VOL. 3, NO. 1, January 2013 ISSN 2225-7217
ARPN Journal of Science and Technology

http://www.ejournalofscience.org

Effects of Sorghum (Sorghum Bicolor (l) Moench) and Groundnut (Arachis Hypogaea l) İntercropping on Some Soil Chemical Properties and Crop Yield Under Rain-Fed Conditions

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ABSTRACT

A field experiment was conducted at the University of Zalingei demonstration Farm, Zalingei, West Darfur State, Sudan, during 2006 and 2007 rainy seasons to evaluate the effects of three row intercropping arrangements of sorghum and groundnut plus control on some soil chemical properties and crop yield. Sorghum(S) and groundnut (G) were mixed in row proportions of 1:1(S_1G_1), 2:1(S_2G_1) and 1:2(S_1G_2), plus sole sorghum as control (S_1). The experiments were arranged in a randomized complete block design with four replicates. The results of soil analysis, by the end of the second growing season as compared to their values by the end of the first season, showed that (S_1G_2) treatment gave the lowest PH (6.53) and the highest nitrogen (0.054%) and organic matter (0.68%) percentages and consequently an increase in electrical conductivity (0.21 dsm^{-1}). Whereas, the sole sorghum (S_1) showed the lowest values for nitrogen (0.063% and 0.032%) , organic matter (0.66 and 0.47%) and electrical conductivity (0.08 and 0. 12 dsm^{-1}) and the highest pH (0.686 and 7.12) by the end of the first and second seasons ,respectively. The results also showed no significant differences between treatments in sorghum head length during both growing seasons, and in 1000-grain weight, number of productive tillers/plant, dry matter weight and total grain yield during the second poorly-distributed rainfall season (2007), whereas, the differences were significant($P\leq 0.05$) during the first well-distributed rainfall season (2006). In case of the secondary crop (groundnut), all crop mixtures showed significant differences ($P\leq 0.01$) in total pod yield and yield components under study except 100- pod weight in the second season. The low yield and yield components of both intercrops in the second season were attributed to end-of-season drought due to early cease of rainfall. In addition to maintaining soil fertility, the results indicated that mixed cropping increased soil moisture content, which resulted in good establishment and better yield of the base crop. In the conditions of this study, the advantages of intercropping concerning maintenance and improvement of soil fertility were slight due to the short duration of the experiment.

Keywords: *Intercropping, Zalingei, Sorghum, Groundnut.*

1. INTRODUCTION

Sullivan (2003), "is the growing of two or more crops in proximity to promote interaction between them." It is popular in rain-fed agriculture, with limited resources, because one crop can exploit a resource that the other is not exploiting fully. This is especially important in the semi- arid tropics, where the growing season is short and soil moisture and fertility are the main constraints [3]. Cereal-legume mixture is the common form of intercropping practiced by most small-scale farmers in the tropics and subtropics. Intercropping conserves soil water by means of reduction of the evaporation losses and increases the organic matter in the soil, which in turn improves soil structure, infiltration and water retention and helps prevent soil erosion. Through biological decomposition and mineralization, the organic matter also can increase the level of soil nutrients available for plant production [7] and [9]. Additional advantages are that intercropping patterns will reduce labor peaks, suppress weeds, reduce risks of pests and diseases [2], stabilize crop yields and returns and optimize the use of natural resources [10] and [13]. Soil fertility determines the ability of soils to produce food for man and animal. Declining fertility of the high lands and sandy soils (away from the valley banks) is a fundamental impediment to crop production and a major reason for low crop yields in the study area. In addition, they Intercropping, according to the definition of are heavily leached and some nutrients are removed by erosion and surface run off, due to their sloping nature, others along with the crops after harvest. The continuous cropping of the same smallholdings with the same crops (mostly cereals), without rotations or fertilizer application, besides the poor land management, have also contributed to degradation and exhaustion of the valuable agricultural lands. The experimental crop varieties were chosen because sorghum is the main food and cash crop, together with pearl millet and groundnuts in West Darfur State. Moreover, the selected crops were planted simultaneously to avoid the risk of crop failure by the end of the growing season as a result of poor and erratic rainfall (350 - 450 mm) which characterizes the area. [5] stated that soil fertility declines when its nutrients content diminishes and/or when it's physical, chemical and biological makeup changes in ways that lower its ability to support and nourish plants. So the fertility and productivity of these lands can be improved by replacing the nutrients from mineral or organic sources, application of crop rotations, or partially returned through crop residues and multiple cropping. The latter alternative could be achieved through growing cereals in association with legumes, which offers the best opportunity for conserving soil fertility through nitrogen fixation and returning greater amounts of organic matter to the soil [12] , thus improving its cation exchange capacity (CEC) and physical and chemical conditions. In

