ADAPTABILITY AND PRODUCTIVITY OF *CASSIA ANGUSTIFOLIA* IN SANDY SOIL OF INDIAN DESERT

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Introduction

A large proportion of human population in developing countries lives in rural areas. Out of this, about 80% of the population still uses traditional medicines for their health care (DeSilva, 1995). *Cassia angustifolia* Vahl. (Sonamukhi or Senna) is an important species (Leguminoceae, sub-family Caesalpinoideae), occurs as perennial shrub in northern Agrica and South-Western Asia. People in these regions have used *C. angustifolia* as a laxative for centuries and it is cônsidered as a "cleansing" herb because of its cathartic effect. The main ingredient 'sennosides' are the hydroxyanthracene glycosides (Leng-Peschlow, 1986), which are generally extracted from leaves and pods. Its content varies from 2.5% to 4% and 3% to 5% in the respective plant parts. Though a basal dressing of 50 kg nitrogen, 25 kg phosphorus and 40 kg potash ha^{-1} with two equal doses of 25 kg nitrogen as top dressing after sowing is recommended, but this species may be grown without fertilizer application and under rainfed condition in dry regions (Gautam, 2002). Being a perennial shrub in nature, if cultivated once *C. angustifolia* may give a regular crop for the next four to five years. Therefore, it may be considered as the perfect crop for restoring barren and infertile lands of dry region.

Arid and semi-arid regions of India are rich in medicinal plants. However, large proportion of barren and infertile lands provides opportunity for cultivation and utilization of *C. angustifolia* in this large tract. Owing to its drought hardy nature *C. angustifolia* is considered to be one of the most important commercial crop in this zone. Resistance to pest attack and browsing put added advantage to this shrub. However, sensitivity of this species to frost is a major constraint in the prevailing set of climatic condition. Therefore, introduction of woody perennial may ameliorate the microclimate and protect this species from frost through canopy cover. Furthermore, it would also be helpful in controlling sand drift if this species is used as surface vegetation in biological methods of sand dune stabilization (Singh and Rathod, 2002).

Therefore, the objective of this study was to find out suitable adult neighbour of *C. angustifolia* with dual benefits of sand drift control and increase in the productivity of the highly fragile landmass involving surface vegetation of medicinal value. It would not only help in sand drift control but also provide opportunity to increase the socio-economic status of the local community.

Study Area and Methodology

Site characteristics : The study was carried out on a shifting dune located 15 km from the District Bikaner (28° 00' N - 73° 18' E) in North-western part of Indian desert. The climate of the area is arid with large variations in rainfall, temperature and wind velocity (Table 1). Mean annual precipitation for the last 25 years was 348 mm whereas the normal potential evapo-transpiration is 1772.4 mm (Rao *et al.*, 1971). However, the rainfall recorded was 508.5 mm, 481.7 mm, 224.4 mm and 188.6 mm in the years 1997, 1998, 1999 and 2000, respectively (Table 1). Mean monthly maximum relative himidity varied from 27% to 92%. Mean monthly maximum and minimum temperature ranged from 21-43°C and 6-29°C, respectively, in which mercury touches 47°C in summer and dips down to freezing point during winter. The soil of the site is loamy sand with very low content of soil organic matter (0.092%), available nitrogen (2.71 mg kg^{-1}) and available phosphorus (3.14 mg kg^{-1}). The soil had a water-holding capacity of 3.9% (w/w) at -0.03 MPa.

Field preparation and planting : *Acacia tortilis, prosopis juliflora* and *Calligonum polygonoides* seedlings of about 20 cm, 40 cm and 15 cm in height respectively, were planted in randomised block design with three replications in September 1996. The spacing between the plants ere 5 m x 5 m and the pit size was 45 x 45 x 45 cm^3. About 10.0 g of DAP (di-ammonium hydrogen phosphate) was spread in each pit as basal dressing and about 20 g of BHC (y-hexachlorobenzene) was used by thoroughly mixing with the soil to protect the seedlings from termite attack at the time of planting. *Cassia angustifolia* was sown in July 1997 to provide sufficient time for the seedlings establishment.

