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Agronomic Evaluation of Sorghum and Cowpea Intercropped at Different Spatial Arrangements

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Abstract - Field experiment was conducted at Gedarif state at two locations for two consecutive seasons (2006 and 2007) under rain-fed conditions, to investigate the effects of intercropping sorghum and cowpea on the performance of sorghum and cowpea. The experiment consisted of six treatments; sole sorghum crop, sole cowpea crop and four spatial arrangements of 2:2, 1:1, 2:1 and 1:2 rows for sorghum alternated with cowpea. Treatments were arranged in a randomized complete block design with four replications. Land Equivalent Ratio (LER) was used to evaluate the productivity. In general, the results indicated that yield significant differences among the spatial arrangements. 1:1 arrangement obtained the highest values of sorghum panicle weight (57g), sorghum grain yield (1079kg/ha), sorghum hay weight (5572kg/ha) and combined total hay weight (7337kg/ha) for both sorghum and cowpea. Moreover, the best total LER (2.11) was obtained under 1:1 spatial arrangement.

Keywords - Intercropping, Cowpea, Sorghum, Land Equivalent Ratio

1. Introduction

Intercropping is a potential beneficial system of crop production. It can be defined as the growing of two or more crops simultaneously on the same area of land. Intercropping offers a better utilization of natural and labor resources, provides safe guards against failure of single crop, gives greater yield and return per unit area, and minimizes the spread of pests and diseases [18]. These crops are not necessarily sown at the same time and their harvest time may be quite different, but usually they occupy together the same land area for a significant part of the growing season. The crops involved in this system are usually harvested separately and their yields are kept separate [20]. Intercropping practices are extensively used by subsistence farmers in the tropic and subtropics. In general intercropping is practiced in Africa, India and Central America [12]. In Sudan, intercropping of cereals with legumes is a predominant feature in the cropping system which practiced in small scales as a means of maximizing the use of limited farm lands as well as attaining food security to the subsistence farmers. In western Sudan, the usual intercrop system practice is a cereal-legume mixture, where millet and sorghum are widely used as a cereal component of intercropping with crops such as a cowpea, groundnut, sesame and roselle [17]. Therefore, this system is considered to help farmers utilizing their limited resources (natural and labor resources) for attaining yield stability, obtaining higher yields per unit area, and having better control of weeds, pests, and diseases. In addition, it provides safe guard against familiar practice of the single crop.

Sorghum (Sorghum bicolor (L) Monech) is a main staple crop in Gedarif state. Beside its use as energy source to human consumption, it draws its great value as source of grain and straw that is used for animal feed [4]. Unfortunately, no proper recommended technologies were under taken by farmers to get ride of problems facing sorghum production in Gedarif state due to frequent cultivation in mono-cropping system, as well as the absence of awareness of farmers to the advantages of crop rotation and mixcropping. Hassan and Elasha [9] stated that growing sorghum as sole crop year after year had caused a serious infestation by noxious weeds like striga and Sudan grass, beside the depletion of soil fertility. Accordingly, the grain yield of sorghum in these areas especially during the last two decades was only about 100 kg/ha. Cowpea (Vigan unguiculta L.) is one of the important food and cash crops in Gedarif. Usually it is grown as a sole crop in limited areas. However, some farmers grow it as mixture with sorghum or pearl millet without particular arrangement The cowpea crop shows a great advantages through its use for human consumption, using the remaining biomass for animal fodder, attaining a good prevention of water run-off and evaporation from the soil surface according to its prostrating growth habit, besides its mothering the germination of Striga hermothica plants and other weeds and

increasing soil fertility through the nitrogen fixation. The main objectives of this research were to :

(1) Assess yield within intercropping compared to pure stand cropping.

(2) Determine the optimum spatial arrangement for the mixture of sorghum with prostrating local cowpea for highest yield.

2. Materials and Methods

2.1. Site of experiment:

The experiment was conducted under rain-fed conditions during two consecutive seasons (2006 /2007-2007/2008.) at the pilot Research Farm of the Faculty of Agriculture and Environmental Science, University of Gedarif at Tewawa (latitude 14˚06` N, longitude 35˚33`E) and Gedarif Research Station Farm at Kilo-6 about 12 Km west of Gedarif city (Eastern of Sudan) (Latitude 14˚, 03`N, longitude 35˚22` E), Gedarif State; Sudan.

