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EFFECT OF INTERCROPPING PATTERN AND PHOSPHORUS FERTILIZER RATE ON GROWTH, YIELD, ACTIVE INGREDIENTS AND SOME COMPETITIVE INDICES OF DILL AND FENUGREEK PLANTS

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ABSTRACT: *The present work was conducted at the Experimental Farm, Faculty of Agriculture (Ghazala Farm), Zagazig University during two seasons of 2012/2013 and 2013/2014. The effect of intercropping patterns of dill and fenugreek at ratios of 1:1, 1:2, 2:1 and 2:2 on alternative rows in comparison with sole cropped of each species and different phosphorus fertilization rates (0.0, 30 and 45 P_2O_5 kg/feddan) and their combination treatments on growth, yield components, active ingredients as well as some competitive indices of both tested crops were studied. Application of 45 P_2O_5 kg/feddan caused significant increase in all of the measured parameters of dill and fenugreek over the other rates under study. Intercropping pattern 1:2 (dill:fenugreek), in most cases, significantly ($p \leq 0.05$) increased the recorded growth parameters, yield components, trigonilline content of fenugreek and volatile oil percentage and yield per plant of dill fruits as well as competition indices of the two components in the two seasons, whereas all intercropping patterns significantly ($p \leq 0.05$) decreased seed, fruit and oil yield per feddan compared to sole stands (control). In addition, from studying competitive indices, it was clear that, the highest land equivalent ratio, area time equivalent ratio, land utilization efficiency and relative crowding coefficient values 1.138 and 1.203, 1.074 and 1.070, 110.58% and 116.90% as well as 1.968 and 2.880 were achieved by the combination treatment between intercropping pattern of one row of dill alternating with two rows of fenugreek combined with phosphorus at a rate of 30 P_2O_5 kg/feddan during the first and second seasons, respectively. Generally, it could be gained from sowing one feddan, by using the intercropping pattern of 1:2 combined with phosphorus fertilization at 30 kg P_2O_5 / feddan, the same yield which would required about 1.138 or 1.203 feddan of each crop singly cultivated.*

Key words: *Dill, Fenugreek, Intercropping patterns, Phosphorus, Competitive indices.*

INTRODUCTION

Dill (*Anethum graveolens* L.) is an annual, aromatic herb plant belongs to *Umbelliferae* family (Bailer *et al.*, 2001). The plant has a potential importance as a medicinal herb that contains volatile oils such as B-camphene, α-pinene, anethole, lonone, umbelliferone and carvone (Sharma 2004 and Dhalwal *et al.*, 2008).

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 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 and Rotaru and Sinclair, 2009).

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

MATERIALS AND METHODS

The present study was conducted at the Experimental Farm, Faculty of Agriculture (Ghazala Farm, Fig.1), Zagazig University during the two seasons of 2012/2013 and 2013/2014. Seeds of both dill and fenugreek were obtained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza and were sown on 15th October during both seasons. Seeds were sown and then immediately irrigated. After three weeks from sowing, seedlings were thinned to be two plants / hill for the two crops. 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 patterns and three phosphorus fertilization rates which were; control (without phosphorus fertilization), 30 and 45 kg P_2O_5 kg / feddan (fed.) as calcium superphosphate (15.5 % P_2O_5). The intercropping system treatments were as follows:

1- Sole cropping patterns of either dill or fenugreek. Such treatment was used as control for both crops.
2- Intercropping pattern of 1:1; since planting one row of dill alternated with one row of fenugreek. Such pattern provides the proportional area of 50: 50 to each of dill and fenugreek, respectively.
3- Intercropping pattern of 1:2; since planting one row of dill alternated with two rows of fenugreek. Such pattern provides the proportional area of 33.3: 66.7 to each of dill and fenugreek, respectively.
4- Intercropping pattern of 2:1; since planting two rows of dill alternated with one row of fenugreek. Such pattern provides the proportional area of 66.7: 33.3 to each of dill and fenugreek, respectively.
5- Intercropping pattern of 2:2; since planting two rows of dill alternated with two rows of fenugreek. Such pattern provides the proportional area of 50: 50 to each of dill 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 ridge. The distances between hills were 20 cm for dill and fenugreek crops. The treatments were arranged in a split-plot design with three replicates, where cropping patterns treatments were randomly distributed in the main plots, while phosphorus rates were randomly arranged in the sub-plots.

All plots were fertilized with nitrogen and potassium fertilizers at the rate of 150 kg/fed. of ammonium sulphate (20.5 % N) and 50 kg/fed. 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 added to the soil at 30, 50 and 70 days after sowing. The two tested crops received the normal agricultural practices whenever they needed.

Table 1. Physical and chemical properties of the experimental farm soil site

Mechanical analysis

Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Soil texture
46.50	26.10	10.52	16.88	Clay

Chemical analysis

pH	E C. (m.mohs / cm)	Organic mater (%)	Soluble cations(meq. / l)				Soluble anions (meq. / l)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^+	Na^+	Cl^-	HCO_3^-	SO_4^{--}	N	P	K
7.87	1.2	1.76	2.8	1.5	1.3	3.8	4.5	1.5	3.4	520	50	590

