



EFFECT OF INTERCROPPING PATTERNS ON GROWTH, YIELD COMPONENTS, CHEMICAL CONSTITUENTS AND COMPETITION INDICES OF ONION, FENNEL AND CORIANDER PLANTS

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ABSTRACT

This investigation aimed to study the effect of intercropping patterns of onion with fennel and coriander on growth, yield components, chemical constituents and competition indices. Simple experiment based on randomized complete block design with three replications was conducted in Agricultural Research Farm, Faculty of Agriculture, Zagazig University, Egypt during winter seasons of 2013/2014 and 2014/2015. Cropping patterns were allocated to the different planting ratios (onion: fennel or coriander as 1:1, 1:2 and 1:3) and sole onion, sole fennel and sole coriander as a control. Results revealed that alternating one row of each of fennel or coriander with three rows of onion, mostly, gave the highest values of growth parameters, yield per plant and volatile oil production as well as chemical constituents of apiaceous crops in the two seasons. Also, intercropping pattern of 1:coriander:2 onion gave the highest values of onion NPK uptake and protein content per bulb. Generally, the highest values of LER (land equivalent ratio), ATER (area time equivalent ratio), LUE (land utilization efficiency) and RCC (relative crowding coefficient) were (1.206 and 1.288), (1.126 and 1.207), (113.81 and 121.99%) and (2.552 and 4.033) in first and second seasons, respectively which were achieved by intercropping pattern of one row of coriander with two rows of onion. Also, aggressivity values indicated that apiaceous component crops (fennel or coriander) were the dominant, whereas onion was the dominated one in intercropping patterns. Generally, these mixtures seem promising in the development of sustainable crop production with a limited use of external inputs. They can be used by the farmers in Sharkia Governorate conditions as they are the most profitable systems with the greatest yield advantages.

Key words: Onion, fennel, coriander, intercropping, growth, yield, LER, ATER, LUE and RCC.

INTRODUCTION

Onion (*Allium cepa* L.) which belongs to family Alliaceae is one of the commercial vegetable and spice crops in Egypt, not only for local consumption but also for exportation. It considered a high cash value crop for Egyptian farmers. This is because the international market demands on the Egyptian dry, fresh and processed onions. Among the constraints for low productivity in onion, imbalanced nutrition is the main limiting factor (Shedeed *et al.*, 2015). Sweet fennel (*Foeniculum vulgare* Mill.) is a plant belongs to the Umbelliferae (Apiaceae)

family, which is an annual, biennial or perennial aromatic herb, depending on the variety (Farrell, 1988; Wichtl and Bisset, 1994). It is native to North Africa, Mediterranean Region, southern Europe and Asia (Abd El-Wahab and Mehasen, 2009). It contains phytochemical hormones (saponins), flavonoids, lipids, proteins and essential oils. Fennel is used in folk medicine as a stimulant, diuretic, carminative and sedative (Charles *et al.*, 1993) and galactagogic, emmenagogic, expectorant and antispasmodic (Chiej, 1984). Coriander (*Coriandrum sativum* L.) is well known plant from Apiaceae family widely spread in Egypt, where it has good

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climatic and soil conditions for high yield and good quality. Coriander is an aromatic herb, cultivated as a summer or winter annual crop, depending on the climatic conditions (Kofidis *et al.*, 2008). Essential oil content is the main criteria for determining the quality of these fruits. Coriander fruits contain from 0.10 to 1.8% of essential oil (Telci *et al.*, 2006), which has a characteristic aroma similar to a mixture of cinnamon and pepper.

Intercropping is one of the most common practices used in sustainable agricultural systems which have an important role in increasing the productivity and stability of yield in order to improve resource utilization and environmental factors such as water, nutrients and light. Among the most important benefits of intercropping is increasing the production per unit area than sole cropping (Banik *et al.*, 2006). However, the advantage of intercropping was obtained when correspondent species were different in the form and spatio-temporal of natural resources in which different physiological and morphological characteristics will be able to make optimal use of environmental factors when cropped in the vicinity of each other.

Onion, fennel and coriander are the most important crops to be included in intercropping practices under Sharkia Governorate conditions. Therefore, the present study on intercropping of onion and other two crops was undertaken to investigate the productivity performance of onion, fennel and coriander components under different intercropping patterns compared to their sole crops and observe the yield performance of the selected component crops as sole and intercrops as well as to evaluate effectiveness of apiaceous intercrops in the management in onion bulb quality.

MATERIALS AND METHODS

This study was performed as simple experiment in randomized complete block design with three replications in Experimental Farm, Faculty of Agriculture (Ghazala Farm), Zagazig University, Egypt, during two winter seasons of 2013/2014 and 2014/2015. Thus, the present work aimed to study the effect of intercropping patterns

between onion with fennel and coriander on growth, yield components and quality and chemical constituents as well as some competitive indices of the three crops.

Onion transplants (cv. Behary Improved) of nearly 45 days old were transplanted on 25th October of both seasons and fruits of fennel and coriander components were sown in the same time. Onion was transplanted at space of 10 cm between hills, on two sides of the row, but fruits of both fennel and coriander were sown at space of 30 cm in one side of the row just after irrigation. After three weeks from planting, germinated plants were thinned to two plants/hill for two apiaceous plants. The physical and chemical properties of the used soil are shown in Table 1.

There were 27 experimental plots each of 21.6 m² included 12 rows; each row was 60 cm apart and three meters in length. Nine planting arrangements were used, each was replicated three times. The spatial arrangements were:

- (1, 2 and 3) Sole onion and sole fennel as well as sole coriander, respectively,
- (4) 1 row of fennel alternating with 1 row of onion,
- (5) 1 row of fennel alternating with 2 rows of onion,
- (6) 1 row of fennel alternating with 3 rows of onion,
- (7) 1 row of coriander alternating with 1 row of onion,
- (8) 1 row of coriander alternating with 2 rows of onion and
- (9) 1 row of coriander alternating with 3 rows of onion.

