INTERCROPPING WHEAT AND FABA BEAN WITH SUGAR BEET IN RELATION TO PRODUCTIVITY AND WATER USE EFFICIENCY

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ABSTRACT

A two-year study was carried out at Sids Agric. Res. Station, Beni-Sweif Governorate, Egypt during 2012/2013 and 2013/2014 winter seasons. The objective of the present research was to evaluate intercropping wheat (*Triticum aestivum* L.) and faba bean (*Vicia faba* L.) with sugar beet (*Beta valgaris* L.) in relation to productivity and water use efficiency as well as economical-feasibility. The ridge width (60 and 120 cm) was allotted in vertical strips and cropping systems (12.5 and 25%) for the intercropping crops were horizontal strips. The results from field experiment intercropping either wheat or faba bean with sugar beet decreased yields of all tested crops in comparison with sole plantings of these crops. Intercropped wheat with sugar beet had severe negative effect on root yield of sugar beet and its attributes than intercropped faba bean with sugar beet. Intercropping wheat or faba bean with sugar beet (25%) on raised-bed (120 cm) increased land equivalent ratio (LER) (1.14 or 1.25). The values of aggressivity for wheat and faba bean were positive (dominant) and sugar beet was negative (dominated). The highest values of applied irrigation water and water consumptive use were recorded at intercropped wheat or faba bean on the 3rd and 4th ridges (60 cm) of sugar beet in the two growing seasons. Intercropping wheat or faba bean with sugar beet on raised-bed (120 cm) gave the highest water use efficiency (W.U.E.) for cereal units in the two seasons. The net return of intercropping wheat or faba bean with sugar beet in all treatments of the two seasons, respectively, was higher compared to sole planting of sugar beat or wheat or faba bean.

Key words: Intercropping; *Beta valgaris* L.; *Triticum aestivum* L.; *Vicia faba* L.; Competitive relationships, Water use efficiency and Net return.

INTRODUCTION

Increasing crops productivity and saving irrigation water are two interrelated issues raising a lot of concern in Egypt. Legume/cereal intercropping pattern is generally more productive than sole crop (**Tsubo and Ogindo 2005**). Furthermore, the biological basis for intercropping involves complementarily of resources used by the two crops (**Barhom, 2001**). However, little work has been done on the effect of reducing the amount of applied irrigation of sugar beet, wheat and faba bean yields under different intercropping patterns. **Lamlom and Ewis (2015)** found that highest values of seasonal water applied (m^3 $fed.^{-1}$) and water consumptive use (cm $fed.^{-1}$) were observed in 2:2 maize/soybean pattern compared to raised-bed 140 cm pattern in the two seasons. On the other hand, the highest values for water use efficiency, i-e.,

1.00, 1.01 in the first season and 0.98 and 1.00 in the second season (cereal units cm^{-1}) water consumed due to raised-bed (120 and 140 cm) patterns was observed, respective.

Sugar beet (*Beta vulgaris* L.) is one of the most important crops not only in Egypt but also all over the world. It can be irrigated with about one-fourth the water utilized by sugar cane. Sugar beet production could be increase through appropriate agronomic practices. Sugar beet cultivated area reached to about 193,482 ha in 2012 season with an average yield of 51.91 t ha^{-1}, while the other strategic winter food crops such as wheat and faba bean (*Vicia faba* L.) which their cultivated area reached about 1419275 and 44082 ha with an average yield of 6.66 and 3.53 t ha^{-1} in 2012 season, respectively, **(Bulletin of The Agricultural Statistics, 2013).** Production and water relations of sugar beet has been widely investigated by many researchers; **Howeil, *et al.* (1987)** and **Ibrahim, *et al.* (1993)** showed that irrigation every two or three weeks, especially for the second half of the growing season of the sugar beet resulted in high yield. The values of water consumptive use were 58.06, 55.04 and 49.86 cm for the 2, 3 and 4 weeks intervals, respectively.

Mixed intercropping pattern with sugar beet is considered highly valuable in regards of net benefits from the same piece of land. It is common practiced when cereals, grain legumes, and root crops are grown together and when little or no tillage is required **(Akinola and Agboola, 1981)**, but the choice of the intercropped crops and plant density of the crops are critical factors for successful mixed intercropping pattern. The selected crops and plant density of the crops per unit area must be complement each other rather than compete of each other with sugar beet yield and consequently the monetary benefits were higher in lentil intercropping as compared to cereals intercropping system. **Atia, *et al.* (2007)** showed that intercropping systems with sugar beet significantly reduced sugar beet traits except sucrose and purity percentages while wheat or faba been intercropped with sugar beet was significantly affected by intercropping systems in both seasons. On the other hand, **El-Kassaby and Leilah (1992)** stated that high yields of roots and sugar were obtained with planting beets on both sides of ridges 70 cm width, 25 cm apart (48000 plants/4200 m^2). **El-Skaikh and Bekheet (2004)** and **Gadallah, *et al.* (2006)** recoded that different intercropping systems of faba bean or wheat with sugar beet resulted in gross return per unit area compared with growing these crops in pure stand.

The objective of the present study was to evaluate intercropping wheat and faba bean with sugar beet on growth, yield, agro–feasibility and water use efficiency.

