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Some Competition Functions and Economics of Different Cotton-Based Intercropping Systems

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ABSTRACT

Studies were carried out into some competition functions and economics of different cotton-based intercropping systems in cotton planted in two patterns viz., 80-cm spaced single rows and 120-cm spaced double row strips (40/120 cm). Intercropping systems were cotton alone, cotton+mungbean, cotton+mashbean, cotton+sesame, cotton+ricebean, cotton+maize, cotton+sorghum, cotton+cowpeas and cotton+soybean. In all the intercropping systems in this study except cotton+sesame, cotton appeared to be highly dominant as it had higher value for relative crowding coefficient "k" than the intercrop. Aggressivity value was minimum for cotton+sesame at both the planting patterns, thereby indicating that sesame was the most competitive crop to cotton. Mashbean and cowpeas proved less competitive with cotton as there was a little difference among their aggressivity values across planting patterns. Higher competitive ratio for sesame also indicated its better competitiveness as compared to all other intercrops grown in association with cotton. Land equivalent ratio values greater than one in all the intercropping systems except cotton+sesame at 80-cm spaced single rows of cotton indicated the yield advantage of intercropping over sole cropping of cotton except in aforementioned case. On the basis of two years data, area time equivalent ratio value indicated an advantage of 1 to 33% in intercropping compared with sole cropping of cotton except cotton+sesame and cotton+ricebean regardless of planting patterns.

Key Words: Competition functions; Planting patterns; Cotton intercropping

INTRODUCTION

Intercropping is a well established practice and there are 12 million hectares under double cropping system in South Asia only (Woodhead *et al.,* 1994). Yield advantages from intercropping are often attributed to mutual complementary effects of component crops, such as better use of available farm resources (Legard & Steel, 1992). Relative crowding coefficient (RCC) plays an important role in determining the competition effects and advantages of intercropping (Willey, 1979). Aggressivity is an important tool to determine the competitive ability of a crop. An aggressivity value of zero indicates that component crops grown in association with other crop are equally competitive. For any other situation, both crops will have same numerical value, but the sign of the dominant species will be positive and that of dominated negative. Gomaa (1991), and Shahid and Saeed (1997) reported dominant effect of cotton having positive 'A' value when grown in association with mungbean, soybean, mashbean and linseed.

Aal (1991) and Raghuwanshi *et al.* (1994) reported higher LER in intercropping as compared to sole crops. The Area time equivalent ratio provides more realistic comparison of the yield advantage of intercropping over that of sole cropping than LER as it considers variation in time taken by the component crops of different intercropping systems. The present studies were, therefore, carried out to study some competition functions and economics of different cotton-based intercropping systems in cotton planted in two patterns.

MATERIALS AND METHODS

The study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad. The experiment was laid out in randomized complete block design with split plot arrangement and four replications. Planting patterns were randomized in main plots and intercrops in subplots. Plot size was 4.8 m x 7 m. Cotton cv. NIAB 78 was sown in 80-cm spaced single rows and 120-cm spaced 2-row strips on May 27 and 29 during *kharif* 1996 and 1997, respectively. Mungbean (*Vigna radiata L.*), mashbean (*Vigna mungo L.*), soybean (*Glycine max L.*), sesame (*Sesamum indicum L.*), maize (*Zea mays L.*), sorghum (*Sorghum vulgare L.*), cowpeas (*Vigna unguiculata*) and ricebean (*Vigna umbellata*) were intercropped in space between the cotton rows/strips next day after sowing of cotton. Each intercrop was also sown as sole crop for determining the land equivalent ratio (LER) and area time equivalent ratio (ATER).

Mungbean, mashbean, sesame and soybean were harvested at their physiological maturity. Ricebean, maize, sorghum and cowpeas were harvested at flowering stage as green fodder. Observations on relevant parameters of all the component crops were recorded by following standard procedures. Competition behavior of component crops across different intercropping systems was determined in terms of relative crowding coefficient, aggressivity, competitive ratio and land and area time equivalent ratios as follows:

i) Relative crowding coefficient (K) = $\frac{Yab}{(Yaa-Yab)} - \frac{Z\,ba}{Zab}$
(Dewit, 1960)

ii) Aggressivity (Aab) = $\frac{Yab}{(Yaa \times Zab)} - \frac{Yba}{(Ybb \times Zba)}$
(McGilchrist , 1965)

iii) Competitive ratio (Cra) = $\frac{Yab}{(Yaa \times Zab)} \div \frac{Yab}{(Ybb \times Zba)}$
(Willey et al. , 1980)

iv) Land equivalent ratio (LER) = La+Lb = $\frac{Yab}{Yaa} + \frac{Yba}{Ybb}$
(Willey, 1979)

v) Area time equivalent ratio (ATER) = $\frac{(Ryc \times tc) \times (Ryp \times tp)}{T}$
(Hiebsch , 1980)

