Zagazig J. Agric. Res., Vol. 44 No. (3) 2017 955-968

Horticultural Science

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

GROWTH, YIELD COMPONENTS AND COMPETITIVE INDICES OF FENNEL AND FENUGREEK AS INFLUENCED BY INTERCROPPING SYSTEM AND PHOSPHORUS FERTILIZER RATE

Hesham F.A. Abd-Elghany, A.A. Meawad and M.A.I. Abdelkader*

Hort. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 20/03/2017 ; Accepted: 27/04/2017

ABSTRACT: The present study was conducted at the Experimental Farm, Faculty of Agriculture (Ghazala Farm), Zagazig University, Egypt during the two seasons of 2012/2013 and 2013/2014. The effect of intercropping systems of fennel and fenugreek at ratios of 1:1, 1:2, 1:3 and 2:1 on alternative rows in comparison with sole cropped of each species and different phosphorus fertilization rates (0.0, 32 and 48 P_2O_5 kg/faddan) and their combination treatments on growth, yield components, oil production as well as some competitive indices of both tested crops. Application of phosphorus at 48 kg P_2O_5/faddan caused significant increase in all parameters of fennel and fenugreek over the other rates under study. Intercropping system 1:3 (fennel: fenugreek), in most cases, significantly increased the recorded growth parameters, yield components, fixed oil content of fenugreek and volatile oil yield per fennel plant as well as competitive indices of the two components in the two seasons, whereas all intercropping systems significantly decreased seed, fruit and oil yield per faddan compared to sole crop (control). In addition, from studying competitive indices, it was clear that, the high land equivalent ratio (1.137 and 1.156), area time equivalent ratio (1.013 and 1.023), land utilization efficiency (107.53% and 108.72%) and relative crowding coefficient (2.143 and 2.917) values were achieved by the combination treatment between intercropping system of one row of fennel alternating with three rows of fenugreek combined with phosphorus at a rate of 32 P_2O_5 kg/faddan during the first and second seasons, respectively. Generally, it could be gained from sowing one faddan, by using the intercropping pattern of 1:3 combined with phosphorus fertilization at 32 kg P_2O_5/faddan , the same yield which would required about 1.137 or 1.156 faddan of each crop cultivated alone. Also this treatment is economic by using small area.

Key words: Fennel, fenugreek, intercropping system, phosphorus rate, competitive indices.

INTRODUCTION

The species of family Apiaceae are well known source of many important herbal products (Ekiert, 2000). *Foeniculum vulgare* Mill (fennel), which belongs to family Umbelliferae (Apiaceae), is an annual plant. Vegetative parts of the plant are used as a green salad while fruits have a pleasant, spicy odour and burning sweet taste, and have pharmaceutical, perfumery and food flavouring used. Fennel fruits contain 1-3% volatile oils, which have disinfectant and anti-inflammatory action, primarily on the respiratory and digestive organs and have an antispasmodic effect on smooth muscle (Stary and Jirasek, 1975). Antioxidant and antimicrobial activity of fennel has also been reported (Ruberto *et al.*, 2000).

The other specie that studied in this research was fenugreek (*Trigonella foenum-graecum* L.) which is an annual crop belonging to the legume family. This crop is native to an area extending from Iran to northern India, but is now widely cultivated in China, north and east Africa, Ukraine and Greece (Petropoulos, 2002). Fenugreek leaves and seeds have been used

***Corresponding author. Tel. :** +2001008002904
Email address: maabdelkader@zu.edu.eg

extensively to prepare extracts and powders for medicinal uses (Basch *et al.*, 2003). Fenugreek is reported to have anti- diabetic, anti-fertility, anticancer, anti-microbial, anti-parasitic and hypocholesterolaemic, effects (Al-Habori and Raman, 2002).

Growing demand for food as a result of an increasing population more and more beside the continuous reduction in agricultural land in Egypt requests a shift to more productive cropping systems. Intercropping is a sustainable practice used in many developed and developing countries and an essential element of agricultural sustainability (Maffei and Mucciarelli, 2003). Intercropping has an important role in increasing the productivity and stability of yield in order to improve resource utilization and environmental factors (Alizadeh *et al.*, 2010).

Phosphorus (P) is one of the essential macronutrients for plant growth and development (Harrison *et al.*, 2002). Phosphorus is an important constituent of bio-molecules like nucleic acids, phospholipids and ATP. Usually the soils are phosphorus deficient because of fixation problems, which makes it less available to the plants especially in clays soils. To overcome the P deficiency, different kinds of phosphate fertilizers are applied to the soil mainly in the case of legumes, which carry inbuilt potential of phosphorus utilization compared to other crops (Gentili *et al.*, 2006; Rotaru and Sinclair, 2009).

The most important aim of this study is maximizing the crop productivity by using different intercropping systems combined with phosphorus fertilization treatments with fennel and fenugreek plants. Besides, studying the effects of using different intercropping systems between fennel and fenugreek, phosphorus fertilization rates and their combination treatments on growth, yield components, oil production as well as some competitive indices of both crops under Sharkia Governorate conditions, Egypt.

MATERIALS AND METHODS

The present study was conducted at the Experimental Farm, Faculty of Agriculture (Ghazala Farm), Zagazig University, Egypt during the two winter seasons of 2012/2013 and 2013/ 2014. Seeds of both fennel and fenugreek were obtained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza and were sown on 10th October during both seasons. Seeds were sown and then immediately irrigated. The mechanical and chemical properties of the experimental farm soil site are shown in Table 1 according to (Chapman and Pratt, 1978).