MATERIALS AND METHODS

A two-year study was carried out at Sids Agricultural Research Station, Beni-Sweif governorate (Middle Egypt, Lat. 29° 04' N, Long. 31° 06' E and 30.40 m above the sea level), during 2012/2013 and 2013/2014 winter seasons to study intercropping wheat (*Triticum aestivum* L.) and faba bean (*Vicia faba* L.) with sugar beet *(Beta valgaris* L.) in relation to growth, productivity and water use efficiency. The soil of the experimental sites was clay loam in texture, with water table level using observation well was ranged between 1.75-1.95 m. EC and pH of the soil in the saturated soil paste were 0.5 dSm^{-1} and 7.9, respectively. The level of available N,P and K were 33.5, 11.7 and 218.5 ppm. respectively and organic matter of 1.6 % **(Jackson, 1967).**

Sugar beet variety 'Cleopatra' and two different field crops, i-e., wheat variety 'Beni-Sweif 1' and faba bean variety 'Misr 1' were used.

1- Ridge Width

W_1 = 60 cm. width

W_2 = 120 cm. width

2- Cropping Systems

S_1

Growing sugar beet on one side of all ridges (60 cm width) with growing wheat in two rows on the other side of the 4th ridge of sugar beet or growing sugar beet on both sides of beds (120 cm width) and growing wheat in two rows on the middle of the 2nd bed (12.5%).

S_2

Growing sugar beet on one side of all ridges (60 cm width) with growing faba bean in one row on the other side of the 4th ridge or growing sugar beet on both sides of beds (120 cm width) and growing faba bean in one row on the middle of the 2nd bed (12.5%).

S_3

Growing sugar beet on one side of all ridges (60 cm width) and growing wheat in two rows on the other side of the 3rd and 4th ridges or growing sugar beet on both sides of beds (120 cm width) and growing wheat in four rows on the middle of the 2nd bed (25%).

S_4

Growing sugar beet on one side of all ridges (60 cm width) and growing faba bean in one row on the other side of the 3rd and 4th ridges or growing sugar beet on both sides of beds (120 cm width) and growing faba bean in two rows on the middle of the 2nd bed (25%).

Sole planting :

Sugar beet: growing on one side of ridges 60 cm width (recommended).

Wheat: growing eight rows on bed (120 cm width).

Faba bean: growing on both sides of the ridge (60 cm width).

Sugar beet, wheat and faba bean cultivars kindly provided by Research Departments at Agricultural Research Center (ARC), Giza, Egypt. A strip-plot design was used. Ridge width was allotted in vertical strips and cropping systems for the intercropping crops were horizontal strips. In addition to individual sole planting each of wheat, faba bean and sugar beet. Each plot included 10 ridges (60 cm width) or 5 beds (120 cm width) and 7 m length (42 m^2).

Sugar beet was sown on 25 and 28th October seasons respectively, and were thinned to one plant/hill spaced at 20 cm under intercropping and sole planting and harvested in 18th and 20th May. While both wheat and faba bean were sown at 20th and 25th November and harvested in 15th and 20th Apr. in 2012/2013 and 2013/2014 seasons, respectively. Faba bean was grown as two plants/hill spaced 20 cm under intercropping and sole plantings. Wheat was grown in rows on back of bed surface spaced 15 cm between rows. Nitrogen fertilizer was applied as Urea (46%N), phosphorus as calcium super phosphate (15% P_2O_5) and potassium as potassium sulfate (48% K_2O). Phosphorus was added before planting, whereas nitrogen and potassium were added in three equal dozes; the first doze after thinning (thirty days after sowing), second and third doze 30 and 60 days after thinning. Recommended sole plantings of all the tested crops were used to estimate the competitive relationships. The preceding summer crop was maize in both seasons. Cultural practices for growing all crops were practiced as recommended.

Data recorded in these study:-

A) Yield and its attributes

At harvest, root length and diameter (cm), root weight/plant (kg), total soluble solids 'T.S.S.' and sucrose (%) were measured on ten guarded plants from each sub plot, meanwhile, root yield/ha (t) was recorded on the basis of sub plot area. Grain yield of wheat per ha (t) and seed yield of faba bean per ha (t) were recorded also on the basis of sub plot area.

B) Competitive relationships

1. Land equivalent ratio (LER)

LER defined as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield (**Mead and Willey 1980**). It is calculated as follows:

$LER = (Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb})$

Where: Y_{aa} = Pure stand yield of crop a (sugar beet)

Y_{bb} = Pure stand yield of crop b (wheat or faba bean)

Y_{ab} = Intercrop yield of crop a (sugar beet)

Y_{ba} = Intercrop yield of crop b (wheat or faba bean)

2. Aggressivity (A).

Aggressivity value was calculated by the formula proposed by **Mc- Gilichrist (1965).**

$$A_{ab} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

Where: A_{ab} = Aggressivity value for the components "a".

Y_{aa} is pure stand yield of crop a, Y_{bb} is pure stand yield of crop b, Y_{ab} is mixture yield of a (when combined with b) and Y_{ba} yield of b (when combined with a).

Z_{ab} is sown proportion of species a (in a mixture with b) and Z_{ba} is sown proportion of species b (in a mixture with a).

C) Soil-water relations:

Soil moisture content was gravimetrically determined in soil samples, which were taken from consecutive depth of 15 cm down to a depth of 60 cm. Soil samples were also collected just before each irrigation, 48 h after irrigation, and at harvest. Field capacity was determined according to **Garcia (1978).** Permanent wilting point and bulk density were estimated according to **Black, *et al.* (1985)** to a depth of 60 cm. Available soil moisture was calculated by subtracting wilting point from field capacity. The average values are presented in Table (1).

Table (1): Field capacity, wilting point, available soil moisture content and bulk density of the experimental fields.

