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Agro-economical Evaluation for Intercropping Sugar Beet and Barley under Combinations of Barley Cutting and Nitrogen Level Treatments

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to investigate the agro-economic effect of intercropping sugar beet and barley under combinations of barley cutting and Nitrogen levels. Field trials conducted using a split plot design with three replications at the Farm of Gemmeiza Agricultural Research Station, Egypt during 2018/2019 and 2019/2020 seasons. Sugar beet planted on both sides of the bed and barley plant on the top of all beds at the rate of 25%of the sole culture. Sugar beet with companion barley under three cut treatments (no cut, cut before heading (C1) and cut after heading (C2)) and three nitrogen fertilization levels (80, 100 and 120kgN/feddan (feddan=4200m2)) were studied, as well as to study competitive relationships land equivalent ratio (LER). Results from this study revealed that cut and nitrogen treatments had significant (0.05%) effects on most traits of sugar beet and barley in both seasons. Significant cuts*N interaction effects were found for sugar beet and barley traits in both seasons. LER. were greater than unit (1.15 and 1.16) by intercropping sugar beet with barley under N fertilizer rate 120kg N/feddan with both no cut and C1. The effect of cuts and nitrogen interaction on LER across the two seasons increase the land usage. The highest yield advantage for RCC (89.49 and 73.54) was recorded with C1 at 120Kg N/feddan in both seasons respectively,

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indicating the effect of barley cuts and N fertilizer rates on yield and aggressivity (AG) values of sugar beet and barely. The highest values Total income (L.E.), Net return and economic return (L.E.) obtained from sugar beet under 120kgN rate * no cut or C1 treatments in both seasons. Agro-economically biplot graph recommended that intercropping barley with sugar beet under 120kg N rate * no cut or C1 drive the maximum values of productivity of sugar beet and competitive relationships and yield of both crops.

Keywords: Agro-economic; net return; sucrose%; LER; RCC.

1. INTRODUCTION

Maximize the land usage to accelerate productivity gains may encourage a rapid closure of the expected food security gap. Intercropping (growing crops in the same area as a mixed stands) is the term of land use cultivation, raising crop system than growing them separately [1]. Common advantages of different forms of intercropping are exploiting more efficiently environments with limiting growth resources [2]. In addition to the better use of growth, better weed management [3], and pest control [4], assurance against failure of crop [1], reduced fertilizer requirement [5] and better soil fertility [6] than sole cropping.

The choice of the component crops in the intercropping cultivation is crucial. Under intercropping system, attention should be given to the crops that can grow together with minimal competition and maximum profit [7]. Among the important crops in the Egyptian agricultural system are the sugar crops. Increasing the sugar yield per unit area of sugar crops is, thus, a national demand and could be achieved by adopting suitable cultural practices and applying intercropping. An agronomic advantage had been demonstrated when sugar beet was intercropped with other winter barley crop [8]. These studies used the land equivalent ratio (LER) developed by [9] & [10] to determine the effectiveness of intercropping relative to sole cropping.

The most important purpose of sugar beet growers is to increase nitrogen use efficiency. In Egypt, the recommended rate of nitrogen for sugar beet varied from 60 to 120 kg per feddan, depending on the use of organic fertilizers and on a range of site-specific characteristics like soil type and climate as well as cropping systems [11], [12], [13]. Effect of nitrogen rates on sugar beet yield and its attributes was studied by [14]. [15] reported high values of root characteristics of pure stand sugar beet when fertilized with 100 to 120 kg N/fed compared to other low levels of mineral nitrogen. Sugar beet is an efficient nitrogen user. [16], [17] reported that crops that do compete for a nutrient might be successfully intercropped with one another in the field in order to control environmental losses of that nutrient.

Barley can grow fast, suppress weed pressure and provide high yield in terms of dry weight. As forage, barley has higher nutritive value than oat, triticale and wheat in intercropping systems [18]. Barley forage had higher digestible dry matter (DM), lower acid detergent fiber (ADF) concentration and higher crude protein (CP) [19]. Cutting barley at early growth stages (45 and 55 DAS) resulted in the production of higher forage yield with higher quality [20].

The use of LER, with such a model, would result in a biased estimate of yield gain towards the intercropping treatments. Therefore, alternative indices were developed to fairly determine effectiveness of intercropping compared to pure stands on an unbiased basis, such as the effective land equivalent ratio (ELER) modified by [21]. This index would provide a realistic estimate to the yield gain of the additive intercropping system compared to the sole crops.

The objective of this investigation was to study the effect of barley plant cuts and different nitrogen fertilizer rates on yield and its components of barley intercropped with sugar beet as well as competitive relationships and net return.

2. MATERIALS AND METHODS

The field experiments were conducted at the Experimental Farm of Gemmeiza Agriculture Research Station, Agricultural Research Center (ARC), Egypt during 2018/ 2019 and 2019/2020 growing seasons.

2.1 Field Experiment

The field experiment included the combination of three cut treatments of barley (no cut, cut before heading and cut after heading) and three nitrogen fertilization levels (80, 100 and 120 kg N/fed) under intercropped, in addition to pure stand sugar beet and barley. Sugar beet was planted on both sides of the bed (120 cm width) and barley plant on the top of all beds distributed at the rate of 25% of the sole culture. The treatments were arranged in a split plot design with three replications, where intercropping pattern occupied the main plot, while the combination of cut treatments of barley and nitrogen fertilizer levels were distributed randomly in the sub plot. The experimental unit area was 4.8 m width × 3 m length= 14.4 m^2 i.e 4 ridges (120 width × 3 m length).

Sugar beet was planted on both sides of the bed (120 cm width) 20 cm apart between hills and thinned to one plant/hill in all intercropping treatments and sugar beet pure stand, which was planted on one side of the ridges (60 cm width) spaced at 20 cm apart between hills to give 35000 plants fed^{-1}.Barley was planted in all intercropping treatments at 25% of sole culture seed rate distributed on the top of sugar beet beds. The sole culture of barley 100% was planted on broadcasting at seed rate of 60 kg fed^{-1}. Diamond cultivar of sugar beet and cultivar of barley Giza 123 were used in this study.