All plants received normal agricultural practices whenever they needed. All plants were fertilized with nitrogen, phosphorus and potassium fertilization at the rate of 200 kg/fad., of ammonium sulphate (20.5%N), 200 kg/fad., of calcium super phosphate (15.5% P₂O₅) and 100 kg/fad., of potassium sulphate (50% K₂O), respectively. Phosphorus and potassium fertilizers were added during soil preparation as a soil dressing application. While, nitrogen fertilizer was divided into three equal portions and were added to the soil after 30, 60 and 90 days from transplanting and sowing.

Table 1. Physical and chemical properties of experimental farm soil

Physical properties (%)	2013/2014 season	2014/2015 season	Chemical properties	2013/2014 season	2014/2015 season
Sand	26.96	26.84	Organic matter (%)	1.64	1.71
Silt	16.68	15.42	pH	7.89	8.10
Clay	56.36	57.74	Available N (ppm)	18.00	17.00
Texture	Clay	Clay	Available P (ppm)	18.90	20.40
			Available K (ppm)	71.20	72.00

Data Recorded

Growth parameters

At harvesting, plant height (cm), number of leaves/plant, for onion were measured as well as plant height (cm), number of branches/plant and total dry weight (g) for fennel and coriander were estimated by taking five random guarded plants from each experimental unit.

Yield and its components

At maturity, onion plants from each experimental unit were manually lifted, field-cured for 15 days, in shady place before assessing bulb size. Onion bulbs were weighted, then separated into four grades according to the Ministry of Economic for onion exportation: Grade 1: bulbs with diameter more than 6 cm, grade 2: bulbs with diameter more than 4.5 to 6 cm, grade 3: bulbs with diameter more than 3.5 to 4.5 cm and grade 4: bulbs with diameter less than 3.5 cm and the following data were recorded: marketable yield as ton/fad. (yield of grades 1 + 2 + 3). Exportable yield as ton/ fad., (yield of grades 1 + 2) and total yield as ton/ fad., (yield of grades 1 + 2 + 3 + 4) as well as average bulb weight and bulb quality as dry matter (%) since, one hundred grams of fresh bulbs was oven dried at 105°C till constant weight and DM (%) was calculated and total soluble solids (TSS) was determined in onion juice by refractometer as Brix°. For fennel and coriander, umbels number/ plant and fruit yield per plant (g/plant) were determined, then total fruit yield per faddan (kg/fad.) was calculated.

Chemical analyses

Samples of dry bulbs of onion and fruits of fennel and coriander were randomly taken from each treatment for chemical analysis. Furthermore,

total nitrogen uptake was determined in bulbs or fruits of each one according to the methods described by Chapman and Pratt (1978) and was multiplied by 6.25 to calculate protein (%), then protein content was determined. Total phosphorus uptake was determined according to the methods adapted by Hucker and Catroux (1980). Potassium uptake was determined by using flame photometer according to the method described by Brown and Lilleland (1946). The volatile oil from air-dried fruits of fennel and coriander plants 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 faddan was calculated.

Competitive indices

Land equivalent ratio (LER)

This parameter gives an indication to the relative land area required, as sole cropping, to produce the same yields achieved by intercropping. 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 onion, fennel and coriander yield recorded per faddan according to Mead and Willey (1980) equation as follows:

$$LER_{\text{onion, fennel}} = L_o + L_f,$$

$$LER_{\text{onion, coriander}} = L_o + L_c$$

$$L_o = \frac{Y_{of}}{Y_{oo}}, \quad L_f = \frac{Y_{fo}}{Y_{ff}}, \quad L_c = \frac{Y_{co}}{Y_{cc}}$$

Where L_o , L_f and L_c are the relative yield of onion, fennel and coriander, respectively, as well as Y_{oo} , Y_{ff} and Y_{cc} are the yields per

faddan of onion, fennel and coriander, respectively, as sole crops and Y_{of} , Y_{fo} and Y_{co} are the yields of onion and fennel as well as coriander, respectively, as intercrops.

Area time equivalent ratio (ATER)

It was calculated according to Hiebsch and McCollum (1987) equation as follows:

$$ATER = \frac{Y_{of}/Y_{oo} \times t_o + Y_{fo}/Y_{ff} \times t_f}{T}$$

$$ATER = \frac{Y_{oc}/Y_{oo} \times t_o + Y_{oc}/Y_{cc} \times t_c}{T}$$

Where: Y_{of} = intercropped yield of onion with fennel, Y_{oo} = sole yield of onion, Y_{fo} = intercropped yield of fennel, Y_{ff} = sole yield of fennel, t_o = the duration of onion in days, t_f = the duration of fennel in days, Y_{oc} = intercropped yield of onion with coriander, Y_{cc} = sole yield of coriander t_c = the duration of coriander in days, and T = the total duration of intercropping system in days.

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:

$$LUE = \frac{LER \times ATER}{2} \times 100$$

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:

$$A_{of} = L_o - L_f, \quad A_{fo} = L_f - L_o$$

$$A_{oc} = L_o - L_c, \quad A_{co} = L_c - L_o$$

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

$$A_{of} = \frac{Y_{of}}{Y_{oo} \times Z_{of}} - \frac{Y_{fo}}{Y_{ff} \times Z_{fo}}$$

$$A_{fo} = \frac{Y_{fo}}{Y_{ff} \times Z_{fo}} - \frac{Y_{of}}{Y_{oo} \times Z_{of}}$$

$$A_{oc} = \frac{Y_{oc}}{Y_{oo} \times Z_{oc}} - \frac{Y_{co}}{Y_{cc} \times Z_{co}}$$

$$A_{co} = \frac{Y_{co}}{Y_{cc} \times Z_{co}} - \frac{Y_{oc}}{Y_{oo} \times Z_{oc}}$$

Where: Y_{of} = yield of onion intercropped with fennel, Y_{oc} = yield of onion intercropped with coriander, Y_{fo} = intercrop yield of fennel, Y_{co} = intercropped yield of coriander, Y_{oo} = sole yield of onion, Y_{ff} = sole yield of fennel, Y_{cc} = sole yield of coriander, Z_{of} = sowing proportion of onion, Z_{fo} = sowing proportion of fennel and Z_{co} = sowing proportion of coriander.

