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COWPEA-CEREAL INTERCROP PRODUCTIVITY IN THE SUDAN SAVANNA ZONE OF NIGERIA AS AFFECTED BY PLANTING PATTERN, CROP VARIETY AND PEST MANAGEMENT

H.A. AJEIGBE, B.B. SINGH and T.O. OSENI[1]
International Institute of Tropical Agriculture (IITA), Kano Station P.M.B.3112,
Sabo Bakin Zuwo Road Kano, Nigeria
[1]Crop Production Programme, School of Agriculture Abubakar Tafawa Balewa, University, Bauchi, Nigeria

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ABSTRACT

Cowpea [*Vigna unguiculata* (L.) Walp.] productivity in the West African sub-region is low due to attacks from insect pests, inefficient cropping system and low yield potential of local varieties. Therefore, to increase productivity, it is necessary to develop suitable agronomic practices and planting arrangement that will maximize the productivity of the improved varieties available from research institutes. A trial comprising ten cowpea–cereals cropping patterns, two cowpea varieties and two spray treatments was conducted in the Sudan Savanna of Nigeria in 1999 and 2000. The cropping patterns involved different row-to-row combinations of cowpea with millet (*Pennisetum glaucum* L. R. Br.) or sorghum (*Sorghum bicolor*). Insecticide spraying increased cowpea grain yield, threshing percentage, harvest index, gross monetary returns significantly under all planting patterns and varieties, but had no significant effect on growth parameters. Sole cowpea produced significantly higher gross monetary returns than other treatments. Cowpea-sorghum systems had higher productivity than cowpea-millet systems. Gross returns on total produce from sole crop cowpea with insecticide spray were almost doubled of the returns from sole cereals. Overall, 2 rows of sorghum : 4 rows of cowpea (2S:4C) system using improved cowpea with insecticide spray, was identified the most promising considering the socio-economic conditions of the resource poor farmers.

Key Words: Cropping systems, Nigeria, *Vigna unguiculata*

RÉSUMÉ

La productivité du niébé (*Vigna unguiculata* L.) en Afrique de l'ouest est faible à cause des attaques d'insectes, du système de culture inefficace et le faible potentiel en rendement des variétés locales. Par conséquent, pour augmenter la productivité, il est nécessaire de développer des pratiques agricoles convenables et des arrangements de plantation qui maximiseront la productivité des variétés améliorées existantes dans les instituts des recherches. Un essai comprenant 10 variétés de niébé et des systèmes de culture des céréales et deux traitements de pulvérisation était conduit dans les savanes Sudanaise du Nigeria en 1999 et 2000. La tendance de culture impliquant différentes combinaisons de culture en lignes du niébé avec millet (*Pennisetum galucum* L., R. Br) et sorgho (*Sorghum bicolor*). La pulvérisation de l'insecticide augmenta significativement le rendement du niébé, le pourcentage de la batteuse, l'indice de récolte, le gain monétaire brut sous toutes les tendances de culture et variétés, mais n'a pas eu d'effet significatif sur les paramètres de croissance. Le niébé seul a produit des grains significativement élevés par rapport aux autres traitements. Le système niébé sorgho avait une productivité élevée compare au système du niébé -millet. Le gain brut sur la production totale du niébé en monoculture avec une pulvérisation d'insecticide était presque le double du gain des céréales en monoculture. En général, le système comprenant deux lignes de sorgho, 4 lignes de niébé (2S :4C) utilisant la variété améliorée avec insecticide pulvérisé, était identifie comme le plus prometteur eu égard aux conditions socio-économiques des pauvres fermiers.

Mots Clés: Systèmes de culture, Nigeria, *Vigna unguiculata*

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] originated in Africa and is an integral part of the traditional cropping systems throughout the continent, particularly in the semi-arid regions of West Africa (Steele, 1972), where soils are poor and rainfall limited (Mortimore *et al.*, 1997). Cowpea cultivation contributes to soil fertility, and provides food, fodder and cash to resource poor farmers.