Sugar beet or barley sole and intercropping (sugar beet + barley) were evaluated under three cut treatments of barley as follows:

2.1.1 Cuts treatment of barley

C0: no cut.
C1: cut before heading (after 55 days after sowing).
C2: cut after heading (after 85 days after sowing).

2.1.2 Nitrogen fertilizer levels

Three levels of nitrogen fertilizer doses (80 “equal the recommended dose of sugar beet”, 100 and 120 kg N fed^{-1}) were applied in the form of ammonium nitrate (33.5% N) at three equal doses distributed before first, second and third irrigations, respectively.

The preceding summer crop was maize in both seasons. Phosphorus fertilizer was added during land preparation in the form of calcium superphosphate (15.5% P_2O_5) at the rate of 200 kg fed^{-1}. Thinning sugar beet took place after45 days after sowing to one plant/hill at 20 cm a part. The other agricultural practices of growing barley with sugar beet were applied as recommended by The Ministry of Agriculture and Land Reclamation. Sowing sugar beet was in 24/10/2018 and 22/10/2019 in the first and second seasons, respectively; and barley was planted after 21 days from sugar beet planted (just before the first irrigation of sugar beet).

Table 1. Physical and chemical properties of the experimental soil during 2018/2019 and 2019/2020 growing season

Soil depth, cm	0 — 30				
Particle size distribution	**2018/ 2019**	**2019/ 2020**	**Total macronutrients, %**	**2018/ 2019**	**2019/ 2020**
Coarse sand, %	5.23	5.19	N	0.144	0.138
Fine sand, %	18.46	18.38	P	0.032	0.033
Silt, %	37.24	37.11	K	0.356	0.349
Clay, %	39.07	39.32	Available N, mg kg^{-1}	33.42	28.14
Texture class	Clay loam	Clay loam	Available P,mg kg^{-1}	10.63	11.11
pH, 1:2.5 (susp.)	7.77	7.75	Available K,mg kg^{-1}	315.72	102.54
EC, dSm^{-1}	1.67	1.63	Organic matter (O.M, %)	2.50	2.52
Soluble ions, meq l^{-1}			Organic carbon (O.C, %)	1.45	1.42
Mg^{2+}	5.32	5.3	C / N ratio	10.07	9.72
Ca^{2+}	6.13	6.11	**DTPA – extractable micronutrients (ppm)**		
Na^{+}	7.46	7.48	Fe	3.83	3.74
K^{+}	0.23	0.25	Br	0.26	0.25
CO_3^{2-}	0.00	0.00	Mn	3.15	3.02
HCO_3^{-}	3.62	3.64	Zn	4.46	4.36
Cl^{-}	8.13	8.15	Cu	1.53	1.49
SO_4^{2-}	7.39	7.35			

This study aimed to determine the effect of intercropping barley cv. (Giza123) with sugar beet cv. Diamond under three cut treatments and three different levels of nitrogen on yield and yield components of both crops. Also, land equivalent ratio (L.E.R.) as well as competitive ratio (C.R.) and yield advantages were studied.

2.2 Soil Sampling and Analysis

A representative soil sample of the field was taken from 0–30 cm layer and used for determining some physical and chemical properties of the studied soil during 2018 and 2019 seasons [22].The mechanical and chemical analyses of the experimental sites are recorded in Table (1).

2.3 Studied Characters

2.3.1 Barley

Plant height (cm), spike length (cm), number of grains/spike, number of spikes/m^2,1000-grain weight (g), grains yield(kg/fed), straw yield(kg/fed) and biological yield) kg/fed) were Measured of barley for pure stand and intercropped, respectively. (Feddan (fed) = 4200m^2).

2.3.2 Sugar beet

At harvest time, five plants were taken randomly from each subplot to estimate the data of yield components. Whereas the top and root yields were calculated from the inner two ridges (two beds) of each sub plot of sugar beet for pure stand and intercropped, respectively, as follows: total plant weight (kg), root weight/plant (kg), root length (cm), root diameter(cm) biological yield (ton/fed), root yield (ton/fed, feddan (fed)=4200m^2), top yield(ton/fed), sucrose %, Sugar yield (ton/fed), Leaf area index and foliage weight (ton/fed).

2.4 Chemical Quality of Sugar in Sugar Beet Root

Samples of 26 g fresh root weight were taken from each sub-plot to determine: Sucrose % according to the methods described by [23] and sugar yield ton /fed (SY).

2.5 Competitive Relationships and Yield Advantages

The following competitive relationships and yield advantages were calculated:

2.5.1 Land equivalent ratio (LER)

It was determined according to the following formula described by [24]:

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

*Where, Yaa and Ybb were pure stand of crop, a (sugar beet) and b (barley), respectively. Yab is intercrop yield of a crop and Yba is intercrop yield b crop.

2.5.2 Relative crowding coefficient (RCC)

RCC, which estimates the relative dominance of one species over the other in the intercropping system [9] was calculated as follows: $K = K_a \times K_b$, $K_a = Y_{ab} \times Z_{ba} / [(Y_{aa} - Y_{ab}) \times Z_{ab}]$; $K_b = Y_{ba} \times Z_{ab} / [(Y_{bb} - Y_{ba}) \times Z_{ba}]$, Where Y_{aa} = Pure stand yield of crop a (sugar beet); Y_{bb} = Pure stand yield of crop b (barley); Y_{ab} = Intercrop yield of crop a (sugar beet); Y_{ba} = Intercrop yield of crop b (barley); Z_{ab} = The respective proportion of crop a in the intercropping system (sugar beet); Z_{ba} = The respective proportion of crop b in the intercropping system (barley).

2.5.3 Aggressivity (A)

Aggressivity represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system [25] was calculated as follows: $A_{ab}=[Y_{ab} / (Y_{aa} \times Z_{ab})]-[Y_{ba} / (Y_{bb} \times Z_{ba})]$; $A_{ba}=[Y_{ba} / (Y_{bb} \times Z_{ba})]-[Y_{ab} / (Y_{aa} \times Z_{ab})]$.

2.6 Economic Evaluations

The yield traits of both sugar beet and barley produced from cropping system were obtained to conduct an economic evaluation for the intercropping yields compared to the pure crops.

