COWPEA GENOTYPE AND ROW ARRANGEMENT EFECTS ON THE PRODUCTIVITY AND ECONOMIC RETURNS OF SORGHUM/COWPEA INTERCROP IN THE NIGERIAN SAVANNA

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Abstract

Sorghum/cowpea intercropping is a major cropping system in the Sudan savanna zone of Nigeria. Six cowpea genotypes (Danila, IT95K-222-14, IT90K-277-2, IT95K-1091-3, IT96D-666 and IT96D-759) and four row arrangements (1:1, 1:2, 2:2 and 2:4 sorghum to cowpea rows) were used in a field experiment conducted at Minjibir near Kano, Nigeria over a two-year period to investigate the effect of cowpea genotype and row arrangement on the productivity of this intercrop. Results indicated that grain yield and yield parameters of intercropped sorghum were not affected by cowpea genotype and row arrangement. However, genotype had significant effect on cowpea grain yield and yield components. Intercropped cowpea grain yield varied from 486 to 886 kg ha-1. Cowpea grain yield and its components were highest at 2:4 row arrangement while lowest values were recorded at 1:1 arrangement where intercrop competition was most intense. Significantly higher partial land equivalent ratio was recorded by IT90K-277-2 and IT95K-222-14 compared with the other genotypes. The highest mean intercrop yield advantage of 26% was recorded using IT95K-222-14. Sorghum in combination with either IT90K-277-2 or IT95K-222-14 gave the highest gross monetary return, which was maximized when, 2S:4C row arrangement was used.

Key words: intercropping, sorghum, cowpea genotypes, grain yield, land equivalent ratio, monetary returns.

INTRODUCTION

Intercropping is a popular and traditional cropping system in the tropical part of the world. It is a strategy used by farmers for increasing crop yields, crop diversity and stability of crop production and returns (Remison, 1980). Willey (1979) observed that the yield advantages in mixed cropping could be substantial especially when the components of the mixture are complementary. Previous studies have indicated that sorghum/cowpea intercropping combination is an important cropping system in the Sudan savanna of Nigeria (Henriet *et al.,* 1997). Sorghum (*Sorghum bicolor* (L.) Moench) being the major crop is planted at the beginning of the rainy season while cowpea (*Vigna unguiculata* (L.) Walp) is intercropped later.

Under the indigenous systems, farmers use local sorghum varieties, which is tall, late maturing and photoperiod sensitive, producing heads at the end of the rainy season. Apart from having long period of vegetative growth, their growth is slow at the initial stage (Oluwasemire *et al*., 2002). Similarly, the cowpea cultivars used for intercropping with sorghum are late maturing, photoperiod sensitive, indeterminate and low yielding. In such intercropping situation, competition among component crops becomes severe since both crops mature almost at the same time. However, a number of improved high yielding cowpea cultivars with a range of maturities and desirable agronomic characters have been developed (Singh and Ntare, 1985; Singh *et al.,* 1997). Intercropping the local sorghum with a fast maturing cowpea variety may ensure efficient utilization of solar radiation wasted at the initial stage as well as reduction of late season competition for water.

Another means of further reduction in competition for growth resources is by manipulating crop arrangement (Natarajan and Willey, 1985). Willey and Rao (1980) observed that increasing the total plant population markedly increased the competitive ability in favour of a component relative to the other. However, Rao and Willey (1980) observed virtually no difference in intercrop advantages between 1:1 and 2:1, sorghum/pigeon pea row arrangements. Hence, the objective of this study was to evaluate the effect of cowpea genotype and row arrangement on the productivity and monetary returns of sorghum/cowpea intercrop.

