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Assessment of Groundnut and Sorghum Intercropping

Nagla, N. Suleman[1], Ahmed M. El Naim[1] & Khalid A. Ibrahim[2]

[1] Department of Crop science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Elobeid, Sudan

[2] Prince Sultan bin Abdul Aziz Center for Research & Environmental Studies & Tourism, King, Khalid University, ABHA, Kingdom of Saudi Arabia

Correspondence: Ahmed M. El Naim, Department of Crop science, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Elobeid, Sudan.

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Abstract

Intercropping approach is to maximizing the use of limited farm lands as well as attaining food security to the subsistence farmers. A field experiment was conducted during two consecutive rainy seasons (2013/14 and 2014/2015) at Sheikan Locality, North Kordofan State, Sudan to investigate the effects of intercropping groundnut with two varieties of sorghum on land use efficiency. The experiment consisted of eleven treatments: three sole crop of groundnut, a local sorghum variety (Zinari) and an improved sorghum variety (Butana) and eight spatial arrangements of 1:1, 1:2, 2:1 and 2:2 rows of groundnut with each of the local or improved sorghum varieties. Treatments were arranged in a randomized complete block design with four replications. Land equivalent ratio (LER), competitive indices and economic analysis were used to evaluate the productivity. The results revealed that the intercropping affected most of the characteristics studied. The results revealed that all competitive ratios (CRs) were less than 1 in all intercropping treatments in both seasons indicating that, all intercropping patterns were advantageous over sole cropping The arrangement of GSV1 2:2 (two groundnut rows alternating with two rows of sorghum var. Butana rows) was the best pattern in terms of land use efficiency, with LERs of 1.46 and highest cash returns (6345.3 SDG). The study concluded that, the arrangement of GSV1 2:2 is the best combination for maximum use of land.

Keywords: competitive ratios, LER, crop net benefit, cropping system

1. Introduction

The increasing global demands for food production, and the need to conserve the natural resources, diversification of planting system is necessary (Banik & Sharma, 2009). Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of humanity, and is in balance with the environment (Gruhn et al., 2000). Intercropping is a cropping system which integrates crop production with soil conservation. Intercropping, the cultivation of two or more crops at the same time in the same field, is a common practice, especially in the tropics and in the developing countries. Benefits of intercropping may be briefed as: better use of resources, improvement of soil fertility by legume components of the system, soil preservation through covering the bare land between the rows, reduction of biotic and abiotic risks by increasing diversity and suppression of weed infestation (Emam, 2003). In the tropical and sub-tropical region, cereal - legumes intercropping is the most popular practice because of its many additional advantages (Willey, 1979). When legumes are used as intercrops, they provide the beneficial effect on soil fertility by fixing atmospheric nitrogen. In Sudan, intercropping of cereals with legumes is 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. Baker (1978) observed that in the tropics, cereals are commonly intercropped with legumes, in the hope that the former will benefit from the

