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Intercropping sunflower with local varieties of cassava in a moist savanna site of Nigeria

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Abstract

A two-year field study examined intra-and inter-row mixtures of 2 local cassava varieties with sunflower at Ogbomoso, Nigeria. There were 8 intercropping and 3 sole crop treatments replicated 4 times in a randomized complete block design. Generally, intercropping depressed the performance of sunflower more than cassava. Cassava and sunflower intercropped at alternate hills and single alternating rows had the poorest growth and yields compared with other planting patterns. There were no significant differences in the growth and yields of cassava and sunflower intercropped in 3 and 5 alternating strips. Light transmission, leaf area index and yields of both crop species followed similar trends under the various planting patterns. Intercropping at 5 alternating strips that allowed the highest leaf area also allowed the lowest light transmission and produced the highest yields. Compared to the slow growing Odongbo, the fast growing Okoyawo cassava significantly suppressed the growth and yield of intercropped sunflower especially when intercropped in alternate hills and single alternating rows. Irrespective of the planting pattern, cassava contributed more to Land Equivalent Ratios (LERs) than sunflower. Whilst Odongbo contributed 21, 34, 18, and 0.05% more than sunflower to LERs, Okoyawo cassava contributed 41, 48, 28, and 30% more than sunflower when interplanted at alternate hills single alternating rows, 3 and 5 alternating strips, respectively. Interplanting Odongbo and sunflower at 3 and 5 alternating strips improved LERs by 72 and 89%, respectively, while an improvement of 46 and 62% were obtained in mixtures of Okoyawo and sunflower for the same planting pattern.

Key words: cassava, sunflower, intercrop, growth, yield

Introduction

Mixed cropping continues to be popular among agronomists and subsistence farmers because it ensures better utilization of crop growth resources (Willey 1979, Krantz et al. 1976, Francis 1981). In the event of an unforeseen environmental hazard affecting the yield of one crop it offers an alternative, so providing a more stable food source overall from the same field (Baker 1980). Although the pattern of mixed cropping varies considerably from one area to another, and even differ among farmers within a single location, the common feature is that each system tends to reflect the farmer's needs, management ability and resources, economic considerations and convenience (Ntare 1990, Andrews 1972, Osiru & Willey 1972, Willey & Osiru 1972).

Cassava (*Manihot esculenta* Crantz) is a major food crop in Nigeria. In the southern Nigeria where it is predominant, it is seldom planted as sole crop due to its long duration to maturity. Intercrops associated with cassava in this region are highly variable and location specific. It is often intercropped with shorter duration crops such as maize, yam, cowpea, melon and vegetables (Njoku & Odurukwe 1986). Sunflower (*Helianthus annuus* L.), a short duration vegetable oil crop was recently introduced into Nigerian agriculture (Ado & Tanimu 1988) to supplement other sources of cooking oil. Despite the great potential of this crop, its adoption rate has remained very low among practising farmers in tropical Africa. This may be attributed to the paucity of information on its state of the art and performance in the cropping system of this part of the world.

Sunflower has not been extensively used as a component of crop mixture in many parts of the world but it has characteristics desirable for intercropping. The erect growth, production under wide row spacing, large and easily harvested head, and its potential use as a staple food suggest that it would be an ideal intercrop for subsistence agriculture in Nigeria. There are conflicting reports about its suitability as an intercrop. Whilst Rice (1974) and Robinson (1984) reported strong allelopathic effects of sunflower on other crop species in USA, Mbiza (1988) and Adetunji (1993) successfully intercropped sunflower with sorghum in the drier regions of Tanzania and Nigeria, respectively. However, the performance of the crop in mixture with major root crops such as cassava and yam has not been properly documented in tropical Africa. Information on the response of this crop in mixture with cassava will enhance its acceptability as a vegetable oil crop in areas where crops are predominant.

This work reports on the growth and yields of intercropped sunflower and cassava using different spatial arrangements.