Season	Soil depth (cm)	Field capacity (%)	Wilting point (%)	Available soil moisture (%)	Bulk density g/cm^3
First	0-15	42.40	20.00	22.40	1.176
	15-30	35.90	18.80	17.10	1.244
	30-45	33.45	15.00	18.45	1.251
	45-60	31.71	14.50	17.21	1.431
Mean		35.86	17.08	18.79	1.276
Second	0-15	44.56	22.17	22.39	1.170
	15-30	37.09	17.66	19.43	1.299
	30-45	35.55	17.92	18.63	1.357
	45-60	33.19	15.80	17.39	1.379
Mean		37.60	18.14	19.46	1.301

Applied water was controlled throughout pipe irrigation of Water Requirement and Field Irrigation Research Department at Sids by the use of value for each plot and water measured by measuring meter.

Water consumptive use (C.U.) was calculated according to **Israelson and Hansen (1962)** as follows:

$$C.U. = \sum_{i=1}^{i=4} \frac{P_{w2} - P_{w1}}{100} \times Bd \times Di$$

where:

C.U. = water consumptive use in (cm) in effective root zone (60 cm).
i = Number of soil layer (15 cm).
P_{w1} = Soil moisture percentage before irrigation.
P_{w2} = Soil moisture percentage, 48 hours after irrigation.
Bd = Soil bulk density (g/cm^3) for this depth.
Di = Soil layer depth (15 cm).

To simplify the comparison between different intercropping patterns on the basis of yield and water use efficiency, the yield of wheat, faba bean and root of sugar beet under intercropping was changed to cereal units **(Brockhaus, 1962).** This method stated that each 100 kg of wheat grains equals to 1.00 cereal unit, 100 kg of faba bean seeds equals to 1.20 cereal unit and 100 kg of root sugar beet equals to 0.25 cereal unit. Thus, the units of wheat, faba bean and sugar beet were added together for each intercropping pattern and used in the calculation of water use efficiency **(Vites, 1965).**

Water use efficiency (WUE) values were calculated for the different treatments by dividing yield in cereal units by consumptive use (C.U.).

$$WUE = Y/C.U.$$

Y = Main product yield (cereal units/ha)
C.U. = Seasonal consumptive use (cm)

D. Farmer's benefit:

Total cost and net return of intercropping culture as compared to recommended sole planting of sugar beet were determined.

1. Total return of intercropping cultures = Price of sugar beet yield + price of wheat or faba bean yield (Egyptian Pound). To calculate the total return, the average of sugar beet and wheat or faba bean prices presented according to the **Bulletin of The Agricultural Statistics (2013).**
2. Net return per ha = Total return – (fixed cost of sugar beet + variable costs of wheat or faba bean according to intercropping pattern).
3. The average of prices of main products are L.E. 386.4, 2576.0 and 4709.6 for ton of sugar beet, wheat and faba bean respectively in 2012 and 2013 seasons.
4. The average of prices of by products are L.E. 200, 608 and 480 for ton of top sugar beet, straw for wheat and faba bean, respectively in 2012 and 2013 seasons.
5. Total costs L.E./ha 10458, 11445 and 11291 for solid sugar beet, wheat and faba bean, respectively.
6. Total costs of intercropped wheat or faba bean with sugar beet = total costs of sugar beet + costs of wheat or faba bean.
7. Costs of intercrop wheat: 273&553 L.E./ha for two and four rows, costs of intercrop faba bean : L.E./ha 560 &1120 for one and two rows, respectively.

Statistical Manipulation

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (**Freed, 1991**). Mean comparisons were done using least significant differences (L.S.D) method at 5% level of probability to compare differences between the means (**Gomez and Gomez, 1984**).

RESULTS AND DISCUSSION

A. Yield and its attributes

1- Ridge width

a. Wheat

Data in Table (2) indicate that ridge width had a significant effect on all traits of sugar beet and straw yield of wheat except grain yield of wheat in both seasons and their combined. Data revealed that decreasing ridge width from 120 to 60 cm increased sugar beet root diameter, root weight per plant, root and top yield per ha, meanwhile, it decreased root length, T.S.S., sucrose percentage and straw yield for wheat per ha. Obviously, decreasing ridge width from 120 to 60 cm increased ($P \leq 0.05$) sugar beet productivity per unit area. On the other hand, grain yield per ha was not affected by ridge width in the first and second seasons and combined analysis of the two seasons.

Table (2): Effect of ridge width on sugar beet and its attributes and wheat yield in the two growing seasons and their combined analysis.

Ridge width (cm)	2012 / 2013								
	Root length (cm)	Root diameter (cm)	Root weight / plant (kg)	Yield of Sugar beet (t/ha)		T.S.S. (%)	Sucrose (%)	Yield of Wheat (t/ha)	
				Root	Top			Grain	Straw
W_1	25.0	11.0	1.04	69.24	28.89	21.2	17.3	1.41	1.82
W_2	25.6	10.8	0.96	67.28	25.13	21.4	17.4	1.43	2.14
$LSD_{0.05}$	0.3	0.1	0.02	0.80	0.63	0.1	0.05	N. S	0.08
Solid	28.3	11.7	1.23	73.75	39.25	20.2	17.1	8.30	13.79
	2013 / 2014								
W_1	26.0	11.3	1.11	70.38	30.07	22.5	17.5	1.43	1.99
W_2	26.7	11.1	1.04	69.58	27.10	22.8	17.6	1.44	2.43
$LSD_{0.05}$	0.3	0.1	0.03	0.39	0.29	0.1	0.04	N. S	0.12
Solid	29.0	11.9	1.29	75.26	39.92	20.8	17.3	8.18	14.75
	Combined data of the two seasons								
W_1	25.5	11.1	1.07	69.81	29.48	21.9	17.4	1.42	1.91
W_2	26.1	11.0	1.00	68.43	26.11	22.1	17.5	1.44	2.29
$LSD_{0.05}$	0.3	0.1	0.03	0.60	0.41	0.1	0.04	N. S	0.10
Solid	28.7	11.8	1.26	74.50	39.59	20.5	17.2	8.24	14.27