However, the actual farm grain yields obtained in the West African sub-region are very low (0.025- 0.300 t ha^{-1}), due to severe attacks from an extensive pest complex (Rachie, 1985), and low use of inputs. Also, most of the farmers still grow cowpea in traditional intercropping systems with cereals (Singh and Ajeigbe, 2001) which cause shading of cowpea. Farmers would welcome modified intercropping systems that would guarantee adequate cereal production while increasing cowpea production. Thus, improving cowpea yields under these intercropping systems, without reducing cereal yields, is the challenge for cowpea researchers. The International Institute of Tropical Agriculture (IITA), in collaboration with National Agricultural Research Systems (NARS) is addressing this challenge by developing improved high yielding varieties that combined resistance to biotic and abiotic stresses and packaging them in improved cropping systems. These varieties with higher grain yields, early maturity, and resistance to several diseases and insect pests are available (Singh and Ntare, 1985; Singh *et al.*, 1997; Singh and Ajeigbe, 2001; Singh *et al.*, 2002) and are widely adapted to the wide range of ecologies. Concerted research on agronomic practices and cropping systems to optimise productivity of the improved varieties are also underway to ensure high productivity under the low input use by resource poor farmers.

The objective of this research was to evaluate selected cowpea-cereals planting patterns and the effect of cowpea variety and pest management, to identify suitable cowpea-cereal system for the resource poor farmers in the savanna zone of Nigeria.

MATERIALS AND METHODS

Experimental sites. The experiments were conducted during the 1999 and 2000 wet seasons at the IITA/Institute of Agricultural Research Farm, Minjibir, Kano State in North central Nigeria (12^{0}08' N 8^0 40'E). The soil was sampled from the experimental plot before land preparation to determine the soil fertility status.

Land preparations, planting and experimental design. The field was prepared by double harrowing with a tractor and application of manure at the rate of 1ton ha^{-1} and compound fertiliser NPK (15:15:150 at the rate of 100 kg ha^{-1} by broadcast. Ridges were then made by a tractor drawn ridger at 75 cm apart and crops manually planted on ridges after a good rain the previous day. Within row spacing of cowpea, sorghum and millet were 20 cm, 25 cm and 100 cm, respectively. Three seeds of cowpea were planted per hill and thinned to two plants per hill at 3 weeks after planting (WAP). Six to ten seeds of millet or sorghum were planted per hill, and thinned to 3 or 2 plants per hill respectively. In 1999, millet and sorghum were planted on the 20th June and cowpeas were planted on the 5 July. In 2000 millet and sorghum were planted on the 17 June and cowpeas were planted on the 6 July. The plots were weeded manually at 3, 5 and 8 WAP. Urea at the rate of 50 kg ha^{-1} was applied to the cereals as top dressing at 4 WAP.

The trials were laid out in a split-split plot design with four replications. Main plots were the insecticide (Cypermethrin+dimethoate EC at 30g + 250g ai ha^{-1}) spray treatments, which consisted of insecticide sprays (2-3) of the cowpea and a no-spray.

The improved cowpea (IT90K-277-2) was sprayed twice with insecticide at flowering and podding while the local variety (Dan Ila) was sprayed three times at vegetative, flowering and podding stages. Subplots consisted of the cowpea varieties, which included an improved variety and a local. The sub-sub plots consisted of 10 planting patterns as follows:

1. Sole Cowpea
2. 1row millet : 4 row cowpea (1M:4C)
3. 2 row millet:4 row cowpea (2M:4C)
4. 2 row millet:2 row cowpea (2M:2C)
5. 1 row millet:1 row cowpea (1M:1C)
6. 1 row sorghum:4 row cowpea (1S:4C)
7. 2 row sorghum:4 row cowpea (2S:4C)
8. 2 row sorghum:2 row cowpea (2S:2C)
9. 1 row sorghum:1 row cowpea (1S:1C)
10. 1 row sorghum+millet: 1 row cowpea. (1MS:1C). Millet being planted on alternate hill of same row as sorghum.

Sole crop of millet and sorghum were included in each replication as check. The gross plot size was 4.5 m x 7 m, while the net plot for yield estimate was 22.5 m^2

Data collection and analysis. The number of days after planting (DAP) to when at least 50% of the plants in the plot had at least one flower was recorded as days to 50% flowering. The DAP to when about 90% of pod present on the plants had dried was recorded as days to 90% pod maturity. Usually, first pod harvest was done on this day. The difference between days to 90% pod maturity and day to 50% flowering was calculated as time taking from flowering to maturity, i.e., days to ripening.

