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Research article

Effect of cropping systems, top feeds and planting geometry on growth, yield and economics of top feeds

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Abstract

The present study was conducted to find out the effect of cropping systems, top feeds and planting geometry on the growth, yield and economics of different top feeds. The experiment was laid out in a split-split plot design with 18 treatment combinations and three replications. The treatments consisted of two cropping systems (C_1-sole crop of top feeds, C_2-intercrop of bajra napier hybrid), three top feeds [(F_1-agathi (*Sesbania grandiflora*), F_2-erythrina (*Erythrina indica*), F_3-drumstick (*Moringa oleifera*)] and three planting geometry (G_1-2 m x 1 m, G_2- 2 m x 0.5 m, G_3-paired system). The data over three years revealed that intercropping top feeds with bajra napier hybrid at a paired system ($C_2F_1G_3$) recorded the highest mean number of branches in all three years. However, intercropping agathi at 2 x 0.5 m ($C_2F_1G_2$) recorded the highest mean leaf stem ratio (0.82). Pooled data over three years also revealed that intercropping agathi at 2 x 0.5 m geometry recorded the highest total green fodder yield (30.16 t ha^{-1}), total dry fodder yield (7.55 t ha^{-1}), gross return (Rs 201200 ha^{-1}), net returns (Rs 139000 ha^{-1}) and B:C ratio (3.25). Hence, among different tree grass combinations, growing agathi with bajra napier hybrid at 2 x 0.5 m geometry was found as most promising system for meeting the fodder requirements of Kerala.

Keywords: Agathi, Bajra napier hybrid, Drumstick, Economics, Erythrina, Fodder yield

Introduction

Livestock production is the backbone of Indian agriculture and plays a key role in providing employment, especially in rural areas. India has 15% of the world's cattle population and there is tremendous pressure on livestock on available feed and fodder as land available for fodder production has been decreasing. Presently, it is estimated that only 4.4% of the total cropped area is devoted to fodder production (GOI, 2019). Feed and fodder constitute about 60 to 70% of cost of milk production (Meena *et al*., 2020), thus cultivated fodder has an important role in meeting the requirement of various nutrients and roughage in our country to produce milk and is most economical as compared to concentrates (Mahanta *et al.*, 2020). Adoption of tree-grass combinations can make a valuable contribution to forage production of our country. But, knowledge of the interaction effects between fodder trees and grasses on their production is limited. In this background, the present study was undertaken to assess the performance of different top feeds under varied planting geometry with and without intercrop.

Materials and Methods

Location of the study: A field experiment was conducted at Instructional Farm, College of Agriculture, Vellayani from April 2018 to April 2021 to assess the performance of different plant species as top feeds under sole and intercropping systems. The site experienced a warm humid tropical climate and the soil of the experimental site was sandy clay loam, which belongs to the order oxisols, Vellayani series. It was strongly acidic (pH 5.37), normal in EC (0.25 dS m^{-1}), high in organic carbon (0.81%) and available phosphorus (40.25 kg ha^{-1}) and low in available nitrogen (188.16 kg ha^{-1}) and potassium (102.68 kg ha^{-1}).

Treatments: The experiment was laid out in a split-split plot design with 18 treatment combinations and three replications. The treatments consisted of two cropping systems (C_1-sole crop of top feeds, C_2-intercrop of bajra napier hybrid), three top feeds [(F_1-agathi (*Sesbania grandiflora*), F_2-erythrina (*Erythrina indica*) F_3- Drumstick (*Moringa oleifera*)] and three planting geometry (G_1-2 m x 1 m, G_2- 2 x 0.5 m, G_3-paired system). The harvest of main crops *viz*., agathi, erythrina and drumstick were taken at an interval of three months. However, the first harvest of bajra napier hybrid was taken 75 days after planting and subsequent harvests at an interval of 45 days. *Agathi (S. grandiflora* (L.) Pers.*)* is a fast-growing perennial, deciduous, or evergreen nitrogen-fixing legume tree that can grow up to 10 to 15 m in height. It is highly palatable and valued fodder for ruminants. *Erythrina (E. indica L.)* is a spreading, deciduous tree legume that can reach a height of 18 to 25 m. It is a multipurpose tree often used in agroforestry systems and also as valuable fodder for ruminants as the foliage has a relatively high protein content that makes it an excellent feed for most livestock. Drumstick (*M. oleifera* Lam.) is also a multipurpose tropical tree commonly known as a miracle tree, or tree of life is rich in nutrients, fast-growing and drought tolerant. Annual green fodder yield of drumstick ranges from 100-120 t ha^{-1} in 4 to 5 cuttings, which is sufficient enough to feed 18 to 20 animals under a mixed feeding system. The variety used for the study was PKM-1 developed by the Horticulture Research Station of Tamil Nadu Agricultural University (TNAU). The bajra napier hybrid variety Suguna, released from Kerala Agricultural University, was used for the study. It has a high tillering capacity (40 tillers per plant) with long, broad leaves and pale green leaf sheath with purplish segmentation and serrated leaf margin, suitable for uplands in all seasons. The average inter-nodal length is 6.5 cm and the leaf stem ratio is 0.82. It has better quality with crude protein content of 9.4% and crude fiber content of 24.0%. The average yield of the variety is 280 to 300 t ha^{-1}.

