

COMPETITIVE PERFORMANCE OF ASSOCIATED FORAGE CROPS GROWN IN DIFFERENT FORAGE SORGHUM-LEGUME INTERCROPPING SYSTEMS

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The competitive response of associated forage crops grown in different forage sorghum-based legume intercropping systems in different geometrical arrangements was executed at University of Agriculture, Faisalabad-Pakistan, on a sandy-clay loam soil for two consecutive years. The planting geometry encompassed; 30 cm spaced single rows, 30 × 30 cm cross planting with intercrops, 45 cm spaced double row strips and 75 cm spaced four-row strips, while the intercropping systems were sorghum alone, sorghum + mungbean, sorghum + clusterbean, sorghum + cowpea and sorghum + sesbania. In different intercropping systems, forage sorghum appeared to be the dominant crop as indicated by its higher values of relative crowding coefficient, competitive ratio and positive sign of the aggressivity. It reflects that forage sorghum grown in association with forage legumes (mungbean, clusterbean, cowpea and sesbania) utilized the resources more aggressively which exhibited the dominated behaviour of forage legume crops. Among the forage intercrops, cowpea proved to be more competitive than the other legume intercrops under study at all planting patterns. Thus, it is suggested that intercropping of cowpea in forage sorghum is the most efficient system of intercropping.

Key words: Competitive factors, intercrops, intercropping, geometric arrangement, sorghum, legumes.

INTRODUCTION

Being an agricultural country, most of the population of Pakistan is dependent on crop and livestock rearing. The fodder crops have great importance for the animals. Forage crops are the principal source of energy for the growth and the maintenance of livestock that not only meet the dietary requirements of millions of people but also contribute more than 30 % on national GNP (Economic Survey of Pakistan, 2004). At present, the condition of the majority of animals is deplorably poor due to underfeeding and malnutrition, which is usually ascribed to fluctuating and inconsistent supply of quality fodder. Although the area under fodder crops decreased from 2.7 to 2.5 million hectares during 1986-87 to 2003-04, but the forage yield per unit area increased from 20.0 to 22.8 t ha⁻¹, which is quite insufficient to meet the forage requirement of about 134.1 million livestock population (Agricultural Statistics of Pakistan, 2004). The development of a sustainable and economically viable intercropping system mainly depends on planting pattern of the associated crop, which is a pre-requisite for getting high forage yield of good quality. According to Finlay (1974), intercropping being a unique cropping system in tropical and sub-tropical regions is particularly popular among small farmers and has become a common practice of farming in developing countries. It offers the possibility of yield advantage relative to monocropping through yield stability and unpruned yield (Willey, 1979). Hence there is a need to explore

the feasibility and other related agro-economic aspects in tropical and sub-tropical conditions of Pakistan. Monocropping of forage crops particularly sorghum, maize, etc., are the common practice of Pakistani growers but these are often grown in mixture on small scale. The previous studies evinced that sorghum could successfully be grown as a component of intercrop combination in tropical areas of the world (Francis *et al.*, 1976 and Okigbo and Greenland, 1976). According to Willey *et al.* (1983), legume and non-legume intercropping in different patterns gave higher yield than monoculture due to efficient utilization of soil and input resources.

In spite of the fact that Pakistan is situated in tropical region having adequate irrigation and land resources with abundant sunshine for plant growth, our fodder yields are very low as compared to their potential yield. The majority of the farmers have small holdings with limited financial resources. Under the circumstances, growing of two or more crops on the same piece of land in a year can be a good way to exploit the natural resources for getting higher forage yield. Ayisi *et al.* (2001) reported higher intercropped sorghum yield when component crops were arranged in alternate rows at 0.90 m spacing. The overall land use efficiency, assessed by the land equivalent ratio, was improved by 11%, however, no yield benefit was observed when component crops were arranged in an alternate row pattern at a narrow row spacing of 0.45 m. Hussain *et al.* (1999) stated that sorghum grown alone or intercropped with guara (*Cymopsis*