Materials and Methods

The experiments reported here were conducted at the Teaching and Research Farm of the Ladoke Akintola University of Technology, Ogbomoso during the early planting seasons of 1996 and 1997. Ogbomoso lies on latitude 8°N and longitude 4°E. This location is in the derived savanna bio-climatic zone, an extensive moist savanna belt immediately above the rainforest zone. The cropping season is relatively long, from April to October followed by a short spell of dry harmattan season. The total rainfall during the experimental period was 765 mm in 1996 and 1211 mm in 1997. A soil sample taken from a depth of 15 cm at the field site before planting was characterised as sandy loam with a pH of 6.8. The organic matter content was 0.55%, total nitrogen 0.17%, available phosphorus 9.8 ppm and potassium 0.16 meq $100g^{-1}$ soil. The soil is classified as ultisol (USDA 1975).

The sunflower cultivar used for the study was Isaanka (an open pollinated cultivar of medium height which matures between 90–100 days after planting) obtained from Institute of Agricultural Research (IAR), Samaru, Zaria. Two high yielding local varieties of cassava namely Odongbo and Okoyawo commonly used as intercrop by local farmers were used for the study. Odongbo matures in 12–15 months depending on soil condition, while Okoyawo is generally harvested at 10–12 months after planting by majority of peasant farmers.

There were 11 treatments: 2 of sole cassava, odongbo and okoyawo; 1 sole sunflowers; and 8 different cassava-sunflower combinations, arranged in a replacement series within and between the rows. Thus for each of the cassava varieties there were 4 cassava-sunflower combinations. These treatments were replicated 4 times in a randomized complete block design. The intra-row plant spacing was 60 cm and the inter-row spacing 90 cm. There were 20 rows per plot and 20 plants per row. There were 32 intercrop and 3 sole crop plots, each measuring 16.2 x 11.4 m. Following ploughing and harrowing, cassava cuttings and sunflower seeds were planted at the stipulated treatment levels. After the first weeding at 3 weeks after emergence, fertilizer (NPK 15–15–15) was applied broadcast at the rate of 125 kg/ha. This is the rate recommended for cassava/maize intercrop in this region by KWADP (1988). The same rate was recommended for sunflower/sorghum intercrop at Samaru, Zaria (Ado & Tanimu 1988).

For sunflower, growth parameters such as plant height, stem diameter and leaf number were measured at anthesis while head diameter, seed yield and total dry weight per plant were measured at maturity. Cassava was harvested at 12 months for tops and fresh tuber yields. Plant height, stem diameter and dry matter yield of plant were also measured at harvest. Representative samples of at least 3 tubers from each plot were selected and analysed for starch and dry matter immediately after harvest. When this could not be completed on the same day, samples from the same replicate were kept in sealed polythene bags and stored in the refrigerator and the analysis was done the next day. Starch was extracted from the pulp and determined after Obigbesan (1977) method. Energy yields were computed using the values in Oyenuga (1968). Leaf area per plant was determined on an automatic leaf area meter, model LI3000. This was later converted to leaf area index (LAI). Light transmission was measured with a Lambda portable light meter LI - COR model 185.

Sunflower seed yield and fresh tuber yield of cassava were determined each year using plants in an area of 16.2 x 3 m^2 at the middle of each plot. These were used to compute the Land Equivalent Ratio (LER) using the formula below:

$$LER = \frac{X_a}{M_A} + \frac{X_b}{M_B}$$

Where X_a and X_b are the component yields of crops A (cassava) and B (sunflower) grown within a mixture, and M_A and M_B are the yields of monocultures of A and B on a similar unit area. Treatment differences were tested by 2-way analysis of variance (Little & Hills 1975) from which standard errors of the differences were calculated.

Results

The 1997 season plants are more vigorous than that of 1996 due to low and poor distribution of rainfall in the latter season. Thus the growth and yields of 1997 plants were higher than that of 1996. However, the effects of intercropping treatments on the performance of the mixture were similar for both seasons, so that means of the 2-year data are described.