Biometric and yield observations: Observations were recorded on growth and yield parameters of top feeds (number of branches, leaf stem ratio, green fodder yield, dry fodder yield and dry matter content). The sample plants collected at each harvest were separated into leaves and stems. The samples were sun-dried and later oven-dried at a temperature of 65 ± 5°C to a constant weight. The dry weight of stem and leaves were recorded separately for each plant and the leaf stem ratio was calculated. A weighted representative sample of green forage was obtained from each plot and dried to constant weight in an oven at 65 ± 5°C. Total dry matter yield was calculated from the dry weight of the sample and expressed as t ha $^{-1}$.

Economics and statistical analysis: The economics of cultivation was worked out based on the cost of cultivation and the prevailing market price of the fodder. The data on various parameters were statistically analyzed using the analysis of variance technique (ANOVA) for split-split plot experiment and the significance was tested by F test (Snedecor and Cochran, 1967). If the effects were found to be significant, CD values were calculated at 5% probability level.

Results and Discussion

Growth parameters

Number of branches: The growth attributes of both components of a silvi pastoral system are an important parameter that decides the productivity of the system (Edo *et al.,* 2017). The introduction of tree to a land use system brings about a whole complex of environmental changes affecting not just available light but also air temperature, humidity, soil temperature, soil moisture content, wind movement and pest and disease complexes (Sileshi *et al*., 2007). These factors might have positively influenced the growth of both species in a silvi pastoral system. In this study, the growth characteristics *viz*., number of branches and leaf stem ratio of top feeds at trimonthly intervals showed a varied response over three years (Table 1). The results of the study revealed that the cropping system failed to exhibit any significant effect on a number of branches of top feeds in the second year. However, intercropping top feeds with bajra napier hybrid (C_2) recorded more branches in both the first and third years. This finding was in agreement with Karthikeyan *et al*. (2018) who noticed that number of branches of *Melia dubia* + hedge lucerne system was more than sole crop of *M. dubia*.

According to Sarvade *et al*. (2014), the selection of suitable tree species and intercrops is very significant in reducing negative tree-crop interactions. In the present study, among the three selected tree fodders, agathi performed well in terms of the number of branches in first year (13.46), second year (12.23) and third year (14.70). The climatic condition of the study area was very much suitable for growing agathi as it grows well under tropical warm, humid climatic conditions with 22 to 30°C mean annual temperatures, 2000 to 4000 mm annual rainfall and an altitude of 800 to1000 m (Cook *et al*., 2005). Agathi is also adapted to a wide range of rainfall zones and soil types. It can be grown on heavy clay, alkaline and saline soils and, poorly drained soils and poorly fertilized soils (Sreekanth *et al*., 2013). Moreover, nodulation and subsequent nitrogen fixation capacity of agathi might have also helped to restore soil fertility, indicating its good soil improvement quality. These features might have been attributed to the better performance of agathi. The study also revealed that the number of branches of top feeds did not vary significantly with respect to planting geometry of top feeds in the second year. However, paired system (G_3) recorded the highest average

Table 1. Effect of cropping system, top feed and planting geometry on growth and yield parameters of top feeds