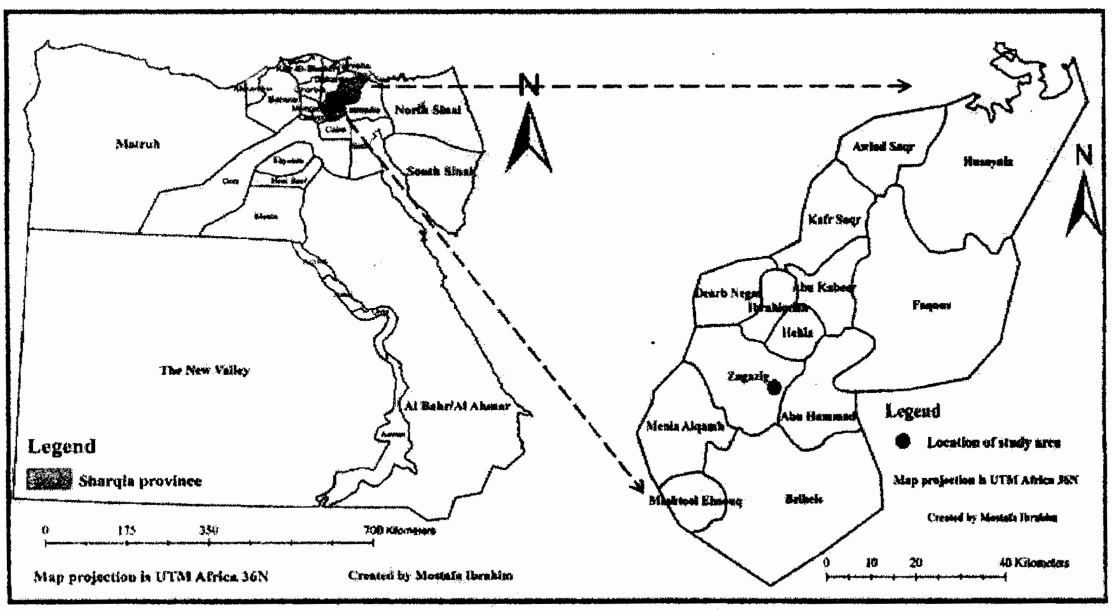

Fig. 1: Study site location in Zagazig County, Sharkia province, Egypt.

Data Recorded:

Plant growth parameters:

Plant height (cm), number of branches plant and total plant dry weight (gm) 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 dill and fenugreek plants, respectivally.

Plant chemical and active ingredients analysis:

After harvesting, a sample of dry fruits or seeds for dill and fenugreek, respectavilly was randomly taken from each treatment for chemical analysis. The volatile oil from air-dried fruits of dill plant was isolated by hydro distillation for 3 hr in order to extract the essential oils according to Guenther (1961) and the oil yield per plant and per feddan was calculated. Seed fixed oil of fenugreek seeds was extracted using petroleum ether in a soxcelt system HT apparatus according to the methods of A.O.A.C. (1984). Then, oil percentage and oil yield per plant and per feddan were calculated. Total chlorophyll content a+b (mg / gm) was determined in dill and fenugreek fresh leaves according to the method outlined by Cherry (1973). The trigonilline content (mg / gm) in seeds of fenugreek was determined according to the equation; trigonilline alkaloid= absorbance of test at 268 nm / absorbance of standard (Gorham, 1986).

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 dill and fenugreek yield recorded per feddan according to the following equation:

LER = Ld + Lf

$$L_d = \frac{Y_{df}}{Y_{dd}}, \quad L_f = \frac{Y_{fd}}{Y_{ff}}$$

where Ydd and Yff are the yields per fed. of dill and fenugreek, respectively, as sole crops and Ydf and Yfd are the yields of dill and fenugreek, respectively, as intercrops (Mead and Willey, 1980).

Area Time Equivalent Ratio (ATER):

It was calculated according to the following equation:

$$ATER = \frac{Y_{df} / Y_{dd} \times t_d + Y_{fd} / Y_{ff} \times t_f}{T}$$

Where: Ydf = Intercrop yield of dill, Ydd = Sole yield of dill, Yfd = Intercrop yield of fenugreek, Yff = Sole yield of fenugreek, td = The duration of dill in days,tf = 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) equation as follows:

$$LUE\ \% = \frac{LER + ATER}{2} x100$$

Aggressivity (A):

Aggressivity value was calculated according to Mc Gilchrist (1965) equation as follows:

1. For combination of 50:50 and 100:100, they were calculated according to the following equations:

$$A_{df} = L_d - L_f$$

$$A_{fd} = L_f - L_d$$

2. For the other combination ratios, the equations used were:

$$Adf = \frac{Ydf}{Ydd \times Zdf} - \frac{Yfd}{Yff \times Zfd}$$

$$Afd = \frac{Yfd}{Yff \times Zfd} - \frac{Ydf}{Ydd \times Zdf}$$

Where: Ydf = Intercrop yield of dill, Yfd = Intercrop yield of fenugreek, Ydd = Sole yield of dill, Yff = Sole yield of fenugreek, Zdf = Sowing proportion of dill and Zfd = Sowing proportion of fenugreek.

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 dill x K fenugreek),

$$Kdill = \frac{Ydf\,Zfd}{(Ydd - Ydf)\,Zdf}$$

$$Kfenugreek = \frac{Yfd\,Zdf}{(Yff - Yfd)\,Zfd}$$

Where Zdf is the sown proportion of dill in mixture with fenugreek and Zfd is the sown proportion of fenugreek in mixture. When the product of the two coefficients (Kdill . 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:

All collected data were analyzed with analysis of variance (ANOVA) procedure using MSTAT- C Statistical Software Package (Michigan State University, 1983). Differences between means were compared by using Duncan multiple range test at 0.05 (Duncan, 1955).

RESULTS AND DISCUSSION:

1. Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on growth parameters of dill and fenugreek plants:

It is quite clear from the data in Tables 2 and 3 that using of 1:2 cropping pattern resulted in significant increase in dill as well as fenugreek plant height, branches number per plant and total dry weight per plant compared with sole dill planting pattern and other intercropping treatments, except plant height of dill in the second season. Furthermore, increasing the number of rows of fenugreek increased the abovementioned parameters under cropping system with one row of dill.

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 similar with those stated by Abdel-Kader *et al.* (2012) on roselle when intercropped with guar, Zhang *et al.* (2015) on *Angelica sinensis* when intercropped with garlic.

