Original Research Article

Effect of intercropping fahl berseem with sugar beet under different nitrogen fertilizer levels on sugar beet productivity

ABSTRACT

A field experiment was carried out at Shandaweel Research Station, Sohag Governorate, Agricultural Research Center, Egypt during the 2020/2021 and 2021/2022 seasons to study the effect of intercropping sugar beet with fahl berseem under three different nitrogen fertilization rates on yield, its components and economic returns. The experiment was laid out in a randomized complete block design using split-plot arrangement with three replicates. Three nitrogen fertilizer levels (165, 190 and 215 kg N /ha) were assigned to the main plots. while the sub-plots were allocated to five intercropping systems 100% sugar beet + three seeding rates of fahl berseem (15, 25 and 35% of its recommended rate of 48 kg/ha), sole sugar beet and sole fahl berseem. The data showed that most of the values of sugar beet traits significantly decreased by increasing the percentage of fahl berseem seeding rates. whereas, reverse trend was found in increasing nitrogen fertilizer levels. The data also showed that all traits of fahl berseem significantly increased by increasing the percentage of fahl berseem seeding rates when intercropped with sugar beet and increasing nitrogen fertilizer level. Data also revealed that the intercropping system IS3 (100% sugar beet + 35% fahl berseem) and fertilized plants with 165 kg N/ha recorded the highest land equivalent ratio (1.30). On the other hand, the intercropping systemsIS1 (100% sugar beet + 15% fahl berseem) and fertilized plants with 165 kg N/ha recorded the lowest land equivalent ratio (1.20). Fahl berseem was the dominate crop, whereas sugar beet was the dominated. The highest gross returns (3398US$/ha) resulted from intercropping system IS3 (100% sugar beet + 35% fahl berseem) and fertilized plants with 215 Kg N/ha. Whereas, the lowest gross returns (2953US$/ha) were obtained from intercropping systems IS1 (100% sugar beet + 15% fahl berseem) with 165 kg N/ha as average in both seasons. From this study, it could be concluded that to obtain the highest gross returns preferred use intercropping system of 35% fahl berseem with 100% sugar beet and application of 215 Kg N/ha.

Keywords: *Sugar beet; Intercropping system; Nitrogen fertilization; Economic returns.*

1. INTRODUCTION

Intercropping systems have a long history and are still a common strategy in developing countries. Intercropping is the cultivation of crop plants in space, time and the combination of production inputs (water irrigation, fertilizers, pesticides, etc.) to give maximum yield under cultural conditions, specific social, political, and economic [1,2]. At present time, sugar

beet intercropping with other crops such as berseem is one of the solutions used in Egypt due to the limited irrigation water and planted area as well as the high cost of fertilizer. Therefore, intercropping sugar beet with fahl berseem is one of the most important practices to increase productivity. Broadly, Egypt surface many problems that affect crop productivity, and sugar crops especially as sugar is a national requirement. One is the intense competition between winter crops (wheat, berseem, etc.,) and sugar beet for water, land, nutrients, and light based on reduced net returns and production expenses. The need to maximize land use and raise farmers' incomes grows as a result. In order to bridge the gap between sugar production and consumption, the sugar beet crop was introduced in the early 1980s [3]. Sugar beet (Beta vulgaris L.) is the second-largest sugar crop in the world and Egypt after sugar cane. Recently, there has been a significant gap between sugar output and consumption in Egypt. Thus, increased sugar output is required to satisfy Egyptian population demand. Using an intercropping technique to boost unit area productivity is one way to increase sugar and berseem production. The C3 crop sugar beet grows slowly, especially in the first phases. It takes time for the crop canopy to grow and be able to receive at least 75% of incident solar irradiance, which encourages intercropping sugar beet with some winter crops to reduce solar energy losses and boost food production per unit area. In Egypt, the area of sugar beet is 720,000 fed (4200 m2) and its production is 14,409,160 tons. [4]. Integrate forage crops and animal production with other crops by intercropping systems can be cultivated intercropping forage crops with grain and sugar crops [5,6]. In the production of fodder, profitability is of paramount importance and intercropping grains and legumes has been shown to enhance economic returns. Sorghum-soybean intercropping systems produced 46% higher financial returns per unit area than mono-cropping [7]. Moreover, improved nutritional quality, LER, and other competitive indices [8]. [9,10]. Yield and its components decreased when wheat intercropped with fahl berseem with increasing the percentage of fahl berseem seeding rates. [11] showed that yield of sugar beet and its components were significantly increased by decreased faba bean plant densities from 37.5% to 12.5%. Further, plant height and seed yield/fed of faba bean, LER, total return/fed, and MAI were increased with the increasing plant population of faba bean from 12.5 to 25 and 37.5% of its sole cropping. The density reduction of faba bean plants in intercropping with sugar beet, leads to a decrease in the density for two crops per unit area. Reducing internal competition between the two crops led to the high efficiency of solar radiation used by sugar beet, and thus, a high conversion of light energy into chemical energy [12]. The plant density of 25% faba bean when intercropped with sugar beet decreased the negative impact on quality, yield, and its components of sugar beet, recorded the highest LER and MAI [13]. According to [14] 12.5% faba bean intercropped with 100% sugar beet produced the maximum root of sugar beet. while when intercropped 33% faba bean with 100% sugar beet recorded the highest land equivalent ratio and net revenue. Intercropping onion with sugar beet recorded the highest net returns and gross income, respectively. Intercropping soybean with sugar beet produced the maximum values of Na and α-amino-N concentrations of sugar beet (2.384 and 2.879 meq. 100 g^{-1} beets, respectively) [15]. The land equivalent ratio was more than 1 in intercropping systems and achieve high land productivity [16]. Intercropping faba bean with sugar beet is especially important to fill in the bean gap [17]. It also improves soil fertility by fixation biological nitrogen). The highest yield values and their components, LER and quality by intercropping 12.50% wheat + 100% sugar beet (7.50 kg of wheat grain in rows on the width ridge of sugar beet) and fertilizer treatment of 75% NPK + bio-fertilizer [18]. Increasing the rate of nitrogen fertilizer from 56 to 224 kg/ha led to a linear increase in root and sugar beet yields but decreased sucrose% [19]. Most of the values of sugar beet characters were significantly influenced by the different rates of nitrogen fertilizer, intercropped plants of sugar beet fertilized with 90 kg N + 30 m3 FYM/fed recorded the highest diameter length roots and followed by intercropping plants of sugar beet that fertilized with 80 kg N + 30 m3 FYM/fed, [20]. [21] found that rising increasing the nitrogen rates from 69 to 92 and 115 kg N/fed significantly increased root diameter, length and weight while it significantly reducing sucrose percentage. [22] showed that the level of nitrogen fertilization increased up to 92 kg/fed leading to a significant increase in root, sugar yields and root fresh weight but decreased sucrose percentage. Increasing the nitrogen rates up to 140 kg N/fed resulted in a significant increase in root length and diameter as well as top and root yield [23]. Increase of 350 kg N/ha were significantly root length and diameter, root and top fresh weights, and root yield, compared to 200 kg N/ha [24]. Sugar beet plants fertilized with high nitrogen fertilizer levels recorded a maximum of root and sugar yield [25]. [26] reported that root diameter and length, fresh weights plant-1 and yields increased with the increasing nitrogen rate. The aim of this study is to obtain the maximum productivities of sugar beet and fahl berseem by using the optimum fahl berseem seed rate and N fertilizer level.