Treatments	No. of branches			Leaf stem ratio			Green fodder yield (t ha^{-1})				Dry fodder yield (t ha^{-1})				Dry matter content (%)		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year	1st year	2nd year	3rd year	Pooled mean	1st year	2nd year	3rd year	Pooled mean	1st year	2nd year	3rd year
Main plot: Cropping system (C)																	
C_1	8.68	8.18	9.18	0.71	0.73	0.69	11.27	12.84	14.23	12.78	2.59	3.25	3.61	3.15	25.37	25.37	25.44
C_2	8.98	7.76	10.19	0.69	0.64	0.74	16.34	18.30	18.91	17.85	3.92	4.57	4.95	4.48	25.15	25.15	25.21
SEM	0.03	0.08	0.13	0.01	0.02	0.005	0.07	0.105	0.09	0.07	0.01	0.03	0.03	0.01	0.06	0.06	0.03
CD (P<0.05)	0.168	NS	0.770	NS	NS	0.014	0.431	0.651	0.565	0.427	0.081	0.205	0.182	0.080	NS	NS	NS
Sub plot: Top feeds (F)																	
F_1	13.46	12.23	14.70	0.77	0.76	0.78	19.71	21.61	22.34	21.22	4.73	5.40	5.75	5.29	25.12	25.02	25.68
F_2	7.36	6.70	8.02	0.69	0.68	0.70	7.97	9.65	10.83	9.48	1.76	2.44	2.77	2.32	25.08	25.42	25.60
F_3	5.66	4.99	6.333	0.64	0.62	0.67	13.73	15.44	16.54	15.24	3.27	3.89	4.33	3.83	25.13	25.33	26.19
SEM	0.12	0.15	0.14	0.01	0.01	0.01	0.10	0.14	0.13	0.10	0.03	0.04	0.03	0.03	0.08	0.08	0.17
CD(P<0.05)	0.384	0.480	0.448	0.02	0.043	0.021	0.291	0.468	0.435	0.291	0.081	0.126	0.085	0.081	NS	0.258	NS
Sub sub plot: Planting geometry of top feeds (G)																	
G_1	8.83	8.10	9.57	0.71	0.74	0.67	12.80	14.53	15.60	14.31	3.01	3.65	4.05	3.57	25.39	25.35	25.96
G_2	8.58	7.78	9.38	0.68	0.65	0.72	14.25	15.91	17.13	15.76	3.35	3.98	4.40	3.91	25.19	25.14	25.73
G_3	9.07	8.04	10.09	0.71	0.67	0.76	14.36	16.27	16.98	15.87	3.40	4.10	4.39	3.96	25.18	25.28	25.79
SEM	0.11	0.19	0.19	0.01	0.01	0.01	0.10	0.15	0.09	0.10	0.03	0.03	0.04	0.03	0.09	0.09	0.10
CD(P<0.05)	0.331	NS	0.555	0.020	0.039	0.014	0.287	0.427	0.565	0.287	0.073	0.098	0.122	0.073	NS	NS	NS

C_1: Sole crop; C_2: Intercrop; F_1: Agathi; F_2: Erythrina; F_3: Drumstick; G_1: 2 m x 1 m; G_2: 2 m x 0.5 m; G_3: Paired system number of branches in both first year (9.07) and third year (10.09) and it was found to be on par with G_1 in both years. This result was in agreement with the findings of Khimani *et al.* (2004) in *Jatropa curcas and* Sharma *et al.* (2017) in *M. composite*.

The interaction between the cropping system and top feeds positively influenced the number of branches and C_2F_1 recorded a higher value in the first year (14.08), second year (12.37) and third year (16.08) and the value was comparable to C_1F_1 in both the first year (12.84) and second year (12.08) (Table 2). This result was consistent with the result of Rivest *et al*. (2010), who noticed more branches of the poplar tree when it was intercropped with soybean. In the present study, the interaction between the cropping system and planting geometry positively influenced the number of branches of top feeds in both first year and second year. However, it was not significant on the third year. The treatment combination C_2G_3 recorded a higher value in the first year (9.33) than that of C_1G_1 (12.37). Considering the interaction between top feeds and planting geometry, an average number of branches was maximum in F_1G_1 during both the first year (13.76) and second year (12.95). It was comparable to F_1G_2 (12.10) in both years. However, in the third year, F_1G_3 recorded a higher value (14.88) and it was found to be on par with F_1G_1 and F_1G_2. This result was consistent with the results of Prasad *et al*. (2010) who found that subabul with a paired system of planting recorded significantly more branches. Furthermore, a significant interaction between the cropping system, top feeds and planting geometry on a number of branches of top feeds was noticed and the significantly higher mean value was noticed in $C_1F_1G_1$ during the second year (12.78). However, $C_2F_1G_3$ had a higher average branch number in both first year (14.76) and third year (16.74) and it was found to be on par with $C_2F_1G_2$ in both years.

Leaf stem ratio: Leaf stem ratio is an important factor determining the selection of diet, quality and forage intake of tropical fodders (Nasreen, 2018). The present study revealed that the leaf stem ratio of top feeds did not exhibit any significant variation with respect to the cropping system in both the first year and second year (Table 1). However, the data varied significantly in the third year and C_2 recorded a higher value (0.74). Regarding different top feeds, agathi exhibited better performance in terms of mean leaf stem ratio in the first year (0.77), second year (0.76) and third year (0.78). Furthermore, drumstick recorded significantly the lowest value (0.64, 0.62 and 0.67 in the first, second and third year, respectively). This finding, however, slightly deviates from the study of Patrick *et al.* (2020), who conducted a study on the productivity of tree fodders in typical home gardens of central Kerala and found that leaf stem ratio of agathi as 1.09 to that of drumstick as 0.66. Among the three planting geometries, G_1 recorded a superior value in both the first year (0.71) and second year (0.74). However, G_3 exhibited better performance in the third year (0.76). This result was in conformity with the findings of Yasin *et al*. (2003) who claimed that wider planting geometry recorded higher leaf-stem ratio in fodder cowpea. More availability of light, water and nutrients offered by wider-spaced trees resulted in increased crown size, leaf area, synthesis of carbohydrates and hormonal growth regulators, which might have further improved the plant height and leaf stem ratio (Baldwin *et al*., 2000; Zhang *et al*., 2013; Thakur *et al*., 2015).

