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Competitive indices assessment of different intercropping patterns of soybean with sorghum

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Abstract
Two field experiments were conducted at the Agricultural Research Station Experimental Farm in Shandaweel, Sohag Governorate, Egypt, during 2021 and 2022 seasons to evaluate the competitive indices of different intercropping patterns of soybean and sorghum. The experiment was set up in a randomized block design with three replicates. Field experiment, consisted of three intercropping patterns (ridge ratio) *viz.* 2:2, 3:3 and 4:2 of sorghum and soybean. The obtained results showed that: the highest sorghum yield was recorded in 4:2 ridge ratio. The highest soybean yield was recorded in 3:3 ridge ratio. Intercropping pattern 4:2 gave the highest land equivalent ratio (1.20 and 1.22) in 1st and 2nd years, respectively. A similar trend to that of the land equivalent ratio (LER) was observed for land equivalent coefficient (LEC), land saved (LS%), area time equivalent ratio (ATER), and land utilization efficiency (LUE%). The data of aggressivity (A) showed that sorghum was the dominant (A positive), whereas soybean was dominated (A negative). The competition ratio (CR) of sorghum was greater than one but less than 1 for the competition ratio of soybean. The highest values of monetary advantage index (MAI) (5721.21 LE/fed) in the second season were observed when intercropping soybean with sorghum at 4:2 pattern, while the lowest value was observed (1878.29 LE/fed) in the first season at 2:2 pattern. The highest benefit-cost ratio (1.50) was recorded under 3:3 pattern. The pattern 4:2 produced the highest gross and net return on average of the two years (30056 and 17906 LE fed^{-1}), respectively. Sole culture of sorghum and soybean yield produced less gross and net return compared to intercropping patterns (2:2, 3:3 and 4:2). It could be concluded that the highest intercropping pattern of sorghum with soybean 4:2 is suitable in terms of productivity and economic.

Keywords: Land equivalent ratio, area time equivalent ratio, land utilization efficiency, monetary advantage index, net return and benefit-cost ratio

Introduction
The best way to boost productivity per unit area of land is crop intensification (Bekele *et al.*, 2016) [6]. Intercropping legumes with cereal crops during the summer season is a common practice in Egypt. Productivity and resource use per unit of land are maximized by intercropping systems (Hamd-Alla *et al.,* 2014) [14]. With declining land units and low soil fertility, intercropping soybean with sorghum production is a practical way to boost productivity and provide protein (Umata *et al.*, 2024) [33]. Hussein *et al.,* (2023) [17] showed that the maximum sorghum and soybean yields and its component, land equivalent ratio (LER) and monetary advantage index were obtained from intercropping system 2 sorghum: 2 soybean compare with 1 sorghum: 1 soybean. and 2 sorghums: 1 soybean. Musa *et al.,* (2021) [24] Found that intercropping soybean with sorghum 4:2 row intercropping gave the highest values of grain weight/plot and grain yield fed^{-1} compared to the other treatments (3:3 and 1:1). Intercropping sorghum with soybean improves soil fertility, weed control, water use, biotic and abiotic stressors, land availability, low economic activity, and food security (Hossain *et al.*, 2020) [16]. More light intensities (up to 10,000 foot-candles/m^2) are used by maize C4 crops than by calven cycle plants C3 crops like cowpea, which may help to maximize the benefits of land per unit area. Additionally, C3 plants produce a lot of CO_2, which is necessary for C4 maize plants to grow a lot of gross photosynthesis (Hamd-Alla 2015) [13]. All of the studied soybean did not influence corn plants because corn, a C4 plant, has a larger capacity for photosynthetic pathways, which is crucial for certain corn traits to be effectively grown throughout growth and development [Regehr *et al.,* 2015; Abdel-Wahab, and Abdel-Wahab 2020] [26, 2].