2.2. Soil type:

Prior to sowing, soil samples were collected within 30cm soil profile using an auger, for determination of soil physical and chemical properties. The soil of the experimental sites is heavy cracking clay soil (vertisol). The approximate P H value was 7.8. Soil analysis data of the experimental sites is shown in Table1.

Table 1. Physical and chemical properties of the soil at the experimental sites

CHARACTER	Location	
	KILO-6	TEWAWA
Coarse sand (%)	06	05
Fine sand (%)	02	02
Silt(%)	18	10
Clay (%)	74	83
PH	8.1	7.6
Bulk density g cm^{-3}	1.74	1.73
Porosity (%)	34	34
Ca Co3 (%)	8.2	7.0
C/N (%)	8.7	10.3
Available P (mg k^{1}soil)	3.0	3.0
Total N (%)	0.031	0.032

2.3. Experimental design:

The experiment was arranged in a randomized complete block design (RBCD) with four replications. The plot size was 4.8m x5m (6 rows of 5 m length, 80 cm a part). The experiment consisted of six treatments comprising sorghum variety Gadambalia and local prostrating cowpea variety, grown in pure stand and in the following sequence of spatial arrangement:

1. One row of sorghum alternated with one row of cowpea (1:1).
2. Two rows of sorghum alternated with one row of cowpea (2:1).
3. One row of sorghum alternated with two rows of cowpea (1:2).
4. Two rows of sorghum alternated with two rows of cowpea (2:2).
5. Sole cowpea rows.
6. Sole sorghum rows.

The seeds of sorghum variety Gadamalia and prostrating local cowpea were obtained from Gedarif agricultural research station. The seeds were treated with Furnisan –D before sowing at the rate of 3g/Kg seed against insects and fungi. Sowing dates were 29th of July, 2006 and 21ist July 2007 for the University of Gedarif and Kilo-6 sites, respectively. Five seeds were placed in each hole for sorghum at spacing of 25cm within row, while for cowpea three seed were placed in each hole at a depth of 5cm. Two weeks after germination the thinning and first weeding processes were simultaneously done. Sorghum plants were thinned to two plants per hole, while cowpea was thinned to one plant per hole. The second weeding was done two weeks from the first, while the third one was done three weeks after the second weeding. Monthly temperature, solar radiation, relative humidity and rainfall were recorded for both locations (Table 2) during the growing seasons.

2.4. General observations:

Soil sample for moisture content samples were taken 30 days after planting and at 60 days for two different depths (0-15, 15-30 cm). The samples were oven-dried at 105˚c for 24 hours to determine the moisture content of soil samples for all treatments. Sorghum parameters recorded were: number of panicles per plant, panicle weight (g), straw weight (kg/ha), grain weight (kg/ha) and 100 seeds weight (g), while for cowpea, five samples of plants were taken from each plot to determine the yield components. In general the following characters were measured:

Number of pods per plant: (This was determined by counting the number of pods/five random plants then divided by five), number of seeds per pod: Number of seeds was determined from random ten pods, 100 seeds weight (g): 100 seeds was counted (four times) from each sample and weighed.

Grain yield (Kg/ha): Determined by weighing the yield of every plot then converted to yield/ha.

2.5. Land equivalent ratio (LER):

It is a way for assessing the benefits of growing two or more crops together and comparing the yield of these two crops when growing in pure stand. It was used to evaluate the productivity of mixed crops [2]. Hence, LER is a measure of

degree by which the intercropping gives higher return to land area than the pure stand. It is calculated using the formula:

$$LER = \frac{\text{Crop A yield in mixture}}{\text{Crop A yield in pure stand}} + \frac{\text{crop B yield in mixture}}{\text{Crop B yield in pure stand}}$$

LER value greater than one, equal to one, or less than one usually shows a yield advantages, no difference or disadvantage for intercropping, respectively.

Table 2. Monthly average of some metrological data at Gedarif during Experiment period

Months	Mean Temperature C° K*		Mean Relative Humidity% K*		Solar radiation (wat/m2/ hour) K*		Rain-fall (mm)			
	2006	2007	2006	2007	2006	2007	2006		2007	
							T*	K*	T*	K*
July	30.05	27.25	72	82	240	158	69.6	37.5	120.4	114.7
August	28.50	28.40	79	82	190	200	266.4	252.5	261.5	239.5
September	29.1 0	29.65	69	76	257	251	118.2	132.0	64.8	94.0
October	13.10	30.65	58	59	284	259	24.8	0.0	8.8	NR

T*, Tewawa, K* Kilo-6, NR. No rain

2.6. Statistical analyses:

Data in each season and location and for both seasons were statistically analyzed using MSTAT-C package. The model followed in the analyses was described by Gomez and Gomez [7]. The Duncan test (DMRT) was used for mean comparison.