Observations recording : Height, crown diameter and collar diameter (10 cm above the ground level) of *A. tortilis, C. polygonoides* and *P. juliflora* were recorded in November 1998 to 2001, just before winter season during which the growth of the plants ceases. Phenological observation on *C. angustifolia* was recorded for sustained productivity on perennial basis without affecting the objective of sand dune stabilization. One plant of each species in each plot was randomly selected for soil sampling to determine soil water content on regular basis and to avoid sampling error due to place variations. Soil samples were collected just before monsoon i.e. June 1999 and 2000 and after monsson i.e. October 1998, 1999, 2000 to monitor water content during water deficit period. Samples were collected from the root zone of the plants using different soil core for 0-25, 25-50 and 50-75 cm soil layers and put immediately into polyethylene bag to avoid water losses during transport to laboratory. Samples were dried at 110°C for constant weight. Gravimetric soil water content was converted to mm using the following equation to give total soil water to the soil depth of 0-75 cm.

$$\text{Soil water (mm)} = \frac{[\text{Soil water (\%)} \times \text{bulk density (g cm}^{-3})] \times \text{soil depth (mm)}}{100}$$

Cassia angustifolia harvesting was done in May 1998 (sprouting of root stock after frost in February 1998) and November 1999 and 2000 (after monsoon

Table 1

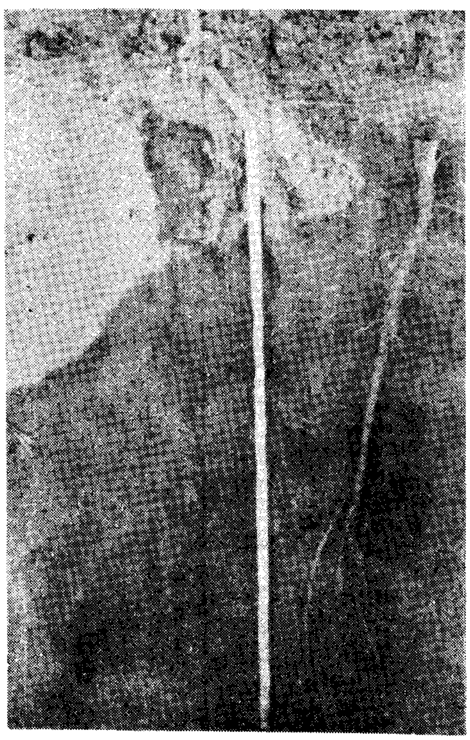
*Climatic conditions of the experimental site Bikaner**

Months	Rainfall (mm)				PET**	Air temperature (^0C)				Relative humidity (%)				WS (kmh^{-1})	
	1997	1998	1999	2000	(mm)	1997	1998	1999	2000	1997	1998	1999	2000	1999	2000
January	6.3	0.0	25.6	4.2	53.3	24.1	23.1	21.3	23.9	75	69	92	72	5.2	5.5
February	3.4	14.8	2.2	0.8	75.3	22.8	26.3	26.6	25.3	70	67	73	68	6.1	7.8
March	22.0	6.8	0.0	0.0	131.4	31.6	31.1	33.9	32.9	69	66	47	43	7.6	8.0
April	44.6	21.9	0.0	0.4	172.4	36.4	38.8	41.0	41.5	59	52	27	36	7.8	9.2
May	37.6	10.1	72.9	0.0	236.8	39.3	43.2	41.6	42.7	56	43	52	51	11.3	15.6
June	109.8	41.5	3.4	13.2	258.3	39.3	41.3	40.7	41.6	73	62	61	57	13.5	15.0
July	41.6	195.1	83.0	135.5	228.2	39.2	38.3	38.7	38.5	72	87	71	68	12.9	11.8
August	71.1	32.2	22.3	25.5	196.6	36.8	39.1	37.3	37.8	79	75	72	74	12.1	13.1
September	5.9	48.3	15.0	3.2	177.7	37.5	36.9	40.2	38.1	71	78	66	65	8.6	10.6
October	163.3	111.0	0.0	2.8	124.7	30.0	34.4	37.8	38.6	89	70	50	41	5.8	5.3
November	0.6	0.0	0.0	3.0	68.3	27.7	30.3	32.8	31.3	81	62	43	54	5.1	4.5
December	2.3	0.0	0.0	0.0	48.8	21.6	26.6	26.9	27.7	91	68	55	58	4.7	5.0
Total (RF)	508.5	481.7	224.4	188.6	1772.4										