Where, Yaa= yield of pure stand of crop 'a'; Yab=intercrop yield of crop 'a'; Ybb=yield of pure stand of crop 'b'; Yba= intercrop yield of crop 'b'; Zab and Zba are sown proportions of crop 'a' and 'b' in an intercropping system; Ryc=relaive yield of crop 'a'; Ryp=relative yield of crop 'p'; tc= duration (days) for crop 'c'; tp=duration of crop 'p'; T= duration for whole system

RESULTS AND DISCUSSION

Relative crowding coefficient (RCC). In all the intercropping systems included in this study except cotton+sesame, cotton appeared to be highly dominant as it had higher value for relative crowding coefficient (k) than the intercrops in different intercropping systems (Table I). It was inferred that the intercropped cotton utilized the resources more competitively than mungbean, mashbean, ricebean, maize, sorghum, cowpeas and soybean, which appeared to be dominated. However, in cotton+sesame intercropping system, sesame had a dominant effect in the utilization of resources and cotton was dominated. Malik *et al.* (1991) and Mohammad (1994) also recorded higher 'Kc' value for cotton as compared to associated crop. As products of the coefficients of the component crops were greater than one except cotton+sesame intercropping, all the intercropping systems except this had yield advantages. Across the intercropping systems, the maximum cotton yield advantage was obtained from cotton+mashbean as indicated by the maximum value of 'K' for this cropping system.

Across the planting patterns, the yield advantage increased in 120-cm apart double row strips of cotton (P_2) over 80-cm apart single rows (P_1) as indicated by the K values for P_1 and P_2 for each intercropping system (Table I). Maize-soybean (El-Edward *et al.,* 1985), wheat-Indian mustard (Singh & Gupta, 1993) as well as wheat-mathra and wheat-gram (Shahid & Saeed, 1997), wheat-Egyptian clover intercropping systems (Ahmad, 1997) have been reported for grain yield advantages over the respective mono culture as evaluated on the basis of RCC.

Aggressivity (A). "A" is an important tool to determine the competitive ability of a crop when grown in association with another crop. The component crops did not compete equally (Table II). Regardless of the planting patterns positive sign with values of cotton, except cotton+sesame at 120-cm apart double row strips of cotton (P_2), indicated the dominant behavior of cotton over all intercrops, which had negative 'A' values. However, in cotton+sesame intercropping system, cotton was dominated and sesame had a dominant behavior. Aggressivity value was minimum for cotton+sesame at both the planting patterns, which indicated that sesame was the most competitive crop to cotton. Mashbean and cowpeas proved to be less competitive with cotton as there was a little difference among their aggressivity values across planting patterns. Many other researchers (Ahmed, 1990; Gomaa, 1991; Shahid & Saeed, 1997) also reported dominant effect of cotton having positive 'A' value when grown in association with mungbean, soybean, mashbean and linseed.

Competitive ratio (CR). CR is an important way to know the degree with which one crop competes with the other. Higher CR values for cotton than those for all the intercrops, except sesame intercropped in 120-cm apart double row strips, indicated that at both the planting patterns, cotton was more competitive than mungbean, mashbean, sesame in 80-cm apart single rows of cotton, ricebean, maize, sorghum, cowpeas and soybean when grown in association with each other (Table II). The competitive ratio was higher for sesame in both the planting patterns followed by sorghum. These results suggest that among intercrops sesame proved to be better competitive than all other intercrops when grown in association with cotton. Anjum (1996), and Shahid and Saeed (1997) reported that lentil was better competitor than other crops when sown in association with wheat.

It is evident from the data pertaining to RCC, A and RC that cotton was the dominant crop in each intercropping system under study except cotton+sesame. Among intercrops, sesame was more competitive with cotton than all other intercrops. The second to follow was sorghum.

