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On-farm evaluation of the productivity of intercropping sunflower with arable crops among smallholder farms in Nigeria and Botswana

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Food production in the sub-Saharan Africa and indeed the entire African continent mostly involved smallholder farmers who are usually rural dwellers, producing crops in mixed intercropping, which often resulted in persistent and continuous poor yield and poor standard of living due to poor financial return causing increase in poverty level. Conceived with the backdrop of lack of awareness about the commercial, nutritional and medicinal potentials of sunflower, an on-farm evaluation of intercropping sunflower with arable crops was initiated among the smallholder farmers in Nigeria and Botswana with a view to improving productivity. A total of two hundred smallholder farmers (with at least 1 hectare of farmland) were purposively selected with four extension workers from four selected farming communities each in southwestern Nigeria and Botswana. Sunflower was intercropped with maize and cowpea respectively. Grain yield of the component crops were measured from all the selected farmers from the four locations, also productivity of the intercrop was evaluated using relative yield (RY) and combine land equivalent ratio (LER) as indices. While cropping pattern significantly affected the grain yield of the component crops at all the locations, the grain yield of the crops in both sole and intercropping at Botswana locations were significantly higher than those obtained from Nigeria locations. The grain yields of the component crops under sole cropping were significantly higher than those under intercropping. However, the combine LER were above 200% better than sole cropping at all locations. It could be concluded that intercropping sunflower with maize and or cowpea or in combination with the three crops highly stabilized the cropping system and thus reduced risk across the years and location which implies that, intercropping sunflower with arable crops could enable the farmers to stabilize the productivity of the unit land and thus enhance food security.

Key words: Intercropping, on-farm, productivity, sunflower, smallholders.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the few crop species that originated in North America (most originated in the Fertile Crescent, Asia or South or Central America) (Skoric, 1992). It was probably first introduced to Europe

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through Spain, and spread to Russia where it was readily b adapted. According to Grieve and Poss (2010), sunflower is valuable from an economic, as well as from an ornamental point of view. Every part of the plant may be utilized for some economic purpose. The leaves form cattle-food and the stems contain fibre which may be used successfully in paper making. The seed is rich in oil, which approaches more nearly to olive oil than any other vegetable oil known and can be largely used as a substitute. While the vibrant, strong sunflower is a recognized worldwide for its beauty, it is also an important source of food. The oil is a valued and healthy vegetable oil and ranked third most important oil crop after soybean and oil palm (Rehm and Espig, 1991), while the seeds are enjoyed as a healthy, tasty snack and nutritious ingredient to many foods (National Sunflower Association 2010). Sunflower plant performs well under drought conditions and other great variety of soils (CAADP, 2008). Despite the significant economic importance of sunflower, its production is unknown to farmers in southwestern Nigeria. However it is considered to be a crop with great potential for enhancing farmers' economic condition if integrated into the existing traditional farming system.

The traditional agricultural systems of crop production are based on growing crops in mixtures (Okigbo and Greenland, 1976; Osiru, 1982; Hauggard-Nielsen et al., 2001). These methods have long been recognized as the common practice among subsistence small-scale farmers. It is characterized with semi-intensive system of agriculture with low-inputs and lack of sufficient land and/or capital with plentiful labour (Vandermeer, 1992; Ntare, 1989). It has been documented by Okigbo (1980), Odo (1991), Chen et al. (2004), Agegnehu et al. (2006) and others that major food crops in humid, sub humid, and semiarid tropical regions include: plantain / banana (*Musa* spp), rice (*Oryza sativa* L), and root crops such as cassava (*Manihot esculenta* Crantz), yam (*Dioscorea* spp.), sweet potato (*Ipomoea batatas* (L.) Lam. and cocoyam (*Xanthosoma sagittifolium* (L.) Schott), sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea may* L.) and cowpea (*Vigna unguiculata* (L.) Walp), millet (*Pennisetum glaucum* (L.) R.Br are produced under mix-intercropping excluding sunflower. Hence the need to evaluate the productivity of sunflower among some adopted arable crops in order to establish the possibility of considering it to be part of the subsistence farming designed to meet the increase in domestic food security especially in the sub Saharan African agro-ecologies.