W_1=width 60 cm of ridge *W_2 = width 120 cm of ridge*

These results may be due to ridge width of 60 cm produced greater number of leaves unit area of sugar beet than ridge width 120 cm. Accordingly, ridge width of 60 cm may be contributed positively to higher photosynthesis in sugar plant than those grown on the other one that reflected on root length and diameter, as well as, root weight per plant. These results are in parallel with those obtained by **Ahmed *et al.* (2010)**.

a. Faba bean

Data in Table (3) reveal that the trend of all traits of sugar beet intercropped with faba bean under different ridges width and straw yield of faba bean per ha were similar to those of sugar beet intercropped with wheat at the same ridge width.

Table (3): Effect of ridge width on sugar beet and its attributes and faba bean yield in the two growing seasons and their combined analysis.

Ridge width (cm)	Root length (cm)	Root diameter (cm)	Root weight/ plant (kg)	Yield of Sugar beet (t/ha)		T.S.S. (%)	Sucrose (%)	Yield of Faba bean (t/ha)	
				Root	Top			Seed	Straw
	2012 / 2013								
W_1	27.2	11.4	1.15	72.12	29.58	21.3	17.4	0.86	1.84
W_2	27.7	11.1	1.03	70.91	25.33	21.5	17.6	0.85	1.95
LSD 0.05	0.4	0.1	0.03	0.77	0.42	0.1	0.1	N. S	0.07
Solid	28.3	11.7	1.23	73.75	39.25	20.2	17.1	4.08	9.53
	2013 / 2014								
W_1	28.1	11.6	1.26	72.80	31.57	22.6	17.6	0.99	2.33
W_2	28.7	11.4	1.10	72.33	27.97	22.8	17.8	1.03	3.30
LSD 0.05	0.3	0.1	0.02	0.34	0.55	0.1	0.1	N. S	0.14
Solid	29.0	11.9	1.29	75.26	39.92	20.8	17.3	4.28	10.50
	Combined data of the two seasons								
W_1	27.6	11.5	1.20	72.46	30.58	21.9	17.5	0.93	2.09
W_2	28.2	11.2	1.06	71.57	26.65	22.2	17.7	0.94	2.63
LSD 0.05	0.3	0.1	0.02	0.56	0.49	0.1	0.1	N. S	0.11
Solid	28.7	11.8	1.26	74.50	39.59	20.5	17.2	4.18	10.01

2- Cropping systems

a. Wheat

Intercropping wheat with sugar beet significantly affected the studied traits of sugar beet in the two seasons and the combined analysis of the two seasons (Table 4). Intercropping wheat with sugar beet decreased root length and diameter, root weight per plant, top and root yield per ha. However it increased T.S.S. and sucrose percentages in comparison with sole sugar beet. Similar results were reported by **El-Shaikh and Bekheet (2004), Gadallah *et al.* (2006) and Attia *et al.* (2007).**

Also, data showed that the highest sugar beet root and top yield per ha was obtained when grown as a solid plants in both seasons and the combined analysis. The root yield was decreased by 5.22%, 5.73% and 4.53% and the top yield decreased by 24.48%, 33.33% and 24.75% when wheat intercropped with sugar beet at 12.5% (S_1). However, the root yield was decreased by 8.61% , 7.81% and 8.20% and the top yield decreased by 37.91%, 31.82% and 34.83% when wheat intercropped with sugar beet at 25% (S_3) in the first and second seasons and the combined analysis, respectively.

Table (4): Effect of cropping systems on sugar beet and its attributes and wheat yield in the two growing seasons and their combined analysis.

Cropping system	Root length (cm)	Root diameter (cm)	Root weight / plant (kg)	Yield of Sugar beet (t/ha)		T.S.S. (%)	Sucrose (%)	Yield of wheat (t/ha)	
				Root	Top			Grain	Straw
	2012 / 2013								
S_1	26.1	11.3	1.07	69.50	29.64	21.1	17.3	1.03	1.46
S_3	24.4	10.5	0.93	67.02	24.37	21.4	17.5	1.82	2.51
LSD 0.05	1.4	0.4	0.11	2.34	1.47	0.3	0.1	0.71	0.58
Solid	28.3	11.7	1.23	73.75	39.25	20.2	17.1	8.30	13.79
	2013 / 2014								
S_1	26.8	11.6	1.15	70.76	29.94	22.5	17.5	1.01	1.53
S_3	25.9	10.9	1.01	69.20	27.22	22.8	17.7	1.87	2.90
LSD 0.05	0.8	0.3	0.10	1.49	1.16	0.2	0.1	0.73	0.66
Solid	29.0	11.9	1.29	75.26	39.92	20.8	17.3	8.18	14.75
	Combined data of the two seasons								
S_1	26. 5	11.4	1.10	70.83	29.79	21.8	17.4	1.02	1.49
S_3	25.2	10.7	0.97	68.11	25.80	22.1	17.6	1.84	2.71
LSD 0.05	1.2	0.3	0.11	1.93	1.32	0.2	0.1	0.72	0.62
Solid	28.7	11.8	1.26	74.50	39.59	20.5	17.2	8.24	14.27

S_1 = Growing sugar beet on one side of all ridges (60 cm width) with growing wheat in two rows on the other side of the 4th ridge of sugar beet and growing sugar beet on both sides of beds (120 cm width) and growing wheat in two rows on the middle of the 2nd bed (12.5%).
S_3 = Growing sugar beet on one side of all ridges (60 cm width) and growing wheat in two rows on the other side of the 3rd and 4th ridges and growing sugar beet on both sides of beds (120 cm width) and growing wheat in four rows on the middle of the 2nd bed (25%).

