

## Herbage Production During Drought in Silvopastoral Systems on a Rocky Rangeland in Arid Zone of India

K.C. Singh and A.S. Rao

Central Arid Zone Research Institute, Jodhpur 342 003, India

**Abstract:** A study on herbage production in silvopastoral systems on rocky rangeland, Bhopalgarh, conducted during drought years 1999 and 2000 with five tree and two shrub species at 14 and 15 year of age revealed that average air dried herbage yield in the inter spaces (10 x 4 m) of different silvopastures was lowest with *Dichrostachys nutans* (620 kg ha<sup>-1</sup>) compared to other silvopastoral systems as well as pasture without trees except *Acacia tortilis* (804 kg ha<sup>-1</sup>). *Acacia tortilis* showed maximum survival (96.66%) and growth in height (4.86 m), collar diameter (16.3 cm), dbh (11.03 cm) and canopy diameter (6.63 m). The survival percentage of *Acacia senegal* and *D. nutans* was 81.66 and 78.33%, respectively, which showed that 3 MPTS viz., *A. tortilis*, *Acacia senegal* and *D. nutans* were found better establishing on rocky rangeland. Among these *A. senegal* was most suitable for long term silvopasture. Leaf fodder yield was maximum in *D. nutans* (8.89 kg tree<sup>-1</sup>) followed by *Azadirachta indica* (6.50 kg tree<sup>-1</sup>), *A. tortilis* (5.00 kg tree<sup>-1</sup>) and *A. senegal* (4.95 kg tree<sup>-1</sup>), while fuel wood yield was highest in *A. tortilis* (68.00 kg tree<sup>-1</sup>). A comparison of weather parameters during good rainfall years with that of drought years (1999 and 2000) revealed that during drought years, the air temperatures were higher by 0.8°C, relative humidity was lower by 4% and duration of bright sunshine hours increased by 0.3 hr day<sup>-1</sup> resulting in higher evaporation rates by 1.5 mm day<sup>-1</sup>. The study on impact of drought showed that the decline in herbage production was highest in *D. nutans* (65%) followed by *Azadirachta indica* (57%), *A. senegal* (54%), *Hardwarckia binata* (52%), *Colophospermum mopane* (51%), *A. tortilis* (49%), *Albizia lebbek* (48%) and in sole grass without tree (47%).

**Key words:** Silvopasture, herbage production, droughtrocky rangelands.

On the degraded rangelands of arid Rajasthan, where animal husbandry occupies an important place and frequent droughts cause scarcity of fodder, silvopastures have proved very promising. Low and erratic rainfall leading to drought is the usual feature of the climate of this region. About 10% of the total area of arid zone of Rajasthan is occupied by rocky rangeland, which is not suitable for crop husbandry, but is most suitable for herbage and top feed production. Management of

such lands through silvopastures for forage production, which is always in short supply (62%), to support 28.6 million head of livestock of arid region of Rajasthan is very important. Because of the large deficit of forage there is a need of re-vegetation of degraded rocky rangelands to increase forage supply and its availability, particularly in drought years. Therefore, a study was carried out on silvopastures for forage production at rocky rangeland, Bhopalgarh.

## Materials and Methods

Field experiment with five fodder trees and two shrubs was carried out during 1999 and 2000 at Range Management and Soil Conservation Centre of Central Arid Zone Research Institute, Bhopalgarh (26°18'N; 73°01'E and 224 m above MSL) in Jodhpur district in randomized block design with three replications. There were 20 plants of each species per plot (40x20 m). Nine-month-old seedlings of seven multi-purpose tree and shrub species (MPTS) were planted in pits at a spacing of 10x4 m in 40x20 m plots with 20 plants of each species in 1985. Each pit of 45x45x30 cm was refilled with a mixture of soil + FYM. Each seedling received 10 L water per irrigation during first two years of establishment.

The observations on plant height, collar and crown diameters after 14 years of planting of different tree and shrub species were recorded and statistically analyzed. Diameter at breast height (dbh) was recorded during 2000 in the tree species viz., *A. tortilis*, *A. senegal*, *A. indica*, *H. binata* and *A. lebbek*, but not in *C. mopane* and *D. nutans* because bole was not formed in these species. In 1999 leaf fodder and fuel wood yields were recorded after 1/3<sup>rd</sup> pruning of lower branches of the crown of two trees of each species. The grass in the interspaces of each tree/shrub species was cut on maturity from 8 m<sup>2</sup> area, air dried and recorded dry weight. Main grasses were *Cenchrus setigerus*, *Dichanthium annulatum* and *Aristida funiculata*. To know the impact of drought during 1999 and 2000 on herbage production, the data during good rainfall years of 1995 and 1996 (Singh, 2000) was taken for analysis.