Production of edible oil has been mainly from oil palm and soybean, which remain inadequate for the ever growing teeming population (FAO, 2003). The increase in the population of developing countries is by far greater than the increase in food and oil production, hence the evidence of malnutrition among the populace and most especially children in the developing countries. Despite the importance of most arable crops in the economy and diet of the people in sub-Saharan Africa, little or no information is known about sunflower hence there is the need for documentation of the yield performance of sunflower especially under intercrop in an on-farm location among the small holder farmers. While studies of arable crops production under different cropping combinations of maize, cassava, yam, cocoyam, okra intercrop have been reported (Agbaje et al., 2002; Alabi and Esobhawan, 2006; Akande et al., 2006) in the southern Nigeria and Botswana, there are no information on yield performance of sunflower in mixture with other crops in the regions. The need to evaluate the yield performance of component crops especially sunflower under different arable crop combination in intercrop among smallholder farmers becomes obvious.

Conceived with the backdrop of lack of awareness about the commercial, nutritional and medicinal potentials of sunflower among the rural farm families where over 70% are very poor (Ekong, 2011); coupled with the fact that Sunflower is known to survive in diverse climatic situation compared to many other arable crops in Nigeria and other sub Sahara Africa, an on-farm research to intercrop sunflower with stable arable crops among the smallholder farmers in Nigeria and Botswana with a view to improving productivity was initiated. This paper therefore documented and showcases the result of on-farm intercropping of sunflower with stable arable crops among smallholder farmers in two agro ecologies of Africa with a view to evaluating the productivity.

MATERIALS AND METHODS

The study was conducted in two Southwestern States (Ogun and Ekiti) of Nigeria and two districts (Southeast and Kgatleng) of Botswana. In Nigeria, Ekiti State with the coordinates of within 7°30'N 4°30'E/ 7.5°N 4.5^{0}E, and Ogun State with 7°00'N 3°35'E/ 7°N 3.583°E were purposively selected in the rainforest and derived savannah zones, respectively. The two states experience approximately eight months (March to October) of bimodal rainfall and five months (November to March) of dry season each year with slightly irregularity in the rainfall distribution annually. In Botswana, Kgatleng district with the coordinate of 24°59'S 25°41'E and Southeast with 24°15'S 26°30'E are located predominantly in flat, tending toward gently rolling tableland. They are dominated by semi-arid climate with an annual rainfall of 538 mm. Most rain falls in summer generally starts in late October and continues to March/April. Prolong dry spells during the rainy season are common and rainfall tends to be localized (Baker, 1987).

Fifty farmers were purposefully selected at each of the locations while 8 extension workers (2 from each location) were involved from the two countries making a total of 208 participants for the study within a time frame of 12 months. Selected socio-economic characteristics of farmers like age, years of formal education, household size, farm size in hectare and distance of farm to home/farmstead were measured by their absolute values. Furthermore, farmers' information on their knowledge of sunflower and utilization and also crop combination planted if they were not practicing mono-cropping were also documented. Structural capacity building workshops organized and conducted for the 200 small holder farmers and the extension officers in the selected communities based on the needs assessment of the smallholder which led to appropriate training on crop production, crop

Table 1. Physico-chemical properties of the soils of the four locations before the commencement of the experiment in 2011 cropping season.

Soil properties	Nigeria		Botswana	
	Ekiti Oye	Ogun Igbesa	Southeast Mogobani	Kgatleng Oodima
pH (H_2O)	5.63	5.70	5.42	5.55
Organic carbon (%)	2.18	1.98	2.34	0.43
Total N (%)	0.37	0.28	0.12	0.13
Available P (ppm)	3.21	3.35	3.42	4.60
Exchangeable cations				
Ca^{2+} cmol/kg^{-1}	1.60	1.48	1.72	1.99
K^{+} cmol/kg^{-1}	0.28	0.29	0.39	0.32
Mg^{2+} cmol/kg^{-1}	0.09	0.11	0.64	0.81
Particle size distribution (soil texture)				
Sand (%)	72.80	72.90	78.20	78.60
Silt (%)	14.60	14.80	12.50	12.30
Clay (%)	12.60	12.30	9.30	9.10
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam

combination methods of intercropping enabled the farmers to increase the plant density per unit area to optimize total yield increase. On-farm planting of maize, cowpea, and sunflower were carried out on the farmers' field. The fields were conventionally prepared with plough using disc plough, harrowed and ridged. The seeds were treated with Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,8,8a-hexa-hydro-exo-1,4-endo-5,8-methanonaphthalene) shortly before planting to control soil borne pest and pathogens. The component crops were planted simultaneously on ridge in alternate single rows (1:1:1 ratio of maize:cowpea:sunflower) using replacement series (Osiru and Willey, 1972) with 0.90 m between rows and stands were maintained at 0.30 m within rows. The land area to each farmer is an average of 1 acre. The maize were applied with 90 kg N/ha and received a basal dose of 26 kg P/ha as single super phosphate and 26 kg K/ha as muriate of potash which were broadcast on the field before harrowing. The established sunflower plants were protected against insects at seedling while cowpea plants were also sprayed with Cypermethrin 10EC, at the rate of 1.5 kg a.i /ha (active ingredient/ hectare) which commenced at flowering and continued at 10 days interval until when the pods were ready for harvest. Chemical weed control was carried out using a formulated mixture of Metrobromuron and Metolachlor applied pre-emergence immediately after planting all the crops at the rate of 3.0 kg a.i /ha. Supplementary hoe weeding was carried out at incidence of weed infestation. Data was subjected to analysis of variance (ANOVA) to determine the magnitude of locations and interaction effects on the yield. Duncan Multiple Range Test (DMRT) and least significant differences (LSD) were used to separate means of significant treatments (Gomez and Gomez, 1984). All analyses were done with the SAS package (SAS, 1990a). Land Equivalent Ratio (LER) was used according to Andrews and Kassam (1976), Willey (1979) as a tool in assessing the productivity of the intercrop over the sole crop. The assessment was based on the apparent grain yields of maize, cowpea, and sunflower on the intercrop.

Land Equivalaient Ratio (LER) = $RY_{maize} + RY_{cowpea.} + RY_{sunflower}$

Where Relative yield (RY) = YI_c / YM_c, YI_c = yield of crop in intercrop and YM_c = yield of crop in solecrop.

RESULTS AND DISCUSSION

Table 1 reveals the physio-chemical properties of the soils of four locations of the two countries. The soils of the two locations in Nigeria were loamy soil with pH that ranged between 5.63 to 5.71 at Ekiti and 5.42 to 5.61 at Ogun State, were slightly acidic due to the previous continuous cropping activities. The soil in Ekiti was of fine grained with higher silt and clay content. The organic matter contents and the nitrogen contents of the soils were low. The soil available P and the exchangeable K were also not high. In Ogun State, the soil is coarse-fine grained granite and gneiss as parent material. The soils in Southeast of Botswana are shallow, ferruginous tropical soil mainly consisting of medium to coarse sands with lower water holding capacity, while that of Kgatleng is of fine grained with higher silt and clay content . The organic matter contents and the nitrogen contents of the soils were low.

Table 2 indicated the average grain yields, of maize, cowpea and sunflower among all the farmers at the four locations where the experiments were conducted. Generally, there was highly significant effect ($p < 0.001$) of locations on grain yield of the entire component crops both in the on- farms and on-stations. There were significant variations in the grain yield of the component crops from one location to the other. Among all the component crops, grain yield were higher at the two locations in Botswana than those of Nigeria. Though the yield of cowpea seems to be the lowest, which may be due to the incidence of pest as pest infestation increased resulting to increase in rate of control, sunflower performed excellently well with the highest yield at Oodima. The highest grain yield of sunflower

Table 2. Grain yield of maize, cowpea, and sunflower as affected by intercropping at the four locations.

Treatment	[+]Maize grain yield (t/ha)	[+]Cowpea grain yield (t/ha)	[+]Sunflower grain yield (t/ha)
On-farm location			
Ekiti State	1.47[c]	0.67[b]	1.37[c]
Ogun	1.24[d]	0.48[c]	1.48[c]
Mogobane (Southeast)	2.64[a]	0.70[b]	1.65[b]
Oodima (Kgatleng)	2 .36[b]	0.93[a]	1.87[a]
SE±	0.125	0.13[7]	0.12[4]
F-test	**	**	**
On-stations			
Ekiti State	2.07	0.33	2.21c
Ogun	1.92	0.58	1.95c
Mogobane (Southeast)	2.14	0.24	3.02b
Oodima (Kgatleng)	2.09	0.72	4.07a
SE±	0.117	0.089	0.087
F-test	ns	**	**
Interaction			
On-farm (df 3)	**	**	**
On-station (df 3)	**	**	**
F × S	ns	ns	ns

[+] In a column means followed by the same letters are not significantly different at 5% level of probability using DMRT; *, ** Significant at 5 and 1% level of probability, ns Not significant.

was obtained at on-station of Oodima followed by Mogobane while the least yield was obtained at Ogun State. The variation in yield may be due to variation in the management methods adopted by the farmers and climatic conditions of the locations.