For cereals, the lengths of 10 randomly picked panicles per plot were measured and the average was recorded as panicle length per plot. Heights of four randomly picked plants per plot were noted at full flowering and the average recorded.

Mature cowpea pods were harvested from the net plots and sun dried to constant weight. The cowpea pods were threshed and the grain was weighed. The stover left after pod harvests were cut and sun-dried until constant weight. The panicles harvested per plot were sun dried until constant weight. The panicles were threshed and the grain sun-dried and weighed as cereal grain weight. The cereal stalk left after cutting of the panicles was sun-dried and weighed. 100 cowpea seeds were randomly taken from each plot and weighed.

Threshing percentage for cowpea and cereals were computed by dividing seed weights by pod/ panicle weights and multiplying by 100. The grain weight as a percentage of the total biomass produced was recorded as harvest index.

After threshing the sorghum, which was usually the last crop to be harvested, the prices of the various grains and stover were recorded from three markets in and around Kano and the mean price were multiplied by plot yields to give economic value of the produce. Data were analysed using Genstat 5 release 3.2. The Standard Errors of differences of means (SED) were calculated at 5% level.

RESULTS

Soil analytical results and rainfall. The soil pH (water) was 6.3, available phosphorus (P) was high 24.7 mg kg^{-1} while organic carbon was 3.9 mg kg^{1} which was low. The soil was loamy sand and classified as hypothermic, typical ustipsammet (Oluwasemire *et al.*, 2002).

In both years, the rain started in May peaking in August and ending in October, with a total of 603 mm in 1999 and 487 mm in 2000; and very similar distributions (Fig. 1).

Plant growth and development. Insecticide application resulted in earlier flowering, maturity and ripening of cowpea compared to the no-spray treatment (Table 1). Cowpea variety IT90K-277-2 flowered and matured earlier than Dan Ila, but days to ripening was similar for these varieties. The planting pattern had no significant effect on the flowering, maturity and ripening of cowpea.

Cereals phenology was not affected by spraying of cowpea, and the cowpea varieties. Days to heading, flowering, maturity and ripening were earlier in millet than sorghum (50, 53, 77 23 vs 78, 82, 126 and 50, respectively). Significant differences ($P<0.05$) were observed for panicle length and plant heights between millet and sorghum.

Cereal productivity. Spray treatment of cowpea and cowpea variety had no effect on grain and stalk yields of cereal (Table 2). Sorghum yielded more than millet with same planting pattern. Planting pattern significantly affected the stalk yields of cereals with the 1M:1C (4691 kg ha^{-1}) and 1MS:1C (4512 kg ha^{1}) producing significantly higher cereal stalk yield than other planting pattern.

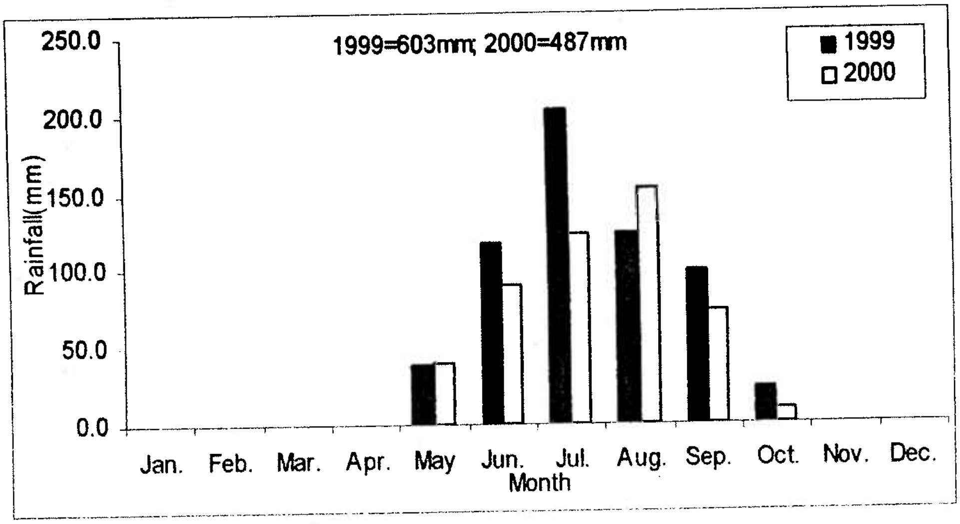

Figure 1. Monthly rainfall (mm) at Minjibir in 1999 and 2000.

