Tropical Agricultural Research and Extension 1 (1): 12-18, 1998.

Beneficial changes in environment and growth characteristics in inter-cropping systems with vegetables and arable crops

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Accepted 03 March 1998

ABSTRACT

Field experiments were conducted in 1985- 88 and in 1995- 97 in Nigeria to determine the effect of melon and okra on the micro-environment and crop growth in mixtures with maize, cowpea and cassava. The vegetables and arable crops were grown alone as well as in inter-crops and grown with or without nitrogen fertilizer. Growing melon between maize rows reduced maximum and diurnal range of soil temperatures by 3-4°C and 4-6°C respectively, and increased soil moisture content in the top 10 cm layer by 4-6 %. Inclusion of the vegetables with the arable crops provided durable ecological protection against weed development. Though vegetative development in okra, cowpea and cassava increased with nitrogen application, this was not accompanied by an increase in the yields of the crops in mixtures. The environment modification in the mixtures was beneficial to melon when grown between widely spaced maize rows and to okra under moderate soil fertility conditions. It is concluded that reasonable beneficial changes in growth environment and good productivity of vegetables can be achieved through inter-cropping, as well as the usual benefit of the companion arable crops.

Key words: cassava, cowpea, inter-cropping, melon, nitrogen fertilizer, okra.

INTRODUCTION

Leaf and fruit vegetables abound in the tropics and their production in mixed cropping has been practised for many years. The different methods of production under this system have evolved alongside a variety of food crop production and farming systems (Olasantan 1992; Roese and Rees 1994). Tropical vegetables and their wild species are grown widely in Africa for several purposes. They make an important contribution to raising nutritional levels by adding protein, vitamins and minerals to the starch-based diets of the people. These crops are also important for generating income for farmers. African farmers also look to vegetables in their mixed systems for many things besides the food and income they obtain. Sometimes there are several eco-physiological reasons for including vegetables in mixtures with arable crops. Unfortunately, this aspect has not featured prominently in inter-cropping studies.

Melon and okra, because of their high leaf area indices and importance in the diets of most Nigerians, are often found in mixtures with food crops in most ecological zones of the country. They are normally the first vegetables sown in mixtures with yam, cassava and maize at the beginning of the major (March-August) season. They are also inter-cropped with food legumes and other arable crops during the minor (August-November) season. Shortly after these vegetable crops are planted, they very rapidly provide leaf cover over the soil surface. In tropical Africa, the ecological value of these vegetables depends largely on their relevance in the control of weeds and modification of growth environment. Any agronomic practice that adversely affects these values, as well as the economic value, will be rejected by farmers. This study was conducted to determine the effects of melon and okra on soil temperature and moisture content and crop growth in mixtures with maize, cowpea and cassava.

MATERIALS AND METHODS

The experiments were sited at Ila-Orangun (8°0'N, 4°54'E), in the dried savannah belt, between 1985 and 1988 and at Abeokuta (7°6'N, 3°17'E), semi-deciduous rain forest belt, between 1995 and 1997 seasons, southwestern Nigeria. The rainfall pattern in the two areas is bimodal, with peaks in July and September and a short dry period in August. Average annual rainfall was about 1590 and 1470 mm in 1985/86 and 1987/88 seasons, respectively, at Ila-Orangun and 1330 mm in 1995/96 season at Abeokuta. The mean monthly minimum and maximum temperatures over the seasons range from 19-23° C and 27-36° C respectively, at Ila-Orangun and from 22-25° C and 29-37° C at Abeokuta (Table 1).

Expriment 1: Maize/melon inter-cropping

This experiment was sited at Ila-Orangun in 1985 and 1986. The soil of the experimental site, which was an Oxic trapudalf, had 1.27 % organic matter, 0.14 total N, 6.8 meq kg^{-1} available P and 19 mmol kg^{-1} exchangeable K, and a pH of 6.3.

Table 1. **Monthly average rainfall and temperature (T) during the experimental period from 1985 to 1988 at Ila-Orangun and From 1995 to 1996 at Abeokuta.**

	Ila-Orangun			Abeokuta		
	Rainfall, mm	T, °C min.	T, °C max.	Rainfall, mm	T, °C min.	T, °C max.
Jan	1.1	21.7	33.0	0.0	23.5	35.8
Feb	11.9	19.6	33.6	46.1	24.9	36.5
Mar	59.5	22.8	35.8	108.0	24.6	35.0
Apr	165.1	23.0	32.3	103.6	24.6	34.1
May	114.7	23.4	30.9	105.8	24.0	32.8
Jun	207.7	22.2	29.8	196.2	23.6	31.3
Jul	254.3	21.3	28.0	201.8	22.9	29.6
Aug	236.0	21.4	27.9	180.7	23.1	29.0
Sept	291.3	21.0	28.9	268.6	23.0	29.7
Oct	153.7	21.5	30.3	102.1	23.3	31.6
Nov	96.7	22.7	31.7	10.9	23.2	34.4
Dec	5.9	19.5	31.6	1.5	24.2	33.7

