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STUDIES ON THE GROWTH OF SOME FODDER AND FUEL TREES UNDER ASSOCIATION WITH DIFFERENT SHRUBS AND GRASSES

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ABSTRACT

While considering the vital role of forest as grazing resource, the importance of fodder cum fuel trees need to be assessed to establish and procure more fuel during greater part of the year. Be sides other parameters, the search on fodder tree evaluation as fodder resource is necessary with other crops. The vital role of wasteland areas and to convert them into productive ecosystems by making use of different shrubs was considered pre-eminent. In this direction, a continuous program for three years was conducted on fundamental cum applied role of shrubland plants in raising biomass productivity.

INTRODUCTION

The untimely rains and periodical droughts lowered down the water table, and it is very likely that large areas would be reduced to severe dry conditions with poor supply of fuel, fodder or either, and it is likely to worsen to a critical nonretrievable condition in near future.

The straight measures to restore denuded grasslands by proper plant cover by cultivating trees of fuel cum fodder have importance under afforestation and crop rotation. This is a system of natural renewable resources for energy and better environment, which perhaps would be a solution to avert further narrowing of the situation.

An important factor in favour of the naturally growing plant species and bushes is that they have permanent and deep root systems, which help to stabilize the soil, control erosion under heavy rains, can tap water and nutrients that are not available to most of the grasses, and consequently remain green while grasses wither.

It was observed that the plants for fodder and fuel like *Leucaena* species, *Sesbania sesban, Sesbania grandiflora, Gliricidia maculata* and *Moringa oleifera* can be cultivated on small scale or in isolated patches (Chandolkar 1982, Damodaran 1984, Dev 1968, Hegde 1983, Relwani et al. 1969). Realizing the potential of these crops, it was thought to take straight measures to restore the denuded areas by using these plant species.

MATERIALS AND METHODS

About 5000 seedlings of *Sesbania sesban, Leucaena leucocephala, Sesbania grandiflora, Moringa oleifera* and *Gliricidia maculata* were raised in nursery and an additional lot of 5000 seedlings was kept ready as backup programme to fill in the gaps. The preparations were done in the April of 1997. Care was taken that raised seedlings in polythene bags were healthy before transplantation.

The plantation was done on a hectare of the wasteland at Kamtha, 12 km away from Nanded. The experimental site was typical black cotton soil. The soil testing was done for field capacity, pH and N contents. The field capacity of soil ranged from 20% to 40% while pH (of the location at three different depths of 15cm, 23cm and 30.5cm) ranged as 7.1, 7.3 and 7.6 respectively. The N % of the soil was invariably low.

The land was prepared by deep plough (23cm), harrowed four times north south and east west to attain fine tilth. 40 cart-load/ha cow dung manure was added, spread and mixed thoroughly. The experimental area was demarked exactly into five environments of 60m × 6m as E_1T_1-E_5T_5 occupying an area of 6m × 240m. The demarcation between E_1T_1-E_5T_5 were interspersed with a strip (1.5m × 240m) in between and on either side of the experimental site. Thus, each block of 60m × 6m covers an area of 240m was designated as tree environment. In all the 5 tree environments, ***Sesbania sesban*** in E_1T_1, ***Leucaena leucocephala*** in E_2T_2, ***Sesbania grandiflora*** in E_3T_3, ***Moringa oleifera*** in E_4T_4 and *Gliricidia maculata* in E_5T_5 were raised. The layout of the experiment was in Complete Randomised Block Design (CRD) with four replications.

Two saplings at the distance of 7.5m × 6m apart were planted in a pit of 0.6m × 0.6m × 0.6m size, about 5 kg mixture of organic manure was added. The saplings were transferred from polythene bags to field in all the 5 Tree Environment established as E_1T_1- Environment, E_2T_2-Environment, E_3T_3-Environment, E_4T_4-Environment, E_5T_5-Environment. In each Tree Environment, 2 sapling of five shrub species were planted at a distance of 1.5m, thus, each tree Environment received five plants species which were later converted to shrub canopy. A tree environment was, thus, provided with a population of 18 trees and 32 shrubs.

The objective was to grow the shrubs as undergrowing coppice, these saplings were trained and trimmed such that they grew into an ideal browse (a second story below tree canopy). The shrub established very well and then allowed to grow to a desirable height to harvest and regrowth regeneration.

The design of experimental layout was conditioned to establish Tree Environment first, then undergrowing shrubs, followed by the grasses as ground carpet for the efficient use of light, water and nutrients.

