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Effect of Ridge Width and Cropping System on Productivity and Land Use Efficiency in Faba Bean-Flax Intercrops

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TWO FIELD experiments were conducted at the Agricultural Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt during 2014/2015 and 2015/2016 seasons. The study to investigate the performance of two faba bean varieties, *i.e.* Giza- 843 and Giza- 2 when intercropped with flax to productivity, land use efficiency, farmer's benefit and control broomrape in faba bean fields under two ridge widths. The experiment included 8 treatments which were the combination of two ridge widths (60 and 120 cm), two cropping systems (intercropping and solid planting) and two faba bean varieties (Giza- 2 and Giza- 843). The experimental design was a split- split plot design in randomized complete block arrangement with three replications. The results indicated that increasing ridge width from 60 to 120 cm decreased number of *Orobanche crenata* m^{-2} but it increased seed yield of the intercrops $plant^{-1}$ and ha^{-1}. Intercropping flax with faba bean decreased number of *Orobanche crenata* -2 and seed yield $plant^{-1}$ and ha^{-1} of both intercrop components. Faba bean cv. Giza- 843 recorded the lowest values of number of *Orobanche crenata* m^{-2} and the highest values of yield and its attributes compared to Giza- 2 variety. Also, faba bean cv. Giza- 843 affected negatively seed yield of flax and its attributes. Most of the studied faba bean and flax traits were affected significantly by the interactions. The amount of fatty acids in flax seed was approximately 12.5 to 14.5% saturated (8.3 to 9.2% of palmitic acid and 4.2 to 5.3% of stearic acid) and 81.7 % to 85.2 % unsaturated fatty acids (20.9 to 22.3% of oleic acid, 13.0 to 14.2 % of ώ6 and 47.8 to 48.7% of ώ3). Total unsaturated fatty acids were not affected significantly by ridge width x cropping system x faba bean variety. 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. Land equivalent coefficient (LEC) exceeded 0.25. The dominance analysis proved that faba bean and flax plants are dominant and dominated components, respectively. The results show that intercropping flax with faba bean variety Giza- 843 in ridges 120 cm width achieved US$ 608.0 ha^{-1} compared to solid planting of faba bean variety Giza- 2 in ridges 60 cm width. Intercropping flax with faba bean variety Giza- 843 in ridges 120 cm width decreased number of *Orobanche crenata* m^{-2} and achieved high yield, LER and net return without any negative effect on total unsaturated fatty acids of flax seed oil compared to the other treatments.

Keywords: Intercropping, Faba bean, Flax, *Orobanche crenata,* Fatty acids, Competitive relationships, Net return.

Introduction

The rising regard on sustainable agriculture enhances the cultivation of legumes as a tool of environmental optimization of resource use and preferment of pest pliability in cropping systems. It is known that weeds compete with crop plants for light, nutrients, soil moisture and space. Broomrape weed (*Orobanche* spp.) is root holoparasites that feed off a wide range of the most important legume crops. Furthermore, broomrape seeds to keep you can repeat vital good for 20 years or more in the nonattendance of the host plant (Kebreab & Murdoch, 1999). They act by attaching themselves to the roots of many plant species to obtain nutrients and water from their host. It is known that *Orobanche crenata* is a main necessity for grain and forage legume on over four Mha of the Mediterranean area (Parker, 2009). Egypt at present satisfies around 70% of its request out of incoming as a result of the effects of competition with other crops, and parasites such as *Orobanche* (ICARDA, 2017).

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The lack of shortage can lead to a significant reinforcement in the weed seed bank, as *Orobanche* types can product more than 500000 seeds per flowering shoot (Pieterse, 1979). Broad kinds of methods of controlling traditional weeds against *Orobanche* have been found to be not good or ineffective for many sensitive crops (Parker, 1991). Recently, difference in appropriate plant arrangement per unit area with the same plant density could be influenced by ridge width. Optimum plant density and suitable plant arrangement per unit area permit crops to achievement resource optimally and produce rise yields (Squire, 1993). Light absorption is strongly following on single plant architecture, as well as, on total canopy structure (Niinemets, 2007). The capability to preserve a rise photosynthetic rate, leaf chlorophyll content, or both and the capacity to minimize photoinhibition can be advanced as oblique check for amended tolerance to branched broomrape (Mauromicale et al., 2008).

Several pleading mechanisms have been revealed in plants reluctant to broomrape offensive, mainly including cell wall build up (Pérez-De-Luque et al., 2005), stamping of vascular tissues (Pérez-De-Luque et al., 2006) and production of toxic combination (Lozano et al., 2007). Accordingly, it is important to address our efforts to the control of this parasite by intercropping flax (*Linum usitatissimum* L.) with faba bean (*Vicia faba* L.), particularly flax was reported to be artificial-hosts of *Orobanche* spp. (Abbes & Kharrat, 2008). It is known that flax seed contains about 15-30% oil and contains 45% saturated and unsaturated fatty acids, basically omega-3 fatty acids (Oomah & Sitter, 2009).

Faba bean production has rejected extremely – often a result of lower net returns as contrasted with the other strategic crops, as well as, sensitivity of some faba bean varieties to *Orobanche crenata*. Faba bean cultivated area reached about one Mha in old lands (Bulletin of Statistical Cost Production and Net Return, 2015). Nowadays, the emission of the new Egyptian faba bean varieties are successfully combating some weakening pests and helping the country to regain its situation as one of the most substantial global producers of faba bean. Therefore, the objective of the present work was to examine the effect of intercropping flax with two faba bean varieties on the infestation with *Orobanche* under two ridge widths to raise monetary return for the Egyptian farmer.

Materials and Methods

Two field experiments were conducted during the winter season of the two successive seasons 2014/015 and 2015/2016 at the Experimental Station of the Faculty of Agriculture, Cairo University (30° 02' N latitude and 31° 13' E longitude, altitude 22.50 m above sea level) at Giza, Egypt. Representative soil samples were taken from each site at the depth of 0-30 cm from the soil surface. The soil analysis of the experimental soil, as an average of the two growing seasons 2014-2015 and 2015-2016, indicated that the soil is clay loam (3.6 % coarse sand, 30.9 % fine sand, 31.4 % silt and 34.1% clay), the pH (paste extract) is 7.67, the EC is 1.88 dSm^{-1}, calcium carbonate is 1.44 %, organic matter is 2.12%, the available nutrients in mg kg^{-1} are Nitrogen (35.30), Phosphorous (8.98) and Potassium (239). The procedure of soil analysis followed the methods of Black (1965). Meteorological variables in the 2014/2015 and 2015/2016 growing seasons of flax were obtained from the Central Laboratory for Agriculture Climate (CLAC), ARC, Egypt (Table 1). The Egyptian cultivars of faba bean (Giza- 2 and Giza- 843) and flax Sakha-2 (a dual purpose for oil and fiber production) was procured from Field Crops Research Institute, Agricultural Research Center (ARC), Giza, Egypt. The experiment included 8 treatments, which were the combination of two ridge widths (60 and 120 cm), two cropping systems (intercropping and solid planting) and two faba bean varieties (Giza- 2 and Giza- 843). The sub plots area included three wide beds (1.20 x 5 m) and either six ridges (0.6 x 5 m) for intercropping and pure stand of faba bean and flax. The main crop, faba bean, was planted at the recommended seeding rate (90 kg/ha) by the Egyptian Ministry of Agriculture, for both the intercropping treatments and pure stands. In the intercropping and pure stand treatments, it was sown in hills (10 cm apart) on both sides of the prepared seed bed and one side of the ridge, and later thinned to two plants $hill^{-1}$.

TABLE 1. Climatic factors of studied region during crop growth period in 2014/2015 and 2015/2016 at Giza Governorate.*

Month	Parameters									
	Temperature (°C)			Mean relative humidity (%)	Mean solar radiation Dgt [MJ m^{-2}]	Wind speed [m sec^{-1}]		Soil temperature (°C)		
	Max	Min	Mean			Max	Aver	Max	Min	Mean
2014/2015 season										
November	25.68	16.40	20.79	65.90	10.47	1.92	0.41	23.21	19.60	21.54
December	20.65	10.70	15.57	68.16	8.79	1.82	0.38	19.37	14.96	17.01
January	21.41	8.93	15.02	72.03	9.82	1.45	0.26	20.27	14.12	16.46
February	22.53	10.40	16.37	67.30	12.90	1.72	0.47	22.64	15.29	18.25
March	25.24	13.10	18.99	55.42	17.06	1.94	0.61	24.89	18.07	21.02
April	29.62	16.10	22.81	49.18	21.71	2.05	0.68	24.71	21.00	22.89
2015/2016 season										
November	25.66	13.90	19.60	65.02	9.63	1.62	0.34	20.69	19.54	20.11
December	23.30	10.80	16.41	67.61	8.34	1.57	0.28	18.29	17.04	17.63
January	20.03	8.25	13.66	58.49	9.33	1.84	0.45	15.66	14.56	15.07
February	20.89	8.92	14.75	55.77	11.46	1.91	0.51	15.78	14.58	15.15
March	25.08	13.20	18.97	55.98	16.84	2.10	0.70	18.98	17.43	18.15
April	27.61	14.00	20.80	48.85	21.45	2.22	0.74	24.51	19.89	22.09

* Data obtained from the Central Laboratory for Agriculture Climate (CLAC), ARC, Egypt.