3. Results and Discussion

3.1. Soil moisture content

Table 3 shows the effect of Effect of intercropping on moisture content at 30 and 60 days after sowing. In general, all treatments showed highest moisture content over sorghum pure stand treatment. This could be attributed to the advantage of intercropping in retention of soil moisture. Similar results were reported by Hassan and Elasha [9]. In all cases, the values of moisture content at 30 days are higher than 60 days, which might be attributed to higher amounts of rainfall at August compared to other late months or might be due to high water consumption by plants after one month period [15]. On the other hand, the moisture records at 15 cm depth were higher than those of 30 cm depth in all seasons and locations. This might be due to the difficulty of water infiltration into the heavy clay soils or to the direct impact of rain-drop on the soil surface that produces crusts and retards infiltration of rain water into the soil [13],[8].

Table 3. Effect of intercropping on moisture content at 30 and 60days after planting (depth15- 30cm) during 2006

Treatments	Tewawa				Kilo 6			
	30 DAS		60 DAS		30 DAS		60 DAS	
	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm
1:1	13.5^{abc}	12.1^{b}	10.3^{a}	12.90^{a}	12.7^{a}	$9.\ 0^{c}$	14.5^{a}	10.1^{ab}
2:1	16.6^{a}	15.8^{a}	13.2^{a}	14.57^{a}	13.1^{a}	13.3^{ab}	13.6^{a}	11.5^{a}
1:2	17.0^{a}	14.3^{b}	10.1^{a}	13.29^{a}	12.6^{a}	11.62^{b}	13.8^{a}	8.5^{bc}
2:2	15.7^{ab}	12.9^{c}	9.4^{b}	4.41^{b}	12.9^{a}	14.0^{a}	14.7^{a}	10.3^{a}
Sole cowpea	10.8^{bc}	16.4^{a}	9.0^{b}	13.0^{a}	12.3^{a}	12.8^{ab}	13.8^{a}	8.27^{bc}
Solesorghum	9.4^{c}	13.7^{b}	7.9^{c}	12.4^{a}	11.3^{b}	11.5^{b}	10.9^{b}	6.6^{c}
SE ±	1.92	1.27	1.63	0.99	1.11	0.70	0.58	0.74

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

3.2. Growth

Table 4, shows the effect of intercropping on forage yield (kg/ha) of cowpea. The arrangement of 1:1 obtained the highest forage yield (5772kg/ha) which could be attributed to the advantage of legume/cereal intercropping and to better utilization of natural resources such as water, light and nutrients. Similar results were reported by Andrews [1]. Also

the enhancement of productivity by mixed legume crop could lead to the increase of crop growth [5], [9]. The highest yield of cowpea forage in both seasons, through the two sites, was exhibited by pure stand cowpea. This superiority could be due to the fact that, prostrating local cowpea could conserve and increase moisture content which later leads to increase of crop growth [16].

Irrespective of combined forage weight of the sole cowpea (2281 kg/ha), the arrangement of 1:1 in mix cropping revealed the highest combined forage weight (1765 kg/ha) as compared to other mix treatments .The variation in forage weight in mix cropping, could be due to different effect of different spatial arrangements in reduction of evaporation which certainly affected the crop growth [10].

Table 4. Effect of intercropping on forage yield (kg/ha) of cowpea.

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	1875^{b}	1812.5^{b}	1650^{b}	1722^{c}
2:1	1300^{c}	2100^{a}	1437.5^{b}	1702^{c}
1:2	1422^{c}	1902^{b}	1662.5^{b}	1792^{b}
2:2	1302^{c}	1850^{c}	1830^{ab}	1725^{c}
5-Sole cowpea	2500^{a}	2150^{a}	2247.5^{a}	2225^{a}
C.V%	17.43	27.36	21.45	25.31
SE ±	1.46.	2.68.	1.89	2.32.