The treatments, replicated three times in a randomized complete block design, consisted of sole maize, sole melon and maize/melon inter-crop in 1:1, 1:2 and 2:2 (maize: melon) row versions. Size of each plot was 5.4 x 4.8 m. Maize (TZESR-W) and melon (Local variety) were planted on 13 April in 1985 and on 5 April in 1986. The maize was planted at a spacing of 90 x 30 cm in pure stands and at a 90 x 60 cm spacing in mixed stands to achieve 37000 plants ha^{-1}. The melon was planted at a spacing of 90 x 60 cm to obtain 19000 plants ha^{-1} in both pure and mixed stands. All plots received 300 kg ha^{-1} 15:15:15 NPK compound fertilizer three weeks after planting and all mixed and maize sole plots received an additional 30 kg N ha^{-1} as Calcium ammonium nitrate (26 % N) three weeks later. Weeding was done manually, at 4, 8 and 12 weeks in sole maize, but only at 4 weeks in sole melon or inter-crops.

Diurnal variation in soil temperatures at 5 and 10 cm depth was measured at four-hourly intervals between 06.00 and 18.00 h with thermometers installed at the centre of the plots. Soil samples were collected at 10 cm depth adjacent to the thermometers and oven-dried at 105^0 C for 24 h to determine gravimetric soil moisture content. All parameters were measured on 28, 29 and 30 May and 22, 23 and 24 June in 1985 and on 20, 21 and 22 May and 16, 17 and 18 June in 1986. Growth characters were determined nine weeks after planting when all vegetative development of both crops had peaked. Maize grain and melon seed yields were determined.

Experiment 2: Cowpea/okra inter-cropping

The experiment was conducted in 1987 and 1988 at Ila-Orangun. The soil had a pH of 6.2, 2.18 % organic matter, 0.12 % total N, 4.5 meq kg^{-1} available P and 9 mmol kg^{-1} exchangeable K. There were two factors: Cropping system (sole cropping and inter-cropping) and N-rates (0, 30 and 60 kg ha^{-1}). A split-plot design with the cropping system as the main plot and N-rates as the sub-plot treatments was fitted into a randomized complete block with three replications. One sole cowpea plot with no applied nitrogen was randomized within each block as a control.

In 1987, planting was on 22 June using okra (cv. 47-4) and cowpea (Ife Brown). The crops were sown at a spacing of 90 x 30 cm in pure stands and at a 90 x 60 cm spacing in mixed stands, respectively, to obtain 37000 and 18500 plants ha^{-1} for each species. Each plot measured 4.5 x 4.2 m. In the 1988 experiment, the seeds of okra (cv. 47-4) and cowpea (cv. IT84E-124) were sown on 25 July using the same spacing as in 1987. Each treatment plot size was 4.5 x 3.6 m. In both years a basal dressing of 30 kg ha^{-1} each of K_2O and P_2O_5 as muriate of potash and single super-phosphate, respectively, was applied to all plots receiving nitrogen. The sub-plots selected randomly were then supplied with either 0, 30 or 60 kg N ha^{-1} as sulphate of ammonia. Weeding was done manually at 4 and 8 weeks in sole okra crop and only at 4 weeks in inter-crop. Foliar and fruit insect pests were controlled regularly before harvesting commenced, with sprays of 600 ml ha^{-1} of Azodrin 60 (containing 600 g L^{-1} WSC) and 400 ml ha^{-1} of Cymbush 10 EC (containing 100 g L^{-1} Cypermethrin) in 500 L water.

Vegetative characters were determined at peak development at 8 weeks and okra fruits were harvested regularly. Cowpea pods were picked, sun-dried and threshed. All harvests were made from the centre four rows.

Experiment 3: Cassava/okra inter-cropping

The experiment was sited at Abeokuta on the Two soil series, an Oxic paleudulf during 1995 to 1997. The top soil of the experimental site had 2.09 % organic carbon, 0.084 % total N, 4.8 meq kg^{-1} available P and 4.6 and 29.2 mmol kg^{-1} exchangeable K and Ca, respectively, and a pH of 5.6.

The treatments, replicated three times in a split plot design, consisted of two cropping systems (sole cropping and inter-cropping) as the main plots and three nitrogen rates (0, 60 and 120 kg ha^{-1}) as the sub-plot treatments. Nitrogen was applied as compound fertilizer (15:15:15 N, P_2O_5, K_2O) and urea (45:0:0:). The compound fertilizer supplied 60 kg ha^{-1} each of N, P_2O_5 and K_2O as a basal dressing and urea supplied the remaining 60 kg N ha^{-1} for the highest N-rate. The sub-plot treatments were randomized within each block. The net sub-plot area was 7 x 5 m. Okra (cv. 47-4) was sown with one plant per hill at an intrarow spacing of 30 cm in pure stands and mid way between every cassava (Odongbo) rows spaced 100 cm apart, with 50 cm between all rows during the minor (August-November) season. The cassava was planted at a spacing of 100 cm within rows in both cropping systems. Nitrogen fertilizer was drilled into furrows midway between okra and cassava rows two weeks after planting. All plots were manually weeded, thrice in sole cassava, twice in sole okra, but only once in cassava/okra inter-crop.

The vegetative characters of okra were determined at 8-9 weeks and of cassava at 12 weeks. The immature okra fruits were harvested every 3 days, starting from October. Cassava was harvested for tuber yield in April 1997.