The interaction between the cropping system and top feeds failed to exhibit any significant effect on the average leaf stem ratio during second year (Table 2). However, agathi + Bajra napier hybrid intercropping system (C_2F_1) exhibited a significantly higher average value in both the first year (0.77) and third year (0.82) and it was found to be on par with C_1F_1 (0.76) in the first year. Similar observations were made by Mehta *et al.* (2017) in drumstick. Regarding the effect of interaction between the cropping system and planting geometry, leaf stem ratio was significantly superior in C_2G_3 in both the first year (0.73) and third year (0.79). However, C_1G_1 recorded a higher value in the second year (0.80). Increasing spacing might reduce the competition for available resources and also it could harness more sunlight through which the photosynthetic rate might also improve. This further added a positive effect on the leaf-stem ratio. A similar result was reported by Prasad *et al.* (2010) in subabul + cowpea intercropping system. Moreover, top feed and planting geometry also exhibited significant interaction with respect to leaf stem ratio and F_1G_1 was significantly superior in both first year (0.78) and the second year (0.83). The value was comparable to F_1G_2 and F_1G_3. However, F_1G_3 recorded a higher leaf stem ratio in the third year (0.81) and it was comparable to F_1G_2 (0.80). The result of the study also revealed that the interaction between cropping system, top feeds and planting geometry was not significant with respect to the mean leaf stem ratio of top feeds in the second year. However, $C_2F_1G_2$ recorded the highest leaf stem ratio in the first year (0.82) and it was on par with $C_2F_1G_1$ (0.78). Moreover, the treatment combination $C_1F_3G_2$ recorded higher value in third year and it was on par with $C_1F_1G_1$, $C_1F_2G_2$, $C_1F_2G_3$, $C_2F_1G_2$, $C_2F_1G_2$, and $C_2F_3G_2$.

Yield parameters

Green fodder yield: Intercropping is a cultivation practice that can contribute to ecological and sustainable intensification in crop production (Jensen *et al*., 2015). In this study, it was observed that intercropping top feeds with bajra napier hybrid produced significantly more total green fodder yield in all three years (Table 1). The pooled data over three years also observed that C_2 recorded 39.67 % more green fodder yield than that

Table 2. Effect of C x F, C x G, F x G and C x F x G interactions on growth and yield parameters of top feeds