This experiment included 15 treatments, which were the combinations between five intercropping systems and three phosphorus fertilization rates which were; control (without phosphorus fertilization), 32 and 48 kg P_2O_5 kg / faddan (fad.) as calcium superphosphate (15.5% P_2O_5). The intercropping system treatments were as follows:

1. Sole cropping system of either fennel or fenugreek. Such treatment was used as control for both crops.
2. Intercropping system of 1:1; since planting one row of fennel alternated with one row of fenugreek. Such system provides the proportional area of 50: 50 to each of fennel and fenugreek, respectively.
3. Intercropping system of 1:2; since planting one row of fennel alternated with two rows of fenugreek. Such pattern provides the proportional area of 33.3: 66.7 to each of fennel and fenugreek, respectively.
4. Intercropping system of 1:3; since planting one row of fennel alternated with three rows of fenugreek. Such system provides the proportional area of 25: 75 to each of fennel and fenugreek, respectively.
5. Intercropping system of 2:1; since planting two rows of fennel alternated with one row of fenugreek. Such system provides the proportional area of 66.7: 33.3 to each of fennel and fenugreek, respectively.

The plot area was 14.4 m^2 (2.00 × 7.20 m) included twelve rows; each row was 60 cm apart and two meters in length. The seeds were sown in hills on one side of row for fennel and the two sides for fenugreek. The distances between hills were 50 cm for fennel and 20 cm for fenugreek

Table 1. Physical and chemical properties of experimental farm soil (average of two seasons)

Mechanical analysis											Soil texture
Clay (%)		Silt (%)	Fine sand (%)			Coarse sand (%)					Sandy clay
43.49		9.10	13.52			33.89					
Chemical analysis											
pH	E C m.mohs/cm	Organic matter (%)	Soluble cations (meq. / l)			Soluble anions (meq. / l)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.87	0.95	0.52	2.8	1.5	1.3	3.8	4.5	1.5	3.4	17.0	8.30	71.0

crop. After three weeks from sowing, seedlings were thinned to be two plants / hill for the two crops. The treatments were arranged in a split-plot design with three replicates, where cropping system treatments were randomly distributed in the main plots, while phosphorus fertilizer rates were randomly arranged in the sub-plots.

All plots were fertilized with nitrogen and potassium fertilizers at the rate of 150 kg/fad., of ammonium sulphate (20.5% N) and 50 kg/fad., of potassium sulphate (50% K_2O), respectively. Phosphorus and potassium fertilizers were added during soil preparation as soil dressing application. While, nitrogen fertilizer was divided into three equal portions and were added to the soil at 30, 50 and 70 days after sowing. The two tested crops received the normal agricultural practices whenever they needed.

Data Recorded

Plant growth parameters

Plant height (cm), number of branches/plant and total plant dry weight (g) were estimated (at 85 days after sowing for each crop) by taking 3 random guarded plants from each experimental unit.

Yield and its components

At harvesting stage, fruit and seed yield/ plant from 9 plants of each replicates were determined, then total fruit and seed yield (kg/ fad.) was calculated for fennel and fenugreek plants, respectivally.

Oil yield per plant

The volatile oil from air-dried fruits of fennel plant was estimated by hydro distillation for 3 hr in order to extract the essential oils according to (Guenther, 1961) and the oil yield per plant was calculated. Seed fixed oil of fenugreek was extracted using petroleum ether in a soxcelt system HT apparatus according to the methods of (AOAC, 1984). Then, oil yield per plant was calculated.

Competitive Indices

Land equivalent ratio (LER)

This gives an indication to the relative land area required, as sole cropping, to produce the same yields achieved by intercropping. The value of unity is the critical value. When the LER is greater than one, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than one, the intercropping negatively affects the growth and yield of the plants grown in mixture. It was determined for fennel and fenugreek yields recorded per faddan according to the following equation:

$$LER = L_f + L_t$$

$$L_f = \frac{Y_{ft}}{Y_{ff}}, L_t = \frac{Y_{tf}}{Y_{tt}}$$

Where: Y_{ff} and Y_{tt} are the yields per fad., of fennel and fenugreek, respectively, as sole crops and Y_{ft} and Y_{tf} are the yields of fennel and fenugreek, respectively, as intercrops (Mead and Willey, 1980).

Area time equivalent ratio (ATER)

It was calculated according to the following equation:

$$ATER = \frac{Yft / Yff \times tf + Yft / Ytt \times tt}{T}$$

Where: Y_{ft} = Intercrop yield of fennel, Y_{ff} = sole yield of fennel, Y_{tf} = intercrop yield of fenugreek, Y_{tt} = sole yield of fenugreek, tf = the duration of fennel in days, tt = the duration period of fenugreek in days and T = the total duration of intercropping system in days (Hiebsch and McCollum, 1987).

Land utilization efficiency (LUE %):

By using LER and ATER values, the land utilization efficiency (LUE %) was calculated according to Mason *et al.* (1986) as follows:

$$LUE\ (\%) = \frac{LER + ATER}{2} \times 100$$

Relative crowding coefficient (RCC)

Another coefficient that is used is the relative crowding coefficient (RCC or K) which is a measure of the relative dominance of one species over the other in a mixture (De Wit, 1960). The K was calculated as:

$$K = (K_{fennel} \times K_{fenugreek}),$$

$$K_{fennel} = \frac{Y_{ft}Z_{tf}}{(Y_{ff} - Y_{ft})z_{ft}},$$

$$K_{fenugreek} = \frac{Y_{tf}Z_{ft}}{(Y_{tt} - Y_{tf})Z_{tf}}$$

Where: Zft is the sown proportion of fennel in mixture with fenugreek and Ztf is the sown proportion of fenugreek in mixture. When the product of the two coefficients (Kfennel × Kfenugreek) is greater than one, there is a yield advantage, when K is equal to one there is no yield advantage, and when it is less than one there is a disadvantage.

Statistical Analysis

Data of the present work were statically analyzed and the differences between the means of the treatments were considered significant when they were more than the least significant or highly significant differences (LSD) at the 5% or 1% levels, respectively by using computer program of Statistix version 9 (Analytical Software, 2008).