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

3.3. Yield and yield's component

3.3.1. Sorghum

The results of sorghum yield and yields components as affected by intercropping arrangements are shown in Tables 5, 6, 7 and 8. Seasonal combined means analyses of number of panicles/m ²over locations showed no significant differences, however, the arrangement of 1:1 had obtained the highest number of panicles/m ²(13), which could be due to absence or reduction in competition between crops that found in a low mix standard (i.e.1:1). The same findings were reported by Singh and Ahuja [20] who had reported a yield increase as a result of intercropping sorghum with cowpea. The highest combined sorghum panicle weight (56.58 g) of 1:1 row arrangement might be due to absence or reduction of competition from one row cowpea plants to sorghum plants. Moreover, it could be due to the considerable high soil moisture content of intercropped treatments over that of pure stand crops. Similar results were reported by Ma *el al.*, [11]. The highest combined grain yield (1078.94 kg/ha) was obtained by treatment 1:1. This could be related to the benefits of the trap crop (cowpea) in reducing *striga* infestation besides its contribution in soil moisture retention and low competition to sorghum plants for nitrogen through its capability of fixing its own nitrogen. Hence, that was manifested to higher number of panicles/m ²; higher panicle weight and finally to a better and high grain yield for sorghum. Similar results were mentioned by Gbehounou and Adango [6] and Hassan and Elasha [9]

Table 5. Effect of intercropping on number of panicles/m2. of sorghum

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	17^{a}	12^{a}	11^{a}	12^{a}
2:1	13^{c}	12^{a}	11^{a}	11^{a}
1:2	11^{d}	12^{a}	11^{a}	11^{a}
2:2	14^{bc}	11^{b}	10^{b}	10^{b}
Sole sorghum	15^{b}	13^{a}	10^{b}	10^{b}
C.V%	14.27	8.25	12.57	12.30
SE ±	1.002	0.66	0.659	0.66

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

Table 6. Effect of intercropping on 100-seed weight (g) of sorghum

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	4.31a	4.93a	4.21a	4.48a
2:1	4.41a	5.01a	4.32a	4.58a
1:2	4.33a	4.66a	4.65a	4.54a
2:2	4.52a	5.19a	4.47a	4.67a
Sole sorghum	4.44a	5.19a	4.64a	4.58a
C.V%	9.11	8.45	10.70	6.75
SE ±	0.20	0.21	0.39	0.15

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

3.3.2. Cowpea

The results of cowpea yield and yields components as affected by intercropping arrangements are shown in Tables 9, 10, 11 and 12. The arrangement of 1:1 had obtained a higher number of pods per plant at all treatments; this may be due to considerable high moisture contents in intercropped treatments over pure stand crops as well as a minimum competition of one row sorghum plants to the grown cowpea plants as compared to other treatments. This is in agreement with the findings of Pal et, al. [19] who found out yield advantages of legumes-cereal intercropping over sole cropping. The spatial arrangement had no significant effect on cowpea pod yield. This was mainly due to the absence of sorghum competition. The same findings were reported by

Muleba and Ezumah [14]. Also spatial arrangement had no significant effect on cowpea seed yield. These observations disagreed with the earlier results of Muleba and Ezumah[14] who reported that the competitive effect of sorghum on yield of cowpea under the mix cropping system could lead to low yield of cowpea seeds

Table 7. Effect of intercropping on panicle weight (g) of sorghum

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	41.46a	57.22a	56.57a	71.06b
2:1	24.97d	38.35c	49.08d	58.37c
1:2	29.56c	39.75c	55.46a	80.64a
2:2	29.86c	42.35b	57.65a	75.15b
Solesorghum	36.32b	35.27d	41.17c	51.86d
C.V%	23.90	26.17	20.75	14.86
S.E ±	4.20	5.66	5.39	4.99

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

Table 8. Effect of intercropping on grain yield (kg/ha) of sorghum

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	1102.72a	1024.25a	1019.74a	1162.03a
2:1	1004.65b	999.50b	984.94b	1088.35b
1:2	965.76c	993.50b	1000.11b	1122.98b
2:2	978.40bc	1002.0b	831.0c	1163.34a
Sole sorghum	816.60d	881.0c	781.34d	904.94c
C.V%	7.84	5.13	20.39	12.63
SE ±	38.12	25.15	94.22	68.79

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

Table 9. Effect of intercropping on number of pods per plant of cowpea

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	11a	13a	13a	14c
2:1	11a	7b	12b	16b
1:2	7b	8b	12b	17a
2:2	11a	7b	11c	17a
Sole cowpea	9b	8b	11c	18a
C.V%	29.68	24.88	3.75	12.14
SE ±	1.47	1.06	0.81	1.01

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

3.4. Land Equivalent Ratio (LER)

The value of land equivalent ratio (LER) indicated better land used in all intercropping treatments (Table 13). In all levels of these arrangements the advantage of intercropping of sorghum and cowpea over pure stand was evident (i-e. partial LER of 1.28, 1.21, 1.21 and 1.18 for producing 1079, 1019, 1020 and 995 kg/ha, respectively). Accordingly, 28%, 21%, 21% and 18% more

Table 10. Effect of intercropping on number of seeds per pod of cowpea.