Plant height, number of branches / plant and total plant dry weight of both dill and fenugreek were significantly increased by all phosphorus fertilization 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 fertilization at (45 kg P_2O_5 per feddan) compared with the other ones under study (Tables 2 and 3). The superior effects of P fertilizer application on growth parameters of dill 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 division as well as for meristim tissues (Marshner, 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 patterns and phosphorus rates indicated that the most values of growth parameters of both components were related to alternating one row of dill with two rows of fenugreek accompanied with 45 kg P_2O_5 / feddan consumption of calcium superphosphate. These results agreed with those obtained by Abusuwar and Omer (2011) on *Clitoria ternatea* intercropped with *Lablab purpureus* and addition phosphorus fertilization.

Table (2): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on some growth parameters of dill plant during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
	Plant height (cm)							
Sole dill	82.00e	85.83bc	88.47a	85.43B	84.60gh	87.57b-d	90.60a	87.59AB
1row :1 row	83.80de	86.27a-c	88.67a	85.91B	85.63d-g	87.37b-e	88.33ab	87.33AB
1row :2 rows	86.57a-c	87.73ab	88.33ab	87.77A	86.73c-f	88.17bc	89.33ab	88.08A
2 rows :1 row	81.53e	82.63de	86.60a-c	83.59C	82.97h	86.33bc	88.83ab	86.49B
2 rows :2 rows	52.83de	85.17cd	87.13a-c	85.04BC	84.97f-d	85.53bc	88.20bc	86.23C
Mean (P)	83.15C	85.55B	87.84A		84.98C	87.26B	89.19A	
	Number of branches / plant							
Sole dill	6.13f	6.67cd	7.23a	6.68a	5.80hi	6.63de	6.97ab	6.47ab
1row :1 row	6.23f	6.60d	6.93b	6.59d	6.00gh	6.53de	7.03ab	6.52ab
1row :2 rows	6.30ef	6.50de	7.30a	6.70a	5.97g-i	6.70cd	7.20a	6.62a
2 rows :1 row	5.60g	6.23f	6.70cd	6.18c	5.73i	6.43ef	6.93bc	6.37b
2 rows :2 rows	6.17f	6.53d	6.83bc	6.51d	6.20fg	6.57de	7.03ab	6.60a
Mean (P)	6.09c	6.51d	7.00a		5.94c	6.57b	7.03a	
	Total dry weight / plant (g)							
Sole dill	11.60f	12.33c-e	14.07a	12.67ab	11.10i	12.50e-g	13.83a-c	12.48ab
1row :1 row	11.83ef	12.47c	13.90ab	12.73a	11.50hi	12.40e-g	13.17c-e	12.36b
1row :2 rows	11.90d-f	12.33c-e	14.20a	12.81a	11.73g-i	13.00de	14.33a	13.02a
2 rows :1 row	11.60f	12.00c-f	13.50b	12.37b	11.53hi	12.13f-h	13.47b-d	12.38b
2 rows :2 rows	10.80g	12.40cd	13.83ab	12.34b	11.27i	12.60ef	14.00ab	12.62ab
Mean (P)	11.55c	12.31b	13.90a		11.43c	12.53b	13.76a	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability

Table (3): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on some growth parameters of fenugreek plant during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
	Plant height (cm)							
Sole fenugreek	35.67ef	37.00de	39.00bc	37.22C	36.00h	37.67ef	39.78cd	37.78D
1row :1 row	36.33ef	38.67bc	40.00ab	38.33AB	36.67f-h	37.33fg	41.00b	38.33C
1row :2 rows	37.00df	39.67ab	40.33a	39.00A	36.33gh	40.00bc	40.33bc	38.89B
2 rows :1 row	36.67d-f	38.00cd	40.33a	38.33AB	36.67f-h	38.78de	41.00b	38.78BC
2 rows :2 rows	35.67f	38.33c	40.67a	38.22B	36.67f-h	40.00bc	42.67a	39.78A
Mean (P)	36.27C	38.33B	40.07A		36.47C	38.73B	40.93A	
	Number of branches / plant							
Sole fenugreek	7.00gh	8.33cd	9.00b	8.11BC	7.00gh	8.00de	9.33b	8.11B
1row :1 row	7.00gh	8.00de	8.33cd	7.78C	6.67h	8.33cd	8.67c	7.89B
1row :2 rows	7.67ef	8.67bc	9.67a	8.67A	7.33fg	9.33b	10.67a	9.11A
2 rows :1 row	6.67h	8.33cd	9.67a	8.22ABC	7.33fg	7.67ef	8.67c	7.89B
2 rows :2 rows	7.33fg	8.67bc	9.00b	8.33AB	6.67h	8.33cd	8.67c	7.89B
Mean (P)	7.13C	8.40B	9.13A		7.00A	8.33B	9.20C	
	Total dry weight / plant (g)							
Sole fenugreek	10.45g	12.82d	14.20bc	12.49 b	10.77i	12.48fg	13.97cd	12.41C
1row :1 row	10.78fg	12.83d	14.25bc	12.62 b	10.97i	12.73f	14.43bc	12.71B
1row :2 rows	11.47ef	13.53cd	15.13a	13.38 a	11.53h	13.77d	15.07a	13.46A
2 rows :1 row	10.80fg	12.87d	14.10bc	12.59 b	10.90i	13.27e	13.97cd	12.71B
2 rows :2 rows	10.43g	11.87e	14.43ab	12.24 b	10.53i	12.23g	14.60ab	12.46BC
Mean (P)	10.79c	12.47b	14.42a		10.94A	12.90B	14.41C	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

2. Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on yield components of dill and fenugreek plants:

Results under discussion in Tables 4 and 5 indicate that, increasing rows number of fenugreek increased fruits and seed yield per plant of dill and fenugreek, respectively, under cropping system with one or two rows of dill. Furthermore, alternating one row of dill with two rows of fenugreek treatment (1:2) significantly increased fruit or seed yield per plant compared with the other ones under study during both seasons. 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 competition within specie. These results are in harmony with those reported by Megawer, *et al.* (2010) on barley intercropped with lupin.