Relative crowding coefficient (K)

Another coefficient that is used, is the relative crowding coefficient (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:

$$K = (K_{\text{onion}} \times K_{\text{fennel or coriander}}),$$

$$K_{\text{onion} \times \text{fennel}} = \frac{Y_{of} Z_{fo}}{(Y_{oo} - Y_{of}) Z_{of}}$$

$$K_{\text{onion} \times \text{coriander}} = \frac{Y_{oc} Z_{co}}{(Y_{oo} - Y_{oc}) Z_{oc}}$$

$$K_{\text{fennel}} = \frac{Y_{fo} Z_{of}}{(Y_{ff} - Y_{fo}) Z_{fo}}$$

$$K_{\text{coriander}} = \frac{Y_{co} Z_{co}}{(Y_{cc} - Y_{co}) Z_{co}}$$

Where Z_{of} is the sown proportion of onion in mixture with fennel, Z_{fo} is the sown proportion of fennel in mixture, Where Z_{oc} is the sown proportion of onion in mixture with coriander and Z_{co} is the sown proportion of coriander in mixture. When the product of the two coefficients ($K_{\text{onion}} \times K_{\text{fennel or coriander}}$) 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.

Competitive ratio (CR)

It is another way to assess competition between different species. The CR gives a better measure of competitive ability of the crops and is also advantageous as an index over K and aggressivity (Willey and Rao, 1980). The

CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops in which they are initially sown. The CR is calculated according to the following formula:

$$CR_{\text{onion} \times \text{fennel}} = \frac{LER_{\text{onion}}}{LER_{\text{fennel}}} \left(\frac{Z_{fo}}{Z_{of}} \right),$$

$$CR_{\text{onion} \times \text{coriander}} = \frac{LER_{\text{onion}}}{LER_{\text{coriander}}} \left(\frac{Z_{co}}{Z_{oc}} \right),$$

$$CR_{\text{fennel} \times \text{onion}} = \frac{LER_{\text{fennel}}}{LER_{\text{onion}}} \left(\frac{Z_{of}}{Z_{fo}} \right),$$

$$CR_{\text{coriander} \times \text{onion}} = \frac{LER_{\text{coriander}}}{LER_{\text{onion}}} \left(\frac{Z_{oc}}{Z_{co}} \right)$$

Statistical Analysis

All collected data were subjected to analysis of variance and means of treatments were compared with the least significant difference (LSD) test at $P \leq 0.05$. The statistical calculations were performed with statistix software version 9 (Analytical software, 2008).

RESULTS AND DISCUSSION

Effect of Intercropping Patterns on Onion Plant

Growth and some quality parameters

Data presented in Table 2 reveal that, alternating one row of coriander with three rows of onion gave the highest values of onion plant height (cm) and leaf number per plant without significant differences in between compared to the other ones under study during the two tested seasons. Furthermore, there was no significant increase in dry matter percentage of onion by using intercropping pattern treatments compared to sole planting pattern. However, in most cases, all intercropping patterns increased the total soluble solids (TSS), while, it decreased the average bulb weight compared to onion sole crop in first and second seasons under study.

It is now clear that using of high row ratio of onion (vs. low ratio of coriander) gave the highest values of plant height and number of leaves per plant as well as dry matter percentage without significant differences in between. This may be attributed to three

factors. Firstly, the high population of onion plants within area unit which increased the above mentioned parameters. Secondly, the low competition between the shorter component crop (onion) and taller one (coriander) on sunlight which might be happened with decreasing the row ratio of onion plants resulting in low growth of onion. Thirdly, the low competition between coriander and onion plants on available nutrients as reported by El-Shamy *et al.* (2008 a) on guar when intercropped with sunflower and Abdelkader *et al.* (2012) on guar intercropped with roselle plant.

Yield and its components

From the data recorded in Table 3, it is clear that, intercropping pattern treatments significantly decreased grade one yield, exportable yield, marketable yield and total yield per faddan compared to sole crop pattern in the first and second seasons. Moreover, alternating one row of fennel with three rows of onion treatment (1:3 pattern) recorded higher increase in grade two yield per faddan compared with the other ones under study. The maximum increase in grade three yield per faddan was obtained from the treatment of (1 row of fennel: 2 rows of onion) and (1 row of fennel: 3 rows of onion) compared to sole crop and other intercropping patterns during the two tested seasons. In addition, alternating one row of coriander with three rows of onion treatment (1:3 pattern) recorded higher increase in grade four yield per faddan compared with the other ones under study.

These results agreed with those found by Abdur-Rashid and Rahmatullah (2006) on sorghum when intercropped with mungbean or guar, Mahapatra (2011) on blackgram when intercropped with sabai grass and Choudhuri and Jana (2015) on potato intercropped with mustard.

Concerning total bulb yield per faddan of onion, it was found that pure stand of onion gave the highest yield per faddan. These paradoxical results may interpreted in the light of that the highest population of onion plants within area unit (faddan) in sole onion pattern could be compensated the high of average bulb weight in this treatment compared with intercropping pattern treatments.