Treatments	No. of branches			Leaf stem ratio			Total green fodder yield				Total dry fodder yield				Dry matter content		
	1^{st} year	2^{nd} year	3^{rd} year	1^{st} year	2^{nd} year	3^{rd} year	1^{st} year	2^{nd} year	3^{rd} year	Pooled mean	1^{st} year	2^{nd} year	3^{rd} year	Pooled mean	1^{st} year	2^{nd} year	3^{rd} year
C_1F_1	12.84	12.08	13.32	0.76	0.78	0.74	15.88	17.36	18.94	17.39	3.72	4.35	4.77	4.28	25.2	25.08	25.16
C_1F_2	7.70	7.61	7.78	0.69	0.73	0.66	8.69	10.29	11.61	10.20	1.91	2.59	2.91	2.47	25.4	25.28	25.03
C_1F_3	5.49	4.56	6.43	0.66	0.67	0.66	9.23	10.87	12.12	10.74	2.14	2.79	3.17	2.70	25.86	25.74	26.13
C_2F_1	14.08	12.37	16.08	0.77	0.73	0.82	23.53	25.87	25.73	25.04	5.74	6.44	6.72	6.30	25.07	24.95	26.19
C_2F_2	7.02	5.79	8.26	0.68	0.63	0.74	7.26	9.01	10.05	8.77	1.61	2.29	2.63	2.17	25.69	25.57	26.18
C_2F_3	5.83	5.42	6.24	0.62	0.56	0.67	18.23	20.02	20.96	19.74	4.40	4.99	5.50	4.96	25.03	24.91	26.26
SEM	0.17	0.21	0.20	0.01	0.02	0.01	0.13	0.20	0.19	0.13	0.04	0.055	0.04	0.04	0.13	0.11	0.23
CD ($P<0.05$)	0.543	0.679	0.634	0.031	NS	0.029	0.412	0.662	0.615	0.412	0.115	0.178	0.120	0.115	NS	NS	NS
C_1G_1	8.97	12.37	9.16	0.71	0.80	0.63	10.63	12.31	13.49	12.14	2.43	3.14	3.42	3.00	25.90	25.58	25.36
C_1G_2	8.26	7.61	8.80	0.67	0.64	0.70	11.01	12.62	13.92	12.52	2.50	3.17	3.53	3.07	25.47	25.15	25.44
C_1G_3	8.80	8.03	9.57	0.69	0.74	0.73	12.16	13.58	15.27	13.67	2.82	3.43	3.90	3.38	25.70	25.38	25.52
C_2G_1	8.69	7.41	9.98	0.70	0.68	0.72	14.96	16.74	17.71	16.47	3.58	4.16	4.68	4.14	25.44	25.12	26.55
C_2G_2	8.90	7.83	9.97	0.69	0.66	0.73	17.50	19.19	20.34	19.01	4.20	4.80	5.28	4.76	25.44	25.12	26.02
C_2G_3	9.33	8.05	10.62	0.73	0.59	0.79	16.56	18.97	18.91	18.07	3.98	4.76	4.88	4.54	25.51	25.19	26.05
SEM	0.16	0.27	0.27	0.01	0.02	0.007	0.14	0.21	0.23	0.14	0.04	0.047	0.06	0.04	0.12	0.13	0.15
CD ($P<0.05$)	0.46	0.78	NS	0.029	0.05	0.02	0.405	0.603	0.681	0.405	0.103	0.138	0.172	0.104	NS	NS	NS
F_1G_1	13.76	12.95	14.58	0.78	0.83	0.73	17.26	18.88	20.22	18.77	4.08	4.68	5.17	4.65	24.19	24.89	25.53
F_1G_2	13.36	12.10	14.63	0.77	0.74	0.80	22.13	23.83	24.97	23.64	5.30	5.95	6.32	5.86	25.22	24.99	25.21
F_1G_3	13.26	11.63	14.88	0.75	0.69	0.81	19.73	22.17	21.82	21.24	4.81	5.57	5.74	5.38	25.4	25.17	26.29
F_2G_1	7.18	6.51	7.85	0.71	0.75	0.68	7.70	9.46	10.46	9.21	1.70	2.37	2.71	2.26	25.73	25.50	25.96
F_2G_2	6.59	6.26	6.92	0.63	0.60	0.66	7.84	9.56	10.65	9.35	1.71	2.40	2.70	2.27	25.35	25.12	25.44
F_2G_3	8.30	7.32	9.29	0.73	0.70	0.76	8.39	9.92	11.38	9.90	1.87	2.55	2.88	2.43	25.88	25.65	25.41

F_3G_1	5.56	4.82	6.30	0.63	0.64	0.61	13.43	15.28	16.11	14.94	3.24	3.90	4.27	3.81	25.89	25.66	26.37
F_3G_2	5.79	4.98	6.59	0.65	0.61	0.69	12.78	14.32	15.79	14.29	3.05	3.60	4.18	3.61	25.53	25.30	26.54
F_3G_3	5.64	5.16	6.11	0.65	0.60	0.70	14.97	16.73	17.73	16.48	3.51	4.17	4.54	4.08	25.26	25.03	25.68
SEM	0.20	0.33	0.33	0.01	0.02	0.008	0.170	0.25	0.29	0.17	0.04	0.06	0.07	0.04	0.19	0.15	0.18
CD (P<0.05)	0.57	0.957	0.962	0.035	0.067	0.025	0.497	0.739	0.834	0.497	0.126	0.169	0.211	0.127	0.647	0.447	0.522
$C_1F_1G_1$	14.25	14.43	14.07	0.78	0.89	0.67	14.76	16.33	17.73	16.27	3.44	4.10	4.47	4.01	25.14	25.02	25.20
$C_1F_1G_2$	12.52	12.19	12.85	0.72	0.69	0.75	15.61	17.13	18.62	17.12	3.60	4.27	4.61	4.16	25.06	24.94	25.20
$C_1F_1G_3$	11.76	10.49	13.03	0.78	0.78	0.79	17.27	18.60	20.47	18.78	4.11	4.68	5.23	4.67	25.39	25.27	24.75
$C_1F_2G_1$	7.49	7.66	7.34	0.71	0.80	0.62	8.04	9.70	10.90	9.55	1.74	2.44	2.73	2.31	25.5	25.38	25.55
$C_1F_2G_2$	6.67	6.45	6.91	0.64	0.61	0.67	8.78	10.60	11.49	10.29	1.91	2.64	2.86	2.47	25.03	24.91	25.04
$C_1F_2G_3$	8.91	8.73	9.10	0.74	0.78	0.70	9.25	10.57	12.45	10.76	2.07	2.70	3.12	2.63	25.67	25.55	24.89
$C_1F_3G_1$	5.17	4.26	6.09	0.66	0.72	0.59	9.10	10.90	11.83	10.61	2.12	2.87	3.06	2.68	26.45	26.33	25.14
$C_1F_3G_2$	5.59	4.55	6.63	0.65	0.62	0.68	8.63	10.13	11.66	10.14	2.00	2.59	3.11	2.57	25.72	25.60	25.84
$C_1F_3G_3$	5.72	4.87	6.57	0.68	0.67	0.70	9.96	11.57	12.88	11.47	2.28	2.92	3.33	2.85	25.42	25.30	26.68
$C_2F_1G_1$	13.27	11.47	15.08	0.78	0.78	0.79	19.76	21.33	22.72	21.27	4.72	5.25	5.88	5.28	24.87	24.75	25.88
$C_2F_1G_2$	14.20	12.00	16.41	0.82	0.79	0.84	28.65	30.53	31.31	30.16	6.99	7.63	8.04	7.55	25.17	25.05	25.87
$C_2F_1G_3$	14.75	12.78	16.74	0.72	0.61	0.84	22.18	25.73	23.16	23.69	5.51	6.45	6.26	6.08	25.19	25.07	25.68
$C_2F_2G_1$	6.86	5.37	8.35	0.71	0.69	0.74	7.36	9.23	10.02	8.87	1.65	2.30	2.69	2.21	25.75	25.63	27.02
$C_2F_2G_2$	6.50	6.07	6.94	0.62	0.58	0.65	6.90	8.53	9.81	8.41	1.51	2.16	2.55	2.08	25.45	25.33	26.88
$C_2F_2G_3$	7.69	5.92	9.47	0.72	0.62	0.82	7.52	9.27	10.31	9.03	1.68	2.40	2.64	2.24	25.87	25.75	25.98
$C_2F_3G_1$	5.94	5.39	6.51	0.59	0.57	0.62	17.76	19.67	20.38	19.27	4.37	4.93	5.48	4.93	25.11	24.99	25.67
$C_2F_3G_2$	5.98	5.41	6.56	0.64	0.59	0.69	16.94	18.50	19.92	18.45	4.09	4.62	5.26	4.65	25.11	24.99	26.91
$C_2F_3G_3$	5.55	5.45	5.65	0.62	0.53	0.71	19.98	21.90	22.58	21.49	4.74	5.42	5.75	5.30	24.88	24.76	26.39
SEM	0.28	0.46	0.47	0.02	0.03	0.012	0.24	0.36	0.57	0.24	0.06	0.08	0.10	0.06	0.22	0.22	25.47
CD (P<0.05)	0.81	1.35	1.36	0.05	NS	0.03	0.70	1.04	1.18	0.70	0.17	0.23	0.29	0.17	NS	NS	0.25

