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Effects of preceding maize (*Zea mays*) and cowpea (*Vigna unguiculata*) in sole cropping and intercropping on growth, yield and nitrogen requirement of okra (*Abelmoschus esculentus*)

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SUMMARY

Field experiments were conducted on Alfisols in Nigeria between 1991 and 1993 to determine the residual effect of maize (*Zea mays*) and cowpea (*Vigna unguiculata*) on the growth, pod yield and N response of a succeeding okra (*Abelmoschus esculentus*) crop. Cowpea and maize were grown alone with 30 and 60 kg/ha of N, P and K, respectively, or intercropped with 60 kg/ha as a basal dressing. The preceding crops had a significant effect on soil nutrient changes, okra growth and yield, and N response of okra. Cowpea increased the N, P and K status of the soil in both sole and mixed stands, compared with sole maize. Leaf area, pod weight and marketable pod yield of okra after sole cowpea or the maize/cowpea intercrop were all significantly higher than after sole maize. Although the application of nitrogen to succeeding okra promoted growth and increased pod yield, this was not accompanied by an increase in the pod yield of okra after sole cowpea or the maize/cowpea treatment beyond 45 kg N/ha. The beneficial effects of the preceding maize/cowpea intercrop on soil fertility, okra pod yield and amounts of N required for okra were partly due to the higher rate of basal nutrients applied as compared to the effects following sole cowpea.

INTRODUCTION

In tropical Africa, the importance of vegetables in traditional agriculture lies in the role they play in its ecophysiology (Olasantan 1988*a*; Ikeorgu & Ezumah 1991) and in improving nutritional standards by adding proteins, vitamins and minerals to the mainly starchy diet of the people. They are also important for generating income for farmers, and for various medicinal and industrial purposes. It has been realised that any intercropping technology which excludes these essential crops will be rejected by farmers (Ikeorgu *et al*. 1989; Olasantan 1992).

In previous papers, Olasantan (1985, 1991) and Olasantan & Aina (1987) reported that intercropping of cowpea (*Vigna unguiculata*) with okra (*Abelmoschus esculentus*) or tomato (*Lycopersicon esculentum*) leads to the production of higher yields compared with sole cropping, and that the system productivity is better at lower than at higher N rates. This paper reports further on the effects of pure and intercropped stands of cowpea on a succeeding okra crop.

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Multiple cropping has generally proved to be effective in improving farm productivity and yield stability, and thus in the sustainability of traditional agriculture. One promising system is that of cereal and grain legume crops grown either in pure or mixed stands followed by vegetables. The poor fertility status of most tropical soils necessitates the use of fertilizers for such intensive cropping. The importance of N as a yield limiting factor in most Nigerian soils has been reported (Agboola & Fayemi 1972; Lucas 1986). However, scarcity and steep rises in the price of N fertilizers have encouraged a search for alternative sources of nitrogen. This has led to renewed interest in biological N fixation and the transfer of the N fixed, either directly to companion non-legume crops or to those grown subsequently as a residual transfer. The beneficial effects of legumes on the productivity of succeeding cereal crops have been described (Jones 1974; Ahlawat *et al*. 1981; Kumar Rao *et al*. 1983).

Cowpea (*Vigna unguiculata*) is an important grain legume crop in tropical Africa. In Nigeria, it is planted on a total land area of 4·2 million ha (55% of the world area for the crop) (Anon. 1990). It is grown most often as an intercrop with maize (*Zea mays*), sorghum (*Sorghum bicolor*) or millet (*Pennisetum glaucum*), although in the humid zone mixtures with maize are the most common combinations. Cowpea is also grown occasionally as a sole crop. However, adequate information is lacking on the residual effects of either sole or intercropped cowpea on the growth and yield of a subsequent vegetable crop. This study was, therefore, carried out to determine the residual effects of cowpea grown either alone or intercropped with maize on the growth, yield and N response of okra.

MATERIALS AND METHODS

Experiments were conducted on Alfisols at the College Research Farm, Ila-Orangun (8° 0′ N, 4° 54′ E), South-Western Nigeria during 1991/92 and 1992/93. The soil had a pH of 5·6, 0·87% organic carbon, 0·05% total N, 5·7 mg/kg available P (Bray's P1) and 2·4, 32·2 and 10·4 mmol/kg exchangeable K, Ca and Mg, respectively.