Total income and net return were calculated for each treatment in Egyptian pounds (LE) using market prices of sugar beet and barley according to Ministry of Agriculture and Land Reclamation, Economic Affairs Sector- Price Bulletin, Egypt. The sugar beet prices were 550 and 600 LE /ton for roots and 280 LE/ ton for top-fresh. Mean while barley prices were LE 600 and 648/ardab (ardab=120kg) of grains and 1000, 1100 LE /ton of straw in 2018/19 and 2019/20, respectively. Solid costs were 12250 and 14290 LE /fed for sugar beet and 10830 and 11250 LE

/fed for barley in 2018/19 and 2019/20, respectively.

[26] used the first two principal components (PC1 and PC2) to display the two-way data in GGE-biplot graph (genotype main effect plus genotype-by-environments interaction). On the other side, [27] employed this method to display the treatment by trait two-way data to shows the genotype by trait (GGT) biplot. Accordingly, [28] showed biplot corresponds to the axes of the abscissa and the ordinate to the economic studied traits in different treatments (cuts*N fertilizer) and denoted as treatment–trait (TT).All statistical analysis and biplot graph presented in this paper were carried out with the procedures of [29].

2.7 Statistical Analysis

The collected data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split-plot design as suggested by [30] using "GenStat" computer software package. Means of treatments were compared using LSD tests at probability 5% level.

3. RESULTS AND DISCUSSION

3.1 Agronomic Traits Mean Performance

3.1.1 First: Sugar beet traits

3.1.1.1 Effect of barley cut on sugar beet

Data of the both studied seasons were in harmony in some traits, confirming the effects of studied factors. Results presented that cut treatments (no cut, cut before heading(Cut 1)and cut after heading(Cut 2) impacted significantly on the sugar beet traits as biological yield, root yield, top yield, sucrose %, sugar yield and leaf area index in both growing seasons (table 2). Meanwhile, root diameter and foliage weight traits were significantly affected by the cutting barley treatments among the intercropping in the 1st and 2nd season, respectively. The highest leaf area index (5.70 – 4.98) was belonged to the no cut of barley in both seasons, respectively. The lowest leaf area index was observed in sugar beet (3.21– 3.56) under cut after heading in both seasons, respectively. Biological yield and foliage weight traits under no cut of barley gave the highest values (39.93 – 12.16 ton/fed), respectively in 1st season and cut1 gave the best values (42.04 –12.00 ton/fed), respectively in the 2nd season. Meanwhile, it was noted that increasing root yield met reduction in foliage weight in the 1st season. Then, results showed that cut1significantly increase in the weight of root yield (29.60 and30.04 ton/fed) and sugar yield (5.19 and 5.37ton/fed) in both seasons, respectively. These results suggested that, cut before heading may be allowed improvement sugar beet yield set (root and sugar) greater than for vegetative growth by decrease the specific competition among root forming and sugar storage [31,32].

The effect of intercropping on the root yield of sugar beet depends on the growth nature of the companion crop. The root yield of sugar beet was significant for pure stands followed by when sugar beet was intercropped with barley under cut1. The increasing in sugar beet root effect may be due to the greater exposure of the sugar beet plant to the solar radiation during root storage stage. This better effect of the solar radiation was reflected on better root growth and higher root yield. On the other hand, the reduction of sugar beet root yield in cut2 may be due to the high competition for soil nutrients which negatively affect and reduces the root yield.

3.1.1.2 Effect of nitrogen fertilizer rate on sugar beet

Data presented in Table (3) reveled that all studied traits of sugar beet were significantly affect by nitrogen rates in both seasons, except total plant weight in both seasons, root weight/plant, Sucrose % and sugar yield in the first season.

Root yield recorded gradual increase by increasing N rate up to 120 Kg/fed in both seasons. The increase accounted to 5.44 % and 13.09 % in the 1st season and 3.58 % and 5.56 % in the 2nd season by increasing N rate from 80 to 100 and 120 Kg/fed, respectively. The root yield increasing may be due to the role of N in growth activity that stimulated the meristematic contributes and increase the cells number thus, cell enlargement. Similar findings were obtained by [15], [13] and [33].

Increasing N rates had significant effect on root quality traits. Mean values cleared that sucrose % and sugar yield ton/fed in 2nd season was significantly increased by increasing N rates. It is suggested that raising sugar yield by increasing nitrogen rate may be due to increase root yield as discussed previously in this table. Similar results were obtained by [15] and [13].

Table 2. Sugar beet agronomic traits as affected by barley cuts under cropping system during 2018/19 and 2019/20 seasons

Cuts	Total plant weight (kg)	Root weight/ plant (kg)	Root length (cm)	Root diameter (cm)	Biological yield (ton/fed)	Root yield (ton/fed)	Top yield (ton)	Sucrose %	Sugar yield (ton/fed)	Leaf area index	Foliage weight (ton/fed)
	2018/19										
No cut	1.17	0.75	33.71	13.76	39.93	27.78	12.46	16.79	4.66	5.70	12.16
Cut1	1.23	0.81	38.19	13.88	38.17	29.60	11.31	17.52	5.19	3.96	8.57
Cut2	1.16	0.81	36.42	13.82	39.48	28.05	11.74	14.25	3.99	3.21	11.42
LSD	NS	NS	NS	NS	0.72	0.325	0.44	0.71	0.51	0.06	1.01
Sole	1.29	1.00	37.13	15.50	42.33	31.96	15.13	16.50	5.27	3.58	10.38
	2019/20										
No cut	1.12	0.74	29.53	13.88	39.14	28.22	10.77	18.45	5.22	4.98	10.93
Cut1	1.19	0.88	33.88	12.53	42.04	30.04	11.50	17.83	5.37	3.85	12.00
Cut2	1.17	0.77	30.39	13.52	39.23	28.00	12.08	15.77	4.41	3.56	11.24
LSD	NS	NS	NS	0.14	0.57	0.55	0.41	1.51	0.65	0.09	NS
Sole	1.37	1.04	35.00	15.43	44.90	31.43	16.47	19.67	6.18	4.35	13.47

Table 3. Effect of nitrogen fertilization rates on studied sugar beet agronomic traits under cropping system during 2018/19 and 2019/20 seasons

