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PRODUCTION POTENTIAL AND QUALITY OF MIXED SORGHUM FORAGE UNDER DIFFERENT INTERCROPPING SYSTEMS AND PLANTING PATTERNS

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A field study was conducted to explore the production potential of diversified forage sorghum-based intercropping systems under different intercropping patterns for two consecutive years. The intercropping systems comprised sorghum alone; sorghum + mungbean; sorghum + clusterbean; sorghum + cpwpea and sorghum + sesbania. The planting patterns were 30 cm spaced single rows, 30 × 30 cm cross planting with intercrop, 45 cm spaced double-row strips (15/45 cm) and 75 cm spaced four row strips. The two-year average data revealed that planting patterns have significant effect on mixed dry & green forage yield. The maximum mixed forage dry matter yield and mixed green forage yield of 24.5 and 68.8 t ha^{-1} were recorded in the planting pattern of 45 cm spaced double row strips. Forage legume intercropping systems reduced the dry and green fodder yield of sorghum, however, the additional harvest of each intercrop compensated more than the loss in forage sorghum yield. Of the intercropping systems, sorghum + cowpea and sorghum + sesbania in the pattern of 45 cm spaced double-row strips proved to be feasible, adoptable, more productive and with high quality nutritious forage and were found to be superior to all other intercropping systems and planting patterns under study.
Keywords: Forage legumes, intercropping, planting patterns, forage sorghum.

INTRODUCTION

Green forage demand for rapidly expanding livestock industry is increasing day by day. Sorghum (*Sorghum bicolor* L.) is an important summer fodder in Pakistan. It is grown successfully both in irrigated as well as rainfed areas of the country. Its fodder is fed to almost every class of livestock and can also be used as hay or silage. However, sorghum fodder is poor in quality due to low protein content and presence of hydrocyanic acid (Hingra *et al.*, 1995). It is, therefore, imperative to improve the quality and quantity of sorghum fodder. Mixed cropping especially with forage legumes can improve both the forage yield and quality, as legumes are a good source of protein (Moreira, 1989).

Traditionally, forage sorghum is grown either by broadcast method or in lines at 30 cm spaced rows as a sole crop. Pakistan is a sub-tropical country having adequate irrigation and land resources with high intensity of sunlight for plant growth. Therefore, possibility of growing two or more crops on the same piece of land in a year needs to be explored for effective and efficient utilization of existing natural resources. Intercropping is a wise pre-time management for increasing potentiality of soil and production per unit area as well as income. Intercropping system is more productive than the sole crop, especially under adverse conditions (Faris *et al*., 1976). Umrani *et al*. (1984) reported that intercropping advantages are substantial and are achieved by growing crops together. Legumes which fix atmospheric nitrogen besides meeting their own N requirements, serve as a viable media for soil enrichment. This eventually helps in meeting the N needs of cereals partially (Ibrar *et al*., 2002). Willey *et al.* (1983) concluded that legume/non-legume intercropping systems gave higher yield than monoculture due to efficient utilization of soil and input resources over time. . Hussain *et al.* (1999) stated that sorghum grown alone or intercropped with guara (*Cyamopsis tetragonoloba* L.) or cowpea (*Vigna unguiculata* L.) gave the highest fresh and dry matter yield when two-row strips of sorghum were intercropped with three rows of guara. Land equivalent ratio was the highest (1.89) for intercropping with three rows of cowpeas.

Now-a-days, interest in intercropping is increasing among the small growers because of their diversified needs and low farm income from monocropping systems. Since, in Pakistan, no systematic research work has been done so far to explore the possibility of intercropping forage legumes in forage sorghum, there is a need to develop an appropriate planting system of forage sorghum facilitating intercropping. The present study was, therefore, designed to explore the feasibility and production potential of different forage sorghum-legume intercropping systems under different planting patterns in irrigated conditions at Faisalabad, with a hope to reach an economically viable and appropriate

forage sorghum-legume intercropping system best suited to the small farmers.

MATERIALS AND METHODS

The experiment was conducted at the University of Agriculture, Faisalabad–Pakistan, for the two consecutive years (2004 and 2005). It was laid down using a randomized complete block design in split-plot arrangement of the treatments with three replications. The planting patterns were kept in main-plots and intercropping treatments in sub-plots. The net plot size was 3.6 m × 7.0 m. The planting patterns consisted of 30 cm spaced single rows, 30 × 30 cm cross planting with intercrop, 45 cm spaced two-row strips (15/45 cm) and 75 cm spaced four-row strips (15/75 cm). The intercropping systems were sorghum alone, sorghum + mungbean, sorghum + clusterbean, sorghum + cowpea and sorghum + sesbania. Forage sorghum variety JS-263 was used as medium of the trial.

