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Intercropping Sunflower with Soyabeans Enhances Total Crop Productivity

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ABSTRACT

There is a need to develop sustainable and productive cropping systems for edible vegetable oilseeds in tropical Africa. Field trials were conducted during the late cropping season (July–Nov.) of 2001 and 2002 to determine the grain yields, and other yield attributes of sunflower and soyabeans and their productivity under monocropping and intercropping. Three sunflower (*Helianthus annuus* L.) varieties (a local adapted var. Funtua and two exotic varieties Isaanka and Record from Argentina) and five improved, high yielding soyabean (*Glycine max* (L.) Merrill) varieties: TGx 1448-2E (late), TGx 1440-1E (late), TGx 1019-2EB (medium), TGx 1740-2F (early) and TGx 1485-1D (early maturing) were used. Funtua had significantly greater head weight and diameter, achene number and weight per head than Isaanka and Record during the dry and relatively hot cropping season of 2001. Cropping system significantly reduced soyabean grain yield in intercropping, relative to monocropping, except when soyabean was intercropped with Isaanka in 2001 and Record in 2002. All yield attributes of both crops exhibited significant positive relationship with grain yields, except height to the lowest pod of soyabean. TGx 1448-2E and TGx 1440-1E intercropped with Isaanka and Record had average grain yield of 1043 and 1081 kg ha^{-1} and land equivalent ratios (LER) of 1.47 and 1.58, respectively. It is recommended that intercropped combination of TGx 1448-2E/Isaanka and TGx 1440-1E/Record be used to improve yields of vegetable oilseeds.

INTRODUCTION

Studies on oilseed production in Africa are mostly restricted to oil palm (*Elaeis guineensis* L.) trees as the dominant crop in most cropping systems because they are believed to be a major income earner (Fabunmi *et al.*, 2004). There is little information on production of oilseed crops. In the tropics, vegetable crops

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are often grown in association with other food crops such as tubers, cereals and food legumes (Olasantan, 1996), one of which is soyabeans [*Glycine max* (L.) Merrill]. The choice of component crops in a cropping system depends on the agro-ecological zone, grower preference and ability to complete the growing cycle. About 50–80% of rain-fed crops are planted as intercrops in developing countries (Osiru, 1982). The potential benefits of successful intercropping of vegetable legumes with sunflower (*Helianthus annuus* L.) include nitrogen fixation, soil erosion control, and improvement of soil structure and organic matter content (Biederbeck & Bouwman, 1994; Kandel *et al.*, 1997). Sunflower production in the tropics appears to be beneficial because its oil is readily extractable for use and it has high content of vitamin E. In the tropics, soyabeans and sunflower are predominantly cultivated as intercrops with cereals such as corn (*Zea mays* L.), sorghum (*Sorghum bicolor* L.) and millet (*Pennisetum typhoides* L.) and rarely as monocrops or intercrops with each other (Agboola, 1979). The relative performance of the component crops in the intercrops depends on time of planting, planting pattern, fertilizer application, compatibility of component crop species and pest (Funkai & Trenbath, 1993; Kandel *et al.,* 1997; Olowe *et al*., 2003; Olowe, 2005; Olowe *et al*., 2006).

Sunflower oil is considered a premium oil because of its light colour, mild flavour, low saturated fat levels and the ability to withstand high cooking temperatures (Anon., 2002; Myers & Minor, 2002). Soyabean is presently the world's most important edible grain legume in terms of total production and international trade (Weiss, 2000). The oil content of soyabean seed varies between 15 and 22% depending on variety, environment and climate. There is an increasing demand for vegetable oil soyabean varieties that have low levels of linolenic acid from the food industry because of its excellent frying and flavour capabilities (Anon., 2007). Consequently, soyabeans and sunflower are gaining importance due to being identified as potential substitutes (Ogunremi, 2000) for the two traditional oil sources, peanut (*Arachis hypogea* L.) and oil palm.