Nitrogen rates	Total plant weight (kg)	Root weight/ plant (kg)	Root length (cm)	Root diameter (cm)	Biological yield (ton/fed)	Root yield (ton/fed)	Top yield (ton)	Sucrose %	Sugar yield (ton/fed)	Leaf area index	foliage weight (ton/fed)
	2018/19										
N1 (80kg)	1.22	0.81	32.56	13.00	36.00	26.82	9.51	16.52	4.43	4.27	9.18
N2 (100 kg)	1.11	0.75	38.36	13.80	39.89	28.28	12.03	16.04	4.55	4.53	11.61
N3 (120 kg)	1.23	0.81	37.41	14.66	41.69	30.33	13.97	15.99	4.86	4.05	11.36
LSD	NS	NS	3.51	0.59	0.62	0.15	0.85	NS	NS	0.03	0.66
	2019/20										
N1 (80kg)	1.08	0.74	28.84	12.53	37.53	27.90	9.50	16.02	4.47	3.70	9.63
N2 (100 kg)	1.18	0.78	31.35	13.50	40.62	28.90	11.23	18.69	5.41	4.52	11.72
N3 (120 kg)	1.22	0.86	33.61	13.90	42.27	29.45	13.61	17.34	5.12	4.17	12.81
LSD	NS	0.09	1.46	0.50	0.45	0.28	0.56	0.97	0.36	0.07	0.42

Table 4. Interaction effect of cuts x nitrogen rates on sugar beet agronomic traits under cropping system during 2018/19 and 2019/20 seasons

Cuts	Nitrogen rates	Total plant weight (kg)	Root weight/ plant (kg)	Root length (cm)	Root diameter (cm)	Biological yield (ton/fed)	Root yield (ton/fed)	Top yield (ton)	Sucrose %	Sugar yield (ton/fed)	Leaf area index	foliage weight (ton/fed)
		2018/19										
No cut	N1	1.23	0.83	31.27	12.60	38.17	25.83	10.00	16.84	4.35	5.69	12.33
	N2	1.10	0.73	34.27	13.87	40.00	27.67	12.70	17.00	4.70	5.76	12.33
	N3	1.18	0.70	35.60	14.80	41.63	29.83	14.67	16.52	4.93	5.64	11.80
Cut1	N1	1.21	0.74	35.00	13.20	33.50	27.96	8.53	17.81	4.98	3.67	5.54
	N2	1.21	0.80	40.60	13.73	39.20	29.36	11.77	17.35	5.10	4.51	9.84
	N3	1.29	0.91	38.97	14.70	41.80	31.48	13.63	17.42	5.49	3.69	10.32
Cut2	N1	1.23	0.88	31.40	13.20	36.33	26.67	10.00	14.92	3.96	3.46	9.67
	N2	1.03	0.72	40.20	13.80	40.47	27.82	11.63	13.78	3.84	3.33	12.64
	N3	1.22	0.83	37.67	14.47	41.63	29.67	13.60	14.05	4.18	2.83	11.96
LSD 0.05		NS	NS	NS	NS	1.07	0.26	NS	NS	NS	0.06	1.14
		2019/20										
No cut	N1	1.07	0.68	27.39	13.33	37.23	27.25	9.97	16.13	4.41	4.09	9.98
	N2	1.12	0.72	29.93	14.00	39.50	28.42	10.43	19.84	5.63	5.54	11.08
	N3	1.16	0.82	31.27	14.30	40.70	28.98	11.90	19.38	5.62	5.31	11.72
Cut1	N1	1.13	0.84	31.33	11.07	39.03	28.88	8.80	15.91	4.60	3.53	10.15
	N2	1.29	0.88	33.48	13.00	43.03	30.42	11.23	19.51	5.94	4.46	12.61
	N3	1.14	0.91	36.84	13.53	44.07	30.82	14.47	18.07	5.58	3.57	13.24
Cut2	N1	1.03	0.70	27.80	13.20	36.33	27.58	9.73	16.03	4.41	3.48	8.76
	N2	1.13	0.75	30.65	13.50	39.33	27.86	12.03	16.72	4.66	3.57	11.47
	N3	1.35	0.86	32.73	13.87	42.03	28.55	14.47	14.57	4.17	3.63	13.48
LSD 0.05		NS	NS	NS	0.87	0.78	0.49	0.97	1.67	0.63	0.12	0.72

Table 5. Impact of cuts on studied barley agronomic traits under cropping system during 2018/19 and 2019/20 seasons

Cuts	Plant height (cm)	Spike length (cm)	No. of grains/ spike	No. of spikes/m^2	1000 grain weight(g)	Biological yield (kg/fed)	Grain yield (kg/fed)	Straw yield(kg/fed)
	2018/2019							
No cut	119.36	7.33	55.93	319.00	49.96	1232.22	443.33	788.89
Cut1	89.89	6.37	50.27	235.78	41.30	932.89	325.91	606.98
Cut2	67.04	5.53	45.07	193.89	38.89	662.78	231.00	431.78
LSD	2.28	0.13	0.78	8.50	1.30	15.93	7.22	13.10
Sole	123.27	7.53	57.20	355.33	53.53	5766.67	1956.40	3810.27
	2019/2020							
No cut	125.60	7.69	58.13	331.33	50.34	1275.56	452.53	823.02
Cut1	92.02	6.63	51.80	251.89	42.58	997.00	347.60	649.40
Cut2	69.39	5.91	47.47	184.22	39.98	716.89	255.47	461.42
LSD	2.57	0.20	1.21	9.78	0.96	39.39	21.18	57.90
Sole	127.20	7.70	58.20	348.00	53.03	5835.33	1982.53	3852.80

3.1.1.3 Effect of interaction between barley cuts and nitrogen rates

Data in Table (4) cleared that the interaction between barley cutting treatments × nitrogen rates had significant effect on sugar beet traits in both seasons. Results illustrated that the interaction effects were highly significant for biology yield, root yield/fed, Leaf area index and foliage weight in both seasons, top yield, sucrose % and sugar yield traits were significant in the 2^{nd} season.