MATERIAL AND METHODS

Field experiments were conducted in the 1999 and 2000 cropping seasons at Minjibir (12^0 08'N, 8^0 32'E; 500m above sea level) near Kano, in the Sudan savanna ecological zone of Nigeria. The soil of the experimental site was sandy loam with pH of 6.6, organic carbon 1.5 g kg $^{-1}$, available P 8.4 mg kg^{-1} and total nitrogen 0.42 g kg $^{-1}$ soil. . The treatments consisted of a factorial combination of six cowpea genotypes and four row arrangements. The cowpea genotypes were made up of one local (Danila) and five improved (IT95K-222-14, IT90K-277-2, IT95K-1091-3, IT96D-666 and IT96D-759) while the row arrangements were 1:1, 1:2, 2:2 and 2:4 sorghum to cowpea rows. Danila is a local photoperiod sensitive medium maturing spreading cowpea type while the five improved genotypes are photoperiod insensitive, medium maturing (70-80 days) with semi-erect growth habit. The local sorghum used is tall (3.0-3.5m), late maturing (about 125 days) with medium sized cream coloured seed. The experimental design was split plot with three replications. Row arrangements constituted the main plots while cowpea genotypes were in the sub-plots. Sole plots of each of the six cowpea genotypes as well as sorghum were also established.

Sorghum was sown on 28 June and 6 June in 1999 and 2000, respectively while cowpea was interplanted on 12 July in both years. Sorghum and cowpea plants were spaced 75cm x 50cm and 75cm x 20cm, respectively. Seeds were over-sown and thinned to 2 plants per stand two weeks after sowing; giving the recommended plant density of 53333 and 133333 plant ha^{-1} for sole sorghum and cowpea, respectively. Intercrop population was a replacement series with 50:50, 33:67, 50:50 and 33:67 for 1:1, 1:2, 2:2 and 2:4 row arrangements, respectively. The gross plots consisted of 14 ridges 6m long (63 m^2) for the 2:4 treatment; 10 ridges 6m long (45 m^2) for the 2:2 and 2:1 treatments; and 8 ridges 6m long (36.0 m^2) for 1:1 treatment. The gross plot size of sole sorghum and cowpea was 6 ridges 6m long (27 m^2). The net plot varied from 6 ridges 4 m long to 2 ridges 4 m long, depending on treatment. All plots received basal dressing of 30 kg N, 13 kg P and 24.3 kg K ha^{-1} as urea, single superphosphate and muriate of potash, respectively before planting. Sorghum was top-dressed at 5 weeks after planting with 30 kg N ha^{-1} as urea.

Weeds were controlled using hand hoes and hand pulling. Cowpea plants were sprayed twice (at flowering and podding stages) against insect pests using the insecticide Delfos (Monocrotophos) at 1L ha^{-1}. The component crops were harvested after physiological maturity. Data collected on sorghum included panicle length, 1000-grain weight, threshing percentage, stover yield and grain yield while for cowpea data on number of pods $plant^{-1}$, number of grains pod^{-1}, 100-grain weight and grain and fodder yields were recorded. Intercrop productivity was evaluated using Land Equivalent Ratio (LER) as described by (Willey, 1979). Gross monetary returns were determined by summing the total naira (₦) value of cowpea and sorghum grain as well as fodder/stover per hectare (sorghum grain = ₦10 kg^{-1}; sorghum stover = ₦1 kg^{-1}; cowpea grain = ₦40 kg^{-1}; cowpea fodder = ₦5 kg^{-1} in 1999 and sorghum grain = ₦20 kg^{1}; sorghum stover = ₦0.5 kg^{1}; cowpea grain = ₦44 kg^{1}; cowpea fodder = N8 kg^{1} in 2000). The data were analyzed using analysis of variance procedure appropriate to split plot design (Genstat 5. Release 3.1, 1993).

RESULTS

Daily rainfall is shown in Figure 1. A total rainfall of 718.7 mm was received in 46 days in 1999 compared with 486.6 mm in 31 days in 2000. The greatest precipitation occurred during the month of July followed by September in 1999. In contrast, August was the wettest month in 2000 while September was relatively dry. The precipitation received in 2000 was fairly evenly distributed between June and September.

Sorghum yield and its parameters responded similarly to the treatments in both years, cowpea genotype and row arrangement having no significant effect on panicle length, threshing percentage, 1000-grain weight and grain yield of sorghum (Table1). However, grain yield of sorghum was significantly lower at 2:4 row arrangement compared with 2:2 and 1:2 arrangements in 1999. Sorghum stover yield was significantly affected by cowpea genotypes in 1999 while row arrangement had a significant effect on stover yield in 2000.