Increasing wheat row number from two to four decreased sugar beet root yield per ha by 3.57, 2.21, 2.88% and top yield by 17.78%, 9.08% and 13.93% in the first and second seasons and the combined analysis, respectively. On the other hand, decreasing plant population of wheat intercropped with sugar beet decreased grain yield per unit area. This reduction reached to 87.59, 87.654 and 87.90% and decreased straw yield by 89.41%, 89.63% and 89.56% when wheat intercropped with sugar beet at 12.5% (S_1), whereas, by 78.07%, 7.14% , 78.17% and decreased straw yield by 81.80%, 80.34%, and 81.01% when wheat intercropped with sugar beet at 25% (S_3) in first and second seasons and their combined analysis, respectively. These results were supported by **Abdel-Galil *et al.* (2014).**

b. Faba bean

Data in Table (5) indicate that intercropping faba bean with sugar beet had negative significant effects on yield components and yield of sugar beet and faba bean in the two seasons and their combined analysis. Intercropping faba bean with sugar beet had slightly negative effects on yield of sugar beet under intercropping conditions. Yield per ha of sugar beet was decreased by 1.17, 2.57and 1.87% and top yield decreased by 22.88%, 20.79%and 21.85% when faba bean intercropped with sugar beet at 12.5% (S_2), and by 3.78, 4.21 and 3.99% and top yield decreased by 37.22%, 30.06 % and 33.62% when faba bean intercropped with sugar beet at 25% (S_4). in the first and second seasons and the combined analysis, respectively. Similar

results were reported by **Toaima (2006).** Legumes in close association with nitrophilous crops have increased crop production **(Waghmare and Singh, 1984),** because of their ability to biological nitrogen fixation, legumes are largely involved in nitrogen facilitation and nitrogen dynamic in the plant community and in agro systems **(Hauggaard-Nielsen and Jensen, 2005 and Fustec *et al.* 2010).** These results are in accordance with those obtained by **Abdel-Galil *et al.* (2014)** who concluded that intercropping sugar beet with faba bean had little negative effect on root yield.

Table (5): Effect of cropping systems on sugar beet and its attributes and faba bean yield in the two growing seasons and their combined analysis.

Cropping systems	Root length (cm)	Root diameter (cm)	Root weight/ plant(kg)	Yield of Sugar beet (t/ha)		T.S.S. (%)	Sucrose (%)	Yield of Faba bean (t/ha)	
				Root	Top			Seed	Straw
	2012 / 2013								
S_2	27.9	11.5	1.15	72.47	30.27	21.2	17.4	0.60	1.24
S_4	26. 9	10.0	1.04	70.56	24.64	21.5	17.6	1.11	2.56
LSD 0.05	0.5	0.1	0.05	1.38	1.14	0.3	0.2	0.44	0.72
Solid	28.3	11.7	1.23	73.75	39.25	20.2	17.1	4.08	9.53
	2013 / 2014								
S_2	28.8	11.8	1.22	73.13	31.62	22.6	17.6	0.73	1.43
S_4	27.9	11.3	1.13	71.90	27.92	22.9	17.8	1.31	3.93
LSD 0.05	0.4	0.2	0.06	1.16	0.84	0.3	0.1	0.48	0.91
Solid	29.0	11.9	1.29	75.26	39.92	20.8	17.3	4.28	10.50
	Combined data of the two seasons								
S_2	28.4	11.6	1.18	72.80	30.94	21.9	17.5	0.67	1.33
S_4	27.4	11.1	1.08	71.23	26.28	22.2	17.7	1.21	3.25
LSD 0.05	0.5	0.2	0.07	0.92	0.99	0.3	0.2	0.47	0.86
Solid	28.7	11.8	1.26	74.50	39.59	20.5	17.2	4.18	10.01

S_2 = Growing sugar beet on one side of all ridges (60 cm width) with growing faba bean in one row on the other side of the 4th ridge of sugar beet and growing sugar beet on both sides of beds (120 cm width) and growing faba bean in one row on the middle of the 2nd bed (12.5%).

S_4= Growing sugar beet on one side of all ridges (60 cm width) and growing faba bean in one row on the other side of the 3rd and 4th ridges and growing sugar beet on both sides of beds (120 cm width) and growing faba bean in two rows on the middle of the 2nd bed (25%).

Increasing faba bean intercrop row number from one to two under intercropping planting decreased root yield per ha by 2.64 ,1.68 and 2.16 % and decreased top yield per ha by 18.60%, 11.70% and 15.06% in first and second seasons and the combined analysis, respectively.

Also, data in Table (5). reveal that decreasing plant population density of faba bean when intercropped with sugar beet decreased seed yield per ha by 85.29, 82.94 and 83.97% and decreased straw yield per ha by 86.99%,86.38% and 86.71% when faba bean intercropped with sugar beet at 12.5% (S_2), whereas, the reduction reached to 72.79%, 69.39%and 71.05% and 73.14%, 62.57% and 67.53% when faba bean intercropped with sugar beet at 25% (S_4) in first and second seasons and their combined analysis, respectively. Similar results were obtained by **Abou -Elela and Gadallah (2012)** who indicated that seed yield of faba bean per unit area was significantly reduced due to intercropping with fodder beet as compared with faba bean solid culture.