A split-plot design was used, with preceding crops in the first year as the main plot treatments and N rate applied to a succeeding okra crop in the second year as the subplot treatments. The three main treatments sown during the first year consisted of sole maize cv.TZESR–W, sole cowpea cv. IT 84E–124 and a maize/cowpea intercrop. The preceding crops were grown in three complete randomized blocks on plots measuring 12·8 × 5·4 m. The crops were sown on the flat after ploughing and harrowing on 9 August 1991 and on 15 August 1992 in two adjacent plots. Maize and cowpea were sown using 90 × 30 cm spacing, giving a population density of 42500 plants/ha for each crop, in sole stands. In the intercropping treatments, a replacement series design was used to formulate component populations. Both crops were grown using 90 × 60 cm spacing, giving a population density of 21250 plants/ha for each crop, in a constant arrangement of one row of maize bordering one row of cowpea, with 45 cm between all rows. Two weeks after emergence, a basal dose of 60 kg/ha of N, P and K was applied to all plots containing maize and 30 kg/ha to cowpea grown alone as 15:15:15 N:P:K compound fertilizer. The crops were grown under rainfed conditions. All plots were hand-weeded and foliar and pod insect pests of cowpea were controlled with regular sprays of 600 ml/ha of Azodrin 60 (containing 600 g/l water soluble chemical (WSC)). Dry shoot weight was determined at peak vegetative development (8 weeks after emergence (WAE)). Harvesting of cowpea pods started in early November and maize was harvested in mid-December, and their residues were spread uniformly in each treatment plot.

During the 1992 and 1993 rainy seasons, the whole experimental site was cleared and tilled manually, and soil samples (0–20 cm depth) were collected based on the previous treatments for estimating fertility status. On 8 May 1992 and 5 May 1993, the whole site was planted with okra (cv. NHAe 47–4) using 90 × 30 cm spacing to give a population density of 42500 plants/ha. Each of the former main plots was divided into three subplots measuring 5·4 × 3·6 m. The subplots, selected randomly, were then given either 0, 45 or 90 kg N/ha as sulphate of ammonia drilled between rows at 2 WAE. A basal dressing of 45 kg/ha each of K_2O and P_2O_5 as muriate of potash and single superphosphate, respectively, was applied to all plots receiving N treatments. All the plots were kept free of weeds manually and clear of foliar pests by applying Furadan 10% (carbofuran) regularly. Plant height (from soil level), leaf or branch number and leaf area were recorded on 56-day-old plants. Leaf area was estimated from the equation: $Y = 115X - 1050$ (Asif 1977), where Y = leaf area (cm^2) and X = the length of midrib (cm). Green immature pods were harvested every 4 days starting from mid-July and their numbers and weights were recorded immediately. Pods without blemish and at least 3·5 cm in length were regarded as marketable. All harvests were made from the centre four rows in all subplots, guard rows being discarded to avoid edge effects.

For each year, data from preceding crops were analysed on the basis of the randomized, complete block design. The results from a succeeding okra crop in 1992 and 1993 were analysed separately for a split-plot design in randomized blocks. After analyses of variance, the differences between treatment means were compared by the least significant difference (L.S.D.) test at 5% probability values.

RESULTS AND DISCUSSION

Studies on preceding crops

Grain and dry matter yields of the preceding crops were as expected in 1991 and 1992 (Table 1), with maize growing well in both pure and mixed stands.

The soil fertility in the top 20 cm layer was compared between the previous crops shortly before the planting of okra in 1992 and 1993 (Table 2). Sole cowpea and the maize/cowpea intercrop improved the soil fertility (e.g. total N) by 26–35% in both years compared to sole maize, whilst cowpea alone was the most efficient in enriching total N and available P. This is probably because of the biological fixation of N, increased available P in the humic substance excreted by cowpea roots and decomposition of its residues after harvest, and the transfer of the N fixed and then P released by the legume directly into the soil (Swaby & Sherber 1958; Ahlawat *et al.* 1981; Stern 1993).

Effect of preceding crops on okra

The preceding crops showed significant differences in their effects on leaf area production, pod weight and green pod yield of okra in 1992 and 1993 (Table 3).

Table 1. *Total dry matter and grain yields of sole and intercropped maize and cowpea which preceded okra in 1991/1992 and 1992/93 in Nigeria*

Preceding crops	Dry shoot weight (g/plant)		Grain weight (g/plant)		Dry matter yield (t/ha)		Grain yield (t/ha)	
	1991	1992	1991	1992	1991	1992	1991	1992
Sole maize	116	103	93	84	5·2	4·6	4·2	3·8
Maize intercrop	154	140	123	107	3·5	3·1	2·8	2·5
S.E. (2 D.F.)	7·76	7·55	6·11	4·69	0·35	0·31	0·29	0·26
Sole cowpea	75	60	44	39	3·4	2·7	1·9	1·7
Cowpea intercrop	73	57	42	25	1·7	1·3	1·0	0·8
S.E. (2 D.F.)	0·41	0·61	0·21	2·86	0·34	0·29	0·18	0·18

Table 2. *Fertility status of the top 20 cm soil profile as affected by preceding crops before planting okra in 1992 and 1993 in Nigeria*