Analysis of variance was performed on growth and yield data of crops in each experiment, based on the design. The differences between treatment means were compared by the least significant difference test at 5 % probability values.

RESULTS AND DISCUSSION

Modification of soil temperature and moisture content

Compared to melon, the maize crop grew more rapidly in height but took a longer period to develop its canopy at a higher level. Thus, maize gave a poorer soil cover than melon. Due to the geometry of its canopy, maize allowed more light to penetrate to lower levels and consequently the amount of radiant energy actually reaching the soil surface was greater than that of melon. However, increased soil temperatures under sole maize during the afternoon and evening periods did not persist into the following morning, perhaps as a result of high night back-radiation (Table 2). When compared with sole melon, the soil temperature below sole maize in the upper 10 cm was significantly reduced by about 1.3^0 C at 06:00 h and raised by 1.6, 3.8 and 1.5^0C at 10:00, 14:00 and 18:00 h, respectively (Table 2).

Table 2. Average diurnal variation and daily range (DR) of soil temperature and soil moisture content in maize/melon intercrop at Ila-Orungan (mean of two years data).

Treatment	May						June					
	Soil temperature, ^{0}C					Soil Moisture, %	Soil temperature, ^{0}C					Soil moisture, %
	6[#]	10	14	18	DR		6	10	14	18	DR	
						5 cm depth						5cm depth
Sole maize	21	26	36	28	15	-	21	24	33	27	12	-
Sole melon	23	24	32	26	9	-	22	23	30	25	8	-
1:1 row	22	24	32	27	10	-	22	23	31	26	9	-
1:2 row	22	24	33	26	11	-	22	23	30	26	8	-
2:2 row	23	24	32	27	9	-	22	23	31	26	9	-
LSD (0.05)	0.76	0.83	1.59	0.65	-	-	0.42	0.42	1.13	0.65	-	-
						10 cm depth						10cm depth
Sole maize	21	24	34	27	13	8.0	21	24	32	26	11	11.5
Sole melon	22	23	30	26	7	12.3	22	22	28	25	6	13.6
1:1 row	22	23	31	26	9	11.8	22	22	29	25	7	13.0
1:2 row	23	23	30	26	7	11.8	22	23	28	25	6	12.8
2:2 row	22	23	31	26	9	11.8	22	23	29	25	7	12.9
LSD (0.05)	0.65	0.42	1.52	0.42	-	1.82	0.42	0.76	1.59	0.42	-	0.78

[#]Hour of day

The soil temperature and moisture content below the maize/melon inter-crop and sole melon did not differ significantly in either month. Soil moisture content at 10 cm was always greater under sole melon or inter-crops than under sole maize; the value below the inter-crops was about 2-6 % greater than that below sole maize four weeks after planting (Table 2). Moreover, diurnal range of soil temperature was appreciably higher by $4\text{-}6^0$ C under sole maize than under sole melon or maize/melon inter-crop. These results showed that shading by the leaf canopy of melon reduced soil temperature and increased soil moisture content. Melon can thus be used as an inter-crop to reduce high diurnal soil and air temperatures, and consequently fluctuations in temperatures and evaporative water losses that have often been found to affect crop growth in the tropics (Lal and Greenland 1977), particularly at the beginning of cropping season. Improved ground cover by melon can also reduce run-off and increase water infiltration. Increased infiltration rate may also be caused by increased earthworm activities as a result of lower soil temperature (Hulugalle and Ezumah 1991).

Suppression of weeds

In this study, three weeding operations were carried out in sole cropped maize and cassava and two in sole cropped okra, but only one with maize/melon, cowpea/okra or cassava/okra inter-crop during crop associations. This shows that shading by the heavier leaf canopy in inter-cropping considerably reduced weed growth. The weeds which usually build up before the sole maize and cassava crops were effectively suppressed by the melon and okra inter-crops. Consequently, light, water and nutrients which might otherwise be wasted and/or used by weeds before the maize and cassava formed full canopy were largely utilized by the vegetables. Growing broad-leaved or spreading type vegetables between the rows of arable crops can thus be used to provide durable ecological protection against weed development and the spread of diseases, insect pests and nematodes for which these weeds serve as host plants. Zuofa *et al.* (1992) observed a considerable reduction in weediness when melon was inter-cropped with cassava and maize. Trenbath (1993) reported that sole crop cowpea grown without insecticide protection in northern Nigeria yielded virtually nothing while cowpea inter-cropped with arable and vegetable crops produced some reasonable seed yield.

Modification of melon and maize growth

Growing maize between melon rows, irrespective of pattern, modified both the growth and yield of the melon crop. Inter-cropping significantly reduced the number of branches, leaves and leaf area and consequently shoot dry weight, number of fruits per plant, seeds per fruit and seed yield of melon. Nevertheless, the stems were longer in melon inter-crop than in the sole crop but the weight per 100 seeds was similar in the two crops (Table 3). However, the reduction in fruit and seed yield was less when melon was grown between wider rows of the maize crop. The reduction in seed yield was mainly due to the reduction in number of fruits per plant. It seems that melon seed yields largely depend on the vegetative growth, which is reflected in the stem length, branch number and leaf area. It would appear from these results that the environment modification by the top storey maize crop was more beneficial to melon when it was grown between widely spaced maize rows than narrow spacing.