The crop was sown on well-prepared fine seedbed in 2nd and 3rd week of March each year and the respective forage legumes were intercropped on the same day according to the specified treatments. A basal fertilizer dose of 50 – 50 kg NP ha^{-1} was applied at the time of sowing by broadcast and mixing it in the soil with cultivator while additional 50 kg N ha^{-1} was applied with first irrigation to meet the full N requirement of forage sorghum. Three irrigations each of 7.5 cm depth were applied at 21 days after germination, 35 days after germination and at full vegetative stage, respectively. All other agronomic practices were kept normal and uniform. Both forage sorghum and legume crops were harvested at full vegetative stage. Standard procedures were followed to collect the data and analyzed by using Fishers analysis of variance techniques (Steel and Torrie, 1984) and the least significant difference (LSD) test at 5% probability level was used to compare the treatment's means.

RESULTS AND DISCUSSION

Mixed green forage yield (sorghum+intercrops)

The interactive and main effects of planting patterns and intercropping systems as well as their interaction on mixed green forage yield ha^{-1} were significant in both years (Table 1). In 2004, significantly the maximum mixed green forage yield (98.8 t ha^{-1}) was recorded for the crop grown in the pattern of 45 cm apart paired rows and intercropped with cowpea (P_3I_3) followed by P_4I_3 and P_2I_3 which were statistically at par with each other and produced mixed forage yield of 90.6 and 87.7 t ha^{-1}, respectively. By contrast, the minimum forage yield (39.01 t ha^{-1}) was obtained from sole sorghum grown in the pattern of 30 × 30 cm (P_2I_0) which was at par with P_1I_0 and P_4I_0 producing on an average forage yield of 39.9 and 40.7 t ha^{-1}, respectively. The differences among P_4I_4, P_2I_4 and P_1I_4 were also non-significant. Similarly, treatment combinations P_1I_2 and P_2I_2 produced statistically similar and lowest yield which amounted to 51.8 and 51.1 t ha^{-1}, respectively, while rest of the treatments combination intermediated. The same trend was exhibited during 2005 with the maximum mixed green forage yield (107.7 t ha^{-1}) of the crop grown in 45 cm spaced paired rows and intercropped with cowpea (P_3I_3) against the minimum of 44.00 t ha^{-1} for the crop planted in 30 cm spaced single rows with no intercropping (P_1I_0) which was at par with P_2I_0 (45.3 t ha^{-1}) and P_3I_0 (46.1 t ha^{-1}). The variation in mixed green forage yield of sorghum intercropped with forage legume might be due to their variable competitive behavior and alleleopathic effects on the component sorghum crop. The increase in mixed green forage yield compared to sorghum grown alone mainly ascribed to more production of vegetation and biomass of component legume crops. These results corroborate the findings of Parlawar *et al*. (1998) who reported an increase in the total green forage yield when sorghum was intercropped with pigeonpea and soybean. In an other study, Thippeswamy and Alagunbagi (2001) also stated that sweet sorghum + field beans planted in 3:2 rows ratio produced significantly higher mixed green fodder (59.50 t ha^{-1}) than sorghum grown alone.

Mixed dry matter yield (t ha^{-1})

The individual effects of planting patterns and intercropping systems as well as their interaction on mixed dry matter yield ha^{-1} were significant in both years. During 2004, significantly, the maximum dry matter yield (29.2 t ha^{-1}) was recorded for the crop grown in 45 cm spaced paired rows and intercropped with cowpea (P_3I_3) followed by P_4I_3 (25.4 t ha^{-1}), P_2I_1 (25.0 t ha^{-1}), P_2I_3 (24.7 t ha^{-1}), P_3I_1 (24.1 t ha^{-1}), P_3I_4, (24.4 t ha^{-1}), P_4I_4 (23.6 t ha^{-1}), P_2I_4 (23.5 t ha^{-1}) and P_1I_1 (23.4 t ha^{-1}) which were statistically similar to one another. Contrarily, the minimum dry matter yield (15.8 t ha^{-1}) was produced by P_4I_0 which was at par with P_2I_0 and P_1I_0 producing dry matter yield of 16.0 and 17. 8 t ha^{-1}, respectively while rest of the interactive treatments intermediated. However, in 2005, the highest dry matter yield of 30.1 t ha^{-1} was obtained from P_3I_3 which was statistically equal to P_2I_3 (29.4 t ha^{-1}), P_2I_4 (28.2 t ha^{-1}), P_4I_3 (28.1 t ha^{-1}) and P_3I_1 (27.7 t ha^{-1}). By contrast, the minimum DM yield of 17.6 t ha^{-1} was recorded for P_2I_0 which was statistically similar to P_1I_0, P_3I_0 and P_4I_0 while rest of interactive treatments intermediated. These results are in line with those of Pandey *et al.* (1998) and Jayanthi *et al*. (1994) who reported maximum mixed dry matter yield.