Table 2 presents the effect of cowpea genotype and row arrangement on the yield components of cowpea. The number of pods per plant of cowpea was affected by cowpea genotype in 2000 only, when Danila had significantly higher number of pods than the other genotypes which were essentially similar. Row arrangement had no influence on number of pods per plant in 2000 but in 1999 2S:4C and 1S:2C row arrangements had higher number of pods compared with 1S:1C while 1S:1C and 2S:2C were at par. In each year, IT95K-222-14 and IT90K-277-2 had the highest number of grains per pod while Danila and IT96D-666 had the least. Row arrangement had significant effect on number of grains per pod of cowpea in 1999 only, when fewer grains were produced per pod at 1S:1C compared with 2S:4C. In each season, IT90K-277-2 and IT95K-222-14 had heavier grains compared with the other genotypes, which had similar grain weight in 1999. However, in 2000 Danila had lighter grains than the remaining genotypes. In both years, grain weight was lighter at 1S:1C row arrangement compared with the other row arrangements which were similar.

Mean cowpea grain yield in the intercrop systems was 667 kg ha^{1}, which was about 50 % less than the mean sole crop yield (Table 3). In intercrop, IT95K-222-14 out-yielded the other genotypes in 1999 while IT95K-222-14 and IT90K-277-2 had statistically similar and higher grain yields compared with the other genotypes in 2000. The local genotype, Daila and IT96D-666 ranked among the lowest yielders in the two seasons. The row arrangement effect showed that in both years, 2S:4C out-yielded the other treatments which were similar. Three of the improved genotypes (IT96D-666, IT90K-277-2 and IT95K-1091-3) had comparable fodder yield with the local spreading genotype, Danila in 1999. However, in 2000 IT90K-277-2 gave a significantly higher fodder yield than all the other genotypes, including Danila (Table 3). In both years, IT95K-222-14 and IT96D-759 had the least fodder yield. Row arrangement had no effect on fodder yield in 2000 whereas in the wetter year 1999 fodder yield was significantly higher at 2S:4C compared with the other treatments that were similar.

The partial land equivalent ratio (LER) of sorghum was affected by cowpea genotype in 2000 only (Table 4), when sorghum in association with IT90K-277-2 had superior partial LER compared with the combination involving either Danila or IT95K-1091-3. On the other hand, the partial LER of sorghum was not affected by row arrangement in the two seasons. Cowpea genotype influenced the partial LER of cowpea in both years. In 1999, IT95K-222-14 had a significantly higher partial LER compared with IT90K-277-2 and IT96D-759, which in turn were superior to Danila and IT96D-666. However, in 2000, IT95K-222-14 and IT90K-277-2 had similar and higher partial LER compared with the other genotypes. Partial LER of cowpea was affected by row arrangement in both seasons with 2S:4C row arrangement having significantly higher partial LER than the other treatments which were at par. Cowpea genotype influenced yield advantage (TLER) of sorghum/cowpea intercrop significantly in 2000 (Table 4). TLER was higher when sorghum was intercropped with IT95K-222-14 and IT90K-277-2 compared with the other intercrops. The effect of row arrangement on yield advantage of sorghum/cowpea intercrop was also significant in 2000 only, when 2S:4C row arrangement was superior to 1S:1C while differences between the other row arrangements were not significant.

In both years, intercropping sorghum with either IT90K-277-2 or IT95K-222-14 resulted in a higher gross monetary returns compared with the other intercrop combinations (Table 5). Higher returns were obtained at 2S:4C compared with the other row arrangements in both seasons.

DISCUSSION

Intercropped cowpea grain yields were generally lower in 1999 than in 2000 in spite of the fact that the former season was wetter. The higher yields in 2000 could be due to the even distribution of rainfall, particularly during the reproductive phase (Figure 1). The number of rainy days between August and October 2000 was 18 compared with 17 days in 1999 whereas 360.4 and 232.0 mm of rainfall were received in the three months in 1999 and 2000, respectively. The month of September was particularly wet (206.2 mm) in 1999 and was accompanied by a lot of cloud cover and high relative humidity, which probably favoured a buildup of insect pests and diseases under intercropping situation. On the other hand, the less but adequate rainfall (70.5 mm) received in September in 2000 hastened crop drying and discouraged the buildup of insect pest and diseases. The relatively even distribution of rainfall during the later stage of crop development in 2000 was also probably responsible for the similarity in sorghum yields in both years despite the difference in total rainfall.