In general, data showed that adding 120 kg N/fed under barley cut treatment before heading (No cut) exhibited the maximum values for sugar beet biology yield and root yield/fed traits, recording (41.80-44.07 ton/fed), and (31.48- 30.82 ton/fed) in the first and second seasons, respectively compared to other treatments. This showed that nitrogen fertilizer at the rate of 120 kg N/fed and barley cut treatment before heading act dependently on biological yield and root yield of sugar beet plant. This result was in the same line with that reported by [31] and [32].

3.1.2 Second: Barley traits

3.1.2.1 Effect of barley cut

Grain yield (kg/fed) and yield traits of barley were estimated for significance using the analysis of variance. Results demonstrate that cut treatments gave significant differences for all barley traits in both growing seasons. Data in Table (5) showed that barley produced the highest significant barley grain yield in their pure stand amounting to 1956.40 and 1982.53kg/fed of both growing seasons, respectively. In the intercropping system with sugar beet, the grain yield of barley decreased by cut treatment. Thus, the lowest grain yield was achieved in case of cut2 (after heading) that gave 231.00 and 255.47 kg/fed of both growing seasons, respectively.

This reduction in grain yield may be due to using up most soil nutrients in growing before cut, then re-vegetative growing late and decrease all yield traits (spike length, grains/spike, 1000-grain weight, biological yield and attendant decrease in grain yield). Similar trend was observed for barley grain yield by [19]. [34] revered that, the characteristics of growth, green fodder, biological yield decreased significantly after first cutting and second.

Also, grain yield varieties fell by 17% and 27% after the first cutting and 35% and 50% after the second cutting in decreased biological yield 10% and 22% after the first cutting and 21% and 39% after the second cutting for both years, respectively. [20] showed that, cutting barley at early growth stages (45 and 55 DAS) resulted in the production of higher forage yield with higher quality. [35] recorded that, The seed and straw yield (2.48 and 9.40 t/ha) was recorded significantly higher in the no cutting for fodder and left for seed only on pooled mean basis; while, cutting at 50 DAS and left crop for seed recorded significantly higher green forage equivalent yield (79.45 t/ha).

3.1.2.2 Effect of nitrogen fertilizer rate

In the intercropping system with sugar beet, mean values in Table (6) established that different N rates had significant effects on grain yield and all yield traits of barley in both growing seasons. In general, it was noted that gradual increased by increasing N rate up to 120 Kg/fed for all barley yield traits in both seasons. Results revealed that the highest grain yield traits were obtained under adding N rate 120 Kg/fed, recording 353.60 and 372.04 Kg/fed for grain yield in both seasons, respectively as the gain of increasing in other yield traits. Meanwhile, the lowest grain yield was obtained under the application of 80 Kg/fed N that gave 311.93 and 329.87 Kg/fed for the two respectively seasons. These results are in accordance with those reported by [15], [13] and [33].

3.1.2.3 Effect of the interaction between cutting and nitrogen rate

Means of barley cuts treatments x nitrogen rates interaction on barley traits in both growing seasons was presented in Table (7).

Results indicated significant differences for barley number of spikes/m^2 and biological yield/fed mean value in the 1^{st} season. Meanwhile, mean values of plant height, 1000-grain weight, grain yield/fed, biological yield/fed and straw yield/fed traits had significant effect only in the 2^{nd} season. Adding120 kg N rate (N3) without cut treatment gave the maximum values for most traits in both seasons, recording (464.53-473.60 kg/fed) for grains yield, (1310.00-1360.00 kg/fed) for biological yield and (845.47-886.40 kg/fed) for straw yield in both seasons, respectively. Meanwhile, 80 kg N rate (N1) under cut treatment after heading (cut2) cleared the lowest values for most traits in both seasons.

Table 6. Impact of nitrogen fertilization rates on studied barley agronomic traits under cropping system during 2018/19 and 2019/20 seasons

Nitrogen rates	Plant height (cm)	Spike length (cm)	No. of grains/ spike	No. of spikes/m^2	1000 grain weight(g)	Biological yield (kg/fed)	Grain yield (kg/fed)	Straw yield (kg/fed)
	2018/2019							
N1 (80)	86.52	6.27	49.67	237.11	41.31	898.89	311.93	586.96
N2 (100)	91.34	6.43	50.60	243.33	43.78	941.89	334.71	607.18
N3 (120)	97.47	6.53	51.00	268.22	45.06	987.11	353.60	633.51
LSD	3.31	0.17	1.03	8.94	1.30	29.75	8.63	30.66
	2019/2020							
N1 (80)	90.90	6.50	51.00	232.33	42.75	953.56	329.87	623.69
N2 (100)	96.84	6.62	51.73	255.89	43.83	973.67	353.69	619.98
N3 (120)	99.27	7.11	54.67	279.22	46.32	1062.22	372.04	690.18
LSD	3.23	0.24	1.45	7.14	0.99	48.11	13.79	41.19

Table 7. Interaction effect of cuts x nitrogen rates on barley agronomic traits under cropping system during 2018/19 and 2019/20 seasons

Cuts	Nitrogen rates	Plant height (cm)	Spike length (cm)	No. of grains/ spike	No. of spikes/m^2	1000 grain weight(g)	Biological yield (kg/fed)	Grain yield (kg/fed)	Straw yield (kg/fed)
		2018/19							
No cut	N1	71.67	7.20	55.20	310.33	47.78	1153.33	415.33	738.00
	N2	96.73	7.30	55.80	317.00	50.69	1233.33	450.13	783.20
	N3	124.00	7.50	56.80	329.67	51.41	1310.00	464.53	845.47
Cut1	N1	67.33	6.30	50.00	205.00	39.43	911.67	304.40	607.27
	N2	88.23	6.40	50.60	233.67	41.12	935.67	325.73	609.93
	N3	118.47	6.40	50.20	268.67	43.35	951.33	347.60	603.73
Cut2	N1	62.13	5.30	43.80	196.00	36.72	631.67	216.07	415.60
	N2	84.70	5.60	45.40	179.33	39.52	656.67	228.27	428.40
	N3	115.60	5.70	46.00	206.33	40.43	700.00	248.67	451.33
LSD 0.05		NS	NS	NS	15.49	NS	51.53	NS	NS
		2019/20							
No cut	N1	121.00	7.40	56.40	311.00	48.14	1190.00	417.20	772.80
	N2	127.33	7.63	57.80	330.33	50.78	1276.67	466.80	809.87
	N3	128.47	8.03	60.20	352.67	52.10	1360.00	473.60	886.40