this experiment therefore, an attempt has been made to study the effects of sorghum + groundnut row intercropping arrangements on a sandy - clay loam soil fertility management (organic matter, total nitrogen, pH and electrical conductivity) under rain-fed conditions.

2. MATERIALS AND METHODS

A field experiment was conducted at the University of Zalingei Farm, Zalingei (Latitude 12^0 54´ N ; longitude 23^0 29´ E and altitude 900 m above mean sea level) , West Sudan , for two rainy seasons 2006 and 2007 on a shallow, surface – crusted sandy loam to clay. Physical and chemical properties of this soil, which were determined from 1 m depth soil profile prior to experimentation in the first season according to methods suggested by [4] are shown in Table 1. Soil bulk density was also measured to a depth of 60 cm, prior to experimentation in the first season, using sampler cores (5.4 cm in diameter and 7.5 cm in height) as described by [4]. Samples were taken at 0 – 20, 20 – 40 and 40 – 60 cm depths and the average values were determined. The treatments which consisted of three row intercropping arrangements viz., alternate single rows of sorghum and groundnuts (S_1G_1) ,two rows of sorghum with single rows of groundnuts (S_2G_1) , single rows of sorghum with two rows of groundnuts (S_1G_2) plus sole sorghum as control (S_1) , were replicated four times in a randomized block design. Soil samples were collected from 0 – 5 cm depth for organic matter content determination, and from 0 – 30cm depth for total nitrogen, electrical conductivity and pH determination [14] by the end of the first and the second growing seasons.

The experimental area was ploughed with a horse - drawn plough (12 cm depth), and divided into 16 plots each 20 m x 4m in size with a buffer zone of 1 m between each two plots. Sorghum (Sorghum bicolor (L.) Moench) variety "Wad Ahmed" was hand sown, in rows (5-7 seeds/hole, thinned to 3 plants/hole after 4 weeks), on 21 and 11 July in the two successive seasons. Inter-row and intra- row spacings were adjusted at 70 cm and 50 cm, respectively, with similar population density (85500 plants/ ha) in sole and intercrop sorghum. In case of intercrop groundnut (Arachis hypogaea L.) variety "Sodarie", two seeds /hall were sown in rows with spacing differed with the different arrangements, while the spacing within the rows was kept constant at 30 cm in both seasons. Two- hoe weeding were carried out at 25' 45 days after sowing during both seasons. Sorghum was harvested on 14 November in both seasons, whereas, groundnut was harvested on 10 November and 18 October in the two successive seasons. Immediately before sorghum harvest, three areas of 1 m^2 each were randomly selected from each plot for measurement of grain yield and yield components. Six plants were randomly selected from each area for measurement of head length and number of productive tillers/plant. Then all plants were cut at soil surface level and air - dried under natural sunlight for three weeks and then weighed for dry matter determination. Six grain samples each of 1000 grains were weighed and the average was calculated for 1000 - grain weight. An area of 2x4 m was selected from the middle of each intercropped plot for determination of groundnut total pod yield. Ten plants were randomly selected from each sample for determination of the average number of pods/plant and 100 - pod weight for each treatment.

