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USING INTERCROPPING SYSTEMS TO OBTAIN HIGH YIELD AND GOOD COMPETITIVE INDICES OF FENNEL AND ONION UNDER DIFFERENT POTASSIUM FERTILIZER LEVELS

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ABSTRACT: In order to obtain high yield components and good competitive indices of fennel and onion, different intercropping systems (sole crop of each components, 1:1, 1:2, 2:1 and 2:2 of fennel: onion, respectively) under different potassium fertilizer levels (0.0, 24 and 48 kg K_2O/feddan) were used. A field experiment was carried out at Experimental Farm (Ghazala Farm), Faculty of Agriculture, Zagazig University, Egypt during the consecutive seasons of 2019/2020 and 2020/2021. The achieved results revealed that, intercropping systems significantly decreased fruit and bulb yield per feddan of fennel and onion, respectively, compared to sole crop of each one. Data obtained clearly that, rate of 24 as well as 48 kg of potassium level/ feddan gave increased of yield components of each fennel or onion plants. Furthermore, aggressivity and competitive ratio values indicated that fennel component were the dominant, whereas onion was the dominated one in different intercropping systems. The highest value of land utilization efficiency percentage (128.91 and 137.67 as well as 136.86 and 135.10) were obtained when fennel intercropped with onion at 2: 1 as well as 2: 2 systems under fertilization level of 24 K_2O/feddan in 1st and 2nd seasons, respectively. Therefore, the intercropping systems of 2:1 and 2: 2 raised yield advantage over the sole crop per unit area as revealed by the highest total land equivalent ratio (LER), area time equivalent ratio (ATER) and land utilization efficiency (LUE%).

Key words: Fennel, onion, intercropping, potassium, yield, volatile oil, LER, ATER and LUE.

INTERODUCTION

Fennel (*Foeniculum vulgare*, Mill.) commonly known as shamar or shamarhaaot is native of Mediterranean countries and it is being a member of the family of Apiaceae (**Mozaffarian, 2013**). Fennel fruits have a pleasant aromatic taste and a fragrant odor. Fennel fruits contain 1.4 to 4.0 percent volatile oil, pale yellow in color (**Omidbaigi, 2008**). Fennel fruits are widely utilized in various food preparation, sauces, candies soups, pickles, pastries, bakery items, liquors etc. The leaves and fruits are digestive, stimulant, carminative, and appetizing utilized for cough, colic, flatulence, constipation, thirst, diarrhea and dysentery (**Telci *et al*., 2019**).

Onion (*Allium cepa* L.) being a member of the family of Alliaceae and the widely planting as biennial herbaceous vegetable crop. Consumption of onions has been rising significantly in the world slightly because of the health benefits they are in possession (**Wang *et al*., 2006**). It is considered one of the important vegetables that are produced over large areas for use in cooking, spices and salads. Onion contains a strong antibiotic, achromatic agent in addition to bacterial, fungicidal, anticancer, antioxidant components such as quercetin and anti-cholesterol (**Baghizadeh *et al*., 2009**).

Intercropping is a ways to improve diversity in an agricultural ecosystem. Intercropping is an age-old usage and enticed worldwide attention

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owing to yield supremacy if the crops choosen are compatible. Intercropping is one of the most serious techniques which combine growing of crops under various geometry of plant (**Ghosh *et al.*, 2006**). Intercropping is used as an example of likely agricultural systems following targets such as: more using of resources, ecological balance, raising the quality and quantity as well as decrease yield spoiling to pests, weeds and diseases (**Mazaheri *et al.*, 2006**).

Potassium (K) has a notable operation in phosphorus and nitrogen uptake, which relates superior vegetative development, concentrated translocation of phosphorus (P) and the piling up of photosynthesis and has pointed out as the reason of an improved rate of photosynthetic and production of carbohydrates (**Abbadi *et al.*, 2008**). This subsequent carbohydrate metabolism and translocation in the end enhanced the crop yield as well as yield quality. Formerly it was found that potassium alleviated the stomatal regulation, improved stomatal closure and raised CO_2 assimilation rate as well as enzyme activity; thus, higher carbohydrates may have resulted in increased yield components (**Oosterhuis *et al.*, 2014**).

In this study, we have attempted (i) to investigate the role of intercropping system for enhancing yield of sole as well as intercropped fennel and onion, (ii) to determine the suitable level of potassium fertilizer for realizing maximum yield and yield advantage and (iii) to estimate the effect of potassium fertilizer management on productivity and competitive indices of fennel/onion intercropping system.

MATERIALS AND METHODS

A field experiment was carried out at the experimental farm of Faculty of Agriculture, Zagazig University, Egypt during the two winter consecutive seasons of 2019/2020 and 2020/ 2021. This study was conducted to evaluate the response of yield components as well as the competitive indices values of fennel and onion plants to different intercropping systems (fennel: onion at various row ratios; 1:1, 1:2, 2:1 and 2:2 compared to sole crop of each component), potassium fertilizer levels (0.0, 24 and 48 kg K_2O/feddan) and their interaction treatments. Table 1 shows the physical and chemical analyses of the experimental soil at a depth of 0-30 cm as reported by **Chapman and Pratt (1978**).