RESULTS AND DISCUSSION

Growth Parameters of Fennel and Fenugreek Plants

Results presented in (Tables 2 and 3) show that using of 1:3 cropping system resulted in significant increase in fennel plant height, number of branches per plant and total dry weight per plant compared with sole fennel planting system and other intercropping treatments. However, the same parameters of fenugreek were increased by using 1 : 2 intercropping system compared to the other ones under study during both seasons. Also, increasing the number of rows planted with fenugreek increased the abovementioned parameters under cropping system with one row of fennel.

This result was in consistent with the common assumption that in legume/non-legume intercropping systems, plants benefit from the direct transfer of fixed N_2 (Graham and Vance, 2000). These results are in harmony with those stated by (Abdelkader, 2012) on roselle when intercropped with guar, (Zhang *et al.*, 2015) on *Angelica sinensis* when intercropped with garlic and (Abdelkader and Hassan, 2016) on dill when intercropped with fenugreek.

Plant height, number of branches/plant and total plant dry weight of both fennel and fenugreek were significantly increased by all phosphorus fertilizer rates compared with control during the two tested seasons. Generally, those parameters were gradually increased with increasing phosphorus rates up to the highest rate. Likewise, the highest values in this concern were obtained by application of phosphorus fertilizer at (48 kg P_2O_5 per faddan) compared with the other ones under study (Tables 2 and 3). The superior effects of P fertilizer application on growth parameters of fennel and fenugreek plants are due to that, P is a part of molecular structure of vitally important compounds, DNA and RNA. In addition, it plays an essential role in photosynthesis and cell

Table 2. Effect of intercropping system, phosphorus fertilizer rate and their combination treatments on growth parameters of fennel at 85 days from seed sowing during 2012/ 2013 and 2013/2014 seasons

Intercropping system (I) (fennel : fenugreek)	Phosphorus fertilizer rate (kg P_2O_5/faddan) (P)							
	0.0	32	48	Mean (I)	0.0	32	48	Mean (I)
	First season				Second season			
	Plant height (cm)							
Sole fennel	71.67	88.00	94.33	84.67	82.00	94.00	99.33	91.78
1 row: 1 row	99.33	106.00	114.33	106.56	104.67	115.33	118.67	112.89
1 row: 2 rows	100.67	113.67	120.33	111.56	106.00	123.67	129.33	119.67
1 row: 3 rows	107.00	121.00	129.33	119.11	118.00	130.33	139.00	129.11
2 rows: 1 row	85.67	94.00	98.00	92.56	85.67	99.00	107.33	97.33
Mean (P)	92.87	104.53	111.27		99.27	112.47	118.73	
LSD at 5%	(I)=4.54	(P)=2.89	(I) × (P) = 6.96		(I)=2.05	(P)=1.42	(I) × (P) = 3.31	
LSD at 1%	(I)=6.61	(P)=3.95	(I) × (P) = 9.75		(I)=2.99	(P)=1.94	(I) × (P) = 4.62	
	Number of branches/plant							
Sole fennel	6.00	7.67	8.67	7.44	6.33	7.33	7.66	7.11
1 row: 1 row	7.67	9.33	11.33	9.44	8.33	10.66	11.66	10.22
1 row: 2 rows	8.67	10.33	11.67	10.22	9.00	10.66	12.33	10.66
1 row: 3 rows	9.67	11.67	13.33	11.56	10.33	12.66	13.66	12.22
2 rows: 1 row	6.67	7.67	8.67	7.67	7.33	8.33	9.33	8.33
Mean (P)	7.73	9.33	10.73		8.26	9.93	10.93	
LSD at 5 %	(I)=0.41	(P)=0.33	(I) × (P) = 0.73		(I)=0.63	(P)=0.41	(I) × (P) = 0.99	
LSD at 1 %	(I)=0.60	(P)=0.45	(I) × (P) = 1.02		(I)=0.92	(P)=0.56	(I) × (P) = 1.38	
	Total dry weight/plant (g)							
Sole fennel	25.85	31.93	37.07	31.62	23.53	34.91	36.20	31.55
1 row: 1 row	32.00	41.00	45.86	39.62	37.26	42.70	44.93	41.63
1 row: 2 rows	36.90	45.96	53.56	45.47	45.85	50.86	61.30	52.67
1 row: 3 rows	40.92	65.13	73.86	59.97	61.03	74.68	87.06	74.26
2 rows: 1 row	31.00	35.47	37.78	34.76	33.63	36.25	38.78	36.22
Mean (P)	33.34	43.90	49.63		40.26	47.88	53.65	
LSD at 5%	(I)=3.16	(P)=1.78	(I) × (P) = 4.53		(I)=1.73	(P)=1.85	(I) × (P) = 3.79	
LSD at 1%	(I)=4.60	(P)=2.43	(I) × (P) = 6.37		(I)=2.51	(P)=2.52	(I) × (P) = 5.24	

Table 3. Effect of intercropping system, phosphorus fertilizer rate and their combination treatments on growth parameters of fenugreek at 85 days from seed sowing during 2012/ 2013 and 2013/2014 seasons