Comment [DAL1]: Very long Introduction, please give an essential information!!!

2. MATERIAL AND METHODS

A field experiment was carried out in Shandaweel Research Station, Sohag Governorate (Upper Egypt) (latitude of 26.33° N and longitude of 31.41° E), during 2020/2021 and 2021/2022 seasons. A split-plot design with three replicates was used. The main plots were assigned three nitrogen fertilizer rates. the sub-plots were allocated to five intercropping system.

The treatments were as follows:

A- Nitrogen fertilizer levels N. (Main plots):

N1- 165 kg N/ha. N2- 190 kg N/ha. N3- 215 kg N/ha.

B- Intercropping systems IS. (Sub-plots):

IS1: 100% sugar beet + 15% fahl berseem seeds (7 kg/ha). Sugar beet seeds were sown on both sides of all raised beds (120 cm width) by growing one plant/hill at 20 cm between hills. One row of fahl berseem was sown in the middle of all beds.

IS2: 100% sugar beet + 25% fahl berseem seeds (12 kg/ha). With the same method as described at (IS1).

IS3: 100% sugar beet + 35% fahl berseem seeds (16.5 kg/ha). With the same method as described at (IS1) and (IS2).

IS4: Sole sugar beet seeds were sown on one side of the ridges (60 cm width) by growing one plant/hill at 20 cm between hills. (100% sugar beet) as recommended.

IS5: Sole fahl berseem was sown at a rate of 48 kg /ha, was grown in flat experimental plots (100% fahl berseem) as recommended.

Sugar beet *(Beta valgaris L.)* cv. Montebeancomultigerm cultivar. Fahl berseem (*Trifolium alexandrinum L*.) cv. Giza1. Each sub-plot 12.6 m2 consisted of three beds, 3.5 m length and 120 cm apart. Sugar beet and fahl berseem were planted on October 15th and 17th in 2020 and 2021seasons, respectively. The preceding summer crop in the two seasons was sorghum. Superphosphate (15.5% P_2O_5) at a rate of 480 Kg/ha and potassium sulphate (48% K_2O) at a rate of 58 kg/ha were applied during seedbed preparation. Nitrogen fertilizer levels were applied as ammonium nitrate (33.5% N) in two equal doses. The first dose and the second doses were added just before the first and second irrigation. The soil of such experiment was clay loam as presented in Table 1.

Comment [DAL2]: Where did you inspire? In the literature? Please indicate an author!!!

Table 1. Some physical and chemical properties of experimental site during the two seasons.