of sole cropping system. This result was in conformity with the findings of Susheela *et al*. (2015) who observed the highest green fodder yield of subabul when it was intercropped with bajra napier hybrid and *Desmanthus*. This result was in consistent with the findings of Kumar (2014). Regarding different top feeds, agathi recorded significantly higher total green fodder yield in the first year (19.71t ha^{-1}), second year (21.61 t ha^{-1}) and third year (22.34 t ha^{-1}). This was mainly because agathi is a leguminous fodder tree, which is suited well to tropical warm, humid climatic conditions and it grows well in a wide range of soils. The result of the study was in line with the result of Thomas *et al*. (2021a), who reported a significantly higher green fodder yield of agathi when it was intercropped with rhodes grass. In all three years, erythrina recorded significantly the lowest total green fodder yield and pooled data over three years revealed that there was a yield reduction in erythrina to the tune of 28.18% than the best treatment. It might be due to poor adaptability of erythrina in the selected area that underlines the importance of the selection of ideal crop component in a given area. This study clearly revealed that yield attributing factors like number of branches and leaf stem ratio were comparatively less for erythrina and these factors might have directly reflected on the green fodder yield. Furthermore, gall wasp attack was prevalent in the study area and that also might have added to the poor performance of the crop. Among the three planting geometries, G_3 recorded the maximum total green fodder yield in the first year (14.53 t ha^{-1}) and second year (16.27 t ha^{-1}) and it was found to be on par with G_2 in both years. However, a reverse trend was noticed in third year. Pooled data over three years also revealed that G_3 recorded a higher green fodder yield (15.87 t ha^{-1}) and it was on par with G_2 (15.76 t ha^{-1}).