Intercropping system (I) (fennel: fenugreek)	Phosphorus fertilizer rate (kg P_2O_5/faddan) (P)							
	0.0	32	48	Mean (I)	0.0	32	48	Mean (I)
	First season				Second season			
	Plant height (cm)							
Sole fenugreek	37.33	37.66	40.00	38.33	38.33	40.33	40.66	39.77
1 row: 1 row	41.33	42.33	41.66	41.77	42.33	44.33	45.00	43.88
1 row: 2 rows	42.00	44.00	44.33	43.44	42.66	43.66	44.66	43.66
1 row: 3 rows	41.66	42.66	44.33	42.88	42.33	43.33	44.66	43.44
2 rows: 1 row	41.66	44.00	43.00	42.88	42.33	44.33	44.66	43.77
Mean (P)	40.80	42.13	42.66		41.60	43.20	43.93	
LSD at 5%	(I)=0.88	(P)=0.58	(I) × (P)= 1.38		(I)=0.63	(P)=0.30	(I) × (P)= 0.83	
LSD at 1%	(I)=1.28	(P)=0.79	(I) × (P)= 1.93		(I)=0.92	(P)=0.40	(I) × (P)= 1.18	
	Number of branches / plant							
Sole fenugreek	6.66	8.33	10.66	8.55	7.00	8.66	10.33	8.66
1 row: 1 row	7.00	8.66	11.33	9.00	7.66	9.66	10.66	9.33
1 row: 2 rows	10.33	12.33	15.00	12.55	11.00	12.66	14.66	12.77
1 row: 3 rows	7.66	9.33	11.66	9.55	9.33	12.33	13.66	11.77
2 rows: 1 row	6.33	7.33	8.66	7.44	6.66	7.66	8.33	7.55
Mean (P)	7.60	9.20	11.46		8.33	10.20	11.53	
LSD at 5 %	(I)=0.38	(P)=0.30	(I) × (P)= 0.66		(I)=0.73	(P)=0.24	(I) × (P)= 0.85	
LSD at 1 %	(I)=0.55	(P)=0.40	(I) × (P)= 0.92		(I)=1.07	(P)=0.32	(I) × (P)= 1.22	
	Total dry weight / plant (g)							
Sole fenugreek	15.52	16.89	17.72	16.71	14.57	15.27	16.68	15.51
1 row: 1 row	16.38	17.15	18.15	17.23	15.56	17.07	17.76	16.79
1 row: 2 rows	18.98	22.80	25.06	22.28	17.37	22.08	23.97	21.13
1 row: 3 rows	17.09	18.21	19.21	18.17	15.94	17.69	19.77	17.80
2 rows: 1 row	14.84	16.72	16.96	16.17	12.86	13.62	15.71	14.06
Mean (P)	16.56	18.35	19.42		15.25	17.14	18.78	
LSD at 5%	(I)=0.38	(P)=0.38	(I) × (P)= 0.80		(I)=0.44	(P)=0.26	(I) × (P)= 0.65	
LSD at 1%	(I)=0.56	(P)=0.52	(I) × (P)= 1.10		(I)=0.65	(P)=0.36	(I) × (P)= 0.92	

division as well as for meristim tissues (Marschner, 1995). These results are in a good line with those reported by (Jalili and Majidi, 2015) on *Satureja hortensis* L.

The comparison of the combination effect between intercropping systems and phosphorus rates indicated that the most values of growth parameters of both components were related to alternating one row of fennel with three or two rows of fenugreek accompanied with 48 kg P_2O_5 /faddan consumption of calcium superphosphate for fennel or fenugreek, respectively. These results agreed with those obtained by Abusuwar and Omer (2011) on *Clitoria ternatea* intercropped with *Lablab purpureus* and addition phosphorus fertilization and Abdelkader and Hassan (2016) on dill when intercropped with fenugreek with 45 kg P_2O_5/faddan application.

Yield Components of Fennel and Fenugreek Plants

Results under discussion in (Tables 4 and 5) indicate that, increasing rows number of fenugreek from one to two increased fruits and volatile oil yield per fennel plant as well as seed and fixed oil yield per fenugreek plant, respectively, under cropping system with one row of fennel. Furthermore, alternating one row of fennel with three or two rows of fenugreek treatment (1 : 3 or 1 : 2 systems) significantly increased fruit or seed yield per plant of fennel and fenugreek, respectively, compared with other ones under study during both seasons. In this regard, (Odhiambo and Ariga, 2001) found that, when maize intercropped with beans in different ratios, the production increased due to reducing competition between the two species compared to the competition within specie. However, these results are in harmony with those reported by (Megawer *et al.*, 2010) on barley intercropped with lupin and (Jalilian *et al*., 2017) on safflower intercropped with bitter vetch. However, fruit yield of fennel/fad., as well as seed yield and fixed oil yield per faddan of fenugreek were significantly decreased with intercropping system treatments compared to sole crop system in the first and second seasons. These results agreed with those found by (Agegnehu *et al.*, 2008) on wheat when intercropped with faba bean.

The maximum increase in fruit and seed yield per plant and per faddan of fennel and fenugreek as well as volatile and fixed oil yield per plant of fennel and fenugreek were observed with phosphorus application at rate of 48 kg P_2O_5 per faddan compared to other phosphorus rates under study during the two tested seasons. In the mean time, there was gradual increase in the above mentioned parameters with increasing phosphorus rates (Tables 4 and 5). Furthermore, phosphorus is essential for the general health and vigorous all in plant some specific factor that have been associated to phosphorus are root development, increasing stalk and more stem strength, improve flower formation and seed production more uniform and earlier crop maturity, increase nitrogen fixing capacity of legumes and improve in crop quality and resistant to plant disease (Abadi *et al.*, 2015). From the abovementioned results it could be suggested that, the supriorty in fennel and fenugreek fruit and seed yield by phosphorus fertilizer application is directly owing to the enhancing effect on growth parameters of fennel and fenugreek plants (Tables 2 and 3), which resulted in increments in metabolites synthized to fruits and seeds and this in turn increase total fruit and seed yield of fennel and fenugreek, respectively.

Similarly, the results given in (Tables 4 and 5) suggest that, the best combination treatment for increasing fruit or seed yield per faddan of fennel or fenugreek, respectively, was that of the treatment of sole crop system combined with phosphorus fertilizer at 48 kg P_2O_5 per faddan compared to the other combination treatments, in most cases. On the contrary, fruit or seed yield/plant was significantly increased with all combination treatments between intercropping systems and phosphorus fertilizer rates (except that of 2: 1 system combined with any phosphorus rate) compared with control [sole crop system and without phosphorus application], in most cases, in both seasons. Moreover, under each treatment of intercropping patterns yield components of both crops were increased with increasing phosphorus fertilizer rates. These results coincided with those found by (Carpici and Tunali, 2012) on vetch intercropped with barley and fertilized with phosphorus and (Abdelkader and Hassan, 2016) on dill when intercropped with fenugreek with adding 30 kg P_2O_5/faddan.

