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Effect of Flax and Faba Bean Intercropping with Sugar Beet on Yield, Quality and Land Use Efficiency

E.M. Abd El Lateef, B.A. Bakry, M.S. Abd El-Salam and A.S.M. Younis

Field Crops Research Dept., National Research Centre, 33 El-Behooth St., Giza, Egypt

Abstract: Two field experiments were conducted in winter seasons of 2017/18 and 2018/19 at the Experimental Farm of the National Research Centre, El-Behaira Governorate to study the effect of intercropping sugar beet with flax and faba bean in 2:2 and 2:4 intercropping patterns. The results showed that both intercropping patterns significantly surpassed solid plantings solid I and solid II in flax length of fruiting zone. Intercropping flax plants with sugar beet under 2:4 pattern attained the highest number of capsules and biological yield plant^{-1} than the other cropping patterns and exceeded the solid II planting, while the intercropping pattern 2:2 surpassed the solid I planting in straw and biological yields plant^{-1}. The relative yield increase of flax and faba bean seed yield plant^{-1} was 32 and 94 % and 22 and 21 % higher than those of solid II plants for 2:2 and 2:4 intercropping systems, respectively. Sugar beet yield of roots plant^{-1} under intercropping patterns 2:2 and 2:4 either with flax or faba bean exceeded that of solid plantings, especially solid II. The relative increase of sugar beet root yield plant^{-1} was 41 and 47 % higher than those of solid II plants due to intercropping patterns 2:2 and 2:4 with flax respectively while the corresponding values when intercropping was practiced with faba bean was 82 and 89 %. Intensive cropping of sugar beet through intercropping increased root yield plant^{-1} as compared with the recommended solid culture plants (solid I). Generally, flax fiber and oil yields as well as protein yield of faba bean fed^{-1} under intercropping patterns were less than the solid patterns SI and SII cropping patterns. Gross sugar yield fed^{-1} ranged between 1.94 to 5.26 and 1.99 to 3.419 ton fed^{-1} under different intercropping patterns with flax and faba bean, respectively while the extractable sugar yield ranged between 1.62 to 4.62 and 1.672 to 2.685 ton fed^{-1} under different intercropping patterns with flax and faba bean, respectively. The total LER (LER_{flax} + $LER_{sugar\ beet}$) was 1.03 and 1.14 and LER ($LER_{faba\ bean}$ + $LER_{sugar\ beet}$) was 9 and 24 % indicating that land use efficiency increased by 3 and 14 % under 2:2 and 2:4 intercropping patterns with flax while they were 9 and 24 % when intercropping was practiced with faba bean at 2:2 and 2:4 intercropping systems, respectively.

Key words: Intercropping · Sugar beet · Flax · Faba bean · Yield · Quality · Land Use Efficiency

INTRODUCTION

In Egypt, the agricultural intensification which includes crop rotation, relay intercropping and intercropping of major crops with other crops had become urgent necessity to optimize the utilizing of limited cultivated area and to maximize the monetary returns of unit area [1]. Several investigators reported agronomic advantage when sugar beet was intercropped with other winter crops like wheat [2, 3], barley [4] and faba bean [5, 6]. And others had been demonstrated many advantages of intercropping sugar beet with flax and faba bean. The intercropping system like sugar beet with cereals, sugar beet with oilseeds and or sugar beet with sugarcane could provide the farmer with high gross returns [7]. The cultivation of sugar beet through intercropping does not permit the land to develop hard pan and intercropping oilseeds or wheat reduced soil compaction [8] and stabilizes the situation regarding yields and economics returns from wheat and maize [9]. Salama *et al*. [10] intercropped faba bean with sugar beet and reported that grain yields of wheat and barley and seed yield of faba bean reached the maximum in the pure stands and reduced by reducing the intercropping percentages of the three companion crops. Values of LER were greater than 1.0 in any intercropping system of sugar

Corresponding Author: Dr. E.M. Abd El Lateef, Field Crops Research Dept., National Research Centre, 33 El-Behooth St., Giza, Egypt.

beet with wheat, barley and faba bean, indicating an advantage of the intercropping patterns for land usage and yield gain.

The intercropping system greatly contributes to crop production by its effective utilization of resources, as compared to the monoculture cropping system [11]. Farghaly *et al*. [5] reported that yield of sugar beet intercropped with onion, faba bean and chickpea were reduced by intercropping. The highest values for land equivalent ratio were observed by sugar beet intercropped with onion, while the lowest were found when sugar beet was intercropped with faba bean. Besheit *et al*. [12] showed that the highest sugar beet quality and productivity were obtained from sugar beet planted on ridges of 100 cm width and intercropped with two onion rows, while intercropping onion on the other side of sugar beet ridges of 50 cm width was higher and negativity affected sugar beet quality and quantity. Abdel Motagaly and Metwally [13] in their study focused on the relative advantage of intercropping systems of sugar beet with onion on the growth and yield, they reported that yield of sugar grown in monoculture was slightly high than obtained from any intercrop combination. The highest values of land equivalent ratio (LER) and gross return were observed when sugar beet intercropping with onion as compared to mono crops of either species and gave the highest economic return for the farmers. Badawy *et al*. [14] studied the effect of intercropping on sugar beet yield and yield components and quality and reported that the sole sugar beet produced the highest foliage, root, sugar percentage and total sugar. Chemical analysis of sugar beet revealed no significant differences among intercropping systems concerning with sodium, α-amino-nitrogen and potassium.

There are very few researches in relation to flax intercropping with sugar beet. Hussein and Metwally [15] studied the intercropping of sugar beet with flax. He indicated that intercropping flax at any seeding rate decreased the growth and hence the yield of sugar beet was almost reduced proportional to the sown proportion of flax where in all cases the intercropped yield and all of its attributes were lower than the solid planting of either sugar beet or flax. The land use efficiency, on absolute or time basis as expressed in land equivalent ratio (LER) or area time equivalent ratio (ATER) was increased when values of 1.56 and 1.44 due to intercropping flax using seed rate of 40 kg fed^{-1}.