There were highly significant differences in the grain yield of the three crops depending on the cropping pattern adopted (Table 3). The grain yields were significantly higher under sole cropping compared to intercropping at the four locations irrespective of the agronomical practices adopted by the farmers. The grain yield of the component crops in sole cropping were almost 50% higher than in intercrop at all the locations. The yield response of cowpea was in line with the results obtained by Olufajo (1988) and Cardoso et al. (1993) on maize where they reported that yield of maize were unaffected by cowpea in intercrop. The results of the cowpea and sunflower conformed to those of Agbaje et al. (2002); Akande et al. (2006) where they indicated that, yield of crops in sole cropping are usually higher than those in intercrop due to lower intra-competition for available resources unlike inter-competition that existed between varieties of crops in intercrop. Yields obtained in intercrop have been found to be potentially influenced by many variables such as competition of the plant with a second crop, changes in plant population density (PPD).

Productivity of intercropping of sunflower with cowpea and maize was evaluated using relative yield (RY) and combine LER as indices. Table 4 revealed the combined LER of the component crops at different locations. Generally, the LER were significantly above unit and they are superior compared to sole cropping. The significantly high values of the combine LER was due to the high value of the relative yield of maize in each location. Measuring the productivity efficiency showed that maize, cowpea, and sunflower in intercrop were more effective (LER > 1.00) than planting in sole-cropping. The intercrop system is highly stable across locations and cropping years. This result is in line with the results of Adetiloye (2001), and Adegbite et al. (2002) at separate locations on evaluating effects of plant population, and sowing pattern of maize and some arable crops.

Although, the management practices varied at different locations in the two countries, the emerging incorporation of sunflower into the existing cropping system among the selected and non-selected farmers is encouraging. The farmers in Botswana usually plant on flat in strip alternate multiple rows (4:4 ratio) using replacement series (Osiru and Willey, 1972) and these might have significant effect on the total crop yield obtained while Nigeria farmers involved spatial alternate single rows (1:1 ratio) method resulting to higher competition among crops and thus

Table 3. Grain yield of component crops as affected by intercropping across the four locations.

Treatment	Southest (Mogobane)			Oodima (Kgatleng)			Ekiti State (Oye Ekiti)			Ogun State (Igbesa)		
	Maize	Cowpea	Sunflower	Maize	Cowpea	Sunflower	Maize	Cowpea	Sunflower	Maize	Cowpea	Sunflower
	Grain yield of crops combination t/ha.											
Sole (S)	2.23	1.11	2.48	3.24	1.58	2.16	1.49	0.75	1.89	2.28	0.76	1.68
Intercrop (I)	1.28	0.73	2.22	2.63	0.62	1.54	0.63	0.52	0.98	1.01	0.38	1.26
SE±	0.095	0.021	0.013	0.38	0.028	0.035	0.017	0.035	0.481	0.094	0.011	0.012
F-test	**	*	**	**	**	*	**	**	**	**	**	**
Interaction												
S × I	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

** Significant at 1% level of probability, ns Not significant.

Table 4. The combine land equivalent ration of the component crops across the experimental locations.

Location	Maize relative yield	Cowpea relative yield	Sunflower relative yield	Land equivalent ratio (LER)
Igbesa	0.99	0.47c	0.67c	2.13
Oye Ekiti	0.95	0.50b	0.66c	2.11
Mogobane (Southeast)	0.88	0.51b	0.70b	2.09
Oodima (Kgatleng)	0.97	0.64a	0.78a	2.39
SE±	0.013	0.012	0.028	0.211
F. test	ns	**	**	ns

[2]In a column means followed by the same letters are not significantly different at 5% level of probability using DMRT, ** Significant at 1% level of probability, ns Not significant.

affect final output of the crops.

Conclusion

It could be established that sunflower in intercropping with arable crops will enhance stability in the cropping system, increase productivity per unit of land and food security of the small holder farmers in semi arid and sub-Saharan Africa. Cropping system significantly affected the grain yield of the component crops at all the locations. The grain yields of the component crops under sole cropping were significantly higher than those under intercropping, however the LER were significantly above unit indicating about 200% superiority compared to sole cropping. The significantly high values of the combine LER was due to the high values of the relative yield of maize and sunflower in each location.

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