B. Competitive relationships

1. Land Equivalent Ratio (LER)

The data in Table (6 A and B) indicate that all the values of LER which obtained, in 2012/2013 and 2013/2014 seasons exceeded the unit. In general, intercropping wheat or faba bean with sugar beet increased LER as compared to sole sugar beet. It ranged from 1.07 due to intercropping two rows of wheat with sugar beet on ridges (60 or 120 cm) to 1.25 due to intercropping two rows of faba bean with sugar beet on beds (120 cm). The advantage of the highest LER by intercropping faba bean with sugar beet over the others could be due to faba bean plants (as legume crop) have ability to biological nitrogen fixation, legumes are largely involved in nitrogen facilitation and nitrogen dynamic in the plant community and in agro systems. It is clear that plant population density of faba bean and sugar beet played a major role in increasing productivity per unit area under intercropping planting where it reached 25 and 100 % of sole planting, respectively. Similar results were obtained by **Abdel-Galil *et al.* (2014)** who found that intercropping faba bean with sugar beet gave higher LER than those of intercropping sugar beet with wheat.

Table (6-A): Effect of ridge width and cropping systems of wheat intercropped with sugar beet on competitive relationships in (combined data across 2012/2013 and 2013/2014).

Ridge width (cm)	Cropping systems	Yield (t/ha)		Relative Yield (RY)		LER	Aggressivity	
		Sugar beet	Wheat	Sugar beet	Wheat		Sugar beet	Wheat
W_1	S_1	70.83	1.01	0.95	0.12	1.07	-0.04	+0.04
	S_3	68.79	1.83	0.92	0.22	1.14	+0.04	-0.04
W_2	S_1	69.43	1.03	0.94	0.13	1.07	-0.08	+0.08
	S_3	67.43	1.86	0.91	0.23	1.14	+0.01	-0.01
Solid		74.50	8.24	----	----	----	----	----

2. Agressivity

The data in table (6-A). show that the aggressivity of wheat were negative while values of sugar beet were positive. This main that sugar beet was the dominant intercrop where as wheat was the dominated when wheat intercropped by 25% from the total density with sugar beet on ridges 60 or 120 width. On the other hand the wheat were positive while values of sugar beet were negative where as wheat was the dominant when wheat intercropped by 12.5% from the total density with sugar beet on ridges 60 or 120 width. This main that sugar beet was the dominated intercrop

Table (6-B): Effect of ridge width and cropping systems of faba bean intercropped with sugar beet on competitive relationships in (combined data across 2012/2013 and 2013/2014).

Ridge width (cm)	Cropping systems	Yield (t/ha)		Relative Yield (RY)		LER	Aggressivity	
		Sugar beet	Faba bean	Sugar beet	Faba bean		Sugar beet	Faba bean
W_1	S_2	73.25	0.68	0.98	0.16	1.14	-0.37	+0.37
	S_4	71.67	1.18	0.96	0.28	1.24	-0.20	+0.20
W_2	S_2	72.36	0.65	0.98	0.16	1.14	-0.32	+0.32
	S_4	70.79	1.23	0.96	0.29	1.25	-0.27	+0.27
Solid		74.50	4.18	----	----	----	----	----

On other hand, in table(6-B) showed that when faba bean intercropped with sugar beet, the highest aggressivity values were apparent by intercropping faba bean on one row of faba bean with sugar beet on ridges of 60 cm width. Sugar beet was the dominated crop whereas faba bean was the dominant in all traits. These results were similar to those obtained by **Waffa Mohamed *et al.* (2005).**

C. Soil-water relations :

Applied irrigation water (A.I.W., m^3/ha)

In arid regions, where water is the limiting factor in the expansion of cultivated area, the management strategy of limited irrigation is to optimize production per unit of water applied rather than to maximize yield per unit of land. Applied irrigation water values are shown in Tables (7 and 8). The obtained results indicated that the highest values of irrigation water applied in the 1st and 2nd seasons (7910.2 and 8180.4 m^3/ha) and (7920.1 and 8215.5 m^3/ha) for intercropped wheat and faba bean, respectively, were recorded at growing sugar beet on one side of ridges (60 cm) and growing wheat in two rows or faba bean in one row on the other side of the 3rd and 4th ridge of sugar beet. The lowest values of applied water (6765.5 and 6920.2 m^3/ha) and (6697.1 and 6975.3 m^3/ha) were obtained with intercropped wheat in two rows or faba bean one row on the middle of the 2nd beds (120 cm) of sugar beet in the first and second seasons, respectively. Therefore, the saved irrigation water applied were (14.1 and 14.6%) and (14.7 and 14.6%) in the first and second seasons, respectively, when intercropped wheat or faba bean with sugar beet on raised beds (120 cm) compared with intercropped on ridges (60 cm). These results are in harmony with those obtained by **Lamlom and Ewis (2015).**

Table (7): Units of cereal, applied irrigation water (m^3/ha) consumptive use (cm) and water) use efficiency (units/cm) under different wheat/sugar beat intercropped patterns in the two growing seasons.