There is a need to develop additional information on the intercropping of sunflower and soyabeans as component crops in tropical Africa so that production can be maximized. This study was undertaken to determine seed yield, yield components and productivity of sunflower and soybean varieties in intercropping systems.

MATERIALS AND METHODS

Site description

Field experiments were performed during the late rainy season June–Nov.

2001 and 2002 at the Teaching and Research Farm of the University of Agriculture, Abeokuta (7° 15′N, 3° 25′E, 140 m above sea level) in the forest-savanna transition zone of southwest of Nigeria. The soils were a sandy loam with a pH of 5.9 and relatively low fertility (organic matter, 1.01%, total N, 0.06 g kg^{-1}; available P, 1.85 mg kg^{-1}; and exchangeable K 0.11 Cmol kg^{-1}). Total rainfall and average air temperature were determined using rain gauge and wet and dry bulb thermometer, respectively. Weather data were collected from the Meteorological Station of the Department of Water Resources and Agroclimatology of the University.

Treatments and experimental design

Five soyabean varieties including early (TGx 1485-1D and TGx 1740-2F), medium (TGx 1019-2EB) and late (TGx 1448-2E and TGx 1440-1E), released by the International Institute of Tropical Agriculture, Ibadan, Nigeria and three open pollinated sunflower varieties: Record, Isaanka (from Argentina) and Funtua (local adapted variety) were used. All soyabean varieties are resistant to pod shattering (Asafo-Adjei & Adekunle, 2001). In the intercrop, soyabean was planted between sunflower rows, with a constant arrangement of two rows of sunflower followed by four rows of soyabean with rows spaced at 60 cm apart.

Crop production

In both years the fields were plowed and disked, and divided into plots measuring 5 × 3 m. Planting of both component crops was done manually on unbedded soil on 11 July 2001 and 6 July 2002. The spacing for sunflower was 60 × 30 cm for plant populations of 55000 and 23000 plants ha^{-1} and for soyabeans was 60 × 5 cm giving 333 000 and 267 000 plants ha^{-1} in monocropping and intercropping, respectively. Weeding was done manually twice at 3 and 6 weeks after planting (WAP). There was no fertilizer, herbicides or irrigation applied simulating the typical producer practices.

Data collection and processing

Five sunflower tagged plants per plot were randomly selected and destructively sampled for determination of yield attributes which included head diameter, head weight, number and weight of achene per head and grain yield. Five soyabean plants per plot were randomly selected and tagged at 5 WAP. These plants were later destructively sampled for determination of numbers and weight of seeds and pods, height to lowest pod, number of branches per plant and grain yield. LER was determined by dividing yields for monocropped sunflower and soyabean by their respective monocropped yields and resulting ratios (relative yields) for the two crops were added to obtain LER values (Willey, 1979). The experiment consisted of 23 treatments: monocropped sunflower varieties (3), monocropped soyabean varieties (5) and 15 intercropped combinations of both crops. The experiment was arranged in a randomized complete block design with three replications. Data collected were subjected to analysis of variance (ANOVA) using MSTATC package (Crop and Soil Sciences Department, Michigan State University, Lansing, U.S.A.). Where F-values indicated significant differences, treatment means were compared using the least significant difference method (Steel & Torrie, 1980) and simple linear correlation analyses were carried out to estimate degree of association between seed yields and yield attributes of both crops.

RESULTS

Total rainfall and average air temperature during the period of experimentation are presented in Table 1. About 32% (290.0 mm) of total rainfall and average air temperature of 19.5°C were recorded in October during the reproductive phase of both crops in 2002 as against 10% (45.5 mm) and 21.6°C in 2001.

Effect of treatments on crop yield and yield attributes

Since the two years of experimentation exhibited contrasting rainfall distribution and mean monthly temperature, the means of the variables determined on both crops were examined as if year was a variable. However, the year effect had no significant effect, except on number of achene per head; cropping system

TABLE 1

Monthly rainfall and average air temperature during the late cropping seasons of 2001 and 2002.