*All data are mean maximum of one month.
** Values are normal potential evapotranspiration (Rao *et al.*, 1971).
WS : Wind speed; RF: rainfall.

growth). Leaves and twigs were separated and fresh weight was recorded. Leaves were air-dried and dry weight of the *C. angustifolia* leaves was recorded. Roots study was carried out on naturally regenerated seedlings of *Cassia angustifolia* in July 2001. Roots were excavated carefully for recently germinated as well as one-year old regenerated seedlings of *C. angustifolia*. Roots of one-year-old seedlings were excavated only up to 120 cm deep soil layer though it was still penetrating deeper soil layers (Fig. 1).

Fig. 1



Root-growth pattern of one-year-old *Cassia angustifolia* seedlings (left as indicated by tape) and *Crotolaria burhia* (right), another species of dry region

Statistical analysis : The data collected were statistically analyzed using SPSS statistical package. Differences in height, crown diameter and collar diameter of standing plant species was tested with one way ANOVA model considering species as the main effect and within plot variation as the error. Average growth parameters per plot were considered as the dependent variables. Biomass of *C. angustifolia* was also tested using one way ANOVA with plant parts as the dependent variable and tree seedlings as the main effect. To know the soil water depletion due to different species, soil water data of October 1998, June 1999, October 1999, June 2000 and October 2000 were tested using two way ANOVA with soil water data as the dependent variable. Species and the soil layers were considered as the fixed effect. Per cent soil water was square root transformed before statistical analysis (Sokal and Rolf, 1981). Since the data were repeatedly collected on same parameters, *C. angustifolia* biomass and soil water data were tested with repeated measure analysis. Duncan Multiple Range Test (DMRT) was applied to each data to obtain homogeneous sub sets.

Results

Growth parameters of tree seedlings : Growth data indicated significant differences in height ($P<0.05$), crown diameter ($P<0.05$) and collar diameter ($P<0.05$) between the species except in years 1998 and 2001 for height and 1999 and 2001 for collar diameter (Table 2). *P. juliflora* attained the maximum height during 1998 ($P<0.05$) and 1999 ($P>0.05$) compared to the other two species. In November 2000 and 2001, the height of *A. tortilis* was the highest. *P. juliflora* was at par to *A. tortilis* and *C. polygonoides*

Table 2

Growth parameters of adult neighbours.

Species	Height (cm)				Crown diameter (cm)				Collar diameter (cm)			
	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001
A. tortilis	175	244	368	407	125	215	329	341	4.6	7.4	8.2	8.4
	(32.3)	(23.9)	(13.1)	(17.5)	(6.0)	(7.4)	(35.5)	(34.1)	(0.26)	(0.11)	(0.11)	(0.07)
P. juliflora	218	276	320	377	249	360	401	492	5.0	6.6	7.0	8.0
	(54.3)	(35.6)	(29.5)	(28.9)	(28.0)	(34.5)	(21.6)	(18.0)	(0.21)	(0.28)	(0.27)	(0.59)
C. polygonoides	149	182	294	338	158	242	382	418	5.7	7.4	7.8	8.6
	(9.5)	(4.0)	(8.9)	(34.1)	(17.6)	(33.1)	(11.5)	(21.1)	(0.17)	(0.46)	(0.51)	(0.87)
ANOVA												
F value	2.63	11.00	11.30	4.76	5.79	22.93	8.31	26.67	12.13	3.11	8.96	0.88
P value	0.15	0.010	0.009	0.058	0.040	0.002	0.019	0.001	0.008	0.118	0.016	0.461