Table 2. Effect of intercropping pattern treatments on onion growth, quality parameters and average bulb weight (g) during 2013/2014 and 2014 /2015 seasons

Parameter	Growth parameters		Bulb quality		Average bulb weight (g)
	Plant height (cm)	Leaf number / plant	Dry mater (%)	Total soluble solids	
First season (2013/2014)					
Sole onion	42.67 c	8.33 a	14.96 a	10.33 b	111.78a
1 row of fennel: 1 row of onion	52.37ab	9.33 a	15.18 a	12.00 a	102.85ab
1 row of fennel: 2 rows of onion	48.67 bc	9.33 a	15.71 a	12.17 a	84.26 d
1 row of fennel: 3 rows of onion	49.33abc	9.33 a	15.04 a	12.67 a	78.81 d
1 row of coriander: 1 row of onion	53.67ab	8.67 a	14.28 a	12.00 a	96.64 c
1 row of coriander: 2 rows of onion	56.00ab	9.33 a	15.01 a	12.33 a	109.04ab
1 row of coriander: 3 rows of onion	56.67 a	10.0 a	15.01 a	12.67 a	99.81 c
Second season (2014/2015)					
Sole onion	43.67 d	7.33 b	14.92 a	10.67 b	111.77a
1 row of fennel: 1 row of onion	48.67bc	9.00 a	15.50 a	11.67ab	102.13 a
1 row of fennel: 2 rows of onion	46.00cd	8.67 a	15.07 a	12.00ab	82.42 d
1 row of fennel: 3 rows of onion	48.67bc	9.00 a	15.32 a	12.00ab	80.91 d
1 row of coriander: 1 row of onion	50.00abc	8.67 a	14.67 a	12.00ab	95.98 c
1 row of coriander: 2 rows of onion	52.67 ab	8.67 a	14.94 a	11.83ab	111.77a
1 row of coriander: 3 rows of onion	53.67 a	9.33 a	14.83 a	12.67 a	98.81bc

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

Table 3. Effect of intercropping pattern treatments on onion yield of different grades and its components (ton/ fad.) during 2013/2014 and 2014 /2015 seasons

Parameters	Grade 1	Grade 2	Grade 3	Grade 4	Exportable yield (1+2)	Marketable yield (1+2+3)	Total yield
	First season (2013-2014)						
Sole onion	3.864 a	2.091 b	0.232 b	0.184 b	5.955 a	6.186 a	6.370a
1 row of fennel: 1 row of onion	1.542 c	1.413 d	0.231 b	0.069 d	2.954 d	3.185 d	3.254de
1 row of fennel: 2 rows of onion	0.963 d	1.949 c	0.511 a	0.019 e	2.912 d	3.423 d	3.441d
1 row of fennel: 3 rows of onion	1.100 d	2.300 a	0.540 a	0.117 c	3.400 c	3.941 c	4.058c
1 row of coriander: 1 row of onion	1.093 d	1.399 d	0.236 b	0.175 b	2.491 e	2.727 e	2.903f
1 row of coriander: 2 rows of onion	2.392 b	2.051bc	0.143 d	0.156 b	4.444 b	4.587 b	4.743b
1 row of coriander: 3 rows of onion	1.552 c	1.009 e	0.195 c	0.356 a	2.561 e	2.756 e	3.111ef
Second season (2014-2015)							
Sole onion	3.621 a	2.024 bc	0.205 d	0.170 b	5.646 a	5.851 a	6.021 a
1 row of fennel: 1 row of onion	1.674 c	1.513 d	0.247bc	0.055 d	3.187cd	3.434 d	3.532 d
1 row of fennel: 2 rows of onion	1.020 d	1.971 c	0.556 a	0.145 b	2.990de	3.546 d	3.602 d
1 row of fennel: 3 rows of onion	1.150 d	2.266 a	0.557 a	0.174 b	3.417 c	3.973 c	4.118 c
1 row of coriander: 1 row of onion	1.006 d	1.412 d	0.253 b	0.174 b	2.18 f	2.670 e	2.845 e
1 row of coriander: 2 rows of onion	2.468 b	2.118 b	0.159 e	0.174 b	4.586 b	4.745 b	4.919 b
1 row of coriander: 3 rows of onion	1.668 c	1.082 e	0.214cd	0.375 a	2.750 e	2.964 e	3.339 d

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

Chemical constituents

The data illustrated in Table 4 indicate that, increasing number of rows of onion under cropping system with one row of fennel mostly decreased total nitrogen, phosphorus and potassium uptake per bulb as well as protein content per plant of onion. Moreover, alternating one row of coriander with two rows of onion treatment (1:2 pattern) recorded higher increase in above mentioned parameters except of potassium uptake per bulb compared with the other ones under study. These results are in accordance with those found by Megawer *et al.* (2010) on barley intercropped with lupine or chickpea and Nurbakhsh *et al.* (2013) on sesame intercropped with bean.

Effect of Intercropping Patterns on Fennel Plant

Growth parameters

Data recorded in Table 5 show that, plant height, number of branches per plant and total dry weight of fennel were increased with intercropping pattern treatments compared to sole crop pattern of fennel plant. Such increase was significant by using that of one row of fennel: three rows of onion (1:3 pattern) in both seasons. Whereas, the treatment of 1 rows of fennel: 1 row of onion (1:1) recorded lower values in this respect compared to the other two ones of intercropping pattern in both seasons. Likewise, the above mentioned parameters were increased with increasing the number of rows of onion under cropping pattern with one row of fennel. These results are in line with those reported by Meawad *et al.* (2003) on roselle intercropped with guar at 1:3 system, Al-Dalain (2009) on potato intercropped with maize and Sarkar and Raghav (2010) on capsicum when intercropped with maize.

Yield components

It is quite clear from the data in Table 5 that, alternating one row of fennel with two and three rows of onion treatments (1:2 and 1:3 patterns) recorded higher increase in number of umbels per plant compared with the other ones under study. Furthermore, fruit yield per plant was increased with intercropping pattern treatments compared to sole cropping pattern. Such increase was significant in the first and second seasons. In addition, fruit yield per faddan of

fennel was decreased with increasing rows number of onion under cropping system with one row of fennel. However, sole crop pattern treatment increased fruit yield per faddan compared with the other intercropping planting patterns under study. Similar results were reported by Naeem *et al.* (2004) on sunflower intercropped with mungbean, Abdur-Rashid and Rahmatullah (2006) on sorghum when intercropped with mungbean or guar and Mahapatra (2011) on blackgram when intercropped with sabai grass.