Effect on growth and development of cassava and sunflower. Cassava and sunflower grown as sole crops were more vigorous than those planted in mixture (Tables 1 and 2). Generally, depression in the growth of the 2 varieties of cassava and sunflower increased with increased severity of intercropping. Compared to sole crop, plant height, stem diameter, leaf number and dry weight of the 2 varieties of cassava were considerably reduced when interplanted in alternate hills and single alternating rows with sunflower. The magnitude of these reductions were highest in Odongbo variety of cassava (Table 1). The growth characteristics of interplanted cassava were similar to that of sole at 3 and 5 alternating rows the sunflower. However, number of days to 50% anthesis was not affected by interplanting methods.

In sunflower, neither growth nor development characteristics were significantly affected when interplanted with Odongbo cassava (Table 2). Growth characteristics such as plant height, stem diameter, leaf number, head diameter and total dry weight of sunflower were significantly reduced when interplanted in alternate hills and single alternating rows with Okoyawo cassava. Interplanting sunflower with

Table 1. Effect of planting methods on the growth and development of cassava planted either as sole or in mixture with sunflower

Planting methods	Plant height (cm)	Stem diameter (cm)	No. of days to 50% anthesis	Leaf no. per plant	Dry weight per plant (g)
Sole Odongbo	38.3	1.4	96.7	28.4	62.4
Alternate hill with sunflower	21.7	0.6	102.3	16.6	27.3
Between row of sunflower	27.8	0.9	95.1	19.3	30.2
Three rows of cassava alternating with 3 rows of sunflower	33.1	1.2	96.3	27.1	58.7
Five rows of cassava alternating with 5 row of sunflower	38.0	1.5	96.4	27.8	61.1
Sole Okoyawo	55.8	1.8	72.5	37.8	87.1
Alternate hill with sunflower	29.6	0.9	73.8	25.1	37.4
Between row of sunflower	34.1	1.1	72.1	29.3	49.3
Three rows of cassava alternating with 3 rows of sunflower	49.7	1.7	72.0	37.1	79.1
Five rows of cassava alternating with 5 row of sunflower	56.1	1.9	72.4	38.3	82.6
SE	0.12	0.10	1.25	0.61	2.11

Okoyawo cassava at 3 and 5 alternating rows did not affect the growth characteristics of sunflower. As observed in the 2 cassava varieties, number of days to 50% anthesis in sunflower was not affected by any of the planting patterns (Table 2).

Effect on yield and yield components of cassava and sunflower. Cassava fresh tuber yield and yield components are in Table 3. Intercropping of the 2 varieties of cassava in alternate hills and single alternating rows with sunflower significantly reduced their fresh tuber and energy yields. The lowest starch ad energy yields and soil nutrient utilization index were also recorded in the 2 cassava varieties when interplanted in alternate hills and single alternating rows with sunflower. The yields and yield components of the 2 cassava varieties interplanted at 3 & 5 alternating rows with sunflower were not significantly different from that of the sole crop of cassava.

In sunflower crop, seed yield and yield components were also significantly affected by the intercropping methods (Table 4). Compared to sole crop, intercropping sunflower in alternate hills and single alternating rows with the 2 cassava varieties significantly reduced its yields and yield components. The magnitude of these reductions were highest in sunflower intercropped with okoyawo variety of cassava. Whilst sunflower yields from 3 and 5 alternating strips were not significantly different from that of sole sunflower, these were significantly higher than the yields obtained from sunflower planted in alternate hills and rows with the 2 varieties of cassava. Irrespective of planting method, the performance of intercropped sunflower was better with odongbo cassava than with okoyawo variety of cassava (Table 4).

Effect on light transmission, leaf area index and land equivalent ratio. The percent light transmission and leaf area index of the intercropped sunflower and cassava are presented in Table 5. Sole sunflower transmitted more light than either of the 2 varieties of cassava. Percent light transmission in cassava was significantly reduced when intercropped with sunflower in alternate hills and single alternating rows. The magnitude of reductions in light transmission was highest in Okoyawo cassava. Compared to sole cassava, there was no significant difference in the amount of light transmitted by the 2 cassava varieties intercropped at 3 & 5 alternating rows with sunflower.