The intercropping and sole dicot intercrop (flax) was sown drilled in four rows (15 cm apart) on top of the seed bed and two rows on the ridge. In its pure stand, faba bean was sown in hills (10 cm apart) on both sides of the beds and one side of the ridge and later thinned to two plants $hill^{-1}$. Sowing of faba bean and flax was during the first week of November in both seasons. Seeds were hand drilled in rows 15 cm apart, with seeding rate of 166.7 kg ha^{-1}. All experimental plots were treated similarly, *i.e.* fertilized and irrigated at the same intervals in each growing season. Single super-phosphate fertilizer (15.5% P_2O_5) at the rate of 24 kg P_2O_5 ha^{-1} was added during field preparation, while potassium was added at the rate of 48 kg K_2O ha^{-1} as Potassium sulphate (48% K_2O). Nitrogen fertilizer was applied at rate of 30 kg N ha^{-1}, in the form of ammonium nitrate (33.5% N), into two equal doses; first and second part were applied at 3 and 9 weeks after planting, respectively. The first irrigation was applied after 21 days from planting and the following irrigations were applied at 21 day intervals. Manual weeding was practiced twice during both seasons. The normal cultural practices of growing flax were followed till it reached full maturity, then harvest was carried out.

Each field experiment was laid out in split-split plot design in randomized complete blocks arrangement, with three replications. The main plot consisted of ridge width (60 and 120 cm width), cropping system (intercropping and solid planting) were allocated to sub plot and faba bean varieties (Giza- 2 and Giza- 843) were assigned to sub sub plot. Each sub-sub plot consisted of 6 ridges or 3 beds of 5 m length with an area of $18m^2$. Figure 1 shows intercropping flax with faba bean and solid plantings of both crops.

The recorded data

Faba bean traits

At full maturity stage (Mid May), ten guarded plants were randomly taken from each sub sub plot to estimate the following traits: Number of *Orobanche crenata* plants m^{-2}, plant height (cm), number of fruiting branches, pods and seeds $plant^{-1}$, number of seeds pod^{-1}, seed yield $plant^{-1}$ (g), seed index (g) and seed and straw yields ha^{-1} (ton). Seed and straw yields ha^{-1} were determined from seed and straw weight of each sub sub plot and converted to ton ha^{-1}.

Flax traits

At full maturity stage (Mid May), ten guarded plants were randomly taken from each sub sub plot to estimate the following traits: Number of fruiting branches and capsules $plant^{-1}$ and seed yield $plant^{-1}$ (g). Seed, straw and fiber yields ha^{-1} were estimated from the middle area of one square meter of each sub-sub plot. Plants were harvested, attached and left to dry, then they were threshed to take off the capsules and weighted to determine straw yield per one square meter and then converted to straw yield in ton ha^{-1}. Seeds were cleaned from straw and other residuals and weighed to the nearest gram and turn into to register seed yield in ton/ha. Flax fiber was detached from the stems by using retting process. Fiber percentage was calculated as percentage of the fiber yield to the air dried straw yield after tearing out fruit capsules. Fiber yield (ton ha^{-1}) was calculated by straw yield (ton ha^{-1}) X fiber (%). Seed oil content (%) was specified by using Soxhlet equipment and petroleum ether (40 – 60°C) as solvent according to A.O.A.C. (2000). Oil yield ha^{-1} (ton) was calculated by multiplying seed yield ha^{-1} by seed oil content.

Quality of flax seed oil

Fatty acids composition were separated according to Vogel (1975) and identified by Gas Liquids Chromatography, Trace GC Ultra, Thermo Scientific (GLC) apparatus according to Farag et al. (1981).

Competitive relationship and yield advantage

Land equivalent ratio (LER)

LER defines as the ratio of area needed under mono cropping to one of intercropping at the same management level to produce an equivalent yield (Mead & 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 (faba bean), Y_{bb} = Pure stand yield of crop b (flax), Y_{ab} = Intercrop yield of crop a (faba bean) and Y_{ba} = Intercrop yield of crop b (flax).

Land equivalent coefficient (LEC)

LEC is a measure of interaction concerned with the strength of relationship (Adetiloye et al., 1983). It is calculated as follows:

$$LEC = L_a \times L_b$$

where L_a = Relative yield of crop a (faba bean) and L_b = Relative yield of crop b (flax).

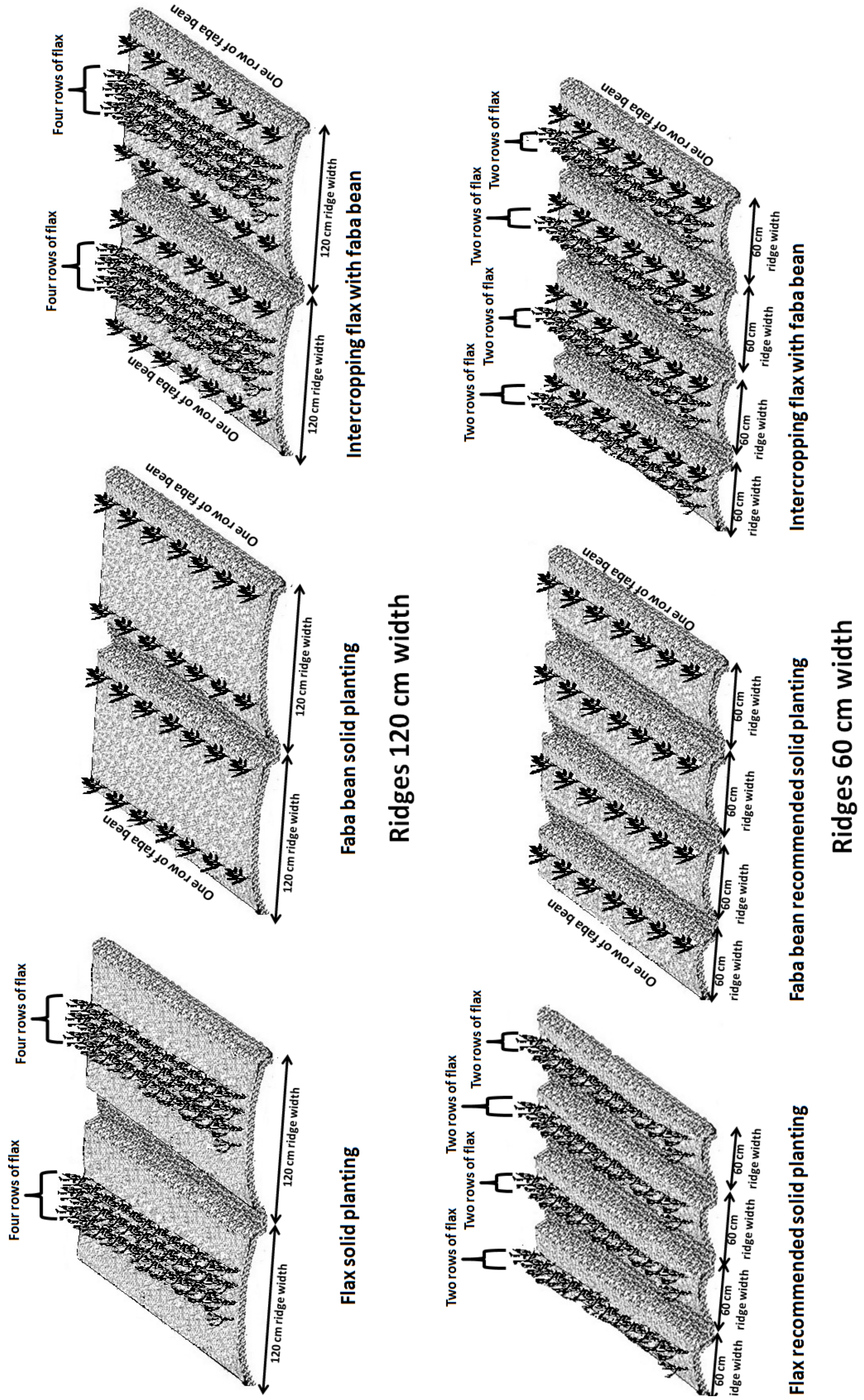

Fig.1. Intercropping flax with faba bean and solid plantings of both crops.

Aggressivity (Agg)

Aggressivity represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system (Willey, 1979) and was calculated as follows :

$A_{ab} = [Y_{ab} / (Y_{aa} \times Z_{ab})] - [Y_{ba} / (Y_{bb} \times Z_{ba})]$; $A_{ba} = [Y_{ba} / (Y_{bb} \times Z_{ba})] - [Y_{ab} / (Y_{aa} \times Z_{ab})]$

where, Y_{aa} = Pure stand yield of crop a (faba bean); Y_{bb} = Pure stand yield of crop b (flax); Y_{ab} = Intercrop yield of crop a (faba bean); Y_{ba} = Intercrop yield of crop b (flax); Z_{ab} = The respective proportion of crop a in the intercropping system (faba bean); Z_{ba} = The respective proportion of crop b in the intercropping system (flax).

Farmer's benefit

It was calculated by determining the total costs and net return of intercropping culture as compared to recommended solid planting of faba bean:

1- Total return of intercropping cultures = Price of faba bean yield + price of flax yield (US dollars \$). Calculation of the total return, the average of faba bean and flax prices presented by Bulletin of Statistical Cost Production and Net Return (2015) was used. The price of faba bean was 288.5 US\$ ton^{-1}, meanwhile the price of flax was 747.7 US\$ ton^{-1} (fiber + seed).

2- Net return ha^{-1} = Total return – (fixed costs of faba bean + variable costs of flax).

Statistical analysis

All data were subjected to statically analysis by the technique of analysis of variance of the split-split plot design according to Steel et al. (1997). After having homogeneity test for error variances by using Bartlett's test (Snedecor & Cochran, 1983), combined analysis of variance was performed. The least significant difference (LSD) test at probability level of 5% was used to determine the statistical differences between means when the F value was significant. The data were statistically analyzed by using the computer statistical software package MSTAT-C (Freed et al., 1989).