Land equivalent ratio (LER). LER is the relative area of sole crop required to produce the yield achieved in intercropping (Khan *et al.,* 1988). LER values were greater than one in all the intercropping systems except cotton+ sesame intercropping system at 80-cm single rows of cotton (Table III) indicating the yield advantage of intercropping over sole cropping of cotton except in aforementioned case. Aal (1991), Raghuwanshi *et al.* (1994) and Rao (1991) also reported higher LER in intercropping as compared to sole crops. In 80-cm apart single rows of cotton, maximum LER was recorded for cotton+mashbean against the minimum for cotton+cowpeas indicating that the yield advantages ranged between 58-32% whereas, it was reduced by 3% in case of otton+sesame intercropped over sole cotton plantation. In other words, it is possible to harvest from a hectare of intercropping equal to that from 1.58 to 1.32 hectare of sole cropping of cotton. Similarly, intercropping in 120-cm apart double row strips of cotton showed maximum LER in case of cotton+mashbean (1.78) and minimum for cotton+sesame (1.06) indicating yield advantages of as high as 78% to as low as 6%, respectively. However,

Table I. Relative crowding coefficeint (RCC) as affected by planting patterns and intercropping systems (average of two years)

Treatment	80-cm spaced single rows of cotton			120-cm spaced 2-row strips of cotton			System		
	RCC Cotton (kc)	RCC Intercrop (ki)	RCC System (K)	RCC Cotton (kc)	RCC Intercrop (ki)	RCC System (K)	RCC Cotton (kc)	RCC Intercrop (ki)	RCC System (K)
Intercropping systems (S)									
S_2 (Cotton + mungbean)	7.73	0.92	7.11	7.11	7.00	3.78	7.36	1.82	13.40
S_3 (Cotton + mashbean)	13.61	0.94	12.79	43.16	3.55	153.21	21.4	2.06	44.10
S_4 (Cotton + sesame)	-1.50	1.29	-3.3	-1.52	2.25	-3.42	-1.50	1.71	-2.56
S_5 (Cotton + ricebean)	1.72	1.04	1.79	10.38	2.46	25.53	3.71	1.59	5.89
S_6 (Cotton + maize)	4.59	0.47	2.16	5.77	1.04	6.00	5.13	0.72	3.67
S_7 (Cotton + sorghum)	3.90	1.50	5.85	3.32	3.64	12.08	3.60	2.34	8.40
S_8 (Cotton + cowpeas)	11.13	0.14	4.56	9.03	0.99	8.94	9.97	0.48	4.79
S_9 (Cotton + soybean)	22.00	0.20	4.40	17.38	0.92	15.99	19.5	0.67	13.0

Table II. Aggressivity (A) and competitive ratio (CR) as affected by planting patterns and intercropping systems (average of two years)

	Agressivity						Competitive ratio					
	P_1[a]		P_2		$P_1 + P_2$		P_1		P_2		$P_1 + P_2$	
	C (Aab)	I (Aba)	C (Aab)	I (Aba)	C(Aab)	I(Aba)	C	I	C	I	C	I
Intercropping systems (S)												
S_2 (Cotton + mungbean)	0.61	-0.60	0.49	-0.49	0.55	-0.55	3.13	0.39	2.20	0.46	2.67	0.43
S_3 (Cotton + mashbean)	0.62	-0.62	0.58	-0.58	0.60	-0.60	2.93	0.34	2.45	0.41	2.69	0.38
S_4 (Cotton + sesame)	0.01	-0.01	-0.04	0.04	-0.03	0.03	1.03	0.97	0.89	1.12	0.96	1.05
S_5 (Cotton + ricebean)	0.49	-0.49	0.56	-0.56	0.53	-0.53	2.63	0.38	2.51	0.40	2.57	0.39
S_6 (Cotton + maize)	0.62	-0.62	0.59	-0.59	0.6	-0.61	3.48	0.29	2.97	0.34	3.23	0.32
S_7 (Cotton + sorghum)	0.53	-0.53	0.44	-0.44	0.49	-0.49	2.60	0.38	2.10	0.48	2.35	0.43
S_8 (Cotton + cowpeas)	0.74	-0.74	0.62	-0.62	0.68	-0.68	4.80	0.20	3.06	0.33	3.98	0.27
S_9 (Cotton + soybean)	0.71	-0.71	0.66	-0.66	0.69	-0.69	3.84	0.26	3.28	0.31	3.56	0.29