The experimental site is an undulating topography, geologically, the formations encountered are largely *paleozoic* in nature with sheets of stratified calcareous sand stone which is exposed at many places. Soils are gravelly with 25 cm deep soil and contain coarse sand (27 to 31%), sand (50 to 60%), silt (2 to 4%) and clay (9 to 16%). The study area receives a mean annual rainfall of 360 mm with air temperatures ranging from 5.5°C to 45.5°C. Potential evapotranspiration in summer ranges from 9 to 19 mm day<sup>-1</sup>. Annual rainfall during the years 1999 and 2000 was 260.4 mm and 259.6 mm, respectively, and highly erratic and caused drought during both the years.

## Results and Discussion

### *Survival percentage of trees and shrubs*

The survival of *A. tortilis*, *D. nutans*, *A. senegal* and *A. indica* was significantly higher as compared to *C. mopane*, *H. binata* and *A. lebbek* (Table 1). Survival percentage recorded in 2000 was maximum in *A. tortilis* (96.6%) followed by *A. senegal* (81.6%), *D. nutans* (78.3%) and *A. indica* (53.3%) and least in *H. binata* (13.3%) followed by *A. lebbek* (16.6%) and *C. mopane* (21.6%). Earlier observations reported by Singh (2000) on survival of seedlings of different MPTS during 2<sup>nd</sup>, 5<sup>th</sup>, 9<sup>th</sup> and 13<sup>th</sup> year of plantation, i.e., in the year 1986, 1990, 1994 and 1998 had followed almost similar trends. Singh (2005) in a study on the relative growth and biomass production of MPTS under silvopastoral system at rangeland, Bhopalgarh, also recorded satisfactory survival in 13-year-old plantation of the trees of *A. tortilis* and

Table 1. Survival and growth performance of trees and shrubs at 14<sup>th</sup> and 15<sup>th</sup> years of age in silvopastoral systems

Trees and shrubs	1999				2000				DBH (cm)
	Survival (%)	Mean plant-height (m)	Mean collar diameter (cm)	Mean crown diameter (m)	Survival (%)	Mean plant-height (m)	Mean collar diameter (cm)	Mean crown diameter (m)	
<i>A. tortilis</i>	96.66	4.69	15.9	6.52	96.66	4.86	16.3	6.63	11.03
<i>A. senegal</i>	81.66	3.68	10.4	5.59	81.66	3.78	10.5	5.93	8.02
<i>A. indica</i>	53.33	4.50	14.3	3.76	53.33	4.67	14.9	3.93	9.30
<i>D. nutans</i> (shrub)	83.33	2.58	7.6	3.56	78.33	2.69	7.9	3.36	—
<i>C. mopane</i> (shrub)	21.66	2.24	6.3	3.05	21.66	2.29	6.4	2.36	—
<i>H. binata</i>	13.33	4.36	9.8	2.68	13.33	4.76	10.4	2.94	6.78
<i>A. lebbek</i>	20.00	3.74	8.6	2.81	16.66	4.16	10.0	3.36	6.87
SEm±	10.569	0.289	1.148	0.368	9.365	0.326	1.303	0.369	0.96
CD 5%	32.570	0.891	3.539	1.133	28.858	1.006	4.017	1.136	3.124

*A. senegal*. Jindal *et al.*, (2000) in a study on the performance of *A. senegal* accessions at rocky rangeland, Bhopalgarh, reported 97.0% survival in the first year of plantation and 79.0% in 6<sup>th</sup> year.

#### Growth of trees and shrubs

Data on plant height revealed highest growth rate in *A. tortilis* (4.86 m) followed by *H. binata* (4.76 m), *A. indica* (4.67 m), *A. lebbek* (4.16 m), *A. senegal* (3.78 m) (Table 1). *C. mopane* showed least plant height (2.29 m), collar diameter (6.40 cm) and crown cover (2.36 m). Plant height of *A. indica*, *H. binata* and *A. lebbek* was at par with *A. tortilis*. *A. senegal* showed lower plant height than *A. tortilis* and was at par with *A. indica*, *H. binata* and *A. lebbek*. There was no significant difference in growth parameters among shrubs, viz., *D. nutans* and *C. mopane* (Table 1). Wide variation in plant height was due to the

