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Effect of intercropping and plant distribution of sorghum with soybean on growth and yield of *Sorghum bicolor*

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Abstract

This field experiment was carried out at special farm at Luxor governorate, Egypt during 2018 and 2019 seasons to study the effect of some intercropping patterns and plant distributions of sorghum (var. Dorado) and soybean (var. Giza-111) on the growth, yield and yield components and the economic return of the sorghum plants. The experimental was laid out in split-split plot with randomized block design in three replications. The plant height of sorghum was significant affected by the different intercropping patterns and plant density in the second season only as a result of the interaction between the number of plants/ hill and the intercropping patterns. The highest values of panicle length were by sole cropping of sorghum compared to the other intercropping patterns. Sowing sorghum – soybean plants as 1:1 side on the same row resulted in the highest values of panicle weight and grain yield /plant of sorghum in the mean of seasons. Sowing of sorghum as sole crop at 15 cm between hills plus two plants /hill followed by 4:2 row intercropping gave the highest values of grain weight /plot and grain yield /feddan (feddan = 0.420 hectares = 1.037 acres) in the two seasons compared to the other treatments. The highest value of land equivalent ratio (1.41) resulted from the use of 3:3 row pattern of intercropping with two plants /hill and 15 cm spacing. Also, there is an increase in the value of the land equivalent ratio (1.29) with the use of the 4:2 row pattern of sorghum-soybean intercropping with 2 plants /hill and 15 cm between hills. The most profitable system was intercropping of sorghum: soybean as 3: 3 or 4:2 row patterns and 15 or 20 cm between hills with planting two plants /hill.

Keywords: intercropping, sorghum, soybean, *Sorghum bicolor*.

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1. Introduction

Egbe (2010) evaluate the influence of plant population density of intercropped soybean with sorghum on its competitive ability and economic yield found that increased density of soybean in the intercrop reduced sorghum yield. All the intercrop combinations had land equivalent ratio (LER) above unity (1.63 - 1.97). Also, under all the densities of soybean tested, suggesting a considerable benefit for intercropping soybean with sorghum. Moreover, in order to find the best planting pattern of soybean with sorghum intercropping, Saberi (2018) pointed out that forage production with intercropping with sorghum and soybean had priority compared to check treatment (sole cropping of sorghum). Field crops and their agronomic characteristics applied in intercropping systems are very important (Aminifar and Ghanbari, 2014). In this respect, intercropping cereal crops with legume plants is usually done to maximize productivity in many parts of the Mediterranean region (Aynehband *et al*., 2010). In Egypt, there is the need to expand the scope of soybean, *Glycine max.* (L.) Merr. Cultivation through intercropping system. Also, there is an increase in the costs of producing soybeans when planted as sole crop, the net returns is lower when compared to strategic summer crops such as sorghum because of the increasing demand for sorghum grains in the Egyptian market. Globally, cultivable land has decreased due to population increase and industrialization. Particularly in Asia and Africa where producers have small plots, agricultural areas are under pressure to produce for human nutrition (Awal *et al*., 2007). While global demand for food increases, agricultural expansion faces more stringent environmental preservation demands and sustainability laws aimed to prevent deforestation (Crusciol *et al*., 2014). Industrialization and globalization in agriculture and food supply endanger the future of humanity and environment. Industrial agriculture based on agrochemical use has negative impact on human health, ecosystem and food quality (Altieri and Nicholls, 2005). Furthermore, although modern industrialized agriculture based on monoculture has resulted in high increased yields, it caused huge costs. Grain sorghum as a staple food grain in several developing countries (Buah and Mwinkaara, 2009) is an important crop in arid and semiarid regions, because of its environmental adaptability. Also, sorghum is one of the most widely adapted forage crops to the arid and semi-arid tropics and dry-temperate areas of the world (Blum, 2004). Moreover, sorghum is grown in Upper Egypt from Giza to Aswan but most of the area (89 thousand hectare) is concentrated in Assiut and Sohag governorates and about 37 thousand hectares in Fayoum governorate (Ezzat *et al.*, 2010). In addition, it is having a double purpose crop; the vegetative parts are used for animal feeding in summer season where green forage crops are not quite available. The total production of grain sorghum in Egypt is less than the needs of the local consumption (Abdel-Motagally, 2010). Therefore, this experiment aims to investigate the effects of different intercropping patterns and planting densities on the growth and production of sorghum (as main crop) and soybean (as