The grass species of *Panicum*, *Pennisetum* and *Teosinte* as ground cover were established in long strips of 0.3m × 60m (in each tree block and four replication) in between shrub plantation, while the seeds of *Amaranthus* were sown in line distance of 0.3 m × 60 m.

A successful three tier green canopy was established against the vagaries of climatic conditions.

T_1E_1	T_2E_2	T_3E_3
$S_1 \times S_2 \times S_3 \times S_4 \times S_5$	$S_2 \times S_3 \times S_4 \times S_5 \times S_1$	$S_3 \times S_4 \times S_5 \times S_1 \times S_2$
$G_1 \times G_2 \times G_3 \times Ap$	$G_1 \times G_2 \times G_3 \times Ap$	$G_1 \times G_2 \times G_3 \times Ap$

T_4E_4	T_5E_5
$S_4 \times S_5 \times S_1 \times S_2 \times S_3$	$S_5 \times S_1 \times S_2 \times S_3 \times S_4$
$G_1 \times G_2 \times G_3 \times Ap$	$G_1 \times G_2 \times G_3 \times Ap$

El Tl - Environment of tree *Sesbania sesban*
E2 T2 - Environment of tree *Leucaena leucocephala*
E3 T3 - Environment of tree *Sesbania grandiflora*
E4 T4 - Environment of tree *Moringa oleifera*
E5 T5 - Environment of tree *Gliricidia maculata*
Si - Ind icates Shrub *Sesbania sesban*
S_2 - Indicates Shrub *Leucaena leucocephala*
S_3 - Indicates Shrub *Sesbania grandiflora*
S_4 - Indicates Shrub *Moringa oleifera*
S_5 - Indicates Shrub *Gliricidia maculata*
G_1 - Indicates Grass *Panicum maxicum*
G_2 - Indicates Grass *Pennisetum typhoidum*
G_3 - Indicates Grass *Euchleana maxicana*
Ap - Indicates Herb *Amaranthus paniculatus*

Table 1: Number of Harvests in shrubs, grasses and *Amaranthus.*

Sr. No.	Name of Species	Harvest		
		I st year (1999-2000)	II nd year (2000-2001)	III rd year (2001-2002)
1.	*Sesbania sesban*	3 harvest	4 harvest	4 harvest
2.	*Leucaena leucocephala*	3 harvest	4 harvest	4 harvest
3.	*Sesbania grandiflora*	2 harvests	4 harvest	4 harvest
4.	*Moringa oleifera*	2 har ʳests	4 harvest	4 harvest
5.	*Gliricidia maculata*	2 harvests	4 harvest	4 harvest
6.	*Panicum maxicum*	3 harvests	6 harvest	6 harvest
7.	*Pennisetwn typhoidum*	6 harvests	6 harvest	6 harvest
8.	*Teosinte maxicana*	3 harvests	3 harvest	3 harvest
9.	Amaranthus paniculatus	3 harvests	3 harvest	3 harvest

Thus, each Tree Environment was a combination of S_1S_5 (shrubs) as aerial and G_1-G_3 (grasses) and *Amaranthus* as ground canopy. The studies on harvest technology confirmed that the harvest at breast height (HBH) yielded high biomass while trees were left unchopped for five years (Kulkarni & Dev 2007).

The harvest operations were carried out, the shrubs from each Tree Environment were harvested at HBH heights with grass species at different times of the season/year. The biomass collected at each harvest as fresh produce was measured as kg/u.a./harvest. The harvested biomass was brought to laboratory for further analysis.

The investigation trials on height of the harvest 150 cm was considered an ideal for regrowth harvest. In the year 1998-1999 harvesting the shrubs was done not under the influence of tree environmental conditions, while in the succeeding years, all the shrub browses were subjected to grow under the influence of tree environment.

About 100 g of biomass from each shrub species from each replicate of Tree Environment was collected in triplicate and dried at constant temperature 98 ± 2°C for dry matter determination till constant weight. The per cent dry matter (dm) was determined and total dm was calculated on dm % basis and represented as dm kg/unit area/harvest. The number of harvests for each shrub species in Tree Environment are presented in Table 1.

The N % analysis of the samples was done. The N was determined and reported as % N. The crude protein (cp) % was calculated by multiplying N % × 6. The cp yields were calculated on dry matter basis and represented as kg cp/unit area/harvest.

The freshly harvested leaf samples of five shrubland species at each harvest were analysed for 1st, IInd and IIIrd year to confirm the findings. The data collected for biomass, dry matter and crude protein yield in shrubland species for three years were subjected for statistical analysis and the results are presented in Tables 2, 3 and 4.