Volatile oil production and some chemical constituents

Data in Table 6 reveal that, intercropping pattern treatments increased significantly volatile oil percentage and oil yield per plant of fennel (except that of 1:1 intercropping pattern treatment in the first season in volatile oil percentage) compared to sole crop pattern in the first and second seasons. Whereas, oil yield per faddan was significantly decreased by using intercropping pattern treatments compared to sole crop. Furthermore, alternating one row of fennel with three rows of onion treatment (1:3 pattern) recorded higher increase in volatile oil percentage and yield per plant compared with the other ones under study. These results are in harmony with those reported by Rao (2000) on java citronella intercropped with red gram, horse gram, and brinjal and Singh *et al.* (2002) on intercropped mint species within sugarcane.

The observed increase in volatile oil yield per faddan of sole fennel compared to intercropping patterns might be largely due to the increase in seed yield per faddan, rather than volatile oil percentage which was increased by using these treatments, as found in this study, since oil yield per faddan equal oil percentage by seed yield per faddan.

The data described in Table 6 indicate that, total nitrogen and phosphorus as well as potassium uptake per plant (g) were increased with intercropping pattern treatments compared to sole cropping pattern. Such increase was significant in the two seasons. Moreover, alternating one row of fennel with three rows of onion treatment (1:3 pattern) recorded significant increase in this respect compared with the other ones under study. Also, the abovementioned parameters were decreased with increasing rows

Table 4. Effect of intercropping pattern treatments on some chemical constituents of onion during 2013/2014 and 2014/2015 seasons

Parameter	Nitrogen uptake / bulb (g)	Phosphorus uptake / bulb (g)	Potassium uptake / bulb (g)	Protein content / bulb (g)
First season (2013-2014)				
Sole onion	3.118 a	0.354 c	3.060 a	19.489 a
1 row of fennel: 1 row of onion	2.996ab	0.412ab	2.774bc	18.727ab
1 row of fennel: 2 rows of onion	2.475 c	0.313 d	2.356de	15.465 c
1 row of fennel: 3 rows of onion	2.362 c	0.334cd	2.307 e	14.763 c
1 row of coriander: 1 row of onion	2.832 b	0.393 b	2.574cd	17.698 b
1 row of coriander: 2 rows of onion	3.202 a	0.428 a	3.002 a	20.013 a
1 row of coriander: 3 rows of onion	2.848 b	0.392 b	2.964ab	17.800 b
Second season (2014-2015)				
Sole onion	3.083 b	0.394 b	3.014 a	19.274 b
1 row of fennel: 1 row of onion	2.993 b	0.399 b	2.768ab	18.724 b
1 row of fennel: 2 rows of onion	2.457 d	0.310 c	2.332 d	15.337 d
1 row of fennel: 3 rows of onion	2.413 d	0.332 c	2.376cd	15.088 d
1 row of coriander: 1 row of onion	2.777 c	0.375 b	2.675bc	17.357 c
1 row of coriander: 2 rows of onion	3.283 a	0.454 a	3.003ab	20.527 a
1 row of coriander: 3 rows of onion	2.960 b	0.398 b	2.866ab	18.487 b

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

Table 5. Effect of intercropping pattern treatments on fennel growth parameters and yield components during 2013/2014 and 2014/2015 seasons

Parameter	Growth parameters			Yield components		
	Plant height (cm)	Branch number / plant	Total dry weight (g)	Umbel number / plant	Fruit yield / plant (g)	Fruit yield / faddan (kg)
First season (2013-2014)						
Sole fennel	94.00 c	8.00 b	72.97 c	45.33 c	14.70 d	653.48 a
1 row of fennel: 1 row of onion	102.67bc	8.67 b	88.07 b	57.67 b	18.96c	421.26 b
1 row of fennel: 2 rows of onion	108.67ab	9.67 b	107.13a	69.00 a	21.40b	317.01c
1 row of fennel: 3 rows of onion	116.67 a	12.00a	112.73a	70.33 a	23.67a	262.96 d
Second season (2014-2015)						
Sole fennel	91.67 c	7.33 c	70.80 d	43.33 c	13.63 d	605.63a
1 row of fennel: 1 row of onion	98.00 b	7.67bc	84.60 c	56.00 b	18.28 c	406.30b
1 row of fennel: 2 rows of onion	111.00 a	9.00 b	106.27b	68.33 a	20.43 b	302.69c
1 row of fennel: 3 rows of onion	115.00 a	12.33a	116.93a	70.67 a	23.70 a	263.33d

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

number of onion under cropping pattern with one row of fennel. Such results hold true in both seasons. These results are in harmony with those found by Meawad *et al.* (2004 a) on guar when it was intercropped with roselle and Khan *et al.* (2006) on sunflower, french bean, vigna radiate, soybean and cowpea when intercropped with them, as well as Abdelkader (2012) on roselle when intercropped with guar plant, regarding the increase in NPK uptake per plant due to intercropping patterns.

Effect of Intercropping Patterns on Coriander Plant

Growth parameters

The results tabulated in Table 7 clear that, alternating one row of coriander with three rows of onion recorded higher values in growth parameters of coriander plant compared to the other cropping pattern treatments under study. Furthermore, plant height, number of branches per plant and total dry weight of coriander were increased with intercropping pattern treatments compared to sole cropping pattern. In addition, the abovementioned parameters were increased with increasing the number of rows of onion under cropping pattern with one row of coriander. These results are in agreement with those reported by Ghosh *et al.* (2007) on tulshi (*Ocimum sanctum*) when intercropped in coconut, Bitew *et al.* (2014) on lupine intercropped with wheat, barley and finger millet and Ahmad *et al.* (2015) on sweet corn when intercropped with cowpea. Furthermore, the increment noticed in plant growth parameters by using intercropping pattern of one row of coriander with three rows of onion might be due to the increase in the availability of light to coriander plant, which increased metabolites of photosynthesis.

Yield components

It is evident from the results in Table 7 that, number of umbels per plant and fruit yield per fennel plant was increased, while, fruit yield per feddan was decreased with increasing rows number of onion under cropping system with one row of coriander. However, alternating one row of coriander with three rows of onion treatment (1:3 pattern) recorded significant increase in number of umbels and fruit yield per plant compared with the other ones under study.