Mechanical analysis		Chemical analysis	
Sand %	24.0	HCO3-	0.26
Silt %	38.2	Cl-	0.28
Clay %	37.8	SO42-	0.65
Soil type	Clay loam	pH, 1:1	7.9
Soluble ions, meq l-1		EC, dSm-1	0.9
Mg2+	0.36	Available N, (mg kg-1)	17.5
Ca2+	0.55	Available P, (mg kg-1)	10
Na+	0.23	Available K, (mg kg-1)	178
K+	0.12	Organic matter (O.M, %)	1.22

Beet was harvested on April 15th in 2020/2021 and 2021/2022 seasons, respectively. Fahl berseem plants were hand clipped at 90 days after sowing. Other cultural managements for sugar beet and fahl berseem crops were applied as recommended for the two crops.

At harvest, a sample of ten plants were taken randomly, from the sole and intercropped plots of sugar beet.
The following data were recorded:

I-Sugar beet characters:

1. Root length (cm).
2. Root diameter (cm).
3. Root weight (gm).
4. Root yield (ton/ha), which were determined on sub-plot weight (kg) and converted to tons/ha.
5. Top-fresh weight(ton/ha), which were determined on sub-plot weight (kg) and converted to tons/ha.
6. Sugar yield (ton/ha) was calculated according to the following equation:
7. Sugar yield (ton/ha) = root yield (ton/ha) x extracted sugar%

Quality characteristics

1. Sucrose% was estimated using “Saccharometer” according to the method described by [27].
2. Extracted sugar% (ES%) was calculated using the following equation of [28]:

$$ES\% = (\text{sucrose\%} - SLM\%) - 0.6$$

(SLM) sugar lost to molasses% = 0.14 (Na + K) + 0.25 (α–amino N) + 0.5

3. Quality index (QI) was calculated according to [29] equation:

$$QI = (\text{extracted sugar\%} \times 100) / \text{sucrose\%}$$

4. Potassium “K”, sodium “Na” and α-amino N concentrations (meq/100 g beet) in roots were estimated as shown by [29].

II- Fahl berseem characters:

1. Plant height (cm)
2. Weight of 1000 seed (g)
3. Seed yield (kg/ha)

Competitive relationships and yield advantages

1- Land equivalent ratio (LER) is defined as the area ratio required under sold crop to intercropping system at the same conditions to obtain an equivalent crop [30]. The land equivalent ratio was determined according to the following formula: where Yaa= sold crop yield (a); Ybb= Sold crop yield (b); Yab= Intercropping yield of crop a and Yba= Intercropping yield of crop b.

$$LER = (\frac{Yab}{Yaa}) + (\frac{Yba}{Ybb})$$

2- Aggressivity (A)As indicated by this parameter's use in determining the competitive relationship between two crops in a mixture by [30]. The aggressivity was calculated as follows: AS= (YIS/YS x ZIS) – (YIB/YB x ZIB), and AB= (YIB/YB x ZIB) – (YIS/ YS x ZIS), where: ZIS= Sown proportion of crop sugar beet (in sugar beet intercropping with fahl berseem); ZIB= Sown proportion of crop fahl berseem (in fahl berseem intercropping with sugar beet).

3- Competitive ratio (CR)it gives a more desirable competitiveness to crops. The competitive ratio simply represents the ratio of the individual LERs of the two- component crops and considers the proportion of crops on they were initially sown as shown by [31]. The competitive ratio was calculated as follows: CRs = (LERs / LERb) (Zlb / ZIs) while CRb = (LERb / LERs) (ZIs / ZIb).

4- System productivity index (SPI) by [32]. It was calculated as follows: SPI=[(SS/LB) ×Lb +Ss, where SS and LB are the yield of sugar beet and fahl berseem in monoculture, Ss and Lb are the yield of sugar beet and fahl berseem in intercropping system.

Economic evaluation

Gross returns

Each treatments total return was calculated using (US$): 35, 13 and 3.5 US$/ton for price of sugar beet root yield, price of the top fresh and US$/kg price of fahl berseem seed yield, respectively, as an average for the two seasons presented by [33].

Statistical analysis:
Data were analyzed by [34] software package. The collected data on sugar beet and fahl berseem were subjected to proper statically analysis of split plot design. Differences between means were compared by LSD at 5% level of significant [35].

3. RESULTS AND DISCUSSION

I-Sugar beet crop:

1. 1. Effect of nitrogen fertilizer levels on yield, its components and quality characteristics of sugar beet:

Data in Table 2, revealed that N fertilizer levels had significant effects on yield and its components of sugar beet. Increasing N-levels to 190 and up to 215 kg N/ha led to a significant increase in yield and its components of sugar beet (8.5 and 11.4%) for root length, (8.6 and 13.4%) for root diameter and (18.5 and 24.3%) for root weight, (4.6 and 7.2%) for root yield and (11.3 and 11.3%) from sugar yield compared to those provided with 165 kg N/ha, in the 1stseason, corresponding to (7.2 and 12.8%) for root length, (8.9 and 14.4%) for root diameter (22.2 and 28.0%) for root weight, (5.6 and 9.1%), for root yield (8.5 and 7.1%) from sugar yield in the 2ndseason, respectively. The increase in this traits may be attributed to the role of nitrogen as an essential element in building-up plant organs and enhancing their growth. These results are in line with those mentioned by [22,23,24].

