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Growth and yield of groundnut, sesame and roselle in an *Acacia senegal* agroforestry system in North Kordofan, Sudan

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Abstract

A field experiment was conducted under rainfed conditions in western Sudan at El-Obeid Research Farm and Eldemokeya Forest Reserve, North Kordofan State, during the growing seasons 2004/05 and 2005/06. The main objective was to investigate the soil physical and chemical properties and yield of groundnut (*Arachis hypogea*), sesame (*Sesamum indicum*) and roselle (*Hibiscus sabdariffa*) of an *Acacia senegal* agroforestry system in comparison with the sole cropping system. Data were recorded for soil physical and chemical properties, soil moisture content, number of pods per plant, fresh weight (kg ha^{-1}) and crop yield (kg ha^{-1}). The treatments were arranged in Randomized Complete Block Design (RCBD) and replicated four times.

Significant differences ($P < 0.05$) were obtained for sand and silt content on both sites, while clay content was not significantly different on both sites. The nitrogen (N) and organic carbon were significantly ($P < 0.05$) higher in the intercropping system in Eldemokeya Forest Reserve compared with sole cropping. Soil organic carbon, N and pH were not significant on El-Obeid site. Yet the level of organic carbon, N, P and pH was higher in the intercropping system.

Fresh weight was significantly different on both sites. The highest fresh weight was found in the intercropping system. Dry weights were significantly different for sesame and roselle on both sites, while groundnut was not significantly different. On both sites intercropping systems reduced groundnut, sesame and roselle yields by 26.3, 12 and 20.2%, respectively. The reduction in yield in intercropping plots could be attributed to high tree density, which resulted in water and light competition between trees and the associated crops.

Keywords: *Acacia senegal*, agroforestry, intercropping, soil properties, groundnut, sesame, roselle, Kordofan

1 Introduction

Acacia senegal gum arabic which is an important cash crop and contributes significantly to the economies of Sudan. More than 80% of the total gum arabic worldwide is collected from *A. senegal* which grows naturally in the gum belt of Sudan. This annual trade is worth around 45 million US$ (Bashir 2001). In addition to producing gum, *A. senegal* is useful as a windbreak, its pods and foliage provide good fodder for livestock and the tough wood of its tap root and stem is used for tool handles. Strong fibers can be obtained from the long, flexible surface roots, and the dense wood yields excellent charcoal (NAS 1986).

A. senegal trees in western Sudan are managed in a time sequence with agricultural crops such as millet, sorghum, groundnut, sesame and watermelon. This agroforestry system is called bush fallow system, which is similar to shifting cultivation allowing a fallow period of 10-15 years. The system was described by many authors (Seif El Din & Obeid, 1971; Awouda, 1973; Hussein, 1983; Badi *et al.*, 1989; Ballal, 1991).

The system is started by clearing of old gum gardens (15-20 years old) for cultivation such as millet, sesame, groundnut, roselle and watermelon. The cleared area is cultivated for a period of 4-6 years, during which time any coppice re-growth is cut back to enhance establishment and growth of agricultural crops. Recently, the area under bush fallow is decreased due to expansion and intensification of agricultural activities, and the increase in human and animal population. In fact, the deterioration of the traditional bush fallow system is the result of the reduced land productivity caused by the

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combined effect of excessive tree cutting, drought and desertification (NKRDP, 2001).

The purpose of the field experiment was to study the effect of *A. senegal* agroforestry system on the growth and yield of groundnuts (*Arachis hypogea* cv. Sodari), sesame (*Sesamum indicum* cv. El-Obeid one), and roselle (*Hibisacus sabdariffa* cv. Shaloft Elnaga) and to assess and compare the economic return and net benefit of the crops grown without trees and in the agroforestry system.