Safina [16] intercropped flax with faba bean and reported that number of fruiting branches and capsules $plant^{-1}$, seed yields $plant^{-1}$ and ha^{-1}, straw and fiber yields ha^{-1} of flax were affected significantly by the cropping system. He indicated that solid planting of flax had higher number of branches and capsules $plant^{-1}$, seed yields $plant^{-1}$ and ha^{-1}, straw and fiber yields ha^{-1} than those of intercropping culture. In other words, intercropping of flax with faba bean decreased numbers of branches and capsules $plant^{-1}$ by 24.0 % and 32.8 %, respectively, than those of solid planting. Also, intercropping flax with faba bean decreased seed yields $plant^{-1}$ and ha^{-1} by 34.92 and 32.08 %, respectively, than those of solid planting. However, reversal magnitude was reported for solid planting due to the increase in reproductive growth of flax plant of solid planting which reflected positively on number of capsules $plant^{-1}$ and finally seed yield $plant^{-1}$. Moreover, solid planting of flax had higher seed oil content than those of intercropping culture. Land equivalent ratio (LER) ranged from 1.63 for intercropping flax with Giza-2 variety in ridges 60 cm width to 1.86 for intercropping flax with Giza-843 variety in ridges 120 cm width.

The objective of this work is to investigate the effect of different cropping systems for some crops (which competing with sugar beet in the new lands. Another objective of the study is to find a position of some crops on the road of extinction like flax in the crop structure in the new lands and growing the crops which reduces the nutritional gap of oils, legumes and sugars.

MATERIALS AND METHODS

Two field experiments were conducted in winter seasons of 2017/18 and 2018/19 at the Experimental Farm of the National Research Centre (latitude of 30.87° N and longitude of 31.17° E and mean altitude 21 m above sea level), El-Behaira Governorate. The experimental soil was sandy. The mechanical and chemical analysis of the soil are presented in Table (1).

Sugar beet var. Baraka, flax var. Sakha-2 and faba bean var Giza-843 were used in this study. The experiment included 6 treatments arranged in a Complete Randomized Block Design (RCBD) with three replications. The size of the experimental plot was 21.6 m^2, each plot contained 6 ridges (6 m long × 3.6 m width); two ridges were left without planting between each two plots to avoid border effect. The tested cropping patterns were distributed randomly in the experimental plots as follows:

Intercropping Patterns

- 2:2 pattern: planting two ridges of flax or faba bean alternating with two ridges of sugar beet.

Table 1: Mechanical and chemical analysis of experimental soil.

Sand %	Silt %	Clay %	pH	Organic matter, %	$CaCo_3$ %	E.C. dS/m	Soluble N, ppm	Available P, ppm	Exchangeable K, ppm
91.2	3.7	5.1	7.3	0.3	1.4	0.3	8.1	3.2	20

Table 2: The theoretical number of plant population densities under various cropping patterns.

Cropping pattern	Flax density m^{-2}	Faba bean fed^{-1}	Sugar beet density fed^{-1}
Flax or faba bean : Sugar beet			
2:2	1000	30000	30000
2:4	1365	20000	20000
Solid I	1500	30000	45000
Solid II	2000	60000	60000

- 2:4 pattern: planting two ridges of flax or faba bean alternating with four ridges of sugar beet. The first pattern provided 50 % of the area for flax faba bean or and 50 % to sugar beet, while the second pattern provided 33.3 % of the area for flax and 66.7 % for sugar beet.

Solid Cultures

Solid Sugar Beet Cultures

Solid I: Sugar beet was planted at the planting density 30,000 plants fed^{-1} by sowing sugar beet seeds in hills 20 cm and row width 70 cm on one side of the ridge.

Solid II: Sugar beet was planted at the planting density of 60,000 plants fed^{-1} by sowing sugar beet seeds in hills 20 cm at row width 70 cm on both sides of the ridge. The density adopted under intercropping patterns.

Solid Flax Cultures

Solid I: Flax was planted at rate of 1500 seeds m^{-2} (recommended practice) according to [17].

Solid II: Flax was planted at rate of 2000 seeds m^{-2}. The solid II plantings were applied to compare the relative performance of sugar beet and flax under solid and intercropping cultures.

Solid Faba Bean Cultures

Solid I: Faba bean was planted at the planting density 30,000 plants fed^{-1} by sowing faba bean seeds in hills 20 cm and row width 70 cm on one side of the ridge.

Solid II: Faba bean seeds were planted at the planting density of 60,000 plants fed^{-1} by sowing faba bean seeds in hills 20 cm at row width 70 cm on both sides of the ridge. The density adopted under intercropping patterns.

The theoretical number of sugar beet and flax plants under different cropping patterns are presented in Table (2).

Faba bean seeds were sown on 30^{th} October and 6^{th} November. Sugar beet seeds were sown on 14^{th} and 21^{th} of November, whereas, flax was planted two weeks later in both seasons of study. Fertilization with 31 kg P_2O_5 fed^{-1} in the form of mono calcium phosphate was carried out during seed bed preparation. The flax plants were thinned to the required densities before the 1^{st} irrigation. The sugar beet and flax were fertilized with 60 and 75 kg N fed^{-1} in the form of ammonium sulphate (20.6 % N), respectively, in two equal doses before the 1^{st} and 2^{nd} irrigation. Faba bean plants were fertilized with 31 kg P_2O_5, 60 kg N and 48 kg K_2O were applied.