Ridge width (cm)	Cropping systems	Main product yield (cereal units/ha)			A. I. W. (m^3/ha)	C.U. (cm)	W.U.E. (units/cm)
		Sugar beet	Wheat	Total			
First season							
W_1	S_1	176.1	10.2	186.3	7870.3	68.4	2.72
	S_3	170.1	18.0	188.1	7910.2	68.8	2.۷۳
Mean		173.1	14.1	187.2	7891.3	68.6	2.73
W_2	S_1	171.4	10.3	181.7	6765.5	61.6	2.95
	S_3	165.0	18.4	183.4	6797.1	61.9	2.96
Mean		163.2	14.4	182.6	6781.3	61.8	2.96
Mean	S_1	173.8	10.3	184.0	7317.9	65.0	2.84
	S_3	167.6	18.2	185.8	7353.7	65.4	2.85
Solid sugar beet		184.4	00.0	184.4	7513.6	65.1	2.83
Solid wheat		000.0	83.0	83.0	5847.3	55.7	1.49
Second season							
W_1	S_1	178.1	10.0	188.1	8110.5	70.6	2.66
	S_3	173.9	18.6	192.5	8180.4	71.5	2.69
Mean		176.0	14.3	190.3	8145.5	71.1	2.68
W_2	S_1	175.8	10.2	186.0	6920.2	62.1	3.00
	S_3	172.2	18.7	190.9	6995.7	63.4	3.01
Mean		174.0	14.5	188.5	6958.0	62.8	3.01
Mean	S_1	177.0	10.1	187.1	7515.4	66.4	2.83
	S_3	173.1	18.7	191.7	7588.1	67.5	2.90
Solid sugar beet		188.2	00.0	188.2	7706.0	66.5	2.83
Solid wheat		000.0	81.8	81.8	5717.3	54.4	1.50

Cereal unit : 100 kg roots of sugar beet = 0.25 unit *100 kg grain of wheat = 1.00 unit*

Consumptive use (C.U., cm) :

Water consumptive use is defined as the water lost from the plant organs, specially leaves surface and namely transpiration, besides that evaporated from the soil surface during the entire growing season. The data in Tables (7 and 8) clearly show that the mean values of water consumptive use during the studied growing seasons were affected by cropping systems. Data revealed that the highest values were recorded when growing sugar beet on one side of the ridge (60 cm) and growing wheat in two rows or faba bean in one row on the other side of the 3rd and 4th ridges of sugar beet in the two growing seasons. This may due to, the more available soil moisture through increasing the irrigation water applied gave a chance for more consumption of water. However, the lowest value of water consumption was found with the treatment that growing sugar beet on both sides of the beds (120 cm) and growing wheat in two rows or faba bean in one row on the middle of the 2nd bed of sugar beet in both seasons.

Table (8): Units of cereal, applied irrigation water (m^3/ha) consumptive use (cm) and water use efficiency (units/cm) under different faba bean/sugar beat intercropped patterns in the two growing seasons.

Ridge width (cm)	Cropping systems	Main product yield (cereal units/ha)			A. I. W. (m^3/ha)	C.U. (cm)	W.U.E. (units/cm)
		Sugar beet	Faba bean	Total			
First season							
W_1	S_2	182.7	7.4	190.1	7890.1	69.5	2.74
	S_4	177.9	13.1	191.0	7920.1	69.7	2.74
Mean		180.3	10.3	190.6	7905.1	69.6	2.74
W_2	S_2	179.7	6.8	186.5	6697.1	60.2	3.10
	S_4	174.9	13.4	188.3	6785.4	61.1	3.08
Mean		177.3	10.1	187.4	6741.3	60.7	3.09
Mean	S_2	181.2	7.1	188.3	7293.6	64.9	2.92
	S_4	176.4	13.3	189.7	7382.8	65.4	2.91
Solid sugar beet		184.4	00.0	184.4	7513.6	65.1	2.٨٣
Solid faba bean		000.0	49.0	49.0	4663.2	34.5	1.42
Second season							
W_1	S_2	183.6	8.8	192.3	8131.2	70.6	2.٧2
	S_4	180.5	15.2	195.7	8215.5	71.9	2.٧2
Mean		182.1	12.0	194.0	8173.4	71.3	2.72
W_2	S_2	182.1	8.8	190.9	6975.3	61.2	3.12
	S_4	179.1	16.1	195.1	6990.7	62.8	3.11
Mean		180.6	12.5	193.0	6983.0	62.0	3.12
Mean	S_2	182.9	8.8	191.6	7553.3	65.9	2.92
	S_4	179.8	15.7	195.4	7603.1	67.4	2.92
Solid sugar beet		188.2	00.0	188.2	7706.0	66.5	2.8٣
Solid faba bean		000.0	51.4	51.4	4575.5	33.5	1.54

Cereal unit : 100 kg root of sugar beet = 0.25 unit 100 kg seeds of faba bean = 1.20 unit

Water use efficiency (W.U.E., units/cm) :

Water use efficiency is considered as the evaluation parameter of the obtained yield (cereal units) per each unit of water consumed (cm). The illustrated data presented in Tables (7 and 8) reveal that intercropping wheat or faba bean with sugar beet planting

on top of raised bed (120 cm) irrigation practice at all intercropping systems gave higher W.U.E. for cereal units, while it was lower under other intercropping patterns and pure-stand of sugar beet or wheat or faba bean in the two growing seasons. Each unit of water consumed about 2.96 and 3.01 cereal units/cm for intercropped wheat and 3.10 and 3.12 for intercropped faba bean when planting sugar beet on both sides of the beds (120 cm) and growing wheat in four rows or faba bean in one row on the middle of the 2nd bed of sugar beet in both seasons, respectively. On the other hand growing sugar beet on one side of the ridges (60 cm) with growing wheat in two rows or faba bean in one row on the other side of the 4th ridge of sugar beet consumed 2.72 and 2.66 for wheat and 2.74 and 2.72 for faba bean cereal units/cm in the two seasons, respectively. These results are similar to those found by **Lamlom and Ewis (2015).**

D. Farmer's benefit

Intercropping wheat with sugar beet increased total and net return by about 1.43 and 0.43% respectively, as compared with recommended sole sugar beet, meanwhile intercropping faba bean with sugar beet increased total and net returns by 6.48 and 5.86%, respectively, as compared with sole sugar beet in the combined data across 2012/2013 and 2013/2014 seasons (Table 9).

