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RESEARCH ARTICLE

Potential of economical productivity of faba bean/onion intercropping patterns under North Sinai conditions.

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Abstract

A field experiment was conducted during two seasons in North Sinai, to study the effects of intercropping and density treatments on yield and the productivity of faba bean and onion plants. Combinations of intercropping and density treatments were used. The experimental design used in this study was RCBD with three replicates in five treatments: single faba beans, and single onions, as well as the three intermodal patterns (faba beans: onions) with the substitution method due to changed density ratios. Three intercropping patterns include different areas of faba bean and onions. The intercropping area ratios occupied by faba bean and onion were 11.8:88.2%, 7.6:92.4% and 4.9:95.1%, respectively, for the three respective manners. Intercropping effects were significant for yields of each crop species. On average, monoculture faba bean yielded 1.965 and 0.462 ton/fed seed dry and straw yields, respectively, as well as a sole onion of 15.95 ton/fed bulb yield. The mean faba bean seeds dry yield and, straw decreased by 17.2% and 3.4%, respectively while, bulbs yield increased by 82.6% when the faba bean plants densities/m^2, in the intercrop, decreased from 4.0 to 2.9 plants/m^2 while increasing the onion plants rate/m^2 from 30 to 50 plants/m^2. The highest total intercrop yield of 15.125 ton/fed and a gross monetary value of 12853 L.E. was obtained when onion intercropped with faba bean in an intercropping pattern of F_3O_3 (including 50 and 2.9 plants/m^2 for onion and faba bean, respectively). The gross monetary value followed the same trend as the total land equivalent ratio.

Keywords: Competitive ratio; faba bean; growth; intercropping; onion; yield.

1. Introduction

Monoculture was widely used in traditional farming systems across the world, where plants are grown on the same land for at least a year (Gallaher, 2009). On the other hand, intercropping is an agronomic structure that includes growing two or more crops on the same field in the same year. To date, three categories have been described within this system, based on the extent of physical association between crops: full, relay, and sequential intercropping, also known as multiple cropping. Also, one of the good issues that can be done to increase the production from the unit area is planting at different densities along with intercropping (Beets, 1982; Ghosh *et al.*, 2004; Sobkowicz, 2006).

Faba beans (*Vicia faba* L.) are an imperative economic crop since of their contribution to the soil and plant system characteristics through biological nitrogen (N) fixation, as it is capable of meeting its nitrogen requirements primarily from the atmosphere, as well as the legumes' high protein content (Matthews and Hary, 2003; Wenxue *et al.*, 2005; Jensen *et al.*, 2010; El-Kholy *et al.*, 2019). However, the extent to

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which legume crops can replace the use of mineral N fertilizers is unknown (Reining, 2005).

Onion (*Allium cepa* L.) is grown in Egypt for local consumption as well as consi der a source of income for many small-scale farmers, commercial growers and it has numerous pharmacological features. Furthermore, it is suitable for planted with faba bean plants. Onions can be eaten fresh, as in a green salad, or in a variety of other forms and used in food processing (Refaey *et al.,* 2016; El-Shaieny *et al.,* 2022). The densities control is one of the cultural practices to control bulb size, shape and yield (Geremew *et al.,* 2010*).*

The North Sinai region is well-known for its diverse features, including low land organic content and nutrients, as well as the presence of calcium carbonate, which directly effects nutrient absorption. As a result, it is classified as low yielding agricultural land, and limited areas of land are under pressure to meet basic demands. As a result, the ability to grow multiple crops in small areas is required (Awad *et al.,* 2022). Therefore, the aim of this work was to investigate intercropping of faba beans and onions with respect to plants and growing traits to see if resources can be used more efficiently compared to single cultivation and thus higher profitability. Both crops are included in the list of compatible crops that can be produced at the El Arish site.

2. Materials and methods

Two field experiments were conducted in the experimental farm at the Agricultural Research Station, Veg. Res. Dept., Hort. Res. Inst., Agric. Res. Center, in El- Arish, North Sinai Governorate, Egypt, during two successive seasons 2020-21 and 2021-22 to study the efficiency of some intercropping and plant density treatments in maximizing faba bean productivity and onions across the Arish location. The experimental unit contained intercropping and density plant treatments in five dripper irrigation lines., the experiment unit area was 30 m^2 established 5 m long and 6 m width. Faba bean "Semillas *cv.*," was sown before planting onions "Giza Red cv.," in Fi (F_1, F_2 and F_3) densities while intercropping onion seedlings consisted of Oi (O_1, O_2 and O_3) cultivation densities as shown in Table 1.The experimental soil texture was sandy loam with pH 7.7, EC 0.74 dS/m, organic matter 0.11 %, and $CaCo_3$ 9.13 % (average of two seasons). However, chemical analysis of irrigation water had EC 4.02 dS/m and pH 7.6 (over two seasons).

Table 1. Experimental treatments as faba bean and onion densities

Treatments	Density (plants/m^2)		Number of row onion	Intra-row Spacing		Planting between dripper irrigation lines	
	Faba bean (cm)	Onion (cm)		Faba bean (cm)	Onion (cm)	Faba bean (cm)	Onion (cm)
Sole faba bean (F)	4	0	0	25	0	100	100
Sole onion (O)	0	50	4	0	10	100	100
intercropping (F_1O_1)	4	30	3	25	10	100	100
intercropping F_2O_2)	3.3	40	4	30	10	100	100
intercropping (F_3O_3)	2.9	50	5	35	10	100	100

The planting of onion and faba bean treatments were on dripper irrigation lines with a distance of 100 cm. The density distributed for each faba bean row and onion group lines plant at the same distance as previously mentioned (100 cm). The density of planting faba bean was 25, 30, and 40

cm in the same planting line at rate densities of 4, 3.3, and 2.9 plants per m^2, respectively, while the onion seedling was in rows between them was 10 cm at a rate 3, 4, and 5 rows distributed between dripper irrigation lines in 100 cm distance. Its density was 30, 40, and 50 bulbs per m^2, respectively. The experimental design used in this study was a randomized complete block design with three replications with five treatments as follows:

1) sole cropping of faba bean at a rate of 25 cm intra-row spacing at density (4 plants /m^2)
2) sole cropping of onion at a rate of 10 cm inter-row spacing× 4 rows at density (50 bulbs /m^2)
3) Intercropping system F_1O_1; since planting one side of faba bean at a rate of 25 cm between plants in the same lines at density (4 plants/m^2) alternated with three rows of onion at density (30 bulbs /m^2)
4) Intercropping system F_1O_1; since planting one side of faba bean at a rate of 30 cm between plants in the same lines at density (3.3 plants/m^2) alternated with four rows of onion at density (40 bulbs /m^2)
5) Intercropping system F_1O_1; since planting one side of faba bean at a rate of 35 cm between plants in the same lines at density (2.9 plants/m^2) alternated with five rows of onion at density (50 bulbs /m^2)

In both years, faba bean seeds and onion bulb seedlings were hands planted in mid-October and mid-December in both seasons respectively. All necessary agricultural practices for production of faba bean have been implemented as followed by the technical recommendations of the Ministry of Agriculture.

2.1. Recorded Data

2.1.1. Faba bean plants

1- Vegetative growth parameters

Five plants from each treatment were randomly taken after 120 days from sowing for recorded plant height (cm), No. branches/plant, No. leaves/plant, both fresh and dry total weight (g).

2- Yield and its components

Green harvest: faba bean pods at the marketable stage were harvested and the following data were recorded; pod length (cm), number of pods/plant, number of seeds/pod, pod weight /plant, green pod weight/m^2 and total green yield /fed.

Dry harvest: Data were recorded from the average of 5 plants taken from each treatment as seed weight/plant (g), seed yield/m^2 (g) and seed yield/fed as well as seed chemical analysis of N, P, K and protein content

2.1.2. Onion plants

Vegetative growth parameters: Fifteen plants from each treatment were randomly taken after 120 days from transplanting and the following data were recorded; plant height (cm), number of leaves/plant, leave weight (g), total fresh weight (g), total dry weight /plant (g) and dry matter/plant (%).

Bulb parameters: Bulb length (cm), bulb diameter (cm), bulb shape index,

Onion bulb yield and chemical: Bulb fresh and dry weights (g) and yield (g/plant, g/m^2 and ton/fed.) as well as TSS, N, P, K and protein content

2.1.3. Competitive relationship

In order to evaluate the competitive effects among component crops and to determine intercropping performance, different indices were calculated as:

1- Land equivalent ratio (LER) is an index of intercropping advantage that indicated the amount of interspecific competition or facilitation in an intercropping system (Fetene, 2003). It was calculated as (Willey, 1979)**,** where, LER > 1 shows intercropping advantage and LER < 1 means monoculture advantage (Mazaheri, 1993).

2- Land Equivalent Coefficient (LEC) is a measure of interaction concerned with the

strength of relationship (Adetiloye *et al.*, 1983) where a yield advantage is obtained if LEC value exceeds 0.2.

3- Competitive ratio (CR) was used to evaluate which one crop competes with the other in an intercropping system (Willey and Rao, 1980; Wahla *et al.*, 2009).

4- Relative crowding coefficient (RCC) was calculated as (De Wit,1960).

5- Aggressivity index by compares the yields between intercropping and sole cropping, as well as their respective land occupancy (Wahla *et al.*, 2009).

6- Relative value total (RVT) proposed by (Alabi and Esobhawan, 2006) offers a solution to a shortcoming in LER which does not account for the economic value of the cultivated crops. So, RVT is very appropriate, particularly to the farmer who is aiming at getting the economic value out of the intercropping enterprise. (Vandermeer, 1992), where RVT > 1 indicates intercropping advantage.

7- Replacement value of intercropping (RVI). is an index that accounts for variable cost of production; hence it is superior to RVT (Moseley, 1994 and Singh et al., 2015).

8- Actual yield loss (AYL) was used to provide detailed information about competition between intercrops as it indicates the equivalent yield gain or loss of component crops in comparison to the respective pure stands (Banik, 1996). As opposed to LER, AYL takes into consideration the actual sown proportion of land occupied by the component crops in the field. A positive AYL value indicates an advantage accrued when crops are grown as intercrops and *vice versa* applies for a negative value (Dhima *et al.*, 2007: Machiani et al., 2018).

9- Monetary advantage index (MAI) was determined according to the equation described by (Willey,1979), to measure the productivity and profitability of intercropping as compared to solid planting of the associated component crops.

2.1.4. Gross return of intercropping cultures

GR = Price of faba bean (dry seeds plus straw) yield/fed + price of onion bulb yield/fed (L.E.).

Net return/fed = Total return – (fixed costs of faba bean + variable costs of onion according to market prices (2020/2021 and 2021/2022).

One kilo of faba bean seeds was L.E. 13 and 0.35 L.E. for faba bean straw as well as L.E. 2.5 for kilo of onion bulb.

2.2. Statistical analysis

Analysis of variance was done on the two-year data for a Randomized Complete Block Design according to (Gomez and Gomez, 1984). Means were compared by Duncan's multiple range tests (Duncan, 1955). For the analysis, the M-stat C software was utilized.

3. Results and discussion

3.1. Faba Bean traits

The results in Table 2. showed that the faba bean plants were significantly influenced by the various factors applied through the experiment in both seasons in all the studied traits except pod weight/m^2, K and N % in 1st season and P % content in the 2nd season. The intercropped faba beans/onions in an intercropping F_3O_3 pattern (2.9 and 50 plants/m^2 for faba bean and onion densities, respectively) recorded higher as a result of all studied traits except pod weight/m^2, total pod yield per feddan, seed/m^2 and seed yield/feddan in which F_1O_1 (4 and plants/m^2 for faba bean and onion densities, respectively) exhibited the heaviest weights during the two seasons.

Table 2. Effect of faba bean plants intercropped densities on vegetative growth, green pod and dry seed yield related traits in 2020-21 and 2021-22 seasons.