Table 1: Some environmental factors for the study area during 2006 and 2007 growing seasons *

Month	Rainfall (mm)		Relative humidity (%)*		Mean monthly temp.(^{0}c)*	
	2006	2007	2006	2007	2006	2007
June	29.5	28.9	44.0	74.0	36.1	31.9
July	121.1	75.0	75.0	91.0	33.1	30.7
August	125.5	190.3	85.0	84.0	30.3	25.1
Sept.	146.7	70.3	89.0	78.0	30.5	26.2
Oct.	11.3	Nil	55.0	47.0	35.3	27.8
Nov.	Nil	Nil	41.0	33.0	31.2	26.4
Total	433.6	459.7				
Mean	72.3	76.6	64.8	67.8	32.8	28.0

*Source: Jebel Marra Rural Development Scheme Meteorological Station

Table 2: Some physical and chemical properties of the soil of the experimental area

Soil properties	Soil depth (cm)				
	0-20	20 – 40	40 – 60	60 – 80	80 – 100
Total sand (%)	66.0	55.3	50.0	44.7	-
Total silt (%)	41.0	15.3	17.7	16.7	-
Total clay (%)	20.0	29.4	32.3	38.6	-
Textural class	SL	SC	SC	SC	-
Soil dry bulk	1.416	1.610	1.661	-	-

density gcm^{-3}					
E C e(dsm^{-1})	0.083	0.144	0.179	0.168	0.188
PH(paste)	5.94	6.62	6.92	6.41	-
Ca Co_3 (%)	0.52	0.83	0.83	0.93	0.86
N (%)	0.048	0.049	0.016	0.008	0.003
P (%)	0.007	0.005	0.005	0.006	0.005
Na (%)	0.016	0.045	0.045	0.028	0.041
K (%)	0.0004	0.0006	0.0006	0.0006	0.0004
Ca (%)	0.0029	0.0084	0.0088	0.0040	0.0082
Mg (%)	0.0044	0.0097	0.0101	0.0097	0.0071
Cl ($MeqL^{-1}$)	1.6	1.3	1.8	1.8	2.0