N-fixed by the latter. Other benefits include maximum resource utilization and income stability (Abalu, 1976) and higher total returns (Elemo et al., 1990). It increases total productivity per unit area through maximum utilization of land, labor and growth resources. Sorghum (Sorghum bicolor (L) monech) is main food crop in Sudan (main staple crop) and the fifth most important crop in many parts of the world grown for food, feed and industrial purposes (El Naim *et al*. 2018). It is also a major crop in many parts of Africa, Central America and some Asian countries (Yalew, 2010). Sorghum is a warm season crop growing well in tropical and subtropical climates. In the Sudan, sorghum is the main staple food crop and comprised 80% by weight of the cereal crops and is grown extensively under irrigated and dry land conditions. Thus, sorghum frequently experiences drought stress during vegetative and reproductive growth (Mohammed et al., 2010). Grain sorghum is the main staple food crop of a large section of population in Africa and India. Sorghum crop adapted to drought areas is a crop of hot, semi-arid tropical environment with 400- 600 mm rain fall areas. The crop thrives well in the temperature range of 16-40 C. Its performance is good with a mean temperature of 27 C (ICRISAT, 1986). Sorghum can be cultivated successfully on nearly all soils, but fertile loamy soils are considered to be the best (EARS, 1999). In Sudan the flour from the grain can be used to make “kisra”, porridge, “gruel” local beer and snack meals like “Balleela” (Awad, 2000). Groundnut or peanut (Arachis hypogaea L.) is grown over 20 million hectares in the tropical and sub-tropical parts of about one hundred countries in the world. The total annual world production amounts to about 25 million tons of unshelled nuts, 70% of which is contributed by India, China and U.S.A. (Khidir, 1997 and El Naim et al, 2011). Groundnut is an excellent source of plant nutrients contains 45-50% oil, 27-33% protein as well as essential minerals and vitamins. They play an important role in the dietary requirements of resource poor women and children and the haulm are used as livestock feed. Groundnut oil is composed of mixed glycerides and contains a high proportion of unsaturated fatty acids, in particular, oleic (50-65%) and linoleic (18-30%), (Young, 1996). Groundnuts are also important in the confectionary trade and the stable oil is preferred by the deep-frying industries, since it has a smoke point of 229.4 ºC compared to the 193.5 ºC of extra virgin olive oil. The oil is also used to make margarines and mayonnaise. Sudan is one of the major groundnut producing countries (El Naim & Eldouma, 2011). Sorghum and groundnut are main crops in North Kordofan State. Beside its use as energy source to human consumption, sorghum draws its great value as source of grain and straw used for animal feed (Suleman et al., 2018). Unfortunately, no proper recommended technologies were undertaken by farmers to get rid of problems that face sorghum and groundnut production in North kordofan 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 mixed cropping. Therefore, this system is considered to help farmers utilize their limited resources (natural and labor resources) for attaining yield stability, obtaining higher yields per unit area, and have better control of weeds, pests, and diseases. In addition, it provides safe guard against familiar practice of the single crop. The intercropping of cereal and legumes is preferred by smallholding farmers due to the ability of the legume to cope with soil erosion and increasing levels of soil fertility. Therefore, the main objectives of this research is to study the effects of different intercropping arrangements on groundnut and sorghum yield and to find the land use advantage and monetary returns compared to mono-cropping.

2. Materials and Methods

2.1 Site of the Experiment

An experiment was conducted under rain fed condition for two consecutive seasons (2013/14 - 2014/15), in Sheikan Locality, North Kordofan State, to evaluate the growth, yield and profitability of groundnut and two sorghum varieties intercropped at different spatial arrangements. The locality latitude (11˚ 15 and 16˚ 30 N) and longitude (27˚ and 32˚ E). The soil is sandy with low fertility. Annual rainfall average ranges between 350-500mm. Average maximum daily temperatures varied between 30 ºC to 35 ºC most of the year (Technoserve, 1987).

2.2 Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with four replicates. The plot size was 4x4 meters. The experiment consisted of eleven treatments comprising groundnut (variety Gubesh), two varieties of sorghum, Zinari (local) and Butana (improved) grown in pure stands and in different spatial arrangements. The eleven treatments tested were:

(1) Sole sorghum var. Zinari.

(2) Sole sorghum var. Butana.

(3) Sole groundnut.

(4) 1:1 one row of groundnut alternating with one row of sorghum var. Zinari.

(5) 1:1one row of groundnut alternating with one row of sorghum var. Butana.

(6) 1:2 one row of groundnut alternating with two rows of sorghum var. Zinari.

(7) 1:2 one row of groundnut alternating with two rows of sorghum var. Butana.

(8) 2:1 two rows of groundnut alternating with one row of sorghum var. Zinari.

(9) 2:1 two rows of groundnut alternating with one row of sorghum var. Butana.

(10) 2:2 two rows of groundnut alternating with two rows of sorghum var. Zinari.

(11) 2:2 two rows of groundnut alternating with two rows of sorghum var. Butana.

The seeds of the crops were obtained form the Arab Sudanese Seeds Company, Elobeid Seeds station.

2.3 Sowing

Before sowing, seeds were treated with Theram at 3 g/kg seed to protect seeds against termites and insects. Sowing dates were 28th of July for the first season and July, 15th for the second season.