Data in Table 2, showed that increasing N-levels from 165 up to 190 kg N/ha significantly improved in sucrose%, extractable sucrose% and quality index, in sugar beet in both seasons, thereafter, it decreased in sodium and potassium contents content in molasses, in the 2nd season, and α-amino N in the 1st and 2nd seasons, recorded with raising nitrogen fertilization level to 165 and/or 190 kg N/ha, in both seasons. These results may indicate that 190 kg N/ha was the best dose recording the highest sucrose, extractable sucrose% and quality index in beet juice, as well as, low in molasses impurities, while the highest N-level may have directed beet plants for more vegetative growth rather than dry matter accumulation. These results are in line with those mentioned by [18,19,20,21,25,26].

Table 2. Effect of nitrogen fertilizer levels on some characteristics of sugar beet in 2020/2021 and 2021/2022 seasons.

Treatment	Root length (cm)		Root diameter (cm)		Root weight (kg)		Top-fresh weight (ton/ha)		Root yield (ton/ha)		Sucrose %	
	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/2 022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022
165 kg N/ha	40.10	37.88	7.07	10.49	1.03	0.99	16.18	16.69	58.63	62.20	15.51	16.44
190 kg N/ha	43.51	40.62	7.68	11.42	1.22	1.21	18.35	18.86	61.30	65.66	16.18	16.97
215 kg N/ha	44.68	42.71	8.02	12.00	1.28	1.27	19.45	20.05	62.84	67.86	15.86	16.42
LSD (0.05)	0.85	0.78	0.18	0.27	0.04	0.04	0.16	0.01	2.05	0.70	0.03	0.23

Table 2: Continued

Treatment	K		Na		α-amino-N		Extractable sucrose%		Quality		Sugar yield (ton/ha)		Sugar lost to molasses%	
	2020 / 2021	2021/ 2022	2020 / 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020 / 2021	2021 / 2022	2020 / 2021	2021 / 2022	2020 / 2021	2021/ 2022	2020/ 2021	2021 / 2022
165 kg N/ha	4.02	3.52	2.16	1.38	3.50	1.25	13.12	14.79	84.52	89.96	7.68	8.83	1.79	1.05
190 kg N/ha	4.17	3.66	1.99	1.62	2.77	1.51	13.97	15.20	86.36	89.57	8.55	9.58	1.60	1.17
215 kg N/ha	4.03	4.12	1.93	1.84	3.01	1.65	13.63	14.53	85.89	88.44	8.55	9.46	1.64	1.30
LSD (0.05)	NS	0.25	NS	0.10	0.34	0.06	0.15	0.25	0.58	0.31	0.33	0.20	0.09	0.04

2. Effect of intercropping systems on yield, its components and quality characteristics of sugar beet:

Data in Table 3 showed that all sugar beet characteristics were significantly affected by intercropping fahl berseem with sugar beet except K, α-amino-N and sugar yield in the first season and Na in the second season. Sole sugar beet surpassed the different intercropping systems in respect to most sugar beet characteristics in both seasons. This finding reflects the adverse effect for intercropping on sugar beet as the result of the competition between fahl berseem and sugar beet for growth elements, i.e., nutrients, carbon dioxide, moisture, light etc. which leads to hindered growth for sugar beet plants. Intercropping fahl berseem at a rate of 15% (IS_1) was superior to the other intercropping systems in respect to all sugar beet characteristics in both seasons. While, intercropping sugar beet with fahl berseem density of 35% recorded the lowest values of most sugar beet characters. The heights values in yield and yield components of sugar beet due to intercropping all beds with fahl berseem a rate seeds of (15%) by (4.9 and 18.6%) for root length, (11.5 and 22.0%) for root diameter, (6.9 and 22.8%) for root weight, (0.56 and 1.73 ton/ha) for top-fresh weight and (3.5 and 7.3%) for root yield, compared to used fahl berseem of seeding rate 25 and 35%, respectively, in the 1stseason, corresponding to (7.8 and 15.0%) for root length, (3.2 and 9.1%) for root diameter (19.0 and 19.0%) for root weight, (1.06 and 2.32 ton/ha) for top-fresh weight and (3.0 and 4.7%) for root yield and (2.2 and 0.75%) from sugar yield in the 2ndseason. These results may be referred to the lower competition among plants for growth factors as sun light, water and nutrients, grown under conditions of the lowest seed rate, which resulted in root longest, thickest and heaviest weight root/plant of sugar beet, compared to higher plant populations, emerged in case of using higher seed rates. The results are in conformity with those of **[9,10,14,15].**