Seasons	2020-2021				2021-2022			
Variables	Densities ratio (faba bean/onion) of intercropping patterns.							
Densities	4	4:30	3.3:40	2.9:50	4	4:30	3.3:40	2.9:50
	Vegetative traits of faba bean plants							
Plant height (cm)	89.76^{b}	84.15^{c}	89.61^{b}	99.25^{a}	93.20c	91.41c	97.56^{b}	103.1^{a}
No. branches	4.59^{ab}	4.06^{b}	5.11^{ab}	5.50a	4.73bc	4.32c	5.21ab	5.79^{a}
No. leaves	262.9^{b}	238.5^{b}	283.2^{b}	331.1^{a}	283.2c	246.3^{d}	300.6^{b}	347.5^{a}
Total fresh weight (g)	237.1^{b}	335.5^{b}	228.3^{c}	262.6^{a}	226.41^{c}	223.6c	262.4^{b}	272.2^{a}
Total dry weight /plant (g)	35.7b^{c}	32.51^{c}	38.12^{b}	42.44^{a}	37.72b	33.79^{c}	41.12^{b}	47.12^{a}
	Green pod yield and related traits							
Pod length (cm)	20.87^{b}	18.27^{c}	22.12^{b}	25.32^{a}	21.68c	20.67c	22.82^{b}	25.68^{a}
No. Pod/plant	28.13^{c}	26.92^{c}	30.33^{b}	33.96^{a}	29.15^{b}	28.27^{b}	33.34a	34.93a
Pod weight/plant (g)	624.2^{bc}	588.23^{c}	683.98b	789.58a	672.79^{bc}	626.25c	701.91b	832.54^{a}
No. seeds/pod	8.28^{ab}	8.24^{b}	8.11b	9.16a	8.33b	8.10b	8.56b	9.33a
Pod green weight g/m^2	2496.81^{a}	2352.0a	2277.6a	2250.3a	2691.1a	2505.0b	2337.3b	2372.7b
Pod green yield (ton/fed.)	10.49^{a}	4.94^{b}	4.91b	4.74b	11.30^{a}	5.26b	4.91b	4.99b
	Seed dry yield and chemical contents							
Seed dry weight/plant (g)	113.93^{b}	106.17^{b}	109.08b	122.19a	120.38b	112.87d	115.20^{c}	132.13^{a}
Seed dry yield g/m^2	455.72^{a}	424.68^{b}	363.26c	348.26c	481.54^{a}	451.48b	383.64c	376.57d
Seed dry yield (ton/fed)	1.91^{a}	0.89^{b}	0.76c	0.73c	2.02a	0.94b	0.80c	0.79c
N %	2.5^{a}	2.4^{a}	2.4a	2.6^{a}	2.9^{ab}	2.^{8bc}	2.8^{b}	3.1a
P %	0.3^{ab}	0.3^{b}	0.3b	0.4^{a}	0.4^{a}	0.4a	0.4^{a}	0.4a
K %	1.9^{a}	1.78a	1.9a	1.9^{a}	2.3a	2ab	2.3a	2.3a
Protein %	15.6^{b}	14.96c	15.2b	16.4^{a}	18.6^{ab}	17.3b	17.5^{b}	19.3a

Means with the same letter (s) are not significantly different according to Duncan's multiple range test at($P \leq 0.05$)

Densities: namely, the intercropped densities were (4, 4:30, 3.3:40 , and 2.9:50 plant/m2 for the planting of faba bean: onion, respectively)

3.2. Onion traits

The plant was significantly influenced by the various factors applied through the experiment in both seasons in all the studied traits (Table 3) except total fresh weight, leaves weight, TSS in 2nd season and bulb shape index in both seasons. Intercropped onion/faba bean pattern with high density of onion plants (F_3O_3 include 50 and 2.9 plants/m^2 for onion and faba bean, respectively), recorded the highest result for all studied traits of both seasons. No significant differences were observed between the three intercropping patterns in No. leaves, leaves weight, both total fresh and dry weight/plant as well as bulb shape index in both seasons, dry matter in 1st season and TSS in 2nd one. Average bulb weight was significantly increased as the onion plant densities of intercropped types increased from 30/4, 40/3.3 to 50/2.9 plants/m^2 resulted in significantly heaviest bulb/plant, bulb/m^2 and bulb yield/fed of F_3O_3 in which the weight/plant and weight/m^2 heavier than monoculture bulb weight. While, the lightest one achieved with F_1O_1. These results are true in both seasons.

3.3. Competitive relationships

The effects of intercropping on crop yields were significant for each crop species (Table 4). On average, monoculture faba bean provided yields of 1.965 and 0.462 ton/fed, of seed dry and straw, respectively as well as sole onion produced 15.95 ton/fed bulb yield. The mean faba bean dry yield decreased (by 17.2% for seeds and 3.4% for straw). Whereas, onion yield increased by 82.6% when the rate/m^2 of faba bean plants, in the intercrop, decreased from 4.0 to 2.9 plants/m^2 with increasing the onion plants rate/m^2 from 30 to 50 plants/m^2. The highest total intercrop yield of 15.125 ton/fed and gross

monetary value of 12853 L.E. were obtained when onion intercropped with faba bean in an intercropping pattern of F_3O_3 (include 50 and 2.9 plants/m^2 for onion and faba bean, respectively). The gross monetary value followed the same trend as the total land equivalent ratio. These results come to an agreement with the findings of (Holland and Brummer, 1999; Agegnehu *et al.*, 2006 a,b; Getahun et al., 2018).

LER (land equivalent ratio) is an index of intercropping advantage that indicated the amount of interspecific competition or facilitation in an intercropping system (Fetene, 2003) are presented in (Tables 4 & 5 and illustrated in Fig. 1).

The results of both seasons were quite similar, the data revealed that the LERs for the intercrop yields of both faba bean and onion were slightly increased as faba bean densities were decreased from 4 to 2.9 plants/m^2 (F_3O_3) and onion densities increased up to 50 plants/m^2 (F_3O_3) with no significant differences between F_2O_2 and F_3O_3 intercropping patterns for faba bean crop in both seasons. It is crucial to find the suitable plant rate/m^2 for the intercropped crops with the purpose of avoid intense overloading or below optimum population density (Khan et al., 2014) found that LER decreased with the increase in seed rates of Brassica in the intercropping system.