Results and Discussion

Faba bean yield and its attributes

Effect of ridge width

Number of *Orobanche crenata* plants m^{-2}, plant height, numbers of pods and seeds plant^{-1}, seed yield plant^{-1}, seed index and seed yield ha^{-1} were affected significantly by the ridge width, meanwhile, number of fruiting branches plant^{-1} and number of seeds pod^{-1} were not affected in the combined data across two seasons (Table 2). Decreasing ridge width from 120 to 60 cm increased number of *Orobanche crenata* m^{-2}, plant height, number of seeds plant^{-1} and straw yield ha^{-1} by 51.47, 1.44, 4.23 and 2.83%, respectively. In other words, increasing ridge width from 60 to 120 cm increased number of pods plant^{-1}, seed yield plant^{-1}, seed index and seed yield ha^{-1} by 5.68, 3.02, 4.98 and 5.20%, respectively. Consequently, it is expected that there was more shading around the plants of the narrowest ridge (60 cm) than those of the widest ridge. So, it is likely that there was higher germination of *Orobanche crenata* seeds to overcome faba bean growth of 60 cm ridge width than those of the other one by a germ tube that was in close proximity to roots of faba bean plant, then elongated towards the root of the faba bean, thereafter developed an organ of attachment which served as a bridge between the parasite and faba bean of the narrowest ridge, and deprived it of water, mineral nutrients and carbohydrates. In this concern, Hibberd et al. (1998) concluded that the number of parasitasion of host plant by the more broomrape would be the more yield loss occurs. Accordingly, one of the possible mechanisms for not contacting with faba bean roots of 120 cm ridge width probably due to the widest ridge furnished suitable plant arrangement per unit area. These results reveal that 120 cm ridge width led to disruption in chemical stimulants in the root exudates of faba bean and thereby maintained a high photosynthetic rate which reflected on enhancing tolerance of the plants to *Orobanche* (Mauromicale et al., 2008) compared with those of the other ridge width.

Effect of cropping systems

Number of *Orobanche crenata* plants m^{-2}, plant height, numbers of fruiting branches, pods and seeds plant^{-1}, seed yield plant^{-1}, seed index and seed yield ha^{-1} were affected significantly by the cropping systems, meanwhile, number of seeds pod^{-1} was not affected (Table 2). Intercropping flax with faba bean decreased number of *Orobanche crenata* m^{-2} by 78.95% and straw yield/ha by 21.25% than those of solid planting. Intercropping flax with faba bean increased number of seeds plant^{-1}, seed yield plant^{-1} and seed yield ha^{-1} by 19.95, 23.60 and 8.13%, respectively than those of solid planting in the combined data across two seasons (Table 2). Consequently, these results reveal that intercropping flax with faba bean could be formed unfavorable under-grown conditions for *Orobanche crenata* growth which enhanced faba bean competitiveness and productivity during growth and development stages.

TABLE 2. Effect of ridge width, cropping system, faba bean variety and their interactions on yield and yield attributes of faba bean, combined data across 2014/2015 and 2015/2016 seasons.

Ridge width	Cropping systems	*Orobanche* m^{-2} (no.)			Plant height (cm)			Fruiting branches/plant (no.)		
		Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza2	Giza 843	Mean
60 cm	Intercropping culture	3.30	2.10	**2.70**	88.20	91.40	**89.80**	0.70	0.90	**0.80**
	Solid planting	18.36	9.10	**13.73**	86.80	79.60	**83.20**	1.30	1.40	**1.35**
	Mean	**10.83**	**5.60**	**8.21**	**87.50**	**85.50**	**86.50**	**1.00**	**1.15**	**1.07**
120 cm	Intercropping culture	2.30	1.80	**2.05**	86.60	95.40	**91.00**	1.20	1.00	**1.10**
	Solid planting	9.60	8.00	**8.80**	80.90	78.20	**79.55**	1.20	1.50	**1.35**
	Mean	**5.95**	**4.90**	**5.42**	**83.75**	**86.80**	**85.27**	**1.20**	**1.25**	**1.22**
Average of cropping system	Intercropping	2.80	1.95	**2.37**	87.40	93.40	**90.40**	0.95	0.95	**0.95**
	Solid	13.98	8.55	**11.26**	83.85	78.90	**81.37**	1.25	1.45	**1.35**
Average of faba bean variety	Giza- 2		**8.39**			**85.62**			**1.10**	
	Giza- 843		**5.25**			**86.15**			**1.20**	
F test $_{0.05}$ Ridge width (W)			**			**			NS	
F test $_{0.05}$ Cropping system (S)			**			**			*	
F test $_{0.05}$ Faba bean variety (V)			**			**			NS	
LSD $_{0.05}$ W x S			0.55			0.28			NS	
LSD $_{0.05}$ W x V			0.16			0.34			NS	
LSD $_{0.05}$ S x V			0.16			0.34			NS	
LSD $_{0.05}$ W x S x V			0.23			0.49			0.26	

*'** Significant at 0.05 and 0.01 levels of probability, respectively; NS = Non-significant.

TABLE 2. Cont.

Ridge width	Cropping systems	Pods plant^{-1} (no.)			Seeds plant^{-1} (no.)			Seeds pod^{-1} (no.)		
		Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean
60 cm	Intercropping culture	7.70	8.40	**8.05**	21.10	26.30	**23.70**	2.80	3.20	**3.00**
	Solid planting	5.90	8.30	**7.10**	19.20	25.00	**22.10**	3.70	3.00	**3.35**
	Mean	**6.80**	**8.35**	**7.57**	**20.15**	**25.65**	**22.90**	**3.25**	**3.10**	**3.17**
120 cm	Intercropping culture	10.70	7.80	**9.25**	27.10	23.40	**25.25**	2.50	3.10	**2.80**
	Solid planting	6.50	7.00	**6.75**	18.30	19.10	**18.70**	2.90	2.80	**2.85**
	Mean	**8.60**	**7.40**	**8.00**	**22.70**	**21.25**	**21.97**	**2.70**	**2.95**	**2.82**
Average of cropping system	Intercropping	9.20	8.10	**8.65**	24.10	24.85	**24.47**	2.65	3.15	**2.90**
	Solid	6.20	7.65	**6.92**	18.75	22.05	**20.40**	3.30	2.90	**3.10**
Average of faba bean variety	Giza- 2		**7.70**			**21.42**			**2.97**	
	Giza- 843		**7.87**			**23.45**			**3.02**	
F test $_{0.05}$ Ridge width (W)			*			*			NS	
F test $_{0.05}$ Cropping system (S)			**			**			NS	
F test $_{0.05}$ Faba bean variety (V)			**			**			NS	
LSD $_{0.05}$ W x S			0.34			0.19			NS	
LSD $_{0.05}$ W x V			0.44			0.21			0.27	
LSD $_{0.05}$ S x V			0.44			0.21			0.27	
LSD $_{0.05}$ W x S x V			0.62			0.29			NS	

*'** Significant at 0.05 and 0.01 levels of probability, respectively; NS = Non-significant.

Table 2. Cont.

Ridge width	Cropping systems		Seed yield plant-1 (g)			Seed index (g)			Seed yield ha-1 (ton)			Straw yield ha-1 (ton)		
			Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean
60 cm	Intercropping culture		17.60	20.40	**19.00**	80.50	84.20	**82.35**	2.41	2.81	**2.61**	4.64	4.31	**4.47**
	Solid planting		15.30	19.50	**17.40**	78.60	81.50	**80.05**	2.28	2.52	**2.40**	5.90	5.46	**5.68**
	Mean		**16.45**	**19.95**	**18.20**	**79.55**	**82.85**	**81.20**	**2.34**	**2.66**	**2.50**	**5.27**	**4.88**	**5.07**
120 cm	Intercropping culture		23.60	20.10	**21.85**	83.80	87.80	**85.80**	2.55	2.90	**2.72**	4.55	4.14	**4.34**
	Solid planting		14.40	16.90	**15.65**	89.10	80.30	**84.70**	2.43	2.64	**2.53**	5.68	5.37	**5.52**
	Mean		**19.00**	**18.50**	**18.75**	**86.45**	**84.05**	**85.25**	**2.49**	**2.77**	**2.63**	**5.11**	**4.75**	**4.93**
Average of cropping system		Intercropping	20.60	20.25	**20.42**	82.15	86.00	**84.07**	2.48	2.85	**2.66**	4.59	4.22	**4.41**
		Solid	14.85	18.20	**16.52**	83.85	80.90	**82.37**	2.35	2.58	**2.46**	5.79	5.41	**5.60**
Average of faba bean variety		Giza- 2		**17.72**			**83.00**			**2.41**			**5.19**	
		Giza- 843		**19.22**			**83.45**			**2.71**			**4.82**	
F test $_{0.05}$ Ridge width (W)				*			**			**			**	
F test $_{0.05}$ Cropping system (S)				**			**			**			**	
F test $_{0.05}$ Faba bean variety (V)				**			**			**			**	
$LSD_{0.05}$ W x S				0.63			0.40			NS			NS	
$LSD_{0.05}$ W x V				0.33			0.28			0.02			NS	
$LSD_{0.05}$ S x V				0.33			0.28			0.02			NS	
$LSD_{0.05}$ W x S x V				0.47			0.39			NS			0.05	

*'** Significant at 0.05 and 0.01 levels of probability, respectively; NS = Non-significant.

With respect to number of *Orobanche crenata* m^{-2}, it is expected that *Orobanche crenata* suffered from root exudates of adjacent flax plants which believed to be very promising tool in controlling this parasite under intercropping conditions (Khalaf, 1992). The root exudates of flax could be involving allelopathic substances that had a negative effects on broomrape (Chittapur et al., 2001). Conversely, it seems that solid culture of faba bean furnished favorable under-ground conditions for germination of *Orobanche crenata* seeds though the absence of chemical stimulants in the root exudates.

These results are comparable to those obtained by ICARDA (2009) where it is reported that intercropping flax with faba bean reduced broomrape and it was a low cost way of dealing with broomrape. Also, Aksoy et al. (2016) showed that flax, which grows as a trap plant can be a major component of broomrape management and therefore reduces the stock of crenata broomrape seeds in soil. They added that flax was the most effective treatment by reducing 25-71% of shoot number of *O. crenata* in the first and second seasons, respectively.