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 cowpea. Intercropping is being looked as an efficient and most economical production system as it not only increases the production per unit area but also improves the resource use efficiency and economic status of the growers. Small growers, instead of meeting their diversified needs and low farm income from the monocropping, start to grow their fodder crops in intercropping system as well. Recently, Bhatti *et al.* (2005) developed a new technique of planting sesame in well spaced multi-row strips which not only give the higher seed yield then the conventional single row planting but also facilitates intercropping, harvesting and handling of the intercrops without any damage to base crop. Sarkar and Chakraborty (2000) and Sarkar *et al.* (2001) also reported competitive behaviour of component crops in different sesame-based intercropping systems in terms of aggressivity, relative crowding coefficient and competitive ratio. No systematic research work in Pakistan has so far been done to explore the competitive behaviour of component crops in different forage sorghum-forage legume intercropping system. The present study was, therefore, planned to evaluate the competitive response of forage sorghum grown in association with different forage legumes under diversified planting patterns.

MATERIALS AND METHODS

The experiment was conducted at agronomic research area, University of Agriculture, Faisalabad–Pakistan, during the year 2004 and 2005, on a sandy-clay loam soil. The planting geometry involved 30 cm spaced single rows, 30 × 30 cm cross planting with intercrops, 45 cm spaced 2-row strips and 75 cm apart 4-row strips, while intercropping systems were sorghum alone, sorghum + mungbean, sorghum + clusterbean, sorghum + cowpea and sorghum + sesbania. Forage legumes were intercropped in forage sorghum on the same day just after the completion of sowing of forage sorghum. The experiment was laid out in randomized complete block design with split-plot arrangement keeping planting geometry in main-plots and intercropping systems in sub-plots with three replications. The net plot size was 3.6 m × 7.0 m. A basal fertilizer dose @ 50-50 kg NP ha⁻¹ in the form of urea and single super phosphate (SSP) was applied at the time of sowing and with first irrigation only to the sorghum crop to meet its full nitrogen requirement. In total three

irrigations each of 7.5 cm were applied during the entire growth period of the crops. The first irrigation was given 21 days after germination, second at 35 days after germination and third at full vegetative stage. The competitive response of associated crops in different forage sorghum-legume intercrops was determined in terms of aggressivity, relative crowding coefficient and competitive ratio using the following formulae.

Competitive Functions

The following abbreviations were used to calculate different competitive functions.

Yaa = pure stand yield of crop "a".

Yab = intercrop yield of crop "a".

Ybb = pure stand yield of crop "b".

Yba = intercrop yield of crop "b".

Zab and Zba are sown proportions of crop "a" and "b" in an intercropping system.

1. Land equivalent ratio

Land equivalent ratio (LER) is the relative area of sole crop required to produce the yield achieved in intercropping (Khan *et al.*, 1988). Land equivalent ratio (LER) was computed using the formula described by Willey (1979).

$$LER = La + Lb = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where

La and Lb are the LERs for the individual crops

2. Aggressivity value

The competitive ability of the component crops in an intercropping system is determined by its aggressivity value. An aggressivity value of zero indicates that component crops are equally competitive. For any other situation, both crops will have the same numerical value, but the sign of dominant species will be positive and that of dominated negative. The greater the numerical value, the bigger the differences between actual and expected yields. Aggressivity (A) shows the degree of dominance of one crop over other when sown together. Aggressivity value was calculated by the formula proposed by McGilchrist (1965).

$$Aab = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zab}$$

Where

Aab = Aggressivity value for the component crop "a".

3. Relative crowding coefficient

The competitive effects and advantages of intercropping systems are also determined by the relative crowding coefficient. According to Wiley (1979), in an intercropping

system each crop has its own RCC (K). The component crop with higher K value is dominant and that with lower "K" value is dominated. To determine if there is a yield advantage of intercropping, the product of the coefficient of both component crops is obtained and that is usually designated as "K". If the product of RCC of two species is equal, less or greater than one, it means that, the intercropping system has no advantage, disadvantage or advantage, respectively. Relative crowding coefficient (K) was proposed by Dewit (1960) which was calculated by the following formula:

$$Kab = \frac{Yab}{Yaa - Yab} - \frac{Zba}{Zab}$$

Where

Kab = Relative crowding coefficient for the component crop "a".