2 Material and Methods

The present study was carried out at the gum arabic experimental research site at Eldemokeya Forest Reserve (Lat.13° 16 N, Long. 30° 29 E, alt. 560 m) which is located 31 km east of El-Obeid town (Lat. 13° 10 N; Long. 30° 12 E). The soil at the experimental site is sandy, locally known as "Goz". The concentrations of organic matter, nitrogen and phosphor are very low, less than one percent. The annual rainfall in this area ranges between 280 and 450 mm, falling in the months from July to September. The mean relative humidity is 34% and varies between 14% in the dry season to 60% in the wet season. The mean annual minimum and maximum temperature range between 20°C and 35°C, respectively. The study was conducted in a 15 years old plantation of *A. senegal*. The trees had an average height of 2.5 m and average crown width of 2 m. The second site is El-Obeid Agricultural Research Farm which located about 1 km North El-Obeid Agricultural Research Station. The soil is classified as sandy. The average rainfall ranged between 200- 350 mm in the months from July to September. The mean relative humidity is 34% and varies between 23% in the dry season and 84% in the wet season. The mean annual minimum and maximum temperature arrange between 20°C and 35°C, respectively. The coldest months were December and January with 14.3 and 12.7°C respectively; the study was conducted in 9 years old plantations. The trees had an average height of 1.8 and average crown width of 2 m.

The experimental design was a randomized complete block with four replications. Each block was divided into seven plots: three plots representing intercropping. Three plots representing the sole cropping, while one plot represents *A. senegal* alone. Plot size was 20×20 m. Intercropping plots had an average of 15 trees per plot. Initially, the experimental sites were manually cleared of undesirable vegetation. Seeds of groundnut, sesame and roselle were sown on 15th of July 2005 and 17th July 2006. Plant holes were manually dug with a hoe at the spacing 60×20 cm, 50×30 cm, and 50×50 cm for groundnut, sesame and roselle, respectively. For groundnut, sesame and roselle, about 4 seeds were placed in each hole and plant were thinned to two per hole, three week later. Two weedings were done 14 and 30 days after sowing. Data were collected from the central rows of each plot, discarding the two marginal rows. At maturity, the number of pods per plant, fresh weight yield (kg ha^{-1}), dry weight (kg ha^{-1}) and crop yield (kg ha^{-1}) were recorded. Analysis of variance was carried out using MSTAT-C statistical package (Fischer, 1990), and the LSD was used for mean comparisons.

3 Results

The experiment was conducted under rainfed environment, and thus the rate and distribution of rainfall during the two seasons was the main factor limiting yield. The rainfall during the 2004/05 growing season was 78.39 mm higher than that of 2005/06 (220.1 mm compared to 142.71 mm) and the distribution during the two seasons was not even.

Table 1 and 2 shows soil particle distribution and soil chemical properties under the gum cultivation cycle at 0.2, 0.4 and 0.6m soil depths at the El-Obeid and Eldemokeya experimental sites, respectively. Sand and silt were higher under intercropping in both Eldemokeya and El-Obeid sites. The clay content was not significantly different in both sites. However, the higher clay content was found under intercropping systems. Sand and silt content decreased with increasing in soil depths in both sites, but clay content increased with increase in soil depth.

Nitrogen, phosphorus and organic carbon were higher under intercropping in Eldemokeya site. The effect of intercropping on soil N, P and pH was not significantly different in El-Obeid site. Yet the level was higher under intercropping system relative to sole cropping system. The result showed that potassium levels were slightly higher in intercropping system compared with the sole cropping. In general the whole results showed that soil properties were ameliorated under intercropping systems compared to sole acacia and sole cropping system. Nonetheless, the level of all chemical properties in both sites except, K, soil pH was slightly higher under intercropping system at the uppermost layer (0.02 m).

The effect of cropping system on soil moisture content in 0.20, 20-40 and 40-60 soil layers are shown in figure 1 and 2. The soil moisture contents were significantly affected by cropping system and soil depths at both sites. The highest soil moisture content in the different soil layers in El-Obeid experimental sites was found under sole cropping system, while the lowest soil moisture content was found under intercropping system. Soil moisture content was highly affected by soil depths. Generally, soil moisture content increased with increase in soil depth. Number of pods per plant and fresh weight (kg ha^{-1}) are shown in Table 3. Analysis of variance indicated significant differences ($P < 0.05$) in number of pods per plant for sesame and roselle in the two seasons in El-Obeid and Eldemokeya experimental site, respectively, while groundnut number of pods per plant was not significantly different in both sites.