Furthermore, fruit yield per faddan was decreased with intercropping pattern treatments compared to sole cropping pattern. Such decrease was significant in the first and second seasons. Generally, sole crop pattern treatment increased fruit yield per faddan compared with the other intercropping planting patterns under study. Similar results were found by Nurbakhsh *et al.* (2013) on sesame intercropped with bean and Singh *et al.* (2014) on mustard intercropped with lentil. In this respect, Amarasingha *et al.* (2015) indicated that intercropped maize yield was only 3% less than that of the maize mono-crop. However, yield of mungbean was 21% less in the intercropping system than the mono-crop system.

Volatile oil production and some chemical constituents

From data presented in Table 8 it is clear that, alternating one row of coriander with three rows of onion treatment (1:3 pattern) recorded higher increase in volatile oil yield per plant compared with the other ones under study. Moreover, intercropping pattern treatments decreased significantly volatile oil percentage and oil yield per faddan of coriander crop except that of 1:1 and 1:2 patterns in volatile oil percentage in the first season compared to sole crop pattern. These results agreed with those reported by Rao (2000) on java citronella intercropped with red gram, horse gram, and brinjal and Singh *et al.* (2002) on intercropped mint species with in sugarcane.

The data reported in Table 8 indicate that, total nitrogen and phosphorus as well as potassium uptake per plant (g) were increased with intercropping pattern treatments except that of potassium uptake per plant in the first season compared to sole cropping pattern. Such increase was significant in the two seasons. Moreover, alternating one row of coriander with three rows of onion treatment (1:3 pattern) recorded significant increase in this respect compared with the other ones under study. Such results hold true in both seasons. These results were also found by Meawad *et al.* (2004 a) on guar when intercropped with roselle and Khan *et al.* (2006) on sunflower, french bean, *Vigna radiate*, soybean and cowpea when intercropped with them as well as Abdelkader *et al.* (2012) on roselle when intercropped with guar plant.

Table 6. Effect of intercropping pattern treatments on volatile oil production and some chemical constituents of fennel plant during 2013/2014 and 2014/2015 seasons

Parameter	Volatile oil production			Chemical constituents		
	Oil percentage	Oil yield / plant (g)	Oil yield / faddan (kg)	Total nitrogen uptake / plant (g)	Total phosphorus uptake / plant (g)	Potassium uptake / plant (g)
First season (2013-2014)						
Sole fennel	3.42 b	0.50 d	22.38a	0.227 d	0.217 d	0.193 d
1 row of fennel: 1 row of onion	3.44 b	0.65 c	14.53 b	0.347 b	0.370 b	0.270 c
1 row of fennel: 2 rows of onion	3.70 a	0.79b	11.73c	0.313 c	0.333 c	0.340 b
1 row of fennel: 3 rows of onion	3.76 a	0.89a	9.91 d	0.463 a	0.473 a	0.473 a
Second season (2014-2015)						
Sole fennel	3.38 d	0.45 d	21.06 a	0.157 c	0.200 d	0.160 d
1 row of fennel: 1 row of onion	3.48 c	0.60 c	15.43 b	0.330 b	0.373 b	0.250 c
1 row of fennel: 2 rows of onion	3.67 b	0.75 b	11.10 c	0.323 b	0.347 c	0.232 b
1 row of fennel: 3 rows of onion	3.77 a	0.89 a	9.94 c	0.493 a	0.503 a	0.467 a

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

Table 7. Effect of intercropping treatments on coriander growth parameters and yield components during 2013-2014 and 2014 -2015 seasons

Parameter	Growth parameters			Yield components		
	Plant height (cm)	Branch number / plant	Total dry weight (g)	Umbels number / plant	Fruit yield / plant (g)	Fruit yield / faddan (kg)
First season (2013-2014)						
Sole coriander	56.67 c	7.67 c	39.01 c	14.14 d	28.00 d	1244.4 a
1 row of coriander: 1 row of onion	64.33 b	13.33 b	41.84 bc	17.38 c	37.00 c	822.2 b
1 row of coriander: 2 rows of onion	74.33 a	15.33 b	44.47 ab	21.24 b	38.67 b	574.2 c
1 row of coriander: 3 rows of onion	76.67 a	18.33 a	46.70 a	24.80 a	41.71 a	263.4 d
Second season (2014-2015)						
Sole coriander	60.00 d	9.33 d	41.04 c	16.04 d	28.48 c	1265.9 a
1 row of coriander: 1 row of onion	64.33 c	14.33 c	43.24 bc	18.21 c	34.47 bc	766.0 b
1 row of coriander: 2 rows of onion	71.00 b	16.00 b	45.77 ab	22.55 b	40.16 ab	595.0 c
1 row of coriander: 3 rows of onion	78.67 a	19.67 a	48.01 a	25.95 a	43.13 a	479.3 c

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

Table 8. Effect of intercropping treatments on volatile oil production and some chemical constituents of coriander during 2013/2014 and 2014/2015 seasons

Parameter	Volatile oil production			Chemical constituents		
	Oil percentage	Oil yield / plant (g)	Oil yield / faddan (kg)	Total nitrogen uptake / plant (g)	Total phosphorus uptake / plant (g)	Potassium uptake / plant (g)
First season (2013-2014)						
Sole coriander	0.920 ab	0.257 c	11.4 a	0.540 c	0.093 d	0.307 a
1 row of coriander: 1 row of onion	0.937 ab	0.346 b	7.70 b	0.723 b	0.127 b	0.397 a
1 row of coriander: 2 rows of onion	0.967 a	0.372 a	5.55 c	0.783 a	0.113 c	0.470 a
1 row of coriander: 3 rows of onion	0.893 b	0.375 a	4.14 d	0.763 a	0.143 a	0.383 a
Second season (2014-2015)						
Sole coriander	0.997 a	0.284 c	12.61 a	0.557 c	0.107 c	0.300 c
1 row of coriander: 1 row of onion	0.953 b	0.329 bc	7.30 b	0.700 b	0.140 b	0.393 b
1 row of coriander: 2 rows of onion	0.967 ab	0.388 ab	5.75 c	0.747 b	0.133 b	0.463 b
1 row of coriander: 3 rows of onion	0.970 ab	0.418 a	4.65 c	0.903 a	0.193 a	0.567 a