SL = Sandy loam
SC = Sandy clay

3. RESULTS AND DISCUSSION

As shown in Table 2, there were decreases in total nitrogen (46.7, 53.8, 49.2 and 41.3%) and organic matter content (15.1, 29.0, 28.8 and 10.5%) for all treatments (S1G1, S_2G_1, S_1 and S_1G_2, respectively), and in soil pH (0.6, 0.2 and 1.7%) for intercropped treatments only (S_1G_1, S_2G_1 and S_1G_2, respectively), as compared to the end of the first season. These decreases in organic matter and consequently nitrogen percentage could be attributed to its decomposition and utilization by the growing crops, or to less organic matter production as a result of moisture stress at flowering and seed development phases of groundnut plants [11] during the second half of the second growing season. They could also be attributed to photosynthesis reduction due to partial shading of groundnut by sorghum plants which could result in reduced nodulation and N-fixation [8] by the legume. These results and inferences were confirmed by the decrease in soil pH in all intercropped treatments and its increase in control, at the end of the second season, which could probably be related to organic acids formation during organic matter decomposition. S_1G_2 treatment recorded the highest percentages of organic matter (0.092, 0.054%) and total nitrogen (0.76, 0.68%) at the end of both seasons, followed by S_1G_1 treatment. On the other hand , the control (S_1) produced the lowest values of nitrogen (0.063, 0.032%) , organic matter (0.66, 0.47%) and electrical conductivity (0.08 , 0.12 dsm^{-1}) , and the highest soil pH (6.86 , 7.12) by the end of the first and second seasons ,respectively . The less decrease in nitrogen and organic matter percentages in intercropped treatments compared to sole sorghum might be attributed mainly to the effect of legume residues on organic matter formation and N-fixation. Moreover, this confirms that intercropping meets one of its motives, i.e. increasing availability of nitrogen and organic matter to the mixed population through fixation by the legume , thus maintaining soil fertility [12]and [16] although the duration of the experiment was not enough to get results reflecting the effect of cereal +legume mixtures on soil fertility .These results are not in accord with what has been reported by [13] that carry over fertility from intercrops may well be lower than that of pure stands , because the two crops having different root types and feeding habits. In 2006,the intercrops stand was relatively good due to well-distributed rainfall, although its amount(433.6mm) was less than that in 2007(459.7mm), where yield and yield components of both intercrops were adversely affected due to poor distribution and early cease of rainfall (7 Sept. 2007) and consequently soil moisture deficit. Similar results were reported by [1] and [15] for sorghum intercropped with short- duration legumes, and by [11] for groundnut grown in mixture under rain-fed conditions. The results showed no significant differences between treatment means in sorghum head length during both seasons. They also showed no significant differences in 1000- grain weight, number of productive tillers/plant, dry matter weight and total grain yield (Table 3), and 100- pod weight (Table 4) during the second season. S_1G_2 treatment was superior in groundnut total pod yield and in all sorghum productivity components, except number of productive tillers/plant where the control (S_1) showed superiority during both seasons. On the other hand, the numbers of pods/plant and 100-pod weight were particularly depressed in (S_2G_1) treatment during both seasons (Table 4). The superiority of (S_2G_1) in number of pods/plant and 100-pod weight and inferiority in total pod yield could mainly be attributed to less number of groundnut rows/unit area and to the expected increase in number and weight of pods due to less competition in space, soil moisture and nutrients. The results of the first season (2006) also revealed that sorghum grain (1.600 t/ha) and dry matter (1.743 t/ha) yields were significantly higher ($P \leq 0.05$) in pure stand (S_1) than in mixtures, with no significant differences from (S_1G_1) and (S_1G_2) treatments in grain yield, and from (S_2G_1) in dry matter weight. Furthermore, (S_1G_1) and (S_2G_1) treatments produced the lowest dry matter (1.425 t/ha) and grain (1.360 t/ha) yields, respectively. These reduced yields in sorghum + groundnut mixtures could be attributed to the reduced number of tillers/plant, as a result of competition in space and nutrients, leaf shedding, and to less accumulated dry matter, which in turn affected by stem length and diameter(which are not presented in this paper)and number of tillers/plant. These results agree with the findings of [17] and [18] that mixtures tillering ability and population density are the main determinants of final grain yield. In contrast, [6] in the Sudan Gezira found that mixing significantly increased the number of tillers in Sudan grass (Sorghum sudanense (Piper.) Stapf) when grown in mixture with phillipesera (Vigna trilobata Verd.) plants. He attributed that to a reduction in the competitive effect in Sudan grass as its seeding rate was decreased from 60 to 15 Kg/ha. Moreover, the availability of soil moisture due to

irrigation and application of N-fertilizers in this experiment could induce vegetative growth and tillering. From the results of the second growing season, it seems that the effect of soil moisture is more critical to sorghum performance than organic matter formation and nitrogen fixation by the associate groundnut. Furthermore, the duration of the experiment, however, is not long enough for consistent results of the effect of cereal + legume mixtures on soil fertility, because soil organic matter makes mineral nutrients (N, P and micronutrients) available to growing plants in small amounts over many years. In addition, crop tissue analysis and soil analysis, by the end of each growing season, are fundamental for more detailed characterization of soil nutrient status.

Table 3: Effects of intercropping on soil pH, electrical conductivity and nitrogen and organic matter percentages by the end of both seasons.