The Recorded Data

Flax: Flax plants were pulled-up at full maturity and then left on the ground for air-drying. Capsules were removed carefully. At harvest the following characters were recorded on a random sample of ten guarded plants from each plot: Plant height (cm), fruiting zone length (cm), technical stem length (cm), number of fruiting branches $plant^{-1}$, number of capsules $plant^{-1}$, seed yield $plant^{-1}$ (g), biological yield $plant^{-1}$ (g). Seed yield $plant^{-1}$ (g), seed yield fed^{-1} (kg), straw yield fed^{-1} (t), biological yield fed^{-1} (t).

Fiber yield determination was carried out as follows:

Flax plants of m^{-2} were pulled at full maturity and then left on the ground for air-drying. Capsules were removed carefully and then retting was carried using warm water.

$$\text{Fiber percentage (\%)} = \frac{\text{Weight of fiber (gm)}}{\text{Weight of straw after retting (gm)}} \times 100$$

Then fiber percentage as multiplied by straw yield fed $^{-1}$ to obtain fiber yield fed $^{-1}$

Faba Bean: Faba bean plants were taken from three replicates and 10 plants were randomly taken from each treatment to estimate yield characters: plant height (cm), number of branches plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1}, seed, straw and biological yields plant^{-1}. Yield per feddan (t): number of plants in the experimental unit area were counted and seed weight of 3 × 3.5 m were determined, then total seed, straw and biological yields were calculated.

Sugar Beet: Plant samples were taken from three replicate and 10 plants were randomly taken from each treatment to estimate root characters: root length (cm), root diameter (cm), root weight (g) and top weight per plant (g). Yield per feddan (t): number of plants in the experimental unit area were counted and top and roots weights of 3 × 3.5 m were determined, then total yield was calculated.

Chemical Determinations: Chemical composition of the roots: a sample of 5 kg of each treatment was taken from the roots for analysis done by the sugar factory in El-Nubaria to determine.

- Gross sugar %: Juice sugar content, which was determined by means of an Automatic Sugar Polarimetric according to [18].
- Extractable white sugar %: Corrected sugar content (white sugar) of beets was calculated by linking the beet non-sugar K, Na and α-amino (expressed as a meq/100 g of beet) according to Harvey and Dutton [19] as follows:

$$ZB = pol - [0.343 (K + Na) + 0.094 AmN + 0.29]$$

where:

ZB = Corrected sugar content (% per beet) or extractable white sugar.

Pol = Gross sugar %.

AmN = α -amino-N determined by the “blue number method”.

- Loss sugar % = Gross sugar % - white sugar %.
- Juice purity percentage: Juice purity % (Qz) = ZB / Pol × 100

Soluble Non-sugar Content: The soluble non-sugars (potassium, sodium and α-amino nitrogen in meq/100 g of beet) in roots were determined by means of an Automatic Sugar Polari metric system. The results of these quality parameters were automatically calculated through the analyzer and the final results were tabulated and sugar yield fed^{-1} was calculated.

- Flax seed oil content was determined using Soxhlet apparatus and petroleum ether (40-60°C) according to [20].
- Faba bean protein yield was determined by determining nitrogen content in seeds according to [20], then multiplied by 6.25 to obtain protein percentage in seeds. Protein yield fed^{-1} was calculated by multiplying protein percentage in seeds by seed yield per feddan.

Land Equivalent Ratio (LER): The land equivalent ratio (LER) for both flax or faba bean and sugar beet was calculated as defined by Willey and Osiru [21] according to the following formula:

$$\text{LER flax or faba bean} = \frac{\text{Intercropped yield of flax or faba bean}}{\text{pure stand yield of flax or faba bean}}$$

$$\text{LER Sugar beet} = \frac{\text{Intercropped yield of sugar beet}}{\text{pure stand yield of sugar beet}}$$

$$\text{Total LER} = \text{LER}_{\text{flax or faba bean}} + \text{LER}_{\text{Sugar beet}}$$

Statistical Analysis: The analysis of variance of the Complete Randomized Block Design was carried out using MSTAT-C Computer Software [22]. After testing the homogeneity of the error according to Bartlett's test, the combined analysis for both seasons was done. Means of the different treatments were compared using the least significant difference (LSD) test at $P < 0.05$.

RESULTS AND DISCUSSION

Effect of Intercropping Sugar Beet with Flax: As presented in Table (3), significant differences were found among different cropping patterns in flax characters fruiting zone length (cm), seed straw and biological yields plant^{-1}, seed straw and biological yields fed^{-1} (kg). However, the differences among cropping patterns in Plant height (cm), technical stem length (cm) and number of fruiting branches plant^{-1} were insignificant. The performance of intercropped flax plants with sugar beet under 2:4 pattern show that it attained the highest number of capsules and biological yield plant^{-1} as compared with the other cropping patterns and exceeded the solid II planting. Regarding straw, seed, biological and oil yields fed^{-1} (Table, 3) it can be easily noticed that under the solid I pattern these criteria

Table 3: Effect of different cropping patterns on flax characteristics (combined means).

Cropping pattern Flax: Sugar beet	Plant height (cm)	Fruiting zone length (cm)	Technical stem length (cm)	No. of fruiting branches plant^{-1}	Biol. yield plant^{-1}	No. of capsules plant^{-1}	Seed yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biol. yield fed^{-1} (t)	Seed yield fed^{-1} (kg)	Straw yield fed^{-1} (t)
2:2	75.9	16.1	59.9	4.5	2.0	28.7	0.66	1.34	1.306	175.7	1.13
2:4	85.8	22.2	63.5	4.3	4.7	35.7	0.78	3.92	1.323	143.1	1.18
Solid I	80.9	20.3	60.6	4.7	5.6	21.0	0.68	4.95	2.802	501.6	2.30
Solid II	79.3	18.0	61.3	4.0	4.7	26.8	0.61	4.14	2.023	402.9	1.62
LSD at 0.05	NS	3.91	NS	NS	1.4	4.6	0.08	1.38	0.35	70.1	0.34

Table 4: Effect of different cropping patterns on sugar beet characteristics (combined means).