Experimental Design

The statistical layout of the current experiment was split-plot design experiment between intercropping systems (five systems) as main plot and potassium fertilizer levels (three levels) as sub-plot in three replicates. The interaction treatments between intercropping systems and potassium levels were consisted of 15 treatments.

Plant Material and Cultivation

The source of fennel fruits was Research Centre of Medicinal and Aromatic Plants, Dokky, Giza, Egypt. In addition, onion seedlings (cv. Giza 6) of nearly 40 days old were used. Both fennel fruits and onion seedlings were sown and transplanted on 10^{th} and 14^{th} October of 1^{st} and 2^{nd} seasons, respectively, in the same time. Fruits of fennel were sown on one side of the ridge at space of 30 cm, but onion was transplanted on the two sides of the ridge at space of 10 cm between hills, just after irrigation. The experimental unit area was 3.5 × 7.20 m^2. Every experimental unit contained twelve ridges with 3.5 m long. Moreover, the distance between ridges was 60 cm. About 3-5 fennel fruits were sown per hill and then it was thinned after 3 weeks to 2 plants/ hill. Surface irrigation system was used to irrigate fennel and onion plants. The number of fennel and onion plants per feddan (4000 m^2) under intercropping systems shown in Table 2. The other agricultural practices were applied to the two components as recommended.

Fertilization Levels and its Time

The two components (fennel and onion) were fertilized with N and P fertilizers at the level of 400 kg/fed., of ammonium sulfate (20.5%N) and 200 kg/fed., of calcium super phosphate (15.5% P_2O_5). K fertilizer source was potassium sulfate (48% K_2O). P fertilizer was added during soil preparation as a soil dressing application. While, N and K fertilizers were divided into four equal portions and were added to the soil after 30, 55, 80 and 105 days from transplanting and sowing.

Table 1. Some physical and chemical analyses of the experimental soil (average of the two seasons)

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Clay
41.39	19.26	15.62	23.73	

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
7.84	0.97	0.56	2.6	1.6	1.4	3.8	4.3	1.8	3.3	19.2	12.4	66.3

Table 2. Number of fennel and onion plants per feddan under different intercropping systems

Intercropping patterns (fennel: onion)	Number of plants/feddan	
	Fennel	Onion
Sole crop	44445	200000
1row of fennel: 1 row of onion	22223	100000
1row of fennel: 2 rows of onion	14667	133400
2row of fennel: 1 rows of onion	29778	66600
2row of fennel: 2 rows of onion	22223	100000

Sampling and Collecting Data

Yield components

After 135 days from sowing date, at harvesting, the central rows of each experimental plot were utilized for determination of fennel yield components. Umbel number per plant, fruit yield per plant (g) was registered and fruit yield per feddan (kg) was counted. Also, the volatile oil from air-dried fruits of fennel plants was isolated by hydro distillation for 3 hr., in order to extract the volatile oils suggested by **Guenther (1961)** and the volatile oil yield per plant and per feddan was calculated.

For onion plants, at maturity stage (150 days after transplanting date) from each experimental unit were manually lifted, field-cured for fifteen days, in shady place before valuing bulb size. Onion bulbs were differentiated into 4 grades as reported by the Ministry of Economic for onion exportation: Grade 1: bulbs have diameter extra than 6 cm, grade 2: bulbs have diameter extra than 4.5 to 6 cm, grade 3: bulbs have diameter extra than 3.5 to 4.5 cm and grade 4: bulbs have diameter less than 3.5 cm then it weighted and the following data were listed: exportable yield as ton/ feddan (yield of grades 1 + 2) as well as marketable yield as ton/feddan (yield of grades 1 + 2 + 3) and total yield as ton /feddan (yield of grades 1 + 2 + 3 + 4).

Competitive indices

Land equivalent ratio (LER)

LER refers to the land amount required for sole crop to produce the same yields as an intercropping system. The most serious virtue is

crucial value. However, the LER is greater than 1, intercropping raises yield advantage. Whenever, LER is gave down than 1 the intercropping passively impacts the yield of fennel and onion grown in mixture. It was estimated utilizing the following equation for fennel fruit yield per feddan and onion total bulb yield per feddan:

$$\text{LER} = \text{Lf} + \text{Lo}\ \text{Lf} = \frac{\text{Yfo}}{\text{Yff}},\ \text{Lo} = \frac{\text{Yof}}{\text{Yoo}}$$

Where, Lf is the relative yield of fennel, Lo the relative yield of onion, Yff and Yoo are the fennel and onion yields per feddan, respectively, as sole planting and Yfo and Yof are the fennel and onion yields, respectively, as mixtures (**Mead and Willey, 1980**).