Table 4. Effect of intercropping system, phosphorus fertilizer rate and their combination treatments on yield components and volatile oil of fennel during 2012/2013 and 2013/2014 seasons

Intercropping system (I) (fennel : fenugreek)	Phosphorus fertilizer rate (kg P_2O_5/faddan) (P)							
	0.0	32	48	Mean (I)	0.0	32	48	Mean (I)
	First season				Second season			
	Fruit yield / plant (g)							
Sole fennel	14.83	16.90	18.36	16.70	16.43	18.03	19.06	17.84
1 row: 1 row	14.95	17.05	20.03	17.34	16.95	18.73	20.20	18.62
1 row: 2 rows	16.96	19.03	20.75	18.91	17.13	18.83	20.08	18.68
1 row: 3 rows	20.98	22.03	23.80	22.27	18.55	20.30	21.98	20.27
2 rows: 1 row	14.85	17.18	18.86	16.96	17.05	18.60	19.13	18.26
Mean (P)	16.51	18.44	20.36		17.22	18.90	20.09	
LSD at 5%	(I)=0.55	(P)=0.34	(I) × (P)= 0.84		(I)=0.60	(P)=0.37	(I) × (P)= 0.90	
LSD at 1%	(I)=0.81	(P)=0.47	(I) × (P)= 1.17		(I)=0.88	(P)=0.50	(I) × (P)= 1.27	
	Fruit yield/faddan (kg)							
Sole fennel	415.33	473.20	514.27	467.60	460.13	504.93	533.80	499.64
1 row: 1 row	209.30	238.70	280.47	242.82	237.30	262.27	282.80	260.79
1 row: 2 rows	158.35	177.64	193.66	176.55	159.90	175.77	187.44	174.37
1 row: 3 rows	146.88	154.23	166.62	155.91	129.85	142.10	153.88	141.94
2 rows: 1 row	323.52	367.08	391.03	360.54	318.24	347.17	357.12	340.84
Mean (P)	250.68	282.17	309.21		261.09	286.45	303.02	
LSD at 5%	(I)=11.5	(P)=6.0	(I) × (P)= 15.9		(I)=9.7	(P)=9.7	(I) × (P)= 16.1	
LSD at 1%	(I)=16.7	(P)=8.2	(I) × (P)= 22.4		(I)=14.2	(P)=14.2	(I) × (P)= 22.5	
	Volatile oil yield/plant (ml)							
Sole fennel	0.50	0.58	0.64	0.57	0.56	0.66	0.67	0.63
1 row: 1 row	0.51	0.60	0.72	0.61	0.59	0.69	0.74	0.67
1 row: 2 rows	0.59	0.67	0.75	0.67	0.60	0.70	0.75	0.68
1 row: 3 rows	0.73	0.80	0.89	0.81	0.68	0.76	0.84	0.76
2 rows: 1 row	0.51	0.60	0.66	0.59	0.59	0.68	0.68	0.65
Mean (P)	0.57	0.65	0.73		0.60	0.70	0.74	
LSD at 5%	(I)=0.01	(P)=0.01	(I) × (P)= 0.03		(I)=0.02	(P)=0.01	(I) × (P)= 0.03	
LSD at 1%	(I)=0.02	(P)=0.02	(I) × (P)= 0.04		(I)=0.03	(P)=0.02	(I) × (P)= 0.04	

Table 5. Effect of intercropping system, phosphorus fertilizer rate and their combination treatments on yield components and fixed oil of fenugreek during 2012/2013 and 2013/2014 seasons

Intercropping system (I) (fennel: fenugreek)	Phosphorus fertilizer rate (kg P_2O_5/faddan) (P)							
	0.0	32	48	Mean (I)	0.0	32	48	Mean (I)
	First season				Second season			
	Seed yield / plant (g)							
Sole fenugreek	4.54	4.94	5.10	4.86	4.41	4.57	4.95	4.64
1 row: 1 row	5.03	5.24	5.37	5.21	4.57	4.61	5.34	4.84
1 row: 2 rows	4.86	5.36	5.68	5.30	4.55	5.05	5.45	5.01
1 row: 3 rows	4.62	5.34	5.44	5.15	4.81	5.32	5.32	5.15
2 rows: 1 row	4.20	4.66	4.97	4.61	4.09	4.30	4.42	4.27
Mean (P)	4.65	5.11	5.31		4.48	4.77	5.09	
LSD at 5%	(I)=0.11	(P)=0.07	(I) × (P)= 0.17		(I)=0.15	(P)=0.11	(I) × (P)= 0.25	
LSD at 1%	(I)=0.16	(P)=0.10	(I) × (P)= 0.24		(I)=0.22	(P)=0.15	(I) × (P)= 0.35	
	Seed yield / faddan (kg)							
Sole fenugreek	317.80	346.03	357.00	340.28	308.93	320.13	346.97	325.34
1 row: 1 row	176.05	183.40	187.95	182.47	160.18	161.35	187.13	169.56
1 row: 2 rows	226.57	249.88	265.00	247.19	212.12	235.43	254.23	233.93
1 row: 3 rows	242.55	280.53	285.78	269.62	252.88	279.13	279.30	270.44
2 rows: 1 row	97.98	108.62	115.85	107.48	95.34	100.23	103.03	99.53
Mean (P)	212.19	233.69	242.34		216.05	223.47	236.96	
LSD at 5%	(I)=9.2	(P)=4.1	(I) × (P)= 11.9		(I)=8.6	(P)=4.4	(I) × (P)= 11.7	
LSD at 1%	(I)=13.4	(P)=5.6	(I) × (P)= 16.8		(I)=12.5	(P)=6.0	(I) × (P)= 16.5	
	Fixed oil yield / plant (ml)							
Sole fenugreek	0.37	0.45	0.47	0.43	0.41	0.43	0.49	0.44
1 row: 1 row	0.44	0.48	0.54	0.49	0.42	0.45	0.55	0.48
1 row: 2 rows	0.43	0.53	0.67	0.54	0.45	0.59	0.70	0.58
1 row: 3 rows	0.40	0.53	0.59	0.51	0.45	0.52	0.55	0.51
2 rows: 1 row	0.34	0.41	0.44	0.40	0.37	0.27	0.44	0.36
Mean (P)	0.40	0.48	0.54		0.42	0.45	0.54	
LSD at 5%	(I)=0.01	(P)=0.01	(I) × (P)= 0.03		(I)=0.06	(P)=0.04	(I) × (P)= 0.10	
LSD at 1%	(I)=0.02	(P)=0.02	(I) × (P)= 0.04		(I)=0.09	(P)=0.06	(I) × (P)= 0.15	

