Original Research Article

Sugar Beet Productivity Response to Intercropping System and Nitrogen Fertilizer

ABSTRACT

A field trials was carried out at Shandaweel Research Station, Sohag Governorate, Agricultural Research Center, Egypt during the 2020/2021 and 2021/2022 seasons to study the influence of intercropping sugar beet with fahl berseem using three different nitrogen fertilization rates on yield, its components, and economic returns. The experiment was laid out in a randomized complete block design using a split-plot arrangement of 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 results revealed that most of the values of sugar beet traits significantly (P<0.05) decreased by increasing the percentage of fahl berseem seeding rates. whereas, a reverse trend was found in increasing nitrogen fertilizer levels. All traits of fahl berseem significantly (P<0.05) increased by increasing the percentage of fahl berseem seeding rates when intercropped with sugar beet and increasing nitrogen fertilizer level. 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 systems IS1 (100% sugar beet + 15% fahl berseem) and 165 kg N/ha recorded the lowest land equivalent ratio (1.20). Fahl berseem was the dominant crop, whereas sugar beet was the dominated. The highest gross returns (3398US$/ha) resulted from intercropping system IS3 (100% sugar beet + 35% fahl berseem) and 215 Kg N/ha. The lowest gross returns (2953US$/ha) were obtained from intercropping systems IS1 (100% sugar beet + 15% fahl berseem) with 165 kg N/ha as average in both seasons. Hence it, To achieve higher gross returns preferred use intercropping system of 35% fahl berseem and 100% sugar beet with application of 215 Kg N/ha.

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

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]. Nowadays, 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 surfaces 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. 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]. Integrating forage crops and animal production with other crops by intercropping systems can be cultivated by 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. In intercropping with sugar beet, the density of faba bean plants decreases, resulting in a reduction in the density of two crops per area of land. 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 gross revenue. The highest values of Na and -amino-N concentrations of sugar beet (2.384 and 2.879 meq. 100 g^{-1} beets, respectively) were achieved by intercropping soybean with sugar beet [15]. The land equivalent ratio was more than 1 in intercropping systems and achieve high land productivity [16]. To bridge the bean gap, intercropping faba bean with sugar beet is crucial [17]. Additionally, fixing biological nitrogen increases soil fertility. Intercropping of 12.50% wheat and 100% sugar beet (7.50 kg of wheat grain in rows on the width ridge of sugar beet) and fertilizer treatment of 75% NPK and bio-fertilizer produced the maximum yield values and their components, land equivalent ratio, and quality. [18]. Roots and sugar beet yield increased linearly when nitrogen fertilizer rate increased from 56 to 224 kg/ha, but sucrose% decreased [19]. The different nitrogen fertilizer rates had a significant impact on the majority of sugar beet character values; intercropped sugar beet plants fertilized with 90 kg N + 30 m3 FYM/fed recorded the longest diameter roots, followed by intercropped sugar beet plants fertilized with 80 kg N + 30 m3 FYM/fed [20]. [21] revealed that while sucrose percentage was significantly reduced, root diameter, length, and weight were greatly increased when nitrogen rates were raised from 69 to 92 and 115 kg N/fed. [22] revealed that increasing the nitrogen fertilization up to 92 kg/fed significantly enhanced root fresh weight, sugar yields, and sucrose percentage while reducing sucrose%. Root length and diameter, as well as top and root production, significantly increased when nitrogen rates were raised to 140 kg N/fed. [23]. An increase of 350 kg N/ha significantly increased root length and diameter, root and top fresh weights, and root yield as compared to 200 kg N/ha. [25]. [26] reported that as the nitrogen rate increased, root length and diameter, fresh weights/plant, and yields significantly increased. The study aims in order to achieve maximum sugar beet productivity by using the optimum fahl berseem seed rate and N fertilizer level.