Sunflower transmitted more light when intercropped with odongbo cassava. While light transmission by sunflower interplanted with cassava at 3 & 5 alternating strips were not significantly different from that of sole sunflower, these were significantly higher than the transmission obtained from sunflower planted in alternate hills and single alternating rows. Okoyawo cassava recorded the highest leaf area index (LAI) (Table 5). When compared with sole crop, the odongbo cassava planted in alternate hills with sunflower had the highest LAI reduction of 63.05% followed by 50.82% reduction from those planted in single alternating rows with sunflower; while the LAI of those planted in 3 & 5 alternating rows were reduced

Table 2. Effect of planting methods on the growth and development of sunflower planted either as sole or in mixture with cassava

Planting methods	Plant height (m)	Stem diameter (cm)	No. of days to 50% anthesis	Leaf no. per plant	Head diameter (cm)	Total dry weight per plant (g)
Sole sunflower	1.7	2.8	58.2	31.5	21.3	285.7
Alternate hill with odongbo cassava	1.8	1.9	56.3	26.3	13.1	157.1
Between row of odongbo cassava	1.6	2.1	58.4	27.1	13.8	163.4
Three rows of sunflower alternating with 3 rows of odongbo cassava	1.7	2.7	58.6	30.4	19.6	287.6
Five rows of odongbo cassava alternating with 5 rows of odongbo cassava	1.8	2.7	57.3	32.0	20.4	293.4
Alternate hill with okoyawo cassava	0.7	0.9	58.1	15.1	10.6	115.4
Between row of okoyawo cassava	0.9	1.1	58.3	17.3	11.3	128.3
Three rows of sunflower alternating with 3 rows of okoyawo cassava	1.1	1.6	56.8	20.1	16.4	191.3
Five rows of sunflower alternating with 5 rows of okoyawo cassava	1.2	1.7	57.7	22.3	18.3	209.6
SE	0.03	0.11	2.13	1.11	0.35	2.36

Table 3. Effect of planting method on the yield and yield factor of cassava planted as sole or in mixture with sunflower

Planting methods	Fresh tuber yield per plant (kg)	Fresh tuber yield (t/ha)	Starch yield (t/ha)	Energy yield (x106 cal/ha)	Soil nutrient utilization index (UI)
Sole Odongbo	3.6	14.4	2.5	38.6	0.68
Alternate hill with sunflower	1.7	4.6	0.5	25.8	0.47
Between row of sunflower	2.0	6.2	0.7	27.1	0.53
Three rows of cassava alternating with 3 rows of sunflower	3.3	13.8	2.3	36.7	0.60
Five rows of cassava alternating with 5 row of sunflower	3.5	14.1	2.4	38.8	0.69
Sole Okoyawo	2.9	11.6	1.8	33.4	0.72
Alternate hill with sunflower	1.2	5.6	0.4	21.1	0.59
Between row of sunflower	1.5	7.3	0.6	24.7	0.64
Three rows of cassava alternating with 3 rows of sunflower	2.1	10.1	1.3	31.1	0.70
Five rows of cassava alternating with 5 rows of sunflower	3.0	11.1	1.6	33.4	0.71
SE	0.22	0.51	0.02	1.32	0.06

by 21.74 and 4.08%, respectively. Similar pattern of reductions in LAI were recorded in okoyawo variety of cassava. For the interplanted sunflower, the magnitude of reductions in LAI were highest when mixed with okoyawo cassava irrespective of the planting pattern (Table 5). Whilst reductions of 70.34 and 61.14% were obtained from sunflower interplanted with okoyawo at alternate hills and single alternating rows respectively, reductions of 49.35 and 46.96% were recorded in sunflower interplanted with odongbo at the same planting ratios.