The major objective of intercropping is to stabilize the field crop production, maximize the use of natural resources, and provide a higher yield (Kadam *et al.*, 2018) [18]. In Egypt, grain sorghum (*Sorghum bicolor* L.) is a cereal crop that is widely grown on an area of around 150,000 hectares. The Food and Agriculture Organization (FAO 2023) [10] reports that this yields an estimated 780,000 tons. Soybean (*Glycine max* L.) is a significant leguminous crop due to its high nutritional content. Given that it is a summer crop, soybean may face competition from other summer crops for the small amount of arable land, so intercropping soybean with summer crops is one solution to increase oilseed production and reduce the food gap resulting from continuous population growth in Egypt. This research aimed to evaluate the competitive indices of different intercropping patterns of soybean with sorghum.

Materials and Methods

Description of the studied area

The field experiment was conducted at the Agricultural Research Station Experimental Farm in Shandaweel, Sohag Governorate, Egypt (latitude of 26.33° N and longitude of 31.41° E) during 2021 and 2022 seasons. The soil of this experiment was clay loam, as shown in Table 1.

Table 1: Soil characteristics of the experimental field before cultivation in 2021 and 2022 seasons

Properties	2021	2022
Mechanical analysis		
Sand%	23.00%	24.40%
Silty%	39.20%	38.50%
Clay%	37.80%	37.10%
Soil texture	clay loam	clay loam
Chemical analysis		
pH	7.66	7.80
Organic matter (g/kg)	12.20	11.60
$CaCO_3$ (g/kg)	15.50	17.60
EC (dS/m^{-1})	1.03	1.21
Available N (mg/kg)	35.20	30.70
Available P (mg/kg)	14.20	11.50
Available K (mg/kg)	238.00	215.00

Experimental treatments and design

The experiment was carried out in a randomized complete block design (RCBD) with three replications.

The intercropping patterns were as follows

- **Sorghum-soybean 2:2:** Two sorghum ridges alternating with another two of soybean. Sorghum was grown in one ridge (60 cm width) with leaving two plant/hill spaced at 20 cm. Soybean seeds were drilled in two ridges, in two plants/hill spaced at 20 cm.
- **Sorghum-soybean 3:3:** Three sorghum ridges alternating with another three of soybean. Sorghum was grown in one ridge (60 cm width) with leaving two plant/hill spaced at 20 cm. Soybean seeds were drilled in two ridges, in two plants/hill spaced at 20 cm
- **Sorghum-soybean 4:2:** Four sorghum ridges alternating with another two of soybean. Sorghum was grown in one ridge (60 cm width) with leaving two plant/hill spaced at 20 cm. Soybean seeds were drilled in two ridges, in two plants/hill spaced at 20 cm.

Sole culture of sorghum and soybean were grown to calculate competitive indices, monetary advantage and economic evaluation. Sole sorghum was grown in one ridge (60 cm width) and thinned to two plants/hill, 20 cm apart between hills. Sole soybean seeds were drilled in two ridges, in two plants/hill spaced at 20 cm.

Sowing methods and management practices

Each plot consisted of 24 ridges (300 cm length and 60 cm width apart) the area of plot was 43.2 m^2. Seeds of sorghum cultivar Dorado and seeds of soybean cultivar Giza 111 were inoculated with *Bradyrhizobium japonicum* and gum Arabic was used as a sticking agent. Wheat crop was the previous winter crop in both seasons. Soybean seeds were sown on 17th and 18th May in 2021 and 2022 seasons, respectively, meanwhile, sorghum was sown two weeks later. Soybean plants were harvested on 18th and 21th September at 2021 and 2022, respectively. Sorghum plants were harvested on 21th and 23th September at 2021 and 2022, respectively. Sorghum was fertilized with 150 kg/fed of calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48.8% K_2O) at rate of 50 kg/fed during land preparation. Nitrogen fertilizer was added at the rate of 100 kg N/fed as (urea 46%N). Soybean was fertilized with 20 kg N/ fed. In this study, the flood irrigation system was used in the first and second seasons. Cultural management, disease, and pest control systems were implemented according to the Egyptian Ministry of Agriculture recommendations for sorghum and soybean crops.

Measurable attributes

A. Sorghum yield and its characteristics: Ten plants were randomly selected from each experimental unit, and the following traits were determined:

- Plant height (cm).
- Panicle length (cm)
- Panicle width (cm).
- 1000-grain weight (g).
- Grain yield (kg/fed) was determined on the whole plot basis then it was transferred to kg/fed (feddan = 0.420 hectares).