Table 3. Effect of inter-cropping on growth and yield of melon and maize at Ila-Orangun (mean of two years' data)

	Sole Crop	Row intercrop (Maize:melon) 1:1	1:2	2:2	LSD (P=0.05)
Melon		Growth character			
No. Of branches plant^{-1}	25	14	19	15	6.1
No. Of leaves plant^{-1}	370	185	251	202	102.0
Leaf area index	6.2	2.3	3.5	2.6	2.2
Stem height, m	2.6	3.3	2.9	3.5	0.42
Shoot dry weight, g plant^{-1}	427	278	319	290	83.0
			Yield		
No. Of fruits plant^{-1}	2.5	1.6	2.2	1.7	0.51
No. Of eeds fruit^{-1}	160	132	139	132	16.2
Weight of 100 seeds, g	15.6	15.3	14.9	13.2	0.34
Seed yield, t ha^{-1}	1.2	0.6	0.9	0.7	0.32
Maize			Tasselling		
No. of days	62	59	60	60	1.54
			Yield character		
Grain yield, t ha^{-1}	3.6	3.1	2.4	3.0	0.61

The study showed that inter-cropping maize with melon did not influence the growth of the maize crop, but the grain yield was reduced in the mixture only when grown with melon in a 1:2 row arrangement (Table 3). This is probably because of the increased vegetative growth of the associated melon and the consequent competition between the two crops. Inter-cropped maize tasselled earlier than the sole crop, and this was due to an increase in soil moisture and the consequent reduction in maximum diurnal soil temperatures and evaporative water losses from the soil surface (Table 2). This shows that reduction in soil temperature and the consequent increase in soil moisture under mixture, caused by melon, was beneficial to the maize crop, particularly during early growth when the soil temperature in pure maize crop was appreciably high and the maize mono-crop was water stressed.

Modification of okra and cowpea growth

Growing cowpea between okra rows did not affect leaf production, days to first harvest and fruit weight of the okra crop, but its height, branch number, fruit production and yield were affected significantly

(Table 4). Sole crop okra grew taller and had more branches and fruits and a greater fruit yield than the inter-crop across different N-rates. This shows that inter-cropping led to reduction in branch production in the okra crop which largely determines fruit production. The replacement series techniques employed to formulate mixture population may also have contributed to the reduction in fruit yield of okra per hectare.

Increasing N-fertilizer rates increased vegetative development of the okra crop, but application of 60 and 30 kg N ha^{-1} in sole and inter-cropping, respectively, gave maximum fruit yield (Table 4). The cropping X N interaction was significant in pod yield, indicating that yield response of okra to nitrogen fertilization differed between the two cropping systems. These results showed that complementary effect of cowpea/okra inter-cropping on the okra crop was evident only at low soil fertility, and cannot be demonstrated under high soil fertility. This was mainly due to improved ground cover provided by the cowpea crop which contributed to reduced soil erosion and hence better retention of soil moisture and fertility, especially nitrogen, for the use of the associated okra crop. The growth environment encountered by okra when grown with cowpea was therefore strikingly beneficial and different from that in monoculture.

When cowpea and okra were inter-cropped without applied nitrogen the growth of the cowpea crop was not affected, but the dry pod weight and grain yields were affected significantly (Table 5). At higher nitrogen rates, cowpea inter-crop grew taller, had more branches and leaves, and produced less pods and seed yield than in the sole crop. The reduction in pod and seed yields was however less with application of 30 than 60 kg N ha^{-1}, mainly because of competition enhancement of okra plants that received 60 kg N ha^{-1} (see Table 4). The okra plant has a stronger upright stem, produces broader leaves ad develops its canopy higher up in space than the cowpea plant. The yield response of cowpea to cropping and N fertilizer treatments differed from that of its vegetative growth. The difference in the stages of development in cowpea and also in the associated okra in relation to resource requirements may have contributed to this.

Table 4. Vegetative and yield characters of okra in sole cropping and inter-cropping with cowpea at different nitrogen fertilizer rates (mean of two years' data).

Nitrogen rate, kg ha^{-1}	Plant height, cm	Branches plant^{-1}	Leaves plant^{-1}	Days to harvest	Fruits plant^{-1}	Weight fruit^{-1}, g	Fruit yield, t ha^{-1}
Sole crop okra							
0	78	2.2	18	60	8	15	4.4
30	90	2.3	22	61	10	14	5.1
60	103	2.6	27	61	11	14	5.6
Mean	90	2.4	22	61	10	14	5.0
Okra inter-crop							
0	74	1.6	18	65	8	14	2.1
30	83	1.9	23	64	9	15	2.6
60	93	2.1	27	64	8	15	2.2
Mean	83	1.9	23	64	8	15	2.3
LSD(P=0.05)							
Cropping	4.60	0.43	NS	NS	0.95	NS	0.39
N rate	6.16	0.37	1.87	NS	0.55	NS	0.37
Cropping x N	NS	NS	NS	NS	*	NS	*