4. Competitive ratio

The competitive ratio is the important tool to know the degree with which one crop competes with the other. Competitive ratio (CR) was calculated by the formula proposed by Willey *et al.* (1979).

$$CRa = \frac{Yab}{Yaa \times Zab} \div \frac{Yba}{Ybb \times Zba}$$

Where

CRa = Aggressivity value for the component crop "a".

RESULTS AND DISCUSSION

1. Land equivalent ratio (LER)

The land equivalent ratio is the relative area of a sole crop required to produce the yield achieved in an intercropping/relay cropping (Khan *et al.*, 1988). If LER value is equal to one, it means that there is no yield advantage but when LER is more than one then there is a yield advantage. The data regarding LER of different intercropping systems presented in Table 1 indicated that LER values were greater than one in all the intercropping systems under different planting patterns. The range of yield advantage varied from 60 to 70% in P₁, 63 to 75% in P₂, 65 to 88% in P₃ and 64 to 77% in P₄. The average across four planting patterns revealed that the maximum yield advantage (77.0 %) was achieved from sorghum + cowpea intercropping system followed by sorghum + clusterbean (66 %) and sorghum + mungbean (65 %). By contrast, the minimum yield advantage (64 %) was recorded for sorghum + sesbania intercropping system.

Variable yield advantages of different intercropping systems under various planting patterns over sole cropping of maize were also reported by Bhatnagar

and Chaplot (1991). Similarly, Dhope *et al.* (1992) reported that sorghum intercropped with soybean in a

3:3 row ratio exhibited higher land equivalent ratio than sorghum intercropped with pigeonpea or *Vigna radiata*. Ali (1993) also obtained the highest green fodder yield, land equivalent ratio and net return from intercropping maize with *Vigna radiata*. However, Srinivasulu *et al.* (2000) concluded the highest land equivalent ratio for pigeonpea + sesame intercropping system irrespective of the spacing of pigeonpea.

2. Aggressivity (A)

Aggressivity is an important competition function to determine the competitive ability of a crop when grown in association with another crop. An aggressivity value of zero indicates that component crops are equally competitive. For another situation, both crops will have the same numerical value, but the sign of the dominant species will be positive and that of dominated negative. The greater the numerical value, the higher is the difference in competitive abilities and the higher the difference between the actual and expected yield. The two-year average data pertaining to aggressivity presented in Table 2 revealed that the component crops did not compete equally. Regardless of the planting patterns, there was a positive sign for sorghum and negative for intercrops showing thereby that the sorghum was dominant while the intercrops were dominated. However, in a sorghum + clusterbean intercropping system under the pattern of 4-row strips, clusterbean was dominant. Aggressivity value was the minimum for sorghum + sesbania under all the four planting patterns which indicated that sesbania was the most competitive crop to sorghum. By contrast, rest of the intercrops proved to be less competitive to sorghum. Many other research workers such as Ahmad (1990), Gomma (1991); Shahid and Saeed (1997), reported the dominant effect of cotton having a positive "A" value when grown in association with mungbean, soybean, mashbean and linseed. While Sarkar and Sanyal (2000) concluded that among the intercrop associations, sesame + groundnut proved to be the best at 3:2 row ratio as the sesame has aggressivity factor (± 0.37).

