhuri, R.K., Rao, K.S., Singh, K. and Saxena, K.G. 2002. Crop productivity under differentially lopped canopies of multipurpose trees in Central Himalaya, India. *Agroforestry Systems* **56**: 57–63.

Singh, P. and Roy, M.M. 1993. Silvipastoral systems for ameliorating productivity of degraded lands in India. *Annals of Forestry* **1**: 61–73.