NS = Not significant * Cropping x N was significant at P=0.05

Table 5. Vegetative characters and dry pod and seed yields of cowpea as affected by inter-cropping with okra at different nitrogen fertilizer rates at Ila-Orangun (mean of two years' data)

Nitrogen rate, kg ha^{-1}	Plant height, cm	Branches plant^{-1}	Leaves plant^{-1}	Dry pod yield, t ha^{-1}	Seed yield, t ha^{-1}
Sole crop	149	4.6	54	2.9	2.1
Inter-crop					
0	154	5.3	52	1.3	1.1
30	168	5.2	58	1.6	1.3
60	182	5.6	64	1.2	0.6
Mean	168	5.4	58	1.4	1.1
LSD (0.05)	12.45	0.59	5.03	0.25	0.22

Modification of okra and cassava growth

Growing cassava between the rows of okra did not influence the growth of the okra crop with or without N fertilization, but the fruit weight and yield were reduced only when nitrogen fertilizer was not applied (Table 6).

The reduction of okra fruit yield in the unfertilized mixtures may be due to rapid depletion of soil nutrients, particularly nitrogen, as the root density and canopy development would be much greater in an additive mixture than in monoculture. Increasing N-fertilizer rate from 0 to 60 or 120 kg N ha^{-1} significantly increased vegetative development, enhanced earliness to fruit harvest, increased fruit formation and fruit yield. The cropping system x N interaction was significant for fruit yield. The difference in the cropping system x N interaction between vegetative growth and fruit yield showed that yield response of okra to N application depended more on the cropping system, compared to vegetative growth response to the N-fertilizer treatment.

Inter-cropping cassava with okra did not affect the growth and root yield of the cassava crop (averaged over the N rates). However, mixing the two crops without nitrogen fertilization resulted in a significant decrease of 25 % in the tuber yield of the cassava crop, compared with the corresponding sole plants with no nitrogen applied. Although the cassava inter-crop produced a greater number of

Table 6. Vegetative and yield characters of okra in sole cropping and intercropping With cassava at different nitrogen fertilizer rates at Abeokuta.

Nitrogen Rate, kg ha^{-1}	Plant height, cm	Branches plant^{-1}	Leaves plant^{-1}	Leaf area, cm^2	Days to harvest	Fruits plant^{-1}	Weight fruit^{-1}, g	Fruit yield, t ha^{-1}
Sole crop								
0	55	1.9	0	872	67	5	11	2.3
60	61	2.4	11	1050	64	7	14	3.3
120	68	3.3	13	1210	61	9	14	4.6
Mean	61	2.5	11	1044	64	7	13	3.4
Inter-crop								
0	55	1.8	8	905	68	6	9	1.2
60	63	2.5	10	1001	65	7	10	3.0
120	67	3.6	11	1165	61	8	12	4.2
Mean	62	2.6	10	1124	65	7	10	2.8
LSD (0.05)								
Cropping	NS	NS	NS	NS	NS	NS	2.05	0.56
N rate	4.83	0.58	1.66	127.7	2.76	1.22	1.82	1.06
Cropping x N	NS	NS	NS	*	NS	*	*	*

NS= Not significant * Cropping x N was significant at P= 0.05.

tubers than the sole crop in the unfertilized plots, the weight of tubers in inter-crop was smaller than that in the sole crop (Table 7). This shows that increased tuber number did not compensate for the reduction in tuber weight, as suggested by significant interaction between cropping x N interaction. In the unfertilized mixed plots, nutrient availability may be reduced rapidly because of the more rapid development of root density and leaf area, and hence the higher nutrient use (Morris and Garrity 1993). When 60 kg N ha^{-1} was applied, inter-cropped cassava recovered rapidly from the growth impairment encountered during crop association and consequently gave some reasonable root yield (28 t ha^{-1}) similar to that obtained when it was grown alone (30 t ha^{-1}). Doubling the nitrogen rate, however, did not result in further significant increase in root yield (31 t ha^{-1}). This may be due to the effect of nitrogen fertilization which persisted for a long time for the use of cassava after associated okra was harvested. Also, part of the nutrients, particularly nitrogen, removed by okra during crop association would be released to the soil by decomposition of okra residues after fruit harvest, for the use of the cassava crop.

Table 7. Vegetative and root yield characters of cassava in sole cropping and inter-cropping with okra at different nitrogen fertilizer rates at Abeokuta.

Nitrogen rate, kg ha^{-1}	Plant height, m	Leaves Plant^{-1}	Tubers Plant^{-1}	Weight Tuber^{-1}, g	Tuber Yield^{-1}, t ha^{-1}
Sole crop					
0	0.8	70	2.8	732	20
60	1.0	78	4.2	771	31
120	1.2	87	3.5	909	33
Mean	1.0	78	3.5	804	28
Inter-crop					
0	1.0	71	3.2	580	15
60	1.2	80	3.4	752	28
120	1.3	85	3.7	887	31
Mean	1.2	79	3.4	740	25
LSD (P-0.05)					
Cropping	NS	NS	NS	55.9	2.80
N rate	0.18	6.6	0.44	112.7	6.0
Cropping x N	NS	NS	*	*	*

N.S. = Not significant * Cropping x N was significant at P=0.05

This study thus indicates that increased nitrogen fertilizer does not necessarily result in good crop yields in mixed systems, particularly with legumes. It also shows that inclusion of vegetables, particularly the broad-leaved and spreading types, with arable crops can reduce maximum and diurnal range of soil temperatures and increase soil moisture content within the root zone. Such systems can also protect the soil against surface runoff, suppress weeds and increase water infilteration rate. Based on the results of this study, it is concluded that in the tropics where vegetables are often found in mixtures with arable crops, reasonable beneficial changes in growth environment and good productivity of vegetables can be achieved, in addition to the usual yield benefits of the arable crops.