Seeds were sown on rows 50 cm apart, with four seeds were placed in each hole for sorghum varieties and three seeds per hole for groundnut crop, which were then thinned to one plants per whole, two weeks later for each crop. The first weeding was after two weeks from sowing and the second weeding was after 30 days.

2.4 Characters Studied

The following parameters were studied:

2.4.1 Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) was used to evaluate the productivity of mixed cropping systems. LER is a measure of the extent to which the intercropping gives a higher return to land area than the pure stand. It is calculated using the formula:

An LER value of less than one, equal to one or greater than one indicates a yield disadvantage, no difference or a yield advantage for intercropping, respectively.

2.4.2 Competitive Indices

Two measures of competitiveness of crops in intercropping, namely, competitive ratio (CR) and the relative crowding coefficient (RCC) were calculated as follows:

(i) Competitive Ratio, CR

$CRa = Yab \times Zba/[Yaa - Yab] \times Zab$

$CRb = Yba \times Zab/[Ybb - Yba] \times Zba$

Where:

‘a’ refers to sorghum and ‘b’ refers to groundnut.

Yab is the yield/unit area of crop ‘a’ intercropped with crop ‘b’ (expressed for the area occupied by both crops)

Yaa is the yield /unit area of crop ‘a’, Yba is the yield / unit area of crop ‘b’ intercropped with ‘a’ (expressed for the area occupied by both crops)

Zab is the proportion of intercropped area initially allotted to crop ‘a’

Zba is the proportion of intercropped area initially allotted to crop ‘b’

CRa is the competitive ratio of ‘a’ species, and

CRb is the competitive ratio of ‘b’ species.

(ii) Relative Crowding Coefficient, RCC

$RCCab = Yab/Yaa - Yab \times Zba/Zab$

$RCCba = Yba / Ybb - Yba \times Zab / Zba$

Where:

‘a’ refers to sorghum and ‘b’ refers to groundnut

RCCab is the relative crowding coefficient of crop ‘a’ intercropped with crop ‘b’, and

RCCba is the relative crowding coefficient of crop ‘b’ intercropped with crop ‘a’.

2.4.3 Economic Analysis

To determine the most profitable groundnut-sorghum intercropping pattern, economic analysis was done through partial budgeting to assess and compare the economic returns and net benefits of the sole and various intercropping systems. The steps were as follows:

The average yields across the sites for both crops and each treatment were calculated.

Gross field benefits for both crops in each treatment were calculated by multiplying the field price of the unit of the crop Sudanese Pound (SDG/kg) by the average yields obtained (kg/ha).

Net benefit was obtained by subtracting the total production cost from the gross field benefits.

The field price of the crop was taken from the market, where the majority of the farmers sell their crops.

Total production costs is the sum of all the costs that vary including labour and input cost and were taken from the Arab Sudanese Seed Company, Elobeid Seed Station in 2014. These indicated that production costs for groundnut and sorghum were 1047.6 and 1273.8 SDG/ha, respectively.

2.5 Statistical Analyses

The collected data were analyzed for the estimation of the statistical parameters according to Sigma Stat. For comparison between means, they were separated using Duncan Multiple Range Test (DMRT), at 0.05 level of significance, according to the procedure designed by Gomez and Gomez (1984).

3. Results and Discussion

3.1 Land Equivalent Ratio (LER)

The reason that LER in most treatments was more than one is perhaps because of fixing and absorbing nitrogen in intercropping sorghum and groundnut. Koocheki et al, (2009) found similar results in intercropping corn and beans, which is consistent with the results of the present work. Also, in intercropping of wheat and lentil, the maximum LER (1.52) was achieved in lentil and 40% wheat as mixed cropping system Akter (2004).