However, fruit yield of dill per feddan as well as seed yield and fixed oil yield per feddan of fenugreek 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 feddan of dill and fenugreek as well as oil yield per feddan of fenugreek were observed with phosphorus application at rate of 45 kg P_2O_5 per feddan compared to the other phosphorus rates under study during the two tested seasons. In the mean time, there was gradual increase in the abovementioned 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 stack 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 superiority in dill and fenugreek fruit and seed yield by phosphorus fertilizer application is directly owing to the enhancing effect on growth parameters of dill 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 dill and fenugreek, respectively.

Table (4): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on some yield components of dill plant during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
	Fruit yield / plant (g)							
Sole dill	12.83 h	14.87df	16.40bc	14.70 C	11.83j	14.47ef	16.60b	14.30 C
1row :1 row	13.60 g	16.17c	16.87b	15.54 B	13.83gh	16.43bc	16.83b	15.70 B
1row :2 rows	14.20 f	16.57bc	17.43a	16.07 A	14.13fg	16.77b	17.93a	16.28 A
2 rows :1 row	13.10gh	14.57ef	15.13d	14.27 D	12.63i	14.80e	15.53d	14.32 C
2 rows :2 rows	13.31gh	15.13d	16.40bc	14.95 C	13.45h	15.97cd	16.93b	15.45 B
Mean (P)	13.41C	15.46 B	16.45 A		13.18C	15.69B	16.77A	
	Fruit yield / feddan (Kg)							
Sole dill	898.3c	1040.7b	1148.0a	1029.0A	828.3c	1012.7b	1162.0a	1001.0A
1row :1 row	476.0h	566.0f	590.7ef	544.2C	484.2h	575.2fg	589.6f	549.5C
1row :2 rows	331.3j	386.5i	406.7i	374.9E	329.7j	391.2i	418.4i	379.8D
2 rows :1 row	611.5e	679.8d	706.2d	665.8B	589.6f	690.7e	724.9d	668.4B
2 rows :2 rows	465.7h	529.7g	574.0f	523.1D	470.9h	558.8g	592.7f	540.8C
Mean (P)	556.57C	640.53B	685.13A		540.53C	645.70B	697.43A	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

Table (5): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on some yield components and fixed oil yield per feddan of fenugreek plant during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
Seed yield / plant (g)								
Sole fenugreek	9.70f	11.50d	12.37c	11.19B	9.60h	10.90f	12.00d	10.83C
1row :1 row	10.07ef	11.30d	12.83b	11.40B	9.87gh	11.50e	13.20bc	11.52B
1row :2 rows	10.13e	13.20ab	13.83a	12.39A	10.30g	13.33bc	13.93a	12.52A
2 rows :1 row	9.90ef	11.30d	12.83b	11.34B	10.03gh	11.43e	13.07c	11.51B
2 rows :2 rows	10.07ef	11.30d	12.83b	11.40B	10.13g	11.70de	13.60ab	11.81B
Mean (P)	9.97C	11.72B	12.94A		9.99C	11.77B	13.16A	
Seed yield / fed. (Kg)								
Sole fenugreek	679.00c	805.00b	865.67a	783.22A	672.00c	763.00b	840.00a	758.33A
1row :1 row	352.67i	395.67h	449.33g	399.22C	345.33g	402.50f	462.00e	403.28C
1row :2 rows	472.90e	616.00e	645.57d	578.16B	480.67e	622.23d	650.23c	584.37B
2 rows :1 row	231.00l	263.63k	299.40j	264.68D	234.09j	266.75i	304.86h	268.57D
2 rows :2 rows	352.33i	395.67h	449.17g	399.00C	354.67g	409.50f	476.00e	413.39C
Mean (P)	417.58C	495.16B	541.83A		417.35C	492.80B	546.62A	
Oil yield / fed. (Kg)								
Sole fenugreek	67.23d	81.47b	91.47a	80.06A	67.89d	78.09b	88.47a	78.15A
1row :1 row	35.47h	41.20g	49.09e	41.92C	34.42g	41.59f	51.44e	42.48C
1row :2 rows	48.55ef	65.29d	72.08c	61.98B	49.83e	69.08d	73.25c	64.05B
2 rows :1 row	22.40k	26.89j	31.72i	27.01E	23.41i	27.74h	32.82g	27.99D
2 rows :2 rows	33.36hi	41.66g	46.57f	40.53D	34.64g	43.81f	50.62e	43.02C
Mean (P)	41.40C	51.30B	58.19A		42.04C	52.06B	59.32A	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

Similarly, the data given in Tables 4 and 5 suggest that, the best combination treatment for increasing fruit or seed yield and oil yield per feddan of fenugreek, respectively, was that of the treatment of sole crop system combined with phosphorus fertilizer at 45 kg P_2O_5 per feddan 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 patterns and phosphorus fertilization rates compared with control [sole crop pattern 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 fertilization rates. These results coincided with those found by Carpici and

Tunali (2012) on vetch intercropped with barley and fertilized with phosphorus.

3. Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on total chlorophyll content (a+b) and some active ingredients of dill and fenugreek plants:

Tables 6, 7 and Fig. 2 pointed out that, the highest values of total chlorophyll content a + b of fenugreek leaves was achieved by alternating one row of dill with two rows of fenugreek (1:2 pattern) in the first season and by (1:1pattern) in the second one compared with the other ones under study. In contrast, the highest values of total chlorophyll content a + b of dill leaves was achieved by alternating one row of dill with one row of fenugreek (1:1 pattern) in the first season and by (1:2 pattern) in the second one compared with the other ones under study. However, trigonilline content of fenugreek seeds recorded the highest values with intercropping patterns 1: 2 and followed by sole crop in the first season and 2:2 followed by 1:2 in the second one, with no significant differences between them.

Furthermore, alternating one row of dill with two rows of fenugreek (1:2 pattern) recorded higher increase in volatile oil percentage of dill and oil yield per plant compared with the other ones under study. However, sole crop system treatment increased volatile oil yield per feddan compared with the other intercropping planting pattern in both seasons. Furthermore, intercropping system treatments significantly decreased oil yield per feddan of dill compared to sole crop pattern in the first and second seasons. These results are in accordance with those found by Nawar and Abdel-Galil (2008) when intercropped sunflower with soybean, Megawer, *et al.* (2010) on barley intercropped with lupine or chickpea and Nurbakhsh, *et al.* (2013) on sesame intercropped with bean.