ACKNOWLEDGEMENT

The author's profound appreciation goes to the Teaching and Research Farm, College of Education, Ila-Orangun, Nigeria for the provision of land and to the Research and Development Centre (RESDEC), University of Agriculture, Abeokuta, Nigeria for financing part of this study.

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Tropical Agricultural Research and Extension 1 (1): 19-22, 1998

Path analysis of fruit yield components of *cucurbita moschata* Duch.

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Accepted 10 February 1998

ABSTRACT

Traits contributing to *Cucurbita moschata* fruit yield were investigated to identify selection aids. Twenty-nine land races were grown at two sites in Zambia during the 1994/95 and 1995/96 wet seasons. The contribution of traits to fruit yield were partitioned by path analysis. Mid-season traits (internode with first female flowers, length of internode with first female flowers, length of primary axis, number of primary branches and number of leaves per plant) exhibited insignificant phenotypic (P) and genotypic (G) direct effects (P, G <0.17) on fruit yield. The length of the primary axis, number of primary branches and number of leaves per plant had genotypic indirect effects of intermediate magnitude on the fruit yield through the number of fruits per plant (-0.27, 0.33, 0.42; respectively). Late season traits (weight of first mature fruit and number of fruits per plant) had significant genotypic direct effects on fruit yield (G=0.67 for both characters). Therefore, in selecting for pumpkin yield, special attention should be given to number of fruits per plant and weight of first mature fruit of each plant.

Key words: *Cucurbita moschata*, correlation, direct and indirect effects, fruit yield, pumpkin.

INTRODUCTION

The most important use of tropical pumpkin, *Cucurbita moschata* Duch. in Zambia is vegetable fruit consumption (Gwanama and Nichterlein 1995). This species is known locally as pumpkin and elsewhere as 'calabaza', 'calabash', 'ayote', 'zapallo' or 'winter squash'. The yield of pumpkins is influenced by many traits individually and jointly (Whitaker and Davis 1962). Although there may be many traits with high correlation to the ultimate product, not all of them may be significantly and directly contributing to it. Path analysis separates the direct and indirect effects of yield contributing traits (Solanki and Shah 1989). Identification of traits with high direct effects on fruit yield would be useful in a breeding program.

One major problem in *C. moschata* breeding is large size of the plants. Single vines can be as long as 15 meters with profuse branching. Recommended production planting densities, of around 1,700 plants per hectare (Van Zijl *et al.* 1978) are not suitable for selection plots because plants form a web with neighbours and observation of individual characters becomes difficult. Therefore, substantial experimental space is required. This is seldom obtainable and when available, introduces high environmental variation and increases the cost of trials.

Therefore reduced number of replications and use of single plant experimental units have been practiced in *C. moschata* breeding (Wessel-Beaver and Flores 1996). Implementation of these solutions results in failure to completely separate environmental variance from treatment variance. Therefore, identification of highly correlated early season selectable traits would be helpful so that inferior plants can be discarded early.

The objective of this study, therefore, was to identify the characters, which are important in selecting for higher fruit yield in tropical pumpkin.

MATERIALS AND METHODS

Twenty-nine land races of *C. moschata* were grown for two seasons at the University of Zambia (UNZA) and Zambia Seed Company (ZAMSEED) farms. Both farms were within 15 kilometers of Lusaka City. Nineteen of the varieties were S_1 genotypes obtained by self pollinating field collected accessions in the 1993/94 season. The remainder was half sib families obtained directly by collecting one pumpkin fruit per land race in 1994.

A randomised complete block design with three replications was used at each site. Each plot consisted of four plants sown on 15 cm high beds. The spacing between beds was 2 m and between plants in a bed also 2 m. The four plants per plot sample size was chosen as the best compromise between single plant, single harvest and large plot, multiple harvest trials (Wehner and Miller 1984). Large plot testing was reserved for advanced trials after the number of genotypes has been trimmed.

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One meter wide borders were left between blocks while no borders were left between plots in a block. Sowing dates were 17 (UNZA) and 23 (ZAMSEED) December 1994 and 21 and 27 December 1995, respectively. An equivalent of 400 kg ha^{-1} 'Compound D' fertiliser ($N:P_2O_5:K_2O = 10:20:1$) was applied. Standard cultural practices were observed. Natural rain was the source of moisture throughout the experiment. The total amount of rainfall received at UNZA was 570 mm in 1994/95 and 790 mm in 1995/96. The ZAMSEED trial received 650 mm and 815 mm, respectively. An abundance of honeybees for adequate pollination was assured from insect pollinated crops grown at the stations for seed production.