B. Soybean yield and its characteristics: Ten plants were randomly selected from each experimental unit, and the following traits were determined:

- Plant height (cm).
- Number of branches/plant.
- Number of pods/plant.
- 100-seed weight (g).
- Seed yield/plant (g).
- Seed yield (t/fed) was determined on the whole plot basis then it was transferred to ton/fed.

C. Competitive indices and yield advantages

1. **Land equivalent ratio (LER):** LER was determined according to Mead and Willey (1980) [20].

$$LER = LER\ (sorghum) + LER\ (soybean)$$

$$LER\ (sorghum) = \frac{grain\ yield\ of\ intercropped\ sorghum}{yield\ of\ sole\ sorghum}$$

$$LER\ (soybean) = \frac{seed\ yield\ of\ intercropped\ soybean}{seed\ yield\ of\ sole\ soybean}$$

2. **Aggressivity (A):** A was determined according to by Willey (1979) [34].

$$A\ (sorghum) = \left(\frac{Yab}{Yaa \times Zab}\right) - \left(\frac{Yba}{Ybb \times Zba}\right)$$

$$A\ (soybean) = \left(\frac{Yba}{Ybb \times Zba}\right) \times \left(\frac{Yab}{Yaa \times Zab}\right)$$

where: Zab = sown proportion of crop sorghum (in sorghum intercropping with soybean); Zba = sown proportion of crop soybean (in soybean intercropping with sorghum)

3. **Competitive ratio (CR):** CR was calculated by Willey and Rao (1980) [36]

$$CR\ (sorghum) = \left(\frac{LER\ (sorghum)}{LER\ (soybean)}\right) \times \left(\frac{ZI\ (soybean)}{ZI\ (sorghum)}\right)$$

$$CR\ (soybean) = \left(\frac{LER\ (soybean)}{LER\ (sorghum)}\right) \times \left(\frac{ZI\ (sorghum)}{ZI\ (soybean)}\right)$$

Where:
ZI (sorghum) = sown proportion of crop sorghum (in sorghum intercropping with soybean);
ZI (soybean) = sown proportion of crop soybean (in soybean intercropping with sorghum).

4. **Relative crowding coefficient (K):** K was calculated by Banik *et al.*, (2006) [4].

$$K = K\ sorghum\ \times K\ soybean$$
$$K\ sorghum = YISor\ \times ZIsoy \div (Yssor - YIsor) \times ZIsor$$
$$K\ soybean = YISoy\ \times ZIsor \div (Yssoy - YIsoy) \times ZIsoy$$

Where; K, K sorghum and K soybean are crowding coefficients of the total, sorghum and soybean respectively. ZI_{sor} and ZI_{soy} are the proportions of sorghum and soybean in the intercropping respectively and the others as described above.
When the K value = 1, K < 1 and K > 1 it refers to that there is no yield advantages, disadvantage and yield advantages in that order.

5. **Land equivalent coefficient (LEC):** LEC was calculated by Adetiloye *et al.*, (1983) [3].

$$LEC = L\ sorghum\ \times L\ soybean$$

where $L_{sorghum}$ = LER of main crop (sorghum) and $L_{soybean}$ = relative yield of intercrop (soybean).

6. **Land saved (LS%):** LS was calculated by Willey (1985) [35].

$$LS\ (\%) = \left(\frac{LER - 1}{LER}\right) \times 100$$

7. **Monetary advantage index (MAI):** MAI according to Ghosh (2004) [11].

$$MAI\ = Commercial\ value\ of\ combined\ crops \times \left(\frac{LER-1}{LER}\right)$$

8. **Area time equivalent ratio (ATER):** ATER calculated by Hiebesch and McCollum (1987) [15].

$$ATER = \frac{[(RY\ sorghum \times D\ sorghum) + (RY\ soybean\ \times D\ soybean\ )]}{D}$$

Where
$RY_{sorghum}$ = Relative yield of sorghum; $D_{sorghum}$ = sorghum duration (day).
$RY_{soybean}$ = Soybean relative yield; $D_{soybean}$ = soybean duration (day).
D = Duration of the whole intercropping systems (day).
When**:** The value of area time equivalent ratio > 1.0 means a yield advantage, value of area time equivalent ratio < 1.0 means a yield disadvantage and value of area time equivalent ratio = 1.0 means no effect of intercropping systems.