Table (9): Financial return as affected by cropping systems and their interactions (combined data across 2012/2013 and 2013/2014).

Treatments	Intercrop		Financial return (L.E./ha)						
	Ridge width (cm)	System	Sugar beet		Intercrop		Total income	Cost	Net
			Root	Top	Yield	Straw			
Sugar beet + Wheat	W_1	S_1	27363	6435	2597	702	37097	10731	26366
		S_3	26579	5356	4711	1620	38266	11011	27255
	Mean		26971	58956	3654	1161	37682	10871	26811
	W_2	S_1	26824	5482	2653	1112	36071	10731	25340
		S_3	26054	4963	4788	1669	37474	11011	26463
	Mean		26439	5223	3721	1391	36773	10871	25902
Mean of cropping system		S_1	27094	5959	2625	907	36584	10731	25853
		S_3	26317	5160	4750	1645	37870	11011	26859
		Mean	26706	5560	3688	1276	37227	10871	26356
Sugar beet + Faba been	W_1	S_2	28301	6698	3199	642	38840	11018	27822
		S_4	27692	5533	5551	1359	40135	11578	28557
	Mean		27997	6116	4375	1001	39488	11298	28190
	W_2	S_2	27958	5680	3059	767	37464	11018	26446
		S_4	27349	4980	5789	1756	39874	11578	28296
	Mean		27654	5330	4424	1262	38669	11298	27371
Mean of cropping system		S_2	28130	6189	3129	705	38152	11018	27134
		S_4	26833	5257	5670	1558	40005	11578	28427
		Mean	27482	5723	4400	1132	39079	11298	27781
Sugar beet sole planting			28787	7918	----	----	36702	10458	26244
Wheat sole planting			----	----	21224	8676	29900	11445	18455
Faba been sole planting			----	----	19684	4805	24489	11291	13198

Net return of intercropping wheat or faba bean with sugar beet reached to L.E. per ha 26356 and 27781 respectively, as compared with recommended sole sugar beet (L.E. per ha 26244). The study suggests that growing two rows of wheat or one

row of faba bean on the third and fourth ridges of sugar beet (60 cm) is more profitable to farmers than recommended sole sugar beet. These results are in harmony with those obtained by **Abdel-Galil *et al.* (2014)** who showed that intercropping faba bean with sugar beet is more profitable to farmers than sugar beet solid culture by using suitable intercropping pattern. They added that intercropping wheat with sugar beet that fertilized by different mineral N fertilizer rates is not profitable to farmers than sugar beet solid culture.

Finally, intercropping wheat or faba bean with sugar beet gave the highest economic return compared to sole planting for each sugar beet, wheat and faba bean. However, intercropping wheat or faba bean with sugar beet on raised beds (120 cm) gave the highest W.U.E. for cereal units.

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تحميل القمح والفول البلدى مع بنجر السكر وعلاقته بالإنتاجية وكفاءة استعمال المياه

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قسم بحوث التكثيف المحصولي – معهد بحوث المحاصيل الحقلية –مركز البحوث الزراعية – الجيزة – مصر‡

أقيمت تجربة حقلية في محطة البحوث الزراعية بسدس – محافظة بنى سويف خلال موسمى ٢٠١٣/٢٠١٢، ٢٠١٤/٢٠١٣ لتقييم تحميل القمح والفول البلدي على إنتاجية بنجر السكر والمحاصيل المحملة وكفاءة إستخدام المياه وكذلك الجدوى الاقتصادية بإستخدام تصميم الشرائح المتعامدة في أربع مكررات حيث وزعت عرض الخط (٦٠ ، ١٢٠سم) في الشرائح الرأسية ونظم التحميل (١٢.٥، ٢٥ %) في الشرائح الأفقية. أوضحت النتائج إن تحميل القمح أو الفول البلدى مع بنجر السكر أدى إلى نقص فى المحصول لجميع محاصيل التجربة مقارنة بالزراعة النقية لهذه المحاصيل كما أن تحميل القمح مع بنجر السكر كان له تأثير سلبى على محصول الجذور لبنجر السكر ومكوناته مقارنة بتحميل الفول البلدى مع بنجر السكر. سجلت أعلى القيم للماء المضاف والاستهلاك المائى الموسمى عند تحميل القمح أو الفول على الخط الثالث والرابع (٦٠ سم) لبنجر السكر في كلا الموسمين. تحميل القمح أو الفول مع بنجر السكر فى وسط المصطبة (١٢٠ سم) فى جميع نظم التحميل أعطت أعلى القيم لكفاءة استعمال الماء بينما سجلت أقل القيم في نظم التحميل الأخرى ونظم الزراعة النقية لجميع محاصيل التجربة فى كلا الموسمين. أدى تحميل القمح أو الفول البلدي (٢٥%) مع بنجر السكر على مصاطب إلى زيادة معدل استغلال الأرض (١.١٤ ، ١.٢٥) وكانت قيم العدوانية للقمح والفول البلدي موجبة (سائدة) بينما قيم بنجر السكر سالبة (مسود).

تشير نتائج الدراسة الى أن تحميل القمح أو الفول البلدي مع بنجر السكر على مصاطب أعطى أعلى عائد اقتصادي وأعلى قيم لكفاءة إستعمال المياه لوحدة الحبوب بالمقارنة بالزراعة المنفردة لبنجر السكر أو القمح أو الفول البلدي.