Cropping pattern Flax: Sugar beet	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Biological yield fed^{-1} (t)	Root yield fed^{-1} (t)
2:2	53.1	18.7	9.4	556.8	968.5	13.6	22.44
2:4	52.4	30.3	7.9	578.4	714.4	27.7	29.31
Solid I	45.5	25.6	6.3	538.2	527.5	51.4	34.94
Solid II	47.1	15.9	9.0	349.4	593.9	54.1	34.61
LSD at 0.05	5.9	12	2.3	92.2	66.4	6.2	7.35

significantly exceeded that under the intercropping patterns. Seed yield fed^{-1} under solid patterns surpassed that under the intercropping patterns. Such reduction under 2:2 pattern can be explained by only 50 % of the cultivated area was occupied by flax plants, whereas under 2:4 pattern only 33.3 % of the cultivated area was occupied by flax plants. For the same reason, the seed yield fed^{-1} under the intercropping pattern 2:2 surpassed that under the intercropping pattern 2:4 in these criteria. The obtained results are on the contrast of those obtained by Safina [16] who reported that Number of fruiting branches and capsules plant^{-1}, seed yields plant^{-1} and ha^{-1}, seed oil content, oil, straw and fiber yields ha^{-1} of flax were reduced significantly by the cropping system. Also, he added that solid planting of flax had higher ($P \le 0.05$) number of branches and capsules plant^{-1}, seed yields plant^{-1} and ha^{-1}, seed oil content, oil, straw and fiber yields ha^{-1} than those of intercropping culture. Meanwhile, intercropping flax with faba bean decreased numbers of branches and capsules plant^{-1} by 24.0 and 32.8 %, respectively, than those of solid planting. Also, intercropping flax with faba bean decreased seed yields plant^{-1} and ha^{-1} by 34.92 and 32.08 %, respectively, than those of solid planting. Moreover, solid planting of flax had higher seed oil content than those of intercropping culture. The obtained results agree with those obtained by [15]. They intercropped flax with sugar beet and reported that flax was intercropped in rows on the top of wide spaced sugar beet ridges and reported that flax seed index followed by the number of capsules plant^{-1} recorded the highest contribution to seed yield fed^{-1}, whereas fiber length and technical length had the greatest contribution to the fiber yield fed^{-1}. The reduction in flax yield fed^{-1} was almost proportional to the sown proportion of flax.

Sugar Beet: As presented in Table 4, significant differences were found among different cropping patterns in sugar beet yield studied characters. The data show that both intercropping patterns significantly surpassed solid plantings solid I and II in plant height, root length and diameter. The performance of intercropped sugar beet plants with flax under 2:2 and 2:4 patterns show that it reported the highest root yield plant^{-1} than the other cropping patterns and significantly exceeded the solid II planting. While the intercropping pattern 2:2 surpassed the solid I planting in biological yields plant^{-1}. From the same table, regarding sugar beet root and biological yields fed^{-1}, it can be easily noticed that under the solid I pattern such criteria significantly exceeded the yields under the intercropping patterns. Root yield per unite area under solid patterns surpassed the yields under the intercropping patterns. Such effect can be attributed to the proportion cultivated with sugar beet that under 2:2 pattern where only 50 % of the cultivated area was occupied by sugar beet plants, whereas under 2:4 pattern only 66.6 % of the cultivated area was occupied by sugar beet plants. For the same reason, the root yield fed^{-1} under the intercropping pattern 2:4 surpassed that under the intercropping pattern 2:2. Osman and Haggag [9] reported that although, root yield of sugar beet decrease with an increase in the number of rows of the intercrop, but no adverse effect sucrose yield was evident. Also, El-Dessougi *et al*. [23] observed that the yield of intercrops was nearly same when intercropped with sugar beet and higher overall productions were realized. On contrast, Masri and Safina [1] recorded that the lowest values of beet root yield and its attributes as well as sugar yield were recorded when sugar beet was intercropped with canola, However, this may be due to the high competition between sugar beet and canola on water,

Table 5: Effect of different cropping patterns on faba bean characteristics (combined means).

Cropping pattern Faba bean : Sugar beet	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	No. of seed plant^{-1}	Seed yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Seed yield fed^{-1} (kg)	Straw yield fed^{-1} (kg)	Biological yield fed^{-1} (kg)
2:2	58.9	3.1	6.3	19.5	11.2	8.2	19.4	400	324	724
2:4	64.7	3.7	7.5	25.0	11.1	10.2	21.3	265	280	544
Solid I	72.3	2.0	4.8	20.3	9.3	6.9	16.2	761	794	1555
Solid II	63.2	2.7	5.3	18.7	9.2	10.3	19.5	634	794	1428
LSD at 0.05	4.0	0.4	1.6	4.8	1.6	1.8	2.9	111.5	118.2	197

radiation and fertilization. The reduction in beet root yield was 29.78 % and 39.39 % when intercropped with canola, while it was 18.47 % and 17.22 % when intercropped with onion. Badawy *et al*. [14] reported that the sole sugar beet produced the highest foliage, root, sugar percentage and total sugar. Chemical analysis of sugar beet plants revealed no significant differences among intercropping systems concerning with sodium, Alpha amino-nitrogen and potassium.