	Rainfall (mm)		Average air temperature (°C)	
Month	2001	2002	2001	2002
July	144.5	325.5	23.8	21.0
August	57.4	110.1	26.5	19.0
September	199.3	148.3	20.6	19.5
October	45.5	297.0	21.6	19.5
November	17.4	54.5	21.4	22.8
Total	464.1	935.4		

affected head diameter and grain yield of sunflower. Variety significantly affected all yield attributes and grain yield of sunflower. Similarly, Year × Variety interaction effect was significant for all the yield attributes, except grain yield. Year × Cropping system and Cropping system × Variety interactions had no effect on the parameters (Table 2).

Year and variety had significant effects on grain yield and all yield attributes (Table 2). Cropping system affected height to the lowest pod, weight of seeds per plant and grain yield of soyabeans. The Year × Cropping system interaction affected height to the lowest pod and number of branches per plant and grain yield. With the exception of numbers of pods and branches per plant, the Year × Variety interaction had no significant effect on other yield attributes and grain yield of soyabeans. The Cropping system × Variety interaction affected weight of seeds per plant and number of pods and branches per plant.

Effect of cropping system and variety on grain yield and yield attributes

Intercropping only significantly affected head diameter, achene weight per head and grain yield in 2002. However, in 2001, the varietal effect was significant for all the yield attributes and grain yield, but did not affect any of the variable in 2002 (Table 3).

Intercropping soyabeans with sunflower affected grain yield of soyabeans in both years, number of pods and branches per plant and height to the lowest pod in 2002 (Table 4). Number of pods and branches per plant were significantly greater when intercropped with sunflower var. Isaanka than with var. Record and Funtua, and the monocrop in 2002. Soyabean intercropped with var. Funtua had the highest height to the lowest pod and the lowest grain yield which was significantly lower than the grain yield of soyabean intercropped with var. Record and the monocrop. In 2001, grain yields of monocropped soyabean and soyabean intercropped with sunflower var. Isaanka were significantly greater than yields of soyabeans intercropped with var. Record and Funtua. The two late maturing soyabean varieties, TGx 1448-2E and TGx 1440-1E, produced significantly greater numbers of pods, seeds and branches, and weight of seeds per plant and grain yield than the early and medium maturing varieties in 2001. Similarly, the two late varieties had greater grain yield than the other three varieties, with the exception of TGx 1485-1D in 2002.

The Cropping system × Variety interaction was significant for grain yield of soyabeans (Table 2). The monocropped soyabean varieties produced higher grain yields than the intercrops and mixture mean yields, except for TGx 1019-2EB intercropped with Record. TGx 1448-2E and TGx 1440-1E had comparatively higher grain yield than TGx 1019-2EB, TGx 1485-1D and TGx 1740-2F. The soyabean-sunflower mean, though lower than the monocrop

TABLE 2

Results of analysis of variance of grain yield and yield attributes of soyabeans and sunflower.

Soybean

Source	df	Height to lowest pod (cm)	Weight of pods/plant (g)	Weight of seeds/ plant (g)	Number of pods/plant	Number of seeds/plant	Number of branches/plant	Grain yield (kg ha^{-1})
Year (Y)	1	42.39**	34.20**	5.14*	10.87**	13.36**	16.82**	33.21**
Cropping system (CS)	3	20.66**	2.36ns	2.75*	1.72ns	2.36ns	1.59ns	8.79**
Y × CS	3	10.02**	1.07ns	0.87ns	3.41*	0.96ns	3.36*	4.27**
Varieties (V)	4	14.62**	3.11*	4.64**	3.82**	3.96**	3.49*	8.16**
Y × V	4	1.31ns	1.43ns	1.25ns	5.42**	1.51ns	3.41*	0.42ns
CS × V	12	1.25ns	1.54ns	2.49**	1.55ns	1.92*	2.88**	1.97*
Y × CS × V	12	1.08ns	0.57ns	0.75ns	0.39ns	0.84ns	3.45**	0.91ns