TABLE 1. Effect of insecticide spray, cowpea varieties and planting pattern on plant growth and phenology of cowpea and cereal at Minjibir, Nigeria

Spray treatments	Cowpea				Cereals				
	Flowering	Maturity	Ripening	Heading	Flowering	Maturity	Ripening	Panicle length (cm)	Plant height (cm)
Spray	51.9	76.7	24.8	63.7	66.2	94.6	29.7	34.9	275
No-spray	52.8	79.1	26.3	63.2	66.3	94.8	29.6	34.4	280
LSD (5%) .	0.80	1.16	1.04	NS	NS	NS	NS	NS	NS
Variety									
IT90K-277-2	47	72.8	26	63.4	66.1	90.7	29.1	34.6	276
Dan Ila	57	83.0	26	63.4	66.4	98.7	30.2	34.6	279
LSD (5%)	0.74	1.31	NS	NS	NS	0.40	NS	NS	NS
System									
1M:1C	52.2	78.1	25.9	49.9	53.3	76.7	23.4	44.2	265
1M:4C	51.7	77.9	26.2	49.8	53.3	76.4	23.1	41.7	262
2M:2C	52.3	78.1	25.8	49.7	53.3	76.4	23.1	43.8	272
2M:4C	52.1	77.8	25.7	49.6	53.2	76.6	23.4	41.8	263
1MS:1C	52.9	77.8	24.9	-	-	-	-	32.9	269
1S:1C	52.5	77.4	24.9	77.8	82.4	126.4	43.9	27.9	293
1S:4C	52.7	78.1	25.4	77.2	82.4	126.4	43.6	27.3	290
2S:2C	52.3	77.6	25.4	77.7	82.3	126.3	44.1	28.3	286
2S:4C	52.4	78.1	25.6	77.5	82.4	126.4	43.9	23.9	298
Sole cowpea	52.3	78.1	25.8						
LSD (5%)	NS	NS	NS	1.20	0.41	0.55	3.04	2.30	12.9

Flowering, maturity and heading refers to time taken (in days) to attain 50% of that physiological stage

Cowpea productivity. On average, the spraying of cowpea increased cowpea grain yield by 657 kg ha-1 (Table 2). IT90K-277-2 produced higher mean grain yields than Dan Ila. The spray by systems interaction was significant for cowpea grain yield in both years (Table 3). Sole cowpea, when sprayed, produced the highest mean cowpea grain yield of 1916 kg ha-1 and was significantly more than other treatments. Cowpea yield with 1M:4C spray was comparable with 1S:4C spray, but significantly higher than other treatments. There was no significant difference between 1S:4C and 2M:4C and 2S:4C.

The 2:2 treatments produced significantly higher grain yield than the 1:1 treatments under spray but were comparable under no spray treatments. Spraying of cowpea significantly reduced fodder yield in 1999, while in 2000, fodder produced by cowpea in no-spray treatments (959 kg ha-1) was not significantly different from the spray treatments (739 kg ha-1) (Table 2). There was significant difference among the systems for mean fodder yield of cowpea in the two years with sole cowpea producing the highest fodder and 1S:1C the lowest.

Yield components. Insecticide spray of cowpea significantly affected the threshing percentage and harvest index of cowpea (Table 4). The sprayed plots produced higher threshing percentage (78) and harvest index (42) than no-spray treatment (68 and 13% respectively). Similarly the cowpea variety IT90K-277-2 produced higher threshing percentage (76) and harvest index (36%) than Dan Ila (70 and 23%) respectively. Significant differences were observed for threshing percentage

TABLE 2. Cowpea and cereal grains and stover yields (kg ha^{-1}) from different spray treatments, cowpea varieties and planting system at Minjibir in 1999 and 2000 in Nigeria