Table 3. Effect of onion plants intercropped densities on vegetative growth, bulb and chemical traits in 2020-21 and 2021-22 seasons

season	2020-2021				2021-2022			
variables	Densities ratio (faba bean/onion) of intercropping patterns.							
Densities	50	30:4	40:3.3	50:2.9	50	30:4	40:3.3	50:2.9
	Onion vegetative traits							
Plant height (cm)	60.50^{ab}	48.00c	58.57b	61.61a	62.30ab	59.65b	50.04c	63.49a
No. leaves	9.02a	7.53b	7.76b	8.00b	9.12a	7.85b	7.98b	8.81ab
Leave weight (g)	51.42a	49.2ab	45.58b	49.90ab	54.73a	48.69a	51.60a	52.87a
Total plant fresh weight (g)	133.25a	129.33b	130.56ab	131.86ab	138.74a	131.90a	133.04a	136.83a
Total plant dry weight (g/plant)	13.34a	10.82b	12.3ab	12.30ab	17.89a	13.58b	14.41b	15.7a^{b}
Dry matter %	10.00^{a}	8.36b	9.42ab	9.33ab	12.9^{a}	10.30c	10.80^{bc}	11.60b
	Bulb traits							
Bulb Diameter (cm)	5.19a	4.60c	4.89b	5.07ab	5.92a	4.54c	4.83bc	5.56ab
Bulb length (cm)	6.51a	5.77b	6.17ab	6.38a	6.69a	5.61b	5.92ab	6.57a
Shape index	1.25a	1.25a	1.26a	1.26a	1.14a	1.24a	1.22a	1.18a
Average Bulb weight (g/plant)	81.83a	71.50b	72.23b	85.76a	84.24a	72.58b	74.93b	86.59a
Bulb weight (g/m^2)	4091.9^{a}	2145.2^{c}	2889.3^{b}	4288.4^{a}	4212.1^{b}	2177.6^{d}	2997.2^{c}	4329.6^{a}
Total Bulb weight (ton/fed.)	17.18^{a}	7.51d	10.11c	15.01b	17.69^{a}	7.62d	10.49^{c}	15.15^{b}
	Chemical traits (%)							
TSS	14.50a	13.04b	14.48a	14.54a	14.6a	14.08a	14.5a	14.8a
N	3.20a	2.59b	2.38b	2.85ab	3.40a	2.59b	2.67b	3.07a
P	0.34a	0.20c	0.26b	0.26b	0.36a	0.27b	0.32^{ab}	0.33^{ab}
K	3.20b	2.16c	2.29c	3.53a	3.42b	2.87d	3.26c	3.72a
Protein %	20.10a	16.20bc	14.87c	17.81b	21.30a	16.18d	16.70c	19.20b

* Means with the same letter (s) are not significantly different according to Duncan's multiple range test at(P ≤0.05)

Densities: namely, the intercropped densities were (4, 4:30, 3.3:40 , and 2.9:50 plant/m2 for the planting of faba bean: onion, respectively)

Table 4. Effect of intercropping on competitive relationships and advantages of combined data.

Traits			Sole	intercropping systems		
				F_1O_1	F_2O_2	F_3O_3
Yield (ton/fed)	Faba bean	Seeds	1.965	0.918	0.781	0.76
		Straw	0.462	208	0.207	0.201
	Onion		15.95	8.285	10.8	15.125
LER		Faba	---	0.46	0.41	0.4
		Onion	---	0.52	0.68	0.95
		F/O	---	0.98	1.08	1.34
CR		Faba	---	6.69	7.28	8.03
		Onion	---	0.15	0.14	0.13
		F/O	---	6.84	7.42	8.15
MAI		1000 L.E.	---	5.959	8.662	12.853
RVI			---	2.277	2.594	3.328

Overall, the LER values of onion were higher than those of faba bean. The maximum LER was 1.35 (1st season) and 1.34 (2nd season) from intercropping F_3O_3 pattern explained that faba bean combined with onion would save nearby 0.35 feddan of land without any drop in combined yield and these two crops are the best companions for offseason irrigated production practices (Getahun et al., 2018).

Therefore, 35% additional land should be used in sole cropping with a view attain the same yield of intercropping, which designates the superiority of the intercrops over pure stands in terms of the use of environmental resources during plant growth and development (Dhima et al., 2007).

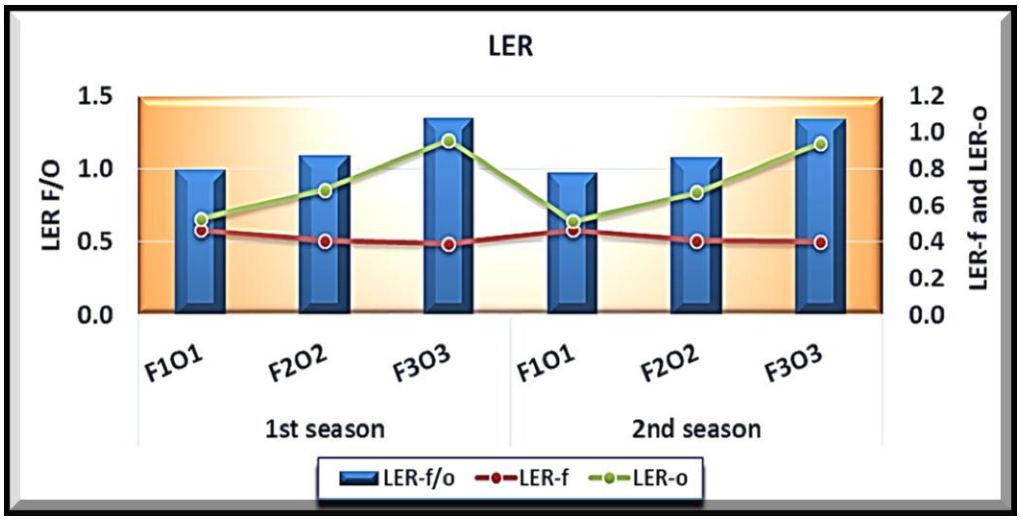

Fig. 1. Land equivalent ratio (LER) for two seasons in faba bean–onion intercropping pattern

Table 5. Land equivalent ratio (LER), competitive ratio (CR) and relative crowding coefficient (RCC) as affected by faba bean-onion intercropping systems.