The result showed that fresh weight (kg ha^{-1}) was significantly affected by cropping system. The increase in fresh weight for groundnut, sesame and roselle was 40%, 19.3% and 8.5%, respectively.

Table 4 shows the dry weight (kg ha^{-1}) and yield (kg ha^{-1}) for groundnut, sesame and roselle in El-Obeid and Eldemokeya experimental site. Significant differences were observed for sesame and roselle dry weight in both sites, while groundnut was not significantly different.

Crop yield was affected by the cropping system in both sites. Intercropping systems reduced groundnuts yield by 26.3% sesame yield by 12% and roselle yield by 20.2%. The lower yield in intercropping systems could be attributed to both above and below ground competition for light and water.

Table 1: *Soil particle size distribution and soil chemical properties under the gum cultivation cycle at three soil depths (0.2, 0.4 and 0.6 m) at El-Obied Research Farm during the growing season 2004.*

Cropping systems	*Particle size distribution*			*Soil chemical properties*				
	Sand	*Silt*	*Clay*	C_{org}	*N*	*P*	*K*	*pH*
Intercropping	93.2	2.7	4.1	0.40	0.016	2.4	0.13	7.4
Sole *A. senegal*	90.7	2.5	6.8	0.21	0.015	2.3	0.12	7.4
Sole cropping	89.3	1.8	8.9	0.20	0.014	2.2	0.11	7.5
SE±	0.14 *	0.11 *	0.13 *	0.06 **	0.008 ^{ns}	0.05 ^{ns}	0.002 *	0.03 ^{ns}
Soil depths								
0-20 cm	94.8	2.5	2.7	0.32	0.018	2.3	0.14	7.4
20-40 cm	90.4	2.0	7.6	0.28	0.015	2.2	0.12	7.4
40-60 cm	89.3	1.7	9.0	0.21	0.013	2.0	0.11	7.5
Means	91.5	2.1	6.4	0.27	0.015	2.2	0.12	7.43
SE±	0.17 **	0.11 **	0.18 ^{ns}	0.18 ^{ns}	0.008 **	0.05 **	0.002 *	0.03 ^{ns}

Asterisks indicate significant differences (* P≤0.05; ** P≤0.01); *ns* indicates no significant difference.

Table 2: *Soil particle size distribution and soil chemical properties under the gum cultivation cycle at three soil depths (0.2, 0.4 and 0.6 m) in Eldemokeya forest reserve during the growing season 2004.*

Cropping systems	*Particle size distribution*			*Soil chemical properties*				
	Sand	*Silt*	*Clay*	C_{org}	*N*	*P*	*K*	*PH*
Intercropping	94.7	2.4	2.9	0.24	0.019	2.38	0.13	7.3
Sole *A. senegal*	92.4	2.0	5.6	0.20	0.016	2.14	0.12	7.3
Sole cropping	90.2	1.5	8.3	0.18	0.03	1.24	0.12	7.2
SE±	0.28 *	0.16 *	0.15 **	0.03 *	0.002 *	0.05 *	0.02 ^{ns}	0.03 ^{ns}
Soil depths								
0-20 cm	94.7	2.9	2.4	0.24	0.019	2.5	0.14	7.4
20-40cm	92.3	2.1	5.6	0.19	0.015	2.3	0.12	7.3
40-60 cm	90.8	1.5	7.7	0.18	0.013	2.2	0.11	7.2
Means	92.6	2.2	5.2	0.20	0.016	2.3	0.12	7.3
SE±	0.28 **	0.16 **	0.03 *	0.07 **	0.007 **	0.05 *	0.03 *	0.03 ^{ns}

Asterisks indicate significant differences (* P≤0.05; ** P≤0.01); *ns* indicates no significant difference.