adaptability of these tree and shrub species to environmental condition on stony rangeland. Singh (2005) identified *A. tortilis* and *A. senegal* to be promising tree species for rocky landforms in arid zone. The collar diameter was also higher in case of *A. tortilis* (16.3 cm) followed by *A. indica* (14.9 cm) and was statistically higher than the other trees. The growth in collar diameter recorded with *A. senegal*, *H. binata* and *A. lebbek* was at par and ranged from 10.0 to 10.5 cm. The diameter at breast height (dbh) was maximum in case of *A. tortilis* (11.0 cm) followed by *A. indica* (9.3 cm) and *A. senegal* (8.0 cm) and minimum in *H. binata* (6.7 cm) and *A. lebbek* (6.8 cm). The canopy spread of *A. tortilis* was also maximum (6.63 m) followed by *A. senegal* (5.93 m). The canopy cover of *A. indica*, *D. nutans* and *A. lebbek* was at par, which ranged from 3.36 to 3.93 m and was minimum in *C. mopane* (2.36

m) and *H. binata* (2.94 m). Singh (2000) also reported similar results on growth parameters of these MPTS. The mean annual increment (MAI) in height of *A. tortilis*, *H. binata*, *A. indica*, *A. lebbek*, *A. senegal*, *D. nutans* and *C. mopane* was 32.4, 31.7, 31.2, 27.7, 25.2, 17.9 and 15.2 cm, respectively. Current annual increment (CAI) in growth of height at the age of 15 years was 42.2, 39.6, 17.7, 16.7, 10.3, 9.8 and 4.8 cm in *A. lebbek*, *H. binata*, *A. indica*, *A. tortilis*, *D. nutans*, *A. senegal* and *C. mopane*, respectively. Therefore, growth of certain MPTS was not much affected by drought as indicated by MAI and CAI of the tree species. *A. tortilis* and *D. nutans* showed maximum survival, growth and fuel wood production. *A. senegal*, a native species and *C. mopane*, an exotic species were found suitable for long term silvopastoral systems and *A. indica* for boundary plantation.

#### Top feed and fuel wood production

Top feed and fuel wood production (air dry) of trees and shrubs after 1/3 pruning of lower branches of the crown were recorded at 14 year of age in 1999. Maximum leaf fodder yield was in *D. nutans* (8.89 kg tree<sup>-1</sup>) followed by *A. indica* (6.50 kg tree<sup>-1</sup>), while maximum fuel wood yield was in *A. tortilis* (68.00 kg tree<sup>-1</sup>) followed by *A. senegal* (43.50 kg tree<sup>-1</sup>) and *D. nutans* (29.50 kg tree<sup>-1</sup>). Total air dry leaf fodder and fuel wood production was also maximum in *A. tortilis* (73.00 kg tree<sup>-1</sup>). Further, 14-year-old plantation of *A. tortilis* would yield fuel wood 16.46 t ha<sup>-1</sup> (Table 2). Similarly, Roy (1991) reported dry leaf fodder yield from 10-year-old trees of top feed species *A. tortilis*, *A. lebbek*, *H. binata*

and *D. cinerea* as 0.5, 4.2, 3.7 and 2.8 kg tree<sup>-1</sup> and fuel wood yield as 11.2, 5.1, 5.5 and 5.6 kg tree<sup>-1</sup>, respectively. The wood/leaf ratio was highest in *A. tortilis* (13.60) followed by *A. senegal* (8.79), *A. indica* (1.35), *C. mopane* (1.79), *A. lebbek* (2.50) and *D. nutans* (3.32) and minimum in *H. binata* (0.53). The lower ratio indicates higher leaf fodder and less fuel wood yield in the form of branches. Singh (2000) also found similar trend in leaf and fuel wood production in 13-year-old plantation of multipurpose trees on rocky rangeland.

#### Herbage yield

Herbage yield was lower than the yield of control pasture (without tree) under all trees and shrubs, but decrease in yield was statistically non-significant except *A. tortilis* and *D. nutans*. Herbage yield among other silvopastoral systems did not differ significantly (Table 3). Reduction in yield under *A. tortilis* might be due to higher tree canopy that intercepted more radiation (Rao *et al.*, 1997). The canopy effect on light interception (shading effect) was found up to 3 m distance from the tree trunk of *A. tortilis*. The reduction in yield of herbage in association with *A. tortilis* may also be due to more competition for moisture during drought years. Singh (2000) reported that in the first 8 years after the establishment of trees, viz., *A. tortilis*, *D. nutans* and *A. indica* did not reduce the yield of understorey grasses as the tree cover did not suppress the growth and dry matter yield of grasses due to competition effect for moisture and light interception. The herbage yield in the interspaces of *D. nutans* also reduced because it regenerated through root suckers and covered the inter spaces