	RCC			CR			LER		
	Faba	Onion	F/O	Faba	Onion	F/O	Faba	Onion	F/O
					2020/2021				
F_1O_1	6.49	0.15	0.96	6.62	0.15	6.77	0.46	0.53	0.99
F_2O_2	8.31	0.18	1.48	6.75	0.15	6.90	0.41	0.68	1.09
F_3O_3	12.30	1.12	13.80	7.20	0.14	7.34	0.39	0.96	1.35
					2021/2022				
F_1O_1	6.44	0.14	0.90	7.36	0.14	7.49	0.46	0.51	0.98
F_2O_2	8.32	0.17	1.39	7.85	0.13	7.98	0.41	0.67	1.08
F_3O_3	12.89	0.83	10.69	8.20	0.12	8.32	0.40	0.94	1.34

Results presented in Table 5 and Fig. 2 showed the effect of intercropping patterns between faba bean and onion on their relative crowding coefficients (RCC). Obtained results revealed that all values of faba bean were higher than those of onion which indicated that faba bean

was the dominant crop whereas onion was the dominated one. The highest coefficients of both crops were found with the intercropping systems F_3O_3 in both seasons. On the whole, Relative crowding coefficients (RCC) revealed again the superiority of F_3O_3 faba bean with onion intercropping manner, followed by those of F_2O_2 one in average of both seasons (Fig. 2). This was attributed to effectual competition of faba bean was its RCC coefficients was very high to that of onion. In addition, most values of the coefficient products (RCC F/O) were higher than one which indicated that there were yield advantages, i.e., the combined intercrop yield was higher than expected (Willey, 1979). Similar results were obtained by (Abd El-lateef *et al.*, 2011).

Likewise, land equivalent coefficient (LEC) is used to determine the strength of the intercropping interaction which referred to as the productivity index because it is a more superior index in evaluating crop mixture performance in terms of mixture productivity (Adetiloye et al., 1983). The study showed that LEC was generally greater than 25% in both F_2O_2 and F_3O_3 treatments as well as slightly in F_1O_1 (Table 6 and Fig. 3). Faba bean-Onion intercropping patterns demonstrated more productivity as was demonstrated by higher LEC values. The results demonstrated that intercropping had yield advantage over sole cropping.

Table 6. Aggressivity and land equivalent coefficient (LEC) as affected by faba bean-onion intercropping systems.

Treatments	Aggressivity		LEC
	Faba	Onion	
	2020/2021		
F_1O_1	0.033	-0.033	0.24
F_2O_2	0.0002	-0.033	0.28
F_3O_3	0.0004	-0.046	0.37
	2021/2022		
F_1O_1	0.0004	-0.046	0.24
F_2O_2	0.001	-0.069	0.27
F_3O_3	0.001	-0.071	0.38

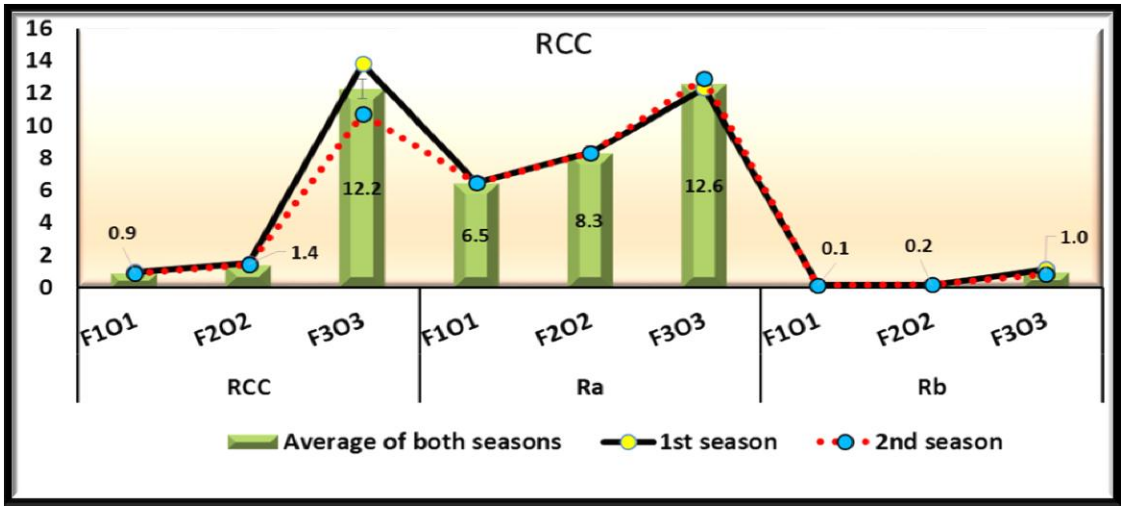

Fig. 2. Relative crowding coefficients (RCC) for two seasons in faba bean–onion intercropping pattern

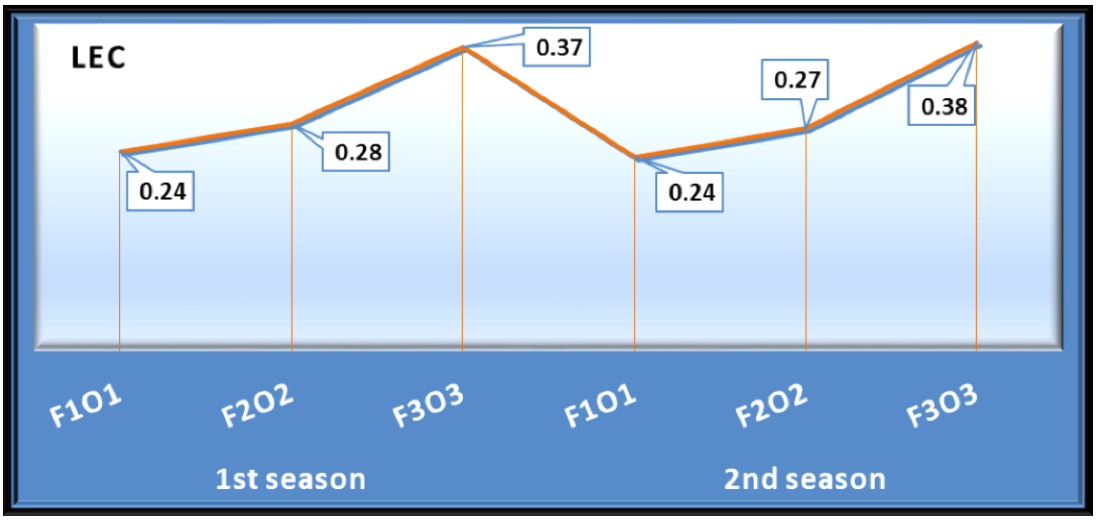

Fig. 3. Land equivalent coefficient (LEC) for two seasons in faba bean–onion intercropping pattern