The Land Equivalent Ratios (LERs) showed that planting of sunflower in 3 and 5 alternating strips with the 2 varieties of cassava made better use of the land than could be made by growing the crops separately (Table 6). In all the planting methods the yields of the 2 cassava varieties made greater contribution to land useage gains (LER) than that of sunflower. The fresh tuber yield of okoyawo cassava made more contribution to the LER than that of odongbo. Intercropping sunflower with either of the varieties of cassava especially at alternating hills and single alternating rows significantly

Table 4. Effect of planting method on the yield of sunflower planted as sole or in mixture with cassava

Planting methods	Seed yield per plant (g)	Seed yield per hectare (kg)	Seeds per head	Seed dry 1000-seed weight (g)	matter yield per plant (g)
Sole sunflower	25.5	2.7	860.2	75.6	16.8
Alternate hill with odongbo	6.8	0.4	506.3	48.3	8.1
Between row of odongbo	7.1	0.6	565.6	51.1	11.2
Three rows of sunflower alternating with 3 rows of odongbo	21.1	2.1	831.3	68.3	14.1
Five rows of sunflower alternating with 5 rows of odongbo	24.7	2.5	838.1	72.4	15.2
Alternate hill with okoyawo	4.3	0.2	411.6	40.1	5.7
Between row of okoyawo	5.2	0.4	496.3	47.3	7.3
Three rows of sunflower alternating with 3 rows of okoyawo	18.6	1.6	684.5	59.3	10.0
Five rows of sunflower alternating with 5 rows of okoyawo	20.4	1.8	809.3	61.4	12.8
SE	1.01	0.11	4.25	2.11	0.36

Table 5. Effect of planting methods on leaf area index and light transmission in intercropped cassava and sunflower

	Light transmission (%)		Leaf Area Index			
			Cassava		Sunflower	
Planting methods	Cassava	Sunflower	Total	Reduction (%)	Total	Reduction (%)
Sole odongbo	66	-	3.68	-	-	-
Sole okoyawo	59	-	4.16	-	-	-
Sole sunflower	-	75	-	-	5.43	-
Odongbo and sunflower in alternate hills	49	58	1.36	63.05	2.15	49.35
Odongbo ad sunflower in alternate rows	52	61	1.81	50.82	2.88	46.96
Three rows of odongbo alternating with 3 rows of sunflower	60	68	2.88	21.74	4.24	21.91
Five rows of odongbo alternating with 5 rows of sunflower	67	74	3.53	4.08	5.11	5.89
Okoyawo and sunflower in alternate hills	32	49	2.46	40.86	1.61	70.34
Okoyawo and sunflower in alternate rows	38	57	2.77	33.41	2.11	61.14
Three rows of okoyawo alternating with 3 rows of sunflower	56	70	3.25	21.87	3.44	36.64
Five rows of okoyawo alternating with 5 rows of sunflower	59	73	3.89	6.49	4.31	20.62
SE	1.02	0.65	0.22	1.34	0.04	2.11

Table 6. Competition ratios, relative yields and land equivalent ratios of cassava-sunflower mixtures as affected by planting methods

	Relative yield		Land Equivalent
Planting methods	Cassava	Sunflower	Ratios
Sole odongbo	1.00	-	1.00
Sole okoyawo	1.00	-	1.00
Sole sunflower	-	1.00	1.00
Odongbo and sunflower in alternate hills	0.32	0.11	0.43
Odongbo ad sunflower in alternate rows	0.43	0.19	0.62
Three rows of odongbo alternating with 3 rows of sunflower	0.95	0.77	1.72
Five rows of odongbo alternating with 5 rows of sunflower	0.97	0.92	1.89
Okoyawo and sunflower in alternate hills	0.48	0.07	0.55
Okoyawo and sunflower in alternate rows	0.63	0.15	0.78
Three rows of okoyawo alternating with 3 rows of sunflower	0.87	0.59	1.46
Five rows of okoyawo alternating with 5 rows of sunflower	0.96	0.66	1.62
SE			

reduced the LERs. When compared with sole crops, the magnitude of these reductions were highest in mixture of sunflower and odongbo cassava.