Effect of faba bean varieties

Faba bean varieties differed significantly in their effect on number of *Orobanche crenata* m^{-2}, plant height, numbers of pods and seeds plant^{-1}, seed yield plant^{-1}, seed index and seed yield ha^{-1}, however, number of fruiting branches plant^{-1} and number of seeds pod^{-1} varieties were not differed (Table 2). Faba bean cv. Giza- 843 was infested by lower number of *Orobanche crenata* m^{-2} ($P \leq 0.05$) than Giza- 2 variety. This effect may be due to the genetic makeup of Giza- 2 variety, which played a major role in physiological process of the plant and reflected negatively on all the internal activities of plant. So, according to Losner-Goshen et al. (1998) it is likely that roots of the susceptible variety secreted higher specific enzymes that make its root cells frailer and more vulnerable to infestation by *Orobanche crenata* than Giza- 843 variety. Consequently, the vessel connection between *Orobanche crenata* and Giza- 843 variety may have been corrupted by the genetic effect of the tolerant faba bean variety. Faba bean cv. Giza- 843 had higher seed yield plant^{-1} and seed yield ha^{-1} by 8.46 and 12.44%, respectively, than the other one. These results show that Giza- 843 variety was more tolerant to *Orobanche crenata* infestation which positively reflected the accumulation of dry materials plant^{-1} than Giza- 2 variety during reproductive stage. These results are in the same context with those obtained by Trabelsi et al. (2015), who found the parasitism index on the new faba bean genotypes varied from 2-6 times less than susceptible 'Badï'.

Effect of the interaction ridge width X cropping systems

Number of *Orobanche crenata* plants m^{-2}, plant height, numbers of pods and seeds plant^{-1}, seed yield plant^{-1} and seed index were affected significantly by the ridge width x cropping systems, while, number of fruiting branches plant^{-1}, number of seeds pod^{-1}, seed and straw yields ha^{-1} were not affected (Table 2). The performance of faba bean growth and development of the widest ridge was better under intercropping conditions compared with the others. These data reveal that cropping systems responded differently ($P \leq 0.05$) to ridge width for number of *Orobanche crenata* m^{-2}, plant height, numbers of pods and seeds plant^{-1}, seed yield plant^{-1} and seed index.

Effect of the interaction ridge width X faba bean varieties

Number of *Orobanche crenata* plants m^{-2}, plant height, numbers of pods and seeds plant^{-1}, number of seeds pod^{-1}, seed yield plant^{-1}, seed index and seed yield ha^{-1} were affected significantly by ridge width x faba bean varieties, meanwhile, number of fruiting branches plant^{-1} and straw yield ha^{-1} were not affected (Table 2). Generally, Giza- 843 variety integrated positively with the widest ridge to give the lowest value of number of *Orobanche crenata* plants m^{-2} which reflected positively on seed yield plant^{-1} through increasing numbers of pods and seeds plant^{-1}, number of seeds pod^{-1} and seed index. Such conditions may enable Giza-843 variety to utilize the environmental resources more than the others. It is important to mention that the differences among these treatments probably due to the interplay of faba bean variety and intra-plant competition of ridge width. These results are in similar to those observed by Bakry et al. (2011) who found that Nubaria-1 variety produced the highest seed and protein yields per faddan when it was seeded at 20 cm between rows and significantly out yielded all other varieties, meanwhile Cairo-25 and Nubaria-1 varieties produced high biological yield per faddan when they were seeded at the highest plant density.

Effect of the interaction cropping systems X faba bean varieties

Number of *Orobanche crenata* plants m^{-2}, plant height, numbers of pods and seeds $plant^{-1}$, number of seeds pod^{-1}, seed yield $plant^{-1,}$ seed index and seed yield ha^{-1} were affected significantly by cropping systems x faba bean varieties, meanwhile, number of fruiting branches $plant^{-1}$ and straw yield ha^{-1} were not affected in the combined data across two seasons (Table 2). It was remarkable to observe that most the studied traits were affected by interaction between cropping systems and faba bean varieties. Giza- 843 variety of intercropping culture had the lowest value of number of *Orobanche crenata* plants m^{-2} compared with the others. Such response might support the flax plants have limited influence in reducing this parasitic weed m^{-2} but this influence was increased largely by intercropping Giza- 843 variety with flax under field conditions than the other variety. Ultimately, these data show that each of these two factors act dependently ($P\leq0.05$) on all the studied traits of faba bean crop except number of fruiting branches $plant^{-1}$ and straw yield ha^{-1}.

Effect of the interaction ridge width X cropping systems X faba bean varieties

All the studied traits were affected significantly by ridge width x cropping systems x faba bean varieties except number of seed pod^{-1} and seed yield ha^{-1} in the combined data across two seasons (Table 2). These results reveal that Giza- 843 variety integrated positively with intercropping culture to decrease *Orobanche* infestation and this effect was increased by increasing ridge width from 60 to 120 cm which reflected negatively on the efficiency of *Orobanche crenata* in the penetration of Giza- 843 variety roots. Accordingly, intercropped Giza- 843 variety of the widest ridge could be playing a major role in regulating natural protection against *Orobanche crenata* m^{-2}, and maintained faba bean productivity. These data show that each of these three factors act dependently ($P\leq0.05$) on all the studied traits of faba bean crop except number of seed pod^{-1} and seed yield ha^{-1}.

Flax yield and its attributes

Effect of ridge width

Numbers of fruiting branches and capsules $plant^{-1}$, seed yields $plant^{-1}$ and ha^{-1}, seed oil content, straw and fiber yields ha^{-1} were affected significantly by the ridge width in the combined data across two seasons, meanwhile oil yield ha^{-1} was not affected (Table 3). Flax sown at 120 cm ridge width had higher number of branches and capsules $plant^{-1}$, seed yields $plant^{-1}$ and ha^{-1}, seed oil content, straw and fiber yields ha^{-1} than those of the other treatments. These results may be due to 120 cm ridge width formed better above and under – ground conditions for flax plants which decreased intra-specified competition between them for requisite growth resources particularly light intensity than those of 60 cm ridge width. Accordingly, it is expected that the widest ridge increased the ability of physiological source of flax plant which maintained photosynthetic process integrity during reproductive stage.

Effect of cropping system

Numbers of fruiting branches and capsules $plant^{-1}$, seed yields $plant^{-1}$ and ha^{-1}, seed oil content, oil, straw and fiber yields ha^{-1} were affected significantly by the cropping system in the combined data across two seasons (Table 3). Solid planting of flax had higher ($P\leq0.05$) 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. In other words, intercropping flax with faba bean decreased numbers of branches and capsules $plant^{-1}$ by 24.00% and 32.80%, 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. These results could be attributed to intercropping culture that declined reproductive growth period, which reduced number of capsules and finally decreased of seeds and consequently seed yield. Reversal magnitude was reported for solid planting since there was an 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. It is apparent that solid planting formed normal environmental conditions for flax growth and development and thereby flax plant maximized the use of natural resources during critical periods of oil yield and its components with the moment of the growth season where more ecological resources are available (Balalic et al., 2012).

TABLE 3. Effect of ridge width, cropping system, faba bean variety and their interactions on yield and yield attributes of flax, combined data across 2014/2015 and 2015/2016 seasons.

Ridge width	Cropping systems	Fruiting branches plant^{-1} (no.)			Capsules plant^{-1} (no.)			Seed yield plant^{-1} (g)			Seed yield ha^{-1} (ton)		
		Giza2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza2	Giza843	Mean	Giza2	Giza843	Mean
60 cm	Intercropping culture	0.90	0.70	**0.80**	18.90	17.30	**18.10**	1.07	0.89	**0.98**	0.91	0.85	**0.88**
	Solid planting	1.30		**1.30**	31.00		**31.00**	1.71		**1.71**	1.31		**1.31**
	Mean	**1.10**	**1.00**	**1.05**	**24.95**	**24.15**	**24.55**	**1.39**	**1.30**	**1.34**	**1.11**	**1.08**	**1.09**
120 cm	Intercropping culture	1.40	0.80	**1.10**	27.00	23.10	**25.05**	1.78	1.19	**1.48**	0.98	0.93	**0.95**
	Solid planting	1.20		**1.20**	33.20		**33.20**	2.07		**2.07**	1.38		**1.38**
	Mean	**1.30**	**1.00**	**1.15**	**30.10**	**28.15**	**29.12**	**1.92**	**1.63**	**1.77**	**1.18**	**1.15**	**1.16**
Average of cropping system	Intercropping	1.15	0.75	**0.95**	22.95	20.20	**21.57**	1.42	1.04	**1.23**	0.94	0.89	**0.91**
	Solid	1.25		**1.25**	32.10		**32.10**	1.89		**1.89**	1.34		**1.34**
Average of faba bean variety	Giza- 2		**1.20**			**27.52**			**1.65**			**1.14**	
	Giza- 843		**1.00**			**26.15**			**1.46**			**1.11**	
F test $_{0.05}$ Ridge width (W)			**			**			**			**	
F test $_{0.05}$ Cropping system (S)			**			**			**			**	
F test $_{0.05}$ Faba bean variety (V)			**			**			**			**	
LSD $_{0.05}$ W x S			0.03			0.28			0.03			NS	
LSD $_{0.05}$ W x V			0.01			0.15			0.01			NS	
LSD $_{0.05}$ S x V			0.01			0.15			0.01			0.006	
LSD $_{0.05}$ W x S x V			0.02			0.22			0.01			NS	

** Significant at 0.01 levels of probability; NS = Non-significant.

TABLE 3. Cont.