3.2 Competitive Indices

The competitive ratio of sorghum <1 indicated that there was less competition between sorghum and groundnut. All competitive ratios (CRs) were less than 1 in all intercropping treatments in both seasons. This index measures the existence of a yield advantage, such that if the competitive ratio is less than 1, then there is an advantage in intercropping (Willey and Reddy, 1981). Thus, in this study, all intercropping patterns were advantageous over sole cropping

The relative crowding coefficient of groundnut intercropped with improved sorghum cultivar at 2:2 arrangements (two rows of groundnut alternating with two rows of sorghum) had higher value and was >1. This indicated yield advantage. The RCCs for sorghum (RCCab) were consistently higher than those for groundnut (RCCba) in intercropping of both seasons. This indicated a generally more competitive ability of the cereal over legume component. The RCCs above unity mean that by introducing groundnut into sorghum fields, groundnut will not have a negative effect on sorghum. Also an RCC less than unity means that higher yield than expected was realized

3.3 Economic Analysis

All the treatments were gave positive net revenues. However, the highest net profits were recorded when planting two rows of groundnut alternating with two rows of sorghum var. Butana (2:2). The arrangements of 1:1 (one row of groundnut alternating with one row of sorghum var. Butana) in the first season had the second highest net profit, while the sole groundnut gave the second net profit in the second season. Generally, intercropping of groundnut with improved sorghum variety was more profitable than intercropping groundnut with local sorghum variety.

Table 1. Effect of intercropping on land equivalent ratio (LER) of groundnut and two sorghum varieties grown during (2013/14 - 2014/15) seasons.

Treatment	Season (2013/14)	Season (2014/15)
G:SV_1 (1:1)	1.32	1.13
G:SV_2 (1:1)	1.21	1.20
G:SV_1 (1:2)	1.03	1.00
G:SV_2 (1:2)	1.03	1.00
G:SV_1 (2:1)	1.01	1.01
G:SV_2 (2:1)	1.02	1.03
G:SV_1 (2:2)	1.46	1.24
G:SV_2 (2:2)	1.27	1.20

G= Groundnut, SV_1= Sorghum Variety Butana, SV_2= Sorghum Variety Zinari

Table 2. Competitive ratio (CR) and yield (Y) relative crowding coefficient (RCC) of groundnut and two sorghum varieties intercropped at different spatial arrangements (2013/14).

Treatments	Ya	Yb	CRa	CRb	RCCab	RCCba
GSV_1 1:1	0.764	0.607	-0.02	0.02	1.8	***2.09***
GSV_2 1:1	0.798	0.424	***0.13***	***-0.13***	***2.9***	***0.89***
GSV_1 1:2	0.702	0.395	***0.24***	***-0.24***	***0.47***	***1.6***
GSV_2 1:2	0.668	0.364	***0.28***	***-0.28***	***0.81***	***1.38***
GSV_1 2:1	0.482	0.546	***-0.28***	***0.28***	***1.73***	***0.77***
GSV_2 2:1	0.450	0.536	***-0.26***	***0.26***	***1.47***	***0.73***
GSV_1 2:2	0.738	0.756	***-0.11***	***0.11***	***1.60***	***5.32***
GSV_2 2:2	0.706	0.551	***0.02***	***-0.02***	***2.09***	***1.59***

G = Groundnut, SV1 = Sorghum (Butana), SV2 = Sorghum (Zinarri).

Ya=Sorghum yield, Yb=Groundnut yield. CRa= Competitive ratio of sorghum.

CRb= Competitive ratio of groundnut.

RCCab= relative crowding coefficient of sorghum.

RCCba= relative crowding coefficient of groundnut.

Table 3. Competitive ratio (CR) and yield (Y) relative crowding coefficient (RCC) of groundnut and two sorghum varieties intercropped at different spatial arrangements (2014/15).

Treatments	Ya	Yb	CRa	CRb	RCCab	RCCba
GSV_1 1:1	0.515	0.537	0.1	0.1	***0.27***	1.37
GSV_2 1:1	0.538	0.464	***0.02***	***-0.02***	***1.67***	***1.38***
GSV_1 1:2	0.475	0.450	***0.1***	***-0.1***	***0.4***	***2.62***
GSV_2 1:2	0.450	0.389	***0.19***	***-0.19***	***0.54***	***1.93***
GSV_1 2:1	0.392	0.524	-0.32	0.32	***1.19***	***0.94***
GSV_2 2:1	0.366	0.492	-0.27	0.27	***1.50***	***0.79***
GSV_1 2:2	0.464	0.623	-0.17	0.17	***0.78***	***3.53***
GSV_2 2:2	0.518	0.534	***0.1***	***0.1-***	***1.51***	***2.01***

Table 4. Partial budgeting for groundnut and two sorghum varieties intercropped at different spatial arrangements during season 2013/2014.