Effect of Intercropping Sugar Beet with Faba Bean

A- Faba Bean: As presented in Table (5), significant differences were found among different cropping patterns in faba bean characters plant height (cm), number of pods plant^{-1}, seed yield plant^{-1} (g), straw yield plant^{-1}, biological yield plant^{-1} (g), seed yield fed^{-1} (kg), straw yield fed^{-1} (t) and biological yield fed^{-1} (t). The data show that intercropping pattern 2:4 significantly surpassed the solid plantings solid I and II in faba bean yield components number of pods plant^{-1}, seed yield plant^{-1} (g), straw yield plant^{-1}, biological yield plant^{-1} (g). The performance of intercropped faba bean plants with sugar beet under 2:4 pattern show that it attained the highest number of pods and biological yield plant^{-1} as compared with the other cropping patterns and exceeded the solid II planting.

Regarding straw, seed and biological yields fed^{-1} (Table, 5), it can be easily noticed that under the solid I pattern such criteria significantly exceeded that under the intercropping patterns. Seed yield fed^{-1} under solid patterns surpassed that under the intercropping patterns. Such effect is due to only 50 % of the cultivated area was occupied by faba bean plants under 2:2 pattern, whereas under 2:4 pattern only 33.3 % of the cultivated area was occupied by faba bean plants. So, the seed yield fed^{-1} under the intercropping pattern 2:2 surpassed that under the intercropping pattern 2:4. The obtained results are on the contrast of those obtained by Safina [16] who reported that solid planting of faba bean had higher number of branches and pods plant^{-1}, seed yields plant^{-1} and ha^{-1}, seed, straw and biological yields ha^{-1} than those of intercropping culture. At the same time, intercropping faba bean with sugar beet increased numbers of pods plant^{-1} by 19.0 and 42 %, respectively, than those of solid planting. Also, intercropping faba bean with flax increased seed yields plant^{-1} by 32 and 20 %, respectively, than those of solid I planting. The obtained results agree with those obtained by Hussein and Metwally [15] intercropped faba bean with sugar beet and reported that yield and its attributes of both components crops and their quality were affected. The results indicated that intercropping faba bean at any seeding rate decreased the growth and hence the yield of sugar beet. This decrease was almost proportional to the sown proportion of faba bean where in all cases the intercropped yield and all of its attributes were lower than the solid planting of either sugar beet or faba bean regarding the area cultivated. Salama *et al*. [10] intercropped faba bean with sugar beet and reported that grain yield of wheat and barley and seed yield of faba bean reached the maximum in the pure stands and reduced by reducing the intercropping percentages of the three companion crops. On the contrary, number of pods and 100-seed weight of faba bean followed an opposite magnitude and reduced by increasing the intercropping percentage.

B-Sugar Beet: Data in Table 6 show significant differences were found among different cropping patterns in sugar beet yield studied characters. The data show that both intercropping patterns significantly surpassed solid plantings I and II in plant height, root length and diameter. The performance of intercropped sugar beet plants with faba bean under 2:2 and 2:4 patterns show that it gave the highest root yield plant^{-1} than the other cropping patterns and significantly exceeded the solid II planting. Such superiority in the productivity of sugar beet plants may be due to the lesser competition between sugar beet and faba bean plants for light, water and nutrients as compared with the solid cropping as well as the nature of the companion crop as it is a leguminous crop which fix N essential to sugar beet especially under intercropping where intensive density is practiced. Similar findings were obtained by Abd El Lateef *et al*. [24] using maize cow pea intercrops. From the same table, regarding sugar beet root and biological yields fed^{-1}, it can be easily noticed that

Table 6: The yield characteristics of sugar beet as affected by various cropping patterns (combined means).

Cropping pattern Faba bean : Sugar beet	Stand thousand plants fed^{-1}	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1}	Total yield plant^{-1} (g)	Shoot yield fed^{-1} (t)	Root yield fed^{-1} (t)	Biological yield fed^{-1} (t)
2:2	12.0	55.0	15.0	5.2	320	337	3.5	12.8	16.3
2:4	15.3	46.0	29.3	5.0	333	357	1.3	18.0	19.3
Solid I	33.0	40.0	26.0	4.7	270	290	1.7	22.7	24.4
Solid II	37.0	39.3	10.6	3.9	176	186	1.2	21.1	22.3
LSD at 0.05	4.5	5.8	12.4	NS	90	74	NS	4.75	6.2

Table 7: The relative yield characteristics of flax or faba bean as affected by various cropping patterns (combined means).

	Flax								Faba bean							
Cropping pattern Flax or faba bean: Sugar beet	No. of capsules plant^{-1}	%	Straw yield Plant^{-1} (g)	%	Seed yield Plant^{-1} (g)	%	Biol. yield Plant^{-1} (g)	%	No. of pods plant^{-1}	%	Seed yield Plant^{-1} (g)	%	Straw yield Plant^{-1} (g)	%	Biol. yield Plant^{-1} (g)	%
2:2	28.7	107	1.35	32	0.66	108	2.01	44	6.3	119	11.2	122	8.2	80	19.4	99
2:4	35.7	133	3.92	94	0.78	128	4.70	104	7.5	142	11.1	121	10.2	99	21.3	109
Solid I	21.0	78	4.95	119	0.68	111	5.63	119	4.8	91	9.3	101	9.6	93	18.9	97
Solid II	26.8	100	4.14	100	0.61	100	4.75	100	5.3	100	9.2	100	10.3	100	19.5	100
LSD at 0.05	4.6		1.38		0.08		1.4		1.6		1.6		1.8		2.9	

under the solid I treatment significantly exceeded the yields under the intercropping patterns. Such effect can be explained that under 2:2 and 2:4 patterns by the lower area occupied by sugar beet where only 50 % and 66.6 % of the cultivated area was occupied by sugar beet plants, respectively. Whereas under pattern only of the cultivated area was occupied by faba bean plants. For the same reason, the root yield fed^{-1} under the intercropping pattern 2:4 surpassed the yields under the intercropping pattern 2:2.