When averaged across the two seasons, IT95K-222-14 and IT90K-277-2 out-yielded the other cowpea genotypes. The high mean yields of these genotypes could be attributed to their relatively high 100-grain weight and number of grains per pod. The local genotype Danila had low 100-grain weight and grain yield presumably because it diverted little assimilate towards grain development, a common phenomenon associated with indeterminate cowpea genotypes (Ntare, 1990). Terao *et al.* (1997) observed that local spreading types of cowpea have low yield potential because of low harvest index and inadequate root system.

The high partial LER recorded by IT90K-277-2 and IT95K-222-14 is a reflection of their higher biological efficiency resulting from better utilization of environmental resources (Willey, 1979) compared with the other genotypes. The total LER which is a measure of intercrop yield advantage in association with sorghum was 24% for IT90K-277-2 and 26% for IT95K-222-14. Cowpea genotype had little effect on the partial LER of sorghum and therefore, variations in intercrop advantage were basically due to variations in cowpea partial LER.

The grain yields of cowpea as well as the yield attributes examined were highest at 2:4 row arrangement probably because at this row arrangement competition between component crops was low due to wide separation in space compared with the other more intimate arrangements (Wahua, 1983). Willey (1979) indicated that legumes make efficient use of environmental resources at wider spatial arrangements. Thus, the low cowpea grain yields and yield attributes at the more intimate row arrangements could be associated with competition for growth resources which tended to become more severe as rows of cowpea relative to cereal decreased. Willey and Rao (1980) opined that changes in spatial arrangement could bring changes in competitive ability of component crops. Excessive shading of legumes by cereals at more intimate crop arrangements reduced P-uptake (Wahua, 1983); N_2-fixation (Wahua and Miller, 1978; Nambiar *et al.,* 1983) and grain yield (Reddy *et al*., 1992). Mean cowpea partial LER and intercrop yield advantage were highest at 2:4 row arrangement and variations in these parameters among row arrangements were due to differences in cowpea grain yields.

Among the genotypes, the superiority of IT95K-222-14 and IT90K-277-2 was further demonstrated by their high gross returns, which resulted from their high grain yields. The higher gross monetary returns at 2:4 row arrangement compared with the other row arrangements was due to the high proportion of cowpea which products (grain and fodder) prices were higher than the companion cereal products. These results corroborate those of Singh and Ajeigbe (2002) who indicated that higher proportion of cowpea is necessary for higher net returns from cereal/cowpea intercropping systems.

It could be concluded that the productivity and monetary returns of sorghum/cowpea intercrop in the Sudan savanna could be improved by planting medium maturing cowpea genotypes such as IT95K-222-14 and IT90K-277-2 in mixture with late sorghum. The advantage of this is that the medium maturing variety of cowpea would be little affected by sorghum in view of slow initial growth rate of sorghum. In addition, the planting of 2 sorghum rows: 4 rows of cowpea in rows spaced 75 cm apart would result in higher productivity and monetary returns of sorghum/cowpea intercrop in this zone.

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Table 1: Effect of cowpea genotype and row arrangement on panicle length, 1000-grain weight, threshing percentage and grain yield of sorghum intercropped with cowpea at Minjibir, 1999 and 2000.