Data in Table (3) indicate that intercropping fahl berseem on sugar beet significantly affected quality characteristics of sugar beet (sucrose%, extractable sucrose% and quality index). The best sucrose%, extractable sucrose% and quality index% of sugar beet due to intercropping all beds with fahl berseem by seeding rate of (35%) with sugar beet. Whereas, the lowest values were observed by seeding rate of (15%). The heights value of quality characters of sugar beet due to intercropping all beds with fahl berseem a seeding rate of (35%) by (8.0 and 3.5%) for sucrose, (11.9 and 4.3%) for extractable sucrose,(0.23 and 0.27 ton/ha) for sugar lost to molasses and (3.5 and 0.8 %) for quality index, compared to used fahl berseem of seeding rate 15 and 25%, respectively, in the 1st season, corresponding to (5.8 and 2.3 %) for sucrose, (7.0 and 2.5%) for extractable sucrose, (0.09 and 0.07 ton/ha) for sugar lost to molasses and (11.6 and 0.2 %) for quality index in the 2nd season. Moreover, it was found that intercropping fahl berseem with sugar beet were significantly affected root sodium content in the 1st season and potassium and α-amino N contents in the 2nd season. Planting sugar beet alone resulted in a significant decrease in sodium content in the 1st season only, while, intercropping

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fahl berseem by a rate seeds of 35% with sugar beet resulted to a decrease α-amino N contents, and a 25% decrease in potassium in molasses, in the 2nd season, without significant in these two traits between 25 and 35% intercropping system. The results are in conformity with those of **[11,12,13,16,18].**

ble 3. **Table 3. Effect of intercropping systems on some characteristics of sugar beet in 2020/2021 and 2021/2022 seasons.**

Treatment	Root length (cm)		Root diameter (cm)		Root weight (kg)		Top-fresh weight (ton/ha)		Root yield (ton/ha)		Sucrose %	
	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022
IS1	43.14	42.44	7.88	11.48	1.24	1.19	18.35	19.28	61.99	66.11	15.35	16.18
IS2	41.13	39.38	7.07	11.11	1.16	1.13	17.79	18.22	59.88	64.18	16.05	16.73
IS3	39.71	36.92	6.46	10.52	1.01	1.05	16.62	16.96	57.80	63.15	16.61	17.12
IS4	47.06	42.86	8.94	12.09	1.31	1.25	19.22	19.66	64.03	67.52	15.39	16.41
LSD (0.05)	**1.78**	**2.01**	**0.38**	**0.36**	**0.05**	**0.05**	**0.28**	**0.12**	**2.60**	**1.46**	**0.51**	**0.30**

Table 3: Continued

Treatment	K		Na		α-amino-N		Extractable sucrose%		Quality		Sugar yield (ton/ha)		Sugar lost to molasses%	
	2020 / 2021	2021/ 2022	2020/ 2021	2021 /2022	2020 / 2021	2021 /2022	2020/ 2021	2021/ 2022	2020/ 2021	2021/ 2022	2020 / 2021	2021 / 2022	2020/ 2021	2021/ 2022
IS1	4.04	3.68	2.93	1.65	3.29	1.59	12.90	14.39	83.98	88.92	8.01	9.13	1.85	1.19
IS2	4.15	3.60	2.07	1.57	2.79	1.30	13.83	15.03	86.15	89.83	8.28	9.26	1.62	1.10
IS3	3.79	3.70	1.64	1.65	3.09	1.28	14.43	15.40	86.87	89.95	8.34	9.33	1.58	1.12
IS4	4.30	4.08	1.46	1.59	3.18	1.71	13.13	14.54	85.35	88.59	8.41	9.43	1.65	1.27
LSD (0.05)	**NS**	**0.25**	**0.38**	**NS**	**NS**	**0.19**	**0.60**	**0.30**	**1.12**	**0.45**	**NS**	**0.20**	**0.12**	**0.07**

0% sugar beet + 15% fahl berseem, IS2= 100% sugar beet + 25% fahl berseem, IS3= 100% sugar beet + 35% fahl berseem, IS4= sole sugar beet and NS meaning; Not significant.

Comment [DAL4]: Must be improved!

3-Effect of interactions between nitrogen fertilizer levels and intercropping systems on yield, its components and quality characteristics of sugar beet:

The interaction between fahl berseem seed rates and N-level (Table 4), had a significant impact on root length, sucrose%, extractable sucrose% and quality index%, as well as α-amino N in molasses in the 1st and 2nd seasons, were resulted from intercropping fahl berseem by a seeds rate of 35 and/or 15% on sugar beet beds with add of nitrogen fertilization level to 215 and/or 190 kg N/ha in both seasons. Likewise, root diameter and sugar yield/fed was markedly affected by the interaction of fahl berseem seed rates and N-level in the 2nd season. While, sodium contents (Na) in molasses had significant influence in the 1st season only, were resulted from intercropping fahl berseem by a seeds rate of 35 and/or 25% on sugar beet beds with add of nitrogen fertilization level to 190 and/or 165 kg N/ha. These results confirmed results of [9,10,13,18,20].

Table 4. Effect of the interaction between N fertilizer levels and intercropping systems on some characteristics of sugar beet in 2020/2021 and 2021/2022 seasons.