RESULTS

Biomass: The two way interaction effect for biomass production in shrubs is presented in Table 2. The data revealed that significant increase in biomass was recorded in shrub *Sesbania sesban* under *Sesbania sesban* tree environment over *Leucaena leucocephala, Sesbania grandiflora, Moringa oleifera* and *Gliricidia maculata.* Highest biomass was recorded in shrub *Leucaena leucocephala* (4251.7 kg/ua) under tree environment of *Leucaena leucocephala.*

On mean basis, significantly highest biomass was recorded in tree environment of *Leucaena leucocephala,* while lowest was in the environment of *Gliricidia maculata.* The biomass was at par in *Sesbania sesban* and *Moringa oleifera.* Similarly at par biomass yields were recorded in tree environment of *Sesbania grandiflora* and *Gliricidia maculata,* 8019.8 kg/ua, while highest biomass was record in *Sesbania sesban* when cultivated with tree environment of *Sesbania sesban* and with *Gliricidia maculata.*

It is evident that *Leucaena leucocephala* and *Sesbania sesban* as shrubs significantly yielded high biomass over *Sesbania grandiflora* and *Gliricidia maculata.* The comparative study revealed that *Sesbania sesban* shrub has an antagonistic effect when cultivated with *Leucaena leucocephala.* The environment *(Moringa oleifera)* significantly yielded high biomass when cultivated with tree *Leucaena leucocephala;* similarly, high biomass was noticed in *Leucaena leucocephala* when cultivated with trees *Moringa oleifera* and *Sesbania sesban.* It did not do well when cultivated with *Sesbania grandiflora* and *Gliricidia maculata.*

The data showed that the biomass in all the shrubland species under the environment of *Leucaena leucocephala* was higher by 46%, in *Sesbania sesban* 31%, in *Moringa oleifera* 25 % and in *Sesbania grandiflora* 8 % over tree environment of *Gliricidia maculata.* It seems that the shrubland species did not do well with *Gliricidia maculata* as far as biomass is concerned. The biomass in shrubland species when cultivated with different tree environmental conditions showed significant differences. The genotype × environment interaction were significant.

Dry matter: Table 3 reveals that interaction effects in dry matter of shrub × environment are significant. Highly significant interactions were revealed in *Leucaena leucocephala* under tree environment of *Leucaena leucocephala* followed by its cultivation as shrub in environment of *Moringa oleifera,* while similar results were noticed under environment of *Sesbania sesban* followed by *Moringa oleifera.* The interaction effects were lowest in the dry matter of *Leucaena leucocephala* shrub under tree environment of *Gliricidia maculata.*

Invariably, the interaction effects were nonsignificant in *Sesbania grandiflora, Moringa oleifera* and *Leucaena leucocephala.* On mean basis, the data reveal that cultivation of shrub in the environment of *Leucaena leucocephala* yielded highest dry matter followed by shrub species cultivation under *Moringa oleifera.* The interaction between biomass and dry matter when considered in the tree environment, *Sesbania sesban,* which stood 2nd in order of merit, remained 3rd in order of merit for dry matter yields. This indicates high photosynthetic efficiency in shrub species under *Sesbania sesban* environment. The high biomass under *Sesbania sesban* resulted in low dry matter production perhaps due to low transpiration ratio under *Sesbania sesban* tree environment, while high dry matter yields in environment of *Moringa oleifera* were due to less dense leaf canopy and fine interception, a contributing factor for high dry matter yields.

The observations on dry matter, presented in Table 3, reveal a similar pattern as in biomass. On the basis of mean values, significant relations were observed in dry matter between the tree environments. An increased in dry matter by 39% *Leucaena leucocephala;* 36 % in *Moringa oleifera;* 33 % in *Sesbania sesban* and 14 % in *Sesbania grandiflora* over tree environment of *Gliricidia maculata.* Interestingly, an increase in biomass by 46 %, while 39% in dry matter in tree environment of *Leucaena leucocephala,* while biomass increase by 39% was observed over tree environment of *Gliricidia maculata.*

Crude protein: The two way interaction, presented in Table 4, on the basis of mean performance, the shrubland species *Leucaena leucocephala* significantly yielded higher crude protein over other four shrub species under environment of *Leucaena leucocephala* tree. Similarly, in shrub *Sesbania sesban* crude protein yields were significantly higher over shrub *Sesbania grandiflora* and *Gliricidia maculata.*