The maximum increase in total chlorophyll content of both crops, trigonilline content of fenugreek seeds, volatile oil percentage and yield per plant and per feddan of dill were produced from the treatment of phosphorus at 45 kg P_2O_5 /feddan compared with the other ones and control (without phosphorus fertilization addition) under study. Such increase was significant in both seasons. Furthermore, the above mentioned parameters were increased with increasing phosphorus rates up to the highest added rate. The same results were found in previous studies on coriander by (Moslemi *et al.*, 2012) and (Hassan *et al.*, 2012) and also on dragonhead (Siad-Al Ahl and Abdou, 2009).

In addition, P application to fenugreek plays a key role in formation of energy rich bonds, phospholipids and it stimulate the development of root system (Jat *et al.*, 2012).

The combination treatment between intercropping pattern of one row of dill + one row of fenugreek (1:1 pattern) and the highest dose of phosphorus was superior in total chlorophyll a+b content of dill, while, 1:2 pattern was superior in total chlorophyll a+b content of fenugreek compared to the other ones under study in the first and second seasons (Tables 6 and 7). Also, the maximum increase in trigonilline content of fenugreek seeds was obtained from combination treatment of 1:2 and 2:2 patterns and phosphorus fertilization at 45 kg P_2O_5 /feddan in the first and second seasons, respectively. Concerning volatile oil percentage and yield per plant, it was found that the highest values were achieved by 1:2 pattern when combined with high rate of phosphorus fertilization. On the other side, volatile oil per feddan was the highest value with combination between sole crop and full dose of phosphorus addition. Likewise, under each treatment of intercropping patterns above mentioned parameters mostly increased with increasing phosphorus fertilization rates.

Table (6): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on volatile oil yield components of dill plant during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
	Volatile oil %							
Sole dill	2.18g	2.47de	2.95b	2.53C	2.20f	2.53cd	2.90b	2.45B
1row :1 row	2.24fg	2.53cd	3.13a	2.63AB	2.27ef	2.50cd	3.05b	2.60B
1row :2 rows	2.28fg	2.63c	3.20a	2.70A	2.28ef	2.67c	3.40a	2.78A
2 rows :1 row	2.17g	2.37ef	3.13a	2.55BC	2.17f	2.42de	2.23a	2.60B
2 rows :2 rows	2.23fg	2.57cd	2.80b	2.53C	2.17f	2.63c	2.92b	2.57B
Mean (P)	2.21C	2.51B	3.04A		2.22C	2.55B	3.10A	
	Volatile oil yield / plant (g)							
Sole dill	0.28k	0.37gh	0.48c	0.38 CD	0.26j	0.37f	0.48c	0.37 C
1row :1 row	0.30jk	0.41ef	0.53b	0.41 B	0.31gh	0.41e	0.51b	0.41 B
1row :2 rows	0.32ij	0.44de	0.56a	0.44 A	0.32g	0.45d	0.61a	0.46 A
2 rows :1 row	0.28k	0.34hi	0.47c	0.37 D	0.28ij	0.36f	0.50bc	0.38 C
2 rows :2 rows	0.30jk	0.39fg	0.46cd	0.38 C	0.29hi	0.42de	0.49bc	0.40 B
Mean (P)	0.30 C	0.39 B	0.50 A		0.29 C	0.40 B	0.52 A	
	Volatile oil yield / feddan (Kg)							
Sole dill	19.56d	25.67b	33.85a	26.36 A	18.26d	25.66b	33.69a	25.87 A
1row :1 row	10.65g	14.34f	18.50d	14.49 C	10.98h	14.38f	17.97de	14.44 C
1row :2 rows	7.56h	10.18g	13.02f	10.25 E	7.53i	10.43h	14.23f	10.73 D
2 rows :1 row	13.24f	16.09e	22.13c	17.15 B	12.77g	16.69e	23.42c	17.63 B
2 rows :2 rows	10.40g	13.59f	16.08e	13.36 D	10.20h	14.72f	17.26de	14.06 C
Mean (P)	12.28 C	15.97 B	20.71 A		11.95 C	16.38 B	21.32 A	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

Table (7): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on total chlorophyll a+b (mg/g fresh weight) and trigonilline content of fenugreek plant during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
Total chlorophyll a+b in fresh leaves (mg/ gm)								
Sole fenugreek	1.077b-e	1.040e	1.107b-d	1.074B	1.060e	1.070de	1.097b-e	1.076BC
1row :1 row	1.060c-e	1.073b-e	1.117bc	1.083B	1.077c-e	1.117a-c	1.143a	1.112A
1row :2 rows	1.063c-e	1.130ab	1.187a	1.127A	1.060e	1.090b-e	1.127ab	1.092B
2 rows :1 row	1.033e	1.053de	1.107b-d	1.064B	1.013f	1.067de	1.120ab	1.067C
2 rows :2 rows	1.043e	1.090b-e	1.123b	1.086B	1.010f	1.080c-e	1.103b-d	1.064C
Mean (P)	1.055C	1.077B	1.128A		1.044C	1.085B	1.118A	
Trigonilline content (mg/ g) in seed								
Sole fenugreek	0.330fg	0.347de	0.373b	0.350AB	0.323fg	0.347de	0.363bc	0.344BC
1row :1 row	0.313h	0.327g	0.357cd	0.332D	0.320g	0.337ef	0.363bc	0.340C
1row :2 rows	0.328g	0.347de	0.390a	0.354A	0.337ef	0.350c-e	0.373ab	0.353AB
2 rows :1 row	0.313h	0.340ef	0.367bc	0.340C	0.323fg	0.350c-e	0.373ab	0.349BC
2 rows :2 rows	0.333fg	0.340ef	0.367bc	0.347B	0.340e	0.357cd	0.383a	0.360A
Mean (P)	0.323C	0.340B	0.371A		0.329C	0.348B	0.371A	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