Values are mean with Sd± in parentheses.

had the lowest height. Crown diameter of the species also varied significantly ($P<0.05$). It was greater for *P. juliflora* followed by *C. polygonoides*. *Acacia tortilis* had less crown diameter compared to the other species in all the three years of observation recording. Collar diameter was greater ($P<0.05$) for *C. polygonoides* in 1998 and at par with *A. tortilis* in 1999 ($P<0.05$). However, at the age of 62 months, collar diameter was at par for all the three species, though *P. juliflora* attained the least collar diameter.

Phenological observation on C. angustifolia : Seeds of *C. angustifolia* germinated within five days of sowing. However, regeneration from naturally dispersed seeds occurred immediately after rain (during monsoon period of July to September) when sufficient soil water availability in there. The phenological expressions occurred twice in a year. *C. angustifolia* plants attained maturity during September. Low temperature in middle of January to first week of February resulted in drying (mortality of shoots) of *C. angustifolia* plants due to frost effect. Rootstock however, re-sprouted during favourable environmental condition of February and March resulting in start of the life cycle in the next season i.e., February to June. Flowering started in October and again in April. Fruiting occured during November to December and again in May to June. Seed dispersal observed in December and again in May-June.

Growth and productivity of C. angustifolia : *Cassia angustifolia* plants attained height of 70-80 cm and crown diameter of 50-60 cm within a period of 5-6 months, when sown. However, under natural regeneration shoot height of one-year-old seedling ranged from 5 to 12 cm.

Above ground biomass of *C. angustifolia* differed ($P<0.05$) due to phenotypic characters of adult neighbour in all the three years of 1998, 1999 and 2000 (Table 3). Biomass production was high with *C. polygonoides* followed by *P. juliflora* association. The lowest biomass was with *A. tortilis*. Repeated measure analysis indicates that yields of *C. angustifolia* varied ($P<0.05$) within the year and was high in May 1998 and decreased in the subsequent year. Considering the biomass allocation, the contribution of stem and leaves ranged 61.9% to 66.7% and 33.3% to 38.1%, respectively. Fresh leaves production varied from 1.47 to 2.86 tonnes ha^{-1} in 1998 to 1.25 to 2.15 tonnes ha^{-1} with *A. tortilis* and *C. pollygonoides*, respectively. Loss in weight during drying of leaves was to the extent of 52% during summer and 56% during November (Table 3). Contribution of leaves was comparatively less in summer (May 1998) as compared to that in November and decreased with age of the plants.

Root growth and development : Root growth study indicated that recently germinated seedlings of *C. angustifolia* attained root length of 30-35 cm at the time of cotyledons opening and plumule appearance. However, the root of one-year-old naturally regenerated seedling of *C. angustifolia* penetrated up to a soil depth of 120 cm (Fig. 1). It suggests better survival strategy of this species under water deficit condition.

Soil water content : Soil water content (SWC) variation due to species was significant ($P<0.05$) in June 1999, June

Table 3

Biomass (tonnes ha^{-1}) of Cassia angustifolia under different neighbours and years.