The observation revealed that as high as 428 kg/ua of crude protein could be recovered from shrub species when cultivated with tree environment of *Leucaena leucocephala* followed by *Moringa oleifera,* while highest crude protein yield was noticed in all the 5 shrubland species when cultivated in tree environment of *Leucaena leucocephala.* The lowest crude protein yields were recorded in the environment of *Gliricidia maculata.*

Interestingly, it was noticed that the shrub *Leucaena leucocephala* showed highest crude protein yield when cultivated with its own tree environment followed by *Moringa oleifera* and *Sesbania sesban.* The crude protein yields were very poor when associated with *Gliricidia maculata* and

Table 2: Two-way interaction: environment × shrub: Biomass Yield in Shrubs/kg/u.a.

Shrub	E1T1	E2T2	E3T3	E4T4	E5T5
S_1	2540.62	1730.3	2177.9	1571.8	2502.37
S_2	2929.12	4251.75	1557.8	3428.4	1245.4
S_3	594.94	713.81	926.06	604.18	620.35
S_4	513.24	482.17	81421	616.01	487.05
S_5	883.75	841.79	683.78	908.95	817.13
Total	7461.67	8019.82	6159.75	7129.34	5672.3
SE	288.09				
CD at.5%	862.38				

Table 3: Two-way interaction: environment × shrub: Dry Matter Yield in Shrubs/kg/u.a.

Shrub	E1T1	E2T2	E3T3	E4T4	E5T5
S_1	537.6	459.41	543.83	444.6	559.06
S_2	792.36	932.93	389.38	856.22	318.3
S_3	134.03	154.7	219.05	135.48	139.62
S_4	112.27	106.93	181.25	132.61	106.33
S_5	106.08	162.7	147.96	199.27	177.38
Total	1682.34	1816.67	1481.47	1768.18	1300.69
SE	62.117				
CD	185.94				

Table 4: Two-way interaction: environment × shrub: Crude Protein Yield in Shrubs/kg/u.a.

Shrub	E1T1	E2 T2	E3T3	E4T4	E5T5
S_1	115.72	95.55	110.30	101.57	116.95
S_2	178.18	206.87	94.94	194.43	77.52
S_3	48.47	55.07	74.37	45.87	43.57
S_4	28.58	27.91	50.8	38.18	28.52
S_5	38.54	42.6	39.61	47.32	37.03
Total	409.49	428.0	370.08	427.37	303.59
SE	12.840				
CD	38.437				

Sesbania grandiflora. As high as 206.8 kg/ua crude protein yield was noticed in tree environment of *Leucaena leucocephala.* The crude protein yield to the extent of 46.7% could be recorded in tree environment of *Leucaena leucocephala* over the yields in tree environment of *Gliricidia maculata.*

The crude protein yields were in the same range in tree environment of *Leucaena leucocephala* and *Moringa oleifera,* while 21.9% higher were recorded over tree environment of *Gliricidia maculata.* In order of merit, tree environment of *Leucaena leucocephala* followed by the environment of *Moringa oleifera, Sesbania sesban, Gliricidia maculata* and *Sesbania grandiflora.* When the specific shrub plant species performance is observed and ranked in order of merit for biomass with regard to environment effects, *Leucaena leucocephala* > tree environment of *Sesbania sesban* > tree environment of *Moringa oleifera* > tree environment of *Sesbania grandiflora* and tree environment of *Gliricidia maculata* follow the merit sequence; while, for dry matter and crude protein the environment of *Leucaena leucocephala* ranked first and the environment of *Gliricidia maculata* last for dry matter and crude protein.

The order for merit was slightly altered, high biomass produced in tree environment of *Leucaena leucocephala* yielded high dry matter and crude protein, whereas low biomass produced in tree environment of *Moringa oleifera* yielded high dry matter and crude protein. This is perhaps due to genotype × environment effect. The high dry matter is on account of effective utilization of intercepted light under multistorey shrub canopy cultivation while high protein yields on account of high nitrogen content.

DISCUSSION

Biomass: The overall performance of the five shrub species when converted into browse and harvested at different time intervals revealed that the biomass yields in *Sesbania sesban* and *Leuceana leucocephala* were significantly increased under different tree environments, while lowest biomass yields were observed in *Moringa oleifera* in E_2T_2. Highly significant biomass increase was observed in *Sesbania sesban* browse when cultivated under its own tree environment (4251.75 kg/ua) followed by 3428.4kg/ua, while lowest when cultivated with *Gliricidia maculata* tree environment for *Leuceana leucocephala* shrub. The magnitude of variation for *Leuceana leucocephala:* $E_2T_2 > E_4T_4 > E_1T_1 > E_3T_3 > E_5T_5$ and *Sesbania sesban*: $E_1T_1 > E_5T_5 > E_3T_3 > E_2T_2 > E_4T_4$.