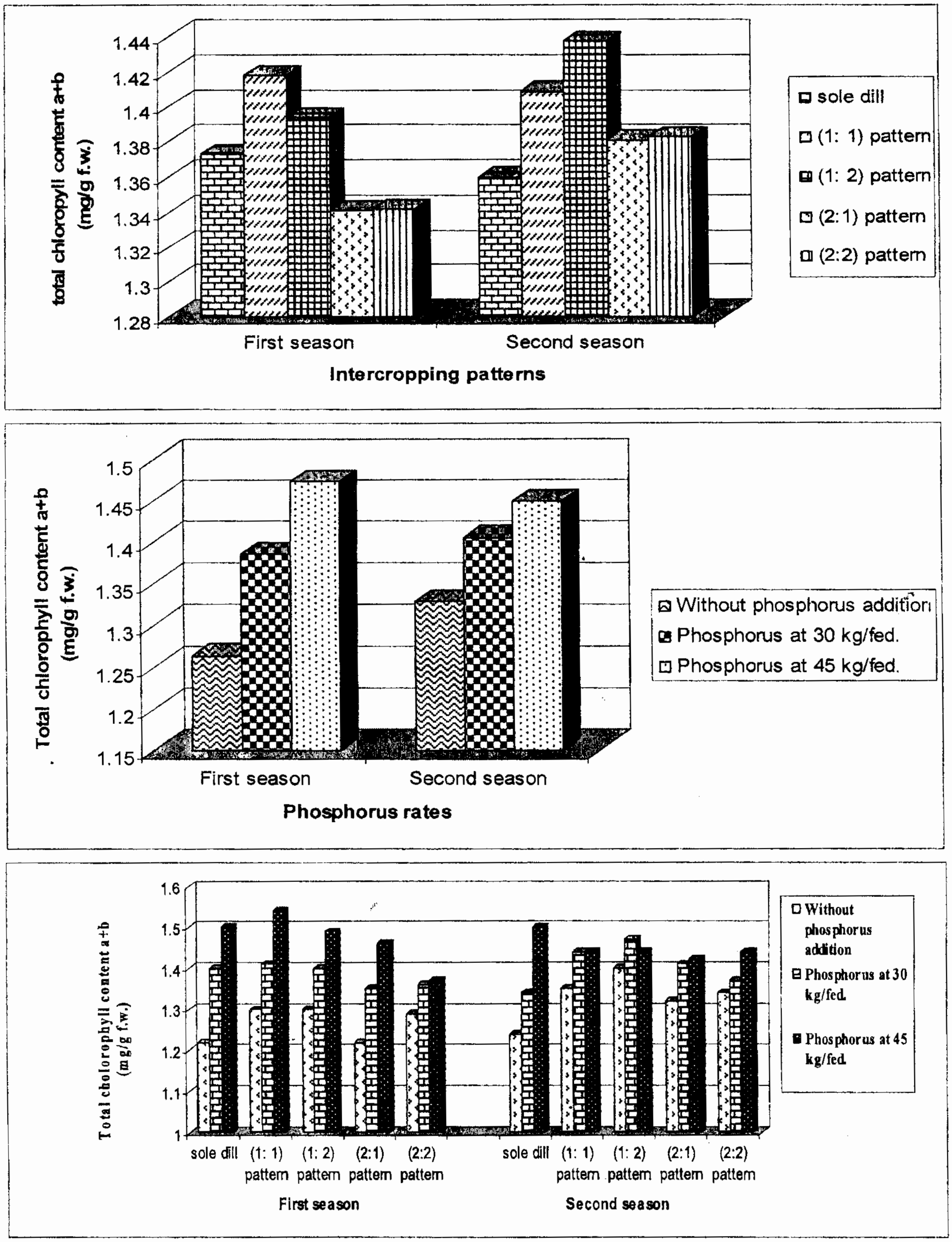

Fig 2: Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on total chlorophyll content a+b of dill during 2013 and 2014 seasons

Consulting the available literature, there was no information concerning the effect of combination treatments between intercropping patterns and phosphorus fertilization rates on chlorophyll content and trigonilline of fenugreek and volatile oil of dill plants.

4. Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on competitive indices of dill and fenugreek plants:

The obtained data in Tables 8 and 9 and Fig. 3 demonstrate that, the land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE) values were greater for dill and fenugreek in mixture of (1:2 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). Indeed, intercropping of dill and fenugreek at 1:1, 1:2 and 2:2 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 pattern in both seasons. 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).

Table (8): Effect of intercropping pattern, phosphorus fertilization rate and their combination treatments on area time equivalent ratio (ATER) and land utilization efficiency (LUE%) during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
	Area Time Equivalent Ratio (ATER)							
1row :1 row	1.006c	0.995cd	0.990cd	0.997C	1.056bc	1.052bc	1.012d	1.039B
1row :2 rows	1.008c	1.074a	1.038b	1.040A	1.054bc	1.135a	1.070b	1.087A
2 rows :1 row	0.994cd	0.954fg	0.932g	0.960D	1.031cd	1.003d	0.957e	0.997C
2 rows :2 rows	0.995cd	0.960ef	0.976de	0.977B	1.053bc	1.045bc	1.030cd	1.042B
Mean (P)	1.001A	0.996A	0.984A		1.049A	1.059A	1.017B	
	Land Utilization Efficiency (LUE%)							
1row :1 row	102.77cd	101.51de	101.15de	101.81B	107.74b-d	107.39b-e	103.46fg	106.20B
1row :2 rows	103.70c	110.58a	106.90b	107.06A	108.44bc	116.90 a	110.26b	111.86A
2 rows :1 row	100.78de	96.77gh	94.67h	97.40D	104.60e-g	101.81g	97.23h	101.21C
2 rows :2 rows	101.70c-e	98.06fg	99.72ef	99.82C	107.39b-e	105.32c-e	105.32d-f	106.52B
Mean (P)	102.24A	101.73A	100.61A		107.07A	108.20A	104.07B	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