Similarly, the competitive ratio of faba bean (CR) in intercropping patterns always exceeded 1.0 in both two seasons and thus was higher than the competitive ratios of onion during both seasons, suggesting that faba bean had greater competitive intensity relative to onion (Table 5 and Fig 4).

Also, our results recommend that faba bean is the leading crop, at least under the present experimental settings, as indicated by the higher RCC, competitive ratios and positive aggressivity (Table 5 and Fig. 2).

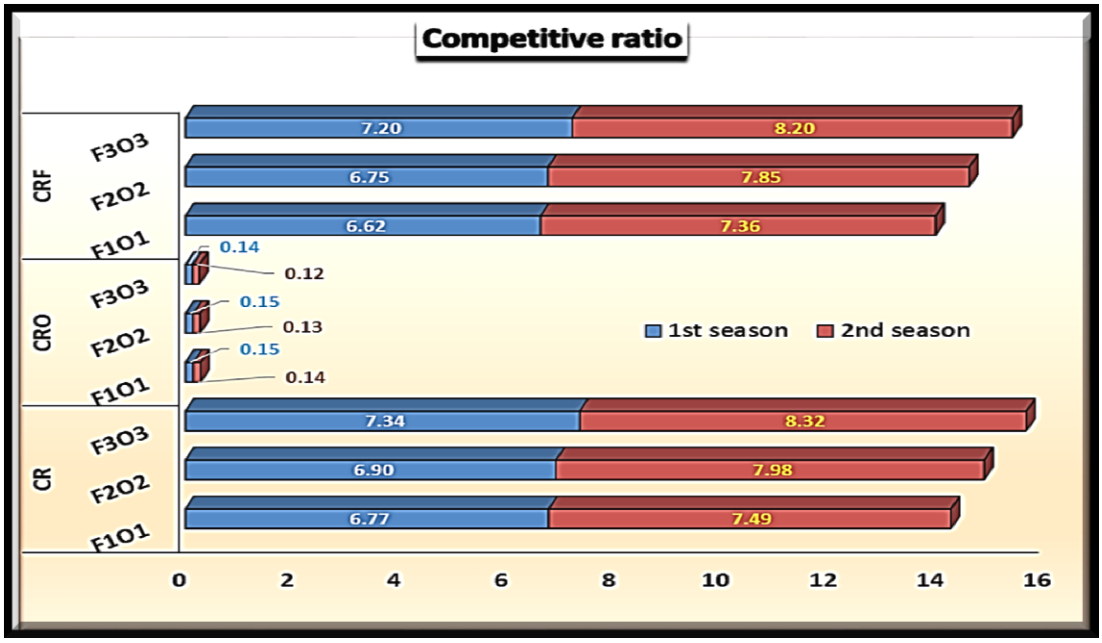

Fig. 4. competitive ratio of potato (CR) for average both seasons and two seasons in faba bean-onion intercropping pattern.

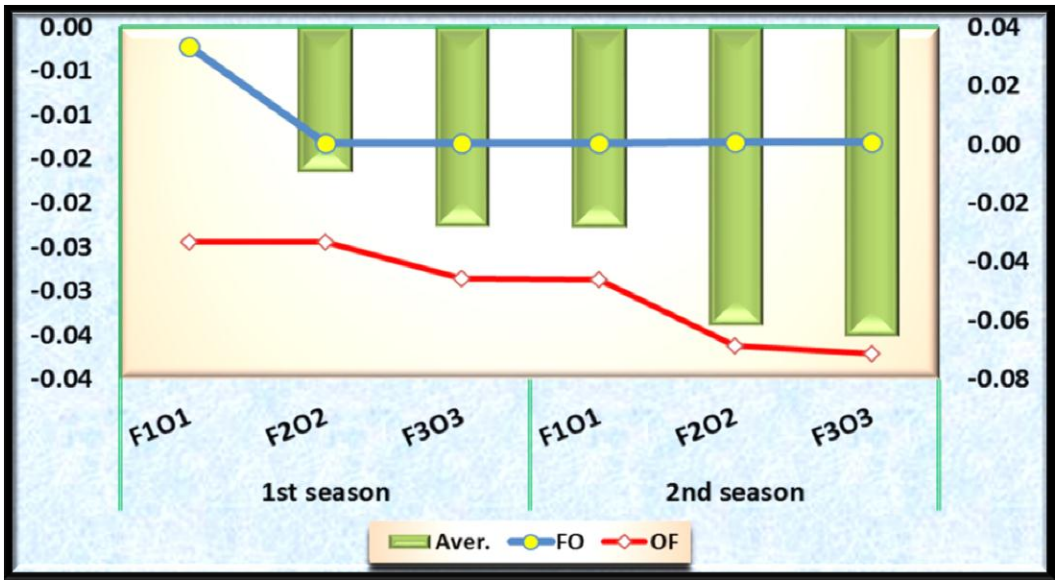

Fig. 5. Aggressivity values in faba bean-onion intercropping pattern in two and average seasons

This discloses that faba bean intercropped with onion utilized the resources more aggressively, and its production was the major factor that determined the overall yields. Aggressivity was pronounced especially under F_1O_1 intercropping pattern. The aggressivity values were negative in all patterns for onion revealing the prevailing effect of faba bean.