Spray Treat.	Cereal*		Cowpea grain			Cowpea stover		
	Grain	Stover	1999	2000	Combined	1999	2000	Combine
Spray	1899	3303	902	740	821	1116	739	928
No-spray	1947	3148	104	223	164	1718	959	1338
LSD (5%)	NS	NS	115	113	62	205	NS	116
Variety								
IT90K-277-2	1926	3120	595	562	571	1499	770	1135
Dan Ila	1921	3331	412	401	406	1335	928	1132
LSD (5%)	NS	NS	83	72	49	NS	81	NS
System								
1M:1C	1435	4691	336	222	279	969	356	662
1M:4C	853	1744	661	697	679	1793	1093	1443
2M:2C	1839	3615	379	321	350	1142	561	452
2M:4C	1225	1732	571	543	557	1573	1119	1346
1MS:1C	2638	4512	235	208	221	916	302	609
1S:1C	3218	3615	277	220	249	582	310	446
1S:4C	1310	1980	643	599	621	1790	1067	1428
2S:2C	2828	3740	333	324	328	955	465	710
2S:4C	1963	2709	519	521	520	1534	944	1239
Sole cowpea			1080	1160	1120	2916	2274	
LSD (5%)	280	487	125	125	87	403	209	225
Sole Millet		2603	4947					
Sole Sorghum	3734	6432						

* Cereals 1999 and 2000 combined

TABLE 3. Effect of planting systems, spray treatments and cowpea varieties on cowpea grain yield (kg ha^{-1}) at Minjibir (Mean of 1999 and 2000), in Nigeria

Variety	IT90K-277-2		Dan Ila		Mean	
System	Spray	No-spray	Spray	No-spray	Spray	No-spray
1M:1C	430	165	458	65	444	115
1M:4C	1225	379	1063	36	1152	208
2M:2C	552	211	573	64	562	137
2M:4C	1089	243	865	29	978	136
1MS:1C	331	102	319	133	325	117
1S:1C	396	139	367	93	382	116
1S:4C	1172	287	901	124	1037	205
2S:2C	574	178	496	66	535	122
2S:4C	1047	224	721	89	884	157
Sole cowpea	2308	521	1524	129	1916	325
LSD (5%)		178			127	

TABLE 4. Selected yield attributes of cowpeas and cereals as affected by spray treatments, cowpea varieties and planting systems at Minjibir, in Nigeria

	Threshing %		Harvest Index %		Branch/ plant	Seed/ pod	Pod/ plant	100 seed (g)	
Crop	Cowpea	Cereal	Cowpea	Cereal	Cowpea	Cowpea	Cowpea	Cowpea	Cereal
Spray treatment									
Spray	78	67	42	27	4.4	11.6	17	16.4	1.9
No-spray	68	68	13	29	4.4	10.6	11	16.1	1.9
LSD (5%)	2.03	NS	2.81	1.06	NS	0.30	4.35	NS	NS
Variety									
IT90K-277-2	76	68	32	28	3.5	11.3	13.2	17.3	1.9
Dan Ila	70	68	23	28	5.3	10.9	14.2	15.2	1.9
LSD (5%)	1.78	NS	2.26	NS	0.50	0.85	NS	0.57	NS
System									
1M:1C	72	67	27	24	3.9	10.6	11.0	16.1	0.8
1M:4C	73	67	27	28	4.6	11.4	16.7	16.9	0.8
2M:2C	72	68	27	28	4.3	10.9	14.7	16.2	0.8
2M:4C	72	68	25	34	5.0	11.2	13.4	16.2	0.8
1MS:1C	75	61	29	24	3.8	10.8	9.5	16.1	1.1
1S:1C	76	67	32	29	3.9	10.6	11.5	15.6	3.3
1S:4C	70	67	26	27	4.6	10.9	12.6	16.4	3.1
2S:2C	75	71	28	28	4.4	11.9	13.9	16.6	3.2
2S:4C	74	71	25	30	4.9	11.4	18.9	16.0	3.1
Sole cowpea	72		26		4.5	11.1	14.6	16.4	
LSD (5%)	3.92	4.54	3.06	3.04	0.50	1.21	3.88	0.74	0.14

of cowpea between the systems with 1S:1C (76%) providing significantly higher value than 1S:4C (70%), 2M:2C, 2M:4C and sole cowpea (72%). Significant differences were observed among the systems for cowpea harvest index. Planting pattern 1S:1C (32%) produced significantly higher harvest index of cowpea than 2M:4C (25%), sole cowpea, 2S:4C and 1S:4C (26, 25 and 26%, respectively).