Table III. Land equivalent (LER) and area-time equivalent ratios (ATER) as affected by intercropping systems and planting patterns (average of two years)

	Land equivalent ratio						After time equivalent ratio					
	[a]P_1		P_2		P_1	P_2	P_1		P_2		P_1	P_2
	(C)	(I)	(C)	(I)	(C+I)	(C+I)	(C_1)	(I_1)	(C_2)	(I_2)	(C_1+I_2)	(C_2+I_2)
Intercropping systems (S)												
S_2 (Cotton + mungbean)	0.90	0.59	0.90	0.81	1.50	1.71	0.90	0.29	0.90	0.40	1.19	1.30
S_3 (Cotton + mashbean)	0.94	0.64	0.98	0.80	1.58	1.78	0.94	0.31	0.98	0.39	1.27	1.38
S_4 (Cotton + sesame)	0.33	0.64	0.33	0.73	0.97	1.06	0.33	0.37	0.33	0.42	0.70	0.75
S_5 (Cotton + ricebean)	0.79	0.61	0.93	0.75	1.40	1.68	0.79	0.14	0.93	0.18	0.93	1.11
S_6 (Cotton + maize)	0.87	0.49	0.89	0.61	1.36	1.43	0.87	0.11	0.89	0.13	0.98	1.02
S_7 (Cotton + sorghum)	0.85	0.67	0.84	0.81	1.52	1.63	0.84	0.15	0.84	0.18	0.99	1.10
S_8 (Cotton + cowpeas)	0.93	0.39	0.92	0.60	1.32	1.52	0.92	0.09	0.92	0.14	1.01	1.06
S_9 (Cotton + soybean)	0.96	0.49	0.95	0.59	1.45	1.54	0.96	0.24	0.96	0.30	1.20	1.26

[a]P_1= 80-cm spaced single rows of cotton; P_2 = 12-cm spaced 2-row strips of cotton; C = Cotton; I = Intercrop

cotton+mungbean, cotton+ricebean and cotton+sorghum also gave higher yield advantages of 71, 68 and 63%, respectively (Table III). As regards planting patterns, LER values in double row strips of cotton were higher than single rows of cotton in all the intercropping systems, which indicated higher bio-economic efficiency of strip plantation over single row plantation. Based on the average of two years and regardless of planting patterns, cotton+mashbean gave the highest LER (1.68) that was closely followed by cotton+mungbean (1.61), cotton+sorghum (1.58). Minimum LER (1.02) was recorded for cotton+sesame. However, LER in intercropping treatments compared with monocropping of cotton was ascribed to better utilization of natural (land and light) and added (fertilizer and water) resources.

Area-time equivalent ratio (ATER). Since land equivalent ratio does not take into account the time for which land is occupied by the component crops of an intercropping system, ATER was also determined. The ATER provides more realistic comparison of the yield advantage of intercropping over that of sole cropping than LER as it considers variation in time taken by the component crops of different intercropping systems. In all the treatments, ATER values were smaller than LER values (Table III), indicating the over estimation of resource utilization in the latter. Thus contrary to LER, ATER is free from problems of over estimation of resource utilization. On the basis of two years average data, ATER value indicated an advantage of 1 to 33% in intercropping compared with sole cropping of cotton except cotton+sesame and cotton+ricebean systems regardless of planting pattern (Table III). ATER was the maximum for cotton+mashbean followed by cotton+ mungbean and cotton+soybean, respectively. Regarding the planting patterns, ATER value for double row strips of cotton were higher than those for single rows of cotton indicating better bio-economic efficiency of strip plantation of cotton over single row plantation. In 80-cm apart single rows of cotton, ATER values indicated yield advantages in the range of 19-27% for cotton+mungbean and cotton+mashbean, respectively which were in the range of 30-38% in case of 120-cm apart double strips of cotton. In sesame and ricebean, ATER was less than one indicating poor utility of resources. It was at par in ricebean and sorghum and cotton alone. Higher values of ATER in intercropped treatments compared with monoculture of cotton were attributed to efficient utilization of natural (land and light) and added (fertilizer and water) resources. Higher ATER values have also been reported in cotton+cowpeas (Allen & Obura, 1983), rice+pigeonpea (Banik & Bagehi, 1994), Cassava+cowpease (Kuruvilla *et al.,* 1994) and wheat+lentil (Ahmad, 1997) associations compared with monoculture of their component crops.

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