3.4. Economic advantage of intercropping

Greatest intercropping indices mainly give the agronomic and yield advantages of intercropping, and do not reflect the economic and absolute yield comparisons (Tamado and Mulatu, 2000; Yayeh *et al.*, 2014). Nevertheless, it is desirable to evaluate yield advantage on monetary basis following (Willey, 1979) formula. Monetary values of the combined intercrop yield of faba bean and onion were calculated according to their price in local market for wholesale after the harvest season (2020/2021 and 2021/2022). The intercropping faba bean with onion showed that MAI was positive in all the intercropping systems and higher above one (Table 7). Obtained values shown in Table 6 indicated that the highest cash advantage was achieved from intercropping system F_3O_3, F_2O_2 and F_1O_1, in descending order under experimental area conditions.

For farmers concerned in attainment maximum income, using F_3O_3 (2.9 and 50 plants/m^2 for faba bean and onion, respectively) intercropping system would be the best treatment (gave 12.053 and 13.654 thousand pounds advantage at 1st and 2nd season, respectively). This indicates that the intercropping systems were more economically feasible weighed compared to monoculture. This conforms to similar results by (Dutta *et al.*, 1994) on maize-rapeseed combinations. Another indicator used in assessment of intercropping is relative value total (RVT), which evaluates intercropping in terms of economic value and solution to the problem with LER that such calculation does not account for the value of the crops that are being sown. RVT calculation is relevant for the farmer that has monetary value as his farming goal (Vandermeer, 1992). By placing the numbers associated with each parameter in the formula of this index, the economic value of each treatments of intercropping can be calculated and interpreted.

Table 7. Actual yield loss (AYL), Relative value total (RVT), replacement value of intercropping (RVI) and MAI as affected by faba bean-onion intercropping systems.

	AYL			RVT		RVI		MAI
	Faba	Onion	Total	Faba	Onion	Faba	Onion	
				2020/2021				
F_1O_1	6.88	0.19	7.07	1.30	1.17	1.67	3.68	5.889
F_2O_2	11.91	0.11	12.02	1.48	1.34	1.42	4.78	7.772
F_3O_3	21.26	0.21	21.46	1.89	1.71	1.37	6.68	12.053
				2021/2022				
F_1O_1	6.88	0.16	7.05	1.25	1.17	1.04	4.32	6.030
F_2O_2	11.97	0.09	12.06	1.42	1.33	0.89	5.65	9.552
F_3O_3	21.94	0.19	22.12	1.82	1.71	0.88	7.93	13.654

In calculations of this study, the daily price tested products were used, so that the price of each kilogram of faba bean seed was calculated about 13 L.E., straw about 0.35 L.E and onion, around 1.75 L.E. These prices were approved by the local market. Treatment F_3O_3 showed the highest value of RVT about 1.8 and 1.765 in the first and second season, respectively (Table 7 and Fig. 6). The results showed that the relative value total of both crops in all intercropping treatments were more than one. This issue indicates the economic advantage of faba bean and onion intercropping more than the sole cropping of both. One reason for the preference of the intercropping over the pure cropping, is the lesser interspecific competition of the crops of intercropping compared to the intraspecific competition of the crops of pure cropping. Similar results were also reported by (Rahimi *et al.*, 2011; Tayefehnuri, 2004) reported that in all the intercropping, the value of RVT is more than one and the highest value was obtained in high density about 1.34 of two plants.

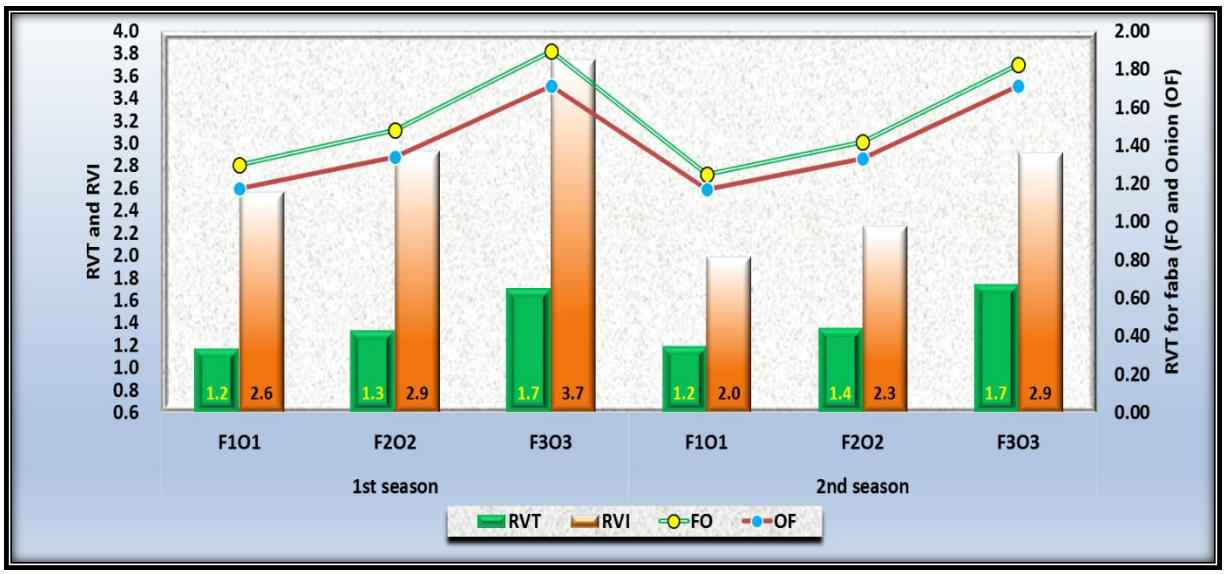

Fig.6. Relative Value Total (RVT) and relative Value of intercropping (RVI) as affected by faba bean-onion intercropping systems

In particular, faba bean AYL_F values were positive and also higher than the faba bean AYL_O values Figure 7, which confirmed the results of aggressivity, RCC and CR values indicating that faba bean was more resistant to yield loss than onion in all intercropping patterns. Also, the total AYL value was more than one in all cropping patterns indicating an advantage of intercropping over monoculture. Similar results have been reported by (Dhima *et al.*, 2007; Mansouri *et al.*, 2013).