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

Effect of Intercropping Patterns on Competitive Indices

Land equivalent ratio (LER) and area time equivalent ratio (ATER)

In assessments of crop productivity of sole cropping systems, a useful expression is mass yield (mass per unit area). However, in intercropping systems, direct comparison is difficult because products are different for the different plant species growing on one piece of land. In this case, crop productivity should be evaluated using a common unit. A widely used method is the land equivalent ratio (LER), Beets (1982). Therefore, area time equivalent ratio (ATER) provides more realistic comparison of the yield advantage of intercropping over sole cropping in terms of variation in time taken by the component crops of different intercropping systems, Willey (1979). LER and ATER were significantly influenced by intercropping pattern treatments (Table 9). The combined yield advantage in terms of LER and ATER indices were the greatest in the cases of 1 coriander: 2 onion intercropping arrangement (1.206, 1.288 and 1.126, 1.207) followed by 1 fennel:1 onion

(1.155, 1.259 and 1.110, 1.188) intercropping pattern arrangement in the first and second seasons, respectively. This could be due to the reason that one to two coriander-onion as well as one to one fennel-onion intercropping arrangement planted in the same inter and intra row spacing gave compatible more efficient total resource exploitation and greater overall production than sole crops and the remaining intercropping arrangements. Whereas, 1 coriander: 3 onion (0.861, 0.935 and 0.796, 0.870), intercropping arrangements showed values less than 1.00, thus indicated the disadvantage. However, similar results were reported by Bantie (2015) on maize intercropped with potato.

Land utilization efficiency (LUE%) and aggressivity (A)

The studied data presented in Table 9 show that, the maximum increase in land utilization efficiency (LUE%) was obtained from the treatment of alternating one row of coriander with two rows of onion (113.81 and 121.99%) in the first and second seasons, respectively, compared with the other ones under study. Such

Table 9. Effect of intercropping pattern treatments on land equivalent ratio LER, area time equivalent ratio ATER, land utilization efficiency percentage LUE% and aggressivity values during 2013/2014 and 2014/2015 seasons

Parameter	LER	ATER	LUE %	Aggressivity	
				Aao**	Aoa**
Intercropping pattern					
First season (2013-2014)					
1 row of fennel: 1 row of onion	1.155 b	1.110 a	112.19 a	0.134 d	- 0.134 d
1 row of fennel: 2 rows of onion	1.025 c	0.975 b	98.49 b	0.647 b	-0.647 b
1 row of fennel: 3 rows of onion	1.040 c	0.980 b	99.04 b	0.758 ab	-0.758 ab
1 row of coriander: 1 row of onion	1.117 b	1.003 b	101.38 b	0.150 d	-0.150 d
1 row of coriander: 2 rows of onion	1.206 a	1.126 a	113.81 a	0.270 c	-0.270 c
1 row of coriander: 3 rows of onion	0.861 d	0.796 c	80.46 c	0.838 a	-0.838 a
Second season (2014-2015)					
1 row of fennel: 1 row of onion	1.259 a	1.188 a	120.09 a	0.074 c	-0.074 c
1 row of fennel: 2 rows of onion	1.099 b	1.043 b	105.37 b	0.602 b	-0.602 b
1 row of fennel: 3 rows of onion	1.121 b	1.056 b	106.75 b	0.825 a	-0.825 a
1 row of coriander: 1 row of onion	1.081 b	0.976 b	98.65 b	0.134 c	-0.134 c
1 row of coriander: 2 rows of onion	1.288 a	1.207 a	121.99 a	0.188 c	-0.188 c
1 row of coriander: 3 rows of onion	0.935 c	0.870 c	87.90 c	0.776 a	-0.776 a

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

** a= apiaceous plants (fennel and coriander) o= onion plant

results hold true in both seasons. While, the treatment of 1 row of coriander: 3 rows of onion recorded lower values in this respect compared to the other intercropping pattern treatments under study in both seasons.

However, Rao (2002) found that the LUE value was 128%, clearly signifying the superiority of intercropping over monocropping of (either of the two crops *i.e.*, rose-scented geranium or corn mint). In addition, the effect of intercropping pattern treatments on aggressivity (A) values of apiaceous (Aao) and onion (Aoa) calculated for fruit and bulb yield per faddan of fennel and coriander and onion, respectively. In particular, Apiaceous plants (fennel and coriander) were the dominant species (Aao positive). Whereas, onion was the dominated one (Aoa negative). Such aggressivity reached its maximum in the 1:3 coriander-onion intercropping pattern in the first season and that

of 1:3 fennel-onion intercropping pattern in the second season.

These results were in accordance with those found, regarding the effect of intercropping treatments on aggressivity (A) values, by Meawad *et al.* (2004 b) suggested that roselle plants were aggressive to guar by using the intercropping system treatments of (2:1) and (3:1), whereas guar plants were aggressive to roselle by using the intercropping system treatments of (1:1) and (1:2). Azraf *et al.* (2006) showed that the intercropping systems of sorghum alone, sorghum + mungbean, sorghum + cluster bean, sorghum+ cowpea and sorghum + sesbania, forage sorghum appeared to be the dominant crop, as indicated by positive sign of aggressivity. El-Shamy *et al.* (2008 b) found that sunflower component crop was the dominant, whereas guar was the dominated one and Singh *et al.* (2014) on mustard intercropped with wheat and lentil.