Discussion

This study showed that the overall performance of the intercrop depended on the variety of cassava, severity of mixture and the difference in the time of reproductive development of the crops involved in the mixture. At all levels of intercropping studied, okoyawo was more aggressive in suppressing the growth of interplanted sunflower. This may be attributed to its characteristic profuse early growth and wide canopy which enables it to further suppress the usual early slow growth of interplanted sunflower. This phenomenon was more pronounced when the 2 crop species were mixed in alternate hills and single alternating rows. Contrarily, the early slow growth of odongbo allowed the interplanted sunflower to thrive which culminated in its better performance compared with what was obtained in mixture with okoyawo variety of cassava.

In the 2 crop species involved in the mixture, almost all the growth and development characters that are susceptible to environmental variables were influenced by the various intercropping methods, while number of days to 50% anthesis which is genetically controlled was least affected. Of all the planting patterns studied, 5 rows of either of the 2 varieties of cassava between 5 rows of sunflower resulted in superior performance of both crop species. The other cropping patterns might have reduced performance of both crop species because of severe competition for nutrients, moisture and light especially when interplanted in alternate hills and single alternating rows. The competition might have been less in the 5 row interplanting method. Similar observations were reported by Adetunji (1993), Crookston & Hill (1976) and Andrews (1972). The major agronomic importance of strip intercropping is the creation of more border rows and, consequently more intercrop and less intra-crop competition. This change in type of competition may be detrimental or beneficial to one or both crops. In this case, it is beneficial to both crops. The magnitude of this benefit or loss varies with the widths of the intercrop strips—narrow strips have greater effect and wide strips less effect. Thus growing both crop species in 5 alternating rows enhanced yield and yield components of the crops more than in other planting patterns.

The disparity in the time of reproductive development of both crop species is advantageous because the two crops did not come to the stage of maximum demand for nutrient and moisture, aerial space and light at the same time. Where this occurred reduction in yield has been reported (Enyi 1973, Fisher 1977). Nevertheless, the attendant intercrop competition was more injurious to sunflower especially when intercropped with okoyawo cassava at alternate hills and single alternating rows. This may be attributed to the more hardy nature of cassava and the fact that cassava remained on the field for more than 5 months after harvesting of sunflower. Thus cassava was able to make substantial recovery from whatever physical competitive and allelophatic (Rice 1974, Adetunji 1993) effects sunflower might have over the crop during the 4 months of their growth together on the field. However, the injurious effect of intercropping competition on sunflower was considerably reduced when intercropped with the slow growing odongbo cassava.

The highest reductions in LAI for cassava and sunflower were recorded when the crops were interplanted in alternate hills. Similarly, light transmission was also lowest in this planting method. These 2 factors, which are very important components of photosynthetic activity of green plant would explain why the total yields of the 2 crop species were lowest under this planting pattern. The relationships between the cassava-sunflower combinations and their monocultures indicated differences in the competitive influence of the component crops at different cropping patterns which resulted in deviations from the expected LER values. The expected LER according to Willey (1979) is the LER value which would have been obtained if each crop in the mixture had experienced the same degree of competition in mixture as in monoculture. Thus each of the crops involved in the mixture is expected to contribute to the expected LER in accordance with its proportion in the intercrop (mixture) ratio. In this study, each of the planting patterns consists of equal proportion of the two crop species. Therefore, given that the LER of a cassava monuculture is 1, the expected LER of the cassava components in each of the cassava-sunflower intercrop is 0.5, if the cassava in mixtures performs as it does in monoculture. The total expected LER is the summation of the expected LER of both crops in each mixture which in this study is equal to 1 for each of the planting patterns.

The deviations from expected LERs as observed in this study fulfills the basic rule of compensation in interspecies relationships (Willey 1979). In such relationships, the yield of one specie surpasses the other and makes up for the inferior performance of the component crop. In this case, the LERs obtained in the cassava-sunflower intercropped in different patterns provides example of compensation in that the yield from cassava contributed more to the total LER than that of sunflower, thereby making LER values higher in the intercrop than in sole crop. This further contradicts the report of Robinson (1984) that intercropping sunflower with maize decreased land productivity. This may be due to the more hardy nature of cassava and the facts that the crop stayed longer on the field than sunflower.