Treatment	Root length (cm)			Root diameter (cm)			Top-fresh weight (ton/ha)			Sucrose%			Na		
	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha
2020/2021															
IS1	39.93	45.07	44.43	7.34	8.08	8.23	16.35	18.85	19.86	14.69	15.71	15.63	3.18	2.73	2.89
IS2	38.60	42.13	42.67	6.64	7.07	7.49	15.60	18.53	19.24	16.12	16.31	15.71	2.21	2.41	1.59
IS3	38.20	39.43	41.50	5.94	6.51	6.94	14.78	17.09	17.99	16.56	16.89	16.39	1.82	1.36	1.73
IS4	43.67	47.40	50.10	8.35	9.07	9.42	17.98	18.94	20.72	14.66	15.79	15.72	1.42	1.46	1.50
LSD (0.05)	**1.70**			**NS**			**0.31**			**0.32**			**0.49**		
2021/2022															
IS1	40.17	41.7	45.47	10.5	11.77	12.16	17.68	19.53	20.62	16.11	16.34	16.09	1.40	1.70	1.83
IS2	37.53	39.23	41.37	10.34	11.33	11.67	16.38	18.85	19.43	16.49	17.31	16.4	1.31	1.63	1.77
IS3	32.63	38.1	40.03	9.42	10.37	11.77	14.84	17.40	18.65	17.19	17.5	16.67	1.41	1.55	1.99
IS4	41.17	43.43	43.97	11.7	12.2	12.38	17.84	19.65	21.49	15.97	16.74	16.54	1.41	1.58	1.78
LSD (0.05)	**1.57**			**0.54**			**0.19**			**0.74**			**NS**		

Table 4: Continued

Treatment	α-amino-N			Extractable sucrose%			Quality			Sugar yield (ton/ha)			Sugar lost to molasses%		
	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha	165 kg N/ha	190 kg N/ha	215 kg N/ha
2020/2021															
IS1	4.30	2.63	2.95	11.96	13.45	13.28	81.41	85.57	84.97	7.06	8.41	8.55	2.13	1.67	1.75
IS2	3.13	2.03	3.22	13.77	14.2	13.51	85.44	87.05	85.96	7.81	8.59	8.43	1.75	1.51	1.60
IS3	3.31	3.21	2.75	14.31	14.7	14.28	86.42	87.03	87.15	8.14	8.46	8.43	1.65	1.59	1.51
IS4	3.25	3.19	3.10	12.43	13.54	13.43	84.79	85.78	85.47	7.7	8.74	8.81	1.63	1.65	1.68
LSD (0.05)	**0.68**			**0.30**			**1.16**			**NS**			**0.19**		
2021/2022															
IS1	1.27	1.69	1.79	14.50	14.53	14.13	90.01	88.96	87.81	8.72	9.33	9.33	1.01	1.21	1.36
IS2	1.15	1.24	1.51	14.91	15.64	14.55	90.37	90.38	88.74	8.8	9.67	9.31	0.99	1.06	1.24
IS3	1.03	1.36	1.44	15.57	15.79	14.84	90.57	90.23	89.04	9.1	9.64	9.26	1.02	1.11	1.23
IS4	1.27	1.69	1.79	14.19	14.85	14.58	88.87	88.72	88.18	8.68	9.67	9.94	1.18	1.29	1.36
LSD (0.05)	**0.12**			**0.50**			**0.62**			**0.40**			**0.07**		

IS1= 100% sugar beet + 15% fahl berseem, IS2= 100% sugar beet + 25% fahl berseem, IS3= 100% sugar beet + 35% fahl berseem, IS4= sole sugar beet and NS meaning; Not significant.

II- Fahl berseem crop:

1. Effect of nitrogen fertilizer levels on characteristics of fahl berseem:

Results presented in Table 5 indicate that the effect of nitrogen rates on fahl berseem traits in the first and second seasons. The data indicated that plant height (cm), weight of 1000 seed (g) and seed yield (kg/ha) were significantly affected by nitrogen fertilizer levels in both seasons. It is clear that the fertilization by 215 kg N/ha gave the highest values of plant height, weight of 1000 seed and seed yield of fahl berseem in both seasons. Furthermore, the lowest values of plant height, weight of 1000 seed and seed yield were obtained by addition 165 kg N/ha in both seasons. It is commonly regarded that nitrogen has an essential function in increasing meristematic activity and protein cell creation, both of which enhance the dry weight of fahl berseem plants [9,36].

Table 5. Effect of nitrogen fertilizer levels on plant height, weightof1000 seed and seed yield of berseem in 2020/2021 and 2021/2022 growing seasons.