2. MATERIAL AND METHODS

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

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):

UNDER PEER REVIEW

IS1: 100% sugar beet and 15% fahl berseem seeds (7 kg/ha). Sugar beet seeds were planted on each side of all raised beds (120 cm width) by growing one plant/hill at 20 cm apart between hills. One row of fahl berseem was sown in the middle of all beds.
IS2: 100% sugar beet and 25% fahl berseem seeds (12 kg/ha). With the same method as described at (IS1).
IS3: 100% sugar beet and 35% fahl berseem seeds (16.5 kg/ha). With the same method as described at (IS1) and (IS2).
IS4: Sole sugar beet the seeds were planted on one side of the ridge (60 cm width) by growing one plant/hill at 20 cm apart between hills. (100% sugar beet) as recommended.
IS5: Sole fahl berseem was sown at a rate of 48 kg /ha, and 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 m^2 consisted of three beds, 3.5 m in length and 120 cm apart. Sugar beet and fahl berseem were planted on October 15th and 17th in the 2020 and 2021seasons, respectively. Previous summer crop in the two seasons was sorghum. Superphosphate (15.5% P_2O_5) at a rate of 480 Kg/ha and potassium sulfate (48% K_2O) at a rate of 58 kg/ha were applied during seed preparation. As ammonium nitrate (33.5% N), nitrogen fertilizer levels were applied in two equal doses. The first dose and the 2nd doses were added just before the 1st and 2nd irrigation. As seen in Table 1, the experiments soil type was clay loam.

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

Mechanical analysis		Chemical analysis	
Sand %	24.0	HCO_3^-	0.26
Silt %	38.2	Cl^-	0.28
Clay %	37.8	SO_4	0.65
Soil type	Clay loam	pH, 1:1	7.9
Soluble ions, meq l^{-1}		EC, dSm^{-1}	0.9
Mg^{2+}	0.36	Available N, (mg kg^{-1})	17.5
Ca^{2+}	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 the 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 was taken randomly, from the sole and intercropped plots of sugar beet.
The following data were recorded:

I-Sugar beet characters:

Root length (cm), root diameter (cm), root weight (gm), root yield (ton/ha), which was determined on sub-plot weight (kg) and converted to tons/ha, top-fresh weight (ton/ha), which was determined on sub-plot weight (kg) and converted to tons/ha, and sugar yield (ton/ha) was calculated according to the following equation:

Sugar yield (ton/ha) = root yield (ton/ha) x extracted sugar%

Quality characteristics

Sucrose% was estimated using "Saccharometer" following the method provided by [27], extracted sugar% (ES%) was calculated using the following equation of [28]:

ES% = (sucrose% – SLM%) – 0.6

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

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

QI = (extracted sugar% x 100) / sucrose%

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

II- Fahl berseem characters:

Plant height (cm), weight of 1000 seeds (g), and seed yield (kg/ha).

Competitive relationships and yield advantages

Land equivalent ratio (LER): is the area ratio necessary under a solid crop to the intercropping system under identical circumstances to produce an equivalent crop [30]. The following equation was used to calculate the land equivalent ratio: where Y_{aa}= solid crop yield (a); Y_{bb}= Solid crop yield (b); Y_{ab}= Crop yield by intercropping a and Y_{ba}= Crop yield by intercropping b.

UNDER PEER REVIEW

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

Aggressivity (A): As demonstrated that this measure is used to assess the degree of competition 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= Crop of sugar beet percentage (in intercropping sugar beet and fahl berseem); ZIB= Sown proportion of crop fahl berseem (in intercropping sugar beet and fahl berseem).

Competitive ratio (CR): gives more desirable competitiveness to crops. The competitive ratio simply represents the ratio of the two-component crops' separate LERs and considers the percentage of crops they were initially sown as shown by [31]. The next technique by which the competitive ratio was calculated: $CR_s = (LER_s / LER_b) (Zlb / ZIs)$ while $CR_b = (LER_b / LER_s) (ZIs / Zlb)$.