Two sets of characters were observed. The first group were mid-season traits observed at 50% flowering (48-65 days after planting), viz. internode with first female flowers, its length (cm), the length of the primary axis (m), the number of primary branches and the number of leaves per plant. The second group were late season characters taken at harvest, namely, the weight of the first mature fruit (kg), the number of fruits per plant and the total fruit yield per plant (kg), while the mean fruit weight (kg) was recorded as a derived variable. Harvesting of all mature fruits was done once for all plots when vines began to wither (at 120 days after planting in first season and 135 days in second season). Maturity of fruits was ascertained by pricking with a forefinger nail. All immature fruits were discarded.

Data analysis

The procedure suggested by Singh and Chaudhary (1985) was employed in the calculation of phenotypic (r_P) and genotypic (r_G) correlations as well as path coefficients at the phenotypic (P) and genotypic (G) levels. This procedure uses plot means in the calculation of phenotypic correlations and genotype means pooled for seasons and locations for genotypic correlations. Phenotypic and genotypic direct and indirect effects were obtained from operations on the respective correlation matrices. Effects of yield components were considered to be:

(1) significant if r_P or $r_G > 0.6$ and significant at $p \leq 0.05$ and P/r_P or $G/r_G > 0.9$

(2) intermediate if r_P or r_G was significant at $p < 0.05$ and $0.6 < P/r_P$ or $G/r_G \leq 0.9$

(3) low in all other cases

RESULTS

The first year experienced a drought at the time of pollination which reduced the number of fruits set and the mean fruit weight. The second year had sufficient rain and comparatively better yield. Data for both years was included because drought is a fairly common occurrence in the country. There was considerable variation in the yield performance of genotypes. Some genotypes yielded very small fruits (< 1 kg) while others had large fruits (5 kg). The mean fruit yield on hectare basis varied from 2.5 Mg to over 23 Mg (Table 1).

Correlations between the yield components were in most cases low and insignificant both at phenotypic ($-0.11 \leq r_P \leq 0.22$) and genotypic ($-0.21 \leq r_G \leq 0.37$) levels. No significant negative correlations were observed either between the yield components or between the yield components and the fruit yield. Phenotypic correlations of mid-season traits to the fruit yield were insignificant, with the exception of number primary branches which was highly significant. However, at the genotypic level, both the length of the primary axis and the number of primary branches had significant correlations to fruit yield. On the other hand late season traits had high and highly significant phenotypic and genotypic correlations ($0.54 \leq r_P \leq 0.71$; $0.60 \leq r_G \leq 0.70$) (Table 2).

Most of the direct and indirect effects of traits on fruit yield were very low. Mean fruit weight and number of fruits per plant had intermediate and significant direct phenotypic effects (P = 0.50, 0.68), respectively. However, the intermediate direct phenotypic effect of mean fruit weight was not associated with a corresponding genotypic effect (G = -0.02). At the genotypic level there were significant direct effects of weight of first mature fruit and number of fruits per plant (G = 0.67 for both characters) on fruit yield. Additionally, the mean fruit weight per plant exerted a significant genotypic effect through the weight of the first mature fruit (G = 0.65). The length of the primary axis, the number of primary branches and the number of leaves per plant had intermediate indirect genotypic effects (G = 0.27, 0.33, 0.42 respectively) via number of fruits per plant (Table 2).

DISCUSSION

The range of fruit yield averaged for two seasons in this study (2.5 - 23.3 Mg ha^{-1}) is low compared to the findings of other investigators. For instance, vine and bush hybrids and inbreds developed in Florida, USA, have been reported to yield between 20-60 Mg ha^{-1} (Maynard 1996). The mean fruit weight in our trial was 1.8 kg and mean number of fruits per plant was 2.4, while in the latter case corresponding values were 3.1 kg and 3.8 fruits per plant. However, direct comparisons may be misleading because only mature (marketable) fruits were considered in our study and land race varieties were employed as the study material. The effect of the drought in the first season also contributed to the low yield.

Nonetheless, our results are indicative of the

Table 1. Performance of *C. moschata* genotypes grown at the University of Zambia and ZAMSEED during the 1994/95 and 1995/96 seasons.

Trait	1994/95		1995/96		Pooled		
	Range#	Mean#	Range#	Mean#	Range#	Mean#	CV (%)
1					14.6 - 22.6	19.0	16.32
2					13.4 - 28.2	22.3	20.46
3	2.5 - 4.5	3.4	2.7 - 5.2	4.2	2.8 - 4.8	3.8	28.45
4	4.9 - 16.5	11.7	5.1 - 18.6	13.3	5.8 - 18.2	12.5	26.11
5	90.7-205.3	162.3	102.9 - 251.7	186.3	112.7 - 225.8	174.3	39.01
6	0.6 - 4.5	1.5	0.6 - 6.2	2.5	0.6 - 5.1	2.0	39.20
7	0.5 - 2.0	1.4	0.7 - 4.8	2.2	0.5 - 2.4	1.8	42.95
8	0.3 - 5.0	1.8	1.2 - 5.5	3.0	0.7 - 5.0	2.4	62.14
9a	0.6 - 3.3	2.4	2.4 - 23.1	6.7	1.0 - 9.3	4.3	59.65
9b	1.5 - 8.2	6.0	6.0 - 57.8	16.7	2.5 - 23.3	10.6	