Treatment	Yield (ton/ha)		Gross (SDG/ha)		Total gross (SDG/ha)	Prod. cost (SDG/ha)	Net benefit (SDG/ha)
	Groundnut	Sorghum	Groundnut	Sorghum	-	-	-
Sole Groundnut	0.898		6286		6286	1047.6	5238.4
Sole Improved sorghum	_	1.200	_	3600	3600	1273.8	2326.2
Sole local sorghum	_	1.073	_	3219	3219	1273.8	1945.2
1:1 improved	0.607	0.764	4249	2292	6541	1160.7	5380.3
1:1 local	0.424	0.798	2968	2394	5362	1160.7	4201.3
1:2 improved	0.395	0.702	2765	2106	4871	1189.4	3672.6
1:2 local	0.364	0.668	2548	2004	4552	1189.4	3353.6
2:1 improved	0.546	0.482	3822	1446	5268	1123.0	4145.0

2:1 local	0.536	0.450	3752	1350	5102	1123.0	3979.0
2:2 improved	0.756	0.738	5292	2214	7506	1160.7	6345.3
2:2 local	0.551	0.706	3857	2118	5975	1160.7	4814.3
C.V%	13.23	14.09					
SE±	1.1452	2.1727					

Prices/kg of groundnut and sorghum are 7 and 3 SDG, respectively

Table 5. Partial budgeting for groundnut and two sorghum varieties intercropped at different spatial arrangements during season 2014/15.

Treatment	Yield (ton/ha)		Gross (SDG/ha)		Total gross (SDG/ha)	Prod. cost (SDG/ha)	Net benefit (SDG/ha)
	Groundnut	Sorghum	Groundnut	Sorghum			
Sole Groundnut	0.800	_	5600	-	5600	1047.6	4552.4
Sole sorghum (Improved)	_	1.060	-	3180	3180	1273.8	1906.2
Sole sorghum (local)	_	0.860	3759	2580	2580	1273.8	1306.2
1:1 improved	0.537	0.515	3248	1545	5304	1160.7	4143.3
1:1 local	0.464	0.538	3150	1614	4862	1160.7	3701.3
1:2 improved	0.450	0.475	2723	1425	4575	1198.4	3376.6
1:2 local	0.389	0.450	2668	1350	4073	1198.4	2874.6
2:1 improved	0.524	0.392	3444	1176	4844	1123.0	3721.0
2:1 local	0.492	0.366	4361	1098	4542	1123.0	3419.0
2:2 improved	0.623	0.464	3738	1392	5753	1160.7	4592.3
2:2 local	0.534	0.518		1554	5292	1160.7	4131.3
C.V%	7.9	5.9					
SE±	0.65	0.70					

Prices/kg of groundnut and sorghum are 7 and 3 SDG, respectively

4. Conclusion

For a farmer interested in getting maximum yield from sorghum in North Kordofan of Sudan, the crop pattern GSV_1 1:1 (one groundnut row alternating with one row of sorghum *var*. Butana) would be the best to use. If groundnut is the chosen crop, GSV_1 2:2 (two groundnut rows and two sorghum rows *var*. Butana) arrangement would be ideal. Where there is no crop bias and the preference is to maximize land use and/or to obtain maximum income, GSV_1 2:2 (two groundnut rows and two sorghum rows *var.* Butana) is the best mixture. The intra row spacing level was used for the different patterns of this study. An expanded study with different inter and intra-row spacing is proposed to determine whether there are greater benefits or yield increases at other levels than those observed this study.

Author Contributions

This research was undertaken by the collaborating authors. Authors Nagla, El Naim designed the study, wrote the protocol, interpreted the data and anchored the field study, gathered the initial data and performed preliminary data analysis. Both authors managed the literature searches and produced the initial draft. Both authors read and approved the final manuscript.

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