Treatment	Plant height (cm)		Weight of 1000 seed (g)		Seed yield (kg/ha)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
165 kg N/ha	103.09	102.32	3.92	3.98	353.15	354.69
190 kg N/ha	105.22	107.28	4.02	4.10	370.31	382.22
215 kg N/ha	107.05	109.21	4.08	4.15	384.28	401.58
LSD $_{(0.05)}$	**0.12**	**0.36**	**0.02**	**0.02**	**0.77**	**0.91**

2. Effect of seeding rates of fahl berseem with sugar beet on fahl berseem:

Data in Table 6 showed that different rates of fahl berseem with sugar beet on fahl berseem had significant effect on plant height (cm), weight of 1000 seed (g) and seed yield (kg/ha) of fahl berseem in both seasons. The obtained data indicated that plant height, weight of 1000 seed and seed yield increased by increasing the percentage of seeding fahl berseem intercropped with sugar beet. It is clear that 35% of fahl berseem seeds with sugar beet caused an increase in seed yield of fahl berseem estimated by 37% and 64% compared to mixing 15% of the recommended rates of fahl berseem in the first and second seasons, respectively. The yield and its component decreased when intercropped sugar beet with fahl berseem with increasing the percentage of fahl berseem seeding rates. These values tended to reduce with increasing seeding rates of fahl berseem in both seasons. These results are in line with those mentioned by [9,10] found that35% of fahl berseem seeds had higher value than 15 and 25% in all the studied traits. These values tended to decrease regularly and consistently with increasing fahl berseem percentage in the mixture in both seasons. [37] stated that the sole of fahl berseem had higher value than all mixtures.

Table 6. Effect of intercropping systems on plant height, weightof1000 seed and seed yield of berseem in 2020/2021 and 2021/2022 growing seasons.

Treatment	Plant height (cm)		Weight of 1000 seed (g)		Seed yield (kg/ha)	
	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
IS1	101.72	97.99	4.02	4.26	188.31	176.03
IS2	104.70	104.22	4.03	4.07	233.71	248.70
IS3	105.30	106.31	3.92	3.89	258.93	290.37
IS5	108.77	116.56	4.07	4.09	796.04	802.88
LSD $_{(0.05)}$	**0.41**	**1.05**	**0.03**	**0.05**	**1.68**	**0.91**

IS1= 100% sugar beet + 15% fahl berseem, IS2= 100% sugar beet + 25% fahl berseem, IS3= 100% sugar beet + 35% fahl berseem and IS5= sole fahl berseem.

3. Effect of the interaction between N-levels and intercropping systems on fahl berseem characteristics:

The effect of interaction between N levels and intercropping system were significantly for plant height, weight of 1000 seed and seed yield in both seasons in Table (7). The maximum plant height was reached when intercropped sugar beet + 25% (IS2) seeding rate of

fahl berseem and the highest level of N (215 kg N/ha). The interaction revealed that maximum values of weight of 1000 seed were obtained when intercropped sugar beet + 15% (IS1) seeding rate of fahl berseem with the high level of N (215 kg N/ha). The interaction effect on seed yield kg/ha. of fahl berseem revealed that the maximum yield was obtained when intercropped sugar beet + 35% (IS3) seeding rate of fahl berseem and the highest level of N (215 kg N/ha). whereas, the lowest yield was obtained when intercropped sugar beet + 15% (IS1) seeding rate of fahl berseem and the lowest level of N (165 kg N/ha). Further, the maximum yield was obtained with sole fahl berseem(IS5) and the high level of nitrogen (215 kg N/ha) as compared with all treatments of N fertilizer levels and intercropping systems. These results are in good agreements with obtained by [9].

Table 7. Effect of the interaction between N-levels and intercropping systems on some characteristics of fahl berseem in 2020/2021 and 2021/2022 growing seasons.

Treatment	Plant height (cm)			Weight of 1000 seed (g)			Seed yield (kg/ha)		
	165 kg N/ha	190kg N/ha	215 kg N/ha	165 kg N/ha	190kg N/ha	215 kg N/ha	165 kg N/ha	190kg N/ha	215 kg N/ha
2020/2021									
IS1	98.45	101.66	105.05	3.93	4.03	4.1	180.33	188.74	195.87
IS2	103.03	104.14	106.94	3.94	4.04	4.1	227.46	230.67	243.01
IS3	104.45	105.54	105.93	3.86	3.92	3.96	254.90	259.83	262.06
IS5	106.45	109.57	110.30	3.96	4.09	4.16	749.93	802.00	836.20
LSD (0.05)	**0.25**			**0.03**			**1.54**		
2021/2022									
IS1	93.63	99.36	100.97	4.15	4.28	4.34	163.65	178.44	186.01
IS2	99.76	104.42	108.47	3.99	4.1	4.11	237.46	247.96	260.7
IS3	105.35	106.34	107.24	3.82	3.9	3.96	279.34	288.4	303.38
IS5	110.52	118.99	120.17	3.96	4.12	4.18	738.33	814.08	856.24
LSD (0.05)	**0.73**			**0.04**			**1.81**		

IS1= 100% sugar beet + 15% fahl berseem, IS2= 100% sugar beet + 25% fahl berseem, IS3= 100% sugar beet + 35% fahl berseem and IS5= sole fahl berseem.

Competitive relationships and yield advantages

Comment [DAL5]: Must be improved!

Land equivalent ratio (LER)

Results presented in Table 8 show that the values of relative yield of sugar beet were higher than those relative yield of fahl berseem over all intercropping systems. The relative yield (RY) of sugar beet decreased with increasing seeding rates of fahl berseem, whereas the relative yield (RY) of fahl berseem increased with increasing seeding rates of fahl berseem. Data also reveal that the intercropping systemIS3 (100% sugar beet + 35% fahl berseem) and fertilized plants with 165 Kg N/ha recorded the highest land equivalent ratio (1.30). Furthermore, the intercropping systemIS1 (100% sugar beet + 15% fahl berseem) and fertilized plants with 165 Kg N/ha recorded the lowest land equivalent ratio (1.20). This result Similar results were obtained by [9,12,15,19].