Relative Yield: Relative yield per plant is an approach to measure the advantage or disadvantage of intercropping where the intercropped plants are grown with the intensification adopted as in solid II plants (The intensified plant density). The intensified plant performance under intercropping is expected to increase or decrease as a result of dominant or dominated crop in the cropping pattern.

Generally, it is obvious that the seed yield of intercropping patterns 2:2 and 2:4 exceeded that of solid plantings, especially solid II (Table, 7). The relative performance of flax seed yield plant^{-1} was 8 and 28 % higher than those of solid II plants due to intercropping. Meanwhile, the yield of seeds of solid II treatment was similar to those of solid I treatment. Intensive cropping of flax through intercropping increase the seed yield plant^{-1} as compared with that of the recommended solid culture (solid I). Such superiority in the productivity of flax plants may be due to the lesser competition between flax and sugar beet plants for light, water and nutrients as compared with the solid cropping. Similar findings were obtained by Abd El Lateef *et al.* [25] using maize-mung bean intercrops.

The relative yield data of faba bean show that yield of seeds with intercropping patterns 2:2 and 2:4 exceeded that of solid plantings, especially solid II (Table, 7). The relative increase of faba bean seed yield plant^{-1} was 22 and 21 % higher than those of solid II plants due to intercropping (Table, 7). Meanwhile, the yield of seeds of solid II treatment was similar to those of solid I treatment. Intensive cropping of faba bean through intercropping increased the seed yield plant^{-1} as compared with that of the recommended solid culture (solid I). Such superiority in the productivity of faba bean plants may be due to the micro climate conditions occurred through the deeper free spaces which decrease the inter plant competition of faba bean plants which led to lesser competition between faba bean and sugar beet plants as compared with the solid cropping. Similar findings were obtained by Abd El Lateef *et al.* [25] using maize-mung bean intercrops.

Data in Table (8) show that the yield of roots plant^{-1} with intercropping patterns 2:2 and 2:4 exceeded solid I and II treatments. The relative increase of sugar beet root yield plant^{-1} when intercropped with flax and faba bean was 41 and 47 % and faba bean 82 and 89 %, higher than those of solid II plants due to intercropping patterns 2:2 and 2:4 respectively, meanwhile, the corresponding values of biological yield plant^{-1} of solid II treatment were 63 and 20 % for flax and 81 and 92 % higher than those of solid II plants for the intercropping patterns 2:2 and 2:4 respectively. Such superiority in the productivity of intercropped sugar beet with flax plants may be due to the lesser competition between sugar beet and flax plants for environmental resources which decreased the intra plant competition between the two crops as compared with the solid cropping. Furthermore, it could be concluded that

Table 8: The relative yield characteristics of sugar beet as affected by various cropping patterns (combined means).

	Flax								Faba bean							
Cropping pattern Flax or faba bean : Sugar beet	Root yield Plant^{-1} (g)	(%)	Biol. yield plant^{-1} (g)	(%)	Root yield fed^{-1} (t)	(%)	Biol. yield fed^{-1} (t)	(%)	Root yield plant^{-1} (g)	(%)	Biol. yield plant^{-1} (g)	(%)	Root yield fed^{-1} (t)	(%)	Biol. yield fed^{-1} (t)	(%)
2:2	557	141	969	163	22	36	14	25	320	182	337	181	12.8	61	16.3	69
2:4	578	147	714	120	29	61	28	50	333	189	357	192	18.0	85	19.3	87
Solid I	538	136	528	89	35	101	51	95	270	153	290	156	22.7	108	24.4	109
Solid II	349	100	594	100	35	100	54	100	176	100	186	100	21.1	100	22.3	100
LSD at 0.05	92	-	66	-	7		6	-	90	-	74	-	4.8	-	6.2	-

Table 9: Effect of cropping patterns on sugar beet quality parameters.

Cropping pattern Flax: Sugar beet	Pol %	Qz %	K %	Na %	aN %	Ext. %
2:2	15.58	83.83	3.19	2.41	3.29	13.06
2:4	15.70	80.02	4.16	3.03	4.05	12.56
Solid I	15.06	78.53	4.64	3.31	3.43	11.83
Solid II	15.06	78.53	4.64	3.40	3.43	11.83

Table 10: Effect of cropping patterns on sugar yield (combined means).

	Flax					Faba bean		
Cropping pattern Flax or faba bean : Sugar beet)	Gross sugar %	Extractable %	Seed yield (kg)	Fiber yield fed^{-1} (kg)	Oil yield fed^{-1} (kg)	Gross sugar %	Extractable %	Protein yield fed^{-1} (kg)
2:2	1.94	1.62	175.7	182	72.41	1.99	1.67	92
2:4	3.35	2.68	143.1	189	53.0	2.83	2.26	61
Solid I	5.26	4.13	501.6	322	185.6	3.42	2.69	175
Solid II	5.21	4.09	402.9	259	149.1	3.18	2.50	152
LSD at 0.05	0.9	0.65	70.5	37	21.1	0.88	0.59	24

intensive cropping of sugar beet through intercropping may increase the root yield plant^{-1}as compared with that of the recommended solid culture (solid I).