System productivity index (SPI): by [32] $SPI=[(Y_{ss}/Y_{bb}) \times Y_{bb}] + Y_{ss}$, where Y_{ss} and Y_{bb} are the sugar beet and fahl berseem yields in monoculture, Y_{ss} and Y_{bb} are the sugar beet and fahl berseem yields in cropping system.

Economic evaluation

Gross returns

Each treatment total return was calculated using (US$): 35, 13 and 3.5 US$/ton for the 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 by [33].

Statistical analysis:
Data analysis by [34] software package. A static split-plot analysis of the collected data on sugar beet and fahl berseem was conducted. LSD was used to compare mean differences with a 5% level of significance [35].

3. RESULTS AND DISCUSSION

I-Sugar beet crop:

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 (P<0.05) effects on sugar beet yield and its components. Increasing N-levels to 190 and up to 215 kg N/ha led to a significant (P<0.05) increase in sugar beet yield and its components i.e. root length, root diameter, root weight, root yield, and sugar yield as compared with those provided with 165 kg N/ha, in the 1st season, corresponding to the same measured parameters in the 2nd season, respectively. The role of nitrogen may be responsible for an increase in these traits as an essential element in building-up plant organs and enhancing their growth. The results that follow match to those mentioned by [22,23,24].

Data in Table 2 indicated that increasing levels of nitrogen from 165 up to 190 kg N/ha significantly (P<0.05) improved sucrose%, extractable sucrose%, and quality index, in sugar beet in the two 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 maximum sucrose, extractable sucrose% and quality index in beet juice, in addition, low in molasses impurities, while the largest N-level may have directed beet plants for more vegetative growth rather than dry matter accumulation. The results that follow match to 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 %

UNDER PEER REVIEW

	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	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 (P<0.05) affected by intercropping fahl berseem and sugar beet except K, α-amino-N, and sugar yield in the 1st season and Na in the 2nd season. Solid sugar beet surpassed the different cropping systems concerning most sugar beet characteristics in the two seasons. This finding reflects the adverse effect of 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. It prevents sugar beet plants from growing properly. Intercropping fahl berseem at a rate of 15% (IS_1) was better than different intercropping systems concerning all sugar beet characteristics in the two seasons. The lowest values of most sugar beet characteristics were found in intercropping fahl berseem and sugar beet densities of 35%. The height values in sugar beet yield and yield components as a result of intercropping all beds with fahl berseem a rate seed of (15%) for root length, root diameter, root weight, top-fresh weight, and root yield, as compared with used fahl berseem of seeding rate 25 and 35%, respectively, in the 1st season, corresponding to the same parameters in the 2nd season. These results may be referred to the lower competition among plants for growth factors such as sunlight, water, and nutrients, grown under conditions of the lowest seed rate, which produced root longest, thickest, and heaviest weight root/plant of sugar beet, compared to higher plant populations, emerged if there is using higher seed rates. The results conform with those of **[9,10,14,15].**

Data in Table (3) indicate that intercropping fahl berseem on sugar beet significantly (P<0.05) affected the quality characteristics of sugar beet (sucrose%, extractable sucrose%, and quality index). The best sucrose%, extractable sucrose%, and quality index% of sugar beet as a result of intercropping all beds fahl berseem by the seeding rate of (35%) and sugar beet. The lowest results, on the other hand, were observed with seeding rate of 15%. The heights value of quality characters of sugar beet a result by intercropping all beds with fahl berseem with a seeding rate of (35%) sucrose, extractable sucrose, sugar lost to molasses, and quality index, compared to used fahl berseem with a seeding rate of 15 and 25%, respectively, in the 1st season, corresponding to those in the 2nd season. Moreover, it was discovered that intercropping fahl berseem and sugar beet significantly (P<0.05) 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 (P<0.05) decrease in sodium content in the 1st season only, while, intercropping fahl berseem by a rate seed of 35% with sugar beet resulting in a significant reduction in 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% cropping system. The results conform with those of **[11,12,13,16,18].**

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	42.8	8.94	12.09	1.31	1.25	19.22	19.66	64.03	67.52	15.39	16.41