Sunflower

Source	df	Head weight (g)	Head diameter (cm)	Number of achene/ head	Weight of achene/head (g)	Grain yield (kg ha^{-1})
Year (Y)	1	0.08ns	0.55ns	24.84**	2.01ns	1.92ns
Cropping system (CS)	5	1.32ns	2.69*	0.42ns	1.81ns	10.50**
Y × CS	5	0.94ns	1.83ns	0.68ns	1.53ns	0.19ns
Varieties (V)	2	13.05**	11.01**	8.79**	11.17**	9.82**
Y × V	2	5.25**	4.16*	8.60**	11.14**	1.89ns
CS × V	10	1.50ns	1.17ns	1.11ns	0.91ns	1.14ns
Y × CS × V	10	0.11ns	0.32ns	0.53ns	0.50ns	0.74ns

ns, *, **, nonsignificant or significant at $p \leq 0.05$ and $p \leq 0.01$, respectively, ANOVA.

TABLE 3

Effect of cropping system and variety on grain yield and yield attributes of sunflower.

Treatment	Head diameter (cm)		Head weight (g)		Achene weight/ head (g)		Number of achene/head		Grain yield (kg ha^{-1})	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Cropping system										
Monocropped sunflower	9.9	10.0	50.9	49.8	36.2	30.5	611	471	811	927
Sunflower/TGx 1448-2E	11.3	11.8	61.1	67.6	38.8	46.3	650	533	456	462
Sunflower/TGx 1485-1D	11.0	9.1	58.7	48.8	39.8	28.4	668	397	489	411
Sunflower/TGx 1440-1E	11.4	10.4	63.2	55.5	41.1	36.8	691	507	412	538
Sunflower/TGx 1740-2F	10.1	10.9	53.6	63.8	38.3	39.5	638	533	550	554
Sunflower/TGx 1019-2EB	11.0	11.2	57.3	65.3	43.0	37.2	724	458	566	527
LSD (5%)	ns	1.4	ns	ns	ns	11.1	ns	ns	ns	204.1
Variety										
Isaanka	10.2	10.0	48.4	54.0	32.6	34.6	580	515	389	553
Record	9.8	10.7	45.4	57.9	32.3	38.4	538	455	491	490
Funtua	12.3	11.0	78.4	63.5	53.8	36.5	874	480	763	666
LSD (5%)	1.1	ns	12.4	ns	7.4	ns	123.0	ns	184.4	ns

ns, **, not significant or significant at $p \leq 0.01$, respectively, LSD.

TABLE 4

Effect of cropping system and variety on grain yield and yield attributes of soyabeans.

Treatments	No. of pods/ plant		No. of seeds/plant		No. of branches/plant		Weight of pods/plant (g)		Weight of seeds/plant (g)		Height of lowest pod (cm)		Grain yield (kg ha^{-1})	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Cropping system														
Monocropped soybean	27	31	40	52	3	4	10.7	16.4	7.1	8.5	12.3	15.1	707	1028
Soyabean/Isaanka	22	40	37	62	3	5	10.3	17.8	7.1	9.2	11.2	12.4	611	682
Soyabean/Record	24	28	30	42	3	4	9.6	13.7	6.0	7.0	11.5	13.1	375	982
Soyabean/Funtua	24	26	43	50	3	4	9.7	13.1	6.5	6.5	12.9	21.6	413	588
LSD (5%)	ns	8.3	8.3	ns	ns	0.8	ns	ns	ns	ns	ns	2.7	183.0	248.3
Variety														
TGx 1448-2E	29	32	57	54	4	4	11.8	16.2	8.2	8.3	10.0	14.7	676	1011
TGx 1485-1D	18	33	29	49	3	5	7.7	14.5	5.3	7.7	12.4	14.5	467	819
TGx 1440-1E	39	28	46	58	4	4	13.9	15.3	9.0	8.5	10.2	12.2	713	1036
TGx 1740-2F	16	30	27	44	2	4	7.7	13.7	5.3	6.8	12.5	16.8	424	613
TGx 1019-2EB	19	31	29	54	2	4	19.2	16.4	5.5	7.6	14.9	19.7	353	620
LSD (5%)	7.7	ns	9.3	ns	0.8	ns	1.9	ns	1.1	ns	1.7	3.0	204.6	277.6

ns = not significant at $p \leq 0.05$, LSD.