Relative crowding coefficient, RCC (K) and competitive ratio (CR)

Data of both seasons in Table 10 suggest that, using intercropping pattern treatments increased relative crowding coefficient RCC (K) compared to 1 coriander : 3 onion intercropping pattern during the two seasons under study. However, the highest values in this respect were achieved by using intercropping pattern of 1:2 coriander-onion which followed by 1:1 fennel-onion intercropping pattern. Such results hold true in the first and second seasons. Competitive ratio (CR) is only used as a measure of intercrop competition (inter-specific competition) Dhima *et al.* (2006). CR of onion and apiaceous plants was significantly influenced by intercropping patterns. Furthermore, intercropped fennel and coriander had higher competitive ratios in all proportions with onion, indicating that apiaceous plants was more competitive (CR apiaceous > one) than onion (CR onion < one). However, in all other mixtures the values of CR for apiaceous (fennel and coriander) were greater than for onion indicating the dominance of apiaceous. Moreover, the CR of onion decreased, whereas the CR of fennel increased as the proportion increased in the mixtures. This corroborates with Trydeman *et al.* (2006) who stated that barley was dominant over lupine in intercrops on the sandy and sandy loam soil site, Bantie *et al.* (2014) on lupine intercropped with

cereals and Bantie (2015) on maize intercropped with potato.

Conclusion

The present study indicated that intercropping of onion with apiaceous plants (fennel and coriander) at different intercropping patterns affected growth, yield of individual species, chemical constituents of the three species (onion and apiaceous) and also the competitive indices of the cropping system. The combined yield advantages in terms of land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE) as well as relative crowding coefficient RCC indices were greatest in the cases of 1:2 coriander-onion cropping pattern followed by 1:1 fennel-onion cropping pattern as intercropping arrangement. In addition, these two intercropping patterns were found to be the most profitable. Also apiaceous plants were the dominant species in both fennel-onion mixtures and in coriander-onion mixture at all intercropping patterns under study. These mixtures seem promising in the development of sustainable crop production with a limited use of external inputs. They could be used by the farmers under Sharkia Governorate conditions as they are the most profitable systems with the greatest yield advantages.

Table 10. Effect of intercropping pattern treatments on relative crowding coefficient RCC (K) and competitive ratio CR during 2013/2014 and 2014/2015 seasons

Parameter Intercropping pattern	RCC (K)	Competitive ratio (CR)	
		CR onion	CR apiaceous
First season (2013-2014)			
1 row of fennel: 1 row of onion	1.632 b	0.972 a	1.226 d
1 row of fennel: 2 rows of onion	1.109bc	0.556 c	1.796 b
1 row of fennel: 3 rows of onion	1.169bc	0.527 c	1.899 b
1 row of coriander: 1 row of onion	1.653 b	0.690 b	1.450 c
1 row of coriander: 2 rows of onion	2.552 a	0.808 a	1.244 d
1 row of coriander: 3 rows of onion	0.567 c	0.437 d	2.287 a
Second season (2014-2015)			
1 row of fennel: 1 row of onion	2.941 b	0.902 a	1.118 c
1 row of fennel: 2 rows of onion	1.526c	0.600 b	1.669 b
1 row of fennel: 3 rows of onion	1.722 c	0.526 b	1.910ab
1 row of coriander: 1 row of onion	1.573 c	0.801 a	1.283 c
1 row of coriander: 2 rows of onion	4.033 a	0.871 a	1.153 c
1 row of coriander: 3 rows of onion	0.774 d	0.492 b	2.063 a

* Means having the same letter (s) within the same column are not significantly different according to LSD all-pairwise comparisons test at 5% level of probability.

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تأثير نظم التحميل على النمو، المساهمات المحصولية، المحتويات الكيميائية، مؤشرات التنافس لنباتات البصل والشمر والكسبرة

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يهدف هذا العمل لدراسة تأثير نظم تحميل البصل مع كل من الشمر والكسبرة على النمو والمساهمات المحصولية والمكونات الكيميائية ومؤشرات التنافس، حيث أجريت تجربة بسيطة في قطاعات كاملة العشوائية في ثلاث مكررات في المزرعة البحثية بكلية الزراعة جامعة الزقازيق خلال الموسمين الشتويين ٢٠١٣/٢٠١٤ و ٢٠١٤/٢٠١٥، وقد رتبّت نظم التحميل بنسب زراعة مختلفة (البصل: الشمر أو الكسبرة بمعدل ١:١ و ٢:١ و ٣:١) بالإضافة لزراعة كل من البصل والشمر والكسبرة منفرداً ككنترول، وقد أظهرت النتائج أنه في معظم الحالات أعطت النباتات المحملة أعلى القيم من حيث صفات النمو الخضري، محصول النبات، إنتاج الزيت العطري والمكونات الكيميائية للنباتات الخيمية عند استخدام نظام التحميل خط واحد من الشمر أو خط واحد من الكسبرة مع ثلاث خطوط من البصل، كما أدى نظام التحميل واحد خط من الكسبرة: خطين من البصل إلى الحصول على أعلى القيم لنبات البصل من حيث امتصاص النيتروجين والفوسفور واليوتاسيوم ومحتوى البصلة من البروتين، وعموماً، فقد تم الحصول على أعلى القيم لنسبة المكافئ الأرضي ونسبة المكافئ الأرضي لعامل الزمن، كفاءة استخدام الأرض ومعامل الحشد النسبي (١,٢٠٦ و ١,٢٨٨) و (١,١٢٦ و ١,٢٠٧) و (١١٣,٨١ و ١٢١,٩٩%) و (٢,٥٥٢ و ٤,٠٣٣) في الموسمين الأول والثاني، على التوالي، عند التحميل بنظام خط واحد من الكسبرة مع خطين من البصل، كما أظهرت قيم العدوانية أن المكونين الخيمييين (الشمر أو الكسبرة) هما المحصولان السائدان بينما البصل هو المسود عليه تحت نظم التحميل، وعموماً، هذه النظم ملائمة لتحسين إنتاجية تلك المحاصيل مع تقليل استخدام المعاملات الإضافية، كذلك يمكن استخدامها بواسطة المزارعين تحت ظروف محافظة الشرقية كنظم ذات عائد مرتفع ذات ميزة محصولية.

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