companion crop) as well as to suggest an appropriate planting pattern which has the preference in terms of production for these two important crops.

2. Materials and methods

The present field experiment was carried out at special Farm at Luxor Governorate, Egypt during 2018 and 2019 seasons to study the effect of different intercropping patterns and plant density of sorghum as main crop and soybean plants as secondary crop on the growth and yield of sorghum (var. Dorado) and soybean (var. Giza -111) as well as the competitive relationships.

2.1 Studied factors

Intercropping patterns including different sorghum - soybean row ratios:1 side of sorghum: 1 side of soybean (on the same ridge), 1 row of sorghum: 1 row of soybean intercropping pattern, 3 row of sorghum: 3 row of soybean intercropping pattern, 4 row of sorghum: 2 row of soybean intercropping pattern and pure stands of sorghum or soybean crops (control). Spacing between hill. Two spacing hill, 15 cm and 20 cm. Number of plant /hill. One plant /hill and two plant /hill.

2.2 Soil analysis

Soil samples were taken at random field area at depth 0- 30 cm from soil surface before soil preparation to measure the chemical and physical soil properties according Page *et al*. (1982) and shown in Table (1).

2.3 Experimental design

During the growing summer seasons 2018 and 2019, sorghum (var. Dorado) grains were sown in the 30th of April in both seasons, in rows of 60 cm apart at spacing 15 or 20 cm between hills. The commonly known (Afear) in hills method of sowing was followed. After 18 days from planting, plants were thinned into one or two plants per hill. Calcium superphosphate (15.5% P_2O_5) was added during bed preparation at the rate of 100 kg/fed. The other recommended cultural practices were carried out during the two seasons. Soybean (var. Giza -111) was sown in the 15th of May in both seasons in rows of 60 cm apart at spacing 15 or 20 cm between hills. After 18 days from planting, plants were thinned into one or two plants per hill. In all treatments' combinations along with monoculture of sorghum or soybean were distributed in split- split plot within randomized complete design with three replications. However, the spacing between hills (15 or 20 cm) was randomly assigned to the main plots; plants per hill (one or two plants) were allotted in sub-plots, while the cropping systems (intercropping or monocultures for both species) devoted to sub- subplots. Each plot consisted of 6 rows (3.5m length and 0.6 m width, plot area was 12.6 m^2).

Table (1): Physical and chemical analysis of the experimental soil sites, during 2018 and 2019 seasons.

Seasons		2018	2019
Physical properties	Sand %	33.45	32.55
	Silt %	28.22	29.20
	Clay %	38.33	38.25
Soil texture		Clay loam	Clay loam
Chemical properties	O.M. %	1.85	1.90
	H CO_3 (meq /100 g soil)	0.59	0.56
	SO^{-}_4 (meq /100 g soil)	0.88	0.83
	Soil pH	7.90	8.05
	E.C. (mmhose /cm)	0.51	0.49
	Ca CO_3%	3.50	3.34

2.4 Studied characters

2.4.1 Growth characters

At harvest (115 days from sorghum sowing), from each plot a sample of 10 plants of sorghum were randomly taken at physiological maturity from two internal rows to measure: plant height (cm), was measured from soil surface to the top of the plant, flag leaves length and width (cm), panicle length (cm), panicle dry weight (gm), grain yield/ plant, grain yield/ plot and total grain yield (ardab)/feddan, (ardab= 140 kg) (feddan = 0.420 hectares = 1.037 acres).