Competitive Indices of Fennel and Fenugreek Plants

The obtained results in (Tables 6 and 7) demonstrate that, the land equivalent ratio (LER) and land utilization efficiency (LUE) values were greater for fennel and fenugreek in intercropping system of (1:3 pattern), there was an advantage of intercropping for exploiting the resources of the environment. A similar trend to that of LER and ATER and LUE was also observed for relative crowding coefficient (RCC). In contrast, by using area time equivalent ratio (ATER) indices there were advantage only by using 1: 3 and 2: 1 systems in the first season. Indeed, intercropping of dill and fenugreek at 1:1, 1:2 and 1:3 were more productive than growing them separately, as can be seen from the above mentioned values which were greater than 1.00. Results were true for all cases determinations except that of 2:1 system in both seasons, in most cases. In this concern, (Natarajan and Willey, 1980) reported that, the most commonly suggested reason for utilize growth resources rather differently, so that when grown together they "complement" each other and make better overall use of resources than when grown separately. Moreover, (Bantie *et al.*, 2014) found that the intercropping of lupine with wheat, barley and finger millet recorded maximum LER and ATER (1.489 and 1.378).

The maximum increase in LER, LUE and RCC were obtained from the treatment of 32 or 48 kg P_2O_5 /faddan , in most cases, compared with the control in the first and second season, respectively. Phosphorus rates had no significant effect on LER, ATER and LUE in the first season.

Furthermore, the advantage of growing species (fennel and fenugreek) in association depends primarily on the degree of inter-crop versus intra-crop competition. Lower inter-crop comparison with intra-crop competition occurs when companion crops differ in their use of growth resources (for example phosphorus element).

The highest value for each of LER, ATER, LUE and RCC (1.137 and 1.156, 1.013 and 1.023 and 107.53% and 108.72% and 20143 and 2.917) was achieved by the combination treatment between intercropping system one row of fennel alternating with two rows of fenugreek with 32 kg P_2O_5/faddan during both seasons, respectively. This result suggest that it could be obtained from one faddan by using this intercropping system and 30 kg P_2O_5/faddan the same yield which would required about 1.14 or 1.16 faddan if each crop cultivated alone. These results are in line with those found by (Abdelkader and Hassan, 2016) on dill when intercropped with fenugreek and combined with 30 kg P_2O_5 / faddan application.

Table 6. Effect of intercropping system, phosphorus fertilizer rate and their combination treatments on land equivalent ratio (LER) during 2012/2013 and 2013/2014 seasons

Intercropping system (I) (fennel: fenugreek)	Phosphorus fertilizer rate (kg P_2O_5/faddan) (P)							
	0.0	32	48	Mean (I)	0.0	32	48	Mean (I)
	First season				Second season			
1 row: 1 row	1.060	1.037	1.070	1.056	1.033	1.027	1.067	1.042
1 row: 2 rows	1.097	1.100	1.120	1.106	1.033	1.083	1.083	1.067
1 row: 3 rows	1.120	1.137	1.127	1.128	1.103	1.156	1.097	1.119
2 rows: 1 row	1.087	1.090	1.087	1.088	1.000	1.000	0.968	0.989
Mean (P)	1.091	1.091	1.101		1.042	1.067	1.054	
LSD at 5%	(I)=0.019	(P)=0.015	(I) × (P)= 0.031		(I)=0.023	(P)=0.027	(I) × (P)= 0.050	
LSD at 1%	(I)=0.029	(P)=0.021	(I) × (P)= 0.044		(I)=0.035	(P)=0.037	(I) × (P)= 0.070	

Table 7. Effect of intercropping system, phosphorus fertilizer rate and their combination treatments on ATER, LUE% and RCC during 2012/2013 and 2013/2014 seasons

Intercropping system (I) (fennel: fenugreek)	Phosphorus fertilizer rate (kg P_2O_5/faddan) (P)							
	0.0	32	48	Mean (I)	0.0	32	48	Mean (I)
	First season				Second season			
	Area time equivalent ratio (ATER)							
1 row: 1 row	0.973	0.957	0.993	0.974	0.957	0.943	0.987	0.962
1 row: 2 rows	0.983	0.990	1.003	0.992	0.927	0.970	0.973	0.957
1 row: 3 rows	1.000	1.013	1.000	1.004	0.973	1.023	0.970	0.989
2 rows: 1 row	1.040	1.040	1.033	1.038	0.953	0.953	0.920	0.942
Mean (P)	0.999	1.000	1.007		0.952	0.972	0.962	
LSD at 5%	(I)=0.014	(P)=0.015	(I) × (P)= 0.031		(I)=0.023	(P)=0.027	(I) × (P)= 0.050	
LSD at 1%	(I)=0.021	(P)=0.021	(I) × (P)= 0.044		(I)=0.035	(P)=0.037	(I) × (P)= 0.070	
	Land utilization efficiency percentage (LUE %)							
1 row: 1 row	101.63	99.43	103.17	101.41	99.46	98.59	102.81	100.29
1 row: 2 rows	103.99	104.26	106.22	104.82	98.15	102.76	102.80	101.24
1 row: 3 rows	105.89	107.53	106.33	106.58	103.77	108.72	103.20	105.23
2 rows: 1 row	106.36	106.62	106.02	106.33	97.71	97.69	94.37	96.59
Mean (P)	104.47	104.46	105.44		99.77	101.94	100.80	
LSD at 5%	(I)=1.657	(P)=1.454	(I) × (P)= 2.890		(I)=2.104	(P)=2.552	(I) × (P)= 4.662	
LSD at 1%	(I)=2.512	(P)=2.004	(I) × (P)= 4.100		(I)=3.189	(P)=3.516	(I) × (P)= 6.539	
	Relative crowding coefficient (RRC)							
1 row: 1 row	1.280	1.153	1.343	1.259	1.153	1.120	1.323	1.199
1 row: 2 rows	1.547	1.570	1.750	1.622	1.177	1.497	1.507	1.393
1 row: 3 rows	1.797	2.143	1.940	1.960	1.773	2.917	1.717	2.136
2 rows: 1 row	1.580	1.593	1.537	1.570	1.017	1.013	0.867	0.966
Mean (P)	1.551	1.615	1.642		1.280	1.637	1.353	
LSD at 5%	(I)=0.213	(P)=0.135	(I) × (P)= 0.306		(I)=0.378	(P)=0.302	(I) × (P)= 0.620	
LSD at 1%	(I)=0.323	(P)=0.186	(I) × (P)= 0.440		(I)=0.573	(P)=0.416	(I) × (P)= 0.883	