3. Relative crowding coefficient (RCC)

Relative crowding coefficient plays a significant role in determining the competition effects and advantages of intercropping. In all the intercropping systems included in this study, sorghum appeared to be dominant as it had higher values for "K" than the intercrops in all the four planting patterns. As regards yield advantage, sorghum + cowpea showed the highest yield advantage under all planting patterns except P₁ where

Table 1. LER as affected by different planting patterns and sorghum-based intercropping systems.
(Two-Years average Data)

Intercropping system	P ₁ (30 cm spaced single rows)			P ₂ (30 × 30 cm cross planting with intercrops)			P ₃ (45 cm spaced double-row strips)			P ₄ (75 cm spaced four- row strips)		
	Sorghum	Intercrop	Total	Sorghum	Intercrop	Total	Sorghum	Intercrop	Total	Sorghum	Intercrop	Total
Sorghum + mung bean	0.92	0.70	1.62	0.92	0.75	1.67	0.90	0.79	1.69	0.83	0.81	1.65
Sorghum + cluster bean	0.87	0.75	1.62	0.88	0.74	1.63	0.92	0.86	1.78	0.78	0.89	1.66
Sorghum + cow peas	0.86	0.84	1.70	0.94	0.81	1.75	0.90	0.98	1.88	0.91	0.87	1.77
Sorghum + sesbania	0.94	0.67	1.60	0.85	0.80	1.65	0.86	0.79	1.65	0.89	0.75	1.64

Table 2. Aggressivity as affected by different planting patterns and sorghum-based intercropping systems.
(Two-Years average Data)

Intercropping system	P ₁ (30 cm spaced single row)		P ₂ (30 × 30 cm cross planting with intercrops)		P ₃ (45 cm spaced double-row strips)		P ₄ (75 cm spaced four- row strips)		System (P ₁ +...+P ₄)/4	
	Sorghum	Intercrop	Sorghum	Intercrop	Sorghum	Intercrop	Sorghum	Intercrop	Sorghum	Intercrop
Sorghum + mung bean	0.22	-0.22	0.17	-0.17	0.11	-0.11	0.02	-0.02	0.13	-0.13
Sorghum + cluster bean	0.12	-0.12	0.14	-0.14	0.06	-0.06	-0.11	0.11	0.05	-0.05
Sorghum + cow peas	0.27	-0.27	0.13	-0.13	-0.08	0.08	0.04	-0.04	0.09	-0.09
Sorghum + sesbania	0.02	-0.02	0.06	-0.06	0.06	-0.06	0.14	-0.14	0.07	-0.07

Table 3. RCC as affected by different planting patterns and sorghum-based intercropping systems.

(Two-Years average Data)

Intercropping system	P ₁ (30 cm spaced single row)			P ₂ (30 × 30 cm cross planting with intercrops)			P ₃ (45 cm spaced double-row strips)			P ₄ (75 cm spaced four-row strips)		
	Sorghum (Ks)	Intercrop (Ki)	K=Ks*Ki	Sorghum (Ks)	Intercrop (Ki)	K=Ks*Ki	Sorghum (Ks)	Intercrop (Ki)	K=Ks*Ki	Sorghum (Ks)	Intercrop (Ki)	K=Ks*Ki
Sorghum + mung bean	10.16	1.32	13.42	10.77	2.01	21.63	7.84	2.79	21.87	3.98	3.39	13.50
Sorghum + cluster bean	5.63	2.02	11.38	6.52	1.91	12.45	10.31	5.02	51.71	2.49	6.89	17.18
Sorghum + cow peas	13.54	1.00	13.60	14.86	3.35	49.76	8.30	6.71	55.69	8.75	5.45	47.68
Sorghum + sesbania	5.11	4.17	21.30	4.80	2.92	14.03	5.09	2.86	14.54	6.84	2.01	13.73

Table 5. Competitive ratio as affected by different planting patterns and sorghum-based intercropping systems.