Preceding crop	pH		Total N (%)		Available (Bray −1) (mg/kg)		Exchangeable K (mmol/kg)	
	1992	1993	1992	1993	1992	1993	1992	1993
Sole maize	5·4	5·5	0·047	0·046	6·5	6·6	2·0	2·2
Sole cowpea	5·7	5·6	0·063	0·062	7·0	7·3	2·4	2·3
Maize/cowpea intercrop	5·6	5·7	0·059	0·060	6·8	6·9	2·3	2·5
S.E. (4 D.F.)	0·08	0·05	0·004	0·005	0·15	0·16	0·14	0·11

Table 3. *Effect of preceding crops and nitrogen application on leaf area, fresh pod yield and yield characters of okra in 1992 and 1993 in Nigeria*

Nitrogen rate (kg/ha)	Leaf area (cm^2)		Pod no/plant		Weight/pod (g)		Green pod yield (g/plant)		Green pod yield (t/ha)	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Sole crop maize										
0	1232	1176	8	8	12·1	12·6	101	105	4·6	4·7
45	1289	1298	9	10	13·1	13·0	119	129	5·5	5·8
90	1369	1352	12	12	14·2	14·4	161	168	7·2	7·4
Mean	1297	1275	10	10	13·1	13·3	127	134	5·8	6·0
Sole crop cowpea										
0	1223	1264	10	9	12·4	13·6	129	123	5·8	5·5
45	1358	1370	11	11	14·8	14·2	163	153	7·4	7·1
90	1503	1472	11	11	14·4	15·0	158	165	7·2	7·4
Mean	1361	1369	11	10	13·9	14·3	150	147	6·8	6·7
Maize/cowpea intercrop										
0	1335	1264	9	10	14·2	13·2	119	130	5·4	5·9
45	1373	1426	11	12	14·4	14·0	157	164	7·2	7·5
90	1430	1538	11	11	15·0	14·8	165	162	7·4	7·3
Mean	1379	1409	10	11	14·5	14·0	147	152	6·7	6·9
S.E. (Error)										
Preceding crop (4 D.F.)	30·5	32·3	0·33	0·19	0·36	0·15	4·99	3·96	0·22	0·20
N Rate (12 D.F.)	29·7	32·1	0·40	0·25	0·42	0·24	3·94	3·85	0·17	0·19
Preceding crop × N (12 D.F.)	60·1	64·6	0·73	0·45	0·78	0·40	8·99	7·82	0·39	0·38

Okra sown after sole cowpea or the maize/cowpea intercrop produced significantly (averaged over the N rates) bigger leaves, heavier pods and higher marketable pod yield per hectare than those after sole maize. Averaging the two year's values, sole maize caused *c*. 7–10% loss in pod weight and *c*. 14–20% loss in pod yield of okra, compared with sole cowpea or the maize/cowpea intercrop, perhaps because the cereal left less available nutrients in the soil (see Table 2) for use by the succeeding okra crop. The previous crops, therefore, had a significant effect in determining most yield characteristics and leaf area of okra in both years. It seems that leaf area and pod size can thus be used as the best estimates of the degree of the effect of the previous crops on marketable pod yield of okra. In Africa, the young leaves and immature pods of okra are eaten as vegetables. The economic value of the crop depends largely on leaf or pod size and quality (Olasantan 1988*b*). Any agronomic practice that adversely affects these qualities will be rejected by farmers.

Effect of nitrogen on okra

Plant height, leaf area and total leaf or branch number in okra differed significantly between N application rates after the preceding crops in both years (Tables 3 and 4). However, the growth response pattern to N treatment did not differ appreciably between previous crops. Application of nitrogen up to 90 kg/ha significantly improved all the growth attributes compared with an application of 0 or 45 kg/ha, particularly with no N applied. However, the yield response of okra varied appreciably when it followed sole maize and sole cowpea or the maize/cowpea intercrop in both years. The yield responses to N after sole cowpea were similar to those after the maize/cowpea intercrop (Table 3). Marketable pod yield and yield characteristics of okra increased proportionally with increase in the rate of N up to 90 kg/ha when it succeeded sole maize. Increasing N rates from 0 to 45 and 90 kg/ha significantly increased the marketable pod yield by 20 and 57% in 1992 and by 24 and 62% in 1993.