	May 1998				November 1999				November 2000			
Tree species	FS	FL	DL	F Total	FS	FL	DL	F Total	FS	FL	DL	F Total
A. tortilis	2.50 (0.20)	1.47 (0.06)	0.76 (0.03)	3.97 (0.15)	2.37 (0.20)	1.43 (0.15)	0.80 (0.09)	3.80 (0.26)	2.45 (0.05)	1.25 (0.13)	0.71 (0.08)	3.70 (0.17)
P. juliflora	3.28 (0.40)	1.88 (0.16)	0.97 (0.08)	5.17 (0.51)	3.13 (0.49)	1.85 (0.18)	1.04 (0.11)	4.98 (0.62)	2.52 (0.08)	1.53 (0.20)	0.87 (0.12)	4.06 (0.25)
C. polygonoides	4.60 (0.10)	2.68 (0.10)	1.39 (0.05)	7.28 (0.20)	4.55 (0.15)	2.80 (0.10)	1.56 (0.56)	7.35 (0.13)	4.32 (0.13)	2.15 (0.18)	1.23 (0.10)	6.46 (0.29)
ANOVA												
F value	46.96	86.02	86.02	78.10	67.08	67.08	67.08	61.48	417.66	20.42	20.42	116.17
P value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000

Values are mean of three replications with Sd+ in parentheses.
FS : fresh weight stem + twigs; FL : fresh weight leaves; DL : dry weight leaves; F total : total fresh weight

Table 4

Seasonal changes in soil water content (% w / w; total in mm in 0-75 cm soil layer) under the influence of different adult neighbours.

Species	Soil layers	Oct. 1998	June 1999	Oct. 1999	June 2000	Oct. 2000
A. tortilis	0-25	1.10±0.17	1.49±0.05	0.34±0.03	0.053±0.005	0.50±0.09
	25-50	1.29±0.06	1.99±0.10	0.55±0.10	0.068±0.015	0.71±0.12
	50-75	1.34±0.05	1.97±0.10	0.68±0.04	0.136±0.014	1.23±0.07
Total (mm)	0-75	14.62	21.39	6.16	1.01	9.58
P. juliflora	0-25	1.13±0.22	1.34±0.09	0.35±0.03	0.051±0.011	0.41±0.05
	25-50	1.17±0.21	1.82±0.05	0.55±0.13	0.106±0.005	0.62±0.06
	50-75	1.24±0.19	1.76+0.07	0.76±0.19	0.137±0.106	1.12±0.26
Total (mm)	0-75	13.90	19.31	6.51	1.04	8.43
C. polygonoides	0-25	1.17±0.11	2.43±0.27	0.43±0.05	0.060±0.005	0.52±0.06
	25-50	1.32±0.08	2.99±0.36	0.65±0.13	0.099±0.010	0.94±0.06
	50-75	1.36±0.21	3.22±0.41	0.88±0.20	0.194±0.021	1.53±0.17
Total (mm)	0-75	15.11	33.91	7.69	1.39	11.74
ANOVA	F value					
	S	0.970	108.94	2.17	14.01	11.60
	D	3.17	26.82	19.16	164.64	104.16
	S x D	0.23	0.45	0.12	5.72	0.90
	P value					
	S	0.397	0.000	0.143	0.000	0.001
	D	0.066	0.000	0.000	0.000	0.000
	S x D	0.917	0.772	0.975	0.004	0.486

Values are mean of three replications with Sd ±

2000 (Table 4). Soil water was high (P<0.01) under *C. polygonoides* compared to *A. tortilis* and *P. juliflora* for all the five times of soil water estimation except in October 1999 during which SWC did not differ significantly. SWC was low under *P. juliflora* during October 1998, June 1999 and October 2000, whereas, it was low under *A. tortilis* during October 1999 and June 2000. Differences in soil water content in different soil layers were also significant (P<0.01) being maximum in 50-75 cm layer. The interaction term species x soil layers was not significant (P>0.05) except in June 2000. Low soil water content during the entire observation period is indicates soil water stress in the area, which received rainfall of 506, 484, 224 and 185 mm in the years 1997, 1998, 1999 and 2000, respectively.

Comparatively greater soil water content in June 1999 was due to rain before soil sampling.