Table 3: *Number of pods per plant and fresh weight* (kg ha^{-1}) *of groundnut, sesame and roselle as affected by cropping systems in El-Obeid Research Farm and Eldemokeya Forest Reserve during the growing Seasons 2004 and 2005.*

Cropping systems	*Number of pods per plant*				*Fresh weight* (kg ha^{-1})			
	El-Obeid		*Eldemokeya*		*El-Obeid*		*Eldemokeya*	
	2004	*2005*	*2004*	*2005*	*2004*	*2005*	*2004*	*2005*
Groundnut								
Intercropping	35 ^{a}	22.0 ^{a}	28.0 ^{a}	19.0 ^{a}	3920 ^{a}	1740 ^{a}	5810 ^{a}	5120 ^{a}
Sole cropping	33 ^{a}	16.0 ^{a}	33.0 ^{a}	18.0 ^{a}	1930 ^{b}	1060 ^{b}	2450 ^{b}	2420 ^{b}
LSD 0.05	3.81 ^{ns}	8.07 ^{ns}	11.31 ^{ns}	2.85 ^{ns}	720 **	430 **	620 **	390 **
%CV	19.39	28.34	24.72	17.38	16.75	14.67	26.16	17.88
Sesame								
Intercropping	48.0 ^{a}	19.0 ^{a}	59.0 ^{a}	23.0 ^{a}	3360 ^{a}	1730 ^{a}	1690 ^{a}	1810 ^{a}
Sole cropping	43.0 ^{b}	12.0 ^{b}	32.0 ^{b}	14.3 ^{b}	1140 ^{b}	730 ^{b}	1390 ^{b}	960 ^{b}
LSD 0.05	4.7 *	4.7 *	14.6 **	2.79 **	420 **	172 **	520 *	380 **
%CV	20.06	15.86	21.48	23.18	12.38	19.48	18.01	24.31
Roselle								
Intercropping	37.0 ^{a}	17.25 ^{a}	43.0 ^{a}	20.0 ^{a}	4110 ^{a}	5810 ^{a}	3390 ^{a}	3220 ^{a}
Sole cropping	27.0 ^{b}	15.0 ^{b}	31.0 ^{b}	13.0 ^{b}	1690 ^{b}	2450 ^{b}	3030 ^{b}	1980 ^{b}
LSD 0.05	4.93 **	1.32 **	9.56 *	13.55 **	150.23 **	620 **	50 **	740 **
%CV	17.92	15.43	26.42	28.88	24.58	26.16	34.17	16.87

Means followed by the same letter in the same row are not significantly different ($P < 0.05$).
Asterisks indicate significant differences (* $P \leq 0.05$; ** $P \leq 0.01$); *ns* indicates no significant difference.

Table 4: *Dry weight* (kg ha^{-1}) *and crop yield* (kg ha^{-1}) *of groundnut, sesame and roselle as affected by cropping systems in El-Obeid and Eldemokeya Forest Reserve during the growing Season 2004 and 2005.*