Soil properties	Treatment*	Depth			
		0 – 5 (cm)		0 – 30 (cm)	
		2006	2007	2006	2007
PH (paste)	S_1G_1	-	-	6.43	6.39
	S_2G_1	-	-	6.59	6.58
	S_1	-	-	6.86	7.12
	S_1G_2	-	-	6.64	6.53
N (%)	S_1G_1	-	-	0.092	0.049
	S_2G_1	-	-	0.080	0.037
	S_1	-	-	0.063	0.032
	S_1G_2	-	-	0.092	0.054
Organic matter (%)	S_1G_1	0.73	0.62	-	-
	S_2G_1	0.69	0.49	-	-
	S_1	0.66	0.47	-	-
	S_1G_2	0.76	0.68	-	-
ECe dsm^{-1}	S_1G_1	-	-	0.11	0.13
	S_2G_1	-	-	0.10	0.14
	S_1	-	-	0.08	0.12
	S_1G_2	-	-	0.15	0.21

*S_1G_1 = 1:1 Sorghum /groundnut row proportion
S_2G_1 = 2:1 Sorghum/ groundnut row proportion
S_1 = Sole sorghum (control)
S_1G_2 = 1:2 Sorghum /groundnut row proportion

Table 4: Effects of intercropping sorghum and groundnut on head length, 1000-grain weight, number of tillers $plant^{-1}$, dry matter and total grain yields of sorghum during 2006 and 2007 cropping seasons.

Treatments	Head length (cm)		1000-grain weight (g)		No. of tillers $plant^{-1}$		Dry matter weight (t/ha)		Total grain weight (t/ ha)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
S_1G_1	16.26 a	15.33 a	26.95 b	17.76 a	1.00 a	0.42 a	1.425 a	1.550 a	1.430 ab	1.333 a
S_2G_1	16.64 a	15.03 a	26.59 b	17.37 a	0.96 a	0.42 a	1.680 b	1.543 a	1.360b	1.300 a
S_1	16.5 a	14.84 a	25.03c	16.44 a	1.29 b	0.46 a	1.743 b	1.460 a	1.600 a	1.234 a
S_1G_2	16.94 a	15.96 a	28.57 a	19.27 a	0.83 a	0.33 a	1.472 a	1.554 a	1.470 ab	1.400 a
S.E.±	0.444 Ns	0.736 Ns	0.603**	1.273 Ns	0.071**	0.070 Ns	0.111*	0.060 Ns	0.094**	0.060 Ns
C.V. (%)	3.82	6.81	3.18	10.16	9.84	24.53	9.89	5.52	9.14	6.51

a – c: Means, within each column, followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to least significant difference Test (L S D
*, **: Significant at 0.05 and 0.01 probability levels, respectively

Keywords

Ns = Not significant
S_1G_1 = 1:1 Sorghum/groundnut row proportion.
S_1 = Sole sorghum

S_2 G_1 =2:1 Sorghum/groundnut row proportion
S_1G_2 =1:2 Sorghum/groundnut row proportion

Table 5: Means of number of pods plant^{-1}, 100 –pod weight and total pod yield of groundnut grown in mixtures with sorghum during 2006 and 2007 cropping seasons.

Treatment	No. of pods plant^{-1}		100-pod weight (g)		Total pod yield (ton ha^{-1})	
	2006	2007	2006	2007	2006	2007
S_1G_1	26.53^{a}	22.85^{ab}	69.55^{a}	64.85^{a}	0.847^{a}	0.694^{a}
S_2 G_1	27.03^{a}	23.43^{a}	66.99^{ab}	64.03^{a}	0.599^{b}	0.491^{b}
S_1	-	-	-	-	-	-
S_1G_2	24.53^{b}	21.00^{b}	65.11^{b}	62.88^{a}	1.114^{c}	0.975^{c}
S.E.±	0.449**	0.860*	1.095**	1.960^{NS}	0.071*	0.040**
C.V. (%)	2.44	8.17	2.31	4.34	11.76	5.70

a – c: Means, within each column, followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to least significant difference Test (L S D.)
*, ** Significant at 0.05 and 0.01 probability levels, respectively
Ns = Not significant
S_1G_1 =1:1 Sorghum/groundnut row proportion
S_1 =Sole sorghum
S_2 G_1=2:1 Sorghum/groundnut row proportion
S_1G_2 =1:2 Sorghum/groundnut row proportion

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