Insecticide spraying of cowpea and cowpea varieties had no significant effect on the threshing percentage of companion cereals in intercropping. However, there were significant differences between the systems for threshing percentage and harvest index of cereals. Threshing percentage and harvest index of millet were significantly lower than that of sorghum. The harvest index of cereals under spray (27%) was significantly lower than the mean under no-spray (29%). Cowpea varieties, however, had no significant effect on the harvest index of the cereal component of the systems.

Gross monetary returns. Spraying of cowpea increased the monetary returns of cowpea-cereal systems (Table 5). The gross monetary returns on cowpea grains, total grains and total produce

TABLE 5. Effect of insecticide spray, cowpea variety and planting system on the gross returns (Naira* ha^{-1}) of the produce at Minjibir, in Nigeria

Year	Grain		Stover		Total		
	Cowpea	Cereal	Cowpea	Cereal	Grain	Stover	Produce
1999	20133	17678	7085	2832	37811	9917	47728
2000	21183	33875	6793	1859	55058	8652	63710
LSD	NS	1231	NS	564	375	NS	5953
Spray treatment							
Spray	34322	25358	5748	2409	59680	8157	67838
No-spray	6994	26195	8130	2281	33189	10411	47728
LSD	2604	NS	789	NS	3817	929	3749
Variety							
IT90K-277-2	24263	25801	6828	2261	50065	9089	59154
Dan Ila	17053	25752	7050	2429	42805	9479	52284
LSD	2039	NS	NS	NS	2764	NS	2931
System							
1M:1C	11610	24321	3846	3848	35931	7693	43624
1M:4C	28562	12792	8855	1361	41354	10216	51570
2M:2C	14625	27395	5100	2817	42020	7917	49937
2M:4C	23362	17767	8410	1285	41130	9695	50825
1MS:1C	9260	38197	3496	3614	47457	7109	54566
1S:1C	10388	46329	2695	3607	56716	6301	63018
1S:4C	26032	19539	8741	1624	45572	10366	55937
2S:2C	13767	42471	4246	3040	56239	7285	63524
2S:4C	21837	28955	7613	2259	50792	9872	60665
Sole cowpea	47136	-	16388	-	47136	16388	63525
LSD	3671	3453	1293	422	5017	1344	5285
Sole millet		39525		3539	39525	3539	43064
Sole sorghum		56675		4978	56675	4978	61653

*Naira : US$ 1 = Naira 110

(grains and stover) were significantly increased by spraying of cowpea. However, spraying of cowpea did not affect the gross returns on cereal grains and stover, while it reduced the returns on cowpea stover. Cowpea variety also affected the gross returns on cowpea grains total grains as well as total produce. The improved variety IT90K-277-2 gave higher returns than the local variety (Dan Ila). Significant differences were also observed between planting patterns for gross returns. Systems involving sorghum produced higher values than the same planting patterns involving millets. Sole cowpea, 1S:4C, 1M:4C and 2S:4C gave significantly higher gross monetary returns on the total produce than 1M:1C 2M:2C and 1MS:1C respectively under sprayed treatment.

DISCUSSION

Plant growth and development. Flower bud and flower abortions were reduced when cowpea was sprayed and this probably accounted for earlier flowering in the spray plots compared to no-spray treatments. Sorghum took longer to boot, flower, ripen and mature than millet, but these were not affected by insecticide spraying of the cowpea nor were they affected by the cowpea varieties. The local sorghum was taller than the local millet, while local millet had longer panicles than sorghum. Panicle length of millet and sorghum seemed to increase with increased proportion of cereals in the systems; this was more pronounced with millet.

Productivity of cowpea-cereal systems. The trial indicated that the use of insecticide (2 to 3 sprays) should be encouraged to increase grain productivity of cowpea in cowpea-cereal systems. This was also the conclusion of several other workers in the past (Alghali, 1991; 1993; Tarawali *et al.*, 2002). The data in this trial confirmed that IT90K-277-2 has higher grain yield potentials and is also more insect resistant than the local variety (Dan Ila). This resulted in its higher yield than Dan Ila in both spray and no-spray conditions, despite Dan Ila receiving more insecticide spray because of its later maturity and aphids/thrips attacks. Dan Ila, a local landrace, was likely to have been selected under intercropped conditions because cowpea is traditionally planted under intercrop (Steele, 1972). This variety, however, did not show superior performance in intercrop over IT90K-277-2, an improved dual variety especially when insect pressures were high. Ntare (1990) recommended development of photoperiod-insensitive cowpea cultivars with improved plant types and a shorter time to maturity, as these improve cowpea performance in cowpea-cereal intercrops. The improved cowpea variety, IT90K-277-2 perfectly fits into these criteria.