Cropping systems	*Dry weight* (kg ha^{-1})				*Crop yield* (kg ha^{-1})			
	El-Obeid		*Eldemokeya*		*El-Obeid*		*Eldemokeya*	
	2004	*2005*	*2004*	*2005*	*2004*	*2005*	*2004*	*2005*
Groundnut								
Intercropping	620 ^{a}	90 ^{a}	340 ^{a}	377 ^{a}	212 ^{a}	505.0 ^{a}	255.8 ^{a}	452.5 ^{a}
Sole cropping	860 ^{a}	630 ^{b}	300 ^{a}	122 ^{b}	331 ^{a}	783.8 ^{a}	309.2 ^{a}	510.0 ^{a}
LSD 0.05	360 ^{ns}	60 *	123 ^{ns}	68 *	112.39 ^{ns}	124.17 ^{ns}	67.72 ^{ns}	73.8 ^{ns}
%CV	32.5	26.59	60.46	54.8	28.05	25.21	18.26	38.7
Sesame								
Intercropping	760 ^{a}	960 ^{a}	250 ^{a}	490 ^{a}	458.7 ^{a}	177.5 ^{a}	300.0 ^{a}	166.8 ^{a}
Sole cropping	220 ^{b}	260 ^{b}	190 ^{b}	340 ^{b}	488.5 ^{a}	285.0 ^{b}	338.8 ^{a}	275 ^{b}
LSD 0.05	21 **	51 **	30 **	130 **	56.21 ^{ns}	40.98 **	72.63 ^{ns}	48.9*
%CV	28.8	25.66	27.39	26.73	26.94	11.81	17.98	14.24
Roselle								
Intercropping	760 ^{a}	810 ^{a}	550 ^{a}	1570 ^{a}	127.0 ^{a}	272.5 ^{a}	300 ^{a}	387.0 ^{a}
Sole cropping	330 ^{b}	610 ^{b}	490 ^{b}	830 ^{b}	158.0 ^{a}	363.0 ^{a}	418.8 ^{b}	422.0 ^{a}
LSD 0.05	140 *	135 **	10 **	400 **	69.39 ^{ns}	91.1 ^{ns}	109.0 *	61.54 ^{ns}
%CV	35.42	22.96	16.68	27.12	32.68	18.06	22.18	30.37

Means followed by the same letter in the same row are not significantly different ($P < 0.05$).
Asterisks indicate significant differences (* $P \leq 0.05$; ** $P \leq 0.01$); *ns* indicates no significant difference.

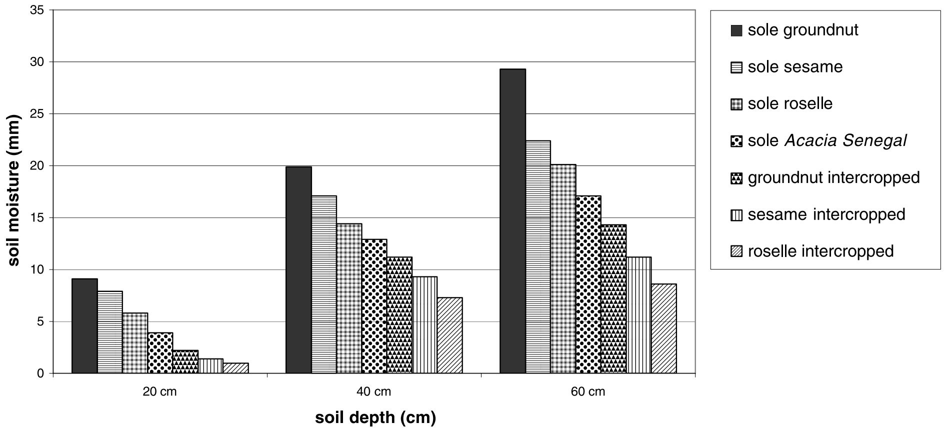

Fig. 1: *Effect of cropping systems on the amount of water (mm) in 0-20, 20-40 and 40-60 cm soil layers at El-Obeid Research Farm*

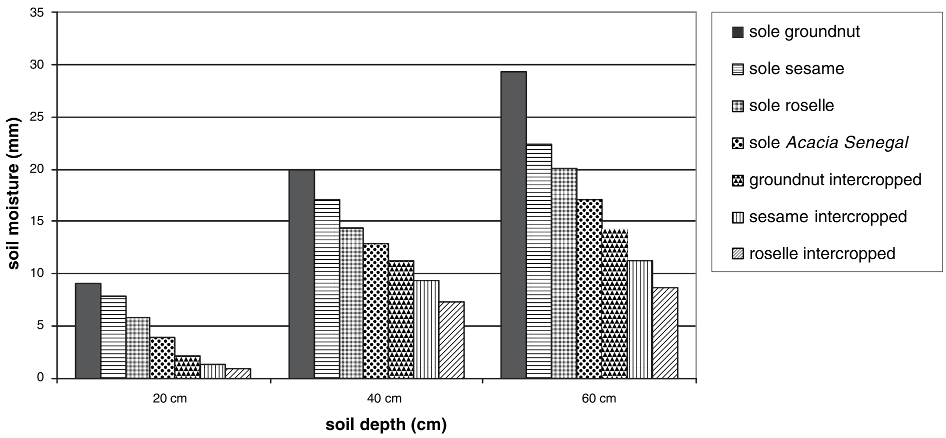

Fig. 2: *Effect of cropping systems on the amount of water (mm) in 0-20, 20-40 and 40-60 cm soil layers at Eldemokeya Forest Reserve*