2.4.2 Land equivalent ratio (LER)

LER is an index of intercropping advantage that indicated the amount of interspecific competition or facilitation in an intercropping system. LER is likely to be lowered towards unity and is expressed in the following equation:

LER = Sorghum intercrop yield /sorghum sole yield + Soybean intercrop yield /Soybean sole yield (Willey, 2006).

2.5 Statistical analysis

The results were statistically analyzed according to Gomez and Gomez (1984) using the computer MSTAT-C statistical analysis package by Freed *et al.* (1989). The least significant differences (LSD) test at probability level of 0.05 was manually calculated to compare the differences among means.

3. Results and Discussion

3.1 Effect of intercropping and plant distribution on the growth characters of sorghum

Data in Table (2) clear that, sowing of sorghum plants on 1:1 row followed by sowing in 1:1 side of the row resulted in the highest values of the sorghum plant height in the two seasons of the study. Meanwhile, the lowest values of the height of sorghum plant were obtained as

a result of sowing of the sorghum plants as monoculture in the two seasons of the study. From Table (3) clear that sole cropping of sorghum followed by intercropping of sorghum: soybean at 4:2 row resulted in the highest values of flag leaf width in the average of the two seasons compared to the rest of the other intercropping pattern. However, the highest value of the flag leaf length as a result of intercropping sorghum: soybean as 4:2 row, while the lowest value as a result of 1:1 row intercropping pattern (Table 4). There are no differences in this trait with all treatments used with sorghum grown as sole crop (Table 5).

Table (2): Plant height of sorghum plant (cm) as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant /hill	Intercropping pattern					M	Spacing between hills	Number of plant /hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	114.7	112.7	109.7	107.0	105.0	109.8	15 cm	1 plant/ hill	111.3	113.3	110.0	109.0	108.3	110.4
	2 plant/ hill	108.3	114.0	109.0	113.0	115.0	111.9		2 plant/ hill	110.7	112.0	107.7	109.7	110.0	110.0
M		111.5	113.3	109.3	110.0	110.0	110.8	M		111.0	112.7	108.8	109.3	109.2	110.2
20 cm	1 plant/ hill	108.0	113.3	115.0	112.3	107.3	111.2	20 cm	1 plant/ hill	110.3	111.3	112.3	109.7	109.0	110.5
	2 plant/ hill	108.7	114.7	106.0	113.3	105.7	109.7		2 plant/ hill	113.3	112.3	109.0	109.7	109.0	110.7
M		108.3	114.0	110.5	112.8	106.5	110.4	M		111.8	111.8	110.7	109.7	109.0	110.6
LSD 5%	Intercropping = n.s							LSD 5%	Intercropping = n.s						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping = n.s								Spacing x intercropping = n.s						
	Plant/ hill x intercropping = n.s								plant/ hill x intercropping = n.s						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

Table (3): Flag leaf width of sorghum plant (cm) as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant / hill	Intercropping pattern					M	Spacing between hills	Number of plant/ hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	5.67	6.00	5.33	5.67	5.67	5.67	15 cm	1 plant/ hill	5.67	5.33	6.00	5.67	5.67	5.67
	2 plant/ hill	5.33	5.67	5.00	5.67	6.00	5.53		2 plant/ hill	6.00	5.33	5.00	6.00	5.33	5.53
M		5.50	5.80	5.20	5.70	5.80	5.60	M		5.80	5.30	5.50	5.80	5.50	5.58
20 cm	1 plant/ hill	5.67	6.00	5.33	5.67	6.00	5.73	20 cm	1 plant/ hill	6.00	5.00	5.67	5.33	6.00	5.60
	2 plant/ hill	5.00	5.67	6.00	5.33	5.67	5.53		2 plant/ hill	5.33	5.67	5.33	6.00	5.67	5.60
M		5.30	5.80	5.70	5.50	5.80	5.62	M		5.70	5.30	5.50	5.70	5.80	5.60
LSD 5%	Intercropping = n.s							LSD 5%	Intercropping = n.s						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Plant/ hill x intercropping = n.s								Intercropping pattern of sorghum- soybean:1 = 1 side: 1 side on the same row; 2= 1 row: 1 row; 3= 3 row: 3 row, 4= 4 row: 2 row and 5= sorghum as sole crop.						
	Spacing x plant/ hill x intercropping = n.s								plant/ hill x intercropping = 0.55						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