Cowpea grain yields were generally reduced by intercropping as observed by several workers (Reddy *et al.*, 1992; Bandyopdhyay and De 1986), but the extent of reduction was minimal in the 2 cereal: 4 cowpea systems. Cowpea grain yield from 2 cereal: 4 cowpea in this trial was less stressed than 1 cereal: 1 cowpea, 2 cereal:2 cowpea and 1 cereal:4 cowpea. Clark and Myers (1994) also noted that cowpea in narrow strips (2:2) yielded average of 46% less than in wide strips (2:4) or in monocrop. They attributed the reduction to the fact that in the narrow strips, both of the cowpea rows were bordered by non-legume, and therefore, competitions were greater than in the wide strips. Therefore, to boost cowpea productivity where farmers can not practice sole cropping, 2 cereal:4 cowpea planting pattern should be recommended. Singh and Ajeigbe (2002) and Singh *et al.* (2004) noted that this system might also be more suitable and help maintain soil fertility because two-thirds of the area is legume and only one-third is cereal.

The reduction in fodder yield, as a result of insecticide spraying of cowpea was partly because of more grain yield and partly because of the delay in cutting of the fodder due to multiple grain harvest resulting in the lost of leaves due to senescence. This affects both quality and quantity of stover. This was also the conclusion of Tarawali *et al.* (1997) and Tarawali *et al.* (2002). The improved cowpea (IT90K-277-2) produced more grain yields than Dan Ila, while for fodder yields both varieties were similar. Thus, IT90K-277-2 should be preferred because of its superior grain as well as fodder yields.

As expected, cereals grain yields in intercropping systems were not affected by insecticide spraying of the cowpea, nor were they affected by the cowpea varieties because insect attacks on cereals was minimal in this location and the sprayings of cowpea were done while the cereals were still at vegetative stage. As expected, grain yields of cereals in the system differed according to the percentage of the cereals in the mixtures. Cereal grain yields obtained from the mixtures generally had higher land equivalent ratios than their sole counterparts.

Generally, sorghum-based systems produced higher biomass than millet-based systems. This is similar to observations made by van Ek *et al.* (1997) in farmer's fields in this region. The higher biomass observed were mainly as a result of the higher biomass produced by the sorghum component of the systems. The cropping pattern had significant effect on cowpea and cereal stovers. High cereal proportion seriously affected cowpea fodder yield because of shading and other competition effect while higher cowpea proportion reduced the cereal stalk yield as expected.

Yield components. Insecticide spraying improved the threshing percentage and harvest index of cowpea as a result of increased pod filling, i.e., increase in seed/pod, pod/plant and grain yield as observed in the trial. The damage caused by insect pests like Maruca pod borer and the pod sucking bugs in no-spray cowpea plots were reduced or eliminated when the plants were sprayed, thereby increasing the threshing percentages. Overall, IT90K-277-2 had higher threshing percentage and harvest index than Dan Ila. This was especially evident in the no-spray treatments indicating that IT90K-277-2 was more resistant to insect pests than Dan Ila. Where cereal proportions were high [1:1], the harvest index was higher indicating that higher competitions affected the cowpea fodder yields in intercropping. This was a further proof of the higher competition obtained in these intercropping systems (1:1 and 2:2) compared to the strip intercropping and sole cropping of cowpea. This was similar to results obtained by Willey (1985) in sorghum-pigeon pea intercropping systems, where he concluded that sorghum competition suppressed early vegetative growth of pigeon pea and therefore harvest index of intercropped pigeon pea were increased.