UNDER PEER REVIEW

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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**

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

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 (P<0.05) impact on root length, sucrose%, extractable sucrose%, and quality index%, in addition α-amino N in molasses in the 1st and 2nd seasons, were as a result of intercropping fahl berseem by a seeds rate of 35 and/or 15% on beds of sugar beet with add of nitrogen fertilization level to 215 and/or 190 kg N/ha in the two seasons. Likewise, root diameter and sugar yield/fed was markedly impacted by the interaction of fahl berseem seed rates and N-level in the 2nd season. While sodium contents (Na) in molasses had a significant (P<0.05) influence in the 1st season only, were as a result of intercropping fahl berseem by a seeds rate of 35 and/or 25% on beds of sugar beet with add of nitrogen fertilization level to 190 and/or 165 kg N/ha. These results confirmed the results of [9,10,13,18,20].

UNDER PEER REVIEW

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

UNDER PEER REVIEW

II- Fahl berseem crop:

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

The results are shown in Table 5 indicate impact of nitrogen rates on fahl berseem characteristics in the 1st and 2nd seasons. The data indicated that plant height (cm), weight of 1000 seed (g), and seed yield (kg/ha) were significantly (P<0.05) affected by nitrogen fertilizer levels in the two seasons. It is clear that the fertilization by 215 kg N/ha provided the largest values of plant height, weight of 1000 seeds, and seed yield of fahl berseem in the two seasons. Furthermore, minimum values of plant height, weight of 1000 seeds, and seed yield were got by adding 165 kg N/ha in the two 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, weight of 1000 seeds and seed yield of berseem in 2020/2021 and 2021/2022 growing seasons.

Treatment	Plant height (cm)		Weight of 1000 seeds (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 and sugar beet on fahl berseem:

Data in Table 6 showed that different rates of fahl berseem and sugar beet on fahl berseem had a significant (P<0.05) effect on plant height (cm), weight of 1000 seed (g), and seed yield (kg/ha) of fahl berseem in the two seasons. The data obtained showed plant height, weight of 1000 seeds, and seed yield increased by increasing the percentage of seeding fahl berseem when intercropped with sugar beet. 35% of fahl berseem seeds and 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 1st and 2nd seasons, respectively. The yield and its component decreased when intercropped fahl berseem and sugar beet with increasing the ratio of fahl berseem seeding rates. These values tended to reduce with increasing seeding rates of fahl berseem in the two seasons. These results match those mentioned by [9,10] found that 35% of fahl berseem seeds had higher values than 15 and 25% in each of the studied characteristics. These values tended to decrease regularly and consistently with increasing fahl berseem percentage in the mixture in the two seasons. [37] stated that the sole of fahl berseem had a higher value than all mixtures.

Table 6. Effect of intercropping systems on plant height, weight of 1000 seeds and seed yield of berseem in 2020/2021 and 2021/2022 growing seasons.

Treatment	Plant height (cm)		Weight of 1000 seeds (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 and 15% fahl berseem, IS2= 100% sugar beet and 25% fahl berseem, IS3= 100% sugar beet and 35% fahl berseem and IS5= sole fahl berseem.

UNDER PEER REVIEW

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

The influence of interaction between N levels and intercropping system was significant (P<0.05) for plant height, weight of 1000 seeds, and seed yield in two seasons in Table (7). The maximum plant height was reached when intercropped sugar beet and 25% (IS2) seeding rate of fahl berseem and the highest level of N (215 kg N/ha). The interaction revealed that maximum values of the weight of 1000 seeds were got when intercropped sugar beet with 15% (IS1) seeding rate of fahl berseem with a 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 got when sugar beet intercropping and 35% (IS3) seeding rate of fahl berseem and the highest level of N (215 kg N/ha). while, lees yield was got when beet intercropped with 15% (IS1) seeding rate of fahl berseem and lees level of N (165 kg N/ha). Further, the maximum yield was got with sole fahl berseem(IS5) and a high level of nitrogen (215 kg N/ha) as compared with all treatments of N fertilizer levels and cropping system. The results obtained are consistent with those reported by [9].