These results suggest that cassava and sunflower can be successfully intercropped without economic loss to cassava farmers in the tropics. However, for increased mixture productivity, the farmer should adopt wider strips and also use a variety of cassava that is early maturing but with less extensive canopy that will interfere less with the photosynthetic activity of sunflower.

References

Adetunji I.A. 1993. Growth and yields of intercropped sorghum and sunflower (*Helianthus annuus* L.) in semi-arid Nigeria. Journal of Agronomy and Crop Science 171: 351–357.

Ado S.G. & Tanimu B. 1988. Sunflower (*Helianthus annuus* L.) germplasm introduction at Samaru, Nigeria. Germplasm Newsletter, Plant Genetic Resource Center/Ethiopia and International Livestock Center for Africa 17: 15–16.

Andrews D.J. 1972. Intercropping with sorghum in Nigeria. Experimental Agriculture 8: 139–150.

Baker E.F.I. 1980. Mixed cropping in northern Nigeria. IV. Extended trials with cereal and groundnuts. Exper. Agric. 16: 361–369.

Crookston R.K. & Hill D.S. 1979. Grain yields and land equivalent ratios from intercropping corn and soyabeans in Minnesota. Agronomy Journal 71: 41–44.

Enyi B.A. 1973. Effects of intercropping maize or sorghum with cowpea, pigeon peas or beans. Experimental Agric. 9: 83–90.

Fisher N.M. 1977. Studies on mixed cropping. II. Population pressures in maize-bean mixture. Experimental Agriculture 13: 185–191.

Francis C.A. 1981. Development of plant genotypes for multiple cropping systems. In: Plant Breeding II (ed. J.K. Frey). Iowa: The Iowa State University Press. p. 125–131.

Krantz B.A., Virmani S.M., Sardar S. & Rao M.R. 1976. Intercropping for increased and more stable agricultural production in the semi-arid tropics. In Symposium on Intercropping in Semi-Arid Areas (Proceedings), Morogoro, Tanzania 10–12 May. p. 114–118.

KWADP (Kwara Agricultural Development Programme) 1988. Project Report. p. 8–10.

Little T.M. & Hills F.J. 1975. Statistical methods in agricultural research. Publication of University of California, Davis, USA. p. 50–61.

Mbiza A.B.C. 1988. Sunflower production: problems and research progress in Tanzania. In: Proceedings of the 4th oil crops network workshop, Hjoro, Kenya 25th – 29th January. p. 135–140.

Njoku B.O. & Odurukwe S.O. 1986. Evaluation of nitrogen fertilizer sources and rates for a cassava-maize intercrop. *In*: Proceedings of the 3rd triennial symposium of the International Society for Tropical Root Crops - Africa Branch, Owerri, Nigeria. 17–23 August. p. 116–120.

Ntare B.R. 1990. Intercropping morpologically different cowpeas with pearl millet in a short season environment in the sahel. Experimental Agriculture 26: 41–47.

Obigbesan G.O. 1977. Investigations in Nigerian root and tuber crops, effect of potassium on starch yields, HCN content and nutrient uptake of cassava cultivars. Journal of Agricultural Science, Cambridge 89: 29–34.

Osiru D.S.O. & Willey R.W. 1972. Studies on mixtures of dwarf sorghum and beans (*Phaseolus vulgaris*) with particular reference to plant population. Journal of Agricultural Science, Cambridge 79: 531–540.

Oyenuga V.A. 1968. Nigeria's foods and feeding stuffs. Ibadan University Press, Nigeria. 17–19.

Robinson R.G. 1984. Sunflower for strip, row and relay intercropping. Agronomy Journal 76(1): 43–47.

Rice E.L. 1974. Allelopathy. Academic Press, New York, 41–48.

USDA (United States Department of Agriculture) 1975. Soil taxonomy: a basic system of soil classification for marking, interpreting soil surveys. USDA Agricultural Handbook No. 436. p. 10.

Willey R.W. & Osiru D.S.O. 1972. Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. Journal of Agric. Science, Cambridge 79: 519–529.

Willey R.W. 1979. Intercropping: its importance and research needs. I. Competition and yield advantages. Field Crop Abstracts 32: 1–10.