Discussion

Phenological observations of *C. angustifolia* indicate that this species attained maturity and flowered twice in a year. Out of this, the second phase occurs from the resprouted rootstock during summer months of May and June. This indicates that *C. angustifolia* remained green and at maturity in the period during which maximum sand drift takes place. Therefore, this observation suggests that *C. angustifolia* would be suitable surface vegetation in control of sand drift. Furthermore, fast root growth and deep root system enhanced the chances of survival of *C. angustifolia* in the dry habitats. Concentrations of fibrous root systems to the top 0-30 cm layer may be an adaptation of this species for efficient utilization of available soil water and nutrients. Ginvish (1986) had also reported greater carbon allocation to roots in unproductive areas in order to gather limiting nutrients. This indicates that species with high root biomass allocation would be more dominant in this unproductive habitat (Tilman, 1988). Greater root growth as compared to shoot growth might provide enough adsorptive surface to exploit water and nutrients from the topsoil during low rainfall and supporting their higher survival in this stress sites. Low soil water content during the observation recording period (expect June 1999, the sampling of which was carried out after an occasional summer rain) indicated that plants met their requirement from the deeper soil layer (below 0-75 cm soil layer) through deep penetrating root system.

Variations in biomass productivity of *C. angustifolia* were probably due to nursing/competitive effect of the adult neighbours. Greater biomass with *C. polygonoides* indicates that this species provide nursing effect to the *C. angustifolia* plants. High soil water content under *C. polygonoides* as compared to *A. tortilis* and *P. juliflora* also supports the nursing influence of this species as the neighbour. Low biomass with *A. tortilis* might be due to competitive effect and or low water availability. Surface spreading crown of *P. juliflora* and *C. polygonoides* might affect wind speed and temperature under the canopy and would be beneficial for growth of *C. angustifolia* and control of sand drift during freezing winter and harsh summer. Comparatively greater soil water content under *P. juliflora* during October 1999 and June 2000 (i.e., without rain) indicates moisture conservation due to surface spreading nature of this species. Furthermore, overstorey vegetation might affect the radiation intensity (Saunders *et al.*, 1991) and probably wind speed, which cause greater evaporation resulting in greater water deficit in surface soil (Gibson and Bachelard, 1986). The statement was also supported by low water content in *A. tortilis* and *P. juliflora* plots, though differences in soil water content may also be due to varying rate of transpiration among the species.

Non-significant variation in biomass of *C. angustifolia* between May 1998 and November 1999 indicates that it maintained constant productivity in both the season. Comparatively low leaves production during summer was probably due to low soil water availability. However, low biomass in November 2000 may be an indicator of decreased productivity of *C. angustifolia* with advancing age of the plants. It was further suggested by decreased average leaves contribution (34.9%) to the total biomass in November 2000 as compared to 37.8% in November 1999. Changes in biomass allocation due to age (Bray, 1963) and season (Cannel and Willet, 1976) have also been observed in other studies.

Conclusions

The results obtained in the present study indicate variations in biomass production depending upon the types of adult neighbours. *P. juliflora* and *C. polygonoides* had larger crown diameter (spreading over the soil surface) and was beneficial in restoration of soil water and probably wind speed. Therefore, *C. polygonoides* was suggested as the best species followed by *P. juliflora* for production from *Cassia angustifolia* and early stabilization of sand dune. Therefore, the combination of *C. polygonoides* and *C. angustifolia* was the best in producing greater biomass in addition to control sand drift and amelioration of environmental condition.