Table (4): Flag leaf length of sorghum plant (cm) as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant /hill	Intercropping pattern					M	Spacing between hills	Number of plant /hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	35.00	35.33	35.33	37.00	35.33	35.60	15 cm	1 plant/ hill	36.33	35.67	35.67	35.33	37.33	36.07
	2 plant/ hill	37.33	34.67	36.00	37.33	35.33	36.13		2 plant/ hill	36.00	35.67	35.33	35.33	35.67	35.60
M		36.20	35.00	35.70	37.20	35.30	35.88	M		36.20	35.70	35.50	35.30	36.50	35.84
20 cm	1 plant/ hill	36.00	34.33	36.00	37.33	36.00	35.93	20 cm	1 plant/ hill	35.67	35.67	36.33	36.33	37.33	36.27
	2 plant/ hill	36.33	35.67	37.33	36.67	35.67	36.33		2 plant/ hill	35.00	36.33	36.00	36.33	35.67	35.87
M		36.20	35.00	36.70	37.00	35.80	36.14	M		35.30	36.00	36.20	36.30	36.50	36.06
LSD 5%	Intercropping = 1.36							LSD 5%	Intercropping = n.s						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping = n.s								Spacing x intercropping = n.s						
	plant/ hill x Intercropping = n.s								Plant/ hill x intercropping = n.s						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

Table (5): Panicle length (cm) of sorghum plant as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant /hill	Intercropping pattern					M	Spacing between hills	Number of plant /hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	24.00	25.67	22.00	24.33	25.67	24.33	15 cm	1 plant/ hill	36.33	24.00	24.00	24.00	25.33	25.33
	2 plant/ hill	25.00	25.67	23.67	23.67	24.67	24.54		2 plant/ hill	36.00	24.33	24.33	24.33	25.33	25.33
M		24.50	25.70	22.80	24.00	25.20	24.44	M		36.20	24.20	24.20	24.20	25.30	25.30
20 cm	1 plant/ hill	25.33	25.33	23.33	26.33	26.33	25.33	20 cm	1 plant/ hill	35.67	24.33	24.67	24.67	26.67	26.67
	2 plant/ hill	24.33	24.00	25.00	24.00	25.67	24.60		2 plant/ hill	35.00	24.33	25.33	24.33	25.33	25.33
M		24.80	24.70	24.20	25.20	26.00	24.98	M		35.30	24.30	25.00	24.50	26.00	26.00
LSD 5%	Intercropping = n.s							LSD 5%	Intercropping = 1.48						
	Spacing x plant/ hill= n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping =n.s								Spacing x intercropping = n.s						
	Plant/ hill x intercropping = n.s								Plant/ hill x intercropping = n.s						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

The findings on this study are similar to those of Undie *et al.* (2012), Muoneke *et al*. (2007), Yunusa (1989) and Alvarenga *et al*. (1998) who did not find significant differences in terms of plant height, between sole maize and intercropping with soybean. Similarly, Thobatsi (2009) and Watiki *et al.* (1993) found that maize intercropped with cowpea did not have any effect on maize growth. On the other hand, Ghosh (2004) further explained that because of the differences in canopy height of soybean and sorghum, the two species not only competed for nutrient water but also for sunlight. Egbe and Kalu (2009) had reported similar observations when different pigeon pea varieties were evaluated under intercropping with sorghum plants. Also, these results are in agreement with those obtained by Dabhlkar *et al*. (1985) and Enyi (1973). Moreover, Ibrahim (1994) observed that sorghum – cowpea mixtures showed higher plant height than pure sorghum.