Sugar Yield: Data presented in Table (9) show that cropping patterns exhibited clear differences in sugar beet quality parameters, which affected sugar extraction. The data show that sugar beet intercropping with flax exhibited clear differences in quality parameters which affected sugar extraction. The minimum sugar % in beet roots expressed as polarity % ranged between 15.06 and 15.7 % with an average of 15.38 %. The highest gross and extractable sugar beet yield resulted from the solid plantings I and II (Table 10). Moreover, it can be noticed that the high purity percentage expressed as (Qz %) under intercropping patterns shared in the partial compensation of the extractable sugar yield. Gross and extractable sugar yield fed^{-1} area under solid patterns surpassed that under the intercropping patterns. Such effect can be explained that under 2:2 pattern where only 50 % of the cultivated area was occupied by sugar beet plants, whereas under 2:4 pattern only 33.3 % of the cultivated area was occupied by sugar beet plants. Gross sugar yield fed^{-1} ranged between 1.94 to 5.26 and 1.99 to 3.419 ton fed^{-1} under different intercropping patterns with flax and faba bean, respectively (Table 10). From the same table extractable sugar yield ranged between 1.62 to 4.62 and 1.672 to 2.685 ton fed^{-1} under different intercropping patterns with flax and faba bean, respectively the reduction in sugar yield fed under intercropping than the solid plantings are due to the area cultivated. Salama *et al.* [10] indicated that the sugar yield of sugar beet decreased with increasing the companion crop percentage in case of the three companion crops in both growing seasons. The sugar beet pure stands produced 7.34 and 7.41 ton sugar yield ha^{-1} in 2013 and 2014, respectively. This amount was around 1.5 to 2.9 tons higher than that produced with the lowest companion crop percentage. Amer *et al.* [26]; Abo Mostafa *et al.* [27] and Aboukhadra *et al.* [28] they attributed this reduction in sugar beet traits to the increased intra- and inter-crop competition between the sugar beet, as a main crop and the high densities of the companion crops. However, the sucrose % of the main crop, sugar beet, was significantly affected by the companion crop percentage in the cropping pattern.

Flax Fiber and Oil Yields and Faba Bean Protein Yield: Data presented in Table (10) show significant differences among cropping patterns in flax fiber and oil yields fed^{-1}.

Table 11: The land equivalent ratios (LER) of flax or faba bean-sugar beet under different intercropping patterns (combined means).

Cropping pattern Flax: Sugar beet	Flax : Sugar beet			Faba bean : Sugar beet		
	LER_{flax}	$LER_{sugar\ beet}$	Total LER (LER_{flax} + $LER_{sugar\ beet}$)	$LER_{faba\ bean}$	$LER_{sugar\ beet}$	Total LER $LER_{faba\ bean}$ + $LER_{sugar\ beet}$)
2:2	0.39	0.64	1.03	0.53	0.56	1.09
2:4	0.29	0.85	1.14	0.35	0.79	1.24
Solid I	1.00	1.00	1.00	1.00	1.00	1.00
LSD at 0.05	0.07	0.02	0.11	0.16	0.13	0.13

Generally, fiber and oil yields under intercropping patterns were less than the solid patterns SI and SII due to the less proportional area under intercropping. It is worthy to note that flax plants cultivated under 2 2 and 2:4 patterns produced similar fiber yield fed-1 although the area under intercropping was 50 and 33 % for the two cropping patterns. This may be due to the greater number of branches formed and greater straw yield plant^{-1} under 2:4 intercropping pattern. Similar tendency was recorded for protein yield fed^{-1} of faba bean. Under solid planting protein yield was greater than the intercropped plants and solid I achieved the highest protein yield fed¬.

Land Equivalent Ratio (LER): The land equivalent ratio (LER) is the phenomenon of over yielding, which was reported by [29]. It means that if LER was more than the unity (LER > 1) an over-yielding phenomenon is occurred and land usage increased and vice versa.

Data presented in Table (11) indicate that LER was greater than the unity (LER > 1) under the two intercropping patterns. The values of LER of each component of flax LER $_{flax}$ and sugar beet LER $_{sugar\ beet}$ were significantly affected by intercropping patterns; as well as the total LER (LER_{flax} + $LER_{sugar\ beet}$). The intercropping pattern of 2:4 had a higher significant value of LER than that of 2:2 pattern. Data in Table (11) show that partial LER for flax (LER_{flax}) were 0.39 and 0.29 while partial LER for sugar beet ($LER_{sugar\ beet}$) were 0.64 and 0.85 for 2:2 and 2:4 intercropping, respectively. The total LER (LER_{flax} + $LER_{sugar\ beet}$) was 1.03 and 1.14 indicating that land use efficiency increased by 3 and 14 % under 2:2 and 2:4 intercropping patterns, respectively.

Data in Table (11) show that partial LER for faba bean ($LER_{faba\ bean}$) were 0.53and 0.35 while partial LER for sugar beet ($LER_{sugar\ beet}$) were 0.56 and 0.79 for 2:2 and 2:4 intercropping, respectively. The total LER ($LER_{faba\ bean}$ + $LER_{sugar\ beet}$) was 1.09 and 1.24 indicating that land use efficiency increased by 9 and 24 % under 2:2 and 2:4 intercropping patterns, respectively. An agronomic advantage had been demonstrated when sugar beet was intercropped with other winter crops like wheat [2, 3] barley [4] and faba bean [5, 6]. Salama *et al*. [10] intercropped faba bean with sugar beet and reported that LER were greater than 1.00 in any intercropping system of sugar beet with wheat, barley and faba bean, indicating an advantage of the intercropping patterns for land usage and yield gain.

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REFERENCES

1. Masri, M.I. and S.A. Safina, 2015. Agro-economic impact of intercropping canola and onion on some sugar beet varieties under different nitrogen rates. J. plant Production, Mansoura Univ. Egypt, 6(10): 1661-1678.
2. Attia, A.N.E., E.M. Said, M.H. Ghonima and M.E.M. Ibrahim, 2007. Impact of nitrogen levels on growth and yield of sugar beet intercropped with faba bean and wheat. J. Agric. Sci., Mansoura Univ., Egypt, 32: 779-792.
3. Aboukhadra, S.H., S.A. Badawy, E.A.T. Salah and D.E.E. El-Shireef, 2013b. Effect of intercropping system of wheat with sugar beet on their productivity and land use. J. Agric. Res., Kafr El-Sheikh Univ. Egypt, 39: 37-54.
4. Khedr, A.H. and E.A.E. Nemeat-Alla, 2006. Response of barley to intercropping with sugar beet under different nitrogen fertilization levels. J. Agric. Sci., Mansoura Univ., Egypt, 31: 4957-4968.
5. Farghaly, B.S., A.A. Zohry and A.A. Bassal, 2003. Crops management for intercropping sugar beet with some essential crops to maximize area unit productivity. J. Agric. Sci., Mansoura Univ. Egypt, 28: 5183-5199.