In three shrub browse *(Sesbania grandiflora, Moringa oleifera* and *Gliricidia maculata)* significantly low biomass yields were observed. The results indicated a differential interaction in biomass yields in *Leuceana leucocephala* under different sets of environments, while in *Sesbania sesban,* the pattern showed that the shrub *Leuceana leucocephala* under E_2T_2 giving highest biomass yields, while *Sesbania sesban* in E_1T_1 and E_5T_5. In *Leuceana leucocephala,* it was E_4T_4, the co-cultivation of *Leuceana leucocephala* with *Moringa oleifera* gave second best yield, while *Sesbania sesban* co-cultivation with *Gliricidia maculata* second best biomass yields were observed. Therefore, the co-cultivation of *Leuceana leucocephala* with *Moringa oleifera, Sesbania sesban, Gliricidia maculata* and *Sesbania grandiflora* are worth recommended.

As low as 157.8 kg in E_4T_4 environment and as high as 2504.37 kg under *Gliricidia maculata* environment were recorded. However, the *Leuceana leucocephala* shrub yielded as high as 3428.4 kg under E_4T_4 environment followed by *Sesbania sesban* environment. Interestingly, in both the shrub species, the biomass performance was high under their own tree environment, but they did well for higher biomass yields in combination with *Gliricidia maculata* and *Sesbania grandiflora,* which indicates synergistic effect. On mean basis, environment E_2T_2 yielded significantly highest biomass followed by *Sesbania sesban* environment, *Moringa oleifera, Sesbania grandiflora,* and lowest in *Gliricidia maculata* environment.

Dry matter: The results for dry matter yields indicate significantly high dry matter in *Leuceana leucocephala* shrub under E_2T_2 environment followed by E_4T_4 environment; a similar trend is exhibited in *Sesbania sesban* environment. As high as 932.93 kg dry matter yields were recorded under its own tree environment followed by E_4T_4 and E_1T_1 environments, while in remaining three shrubs, the dry matter yields were on lower side. On mean basis, significantly high dry matter yields were observed in E_2T_2 environment followed by E_4T_4 environment when biomass dry matter yields were taken into consideration; high biomass produce under E_1T_1 environment yielded low dry matter.

The results confirmed that high biomass produce need not yield high dry matter while low biomass produce under E_5T_5 environment, yielded high biomass. This confirms the co-cultivation of *Sesbania sesban* shrubs with *Sesbania grandiflora* significantly yielded high dry matter and less biomass. Remaining three shrub species, however, did not reach significant level; the data indicate that out of five shrubs species, only two out-yielded *Sesbania sesban* and *Leuceana leucocephala* for biomass and dry matter.

Crude protein: The crude protein yields showed a similar trends; high crude protein yields in *Leuceana leucocephala,* when cultivated under its own tree environment, followed by *Moringa oleifera* and *Sesbania sesban* environments while under *Gliricidia maculata* environment, the crude protein yield in *Sesbania sesban* under its own environment yielded high crude protein followed by its cultivation with *Moringa oleifera, Sesbania sesban, Sesbania grandiflora* and *Gliricidia maculata.* This indicated that the shrub *Sesbania sesban* cultivation under *Leuceana leucocephala* environment significantly yields high crude protein. Hence, not recommended on the ground of nutritional status. Its co-cultivation with *Sesbania grandiflora* affected crude protein yields, hence, crude protein parameters damaged to a large extent. On mean basis, not much difference in crude protein yields were observed between E_2T_2 and E_4T_4 environments.

The biomass, dry matter and crude protein yields were found invariably low under *Gliricidia maculata* environment and highest in E_2T_2 environment, therefore, cultivation of five shrubland species under *Leuceana leucocephala* tree environment is desirable, followed by all shrub species association with *Sesbania sesban* tree for biomass yields while high biomass and crude protein yields under *Moringa oleifera* is desirable. The difference in biomass yields between E_1T_1 and E_4T_4 is due to shrub × environment interaction effect which did not significantly affect the crude protein yields.

Established multistoried shrub species helped to step up yields clock, with shrub system forming a composite system. The results with regards to wasteland utilization were unique. The co-cultivation of shrub lands species under varying tree environments behaved eco-friendly for high biomass productivity.

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