4 Discussion

The higher sand, silt and clay content under the intercropping systems could be attributed to the dense vegetation cover made by the trees and shelter they provided to soil from wind erosion. Similar results have been reported by Sanchez (1987) for *Faidherbia albida* in the Sahel and *Prosopis cineraria* in Rajistan, India, where increased clay content had been found beneath the canopy of these trees. Generally, trees and biomass from trees can improve and maintain soil physical properties (Young, 1997).

Nitrogen and phosphorus were higher under the intercropping systems. These results are in agreement with several studies (Deans *et al.*, 1999; Kumar *et al.*, 1998). In this study the higher soil nitrogen content under the intercropping systems could be attributed to a direct N input from tree to soil and due to litter mineralization. The result showed organic carbon levels were slightly higher in intercropping system at El-Obeid, similarly the level of P, organic carbon and N were higher under intercropping and Pure *A. senegal* at Eldemokeya experimental site.

Soil organic carbon was comparatively higher under the intercropping systems. This could be attributed to their dense vegetation cover. Conversely, the lower organic carbon content under the sole cropping systems may be attributed to scant vegetation and continuous cropping with subsequent removal of plant residues. This result is in strong agreement with the nutrient accumulation patterns found for this species *A. senegal* (Hussein, 1990; Hussein & El Tohami, 1989; Deans *et al.*, 1999; Gerakis & Tsangarakis, 1970).

In general the whole results showed that soil properties were ameliorated under intercropping systems compared to sole acacia and sole cropping system.

The increase in the height growth for sesame and roselle may attribute to better growth environment provided by the trees. During the experiment it was observed that the groundnut plants suffered from water deficiency in the intercropping plots.

The high fresh weight of groundnut, sesame and roselle in the intercropping systems could be attributed to shading effect which limits fruit production more than vegetative growth. Gaafar (2005) in the same site found that the yield and biomass production for sorghum and roselle was affected by intercropping. This was attributed to the decrease in yield and biomass production due to competition between the trees and associated crops for top soil water. The increase in fresh weight for groundnut, sesame and roselle was 40%, 19.3% and 8.5% respectively.

In the present study, intercropping increase sesame yield by 6 and 11% in the first season and 37 and 39% in the second season for El-Obeid and Eldemokeya experimental site, respectively.

In the present study, the decrease in crop yield was 26.3, 12 and 20.2% for groundnut, sesame and roselle, respectively. The decrease in crop yield was attributed to water and light competition between the trees and the associated crops. In the same site Gaafar (2005) reported that, *A. senegal*, when planted at low density of 266 tress/ha, reduced the roselle flower yield by about 26% and the above ground biomass production by 37%, sorghum grain yield by 19% and the sorghum biomass production by 9%. El Tahir (2006) in the same site found that sorghum grain yield, stover and total dry matter production were not significantly different within a system, but were slightly higher in intercropping system at low tree densities. The higher production of grains, stover and total dry matter in intercropping sorghum at low tree densities in comparison to the other systems could perhaps be due to wider spacing, which may reduce below ground competition between trees and sorghum plants for nutrients and soil moisture.

A. senegal agroforestry systems plays an important role in environmental conservations and also makes full use of the available resources compared with the sole cropping and sole *A. senegal*. In dry land areas such as Kordofan, where the drought and desertification, and the mis use of the major resources is the main characteristic of agricultural production *A. senegal* agroforestry, had a considerable potential, to protect the environment and to diversity of the farmer income.

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