Conclusion

This study suggests that fennel/fenugreek association should be used by farmers instead of fennel sole crop, especially at 1:3 cropping system, under Sharkia Governorate condition. The use of phosphorus rates of 32 P_2O_5 kg/faddan for both crops, in the intercropping pattern of 1:3, resulted in increases in fennel and fenugreek growth, yield components and oil yield besides maximized land equivalent ratio as well as land utilization efficiency. Also, it is economic treatment.

REFERENCES

Abadi, B.H.M., H.R. Ganjali and H.R. Mobasser (2015). Effect of mycorrhiza and phosphorus fertilizer on some characteristics of black cumin. Biol. Forum An Int. J., 7 (1): 1115-1120.

Abdelkader, M.A.I. (2012). Effect of intercropping and fertilization on some medicinal plants. Ph. D. Thesis, Fac. Agric., Zagazig Univ., Egypt.

Abdelkader, M.A. and H.M.S. Hassan (2016). Effects of intercropping pattern and phosphorus fertilizer rate on growth, yield, active ingredients and some competitive indices of dill and fenugreek plants. Minufiya J. Agric. Res., 41 (1): 141-160.

Abusuwar, A.O. and E.A. Omer (2011). Effect of intercropping, phosphorus fertilization and rhizobium inoculation on the growth and nodulation of some leguminous and cereal forages. Agric. Biol. J. N. Ame., 2 (1): 109-124.

Agegnehu, G., A. Ghizaw and W. Sinebo (2008). Yield potential and land-use efficiency of wheat and faba bean mixed intercropping. Agron. Sustain. Dev., 28 (4): 257-263.

Al-Habori, M. and A. Raman (2002). Pharmacological Properties in Fenugreek - The genus *Trigonella* (1st edition) by G.A. Petropoulos (ed.), Taylor and Francis, London and New York, 10: 163-182.

Alizadeh, Y., A. Koocheki and M. Nassiri Mahallati (2010). Yield, yield components and potential weed control of intercropping bean (*Phaseolus vulgaris* L.) with sweet basil (*Ocimum basilicum* L.). Iranian J. Field Crops Res., 7 (2): 541-553.

Analytical Software (2008). Statistix Version 9, Analytical Software, Tallahassee, Florida, USA.

AOAC (1984). Official Methods of Analysis "12th Ed Association of Official Analysis Chemists, Washington DC, USA.

Bantie, Y.B., F.A. Abera and T.D. Woldegiorgis (2014). Competition indices of intercropped lupine (Local) and small cereals in additive series in west Gojam, North Western Ethiopia. Ame. J. Pl. Sci., 5 : 1296-1305.

Basch, E., C. Ulbricht, G. Kuo, P. Szapary and M. Smith (2003). Therapeutic applications of fenugreek. Alt. Med. Rev., 8: 20-27.

Carpici, E.B. and M.M. Tunali (2012). Effects of the nitrogen and phosphorus fertilization on the yield and quality of the hairy vetch (*Vicia villosa* Roth.) and barley (*Hordeum vulgare* L.) mixture. Afr. J. Biotechnol., 11 (28): 7208-7211.

Chapman, D. H. and R. F. Pratt (1978). Methods Analysis for Soil, Plant and Water. Univ. Calif. Div. Agric. Sci., 16: 38.

De Wit, C.T. (1960). On competition. Verslag Landbouw-Kundige Onderzoek, 66: 1–28.

Ekiert, H. (2000). Medicinal plant biotechnology: the Apiaceae family as the example of rapid development. Pharmazie, 55 : 561–567.

Gentili, F., L.G. Wall and K. Huss-Danell (2006). Effects of phosphorus and nitrogen on nodulation are seen already at the stage of early cortical cell divisions in *Alnus incana*. Ann. Bot., 98:309-315.

Graham, P.H. and C.P. Vance (2000). Nitrogen fixation in perspective: a review of research and extension needs. Field Crops Res., 65 : 93-106.

Guenther, E. (1961). The Essential Oils. D. Von Nostrand Comp., New York, 1: 236.

Harrison, M.J., G.R. Dewbre and J. Liu (2002). A phosphate transporter from *Medicago truncatula* involved in the acquisition of

phosphate released by Arbuscular mycorrhizal fungi. Plant Cell, 14: 2413-2429.

Hiebsch, C.K. and R.E. McCollum (1987). Area×time equivalency ratio: a method for evaluating the productivity of intercrops. Agron. J. 79: 15–22.