Ridge width	Cropping systems	Seed oil content (%)			Oil yield ha[-1] (ton)			Straw yield ha[-1] (ton)			Fiber yield ha[-1] (ton)		
		Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean
60 cm	Intercropping culture	26.52	26.58	**26.55**	0.24	0.22	**0.23**	4.80	4.50	**4.65**	0.66	0.64	**0.65**
	Solid planting	27.68		**27.68**	0.36		**0.36**	5.50		**5.50**	0.69		**0.69**
	Mean	**27.10**	**27.13**	**27.11**	**0.30**	**0.29**	**0.29**	**5.15**	**5.00**	**5.07**	**0.67**	**0.66**	**0.66**
120 cm	Intercropping culture	**26.83**	**26.87**	**26.85**	0.26	0.24	**0.25**	5.90	5.30	**5.60**	0.73	0.69	**0.71**
	Solid planting	27.77		**27.77**	0.38		**0.38**	6.60		**6.60**	0.78		**0.78**
	Mean	**27.30**	**27.32**	**27.31**	**0.32**	**0.31**	**0.31**	**6.25**	**5.95**	**6.10**	**0.75**	**0.73**	**0.74**
Average of cropping system	Intercropping	26.67	26.72	**26.70**	0.25	0.23	**0.24**	5.35	4.90	**5.12**	0.69	0.66	**0.68**
	Solid	27.72		**27.72**	0.37		**0.37**	6.05		**6.05**	0.73		**0.73**
Average of faba bean variety	Giza- 2		**27.20**			**0.31**			**5.70**			**0.71**	
	Giza- 843		**27.22**			**0.30**			**5.47**			**0.70**	
F test $_{0.05}$ Ridge width (W)			**			NS			**			**	
F test $_{0.05}$ Cropping system (S)			**			**			**			**	
F test $_{0.05}$ Faba bean variety (V)			**			NS			**			*	
LSD $_{0.05}$ W x S			0.04			0.03			NS			0.01	
LSD $_{0.05}$ W x V			NS			0.02			NS			NS	
LSD $_{0.05}$ S x V			0.01			NS			0.17			0.02	
LSD $_{0.05}$ W x S x V			NS			0.02			NS			NS	

*’** Significant at 0.05 and 0.01 levels of probability, respectively; NS = Non-significant.

Effect of faba bean varieties

Faba bean varieties significantly affected numbers of fruiting branches and capsules plant^{-1}, seed yields plant^{-1} and ha^{-1}, seed oil content, straw and fiber yields ha^{-1} in the combined data across two seasons, meanwhile oil yield ha^{-1} was not affected (Table 3). Intercropping flax with Giza- 2 variety increased numbers of branches and capsules plant^{-1}, seed yields plant^{-1} and ha^{-1}, oil, straw and fiber yields ha^{-1} by 20.00, 5.23, 13.01, 2.70, 3.33, 4.20 and 1.42%, respectively, compared to intercropping Giza- 843 variety. It seems that the genetic effect of Giza- 2 variety played a major role in canopy structure of the plant which led to greater ability of flax to competition with faba bean for climatic and edaphic environmental conditions which reflected on number of branches and capsules plant^{-1} that reflected on crop productivity.

Effect of the interaction ridge width X cropping systems

Numbers of branches and capsules plant^{-1}, seed yield plant^{-1}, seed oil content, oil and fiber yields ha^{-1} were affected significantly by ridge width x cropping systems in the combined data across two seasons, meanwhile seed and straw yields ha^{-1} were not affected (Table 3). Flax of 120 cm ridge width achieved the highest number of capsules plant^{-1}, seed yield plant^{-1}, oil and fiber yield ha^{-1} compared with the others under solid planting conditions. Also, it is important to mention that there were no significant differences between 60 and 120 cm ridge widths for oil yield ha^{-1} under solid planting conditions. These results reveal that performance of flax growth and development of the widest ridge was better under solid plating conditions compared with the others. These data indicate that cropping systems responded differently ($P \leq 0.05$) to ridge width for branches and capsules plant^{-1}, seed yield plant^{-1}, seed oil content and oil and fiber yields ha^{-1}.

Effect of the interaction ridge width X faba bean varieties

Numbers of fruiting branches and capsules plant^{-1}, seed yield plant^{-1} and oil yield ha^{-1} were affected significantly by ridge width x faba bean varieties in the combined data across two seasons, meanwhile seed yield ha^{-1}, seed oil content, straw and fiber yields ha^{-1} were not affected (Table 3). Giza-2 variety interacted positively with the widest ridge to give the highest numbers of branches and capsules plant^{-1}, seed yield plant^{-1} and oil yield ha^{-1} compared with the others. These data reveal that faba bean varieties responded differently ($P \leq 0.05$) to ridge width for numbers of branches and capsules plant^{-1}, seed yield plant^{-1} and oil yield ha^{-1}.

Effect of the interaction cropping systems X faba bean varieties

Numbers of branches and capsules plant^{-1}, seed yields plant^{-1} and ha^{-1}, seed oil content, straw and fiber yields ha^{-1} were affected significantly by cropping systems x faba bean varieties in the combined data across two seasons, meanwhile oil yield ha^{-1} was not affected (Table 3). Solid planting of flax had the highest branches and capsules plant^{-1}, seed yields plant^{-1} and ha^{-1}, seed oil content, straw and fiber yields ha^{-1} compared with the others. These data indicate that there was an effect ($P \leq 0.05$) of cropping systems x faba bean varieties on numbers of fruiting branches and capsules plant^{-1}, seed yields plant^{-1} and ha$^{-1,}$ seed oil content, straw and fiber yields ha^{-1}.

Effect of the interaction ridge width and cropping systems X faba bean varieties

Numbers of branches and capsules plant^{-1}, seed yield plant^{-1} and oil yield ha^{-1} were affected significantly by ridge width x cropping systems x faba bean varieties in the combined data across two seasons, meanwhile seed yield ha^{-1}, seed oil content, straw and fiber yields ha^{-1} were not affected (Table 3). These results show that Giza-2 variety integrated positively with intercropping culture to increase numbers of branches and capsules plant^{-1}, seed yield plant^{-1} and oil yield ha^{-1} and this effect was increased by increasing ridge width from 60 to 120 cm. These data show that each of these three factors act dependently ($P \leq 0.05$) on numbers of branches and capsules plant^{-1}, seed yield plant^{-1} and oil yield ha^{-1}.

Quality of flax seed oil

Quality of flax seed oil included palmitic acid, stearic acid, oleic acid, linoleic acid (ώ6), α-linolenic acid (ώ3), total saturated fatty acids (TS), total unsaturated fatty acids (TUS) and ratio of unsaturated-saturated fatty acids (US/S). Gas chromatography checked five prevalent fatty acids; linolenic, linoleic, oleic, palmitic and stearic acids (Table 4). The US/S fatty acid ratio is substantial in medicinal and nutritional aspects (Gurr et al., 2002).

TABLE 4. Effect of ridge width, cropping system, faba bean varieties and their interactions on relative percentage of fatty acids composition, combined data across 2014/2015 and 2015/2016 seasons.

Ridge width	Cropping systems	Palmitic acid (C:D, 16.00) Giza 2	Palmitic acid Giza 843	Palmitic acid Mean	Stearic acid (C:D, 18.00) Giza2	Stearic acid Giza 843	Stearic acid Mean	Oleic acid (C:D, 18.01) Giza2	Oleic acid Giza 843	Oleic acid Mean	Linoleic acid (ώ6) (C:D, 18.02) Giza 2	Linoleic acid Giza 843	Linoleic acid Mean
60 cm	Intercropping culture	8.50	9.00	**8.75**	4.50	5.00	**4.75**	21.80	21.50	**21.65**	14.00	13.40	**13.70**
	Solid planting	8.30		**8.30**	4.20		**4.20**	22.30		**22.30**	14.20		**14.20**
	Mean	**8.40**	**8.65**	**8.52**	**4.35**	**4.60**	**5.07**	**22.05**	**21.90**	**21.97**	**14.10**	**13.80**	**13.95**
120 cm	Intercropping culture	8.80	9.20	**9.00**	4.70	5.30	**5.00**	21.60	20.90	**21.25**	13.60	13.00	**13.30**
	Solid planting	8.60		**8.60**	4.60		**4.60**	22.00		**22.00**	13.90		**13.90**
	Mean	**8.70**	**8.90**	**8.80**	**4.65**	**4.95**	**5.30**	**21.80**	**21.45**	**21.62**	**13.75**	**13.45**	**13.60**
Average of cropping system	Intercropping	8.65	9.10	**8.87**	4.60	5.15	**4.87**	21.70	21.20	**21.45**	13.80	13.20	**13.50**
	Solid	8.45		**8.45**	4.40		**4.40**	22.15		**22.15**	14.05		**14.05**
Average of faba bean variety	Giza- 2		**8.55**			**4.50**			**21.92**			**13.92**	
	Giza- 843		**8.77**			**4.77**			**21.67**			**13.62**	
F test $_{0.05}$ Ridge width (W)			*			*			*			*	
F test $_{0.05}$ Cropping system (S)			**			**			**			**	
F test $_{0.05}$ Faba bean variety (V)			NS			**			*			**	
$LSD_{0.05}$ W x S			NS			NS			NS			NS	
$LSD_{0.05}$ W x V			NS			NS			NS			0.26	
$LSD_{0.05}$ S x V			NS			0.25			0.31			0.26	
$LSD_{0.05}$ W x S x V			NS			NS			NS			0.37	

*'** Significant at 0.05 and 0.01 levels of probability, respectively; NS = Non-significant.

TABLE 4. Cont.