3.2 Effect of intercropping and plant distribution on the yield and yield components of sorghum

From Table (5), the sole cropping of sorghum resulted in the highest values of panicle length in the average of the two seasons compared to the rest of the other intercropping pattern. It is also proved that sowing sorghum: soybean plants as 1:1 side on the same row followed by sowing sorghum as sole crop resulted in the highest values of panicle weight /plant of sorghum, while the lowest value of the panicle weight was obtained from intercropping as 3:3 row in the mean of seasons. However, the highest value of panicle weight /plant of sorghum was due to sowing sorghum plants as one plant /hill at 20 cm between hills in the two seasons (Table 6). It is also noticed from the Table (7) that sowing sorghum: soybean plants as 1:1 side on the same row pattern followed by sowing sorghum as sole crop resulted in the highest values of grain yield /plant of sorghum in the mean of seasons. Meanwhile, the lowest value of the grain yield /plant was obtained from 3:3 row pattern in the mean of seasons. However, the highest value of grain yield /plant of sorghum were due to sowing sorghum plants with soybean as 1:1 side on the same row intercropping with 20 cm between hills and one plant /hill in the two seasons. Table (8) shows that there was a significant effect of each of the

intercropping pattern and the interaction between the distance between hills and intercropping pattern on the grain weight /plot in the two seasons of the study. Sowing of sorghum as sole crop, followed by 4:2 row intercropping pattern with soybean resulted on the highest value of the grain yield /plot, while 1: 1 side on the same row intercropping pattern gave the lowest value in the mean of seasons. However, sowing sorghum plants as monoculture at 15 cm between hills plus 2 plants /hill followed by sowing as 4 row: 2 row intercropping of sorghum- soybean with the same density gave the highest values of grain weight /plot for sorghum in the mean of seasons of the study compared to the rest of the treatments.

Table (6): Panicle weight /plant (gm) of sorghum plant as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant /hill	Intercropping pattern					M	Spacing between hills	Number of plant /hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	73.00	68.33	64.33	64.67	70.00	68.07	15 cm	1 plant/ hill	74.67	55.00	56.33	64.67	74.00	64.93
	2 plant/ hill	68.33	59.67	58.67	53.67	56.00	59.27		2 plant/ hill	56.00	53.00	52.00	55.67	64.33	56.20
M		70.70	64.00	61.50	59.20	63.00	63.68	M		65.30	54.00	54.20	60.20	69.20	60.58
20 cm	1 plant/ hill	103.3	86.00	67.33	80.67	76.67	82.80	20 cm	1 plant/ hill	91.33	73.33	66.67	69.67	80.00	76.20
	2 plant/ hill	70.00	68.00	64.33	63.67	65.00	66.20		2 plant/ hill	66.00	65.00	64.33	65.67	64.33	65.07
M		86.70	77.00	65.80	72.20	70.80	74.50	M		78.70	69.20	65.50	67.70	72.20	70.66
LSD 5%	Intercropping = 6.95							LSD 5%	Intercropping = 4.19						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping = n.s								Spacing x intercropping = 5.90						
	Plant/ hill x intercropping = n.s								Plant/ hill x intercropping = 5.93						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