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SUMMARY

Growth and productivity of *Cassia angustifolia* was studied during 1997 to 2000 in presence of adult neighbours namely *Acacia tortilis, Prosopis juliflora* and *Calligonum polygonoides*. The objectives were to find out suitable combination to control sand drift and to increase overall productivity of arid area. Seedlings of above species were planted in September 1996, whereas the *C. angustifolia* was sown in July 1997. Growth of woody perennials, growth, phenology, biomass productivity and root study of *C. angustifolia* and soil water content were the recorded observations. *C. angustifolia* flowered twice in a year and remains green during peak summer of May and June and therefore would be beneficial in sand drift control. It had deep penetrating roots to gather limiting resources in this unproductive land. Production of *C. angustifolia* was higher ($P<0.05$) with *C. polygonoides* as compared to *P. juliflora* and *A. tortilis*. Soil water content was higher under *C. polygonoides* than that under other two species and suggested to be due to spreading type of canopy. Fresh weight of stem + twigs and leaves of *C. angustifolia* ranged from 61.9% to 66.7% and 33.3% to 38.1%, respectively with total above ground biomass production of 3.70 to 7.35 tonnes ha^{-1}. There was no difference between biomass of summer and autumn harvesting, though the production decreased with age of the plants. The combination of *C. polygonoides* and *C. angustifolia* was best to increase production of this dry land with additional benefits of sand drift control.

भारतीय मरूभूमि की रेतीली मृदा में *कैसिया एंगस्टिफोलिया* की अनुकूलनीयता और उत्पादकता

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सारांश

कैसिया एंगस्टिफोलिया की बढ़वार और उत्पादकता का 1997 से 2000 तक इसके व्यस्क पड़ोसियों अर्थात् *अकेसिया टोर्टइलिस, प्रोसोपिस जुलीफ्लोरा* और *कैलिगोनम पोलिगनाइडिस* की उपस्थिति में अध्ययन किया गया । इनका उद्देश्य था इस शुष्क क्षेत्र में रेत का उड़कर निकलना रोकना तथा क्षेत्र की समग्र उत्पादकता बढ़ाने के लिए उपयुक्त संयोगों को

मालूम करना । उपर्युक्त पादप जातियों के पौधे सितम्बर 1996 में रोपे गए थे जबकि *के० एंगस्टिफोलिया* का बीज जुलाई 1997 में बोया गया । काष्ठीय बहुवर्षियों की बढ़वार तथा *कै० एंगस्टिफोलिया* की वृद्धि, ऋतुजैविकी, जैवपुंज उत्पादकता और जड़ों का अध्ययन तथा मृदा की जलमात्रा के प्रेक्षण आलेखित किए गए । *कै० एंगस्टिफोलिया* पर वर्ष में दो बार फूल आए तथा मई और जून की शिखर गर्मियों में यह हरा बना रहता है और इसलिए यह रेत उड़कर निकलना रोकने में भी लाभकारी रहेगा । इसमें नीचे गहराई में जाती जड़ें होती है जो इस अनुत्पादक प्रदेश के सीमित संसाधनों को एकत्र कर लेती हैं । *कैसिया एंगस्टिफोलिया* का उत्पादन *प्रो० जुलीफ्लोरा* और *अ० टोर्टाइलिस* के साथ रहने की तुलना में *कै० पोलिगनायडिस* के साथ रहने पर ज्यादा (पी< 0.05) रहा । अन्य दो जातियों के साथ रहने की तुलना में *कै० पोलिगनायडिस* के नीचे इसे उगाने से मृदा नमी भी अधिक रही जो यह सुझाता है कि ऐसा वितान के फैला रहने के प्ररूप से हुआ होगा । तने+ टहनियों और पत्तियों को मिलाकर *कै० एंगस्टिफोलिया* का ताजा भार क्रमश: 61.9% से 66.7% तक और 33.3% ये 38.1% तक रहा जबकि भूमि से ऊपर का कुल जैवपुंज उत्पादन 3.7Q से 7.35 टन प्रति हैक्टर पाया गया । ग्रीष्म कटाई और शरद कटाई के जैवपुंजों में कोई अन्तर नहीं निकला; यद्यपि पादप की उम्र बढ़ने के साथ उत्पादन कम होता चला गया । निष्कर्षत: इस शुष्क भूमि का उत्पादन बढ़ाने के लिए *कै० पोलिगनायडिस* और *कै० एंगस्टिफोलिया* का संयोग सर्वोत्तम रहता है जिसके साथ अतिरिक्त लाभ रेत उड़कर निकलना, रूक जाने का मिलता है ।

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