9. **Land Utilization Efficiency (LUE%):** LUE was determined by Mason *et al.*, (1986) [19].

$$LUE\% = \frac{LER + ATER}{2} \times 100$$

D. Economic evaluation
The prices of grain yield sorghum 9.7 LE/kg and seed yield soybean 21954 LE/ton (Bulletin, 2022) [7]. To calculate the gross returns = price of sorghum yield + price of soybean yield. Net return was calculated by subtracting the total cost of cultivation from gross return. Benefit-cost ratio is a standard that calculates the ratio of benefits to costs. The BCR is an indicator of profitability expressed in monetary terms relative to its costs. B:C ratio = Net return/Cost of cultivation.

Statistical analysis
Data were analyzed by SAS program version 9.2 (2009) [29] software package according by Gomez and Gomez (1984) [12]. Means were compared by Least Significant Difference (LSD) at 5% level of significant **(**Snedecor and Cochran 1980**)** [32]**.**

Results and Discussion
A. Sorghum
Effect of intercropping patterns on yield and its attributes of sorghum
Data presented in Table 2 reveal that intercropping patterns had a significant ($p < 0.05$) effect on all studied traits in the first and second seasons. The height of sorghum plant under intercropping pattern 4:2 was more than the patterns 3:3 and 2:2 in the first and second seasons. These results may be due to competition of associated crops for intercepted the light intensity (Said and Hamd-Alla 2018 and El-Mehy *et al.*, 2016). [27, 8]. The highest panicle length (31.33 and 32.08 cm) was recorded from the intercropping pattern 4:2 followed by the pattern 3:3 (30.74 and 31.23 cm), while the lowest panicle length (28.70 and 29.58cm) was recorded from the patterns 2:2 in the first and second seasons, respectively. The highest panicle width of sorghum (6.03 and 6.27 cm) was obtained from the intercropping pattern 4:2 in the first and second seasons, respectively. 3:3 pattern recorded the second ranked, while 2:2 pattern was the lowest values in the first and second seasons. Here, the maximum of mean values thousand grain weight of sorghum was produced from the pattern 4:2 followed by the pattern 3:3 then 2:2. Regarding the grain yield of sorghum the highest yield (1943.72 and 2080.65 kg fed^{-1}) was recorded from the pattern 4:2 followed by pattern 3:3 (1450.25 and 1567.86 kg fed^{-1}) in the first and second seasons, respectively. While the lowest grain yield (1390.18 and 1471.5 kg fed^{-1}) was recorded from pattern 2:2 in the first and second seasons, respectively. These results revealed that competition of sorghum plants in pattern 4:2 was lower than in 3:3 and 2:2 patterns because sorghum plant population density under pattern 4:2 reached 66.7

% of sole culture compared to 50% in the other pattens 3:3 and 2:2. These results are in accordance with those obtained by [Metwally *et al.*, 2009; Abdel-Galil *et al.*, 2014; El-Shamy *et al.*, 2015; El-Mehy *et al.*, 2016; Kadam *et al.*, 2018; Musa *et al.*, 2021 and Hussein *et al.*, 2023] [21, 1, 9, 8, 18, 24, 17].

Table 2: Effect of intercropping patterns on yield and its attributes of sorghum in 2021 and 2022 seasons

Intercropping patterns	Plant height (cm)	Panicle length (cm)	Panicle width (cm)	1000-grain weight (g)	Grain yield (kg/fed)
2021					
2:2	148.47	28.70	5.41	29.23	1390.18
3:3	153.50	30.74	5.72	30.17	1450.25
4:2	156.03	31.33	6.03	31.47	1943.72
LSD at 5 %	0.19	0.16	0.05	0.18	44.95
Sole	158.64	32.09	6.31	32.09	2403.11
2022					
2:2	151.47	29.58	5.80	30.37	1471.50
3:3	156.27	31.23	6.15	31.58	1567.86
4:2	161.15	32.08	6.27	33.19	2080.65
LSD at 5 %	0.18	0.10	0.12	0.17	100.45
Sole	162.69	32.81	6.76	33.85	2523.47

2:2 = alternating ridges 2 sorghum: 2 soybeans. 3:3 = alternating ridges 3 sorghum: 3 soybean and 4:2 = alternating ridges 4 sorghum: 2 soybean.