Table (9): Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on aggrissivity values (A) and relative crowding coefficient (RCC) during seasons of 2013-2014

Intercropping patterns (dill : fenugreek) (I)	Phosphorus rate (Kg P_2O_5/fed.) (P)							
	0.0	30	45	Mean(I)	0.0	30	45	Mean(I)
	First season				Second season			
Aggrissivity values of dill (Adf)								
1row :1 row	+0.530	+0.543	+0.514	+0.529	+0.070	+0.040	-0.043	+0.022
1row :2 rows	+0.065	-0.033	-0.054	- 0.007	+0.123	-0.062	-0.080	-0.006
2 rows :1 row	+0.000	-0.005	-0.116	-0.041	+0.021	-0.027	-0.155	-0.054
2 rows :2 rows	+0.011	+0.051	-0.005	+0.019	+.041	+0.015	-0.056	+0.000
Mean (P)	+0.151	+0.139	+0.085		+0.064	-0.008	-0.083	
Aggrissivity values of fenugreek (Afd)								
1row :1 row	-0.530	-0.543	-0.514	-0.529	-0.070	-0.040	+0.043	-0.022
1row :2 rows	-0.065	+0.033	+0.054	+ 0.007	-0.123	+0.062	+0.080	+0.006
2 rows :1 row	-0.000	+0.005	+0.116	+0.041	-0.021	+0.027	+0.155	+0.054
2 rows :2 rows	-0.011	-0.051	+0.005	-0.019	-.041	-0.015	+0.056	-0.000
Mean (P)	-0.151	-0.139	-0.085		-0.064	+0.008	+0.083	
Relative Crowding Coefficient (RCC)								
1row :1 row	1.220cd	1.156de	1.146de	1.174B	1.492cd	1.472cd	1.268de	1.410BC
1row :2 rows	1.347c	1.968a	1.617b	1.644A	1.682bc	2.880a	1.971b	2.178A
2 rows :1 row	1.117de	0.920fg	0.848g	0.962C	1.326d	1.169de	0.960e	1.152C
2 rows :2 rows	1.175c-e	1.006e-g	1.080d-f	1.087B	1.484cd	1.454cd	1.366cd	1.435B
Mean (P)	1.215AB	1.262A	1.173B		1.496B	1.744B	1.391A	

* Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability..

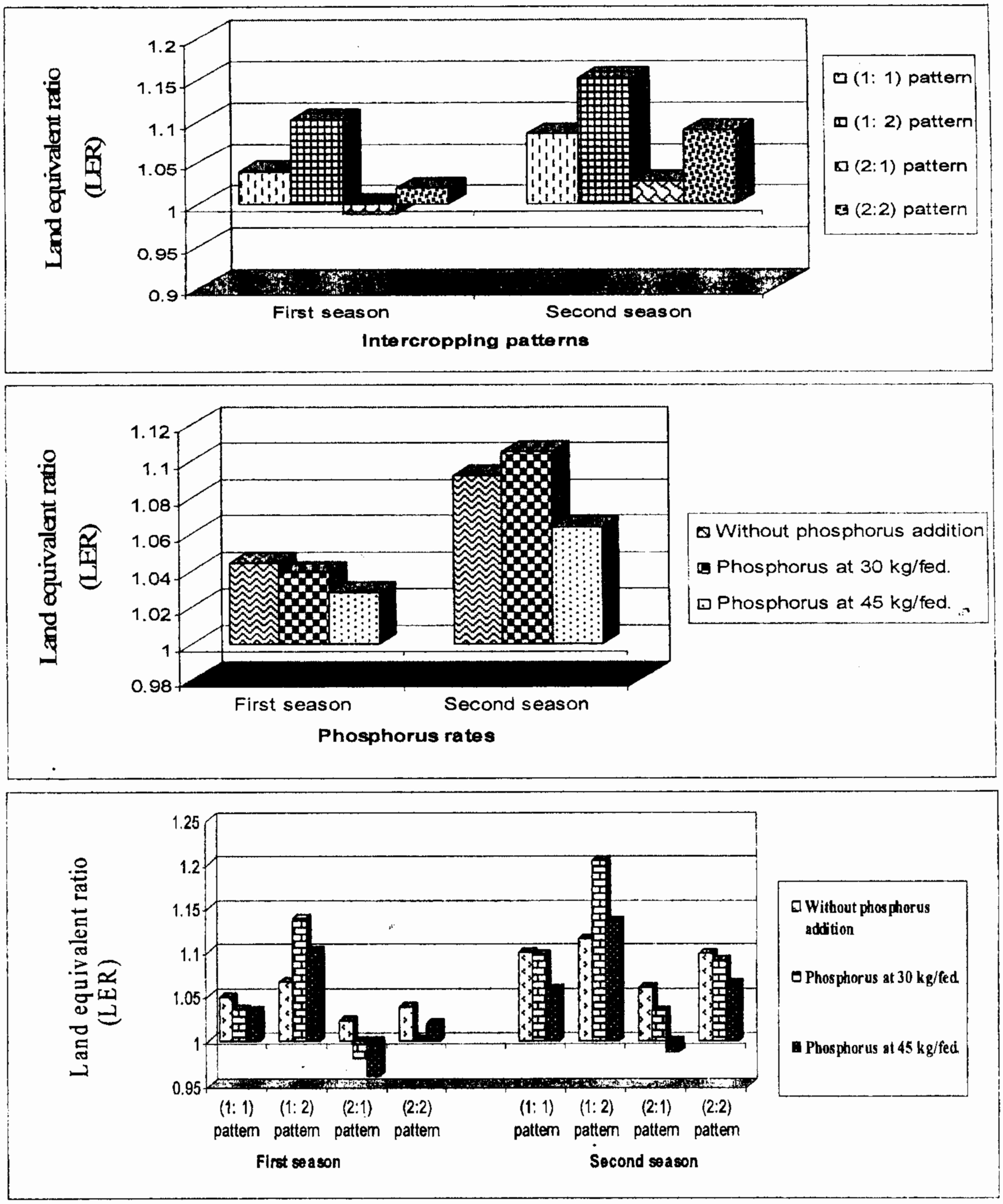

Fig 3: Effect of intercropping patterns, phosphorus fertilization rate and their combination treatments on land equivalent ratio (LER) of intercropping dill and fenugreek during 2013 and 2014 seasons

It is known that an aggressivity value of zero indicates that the component crops are equally competitive. For any other situation, two crops will have the same numerical value by positive for the dominant crop and negative for the dominated one. The greater the numerical value, the larger the difference in competitive abilities.