Table (7): Grain yield /plant (gm) of sorghum plant as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant / hill	Intercropping pattern					M	Spacing between hills	Number of plant/ hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	58.67	49.00	47.67	47.33	56.33	51.80	15 cm	1 plant/ hill	50.67	39.67	40.67	52.67	58.33	48.40
	2 plant/ hill	55.00	44.00	42.33	39.00	44.67	45.00		2 plant/ hill	43.67	37.33	33.33	42.33	47.33	40.80
M		56.80	46.50	45.00	43.20	50.50	48.40	M		47.20	38.50	37.00	47.50	52.80	44.60
20 cm	1 plant/ hill	75.00	60.33	52.00	62.67	58.33	61.67	20 cm	1 plant/ hill	72.33	51.67	51.67	57.00	65.00	59.53
	2 plant/ hill	53.00	51.33	51.33	51.33	50.00	51.40		2 plant/ hill	51.67	49.33	51.00	50.33	51.67	50.80
M		64.00	55.80	51.70	57.00	54.20	56.54	M		62.00	50.50	51.30	53.70	58.30	55.16
LSD 5%	Intercropping =6.35							LSD 5%	Intercropping = 4.30						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping = n.s								Spacing x intercropping = n.s						
	Plant/ hill x intercropping = n.s								Plant/ hill x intercropping = 6.08						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

Table (8): Grain weight /plot (kg) of sorghum plant as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant /hill	Intercropping pattern					M	Spacing between hills	Number of plant /hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	1.15	1.22	1.20	1.90	2.72	1.64	15 cm	1 plant/ hill	0.98	1.39	1.04	1.69	2.81	1.58
	2 plant/ hill	1.85	2.12	2.10	3.43	3.87	2.67		2 plant/ hill	1.64	1.78	2.02	2.92	4.32	2.54
M		1.50	1.67	1.65	2.67	3.29	2.15	M		1.31	1.59	1.53	2.31	3.57	2.06
20 cm	1 plant/ hill	1.34	1.20	1.02	1.44	2.13	1.43	20 cm	1 plant/ hill	1.27	0.95	0.92	1.19	2.34	1.33
	2 plant/ hill	1.88	1.88	1.89	2.47	3.46	2.32		2 plant/ hill	1.77	1.77	1.84	2.41	3.43	2.25
M		1.61	1.54	1.46	1.96	2.79	1.87	M		1.52	1.36	1.38	1.80	2.89	1.79
LSD 5%	Intercropping = 0.238							LSD 5%	Intercropping = 0.198						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping =0.336								Spacing x intercropping = 0.280						
	Plant/ hill x intercropping = n.s								Plant/ hill x intercropping = n.s						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

Table (9) shows that the intercropping pattern, the interaction between intercropping and spacing between hills as well as the interaction between intercropping and number of plants /hill have a significant effect in the two seasons on the grain yield /feddan of sorghum. Sole cropping of sorghum followed by 4:2 row patterns gave the highest value of the grain yield/ feddan, while the lowest value of this character was due to sowing sorghum: soybean as 1:1 side on the same row in the mean of seasons. However, sowing sorghum as monoculture with two plants /hill and 15 or 20 cm between hills, followed by 4:2 row pattern at 15 cm between hills and two plants /hill resulted in the highest productivity in the mean of seasons of the study. Sowing sorghum in alternate holes with either of the two legumes (PS2, CS2) tended to increase final seed yield but the increase was not significant. The same finding was reported by Baker (1979), who showed that there was no significant increase in sorghum yield in mixture with legumes as compared to sole crop. Also, similar results were reported by Bandyopadyay and De (1986).

Table (9): Grain yield / feddan (artaba) of sorghum plant as affected by plant distribution and different intercropping patterns with soybean during 2018 and 2019 seasons.