#: Range of genotype means across locations

1 = Internode with first female flower, 2 = length of internode with first female flower (cm), 3 = length of primary vine (m), 4 = number of primary branches, 5 = number of leaves per plant, 6 = weight of first mature fruit (kg), 7 = mean fruit weight per plan (kg)t, 8 = number of fruits per plant, 9a = fruit yield per plant (kg), 9b = fruit yield per hectare (Mg).

situation in unimproved land races in a low yield, semi-arid environment.The significant phenotypic correlations of mean fruit weight per plant and of number of fruits per plant with yield agree with the findings of Gopalakrishnan *et al.* (1980) and Chigwe (1991). However, Chigwe (1991)

Table 2 Effects of fruit yield components on *C. moschata* fruit yield and correlation of yield traits. (Phenotypic (P) and genotypic (G) direct effects on diagonal, indirect effects above diagonal, phenotypic (r_P) and genotypic (r_G) correlation coefficients below diagonal.)

Trait				Trait					Trait
	1	2	3	4	5	6	7	8	
1	0.02	0.00	0.00	0.02	0.01	0.00	- 0.06	0.07	1 P
	0.03	0.00	0.00	0.04	- 0.04	- 0.14	0.00	0.01	G
2 r_P	0.22	0.00	0.02	0.01	0.01	- 0.01	- 0.05	0.14	2 P
r_G	0.01	- 0.02	0.02	0.02	- 0.03	- 0.09	0.00	- 0.11	G
3 r_P	0.05	0.34**	0.05	0.02	0.01	0.01	0.03	0.19	3 P
r_G	- 0.20	0.44*	0.04	0.04	- 0.05	0.12	0.00	0.27	G
4 r_P	0.30**	0.22	0.37**	0.06	- 0.01	0.01	0.05	0.29	4 P
r_G	0.36	0.16	0.40*	0.11	- 0.10	0.11	0.00	0.33	G
5 r_P	0.08	- 0.06	- 0.01	0.13	- 0.09	0.01	0.03	0.07	5 P
r_G	0.23	0.17	0.33	0.65**	-0.16	- 0.07	0.00	0.42	G
6 r_P	- 0.07	- 0.08	0.09	0.15	0.08	0.06	0.48	0.07	6 G
r_G	- 0.21	- 0.13	0.18	0.17	- 0.11	0.67	-0.02	0.01	G
7 r_P	- 0.11	- 0.10	0.05	0.09	0.06	0.97**	0.50	- 0.01	7 P
r_G	0.18	- 0.16	0.17	0.12	- 0.16	0.98**	-0.02	- 0.08	G
8 r_P	0.11	0.21	0.28*	0.42**	0.10	0.10	-0.02	0.68	8 P
r_G	0.01	0.23	0.40*	0.49**	0.63**	0.02	-0.11	0.67	G
9 r_P	0.05	0.13	0.29	0.41**	0.02	0.61**	0.54**	0.71**	
r_G	- 0.12	0.06	0.41*	0.47*	0.29	0.70**	0.60**	0.66**	

Residual effect: Phenotypic = 0.413, genotypic 0.294

***=significant at p-<0.05, ** =significant at p-<0.05, 1 = Internode with first female flower, 2= length of internode with first female flower, 3= length of primary vine, 4= number of primary branches, 5= number of leaves per plant, 6= weight of first mature fruit, 7= mean fruit weight per plant, 8= number of fruits per plant, 9= fruit yield per plant.**

suggested also that the mean fruit weight could be used directly in selecting for higher fruit yield. The results of this study show that, at the genotypic level, mean fruit weight only affected fruit yield through weight of first mature fruit. Hence restricted selection using primary vine, simultaneously with number of fruits per plant, would have to be applied. One cause for deviations from Chigwe's findings is due to the fact that only data of the 25 top yielding genotypes among his 121 test land races were reported. The mean yield of these selected land races was 25.5 Mg ha^{-1}. Our best yielding genotype (57.8 Mg ha^{-1}) during the second season out-yielded his best land race (41.9 Mg ha^{-1}). His results, therefore, were biased for elite land races and favourable environments. Traits observed in the middle of the growth season failed to show significant direct effects on fruit yield. Reducing selection populations on the basis of the length of the primary axis, the number of primary branches and the number of leaves per plant would be helpful since they had intermediate indirect and direct effects through the number of fruits per plant.

CONCLUSION

In the improvement of *C. moschata* land races maximum importance should be accorded to the number of fruits per plant and weight of first mature fruit as they have high genotypic and phenotypic direct effects on fruit yield. The length of the primary axis, the number of primary branches and the number of leaves per plant selected simultaneously with number of fruits per plant would also be helpful as early season selection aids.

ACKNOWLEDGEMENTS

We are very grateful to the German Government and its Technical Cooperation Agency (GTZ) for funding this project and ZAMSEED for experimental space at their farm.

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