Table 1. Mean values of green fodder yield and protein contents as affected by different planting patterns and intercropping systems.

Treatments	Mixed green forage yield (t ha^{-1})		Mixed dry matter yield (t ha^{-1})		Crude protein of mixed forage (%)	
	2004	2005	2004	2005	2004	2005
A. Planting Geometry						
P_1 (30 cm spaced single rows)	57.4 c	66.3 c	20.5 c	23.5 b	14.66	14.91
P_2 (30 × 30 cm cross planting with intercrop)	59.7 b	68.5 b	21.5 bc	24.8 a	14.61	15.60
P_3 (45 cm spaced double-row strips)	65.7 a	72.1 a	23.1 a	25.9 a	14.40	15.19
P_4 (75 cm spaced four- row strips)	60.7 b	68.0 b	21.9 ab	25.2 a	14.96	15.12
$LSD_{(0.05)}$	1.8	1.3	1.9	1.3	NS	NS
B. Intercropping systems						
I_0 (Sorghum alone)	40.5 e	44.9 e	16.5 d	18.5 b	9.69 c	9.74 c
I_1 (Sorghum + mung bean)	58.9 c	66.4 c	24.0 ab	26.9 d	14.36 b	14.75 b
I_2 (Sorghum + cluster bean)	54.9 d	64.6 d	19.9 c	23.4 c	14.73 ab	14.76 b
I_3 (Sorghum + cow peas)	98.0 a	96.9 a	25.0 a	28.1a	14.40 b	14.57 b
I_4 (Sorghum + sesbania)	61.2 b	70.8 b	23.5 b	27.2 ab	14.89 a	16.74 a
$LSD_{(0.05)}$	1.4	1.4	2.0	1.2	0.38	0.70
C. Interaction						
P_1I_0	39.9 kl	44.0 k	17.8 hi	18.1 i	9.50	9.53
P_1I_1	56.4 gh	65.2 gh	23.4 bcd	26.1 c-f	14.42	14.66
P_1I_2	51.8 ij	63.7 hi	18.5 gh	21.4 gh	14.73	14.57
P_1I_3	78.9 c	85.6 c	20.6 fg	25.0 ef	14.44	14.74
P_1I_4	60.3 ef	72.5 d	22.4 c-f	26.8 cde	15.07	15.68
P_2I_0	39.0 l	45.3 k	16.0 i	17.6 i	9.62	9.64
P_2I_1	60.3 ef	65.4 gh	25.0 b	26.9 cde	14.35	14.94
P_2I_2	51.1 j	65.5 gh	18.4 gh	22.0 g	14.61	14.81
P_2I_3	87.7 b	96.3 b	24.7 bc	29.4 ab	14.58	15.33
P_2I_4	60.2 ef	70.0 ef	23.5 bcd	28.2 abc	14.90	17.31
P_3I_0	42.5 k	46.1 k	16.5 hi	19.4 hi	9.79	9.85
P_3I_1	59.9 ef	70.3 e	24.1 bc	27.7 a-d	14.14	14.62
P_3I_2	62.6 de	67.3 fg	21.1 ef	25.6 def	14.57	14.63
P_3I_3	98.8 a	107.7 a	29.2 a	30.1 a	14.26	14.26
P_3I_4	64.9 d	69.3 ef	24.4 bc	26.5 c-f	14.62	17.25
P_4I_0	40.7 kl	44.2 j	15.8 i	19.1 hi	9.85	9.92
P_4I_1	58.9 fg	64.9 hgi	23.4 ib-e	26.9 cde	14.54	14.77
P_4I_2	51.0 hi	62.1 i	21.5 def	24.5 f	15.02	15.03
P_4I_3	90.6 b	98.1 b	25.4 b	28.1 abc	14.32	13.94
P_4I_4	59.5 f	70.7 de	23.6 bcd	27.4 b-e	14.55	16.72
$LSD_{(0.05)}$	2.9	2.8	2.29	2.38	NS	NS

Means not sharing a letter differ significantly using LSD at 5% probability level.