Cuts	**Nitrogen rates**	**Plant height (cm)**	**Spike length (cm)**	**No. of grains/ spike**	**No. of spikes/m²**	**1000 grain weight(g)**	**Biological yield (kg/fed)**	**Grain yield (kg/fed)**	**Straw yield (kg/fed)**
Cut1	N1	86.20	6.47	50.80	231.33	41.25	928.33	333.07	595.27
	N2	92.53	6.57	51.40	252.67	42.41	972.67	334.00	638.67
	N3	97.33	6.87	53.20	271.67	44.07	1090.00	375.73	714.27
Cut2	N1	65.50	5.63	45.80	154.67	38.85	742.33	239.33	503.00
	N2	70.67	5.67	46.00	184.67	38.30	671.67	260.27	411.40
	N3	72.00	6.43	50.60	213.33	42.79	736.67	266.80	469.87
LSD 0.05		5.60	NS	NS	NS	1.72	83.34	23.88	71.34

Table 8. Effect of the interaction between different barely cuts and nitrogen fertilizer levels on land equivalent ratio (LER) across two seasons

Cut	**N rates**	**Land equivalent ratio (LER)**					
		2018/2019			**2019/2020**		
		RY $_{Sugar\ beet}$	**RY $_{barley}$**	**LER**	**RY $_{Sugar\ beet}$**	**RY $_{barley}$**	**LER**
No cut	N1 (80)	0.81	0.21	1.02	0.85	0.21	1.07
	N2 (100)	0.87	0.23	1.10	0.89	0.24	1.13
	N3 (120)	0.93	0.24	1.17	0.91	0.24	1.15
Cut1	N1 (80)	0.87	0.16	1.03	0.90	0.17	1.07
	N2 (100)	0.92	0.17	1.09	0.95	0.17	1.12
	N3 (120)	0.98	0.18	1.16	0.96	0.19	1.16
Cut2	N1 (80)	0.83	0.11	0.94	0.86	0.12	0.99
	N2 (100)	0.87	0.12	0.99	0.87	0.13	1.00
	N3 (120)	0.93	0.13	1.06	0.89	0.14	1.03

This interactive effect of barley cuts treatments and nitrogen rates under intercropping system have been studied by [36] and [37].

Accordingly, adding 120 kg N/fed (N_3**)** under barley cut treatment before heading (cut1) revealing the best values for sugar beet root yield had contrary effect on barley yield (relatively medium values) production under intercropping. These results are in general agreement with those obtained by [36] and [37].

3.2 Competitive Relationships

3.2.1 Land equivalent ratio (LER)

Competitive relationship, land equivalent ratio (LER) can be used to determine the effectiveness of each intercropping sugar beet accompanied with the tested barely companion crop (under three cuts and nitrogen treatments) compared to sole (pure). Calculated values of LER in Table (8) were increased than one in both seasons by the interaction between barley cuts with N fertilizer treatments in most cases. Obtained data showed that LER values of different intercropping treatments ranged between 0.94 to 1.17 (Cut2N1) and (No cut N3), respectively and 0.99 to 1.16 for treatments of (Cut2N1) and (Cut1N3), respectively in the both seasons. LER values cleared that all intercropping treatments gave values higher than unit except Cut2N1 and N2 in 1st season and Cut2N1 in the 2nd season. These results are in general agreement with those obtained by [38], [39], [40] and [41].

Adding 80 kg N (N1) under barley cut after heading (cut2) revealed the lowest LER in both seasons. Meanwhile, the highest LER estimates recorded increasing by 17% and 16% in first and second seasons, respectively.

Results indicated that most treatments were positive; suggesting efficient utilization of land resource by growing both crops together under these treatments, especially adding 120 kg N (N3) under barley cut before heading (cut1) and no cut to obtain the most land equivalent ratio (LER) estimates.

3.3 Relative Crowding Coefficient (RCC)

Results in Table 9 indicate that relative crowding coefficient (RCC) were more than one and this means that all treatments achieved yield advantages than solid planting of sugar beet or barely. The highest yield advantage for RCC (89.49and 73.54) was recorded with Cut1 at 120 Kg N/fed. in both seasons respectively and the lowest value of RCC (3.91and 6.14) was showed by using Cut2 at 80 Kg N/fed. in both seasons respectively. These results are in accordance with those observed by [39], [40] and [41].These data reveal that canopy structure of Cut1 in Barely with 120N for intercropping with sugar beet, which reflected positively on decrease in the competitive pressure between them.

Table 9. Effect of the interaction between different barely cuts and nitrogen fertilizer levels on Relative Crowding Coefficient (RCC) and Aggressivity (Ag) across two seasons

Cut	N rates	Relative Crowding Coefficient (RCC)						Aggressivity (Ag)			
		2018/2019			2019/2020			2018/2019		2019/2020	
		K_{sugar} beet	K_{barley}	RCC	K_{sugar} beet	K_{barley}	RCC Total	Ag sugar beet	Ag barley	Ag sugar beet	Ag barley
No cut	N1 (80)	5.27	1.35	7.1	8.15	1.33	10.86	-0.05	+0.05	+0.31	-0.31
	N2 (100)	8.07	1.49	12.05	11.84	1.53	18.23	-0.07	+0.07	-0.05	+0.05
	N3 (120)	17.55	1.56	27.32	14.78	1.57	23.19	-0.02	+0.02	-0.04	+0.04
Cut1	N1 (80)	22.8	0.92	21.00	12.03	1.00	12.03	+0.31	-0.31	+0.31	-0.31
	N2 (100)	14.12	1.00	14.12	37.56	1.01	38.04	+0.32	-0.32	+0.37	-0.37
	N3 (120)	82.84	1.08	89.49	62.9	1.17	73.54	+0.34	-0.34	+0.28	-0.28
Cut2	N1 (80)	6.30	0.62	3.91	8.95	0.69	6.14	+0.49	-0.49	+0.50	-0.50
	N2 (100)	8.40	0.66	5.55	9.74	0.76	7.36	+0.51	-0.51	+0.45	-0.45
	N3 (120)	16.21	0.73	11.8	9.21	0.78	7.16	+0.52	-0.52	+0.43	-0.43

3.4 Aggressively (Ag)

Results presented in Table 9 indicates the effect of barley plant cuts and different nitrogen fertilizer rates on yield on aggressivity values of sugar beet and barely yields. It is known that an aggressivity value of zero indicates that, both component crops are equally competitive. For any other situation, both crops will have the same numerical value by positive for the dominant crop and negative for the dominated one. The greater the numerical value, the larger the differences in competitive abilities [38], [39], [40] and [41].