6. Gadallah, R.E., A.M. Abdel-Galil and F.R. Nawar, 2006. Maximizing productivity by intercropping some winter crops on sugar beet. J. Agric. Sci. Mansoura Univ. Egypt, 31: 4957-4968.
7. Lal, M. and N. Mukerji, 1998. Productivity of intercropping system in sugarcane with sugar beet and wheat. Madras Agric. J., 80(4): 177-179.
8. Gazdag, L., 2000. The returns to wheat, maize, sunflower and sugar beet in the KSZE production system. Gazdálkodás, 32(11): 46-48.
9. Osman, M.S. and M.E.A. Haggag, 2000. A study on the feasibility of intercropping sugar beet with other winter crops. Res. Bul., Fac. Agric., Ain Shams Univ., Egypt, pp: 1-7.
10. Salama, Dina S.A., El-S. El-Karamity and A.I. Nawar, 2016. Additive Intercropping of wheat, barley and faba bean with sugar beet: impact on yield, quality and land use efficiency. Egypt. J. Agron., 38(3): 413-430.
11. Zhang, F.S. and L. Li, 2003. Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. Plant Soil, 248: 305-312.
12. Besheit, S.Y., A.M. Abo Elwafa, A.S. Abo El-Hamd and M.A. Bekheet, 2002. Quality and productivity of sugar beet as affected by intercropping onion in various densities. Al-Azhar J. Agric. Res., 36: 87-101.
13. Abdel Motagally, F.M.F. and A.K. Metwally, 2014. Maximizing productivity by intercropping onion on sugar beet. Asian J. Crop Sci., 6(3): 226-235.
14. Badawy, Shimaa A.E. and G.A. Shalaby, 2015. Effect of intercropping of sugar beet with onion and garlic on insect infestation, sugar beet yield and economics. J. Plant Production, Mansoura Univ., 6(6): 903- 914.
15. Hussein, M.M. and S.A. Metwally, 2012. Effect of intercropping flax in different seeding rates in fields of sugar beet under nitrogen fertilization levels on yield, quality and land use efficiency attributes. Zagazig J. Agric. Res., 39: 9-29.
16. Safina, S.A., 2017. Effect of ridge width and cropping system on productivity and land use efficiency in faba bean-flax intercrops Egypt. J. Agron., 39(3): 357-381.
17. Kandil, A.A., A.A. Hob Allah, D.M. El-Hariri, M.S. Zeidan and B.A. Bakry, 2008. Effect of seeding rate on yield and quality traits of some flax varieties (*Linum usitatissmum* L.) grown in newly reclaimed sandy soils. Egypt. J. Appl. Agric. Res. (NRC), 1(1): 69-81.
18. McGinnus, R.A., 1971. Sugar Beet Technology. 2nd Ed. Sugar Beet Development Foundation, Fort., Color, U.S.A.
19. Harvey, G.W. and J.V. Dotton, 1993. Root quality and processing. In: Cooke D.A., Scott R.K. (eds): The Sugar Beet Crop Science into Practice. London, Chapman & Hall, pp: 571-617.
20. A.O.A.C., 1990. Official Methods of Analysis. 20*th* edition. Association of Official Analytical Chemists, Arlington, Virginia, U.S.A. (No.920.39).
21. Willey, R.W. and D.S. Osiru, 1972. Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular references to plant population. J. Agric. Sci., 79: 519-529.
22. MSTAT-C 1988. MSTAT-C, a microcomputer program for the design, arrangement and analysis of agronomic research. Michigan State University, East Lansing.
23. El-Dessougi, H., A. Dreele and N. Claassen, 2003. Growth and phosphorus uptake of maize cultivated alone, in mixed culture with other crops or after incorporation of their residues. J. Pl. Nut. Soil Sci., 166(2): 254-261.
24. Abd El Lateef, E.M., M.S. Abd El-Salam, S.F. El-Habbasha and M.A. Ahmed, 2015. Effect of maize - cowpea intercropping on light interception, yield and land use efficiency. Int. J. Chem. Tech. Res., 8(6): 556-564.
25. Abd El Lateef, E.M., M. Hozayn and Magda H. Mohamed, 2010. Effect of maize-mungbean intercropping on light interception, yield and land use efficiency. Bull. NRC, 35(2): 169-184.
26. Amer, M.I., M.M. Radi, K.A. Ali and S.S. Zalat, 1997. Intercropping faba bean (*Vicia faba* L.) cultivars to three sowing dates under different plant densities in North Delta. J. Agric. Res., Tanta Univ. Egypt, 18: 591-599.
27. Abou Mostafa, R.A.I., El. El-Abbas, E.M. Rabie and Kh.A. Aboshady, 2012. Agronomic and economic evaluation for some patterns of intercropping faba bean with sugar beet under two sowing dates. J. Agric. Res., Kafr El-Sheikh Univ. Egypt, 38: 443-457.
28. Aboukhadra, S.H., S.A. Badawy, S.E.A. Toaima and D.E.E. El-Shireef, 2013a. Effect of intercropping system of faba bean with sugar beet on their productivity and land use. Minufiya J. Agric. Res. Egypt, 38: 1501-1518.
29. Francis, C.A., 1986. Introduction: Distribution and Importance of Multiple Cropping. Pages 1-20 in Multiple cropping systems (Francis, C.A., ed.). Macmillan Publ. Co., New York, USA.