B. Soybean

Effect of intercropping patterns on yield and its attributes of soybean

The data from given Table 3 show that the intercropping patterns affected yield and its attributes significantly ($p < 0.05$) of soybean in 1st 2nd seasons. Intercropping patterns 3:3 and 2:2 had the tallest plants compared with the patten 4:2 may be due to competition of associated crops for intercepted the light intensity (Said and Hamd-Alla 2018 and El-Mehy *et al.*, 2016) [27, 8]. The maximum of mean values number of branches/plant, number of pods/plant, weight of 100 seed yield/plant and seed yield of soybean were recorded in the patten 3:3 followed by pattern 2:2. The minimum of values number of branches/plant, number of pods/plant, weight of 100 seed yield/plant and seed yield were recorded in case of 4:2. The reduction in yield and its attributes may be due to plant population density under pattern 4:2 reached 33.3 % of sole culture compared to 50% in the other pattens 3:3 and 2:2. In addition, the shading from top of sorghum plants to top of intercropped soybean which in turn decreased interception of solar radiation. Similar findings were obtained by **[**Metwally *et al.*, 2009, El-Mehy *et al.*, 2016; Said and Hamd-Alla 2018; Musa *et al.*, 2021 and Hussein *et al.*, 2023] [21, 8, 27, 24, 17]. Furthermore, severe intra- and inter-specific competition among soybean C_3 plants and sorghum C_4 plants for light, water and nutrients and soybean did not influence corn plants because corn, a C4 plant, has a larger capacity for photosynthetic pathways, which is crucial for certain corn traits to be effectively grown throughout growth and development. This is in line with the finding of [Hamd-Alla 2015; Regehr *et al.*, 2015 and Abdel-Wahab and Abdel-Wahab 2020] [13, 26, 2].

Table 3: Effect of intercropping patterns on yield and its attributes of soybean in 2021 and 2022 seasons

Intercropping patterns	Plant height (cm)	Number of branches/plant	Number of pods/plant	Weight of 100 seed (g)	Seed yield/ plant (g)	Seed yield (t/fed)
2021						
2:2	93.13	3.36	109.70	17.52	121.56	0.593
3:3	102.25	4.03	117.08	20.02	125.49	0.610
4:2	84.71	2.82	102.24	15.44	119.40	0.470
LSD at 5 %	0.50	0.07	1.81	0.47	0.68	0.03
Sole	103.25	4.11	119.55	23.16	128.42	1.19
2022						
2:2	92.40	3.33	110.38	19.12	121.93	0.621
3:3	100.62	3.82	116.46	22.99	124.21	0.634
4:2	86.46	2.93	102.97	16.24	120.18	0.502
LSD at 5 %	0.06	0.05	0.45	0.29	0.46	0.09
Sole	104.87	4.66	121.25	24.23	129.63	1.25

2:2 = alternating ridges 2 sorghum: 2 soybeans. 3:3 = alternating ridges 3 sorghum: 3 soybean and 4:2 = alternating ridges 4 sorghum: 2 soybean.

C. Competitive indices and yield advantages

Understanding the level of competition between different crop types is important. Therefore, land equivalent ratio (LER), aggressivity (A) and competition ratio (CR) relative crowding coefficient (K), land equivalent coefficient (LEC), land saved (LS%), monetary advantage index (MAI), Area time equivalent ratio (ATER) and Land utilization efficiency (LUE%) gives a better measure of competitive ability of crops and can prove a better index as compared to aggressivity.