TABLE 5

Cropping system × Variety interaction on soyabean grain yields.

Cropping system	Variety	Grain yield (kg ha^{-1})
Monocrop	TGx 1448-2E	1079
	TGx 1485-1D	706
	TGx 1440-1E	1128
	TGx 1740-2F	832
	TGx 1019-2EB	590
Soyabean/Isaanka	TGx 1448-2E	1043
	TGx 1485-1D	407
	TGx 1440-1E	665
	TGx 1740-2F	433
	TGx 1019-2EB	427
Soyabean/Record	TGx 1448-2E	565
	TGx 1485-1D	602
	TGx 1440-1E	1081
	TGx 1740-2F	521
	TGx 1019-2EB	622
Soyabean/Funtua	TGx 1448-2E	630
	TGx 1485-1D	654
	TGx 1440-1E	537
	TGx 1740-2F	288
	TGx 1019-2EB	309
Soyabean intercrop mean	TGx 1448-2E	746
	TGx 1485-1D	621
	TGx 1440-1E	761
	TGx 1740-2F	414
	TGx 1019-2EB	453
LSD (0.05)		335.4

of soyabean varieties was only significant for TGx 1440-1E and TGx 1740-2F (Table 5). The monocropped sunflower yield was significantly greater than the yields of all intercropping treatments in 2002 (Table 3). However, the interaction effect was not significant when averaged over two years (Table 6).

On average all 15 cropping systems, except TGx 1440-1E/Isaanka, TGx 1740-2F/Isaanka and TGx 1740-2F/Funtua had a higher land use advantage (i.e. LER >1.00) over their monocrops. Record and TGx 1019-2EB had the highest mixture means LER of 1.44 and 1.37 among sunflower and soyabean varieties, respectively (Table 7). Intercropping of the soyabean varieties with Record resulted in a land use advantage value that ranged between 4–76% over their monocrops. However, this advantage was only significantly better in intercropping with TGx 1019-2EB and TGx 1440-1E then for TGx 1448-2E.

Weights of pods and seeds per plant and numbers of pods and seeds per plant were positively related, while height to the lowest pod was negatively related to soybean grain yield. Head weight, head diameter, number and weight

TABLE 6

Cropping system x Variety interaction on sunflower grain yield.

Cropping system	Variety	Grain yield (kg ha^{-1})
Monocrop	Isaanka	854
	Record	689
	Funtua	1066
Sunflower/TGx 1448-2E	Isaanka	427
	Record	356
	Funtua	594
Sunflower/TGx 1485-1D	Isaanka	396
	Record	399
	Funtua	364
Sunflower/TGx 1440-1E	Isaanka	308
	Record	430
	Funtua	712
Sunflower/TGx 1740-2F	Isaanka	374
	Record	524
	Funtua	680
Sunflower/TGX 1019-2EB	Isaanka	439
	Record	495
	Funtua	595
Sunflower intercrop mean	Isaanka	389
	Record	441
	Funtua	595
LSD (0.05)		ns

ns = not significant.

TABLE 7

Land equivalent ratio (LER) of sunflower/soyabean intercropping.

Sunflower varieties	Soyabean varieties					Intercrop mean
	TGx 1448-2E	TGx 1485-1D	TGx 1440-1E	TGx 1740-2F	TGx 1019-2EB	
Isaanka	1.47	1.04	0.95	0.96	1.24	1.13
Record	1.04	1.43	1.58	1.39	1.76	1.44
Funtua	1.13	1.26	1.15	0.99	1.11	1.13
Intercrop mean	1.21	1.24	1.23	1.11	1.37	
LSD (5%)	0.5					

Significant at $p \leq 0.05$, LSD.