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	10a	11a	10a	11a
2:1	9a	9b	10a	12a
1:2	9a	10a	9a	11a
2:2	9a	9b	9a	11a
Sole cowpea	8b	9b	9a	12a
C.V%	17.10	21.98	9.12	14.51
S.E ±	0.79	1.12	0.44	0.84

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

Table 11. Effect of intercropping on 100-seed weight (g) of cowpea

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	22.39a	26.26a	23.72a	21.62a
2:1	22.45a	25.35a	22.45a	20.26a
1:2	23.3a	22.74b	23.89a	20.63a
2:2	23.64a	26.72a	23.38a	21.06a
Solecowpea	23.74a	27.32a	23.34a	20.72a
C.V%	5.34	8.91	10.87	8.13
SE ±	0.62	1.14	1.27	0.85

Similar letters are not significantly different at the 0.05 level of probability according to Duncan multiple range test

Table 12. Effect of intercropping on seed yield (kg/ha) of cowpea

Treatments	2006		2007	
	Tewawa	Kilo-6	Tewawa	Kilo-6
1:1	408.4b	372.5b	383.4b	393.9c
2:1	412.0b	360.0b	385.4b	364.8d
1:2	416.0b	345.0c	390.0c	402.4b
2:2	425.0b	360.0b	399.5b	403.4b
Solecowpea	472.0a	453.0a	460.67a	519.6a
C.V%	7.92	15.72	11.52	17.52
SE ±	16.91	28.75	23.25	36.45

Similar letters are not significantly different at the 0.05 level of probability

according to Duncan multiple range test

Land would be required to produce the same yields (1079 kg /ha, 1019 kg /ha, 1020 kg /ha and 995 kg /ha) as the same area planted in an intercrop combination. Irrespective of the highest sorghum grain yield (1079 kg /ha) which was obtained under the combination of one sorghum row and one cowpea row (1:1), these results explain the capability of sorghum to develop better grain yields when mixed with cowpea. Similar results were detected by Hassan and Elasha [9]. Moreover, Willy [22] reported the same results for yield advantages of 25% under mix cropping (LER=1.25) in the millet-groundnut intercrop. Cowpea intercrop yields (394,381, 388 and 396 kg/ha at spatial arrangements 1:1, 2:1, 1:2 and 2:2 respectively) were lower than those of pure stand (477 kg /ha) and resulted to partial LER of 0.83, 0.80, 0.82 and 0.83, respectively. On the other hand, the total LER of 2.11, 2.01, 2.03 and 2.01 over the spatial arrangements (1:1, 2:1, 1:2 and 2:2 respectively) indicate that at least a double more land (100%) would be needed to produce the combined yields of both two crops if they were to be grown as pure stands, however 111% more land would be needed for this purpose in case of the best arrangement (i.e. 1:1). In northeast Brazil, Bezerra Neto *et al*. [3] found that total LER for cowpea/sorghum intercrop was higher in the spatial arrangement of 1:1, compared to other arrangements.

Table 13. Effect of intercropping on land equivalent ratio (LER) of sorghum and cowpea

Treatments	Partial LER		Total (LER)
	Sorghum	Cowpea	
1 : 1	1.28	0.83	2.11
2 : 1	1.21	0.80	2.01
1 : 2	1.21	0.82	2.03
2 : 2	1.18	0.83	2.01

4. Conclusions

The partial Land Equivalent Ratios (LER) which were obtained from arrangements of 1:1, 2:1, 1:2 and 2:2, respectively, had significantly indicated the advantage of sorghum intercropping over pure stand. The highest sorghum grain yield was obtained under 1:1 arrangement, while cowpea seed yield under the pure stand treatment was higher than those of intercropping.

For attaining higher total crop yield per unit area of land, where there is no crop bias and the preference is to maximize land use and or to obtain maximum income, the practice of planting one row of sorghum alternated with one row of local cowpea (1:1) is better mixture for both locations and seasons.

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