1. **Land equivalent ratio (LER):** The results reveal that values of land equivalent ratio were greater than unit for soybean with sorghum under different intercropping patterns than grown in sole of sorghum. Sorghum was higher contributor with higher (LER sorghum) values in all intercropping patterns compared to (LER soybean) values of soybean Table 4. Intercropping pattern 4:2 gave the highest LER (1.20 and 1.22), while pattern 2:2 recorded the lowest values of LER (1.07 and 1.08) in the 1st and 2nd, respectively. This may be because decreased soybean plant density 33.3% would minimize the negative effects and allow more light penetration within sorghum plants. Intercropping patterns generally increased land equivalent ratio values and recorded yield advantages. This may be due

to decreased soybean plant density could minimize the negative effects of intraspecific competition and allowed more light penetration within soybean plants. This result confirms the findings by [Metwally *et al.*, 2009; El-Mehy *et al.*, 2016; Said and Hamd-Alla 2018; Musa *et al.*, 2021; Hussein *et al.*, 2023 and Singh *et al.*, 2024] [21, 8, 27, 24, 17, 31].

2. **Aggressivity (A):** Data indicate that in all intercropping patterns sorghum was the dominant crop, whereas soybean was the dominated one in 1st and 2nd seasons Table 4. The values of A for sorghum were positive, whereas it was negative for soybean. These results are in line with the outcomes of [El-Mehy *et al.*, 2016 and Baraki *et al.*, 2023] [8, 5].
3. **Competition ratio (CR):** Results in Tables 4 reveal that in all intercropping patterns CR sorghum was greater than one but less than 1 for CR soybean that means that competition became more severe for sorghum compared to soybean. Thus, sorghum was more yield efficient when intercropped compared to soybean. The same outcomes were reported by (El-Mehy *et al.*, 2016 and Hussein *et al.*, 2023) [8, 17].
4. **Relative crowding coefficient (K):** K is the measure of any yield benefit or disadvantage on by the intercropping pattern. The total relative crowding coefficient was greater than unity in three of the intercropping patterns Table 4. This indicating all intercropping patterns were advantageous. The highest values were recorded under 4:2 pattern (2.76 and 3.13) in 2021 and 2022 seasons, respectively. Similarly, [El-Mehy *et al.*, 2016 and Baraki *et al.*, 2023] [8, 5].
5. **Land equivalent coefficient (LEC):** was a measure of the interaction between intercropping patterns with the strength of the relationship. At least 25% must be the estimated productivity coefficient. If the land equivalent coefficient value is more than 0.25, it indicates the yield advantage. The LEC ranged from 0.29 - 0.33 (Table 4). The highest LEC (0.33) in the second season was obtained under 4:2 pattern. While, the lowest value 0.29 was obtained under 2:2 pattern in the second season. Result is in conformity with (Shehata and Hamd-Alla 2023) [30].
6. **Land saved (LS%):** In terms of the land saved, the largest is (18.34 %) obtained from pattern of 4:2 in the second season (Table 4). This means that it could cost about 0.183 fed if the sole culture system produced the same yield harvested from one fed by the intercropping system. In the other hand, the lowest LS% (6.92%) was obtained from pattern of 2:2 in the second season. This indicates that the land saved % in this study was greater than zero. All intercropping pattern has a benefit in terms of the land saved. This is in line with the finding of (Baraki *et al.*, 2023) [5].
7. **Monetary advantage index (MAI):** The most important index is the Monetary advantage index difference among the intercropping patterns. These values were positive due to intercropping sorghum with soybean under intercropping patterns (Table 4). The highest monetary advantage index value 5721.21 L. E/ fed was obtained under pattern of 4:2 in the second season. While, the lowest value 1878.29 LE/ fed was obtained under pattern of 2:2 in the first season. These results indicated that intercropping sorghum with soybean helped the yield of the two crops sorghum and soybean. Especially, when soybean intercropped with sorghum in 4:2 ridge ratio. The present findings are well in agreement with that of [Hamd Alla *et al.*, 2014; Baraki *et al.*, 2023 and Hussein *et al.*, 2023] [14, 5, 17].
8. **Area time equivalent ratio (ATER):** Land area and crop duration (time) have an impact on crop productivity. The yield advantage of intercropping over separate cropping can be more precisely evaluated using the area time equivalent ratio because it accounts for the variations in time spent by the crops that make up different intercropping systems. The highest ATER (1.12) was obtained at pattern 4:2 in the second season (Fig. 1). The lowest area time equivalent ratio (0.99) at patten 2:2 in the first season. According to these values, intercropping systems have better component crop compatibility and better utilization of resources (nutrients, light and moisture) through reduced interspecific interaction. These results agree with those obtained by [Mohammed *et al.*, 2022; Baraki *et al.*, 2023; Morsy and Abdel-Gawad 2023 and Sai and Kumari 2024) [22, 5, 23, 28].
9. **Land utilization efficiency (LUE%):** The highest land utilization efficiency (117.31%) was obtained at pattern 4:2 in the second season (Fig. 2). The lowest land utilization efficiency (103.43%) at patten 2:2 in the first season. According to these values, intercropping patterns enhancing utilizing of environmental resources (nutrients, light, water and land). This work's results are in harmony with those found by (Mohammed *et al.*, 2022) [22].