Application of N up to 90 kg/ha after sole cowpea or the maize/cowpea intercrop increased the pod weight and marketable pod yield of okra plants but the results were significant only to 45 kg/ha. When okra followed sole cowpea, the application of 45 kg N/ha significantly increased the marketable pod yield by 28 and 30% in 1992 and 1993, respectively, compared with no N applied. Increasing the N rate to 90 kg/ha, however, did not further increase pod yield significantly (23 and 33% in 1992 and 1993, respectively). When okra succeeded the maize/cowpea intercrop, increasing N rates from 0 to 45 kg/ha caused between 27 and 33% significant gain in pod yield, but increasing the rates to 90 kg/ha did not result in a further significant gain (between 24 and 37%) in both years. Comparatively, pod yield of okra with 0 kg N/ha after sole cowpea or the maize/cowpea intercrop was 21% higher than that after sole maize, but similar to the pod yield of okra plants receiving 45 kg N/ha after sole maize. There was no significant difference between pod yields of okra with 45 kg N/ha after sole cowpea or the maize/cowpea intercrop and that with 90 kg N/ha after sole maize.

The highly significant okra yield increases obtained from 45 kg N/ha applied after cowpea in both sole and mixed stands indicates that supplemental nitrogen is necessary in multiple cropping. The significant previous crop $\times$N interaction indicated that the beneficial effect of the preceding food legume was the result of increased okra yields at a low N rate. The legume might have provided part of the N needed by the succeeding okra crop. This is as a result of the possible influence of decomposed cowpea residues on increase in soil nutrient status and availability (Table 2), as leaching, and surface runoff and erosion seem to be marginal in the dry season (i.e. the period between the preceding crops and the succeeding okra). In this study, it would appear that the beneficial effect of preceding sole and intercropped cowpea on a following okra crop was evident only at low rates of N and could not be demonstrated when larger amounts of N were applied to the okra. This is probably due to increased leaf and branch production (see Tables 3 and 4) and the consequent mutual shading by okra leaves at 90 kg N/ha, causing strong competition for incident light available for floral bud and pod formation. Furthermore, the basal dressing of 45 kg/ha of each of P and K applied to all plots that received N treatment, to help lead to a better balance of macronutrients, might have contributed to increased okra pod yield at low N rates. This is possible due to the effect of the basal dressing on increase in soil nutrient concentrations and on the availability of native N, added N and residual N fixed by the previous legume, thereby having a direct influence on the amounts of N required for okra.

It is interesting to note that sole cowpea and the cowpea/maize intercrop had similar residual effects in this study in terms of soil nutrient changes and growth and nitrogen response of the succeeding okra crop. The unexpected beneficial residual effects of the cowpea/maize treatment may be attributed mainly to the higher basal dressing of 60 kg/ha of N, P and K applied, compared to 30 kg/ha on the sole cowpea. The replacement series design used to formulate the cowpea/maize population may possibly have contributed by reducing maize competition for nutrients, especially nitrogen. It may also have contributed by reducing shading of cowpea by maize, and thus promoting cowpea growth and enhancing N fixation and its transfer to the succeeding okra. Patra *et al.* (1986) observed substantial fixation of N by the

Table 4. *Effects of preceding crops and nitrogen application on plant height and number of branches and leaves per plant in okra in 1992 and 1993 in Nigeria*

Preceding crop	Nitrogen rate (kg/ha) 0		45		90		S.E. (D.F.)	
	1992	1993	1992	1993	1992	1993	1992	1993
				Plant height (cm)				
Sole maize	51	47	59	57	69	61	1·70	1·52
Sole cowpea	52	45	61	58	69	67	(12)	(12)
Maize/cowpea intercrop	53	45	62	61	71	64		
Mean	52	46	61	59	70	64		
				No of branches/plant				
Sole maize	3	3	4	4	5	6	0·22	0·19
Sole cowpea	4	3	5	5	6	6	(12)	(12)
Maize/cowpea intercrop	4	3	5	4	6	5		
Mean	3·7	3·0	4·7	4·3	5·7	5·7		
				No of leaves/plant				
Sole maize	8	7	9	8	10	11	0·29	0·41
Sole cowpea	7	7	8	9	10	12	(12)	(12)
Maize/cowpea intercrop	9	6	9	8	11	12		
Mean	8·0	6·7	8·7	8·3	10·3	11·7		

legume component in wheat/green gram and maize/cowpea intercrop systems using a replacement series design. The nitrogen fixed by cowpea during association with maize has been shown not to be transferred directly to the cereal, but to the soil as residual N for the benefit of succeeding crops (Agboola & Fayemi 1971; Ofori *et al.* 1987; Stern 1993).

These results show that in countries where both the young leaves and fresh pods of okra are used as human food, reasonable pod yield and leaf harvests can be achieved by adopting appropriate rotation with food legumes either in pure or mixed stands. Furthermore, in tropical Africa, where N fertilizers are scarce and represent a costly input into crop production, growing vegetables such as okra after food legumes, either in pure or mixed stands with judicious basal fertilizer treatment, in a short rotation, can supply part of the N required for such multiple cropping. There is a need to examine further the effects of various sources of legume N on the growth and N response of the subsequent vegetable crop.

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