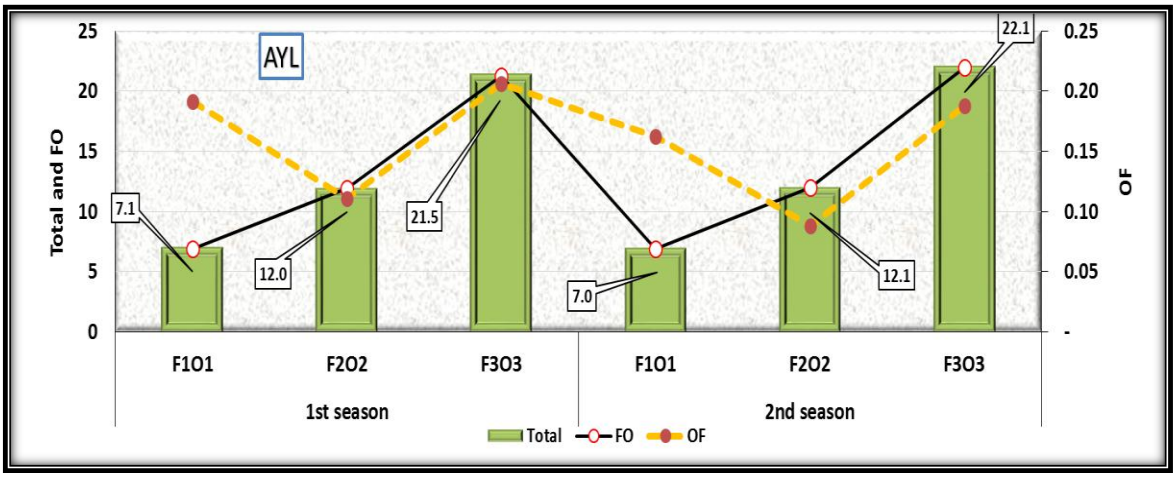

Fig. 7. Actual yield loss (AYL) as affected by faba bean-onion intercropping systems

Relative Value of Intercropping (RVI) should be well-thought-out since it joins the farmers to the real-world situation, and the cost of production is considered. RVI of intercropping shows that faba bean/onion intercrops has >100% economic advantage over monocrops (as average of both crops over both seasons, Table 7 and Fig 7), this may be the reason why the farmers are still planting them together. The economic implication of this study is that any strategy that reduces cost of production in faba bean/ onion intercrops will increase its profitability and attractiveness to farmers. Such policies as price support and subsidizing of inputs are example of such strategies. However, more investigations should be carried out, using diverse planting arrangements, so that the appropriate densities that will maximize the economic advantages of the intercropping of the faba bean/onion can be recommended to the farmers. The higher yielding of the onion integrated treatments over those with faba bean, as noted in Table 7 for RVI, and most indices may be attributed to the phenological differences between these crops. For example, the faba bean was harvested through March month when onion was at bulb formation stage. This may have allowed onion to utilize the water remaining in the soil and nutrients mineralized from residues of the harvested faba bean resulting in optimum yield. Such findings were reported by (Hinsinger *et al.*, 2011) under maize and faba bean intercropping system.

3.5. Economic evaluation

The highest gross income and net return values were recorded with F_3O_3 followed by F_2O_2 with high differences (Table 8). Results also showed that the increases in net return reached 24.4 and 24.8%, in the first and second seasons, respectively by F_3O_3 intercropping pattern compared with sole culture of onion, which increases farmer's benefit by about LE 5000 per feddan. The results suggest that intercropping faba bean cultivar with onion was more profitable to farmers than sole culture of onion. These findings are parallel with those obtained by (El-Dein, 2015) who showed that

intercropping faba bean with onion was more profitable to farmers than onion or faba bean sole cultures.

Table 8. Economic return of intercropping faba bean cultivars with onion in 2020/2021 and 2021/2022 growing seasons

Treatments	Income				Gross income (LE/fed)	Net return LE/fed
	Straw	Seed	Straw+Seed	Onion bulbs		
F_1O_1	71.538	11570	11641.5	20775.0	32416.5	10887.1
F_2O_2	69.719	9880	9949.7	27025.0	36974.7	15279.6
F_3O_3	66.557	9490	9556.6	37750.0	47306.6	25504.3
Sole faba bean	157.150	24830	24987.2	-	24987.2	8587.2
Sole onion	-	-	-	39500.0	39500.0	20500.0
F_1O_1	74.354	12220	12294.4	20650.0	32944.4	10339.6
F_2O_2	75.206	10400	10475.2	26975.0	37450.2	14565.4
F_3O_3	73.896	10270	10343.9	37875.0	48218.9	25153.0
Sole faba bean	165.99548	26260	26426.0	-	26426.0	11426.0
Sole onion	-	-	-	40250	40250.000	20150.0

* Onion prices were LE 2500/ton of bulbs, meanwhile faba bean prices were LE 13000/ton of seed and LE 350/ton of straw.

* Production costs were about LE 21000/fed for intercropping culture system and average LE 16500 and 21050/fed for the solo culture of faba bean and onion, respectively.

4. Conclusion

The present study concludes that intercropping of faba bean with onion may affect yield, competition between the 2 species (*Vicia faba* and *Allium cepa*.), and economics of mixtures as compared to monoculture of the same species. Regardless of various varieties, faba bean-onion intercropping had the yield advantages of intercropping and optimum exploitation of the environmental resources as opposed to other intercropping systems. Additionally, these 3 intercropping patterns (F_1O_1, F_2O_2 and F_3O_3) were observed to be the most profitable. Generally, although faba bean crops had lower yield in mixture but are more expensive in markets, solitary planting of them would not reach the profitable level gained with onion or other crops cited in literature. On the other hand, mixtures with faba bean and onion resulted in significant advantages of intercropping as confirmed by the economic and land use efficiency values. Faba bean "Semillas *cv*.,", intercropped with onion, cv., "Giza red" in F_3O_3 intercropping pattern presented the greatest monetary advantage. Such a system can be easily practiced especially by peasants from the north Sinai regions in Egypt, as well as in other countries that have similar climate. Therefore, with a higher socio-economic return for farming system, as well as soil conservation can be improved in such environments.

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Consent for Publication
Not applicable.
Conflicts of Interest
Declare no conflict of interest.

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