First season (2018)								Second season (2019)							
Spacing between hills	Number of plant /hill	Intercropping pattern					M	Spacing between hills	Number of plant /hill	Intercropping pattern					M
		1	2	3	4	5				1	2	3	4	5	
15 cm	1 plant/ hill	3.30	3.49	3.43	5.43	7.76	4.68	15 cm	1 plant/ hill	2.81	3.98	2.98	4.84	8.02	4.53
	2 plant/ hill	5.29	6.05	6.00	9.81	11.05	7.64		2 plant/ hill	4.69	5.09	5.78	8.34	12.35	7.25
M		4.30	4.80	4.70	7.60	9.40	6.16	M		3.80	4.50	4.40	6.60	10.20	5.90
20 cm	1 plant/ hill	3.84	3.43	2.91	4.12	6.08	4.07	20 cm	1 plant/ hill	3.62	2.71	2.64	3.40	6.69	3.81
	2 plant/ hill	5.38	5.37	5.41	7.05	9.88	6.62		2 plant/ hill	5.06	5.07	5.26	6.89	9.80	6.42
M		4.60	4.40	4.20	5.60	8.00	5.36	M		4.30	3.90	3.90	5.10	8.30	5.10
LSD 5%	Intercropping = 0.680							LSD 5%	Intercropping = 0.566						
	Spacing x plant/ hill = n.s								Spacing x plant/ hill = n.s						
	Spacing x intercropping =0.962								Spacing x intercropping = 0.801						
	Plant/ hill x intercropping = 0.962								Plant/ hill x intercropping = 0.801						
	Spacing x plant/ hill x intercropping = n.s								Spacing x plant/ hill x intercropping = n.s						

Intercropping pattern of sorghum- soybean: 1 = 1 side: 1 side on the same row, 2= 1 row : 1 row; 3= 3 row : 3 row;. 4= 4 row : 2 row and 5= sorghum as sole crop.

However, Salih (2002) observed increase in grain yield of sorghum when intercropped with soybean. In this respect, in maize–soybean intercropping, maize is dominant (Huxley and Maingu, 1978) and, being a plant with the C_4 carbon assimilation pathway, is usually more competitive than legumes due to rapid initial growth (Maingi *et al*., 2001). There have been several reports of experiments conducted in other locations, such as those of Yunusa *et al.* (1989), Weil and McFadden (1991) and Carruthers *et al.* (2000), who found that maize yields, were not affected by the presence of soybean.

3.3 Land equivalent ratio (LER)

It is clear from the Table (10) that the value of LER exceeds one in more than one case of intercropping patterns, and the highest value (1.41 and 1.40) resulted from the use of 3:3 row pattern of sorghum- soybean plants with two plants/ hill and the distance between hills is 15 or 20 cm, respectively. Also, there is an increase in the value of the LER (1.29 and 1.19) with the use of the 4:2 row pattern of sorghum- soybean intercropping with two plants /hill and the distance between hills is 15 or 20 cm, respectively. The result of a 1:1 row

pattern with 15 cm between hills also resulted in 1.18 and 1.05 of LER by planting two plants or one plant /hill, respectively. On the other hand, there was no point in intercropping sorghum-soybean with 1:1 side on the same row pattern as the LER value was less than one. LER greater than 1.00 has also been reported with maize-soybean (Yusuf *et al*., 2012), maize-cowpea (Dahmardeh *et al*., 2010) and maize-beans (Yilmaz *et al*., 2008).

Table (10): LER values as affected by intercropping patterns and plant distribution of sorghum: soybean in the mean of 2018 and 2019 seasons.

Spacing between hills	Number of plant /hill	Intercropping patterns			
		1:1 side/ row	1:1 row	3:3 row	4:2 row
15 cm	1 plant/ hill	0.63	1.05	0.99	0.98
	2 plant/ hill	0.77	1.18	1.41	1.29
20 cm	1 plant/ hill	0.82	0.92	0.89	0.81
	2 plant/ hill	0.77	0.97	1.40	1.19

Also, the higher productivity of the sorghum- soybean intercropping compared to the sole crop may have resulted from complementary and efficient use of growth resources by the component crops (Li *et al*., 2006). On the other hand, the lower LER observed in the other patterns of intercropping can be explained by the findings of Ofori and Stern (1987) who reported that light is the most important factor determining LER of maize and soybean intercropping and LER declines when legume becomes severely shaded as shown by Light measurements.

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