Treatment	Panicle length (cm)		1000-grain weight (g)		Threshing %		Grain yield (kg ha[1])		Stover yield (kg ha[1])	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Cowpea genotype (G)										
Danila	38.5	34.8	31.4	27.4	62.8	58.8	1073	1077	4415b	3510
IT90K-277-2	37.6	31.6	30.8	26.5	60.0	60.7	1127	1274	6299a	4016
IT95K-1091-3	38.1	31.0	31.3	26.8	63.9	55.4	1020	1061	3867b	3505
IT95K-222-14	37.2	32.6	30.4	29.7	64.7	61.6	1128	1213	4800ab	3872
IT96D-666	40.1	32.9	32.2	27.1	63.2	60.0	1204	1197	4428b	3758
IT96D-759	39.0	32.5	30.7	27.0	63.9	57.5	1106	1172	5126ab	3610
SE ±	1.35	1.36	0.86	1.90	2.98	2.08	91.08	79.0	532.6	271.8
Row arrangement (R)										
1S : 1C	37.8	32.8	31.9	28.0	63.4	60.8	1054ab	1139	5339	5047a
2S : 2C	37.4	33.1	30.7	27.4	62.6	56.4	1281a	1176	5317	3846b
1S : 2C	39.3	34.3	32.1	26.8	67.8	57.7	1230a	1097	5137	3016c
2S : 4C	39.2	30.1	29.7	27.6	58.3	61.1	873b	1250	3497	2873c
SE ±	1.68	1.85	0.73	0.91	3.71	1.90	72.1	87.1	660.1	199.8
G x R interaction	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sole sorghum grain yield							1411	1611		

Means followed by the same letter (s) within treatment are not significantly different at 5% using DMRT;
S = sorghum; C = cowpea; ns = not significant

Table 2: Effect of cowpea genotype and row arrangement on the yield components of cowpea intercropped with sorghum at Minjibir, 1999 and 2000.

Treatment	Number of pods/plant		Number of grains/pod		100-grain weight (g)	
	1999	2000	1999	2000	1999	2000
Cowpea genotype (G)						
Danila	20.1	45.7a	10.8d	13.6c	13.6b	14.9d
IT90K-277-2	21.3	37.6b	12.8bc	14.4abc	16.6a	18.1a
IT95K-1091-3	20.6	35.0bc	13.5ab	15.7a	13.8b	16.3c
IT95K-222-14	21.8	31.6c	14.5a	15.1ab	16.2a	18.7a
IT96D-666	20.1	32.5bc	12.1c	13.4c	13.3b	16.9bc
IT96D-759	20.3	33.6bc	12.8bc	14.1bc	14.4b	17.3b
SE ±	1.00	1.82	0.40	0.38	0.36	0.27
Row arrangement (R)						
1 S : 1 C	18.6b	35.9	11.5b	14.5	13.4b	16.5b
2 S : 2 C	20.3ab	32.9	13.0ab	13.9	15.0a	17.2a
1 S : 2 C	21.3a	37.1	12.9ab	14.7	14.8a	17.2a
2 S : 4 C	22.5a	38.0	13.5a	14.8	15.5a	17.2a
SE ±	0.72	2.56	0.45	0.44	0.29	0.14
G x R interaction	ns	ns	ns	ns	ns	Ns

Means followed by the same letter (s) within treatment are not significantly different at 5% using DMRT;
S = sorghum; C = cowpea; ns = not significant

Table 3: Effect of cowpea genotype and row arrangement the grain and fodder yields (kg ha1) of cowpea intercropped with sorghum at Minjibir in 1999 and 2000.

Treatment	Grain yield				Fodder yield	
	Sole crop		Intercrop			
	1999	2000	1999	2000	1999	2000
Cowpea genotype (G)						
Danila	1142b	1217ab	424d	660bc	2011a	583bc
IT90K-277-2	1876a	1576a	682b	999a	1667a	793a
IT95K-1091-3	1454b	1264ab	554c	772b	1510ab	510bcd
IT95K-222-14	1791ab	1370a	835a	938a	977bc	387d
IT96D-666	1261b	901c	340d	632bc	1742a	595b
IT96D-759	1380b	823c	607bc	558c	755c	443cd
SE ±	292.0	284.9	34.22	53.81	201.58	48.0
Row arrangement (R)						
1 S : 1 C			410b	604b	946b	552
2 S : 2 C			462b	675b	1065b	472
1 S : 2 C			497b	737b	1417b	623
2 S : 4 C			926a	1023a	2346a	559
SE ±			75.66	64.35	233.34	80.33
G x R interaction			ns	ns	ns	ns

Means followed by the same letter (s) within treatment are not significantly different at 5% using DMRT;
S = sorghum; C = cowpea; ns = not significant

Table 4: Effect of cowpea genotype and row arrangement on sorghum and cowpea partial land equivalent ratio (LER) and total LER