D. Economic evaluation

The economic profitability of an intercropping system is recognized as one of the most important indices to compute the advantage or disadvantage of mixed cropping in financial profitability. The data related to gross return under different intercropping patterns presented in Table 5. The result show that gross return of all intercropping patterns was found to be superior to sole cultures of sorghum or soybean. The maximum values of gross and net returns L.E. 30056 and 17906 fed^{-1} were achieved under the pattern 4:2, the lowest values of gross and net returns were L.E. 27161 and 15861 fed^{-1} recorded in 2:2 pattern. Highest benefit cost ratio (1.50 and 1.47) was recorded under 3:3 and 4:2 patterns, respectively. Similar results were found in this regard by [El-Mehy *et al.*, 2016 and Patel *et al.*, 2025] [8, 25].

Table 4: Effect of intercropping patterns on competitive indices (LER, A, CR, K, LEC, LS% and MAI) in 2021 and 2022 seasons

Intercropping pattern	LER			A		CR		K			LEC	LS%	MAI LE/fed
	LER sorghum	LER soybean	LER	A sorghum	A soybean	CR sorghum	CR soybean	K sorghum	K soybean	K			
2021													
2:2	0.58	0.50	1.07	+0.17	-0.17	1.17	0.86	1.37	0.98	1.35	0.29	6.92	1878.29
3:3	0.60	0.51	1.12	+0.18	-0.18	1.18	0.85	1.52	1.05	1.60	0.31	10.40	2938.44
4:2	0.81	0.39	1.20	+0.02	-0.02	1.01	0.99	1.06	2.61	2.76	0.32	16.93	5088.28
2022													
2:2	0.58	0.50	1.08	+0.17	-0.17	1.18	0.85	1.40	0.98	1.38	0.29	7.33	2150.21
3:3	0.62	0.50	1.13	+0.23	-0.23	1.23	0.81	1.64	1.02	1.67	0.31	11.14	3599.17
4:2	0.82	0.40	1.22	+0.02	-0.02	1.02	0.98	1.17	2.67	3.13	0.33	18.34	5721.21

2:2 = alternating ridges 2 sorghum: 2 soybeans. 3:3 = alternating ridges 3 sorghum: 3 soybean and 4:2 = alternating ridges 4 sorghum: 2 soybean.