Ridge width	Cropping systems	α-Linolenic acid (ώ3) (C:D, 18.03)			Total saturated fatty acids (TS)			Total unsaturated fatty acids (TUS)			Ratio of unsaturated fatty acids to saturated fatty acids (USS^{-1})		
		Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean
60 cm	Intercropping culture	48.30	48.00	**48.15**	13.00	14.00	**13.50**	84.10	82.90	**83.50**	6.46	5.92	**6.19**
	Solid planting	48.70		**48.70**	12.50		**12.50**	85.20		**85.20**	6.81		**6.81**
	Mean	**48.50**	**48.35**	**48.42**	**12.75**	**13.25**	**13.00**	**84.65**	**84.05**	**84.35**	**6.63**	**6.36**	**6.50**
120 cm	Intercropping culture	48.20	47.80	**48.00**	13.50	14.50	**14.00**	83.40	81.70	**82.55**	6.17	5.63	**5.90**
	Solid planting	48.50		**48.50**	13.20		**13.20**	84.40		**84.40**	6.39		**6.39**
	Mean	**48.35**	**48.15**	**48.25**	**13.35**	**13.85**	**13.60**	**83.90**	**83.05**	**83.47**	**6.28**	**6.01**	**6.14**
Average of cropping system	Intercropping	48.25	47.90	**48.07**	13.25	14.25	**13.75**	83.75	82.30	**83.02**	6.31	5.77	**6.04**
	Solid	48.60		**48.60**	12.85		**12.85**	84.80		**84.80**	6.60		**6.60**
Average of faba bean variety	Giza- 2	**48.42**			**13.05**			**84.27**			**6.45**		
	Giza- 843	**48.25**			**13.55**			**83.55**			**6.18**		
F test $_{0.05}$ Ridge width (W)		*			NS			**			**		
F test $_{0.05}$ Cropping system (S)		**			NS			**			**		
F test $_{0.05}$ Faba bean variety (V)		NS			NS			**			**		
$LSD_{0.05}$ W x S		NS			NS			NS			0.03		
$LSD_{0.05}$ W x V		NS			2.39			NS			0.01		
$LSD_{0.05}$ S x V		NS			NS			0.31			0.01		
$LSD_{0.05}$ W x S x V		NS			3.39			NS			0.01		

*'** Significant at 0.05 and 0.01 levels of probability, respectively; NS = Non-significant.

Analysis of fatty acids of flax seed from Egyptian cultivars showed that the main compounds of this oil included linolenic acid, linoleic acid, oleic acid and stearic acid, respectively (El-Beltagi et al., 2007 and Choo et al., 2007) which was dissimilar from our outcomes. However, the results of other studies which specified that the major unsaturated fatty acids in the oils samples were linolenic, oleic and linoleic, respectively (Bayrak et al., 2010 and Popa et al., 2012) are in agreement with our findings.

Effect of ridge width

Palmitic acid, stearic acid, oleic acid, ώ6, ώ3, TUS and US/S were affected significantly by the ridge width in the combined data across two seasons, but TS was not affected (Table 4). Increasing ridge width from 60 to 120 cm resulted in higher ($P \leq 0.05$) values of palmitic acid and stearic acid but the reverse was true with oleic acid, ώ6, ώ3, TUS and US/S. It is expected that the widest ridge received more solar radiation that make the surrounding environment with flax warmer than the other ridge width treatment and reflected on all the studied traits of quality of flax seed oil. When seed development happened through high temperatures, the fatty acid profile was higher in monounsaturated and saturated fatty acids and lower in polyunsaturated fatty acids, contrasted to seed development under lower temperatures (Denga & Scarthb, 1998). These results indicate that flax of 60 cm ridge width affected positively quality of flax seed oil (oleic acid, ώ6, ώ3, TUS and US/S).

Effect of cropping systems

Palmitic acid, stearic acid, oleic acid, ώ6, ώ3, TUS and US/S were affected significantly by the cropping systems, while TS was not affected (Table 4). Intercropping flax with faba bean increased ($P \leq 0.05$) concentration of palmitic acid and stearic acid by 4.97 and 10.68%, respectively, than those of solid planting. In other words, solid culture of flax had higher values of oleic acid, ώ6, ώ3, TUS and US/S than those of intercropping culture. Intercropping culture may be enhanced more warm environment around flax plants which responded to higher temperatures by reducing the level of un-saturation of their membrane fatty acids (Williams et al., 1988) compared with those of the other treatment. Also, the decrease in the US/S observed in solid planting of flax, suggested a potential role of temperature on the activity of oleate desaturase in the developing seeds. This was due to the synthesis or activation of oleate desaturase at low temperature and the reversible repression of this enzyme at high temperature (Flagella et al., 2002). These results show that intercropping flax with faba bean affected negatively quality of flax seed oil by increasing concentration of oleic acid, ώ6, ώ3, TUS and US/S.

Effect of faba bean varieties

Faba bean varieties affected significantly stearic acid, oleic acid, ώ6, TUS and US/S in the combined data across two seasons, meanwhile palmitic acid, ώ3 and TS were not affected (Table 4). Faba bean cv. Giza- 2 increased concentration of oleic acid, ώ6 and US/S by 1.15, 2.20 and 4.36%, respectively, than the other variety. These results reveal that Giza- 843 variety affected negatively quality of flax seed oil. It is known that Giza- 843 variety taller and have greater number of branches plant^{-1} than Giza- 2 which reflected on bigger canopy structure. Consequently, Giza- 843 variety may decreased US/S of flax seed oil.

Effect of the interaction ridge width X cropping systems

US/S was affected significantly by ridge width x cropping systems, meanwhile, palmitic acid, stearic acid, oleic acid, ώ6, ώ3, TS and TUS were not affected in the combined data across two seasons (Table 4). Flax of 60 cm ridge width had the highest value of US/S which reflected positively on quality of flax seed oil under solid planting conditions compared with those of the other treatments. These data show that cropping systems responded similarly ($P > 0.05$) to ridge width for palmitic acid, stearic acid, oleic acid, ώ6, ώ3, TS and TUS except US/S of flax seed oil.

Effect of the interaction ridge width X faba bean varieties

ώ6, TS and US/S were affected significantly by the interaction ridge width x faba bean varieties, meanwhile, palmitic acid, stearic acid, oleic acid, ώ3, TS and TUS were not affected in 2014/2015 and 2015/2016 seasons (Table 4). Generally, Giza- 2 variety integrated positively with the narrowest ridge to give the highest values of ώ6 and US/S which reflected positively on quality of flax seed oil compared with those of the other treatments. These data indicate that each of these two factors act dependently ($P \leq 0.05$) on ώ6, TS and US/S of flax seed oil.

Effect of the interaction cropping systems X faba bean varieties

Stearic acid, oleic acid, ώ6, TUS and US/S were affected significantly by cropping systems x faba bean varieties, meanwhile palmitic acid, ώ3 and TS were not affected in the combined data across two seasons (Table 4). Solid planting of flax interacted positively with faba bean cv. Giza- 2 to achieve the highest values of oleic acid, ώ6, TUS and US/S which reflected positively on quality of flax seed oil compared with those of the other treatments. These data reveal that each of these two factors act dependently ($P \leq 0.05$) on stearic acid, oleic acid, ώ6, TUS and US/S of flax seed oil.

Effect of the interaction ridge width X cropping systems X faba bean varieties

ώ6, TS and US/S were affected significantly by ridge width x cropping systems x faba bean varieties, meanwhile palmitic acid, stearic acid, oleic acid, ώ3 and TUS were not affected in the combined data across two seasons (Table 4). In general, it seems that intercropped flax of 120 cm ridge width interacted with faba bean cv. Giza- 843 to achieve acceptable quality of flax seed oil compared with those of the other treatments. These data indicate that each of these three factors act dependently ($P \leq 0.05$) on ώ6, TS and US/S of flax seed oil.

Competitive relationships

Land equivalent ratio (LER)

The values of land equivalent ratio were estimated by using data of sole crops. LER of more than 1.00 indicates yield advantage, equal to 1.00 indicates no gain or no loss and less than 1.00 indicates yield loss (Vandermeer, 1989). The total LER values were better than one in all the studied treatments. Land equivalent ratio ranged from 1.63 of intercropping flax with Giza-2 variety in ridges 60 cm width to 1.86 of intercropping flax with Giza- 843 variety in ridges 120 cm width (Fig. 2). LER of 1.86 indicates that the planted area to sole cultures would need to be 86 % greater than the planted area to intercrop to produce the same combined yields (*i.e*. 86 % more land would be required as a sole crop to produce the same yield as intercropping). Generally, these results reveal that intercropping flax with Giza-843 variety interacted positively with the wide ridge to decrease inter and/or intra-specific competition between plants of the intercrops and/or between plants of faba bean, respectively, for available environmental conditions.

Land equivalent coefficient (LEC)

Land equivalent coefficient was a measure of interaction concerned with the intensity of relationship. LEC is used for a two- crop mixture, the minimum expected productivity co-efficient (PC) is 25 per cent, that is, a yield advantage was obtained if LEC values override 0.25. With regard to intercropping flax with faba bean, LEC ranged from 0.64 of intercropping flax with Giza- 2 variety in ridges 60 cm width to 0.82 of intercropping flax with Giza- 843 variety in ridges 120 cm width (Fig. 3). The highest advantage of intercropping flax with Giza- 843 variety in ridges 120 cm width over the others could be due to decrease inter and intra-specific competition between the same species and the two species for above and underground environmental conditions to achieve higher economic yield of both species per unit area compared to the others.

Aggressivity (Agg)

Aggressivity defines the variation in competitive ability of the component crops in intercropping association. The positive sign indicates the dominant component and the negative sign mentions the dominated component. Higher numerical values of aggressivity indicate greater difference in competitive ability, as well as, bigger diversity between current and predictabled yield in both crops. The results indicate that the value of aggressivity of faba bean was positive for all treatments, while, the values of aggressivity were negative for all intercropped flax with faba bean plants in the combined data across two seasons (Fig. 4). These data show that faba bean and flax plants are dominant and dominated components, respectively.