Treatment	Sorghum LER		Cowpea LER		Total LER	
	1999	2000	1999	2000	1999	2000
Cowpea genotype (G)						
Danila	0.81	0.67b	0.21d	0.34bc	1.02	1.01b
IT90K-277-2	0.84	0.79a	0.33b	0.51a	1.18	1.30a
IT95K-1091-3	0.84	0.66b	0.28c	0.39b	1.10	1.05b
IT95K-222-14	0.88	0.75ab	0.42a	0.48a	1.29	1.23a
IT96D-666	0.85	0.74ab	0.17d	0.32bc	1.02	1.06b
IT96D-759	0.87	0.73ab	0.30bc	0.28c	1.17	1.01b
SE ±	0.07	0.03	0.02	0.03	0.08	0.04
Row arrangement(R)						
1 S : 1 C	1.00	0.71	0.20b	0.31b	1.19	1.01b
2 S : 2 C	0.91	0.73	0.23b	0.34b	1.14	1.07ab
1 S : 2 C	0.87	0.68	0.25b	0.37b	1.12	1.06ab
2 S : 4 C	0.62	0.78	0.46a	0.52a	1.08	1.30a
SE ±	0.07	0.05	0.04	0.03	0.07	0.07
G x R interaction	ns	ns	ns	ns	ns	ns

Means followed by the same letter (s) within treatment are not significantly different at 5% using DMRT;
S = sorghum; C = cowpea; ns = not significant

Table 5: Effect of cowpea genotype and row arrangement on gross monetary returns (Naira/ha) from sorghum/cowpea intercrop (grain and fodder/stover) at Minjibir, 1999 and 2000.

Treatment	1999	2000	Combined
Cowpea genotype (G)			
Danila	42,160b	56,999b	49,579b
IT90K-277-2	53,184a	77,788a	65,486a
IT95K-1091-3	43,777b	60,970b	52,374b
IT95K-222-14	54,365a	70,564a	62,465a
IT96D-666	38,778b	58,387b	48,582b
IT96D-759	44,241b	53,341b	48,791b
SE ±	2180.4	2784.7	1682.0
Row arrangement (R)			
1 S : 1 C	37,009b	56,296b	46,652b
2 S : 2 C	41,932b	58,919b	50,425b
1 S : 2 C	44,402b	60,860b	52,631b
2 S : 4 C	60,997a	75,920a	68,459a
SE ±	2648.5	4108.3	2438.2

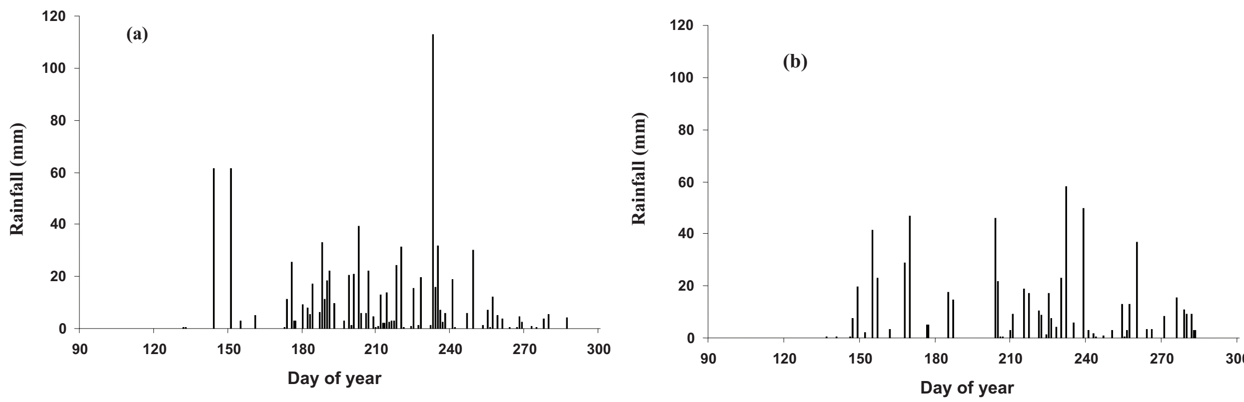

Figure 1. Daily rainfall distribution during 1999 (a) and 2000 (b).

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