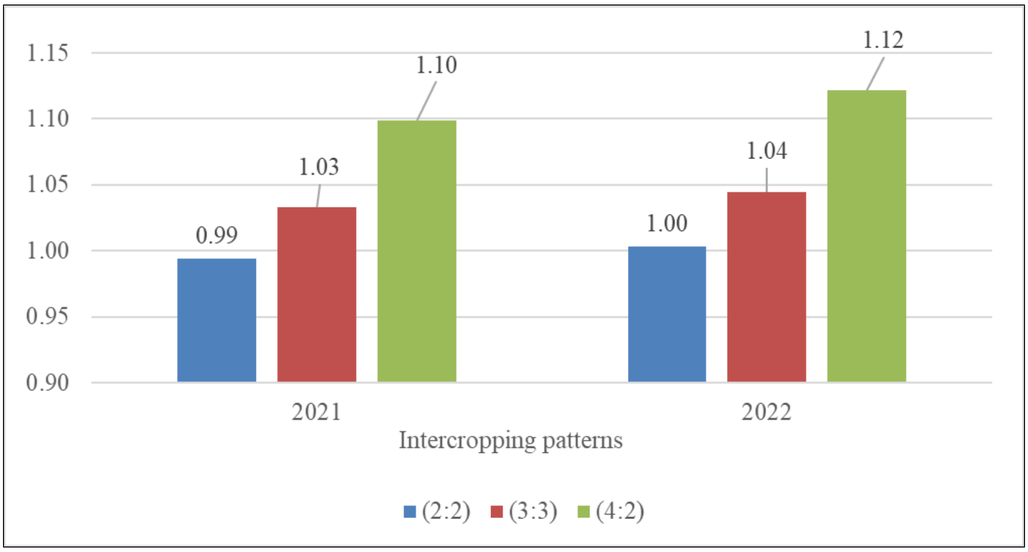

Fig 1: Area time equivalent ratio (ATER) under different intercropping patterns

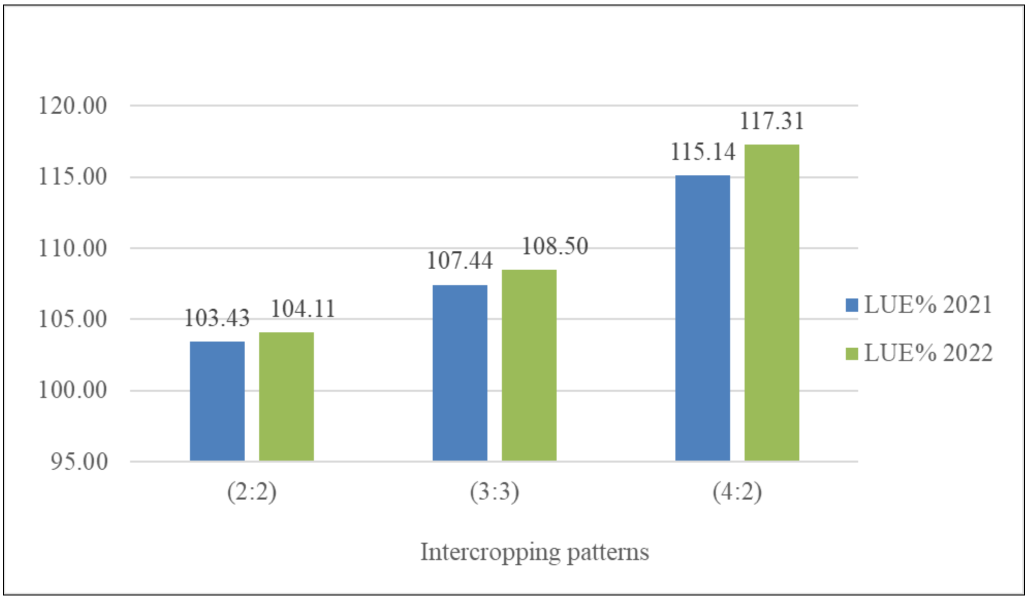

Fig 2: Land utilization efficiency (LUE%) under different intercropping patterns

Table 5: Effect of intercropping patterns on economic evaluation (Two years pooled data)

Intercropping patterns	Gross return (LE/fed)	Cost of cultivation (LE/fed)	Net return (LE/fed)	B:C ratio
2:2	27161	11300	15861	1.40
3:3	28249	11300	16949	1.50
4:2	30056	12150	17906	1.47
Sole sorghum	23894	13942	9952	0.71
Sole soybean	26784	15032	11752	0.78

2:2 = alternating ridges 2 sorghum: 2 soybeans. 3:3 = alternating ridges 3 sorghum: 3 soybean and 4:2 = alternating ridges 4 sorghum: 2 soybean.

Conclusion

Among various intercropping patterns, (4:2) four sorghum ridges alternating with another two of soybean is suitable for productivity and economic profitability.

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Conflict of Interest

All authors declare no conflict of interest in publishing this manuscript.

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