However, cowpea varieties did not significantly affect the cereal harvest index and the cereal stalk yield. Cereal harvest indices were also significantly affected by planting systems. The differences arose from both the cereal crops and the composition. It was interesting to note that in millet systems, the cereal harvest index of 1M:1C was significantly lower than other planting pattern including 2M:2C. This showed that the stalk yields in this system were higher compared to other systems. In the 1 cereal : 1 cowpea systems, the cereal rows were bordered by cowpea allowing for lower competition for the cereals in the vegetative stage and, therefore, maximum stalk production. Sorghum had lower harvest index than millet because of the higher stalk yields of sorghum.

IT90K-277-2 is a semi-erect medium maturing cowpea variety and was expected to have fewer branches per plant as was the case in this trial, compared to Dan Ila, a semi-spreading medium maturing land race. At higher cereal proportion of 1:1 and 2:2, the branch per plant was significantly less than other treatments. This confirmed the results of Egharevba (1984) who noted that the competition imposed by sorghum on cowpea when intercropped not only affected leaf area development and grain yield but also dry matter and a number of morphological characters such as plant heights and number of branches per plant. However, the 2 cereal: 2 cowpea arrangement had higher number of cowpea branch per plant than 1 cereal: 1 cowpea showing that there was less competition (especially for light) under this system than the 1 cereal:1 cowpea.

Spraying of the cowpea plants did not affect the resulting 100 seed weight implying that the higher grain yield obtained from the sprayed treatments were as a result of higher number of pods per plant and seeds per pod both of which were significantly higher under sprayed treatments.

Gross monetary returns. Mean gross returns on total grains from the improved cowpea IT90K-277-2 based systems were significantly higher than that from the local Dan Ila cowpea based systems. This was mainly due to differences in the returns on cowpea grains of these systems, as there were no significant differences in the returns on cereal grain between the cowpea varieties.

Sorghum–cowpea system had significantly higher returns on total grain than millet-cowpea systems of similar planting pattern because of the higher yield of sorghum compared to millets and not the effect of the cereals on the cowpea. This is in agreement with van Ek *et al.* (1997) who from a cropping systems study in this area, noted that millet-based cropping systems were lower yielding than sorghum-based cropping systems.

When the effects of spray and cowpea variety were separated, it was found that all the systems under spray had higher returns on total grains than on sole millet and sole sorghum, irrespective of the cowpea varieties and years except for 1 M:1C which had less value than sole sorghum. It, therefore, means that gross returns on total grain from sole cowpea or any of the cowpea-cereal intercrop sprayed system were higher than returns on grain of sole cereal. This is because cowpea is a high value crop compared to cereals and, therefore, it should be encouraged in the system. This is not only for the agronomic and soil fertility benefits, but also for higher financial returns to resource poor farmers. Under no-spray conditions, it was better to have higher cereal proportion (50%) and to use sorghum because of the higher productivity. Sole cowpea, using the improved variety (IT90K-277-2) and sprayed, was the most productive in terms of total grain value. This was followed by 2S:4C and then the 2S:2C systems. Spraying of cowpea should, therefore, be encouraged in the system for farmers to obtain maximum benefit from their cowpea-cereal systems. Gross returns of the total products from IT90K-277-2 based systems were significantly higher than the value of the total products from Dan Ila based systems. Here again, cowpea grain was the determinant of higher returns on total product.

Cowpea crop from the 2 cereal :4 cowpea was less stressed than the 1 cereal:1 cowpea and 2 cereal:2 cowpea systems and, therefore, to increase cowpea productivity in intercropping, 2:4 will be preferred to other systems. Singh and Ajeigbe (2002) stated that farmers had great interest in this system because it provides sufficient cereal for home consumption and a large amount of additional cowpea, part of which can be used as nutritious food at home and for cash. Strip cropping also ensures maximum benefit from minimum use of inputs. The 1 tonne manure ha^{-1} used in this experiment can be generated in the homestead by the farmers who are already used to keeping ruminants. The higher proportion of legumes ensures reduction in nitrogen fertiliser needs. Three bags of fertiliser ha^{-1} (2 of NPK and 1 of urea for top dress on cereals) are, therefore, recommended compared to six bags for sole sorghum (Singh *et al.*, 1983). The 2:4 system also encourages rotation of cereal and cowpea rows, the top dressing of cereal rows with urea and insecticide spraying of cowpea. This system is, therefore, likely to be more sustainable and favourable to the long time soil fertility maintenance, it is also beneficial to crop-livestock integration because of improve quality of resulting residue which has higher legume composition than local practice.

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