However, the positive sign for sugar beet in cut before heading and cut after heading and the negative one for Barely may be due to the ability of the shorter component to compete with the taller component for available nutrients, especially N in this respect. This further, emphasizes that sugar beet is able to acquire more resources than that Barely in the both seasons.

3.5 Monetary Benefits

3.5.1 Sugar beet root yield

Impact of intercropping sugar beet with barley was assessed by measuring the crop productivity under different barley cuts treatments with N rates and resultant impact on the net returns (Table 10). Sole cropping sugar beet showed the highest beet root yield 31.96 and 31.43 ton/fedin both seasons. It was observed that sugar beet fertilized with 120 kg N/fed gave the highest beet root yield either in sole crop or when intercropped with barley under barley cut before heading recording 31.48 and 30.82 ton/fed in both seasons. Meanwhile, companion barley sole gave yield 13.04 and13.22 ard/fed. However, adding 120 kg N (N3) with no cut gave yield 3.09 and 3.16 ard/fed.

3.6 Economic Evaluation

3.6.1 Cost of production and total income

3.6.1.1. Net return and benefit/ cost ratio

Results in (Table 10) showed economic evaluation of sugar beet intercropping with barely under cuts at different levels of nitrogen fertilizer practices. Both sole sugar beet and barley cultivation recorded the minimum cost of production. Total cost of sole sugar beet gave 12250 and 14290 LE/fed, respectively in both seasons. While, cost of sole barley was 10830 and 11250 LE/fed, respectively in the two seasons. On the other side, the highest total production cost (14300 and 15850 LE/fed) were recorded by barley fertilized with 120 kg N/fed and cutting before heading in both seasons. Total income and net return (LE/fed) for all intercropping treatments were found to be superior to solid cultures of sugar beet and barley as shown in Table (10).

Results cleared that the highest values of total income being 21388.7 LE/fed achieving the highest net return of 7288.7 LE/fed resulted from barley without cutting and adding 120 Kg N/fed fertilizer in the 1stseason, followed by total income by cutting barley before heading and applying of 120 N kg/fed. However, total income of 23818.3 LE/fed was attained the highest net return of 7968.3 LE/fed under cutting barley before heading and adding 120 Kg N/fed in the 2nd season, followed by total income under no cut and 120 Kg N/fed treatment. On the other side, the lowest values of total income and net return were 17536 and 3736 LE/fed in the 1stseason and 19738.7 and 4488.7 LE/fed in the 2ndseason, respectively that obtained by cutting barley plants after heading and adding 80 Kg N/fed.

3.7 Benefit Cost Ratio

Results presented in Table (10) revealed that no cut+N3 and cut1+N3 treatments achieved the highest net return in the 1st and 2nd seasons, respectively. The benefit/cost ratio recorded the highest value of 0.52 by adding120 kg N rate without cutting in the 1st season. The highest benefit/cost ratio was obtained in case of adding 120 Kg N/fed and cutting barely before heading being 0.50 in the 2nd season. Meanwhile, the lowest value of benefit/cost ratio was obtained by adding80 kg N/fed and cutting barley after heading recording 0.27 and 0.29 for the 1st and 2nd seasons, respectively.

Economically, companion intercropping barley with sugar beet under both treatments of adding120kg N rate without barley cutting and cutting barely before heading proved its superiority over other treatments under cropping and sole crops.

3.8 Treatment- Traits (TT) Agro-economically Biplot

The good tool graphical method, Treatment-Traits (TT) biplot was used to determine the

Table 10. Economic evaluation of sugar beet intercropped with barely under cuts and different levels of nitrogen fertilizer practices for seasons of 2018/19 and 2019/20

Cuts	N rates	Barely Grain yield (L.E)	Barely straw yield (L.E)	Sugar beet Root yield (L.E)	Sugar beet FW yield (L.E)	Total income/ fed (L.E.)	Cost /fed (L.E.)	Net return/ fed (L.E.)	Benefit/ Cost ratio (B/C)
2018/2019									
No cut	N1	2076.7	738	13336.7	3453.3	19604.7	13600	6004.7	0.44
	N2	2250.7	783	13833.3	3453.3	20320.7	13850	6470.7	0.47
	N3	2322.7	845	14916.7	3304.0	21388.7	14100	7288.7	0.52
Cut1	N1	1522.0	607.2	13980.0	1551.3	17660.3	13800	3860.7	0.28
	N2	1628.6	609.9	14678.3	2756.0	19673.0	14050	5623	0.40
	N3	1738.0	603.7	15738.3	2890.3	20970.7	14300	6670.7	0.47
Cut2	N1	1080.3	415.6	13333.3	2706.7	17536.0	13800	3736.0	0.27
	N2	1141.3	426.4	13911.7	3540.0	19021.7	14050	4971.7	0.35
	N3	1243.3	451.3	14836.7	3348.7	19880.0	14300	5580.0	0.39
Sole sugar beet culture				17578	2906	17484	12250	5231	0.43
Sole Barely		9782	3810			13592	10830	2763	0.26
2019/2020									
No cut	N1	2252.7	850.0	15449.3	2790.7	21343.0	15000	6343.0	0.42
	N2	2520.7	891.0	15629.2	2921.3	21962.0	15300	6662.0	0.44
	N3	2557.7	975.3	15940.3	3332.0	22805.0	15600	7205.0	0.46
Cut1	N1	1798.7	655.0	15884.0	2464.0	20801.3	15250	5551.3	0.36
	N2	1803.7	702.7	16731.0	3145.3	22382.3	15550	6832.3	0.44
	N3	2029.0	786.0	16952.8	4050.7	23818.3	15850	7968.3	0.50
Cut2	N1	1292.3	553.3	15167.2	2725.3	19738.7	15250	4488.7	0.29
	N2	1405.3	452.3	15324.8	3369.3	20552.0	15550	5002.0	0.32
	N3	1440.7	517.0	15702.5	4050.7	21710.7	15850	5860.7	0.37
Sole sugar beet culture				18858	3771.6	20215	14290	5925	0.41
Sole Barely		10705	4237			14943	11250	3963	0.35

FW: forage weight//fed (ton) for sugar beet

effects of the measured treatments on the multiple economic traits for both sugar beet and barley yield in the same biplot graph. In TT biplot, the treatment that combines several good agro-economical traits (highest yield + total income + net return) in its composition consider as the best treatment [28].