Generally, the highest passive values of aggressivity were gained by intercropping flax with faba bean cv. Giza- 843 in ridges 60 cm width; meanwhile intercropping flax with faba bean cv. Giza-2 in ridges 60 cm width had the lowest negative values of aggressivity. Obviously, intercropping flax with faba bean cv. Giza- 843 in ridges 60 cm width is more aggressive compared to the other treatments.

Farmer's benefit

Intercropping flax with faba bean increased total and net returns as compared with solid cultures of both crops in the combined data across two seasons (Table 5). Total return of intercropping flax with faba bean was increased by 91.22% as compared with faba bean solid culture, respectively. Net return ranged between US$ 11.7/ha by growing faba bean variety Giza- 2 in ridges 60 cm width to US$ 619.7/ha by intercropping flax with faba bean variety Giza- 843 in ridges 120 cm width. The results show that intercropping flax with faba bean variety Giza- 843 in ridges 120 cm width achieved US$ 608.0/ha compared to solid planting of faba bean variety Giza- 2 in ridges 60 cm width. The study indicates that intercropping flax with faba bean variety Giza- 843 in ridges 120 cm width was more profitable to farmers than solid planting of faba bean variety Giza- 2 in ridges 60 cm width. These outcomes are in regularity with those gained by Abbas et al. (2006) who found that intercropping two rows of flax with faba bean gave the highest economic return for the farmers.

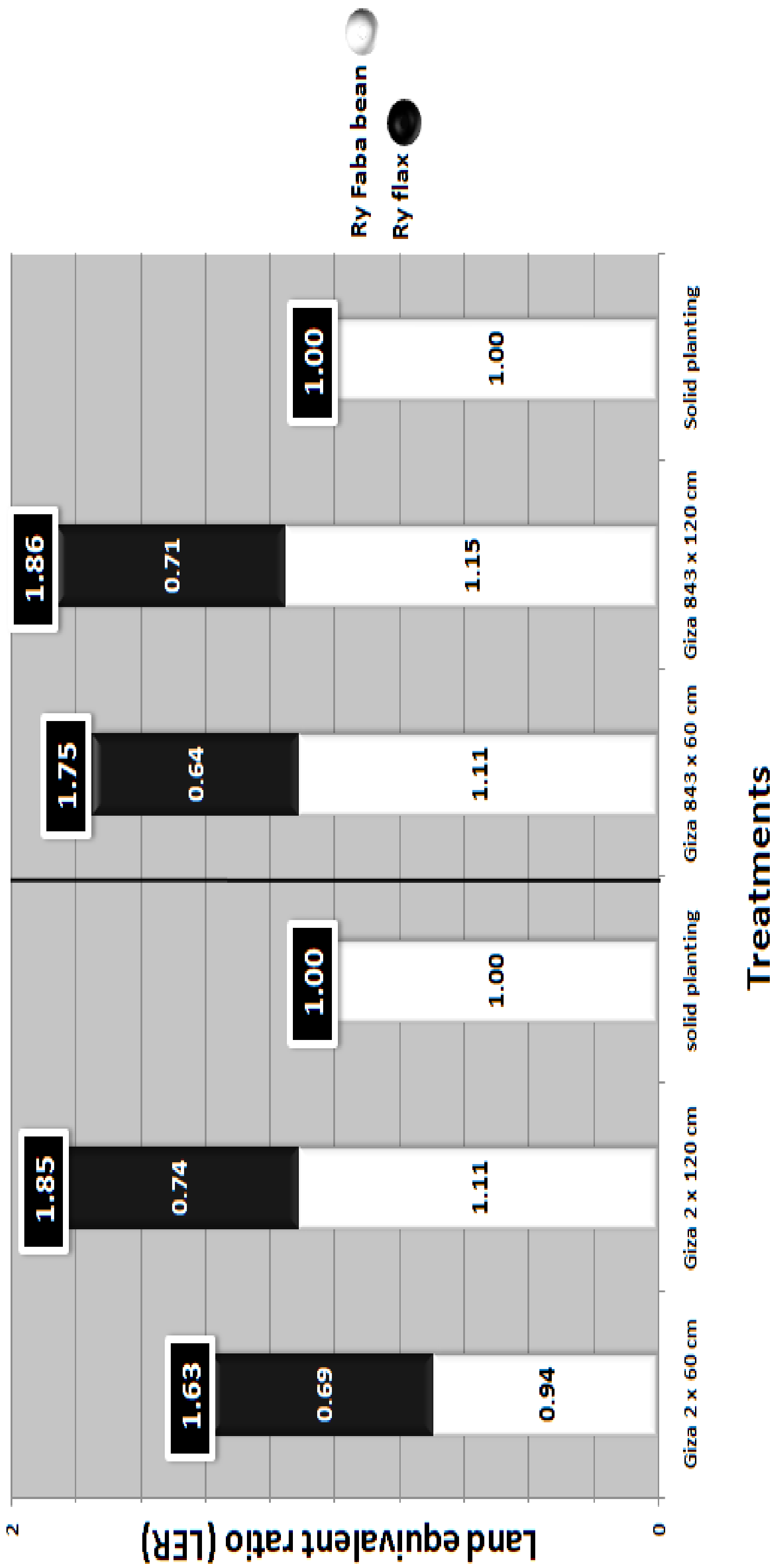

Fig. 2. LER as affected by ridge width, cropping system, faba bean variety and their interactions, combined data across 2014/2015 and 2015/2016 seasons

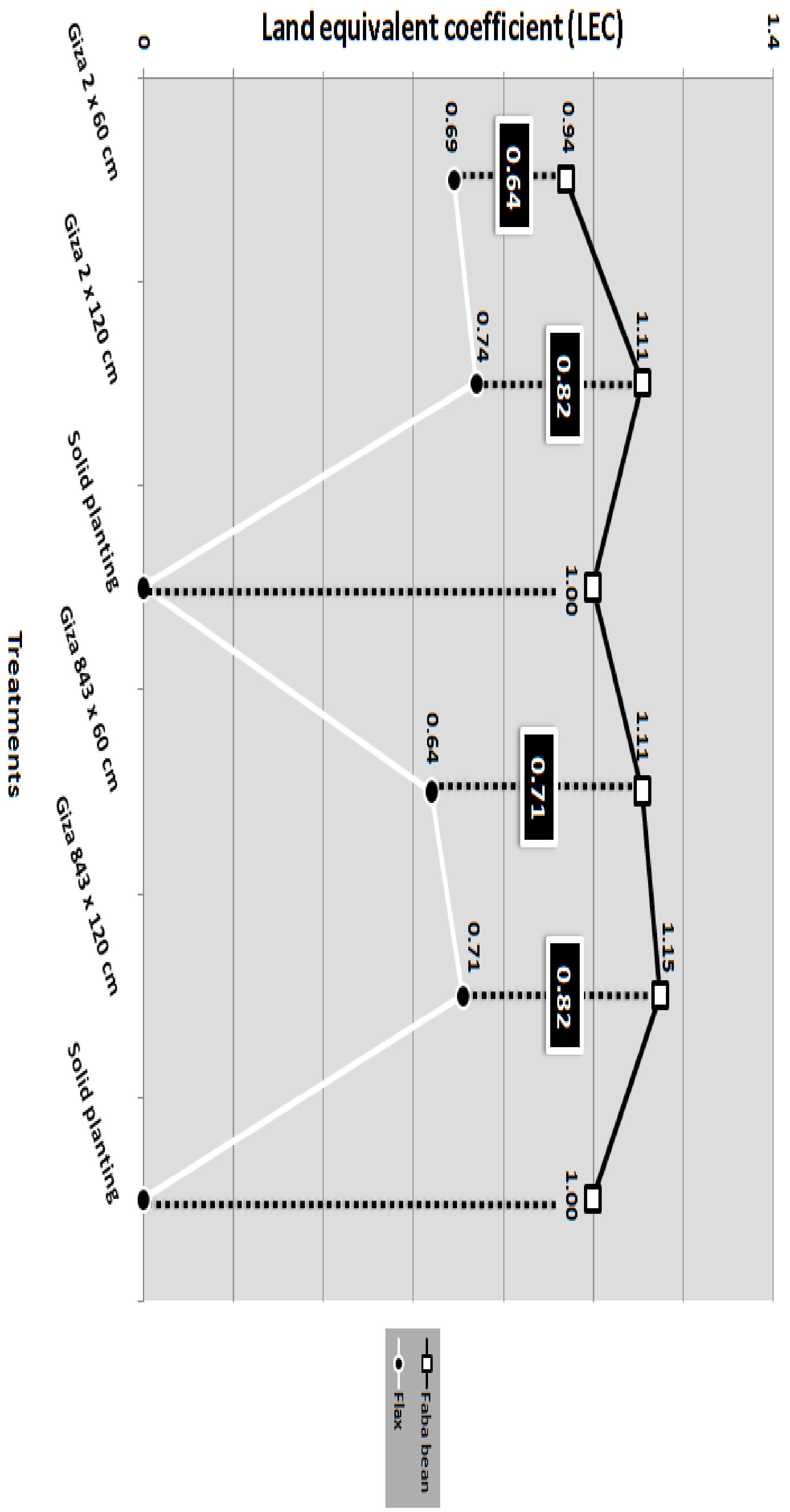

Fig. 3. LEC as affected by ridge width, cropping system, faba bean variety and their interactions, combined data across 2014/2015 and 2015/2016 seasons.