TABLE 8

Correlation analysis between grain yield and yield attributes of soyabean and sunflower.

Soyabean	Height to the lowest pod	Weight of pods/plant	Weight of seeds/plant	Number of seeds/plant	Number of pods/plant	Number of branches/plant
Grain yield	–0.92**	0.77*	0.94**	0.93**	0.90**	0.88**

Sunflower	Head weight	Head diameter	No. of achene/head	Weight of achene/head
Grain yield	0.99**	0.99**	0.94*	0.99**

*,** – significant at $p \leq 0.05$ and $p \leq 0.01$, respectively, Pearson product-moment.

of achene per head exhibited significant positive relationship with sunflower grain yield (Table 8).

DISCUSSION

Intercropping soyabean and sunflower is a worthwhile enterprise in the tropics. Intercropping of compatible crop species stabilizes returns over seasons since more than one commodity is derived from the system and the components can compensate for each other in case of price fluctuation in any of the components (Osiru, 1982). Furthermore, sunflower is a crop well adapted to intercropping because it exhibits minimal land cover and is considered to be a drought resistant crop (Putman, 1986). The three sunflower varieties grown in monoculture produced grain yields from 689 to 1006 kg ha^{-1} relative to the current African average of 947 kg ha^{-1} for sunflower (FAO, 2004). The intercrop and mixture mean yields of the sunflower varieties were similar to those of the monocrop probably because of enhanced productivity of individual plants under intercropping conditions. This could be due to reduced interplant competition among sunflower stands compared with those in monocrop and absence of appreciable interspecific competition by soyabean (Shivaramu & Shivashankar, 1992). Conditions of the 2002 cropping season were more favourable for soyabean and sunflower production because they were wetter and cooler than in 2001. Although changes in microclimate due to intercropping were not investigated in this study, Olasantan (2007) and Olasantan *et al.* (2007) revealed that substantial variations in soil moisture, light interception, and air, canopy and soil temperatures under intercropping were favourably modified to benefit the growth of component crops. However, lack of appreciable yield reduction of Record and Isaanka in the mixtures suggests that these varieties have some level of compatibility with soyabean, especially TGx 1440-1E and TGx 1448-2E, compared with var. Funtua under tropical conditions. The potential of production and intercropping of sunflower with other crops like cowpea and sesame in the forest-savanna transition zone have been reported (Olowe *et al.*, 2003, 2006; Olowe, 2005, 2006).

The two late soyabean varieties TGx 1448-2E and TGx 1440-1E had greater growth and yield performance than the early TGx 1485-1D and TGx 1740-2F and medium maturing variety TGx 1019-2EB in both years, possibly because the late varieties were able to utilize the residual soil moisture in October and November for pod filling.

Although intercropping reduced some yield attributes of sunflower, particularly in 2002, the combine yields of both crops should be taken into consideration. Sunflower grain yield strongly depended on average head weight, head diameter and number and weight of achene per head, indicating that these attributes are functions of yield and the higher their values, the higher the grain yield of sunflower. Intercrops of TGx 1448-2E/Isaanka and TGx 1440-1E/Record had on average 47 and 58%, respectively, more grain yield than they produced as monocrops. Across soyabean varieties, it appears that sunflower variety Record is the most compatible variety based on its LER. Genotype variation in response of sorghum to intercropping with soyabean have been reported (Galway *et al.,* 1986)

The results indicate that sustainable production of TGx 1448-2E/Isaanka and TGx 1440-1E/Record intercrop combinations can be successfully practised by small scale growers in the forest-savanna transition zone. However, for commercial production of sunflower, var. Funtua and soyabean var. TGx 1448-2E, TGx 1440-1E and TGx 1740-2F are better grown in monoculture since var. Funtua is a local and well adapted variety that can give optimum yield even under marginal growing conditions and the soyabean varieties meet the food industry requirement (large seed size), and are also well adapted high yielding varieties with pod shattering resistance trait.

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