(Two-Years average Data)

Intercropping system	P ₁ (30 cm spaced single row)		P ₂ (30 × 30 cm cross planting with intercrops)		P ₃ (45 cm spaced double-row strips)		P ₄ (75 cm spaced four-row strips)		System (P ₁ +...+P ₄)/4	
	Sorghum	Intercrop	Sorghum	Intercrop	Sorghum	Intercrop	Sorghum	Intercrop	Sorghum	Intercrop
Sorghum + mung bean	1.31	0.70	1.23	0.75	1.14	0.79	1.02	0.81	1.17	0.76
Sorghum + cluster bean	1.16	0.75	1.19	0.74	1.07	0.86	0.88	0.89	1.07	0.81
Sorghum + cow peas	1.40	0.67	1.16	0.81	0.92	0.98	1.05	0.87	1.13	0.83
Sorghum + sesbania	1.03	0.84	1.07	0.80	1.08	0.79	1.18	0.75	1.09	0.79

sorghum + sesbania exhibited the highest yield advantage (Table 3). By contrast, the minimum yield advantage was recorded for sorghum + clusterbean under P_1 and P_2 and for sorghum + mungbean under P_3 and P_4 . The rest of the intercropping systems, however, intermediated. These findings are supported by Sarkar *et al.* (2001) who reported that in a sesame + groundnut intercropping, sesame had the maximum product of crowding coefficient ($K = 4.58$) than other intercrop combinations. Similarly, Sarkar and Chakraborty (2000) obtained the highest value of product coefficient when sesame was intercropped with greengram.

Relative crowding coefficient (RCC) of different intercropping systems

In all the intercropping systems included in this study, sorghum appeared to be dominant as it had higher value for "K" than the intercropping systems (Table 4). It is thus concluded that sorghum utilized the resources more competitively than intercrops, which appeared to be dominated. Among the intercropping systems, the maximum yield advantage was obtained from sorghum + sesbania as indicated by its maximum value of K (22.52) followed by sorghum + cowpea (10.80) against the minimum for sorghum + mungbean (9.64). These results are supported by the findings of El-Edward *et al.* (1985), Singh and Gupta (1993), Shahid and Saeed (1997) and Ahmad (1997) who reported yield advantage over the respective monocultures as evaluated on the basis of RCC (K).

Table 4. RCC as affected by different sorghum-based intercropping systems.

(Two-Years average Data)

Intercropping system	Sorghum (Ks)	Intercrop (Ki)	System $K=K_s \times K_i$
Sorghum + mung bean	7.3	1.32	9.64
Sorghum + cluster bean	5.3	2.02	10.71
Sorghum + cow peas	10.7	1.00	10.80
Sorghum + sesbania	5.4	4.17	22.52

4. Competitive ratio (CR)

Competitive ratio (CR) is another way to know the degree with which one crop competes with the other crops. On the basis of two year average data, lower CR values for intercrops than the based sorghum crop indicated that all the intercrops under study were less competitive than sorghum when grown in association with each other under all the four patterns of planting (Table 5).

The average over four planting patterns, indicated that the CR was higher for sorghum + mungbean (1.17) followed by sorghum + cowpea (1.13) compared to the minimum (1.07) for sorghum + clusterbean preceded by sorghum + sesbania (1.09). It is thus evident from the data regarding RCC and CR that sorghum crop in each intercropping system was dominant while intercrops were dominated. Among the intercrops, cowpea and clusterbean proved to be the better competitive when grown in association with sorghum. The next to follow were sesbania and mungbean. Anjum (1996) and Shahid and Seed (1997) reported that lentil was a better competitor than other intercrops when grown in association with wheat. Similarly, Sarkar and Chakraborty (2000) also reported a modest competitive ratio when sesame was intercropped with mungbean in 1:1 ratio

CONCLUSION

Based on land equivalent ratio (LER), all the intercropping systems showed substantially higher yield advantages than sole cropping. However, the highest yield advantage of 88 % was recorded for sorghum + cowpea intercropping system under the pattern of 45 cm spaced double-row strips. In different intercropping systems, forage sorghum appeared to be the dominant crop as indicated by its higher values of relative crowding coefficient, competitive ratio and positive sign of the aggressivity. It reflects that forage sorghum grown in association with forage legumes (mungbean, clusterbean, cowpea and sesbania) utilized the resources more aggressively which exhibited the dominated behaviour of forage legume crops. Among the forage intercrops, cowpea proved to be more competitive than the other legume intercrops under study at all planting patterns. Thus, it is suggested that intercropping of cowpea in forage sorghum is the most efficient system of intercropping.

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