Aggressivity (A)

Presented data in Table 6 reveal that, the aggressivity in all intercropping systems and nitrogen fertilization combination, fahl berseem was the dominant intercrop component whereas sugar beet was the dominated as the average of two seasons. This is indicated that fahl berseem had higher competitive ability compared with sugar beet. Similar results were obtained by [19,38,39].

Competitive ratio (CR)

The competitive ratio term may assist in determining the competition balance that between intercropping systems and sole cropping is most likely to give component crops the greatest yield advantages. Data presented in Table 8 show that, the CR values of fahl berseem was higher compare with sugar beet as the average of two seasons. The CR of IS1 was higher as compared to IS2 and

IS3as the average of two seasons. Result herein is in harmony with those obtained by [9].

System productivity index (SPI)

The system productivity index shows that intercropping systems are more productive and stable than mono cultures. Results presented in Table 8 shows that intercropping systems IS2 and IS3with 215 kg N/ha produced the highest system productivity index values were 84.84 and 84.82, respectively. whereas the lowest system productivity index values were recorded in intercropping systems IS1 with 165 kg N/ha. This result indicates a relatively stable productivity by intercropping sugar beet with 25% fahl berseem under intercropping systems. These result was confirmed with what was found by [39].

Economic Evaluation

Gross returns

Results in Table 8 reveal that increasing seeding rates of fahl berseem and level of nitrogen increased gross returns also intercropping systems under nitrogen fertilizer levels treatments gained the highest gross returns compared with sole sugar beet and fahl berseem. The highest gross returns(3398US$/ha) resulted from intercropping system IS3 (100% sugar beet + 35% fahl berseem) and fertilized plants with 215 Kg N/ha. While the lowest gross returns(2953US$/ha) were obtained from intercropping systems IS1 (100% sugar beet + 15% fahl berseem) with 165 kg N/ha as average in both seasons. Similar results were obtained by [9,12,13,14,16,19,20,39].

Table 8: Effect of nitrogen fertilizer levels, intercropping systems and their interaction on competitive relationships and total income in both seasons.

Treatment		L sugar beet	L berseem	LER	A_s	A_b	CR_s	CR_b	SPI	Gross returns USD ha^{-1}
Cropping Systems	Nitrogen fertilizer levels									
IS1	165 kg N/ha	0.97	0.23	1.20	-0.57	+0.57	0.63	1.59	75.39	2953
	190 kg N/ha	0.98	0.23	1.21	-0.54	+0.54	0.65	1.55	79.74	3156
	215 kg N/ha	0.98	0.23	1.21	-0.53	+0.53	0.65	1.54	82.00	3262
IS2	165 kg N/ha	0.94	0.31	1.25	-0.31	+0.31	0.75	1.33	78.74	3090
	190 kg N/ha	0.94	0.30	1.24	-0.24	+0.24	0.80	1.26	82.07	3267
	215 kg N/ha	0.95	0.30	1.25	-0.25	+0.25	0.79	1.26	84.84	3391
IS3	165 kg N/ha	0.94	0.36	1.30	-0.09	+0.09	0.91	1.10	81.40	3187
	190 kg N/ha	0.91	0.34	1.25	-0.05	+0.05	0.94	1.06	83.03	3304
	215 kg N/ha	0.91	0.33	1.24	-0.05	+0.05	0.95	1.05	84.82	3398
IS4	165 kg N/ha									2432
	190 kg N/ha									2568
	215 kg N/ha									2664
IS5	165 kg N/ha									2604
	190 kg N/ha									2828
	215 kg N/ha									2962

IS1= 100% sugar beet + 15% fahl berseem, IS2= 100% sugar beet + 25% fahl berseem, IS3= 100% sugar beet + 35% fahl berseem, IS4= sole sugar beet and IS5= sole fahl berseem.

Comment [DAL6]: Must be improved

CONCLUSION

It could be concluded that all values of sugar beet traits significantly decreased by increasing in the percentage of fahl berseem seeding rates when intercropped with sugar beet, whereas, reverse trend was found

by increasing nitrogen fertilizer levels. The data also showed that all traits of fahl berseem significantly increased by increasing percentage of fahl berseem when intercropped with sugar beet and increasing nitrogen fertilizer levels. The highest gross returns(3398US$/ha) resulted from intercropping system IS3 (100% sugar beet + 35% fahl berseem) and fertilized plants with 215 Kg N/ha. While the lowest gross returns (2953US$/ha) were obtained from intercropping systems IS1 (100% sugar beet + 15% fahl berseem) with 165 kg N/ha as average in both seasons. From this study it could be concluded that to obtain the highest gross returns preferred use intercropping system 35% fahl berseem with 100% sugar beet and application of 215 Kg N/ha.

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