Average data over two seasons of the 9 different treatments (cuts* N fertilizer treatments combinations) were graphically representation as illustrated in Figure (1).TT biplot summarized interrelationships among measured treatments (cuts-fertilizer treatments) toward traits, explaining amount obtained of the total variation. The first two principal components for PC1 and PC2 explained 78.94% and 12.38%, together explained that there is about 91.32% of the total variation for the both crops economic traits across treatments Both PC's reflected more than 60% of the total variation, Then TT biplot model achieved the fit goodness [26].

Fig. 1 showed which (cuts -fertilizer combination) treatments combination-won- where-for for the both crops economic traits under intercropping. The treatment which occupied the biplot vertex position is known as vertex treatment. The vertex treatment for each sector had the greatest values for all traits falling within that sector that could be candidates for developing growth and intercropping return yield. It was noticed that, the treatments generated a biplot with C1N3, C0N3, C0N2, C0N1, C2N1 and C1N1 at the vertex of polygon (Fig. 1). These vertex treatments illustrated superior performance for the economic traits allocated within each sector. Among the vertex treatments C1N3(cut before heading + 120N supplements) revealed superior performance for the total income/fed (Income2), net return/fed (Net2),root yield price (Root1,2) and forage yield price (Forage2), indicating that these treatments could be exploited for the development these return yield in both crops economic traits. Then, C2N3 inhibit forming grains or straw to direct root and forage yield.

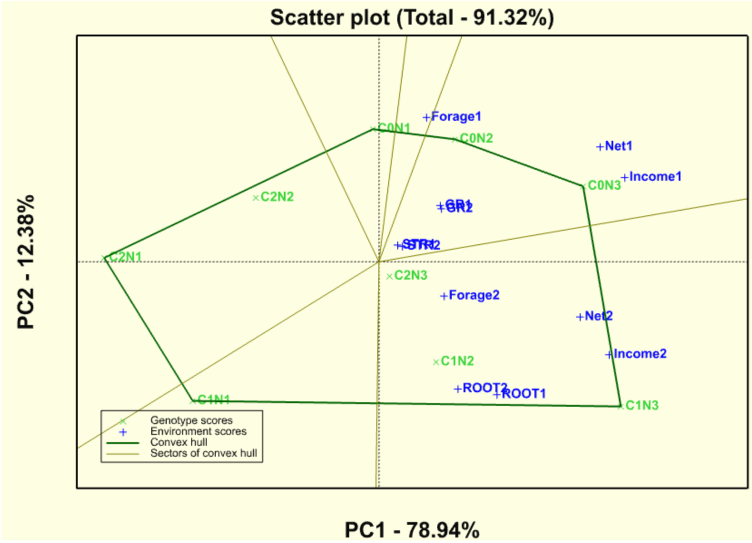

Fig. 1. Polygon (which won where) view of the sugar beet and barley treatment-by-trait (TT) agro-economically biplot of nine treatments for twelve economic traits, showing which treatment had the highest values for which traits

Where: *C0N, without cut + 80 unit of nitrogen; CON2, without cut + 100 unit of nitrogen; C0N3, without cut + 120 unit of nitrogen; C1N1, cut before heading + 80 unit of nitrogen; C1N2, cut before heading + 100 unit of nitrogen; C1N3, cut before heading + 120 unit of nitrogen; C2N1, cut after heading + 80 unit of nitrogen; C2N2, cut after heading + 100 unit of nitrogen; C2N3. cut after heading + 120 unit of nitrogen; Forage1, forage yield price for first season; Forage2, forage yield price for second season; Root1, root yield price for first season; Root2, root yield price for second season; GR1, grain yield price for first season; GR2, grain yield price for second season; STR1, straw yield price for first season; STR2, straw yield price for second season; Incom1, the total income/fed for first season; Incom2, the total income/fed for second season; Net1, net return/fed for first season; Net2, net return/fed for second season*

However, C0N3(without cut + 120N supplements) and C0N2(without cut + 100N supplements) cleared good behavior for the total income/fed (Income1) and Net return/fed (Net1) in the 1st season. Meanwhile, grain yield price (GR1,2) and straw yield price (STR1,2) in both seasons, suggesting that C0N3 and C0N2 may had role in enhancement the both barley grain and straw yield. The other cut- fertilizer treatments under intercropping C2N1(cut after heading + 80N supplements),C1N1(cut before heading + 80N supplements) and C1N1 (without cut + 80N supplements) treatments located in the left side of graph were not characterized for any trait. These treatments were the inferior for all measured traits. These results pointed to the decrease fertilizer (80N) may inhabit the yield-traits growth, suggesting that N-fertilizer was most importantly the root and grain productivity under different cuts treatments.

These results indicate that the view of TT bi-plot polygon is good in summarizing and explaining the interaction pattern between treatments and economic traits.

4. CONCLUSION

The previous results showed that the total yield of barley and sugar beet can be improved by adopting certain intercropping patterns. The calculated LER exceeded unity in most treatments, indicating that intercropping was advantageous due to higher exploitation of the limited environmental resources. Also, from results it could be recommended that planting intercropping barley with sugar beet under both treatments of adding 120 kg N rate without barley cutting (Cut0N3) and cutting barely before heading (Cut1N3) to obtain the maximum values in sugar beet growth, yield, and yield attributes, land usage, competitive relationships as well as total income and yield advantages of both crops under the climatic conditions of Gemmeiza district, Egypt.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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