Crude Protein (CP) of mixed forage (%)

The individual effect of intercropping systems on CP percentage of mixed forage was significant while the interactive and main effects of planting patterns were non-significant in both years. During 2004, the maximum CP percentage (14.89) was recorded for sorghum + sesbania mixed forage which was at par with that recorded for sorghum + cowpea forage. The

Table 2. Economic benefit of forage sorghum-legumes intercropping systems under various planting geometries.

	Sorghum alone	Sorghum + mung bean	Sorghum + cluster bean	Sorghum + cow peas	Sorghum + sesbania
Yield (t ha^{-1}) from system as a whole (P_1+P_2+P_3+P_4)/4					
Sorghum	42.5	38.5	36.8	39.3	36.9
Intercrop		24.4	22.9	53.6	29.1
Adjusted yield (t ha^{-1})					
Sorghum	36.1	32.7	31.3	33.4	31.4
Intercrop		20.7	19.5	45.6	24.7
Gross benefits (Rs. ha^{-1}) from system as a whole (P_1+P_2+P_3+P_4)/4					
Sorghum	27075	25525	23475	25050	23550
Intercrop		15525	14625	34200	18525
Total	27075	40050	38100	59250	42075
Total cost that vary (Rs. ha^{-1})					
Sorghum	4560	4560	4560	4560	4560
Intercrop		1335	2460	2260	1360
Total	4560	5895	7020	6820	5920
Net field benefits (Rs. ha^{-1})					
Net benefits P_1	26775	38775	36780	52425	42600
Net benefits P_2	26925	40725	37125	58650	41475
Net benefits P_3	27600	41475	41400	65775	42750
Net benefits P_4	27075	39450	36975	60075	40830
Net benefits From system as whole	27094	40106	38070	59231	41914

differences among sorghum + mungbean, sorghum + clusterbean and sorghum + cowpea were also non-significant showing CP percentage of 14.36, 14.73 and 14.40, respectively. Contrarily, the minimum CP percentage of 9.69 was found in sorghum alone. Almost similar trend was exhibited in 2005 with the highest CP percentage (16.74) in mixed sorghum + sesbania forage and the minimum (9.74) in sorghum forage grown alone. However, the differences among sorghum + mungbean, sorghum + clusterbean and sorghum + cowpea mixed forage were non-significant showing CP percentage of 14.75, 14.76 and 14.57, respectively. Promotive effect of legume intercrops on protein concentration of main crop has also been reported by Tripathy *et al.* (1997), Krishna *et al*. (1998) and Mpairwe *et al.* (2002).

Field benefits of different forage sorghum-based intercropping systems

The economic analysis (Table 2) showed that the gross benefit ratio varied from Rs.27075 (sorghum alone) to Rs. 59250 ha^{-1}, among different intercropping systems. The highest gross benefit of Rs. 59250 ha^{-1} was obtained from sorghum + cowpeas intercropping system followed by sorghum + sesbania (Rs. 42075 ha^{-1}) and sorghum + mungbean (Rs. 40050 ha^{-1}). However, the sorghum + clusterbean intercropping system gave the minimum gross benefit of Rs. 38100 ha^{-1}. The total variable cost that vary was the highest (Rs. 7020) in intercropping system of sorghum + clusterbean. The next to follow were intercropping systems of sorghum + cowpeas, sorghum + sesbania and sorghum + mungbean with total variable cost of Rs. 6820, 5920 and 5895 ha^{-1}, respectively. It is evident from the above discussion that the net benefit of all intercropping systems in the pattern of 45 cm spaced two-row strips and 75 cm spaced four-row strips were higher than those achieved from planting sorghum in 30 cm spaced single rows and 30 × 30 cm cross planting with legumes. Whereas the intercropping systems sorghum + cowpeas, sorghum + sesbania, sorghum + clusterbean and sorghum + mungbean gave net benefit of Rs. 59231, 41914, 38070 and 40106 ha^{-1}, respectively.

CONCLUSION

In conclusion, intercropping forage sorghum with cowpeas in all the four planting patterns approved to be more productive and profitable than the monocropping of sorghum.

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