Table 2. Top feed production from 14 year old trees and shrubs

Tree species	Dry leaf fodder yield		Dry fuel wood yield		Total		No. of existing trees ha <sup>-1</sup>
	kg tree <sup>-1</sup>	t ha <sup>-1</sup>	kg tree <sup>-1</sup>	t ha <sup>-1</sup>	kg tree <sup>-1</sup>	t ha <sup>-1</sup>	
<i>Acacia tortilis</i>	5.00	1.21	68.00	16.46	73.00	17.67	242
<i>Acacia senegal</i>	4.95	1.01	43.50	8.87	48.45	9.88	204
<i>Azadirachta indica</i>	6.50	0.87	8.75	1.16	15.25	2.03	133
<i>Dichrostachys nutans</i> (shrub)	8.89	1.85	29.50	6.14	38.39	7.99	208
<i>Colophospermum mopane</i> (shrub)	1.40	0.08	2.50	0.14	3.90	0.22	54
<i>Hardwickia binata</i>	4.23	0.14	2.25	0.07	6.48	0.21	33
<i>Albizia lebbek</i>	4.20	0.21	10.50	0.53	14.70	0.74	50

and thereby intercepted more incoming radiation for growth of understorey grasses. *D. nutans* intercepted more than 85% of the incoming radiation and thus seriously affected the grass growth in association with the shrub. Singh (2005) in 13-year-old tree plantation recorded significant reduction in herbage yield under *A. tortilis* compared to pasture without tree on rocky rangeland, Bhopalgarh. *Allelopathic* effects of *A. tortilis* on grasses (Sundarmoorthy and Kalra, 1991) could be another factor responsible for reduction in yield.

#### Drought impact on herbage production

A comparison of weather parameters at Bhopalgarh during good rainfall years (1995 and 1996) with that of drought years (1999 and 2000) revealed that during drought years the mean annual maximum and minimum air temperatures were higher by 0.8°C, relative humidity was lower by 4% and duration of sunshine hours increased by 0.3 hr day<sup>-1</sup> resulting higher evaporation rates by 1.5 mm day<sup>-1</sup>. Distribution of rainfall during the growing season also affected forage yield of grass. The yield

was maximum between 180 and 250 mm of well distributed growing season rainfall.

The impact of drought on herbage production was studied by comparing the average productivity during two good rainfall years (1995 and 1996) with the mean productivity obtained during two drought years (1999 and 2000). During these two rainfall years, the annual rainfall was 260 mm in 1999 and 259 mm in 2000. The impact of such a decline in rainfall from 552 mm during 1995 to 260 mm in 1999 (reduction by 59%) on herbage production at Bhopalgarh is given in Table 3. The decline in herbage production during drought years compared to good rainfall years was highest in *D. nutans* (65%) followed by *A. indica* (57%), *A. senegal* (54%), *H. binata* (52%), *C. mopane* (51%), *A. tortilis* (49%), *A. lebbek* (48%) and minimum in sole grass without tree (47%). *A. indica* leaves make very good fodder for sheep, goats and camels and are heavily lopped during drought years. *D. nutans* and *C. mopane* also provide green browse material for sheep and goats in drought years. Therefore, with the established

Table 3 Herbage production ( $\text{kg ha}^{-1}$ ) in silvopastoral systems during good rainfall years (1995 and 1996) and drought years (1999 and 2000) at Bhopalgarh

Silvopasture	Herbage production in good rainfall years			Herbage production during drought years			Reduction in herbage production (%) due to drought
	1995	1996	Mean	1999	2000	Mean	
<i>Acacia tortilis</i>	1488	1688	1588	854	753	804	49
<i>Acacia senegal</i>	2542	1998	2270	1025	1083	1054	54
<i>Azadirachta indica</i>	2604	1988	2296	982	993	988	57
<i>Dichrostachys nutans</i> (shrub)	1920	1599	1760	629	610	620	65
<i>Colophospermum mopane</i> (shrub)	2608	1943	2276	1154	1100	1127	51
<i>Hardwickia binata</i>	2492	2066	2279	1138	1066	1102	52
<i>Albizia lebbek</i>	2492	1972	2232	1187	1150	1169	48
Control (without tree)	2737	2310	2524	1390	1300	1345	47
SEM $\pm$	288	220	3122	162.8	115.9	120.8	
CD 5%	860	660	-	493.9	351.6	366.3	

Source: The data for comparison of herbage production for years 1995 and 1996 are taken from Singh, 2000.

silvopastoral systems, particularly the land which is not suitable for crop husbandry, herbage as well as top feed production is possible during drought years for sustainable livestock production in arid region.

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