Regarding the interaction between the cropping system and top feeds, total green fodder yield was significantly superior in C_2F_1 in the first year (23.53 t ha^{-1}), second year (25.87 t ha^{-1}) and third year (0.82; Table 2). A similar observation was made by Thomas *et al.* (2021a) where intercropping agathi with different grass species provided approximately five times more green fodder yield than sole cropping of agathi. Considering the interaction between the cropping system and planting geometry, higher total green fodder yield was noticed in C_2G_2in all three years (17.50, 19.19 and 20.34 t ha^{-1}, respectively) and it was found to be on par with C_2G_3 in the second year (18.97 t ha^{-1}). This might be due to the fact that under wider spacing, more space was available above and below ground level and that reduced the competition for resources like water, light and nutrients. A similar finding was reported by Chauhan and Dhiman (2007) when a poplar tree was intercropped with wheat. The result also revealed that growing agathi at a narrow spacing of 2 x 0.5 m (F_1G_2) registered significantly higher total green fodder yield in all three years. Considering the interaction between the cropping system, top feed and spacing, $C_2F_1G_2$ was found to be the best treatment in all three years (Fig 1). Since intercropping provided better microclimatic conditions for the growth of the main crop and among the three top feeds, agathi was better suited for the selected area. Furthermore, narrow spacing of 2 x 0.5 m accommodated more plants per unit area and it was a crucial factor that improved yield. Similar findings were made by Stacciarini *et al.* (2010) who opined that narrow spacing improved the crop yield in maize due to reduced weed competition and optimized sunlight interception.

Dry fodder yield: Dry fodder yield is a function of green fodder yield and dry matter content. The study revealed that growing top feeds along with bajra napier hybrid (C_2) registered significantly higher dry fodder yield in all three years (3.92, 4.57 and 4.95 t ha^{-1}, respectively). Pooled data over three years revealed that C_2 recorded a 42.22% yield increment than sole cropping of top feeds (Table 1). Intercropping reduces runoff, soil and nutrient losses and improves the soil moisture availability. These factors might have favored better growth and green fodder yield, which ultimately reflected on dry fodder yield of the associated top feed in the study. The study was also in agreement with the observations of Raj *et al*. (2016) who reported that among different combinations of silvi pastoral systems, higher dry matter yield was noticed when bajra napier hybrid was intercropped with mulberry and calliandra. Similar findings were also made by Patel *et al.* (2002) in eucalyptus + cowpea and Gill (2005) in acacia + pulse intercropping systems. Considering three different top feeds that were grown in subplot, agathi registered significantly higher dry fodder yield in all three years. Different yield attributing factors like number of branches and leaf stem ratio were significantly higher in agathi as compared to erythrina and drumstick and these factors had direct influence on dry fodder yield of top feeds. This result was in agreement with the findings of Baba *et al*. (2011) in grass-legume mixture. However, erythrina recorded the lowest dry fodder yield in all three years. Planting geometry is one of the most

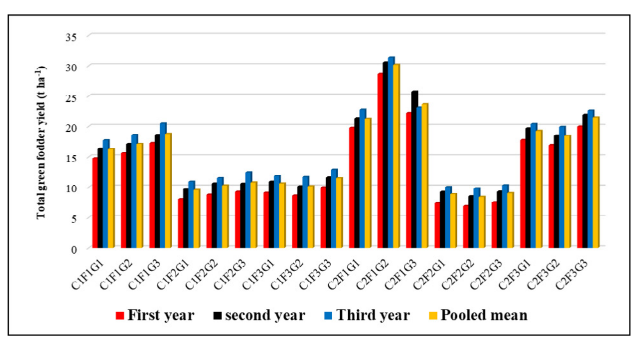

Fig 1. Interaction effect of cropping system, top feeds and planting geometry on total green fodder yield of top feeds (t ha^{-1})

Table 3. Economics of cultivation influenced by cropping system, top feeds and planting geometry

Treatments	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B: C ratio
Cropping systems (CS)			
Agathi (sole crop) + 2 m x 1 m	41500	16300	1.64
Agathi (sole crop) + 2 m x 0.5 m	45750	20250	1.79
Agathi (sole crop) + Paired row	52250	26550	2.03
Erythrina (sole crop) + 2 m x 1 m	28000	3000	1.16
Erythrina (sole crop) + 2 m x 0.5 m	29000	5000	1.0
Erythrina (sole crop) + Paired row	27000	3000	1.20
Drumstic (sole crop) + 2 m x 1 m	28560	5560	1.24
Drumstic (sole crop) + 2 m x 0.5 m	25750	3750	1.17
Drumstic (sole crop) + Paired row	26250	2250	1.09
Agathi + B x N Hybrid + 2 m x 1 m	180000	120000	3.0
Agathi + B x N Hybrid + 2 m x 0.5 m	201200	139000	3.25
Agathi + B x N Hybrid + Paired row	121400	59400	1.95
Erythrina + B x N Hybrid + 2 m x 1 m	170600	109600	2.79
Erythrina + B x N Hybrid + 2 m x 0.5 m	176400	114400	2.84
Erythrina + B x N Hybrid + Paired row	133400	71400	2.15
Drumstic + B x N Hybrid + 2 m x 1 m	164600	103600	2.69
Drumstic + B x N Hybrid + 2 m x 0.5 m	170000	109000	2.78
Drumstic + B x N Hybrid + Paired row	119200	58200	1.95

important considerations to avoid competition and for the effective utilization of resources among agricultural crops and trees (Mohammed *et al*., 2018). Maximum yield of a particular crop in a given environment could be obtained by adopting row spacing in which minimum competition among the crops are noticed. This could be achieved with optimum spacing, which not only utilizes soil moisture and nutrients more effectively but also avoids excessive competition among the plants. In this study, a paired system of planting (G_3) was found to be significantly superior with respect to total dry fodder yield in both the first year (3.40 t ha^{-1}) and the second year (4.10 t ha^{-1}). However, growing top feeds at 2 x 0.5 m (G_2) recorded maximum dry fodder yield in third year (4.40 t ha^{-1}) and the value was comparable with G_3 (4.39 t ha^{-1}). A similar result was reported by Thomas *et al*. (2021b).