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

Treatment	Plant height (cm)			Weight of 1000 seeds (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 and 15% fahl berseem, IS2= 100% sugar beet and 25% fahl berseem, IS3= 100% sugar beet and 35% fahl berseem and IS5= sole fahl berseem.

Competitive relationships and yield advantages

Land equivalent ratio (LER)

The results shown in Table 8 demonstrate that the values of the relative yield of beet were more significant than those the relative yield of fahl berseem over all intercropping systems. The RY of beet lowered with increasing seeding rates of fahl berseem, whereas the RY of fahl berseem increased with increasing seeding rates of fahl berseem. Data also reveal 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). Furthermore, the intercropping system IS1 (100% sugar beet and 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 revealed that, the aggressivity in all intercropping systems and nitrogen fertilization combination, fahl berseem was the dominant intercrop component while beet was the dominated as the average of two

UNDER PEER REVIEW

seasons. It is clear from this that fahl berseem had higher competitive ability compared with beet. The same results were achieved by [19,38,39].

Competitive ratio (CR)

The competitive ratio term may assist during the competition determination balance 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 were higher compared with beet as an average of both seasons. CR of IS1 was higher in comparison to IS2 and IS3 as an average of the two seasons. The result herein is in harmony with those obtained by [9].

System productivity index (SPI)

The system productivity index shows that cropping systems are more productive and stable than mono cultures. The results are shown in Table 8 proved that intercropping systems IS2 and IS3 with 215 kg N/ha provided the greatest system productivity index values 84.84 and 84.82, respectively. While the minimum system productivity index values were recorded with intercropping system IS1 with 165 kg N/ha. This result indicates relatively stable productivity by intercropping beet and 25% fahl berseem under different cropping systems. This result was confirmed by what was found by [39].

Economic Evaluation

Gross returns

Results in Table 8 revealed that increasing seeding rates of fahl berseem and level of nitrogen increased gross returns also cropping systems and nitrogen fertilizer levels treatments gained the highest gross returns as compared to solid beet and fahl berseem. The intercropping system IS3 (100% beet and 35% fahl berseem) and fertilized plants with 215 Kg N/ha produced the highest gross returns (3398 US dollars per hectare). While the minimum gross returns (2953US$/ha) were got from intercropping system IS1 (100% beet + 15% fahl berseem) with 165 kg N/ha as average in the two seasons. The same results of this one were achieved by [9,12,13,14,16,19,20,39].

Table 8: Effect of nitrogen fertilizer level, intercropping system, and their interaction on competition relationships and gross returns in the two seasons.

Treatment		L sugar beet	L berseem	LER	A_S	A_b	CR_s	CR_b	SPI	Gross returns USD ha^{-1}
Intercropping 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

UNDER PEER REVIEW

	215 kg N/ha		2962

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

CONCLUSION

It could be concluded that most of the values of sugar beet characteristic significantly decreased by increasing the percentage of fahl berseem seeding rates when intercropping with beet, whereas, a reverse trend was found by increasing nitrogen fertilizer levels. The data also showed that all traits of fahl berseem increased significantly with a rise in the percentage of fahl berseem with beet and increasing nitrogen fertilizer levels. The intercropping system IS3 (100% beet and 35% fahl berseem) and fertilized plants with 215 Kg N/ha produced the highest gross returns (3398 US dollars per hectare). While the minimum gross returns (2953US$/ha) were got from intercropping system IS1 (100% beet + 15% fahl berseem) with 165 kg N/ha as average in the two seasons. Finally, from this study, we concluded that to achieve higher gross returns preferred use intercropping system of 35% fahl berseem and 100% sugar beet with application of 215 Kg N/ha.

UNDER PEER REVIEW

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UNDER PEER REVIEW

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UNDER PEER REVIEW