Jalilian, J., A. Najafabadi and M.R. Zardashti (2017). Intercropping patterns and different farming systems affect the yield and yield components of safflower and bitter vetch. J. Pl. Comb., 12 (1): 92-99.

Jalili, F. and F. Majidi (2015). The effect of N, P and Micronutrients on Yield and Essential Oil of *Satureja hortensis* L. Adv. Environ. Biol., 9 (3): 892-897.

Maffei, M. and M. Mucciarelli (2003). Essential oil yield in peppermint/soybean strip intercropping. Field Crops Res., 84: 229-240.

Mason, S.C., D.E. Leihner and J.J. Vorst (1986). Cassava-cowpea and cassava-peanut intercropping. 1. Yield and land use efficiency. Agron. J., 78: 43-46.

Marschner, H. (1995). Mineral of Higher Plants. 2nd Ed., New York, Acad. Press.

Mead, R. and R.W. Willey (1980). The concept of a 'land equivalent ratio' and advantages in yields from intercropping. Exp. Agric., 16 : 217–228.

Megawer, E.A., A.N. Sharaan and A.M. El-Sherif (2010). Effect of intercropping patterns on yield and its components of barley, lupin or chickpea grown in newly reclaimed soil. Egypt. J. Appl. Sci., 25 (9): 437-452.

Natarajan, M. and R.W. Willey (1980). Sorghum- pigeonpea intercropping and the effects of plant population density. I-Growth and yield. J. Agric. Sci. Camb., 95: 51-58.

Odhiambo, G.D. and E.S. Ariga (2001). Effect of intercropping maize and beans on striga incidence and grain yield. 7th Eastern and Southern Afr. Regional Maize Conf., 183-186.

Petropoulos, G.A. (2002). Fenugreek- The genus *Trigonella*, Taylor and Francis, London and New York.

Ruberto, G., M.B. Barattata, S.G. Deans and H.D.I. Dorman (2000). Antioxidant and antimicrobial activity of *Foeniculum vulgare* and *Crithmum maritimum* essential oils. Planta Medico., 66:687-693.

Rotaru, V. and T. R. Sinclair (2009). Interactive influence of phosphorus and iron on nitrogen fixation by soybean. Environ. and Experim. Bot., 66: 94-99.

Stary, F. and V. Jirasck (1975). A Concise Guide in Colour Herbs. Hamlyn; London, New York, Sydney, Toronto.

Zhang, X.H., D.Y. Lang, E.H. Zhang and Y.J. Zhang (2015). Effect of intercropping of *Angelica sinensis* with garlic on its growth and Rhizosphere microflora. Int. J. Agric. Biol., 17: 554-560.

تأثير نظام التحميل ومعدل السماد الفوسفاتي على النمو ومكونات المحصول والعلاقات التنافسية لنباتات الشمر والحلبة

هشام فرج أحمد عبد الغني - علي عبد الحميد معوض - محمد أحمد إبراهيم عبد القادر

قسم البساتين – كلية الزراعة – جامعة الزقازيق - مصر

أجري هذا العمل بالمزرعة التجريبية بكلية الزراعة (مزرعة غزالة) جامعة الزقازيق خلال موسمي ٢٠١٢/٢٠١٣ و٢٠١٣/ ٢٠١٤ لدراسة تأثير نظم التحميل بين الشمر والحلبة بنسب ١:١ و ٢:١ و٣:١ و١:٢ علي خطوط متبادلة مقارنة بزراعة كل نوع علي حده ومعدلات مختلفة من السماد الفوسفاتي (صفر، ٣٢ أو ٤٨ كجم فو٢أ٥/فدان) ومعاملات التداخل بينهما على النمو ومكونات المحصول وإنتاج الزيت وبعض العلاقات التنافسية لكلا النوعين، أدت المعاملة بالفسفور بمعدل ٤٨ كجم فو٢أ٥/فدان إلى زيادة معنوية فى جميع صفات الشمر والحلبة مقارنة بالمعدلات الأخرى تحت الدراسة، أدى نظام التحميل ١: ٣ فى أغلب الأحيان إلى زيادة معنوية فى صفات النمو الخضري والمكونات المحصولية ومحتوى الحلبة من الزيت الثابت والنسبة المئوية للزيت العطري والمحصول/نبات في ثمار الشمر والعلاقات التنافسية لكلا المحصولين خلال الموسمين، بينما انخفض محصول البذور والثمار والزيت للفدان مقارنة بالزراعة المنفردة (الكنترول)، بالإضافة إلى ذلك، من خلال دراسة العلاقات التنافسية، يتضح أن أعلى قيم لكل من نسبة المكافئ الأرضي ونسبة المكافئ الأرضي لعامل الزمن وكفاءة استخدام الأرض ومعامل الحشد النسبي ١,١٣٧ و١,١٥٦، ١,٠١٣ و١,٠٢٣، ١٠٧,٥٣% و١٠٨,٧٢% و٢,١٤٣ و٢,٩١٧ تحصل عليها من معاملة التفاعل بين نظام التحميل بزراعة خط من الشمر مع ثلاث خطوط من الحلبة مع إضافة التسميد الفوسفاتي بمعدل ٣٢ كجم فو٢أ٥/فدان خلال الموسم الأول والثاني، على الترتيب، عموماً، يمكن الحصول من فدان واحد محمل باستخدام نظام التحميل ٣:١ والتسميد الفوسفاتي بمعدل ٣٢ كجم فو٢ أ٥/فدان، نفس المحصول الناتج من زراعة حوالي ١,١٣٧ و١,١٥٦ فدان إذا زرعا كلا المحصولين منفرداً، وبالتالى تكون هذه المعامله إقتصاديه بإستخدام مساحه أقل للزراعة.

المحكمـــــون:

١- أ.د. صفاء مصطفى محمد مصطفى أستاذ الزينة المتفرغ – كلية الزراعة – جامعة بنها.

٢- د. أحمد شـــاكر حســـين جنـدي أستاذ الزينة المساعد – كلية الزراعة – جامعة الزقازيق.