In the mean time, dill component intercropped with fenugreek (Adf) was the aggressor crop in 1:2 and 2:1 cropping patterns. The highest values of aggressivity for dill on fenugreek were 0.529 and 0.022 with intercropping system 1:1 in the first and second seasons, respectively, the corresponding figures were - 0.529 and - 0.022 for fenugreek plants. Meanwhile, fenugreek component intercropped with dill (Afd) was the aggressor crop in 1:1 and 2:2 cropping patterns. These results are in accordance with those found, regarding the effect of intercropping treatments on aggressivity (A) values, by El-Shamy *et al.* (2008) found that sunflower component crop was the dominant, whereas guar was the dominated one.

The maximum increase in LER, ATER, LUE and RCC were obtained from the treatment of 30 kg P_2O_5 /feddan, in most cases, (1.039 and 1.105), (0.996 and 1.059), (101.73 and 108.2 %) and (1.262 and 1.744) compared with the other ones under study in the first and second season, respectively. Phosphorus rates had no significant effect on LER, ATER and LUE in the first season. Concerning aggressivity values, it is clear that dill component crop was the dominant, whereas fenugreek was the dominated one.

Furthermore, the advantage of growing species (dill 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 LER, ATER, LUE and RCC (1.138 and 1.208, 1.074 and 1.059 and 110.58% and 116.90% and 1.968 and 2.880) were achieved by the combination treatment between intercropping pattern one row of dill alternating with two rows of fenugreek with 30 kg P_2O_5 /feddan during both seasons, respectively. This result suggest that it could be obtained from one feddan by using this intercropping system and 30 kg P_2O_5 /feddan the same yield which would required about 1.14 or 1.20 feddan if each crop cultivated alone. Such aggressivity reached to its maximum values (0.543 and 0.155) by using combination treatment of 1:1 intercropping pattern treatment, 30 kg of phosphorus per feddan and combination treatment of intercropping pattern of (2:1) with 45 kg of phosphorus per feddan in the first and second seasons, respectively.

Consulting the available literature, there was no information concerning the effect of combination treatments between intercropping patterns and phosphorus fertilization rates on competitive indices of dill and fenugreek plants.

Conclusion:

This study suggests that dill/fenugreek association should be used by farmers instead of dill sole crop, especially at 1:2 cropping pattern, under Sharkia Governorate condition. The use of phosphorus rate at 30 P_2O_5 kg/feddan for both the crops, in the intercropping pattern of 1:2, resulted in increases in dill and fenugreek growth, yield, active components and maximized land equivalent ratio as well as land utilization efficiency.

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تأثير نظام التحميل ومعدل السماد الفوسفاتي على النمو والمحصول والمواد الفعالة وبعض العلاقات التنافسية لنباتات الشبت والحلبة

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الملخص العربى

أجري هذا العمل بالمزرعة التجريبية بكلية الزراعة (مزرعة غزالة) جامعة الزقازيق خلال موسمي ٢٠١٢/٢٠١٣ و ٢٠١٣/٢٠١٤. دُرِس تأثير نظم التحميل بين الشبت والحلبة بنسب ١:١ و ٢:١ و١:٢ و٢:٢ علي خطوط متبادلة مقارنة بزراعة كل نوع علي حده ومعدلات مختلفة من التسميد الفوسفاتي (صفر، ٣٠ أو ٤٥ كجم فو٢ أ٥ /فدان) ومعاملات التداخل بينهما على النمو ومكونات المحصول والمواد الفعالة وبعض العلاقات التنافسية لكلا النوعين. أدت المعاملة بـ ٤٥ كجم فو٢ أ٥ / فدان إلي زيادة معنوية فى في جميع صفات الشبت والحلبة مقارنة بالمعدلات الأخرى تحت الدراسة. أدى نظام التحميل ١: ٢، فى أغلب الأحيان، إلى زيادة معنوية (عند مستوى معنوية ٠,٠٥) فى صفات النمو الخضري والمكونات المحصولية ومحتوى الحلبة من التريجونيللين والنسبة المئوية للزيت العطري والمحصول /نبات في ثمار الشبت 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 لنسبة المكافئ الأرضي ونسبة المكافئ الأرضي لعامل الزمن وكفاءة استخدام الأرض ومعامل الحشد النسبي ١,١٣٨ و١,٢٠٣، ١,٠٧٤ و١,٠٧٠، ١١٠,٥٨٪ و١١٦,٩٠ ٪ و١,٩٦٨ و٢,٨٨٠ تحصل عليها من معاملة التفاعل بين نظام التحميل بزراعة خط من الشبت مع خطين من الحلبة مع إضافة التسميد الفوسفاتي بمعدل ٣٠ كجم فو٢ أ٥ / فدان خلال الموسم الأول والثاني، على الترتيب. عموماً، يمكن الحصول من فدان واحد محمل باستخدام نظام التحميل ٢:١ والتسميد الفوسفاتي بمعدل ٣٠ كجم فو٢ أ٥ / فدان، نفس المحصول من زراعة حوالي ١,١٣٨ و١,٢٠٣ فدان إذا زرعا كلا المحصولين منفردا.