The interaction between the cropping system and top feeds with respect to total dry fodder yield followed the same trend as green fodder yield (Table 2). Intercropping agathi with bajra napier hybrid (C_2F_1) recorded significantly higher dry fodder yield in first year (5.74 t ha^{-1}), second year (6.44 t ha^{-1}) and third year (6.72 t ha^{-1}). The pooled data over three years also revealed that C_2F_1 recorded 65.55% more yield than C_2F_2, which recorded the lowest yield. Regarding the interaction between the cropping system and planting geometry, C_2G_2 noticed maximum total dry fodder yield in all three years and it was comparable with C_2G_3 (4.76 t ha^{-1}) in the second year. Trees with sufficient growing space show better growth and withstand pests and diseases effectively (Krishna, 2006). With respect to the interaction between top feeds and planting geometry, growing agathi at 2 x 0.5 m (F_1G_2) was superior with respect to dry fodder yield in first year (5.30 t ha^{-1}), second year (5.95 t ha^{-1}) and third year (6.32 t ha^{-1}). Considering the interaction between the cropping system, top feeds and planting geometry, the total dry fodder yield was significantly superior in $C_2F_1G_2$ in all three years. These results indicated that among the three selected top feeds, agathi performed well under the climatic conditions of the study area. Furthermore, optimization of sunlight interception at narrow row spacing and increased plant density might have contributed to increased yield.

Dry matter content: The mean dry matter content of top feeds did not exhibit any significant interaction with respect to cropping system and planting geometry in all three years of the study (Table 2). However, among different top feeds, the highest dry matter content was noticed in erythrina in the second year (25.42%) and it was on par with the drumstick (Table 1). The dry matter content of top feeds was not significant with respect to the interaction between the cropping system and top feeds as well as the cropping system and planting geometry.

However, dry matter content significantly varied with respect to the interaction between top feeds and planting geometry in all three years and the highest value was noticed by F_3G_1 in the first year (25.89%). Dry matter content of top feeds varied significantly with respect to the interaction between cropping systems, top feeds and planting geometry during the third year of the study and a higher value was noticed in $C_2F_2G_1$ and it was comparable to that of $C_2F_3G_1$, $C_2F_2G_2$ and $C_1F_3G_2$.

Economics

The study revealed that highest economic return in terms of gross return (Rs 201200 ha^{-1}), net returns (Rs 139000 ha^{-1}) and B:C ratio (3.25) were noticed when bajra napier hybrid was intercropped with agathi at 2 x 0.5 m planting geometry ($C_2F_1G_2$), followed by intercropping bajra napier hybrid with agathi in 2 x 1 m planting geometry (Table 3). All the intercropped treatments had B: C ratio of more than two, indicating better economics of intercropping top feeds with bajra napier hybrid. In forage production, profitability has utmost importance and intercropping fodder trees with grass has been proven to improve the economic returns. Similar results were also documented by Place *et al*. (2009). Susheela *et al*. (2015) also found a higher B:C ratio when bajra napier hybrid intercropped with subabul and desmanthus. However, sole cropping erythrina at 2 m x 0.5 m geometry ($C_1F_2G_2$) resulted in the lowest gross return (Rs 29000 ha^{-1}), net returns (Rs 5000 ha^{-1}) and B: C ratio (1.0). This might be due to the lower adaptability of erythrina in the studied area. The results of the present study also documented that integration of top feeds with bajra napier hybrid had a favorable effect on the overall fodder production. In this study narrow spacing of 2 m x 0.5 m recorded higher green and dry fodder yields, which in turn increased the net return and B: C ratio. Higher foliage yield of narrow-spaced crops might have directly improved the economic return from the system. This finding was in consistent with the observations of Thakur *et al*. (2015) and Keerthi *et al*. (2015).

Conclusion

It was concluded that among different treatment combinations, intercropping agathi with bajra napier hybrid at 2 m x 0.5 m recorded the highest number of branches, leaf stem ratio, green fodder yield, dry fodder yield, net return and B: C ratio. While sole cropping erythrina with 2m x 1m geometry ($C_1F_2G_1$) recorded the lowest green fodder yield, dry fodder yield, net returns and B:C ratio.

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