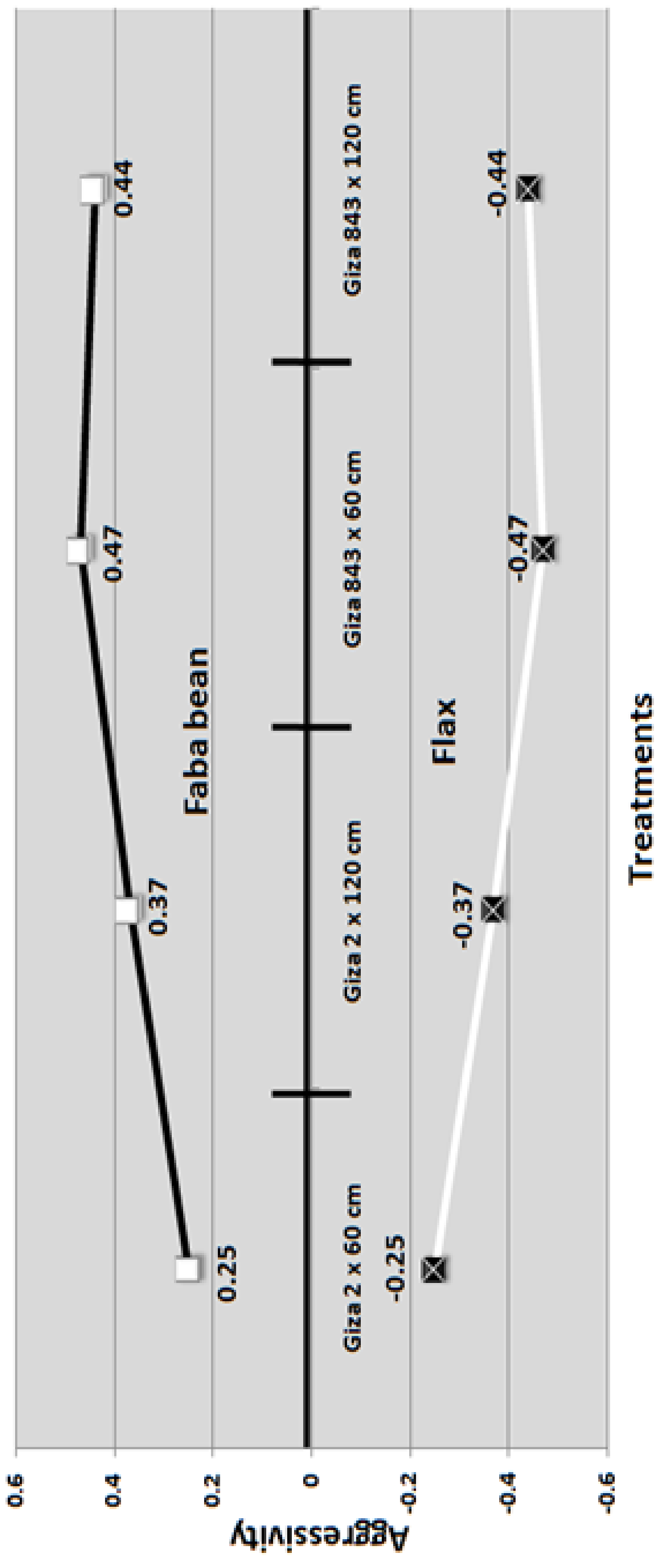

Fig. 4. Aggressivity as affected by ridge width, cropping system, faba bean variety and their interactions, combined data across 2014/2015 and 2015/2016 seasons.

TABLE 5.Financial return as affected by ridge width, cropping system, faba bean variety and their interactions, combined data across 2014/2015 and 2015/2016 seasons.

Ridge width	Cropping systems	Faba bean (US$ha^{-1})			Flax (US$ha^{-1})								
					Seed			Fiber			Fiber + seed		
		Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean
60 cm	Intercropping culture	695.0	810.0	**752.5**	319.0	298.7	**308.8**	261.4	253.5	**257.4**	580.4	552.2	**566.3**
	Solid planting	657.0	727.0	**692.0**	460.4		**460.4**	273.3		**273.3**	733.7		**733.7**
	Mean	**676.0**	**768.5**	**722.2**	**389.7**	**379.5**	**384.6**	**267.3**	**263.4**	**265.3**	**657.0**	**642.9**	**649.9**
120 cm	Intercropping culture	735.0	836.0	**785.5**	344.4	326.8	**335.6**	289.1	273.3	**281.2**	633.5	600.1	**616.8**
	Solid planting	701.0	761.0	**731.0**	485.0		**485.0**	308.9		**308.9**	793.9		**793.9**
	Mean	**718.0**	**798.5**	**758.2**	**414.7**	**405.9**	**410.3**	**299.0**	**291.9**	**295.0**	**713.7**	**697.8**	**705.7**

Prices of main products are that of 2015: US$ 288.5 for ton of faba bean seeds and US$ 747.7 for ton of flax (fiber + seed).

TABLE 5. Cont.

Ridge width	Cropping systems	Total return (US$ha^{-1})			Costs(US$ha^{-1})			Net return (US$ha^{-1})		
		Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean	Giza 2	Giza 843	Mean
60 cm	Intercropping culture	1275.4	1362.2	**1318.8**	816.4	816.4	**816.4**	459.0	545.8	**502.4**
	Solid planting	657.0	727.0	**692.0**	645.3	645.3	**645.3**	11.7	81.7	**46.7**
	Mean	**966.2**	**1044.6**	**1005.4**	**730.8**	**730.8**	**730.8**	**235.3**	**313.7**	**274.5**
120 cm	Intercropping culture	1368.5	1436.1	**1402.3**	816.4	816.4	**816.4**	552.1	619.7	**585.9**
	Solid planting	701.0	761.0	**731.0**	645.3	645.3	**645.3**	55.7	115.7	**85.7**
	Mean	**1034.7**	**1098.5**	**1066.6**	**730.8**	**730.8**	**730.8**	**303.9**	**367.7**	**335.8**

Prices of main products are that of 2015: US$ 288.5 for ton of faba bean seeds and US$ 747.7 for ton of flax (fiber + seed).

Conclusion

It could be inferred that intercropping flax with faba bean variety Giza- 843 in ridges 120 cm width achieved lower number of *Orobanche crenata* in faba bean fields and higher system productivity and monetary benefit with good quality of flax seed oil.

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تأثير عرض الخط ونظام الزراعة على الإنتاجية وكفاءة إستخدام الأرض في الفول البلدي والكتان المحمل

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أجريت تجربتين حقليتين خلال موسمي 2015/2014 و 2016/2015 على التوالي في محطة التجارب والبحوث الزراعية بكلية الزراعة جامعة القاهرة بالجيزة لدراسة أداء صنفين من الفول البلدي جيزة 843 و جيزة 2 تحت الزراعة المحملة مع الكتان على الانتاجية وكفاءة استخدام الارض والعائد المزرعي ومقاومة الهالوك في حقول الفول البلدي المنزرعه على خطوط مختلفة العرض. وتشمل التجربة 8 معاملات هي: الزراعة على خط عرضة 60 سم و 120 سم ، ونظامين زراعة هم الزراعة المحملة والزراعة المنفردة وصنفين من الفول البلدي جيزة 843 وجيزة2. وكان التصميم التجريبي القطع المنشقة مرتين في توزيع القطاعات الكاملة العشوائية مع 3 مكررات. وأشارت النتائج إلى أن زيادة عرض الخط من 60 إلى 120 سم ادت إلى قلة عدد الهالوك في المتر المربع ولكن زاد محصول النبات المحمل ومحصول الهكتار. تحميل الكتان مع الفول البلدي ادى إلى انخفاض الهالوك في المتر المربع وكذلك محصول النبات المحمل ومحصول الهكتار لكلا المحصولين في الزراعة المحملة. سجل الصنف جيزة 843 اقل القيم في عدد الهالوك في المتر المربع كما سجل اعلى القيم للمحصول ومكوناتة بالمقارنة بالصنف جيزة 2. أيضا أظهر الصنف جيزة 843 تأثيرا سلبيا على محصول بذور الكتان ومكوناتة. معظم الصفات المدروسة للفول البلدي والكتان تأثروا معنويا بالتفاعلات المختلفة. وكانت كمية الأحماض الدهنية في بذور الكتان حوالى 12.5 إلى 14.5٪ مشبعة (8.3 إلى 9.2٪ من حمض البالمتيك و 4.2 إلى 5.3٪ من حامض الستريك) و 81.7٪ إلى 85.2٪ من الأحماض الدهنية غير المشبعة (20.9 إلى 22.3٪ من حمض الأوليك، 13.0 إلى 14.2٪ اوميجا6 و 47.8 إلى 48.7٪ اوميجا3). واظهرت النتائج انة لم يتأثر مجموع الأحماض الدهنية غير المشبعة بشكل ملحوظ من خلال التفاعل بين عرض الخط ونظام الزراعة وأصناف الفول البلدي. تراوح المعدل المكافيء لانتاجية الأراض من 1.63 للكتان المحمل مع صنف الفول البلدي جيزة 2 والمنزرع علي خط عرضة 60 سم إلى 1.86 للكتان المحمل مع صنف جيزة 843 والمنزرع على خط عرضة 120 سم. وقد تجاوز المعامل المكافئ لانتاجية الأرض 0.25. أثبت تحليل السيادة أن نباتات الفول هي المسودة والكتان هي السائدة. أظهرت النتائج أن الكتان المحمل مع صنف الفول البلدي جيزة 843 والمنزرع على عرض خط 120 سم اعطي عائد 608.0 دولار/ هكتار مقارنة بزراعة صنف الفول جيزة 2 منفردا والمنزرع علي خط عرضة 60 سم. تحميل الكتان مع صنف الفول جيزة 843 والمنزرع على خط عرضة 120 سم ادى إلى انخفاض عدد نباتات الهالوك كريناتا في المتر المربع، كما حقق اعلى قيمة في المحصول و معدل مكافيء انتاجية الأرض، دون أي تأثير سلبي على مجموع الأحماض الدهنية غير المشبعة في زيت بذور الكتان مقارنة مع غيرها من المعاملات.