Area time equivalent ratio (ATER)

Since, LER does not take into calculation the time for which land is established by crops of an intercropping system, ATER was also calculated as reported by (**Hiebsch and McCollum, 1987**). It was determined according to the following equation:

$$\text{ATER} = \frac{\frac{\text{Yfo}}{\text{Yff}} \times \text{tf} + \frac{\text{Yof}}{\text{Yoo}} \times \text{to}}{\text{T}}$$

Where: Yfo = intercrop yield of fennel, Yff = sole yield of fennel, Yof = intercrop yield of onion, Yoo= sole yield of onion, tf = the duration of fennel in days (135 days), to = the duration period of onion in days (150 days) and T = the total duration of mixture system between fennel and onion in days (150 days).

Land utilization efficiency percentage (LUE %)

A measure of the percentage of land use efficiency when it is greater than 100% indicates that there is a crop advantage equal to the higher percentage. By utilizing LER and ATER values, the land utilization efficiency percentage (LUE %) was calculated according to **Mason *et al.* (1986)** equation as next:

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

Aggressivity (A)

Aggressivity (A) values indicates that the means have a positive sign is that this crop is dominant specie, while the negative sign for the dominated one. It was calculated according to the equation reported by **Mc Gilchrist (1965)** as next:

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

$$\text{Aggressivity fennel to onion (Agfo)} = \text{Lf} - \text{Lo}$$

$$\text{Aggressivity onion to fennel (Agof)} = \text{Lo} - \text{Lf}$$

2. For the other intercropping ratios, the equations utilized were:

$$\text{Agfo} = \frac{\text{Yfo}}{\text{Yff} \times \text{Zfo}} - \frac{\text{Yof}}{\text{Yoo} \times \text{Zof}}$$

$$\text{Agof} = \frac{Yof}{Yoo \times Zof} - \frac{Yfo}{Yff \times Zfo}$$

Where: Yfo = intercrop yield of fennel, Yof = intercrop yield of onion, Yff = sole yield of fennel, Yoo = sole yield of onion, Zfo = planting proportion of fennel and Zof = planting proportion of onion.

Competitive ratio (CR)

It's another indicator to detect how competitive various species. The competitive ratio (CR) is a preferable indicator of a crop's competitive aptitude, and it may also be utilized to compare aggressivity (**Willey and Rao, 1980**). The competitive ratio marks the percentage of the two plants in which they are primarily seeded by calculating the ratio of relative yield of every crop. The following equation is utilized to calculate the CR:

$$\text{CR fennel} \times \text{onion} = \frac{Lf}{Lo} \times \left(\frac{Zof}{Zfo}\right)$$

$$\text{CR onion} \times \text{fennel} = \frac{Lo}{Lf} \times \left(\frac{Zfo}{Zof}\right)$$

Statistical Analysis

Data of the present study were statically determined and the various between the obtained means of the treatments were behold significant when they were extra than the least significant variations (L.S.D at the 5% level), by utilizing computer program of Statistix version 9 (**Analytical Software, 2008**).

RESULTS AND DISCUSSION

Yield Components of Fennel Component

Data recorded in Tables 3 and 4 reveal that, intercropping of fennel with different row ratios of onion significantly affect fruit and volatile oil yield components of fennel plants; highest umbel number per plant, fruit yield as well as volatile oil percentage and yield per plant were recorded at intercropping system than that of sole crop. In general, alternating one row or two rows of fennel by two rows of onion recorded the high values of these parameters compared to the other intercropping systems under study in both seasons. In this regard, the fresh and dry mass of umbels/plant, relative and absolute yield as well as essential oil content of fennel were improved under the intercrop with cowpea (**De Carvalho *et al*., 2014**). Also, fennel essential oil percentage and content were higher in all intercropping system than in solid planting (**Mohammadi and Rezaei-Chiyaneh, 2019**). The highest values of fruit and volatile oil yield per feddan (1267.6 and 1311.6 kg/feddan as well as 34.48 and 34.62 l/feddan) were recorded with sole crop in 1st and 2nd seasons, respectively. Moreover, increasing rows number of onion from one to two under one row or two rows of fennel significantly decreased fruit and volatile oil yield per feddan in the two tested seasons. **Yadav *et al*. (2017)** demonstrated that the highest seed yield was recorded significantly with fennel sole as compared to intercropping systems. In the same time, **Mohammed *et al*. (2021)** found that all intercropping patterns (1:2, 1:3 and 2:3 roselle: cluster bean row ratios) significantly reduced roselle sepals yield per feddan in comparison with sole crop.

In addition, using potassium fertilizer at 24 or 48 K_2O/ feddan levels significantly increased fennel umbel number per plant also fruit yield per plant and per feddan (Table 3) as well as volatile oil percentage and yield per plant and per feddan (Table 4) compared to control in both seasons. The highest values in yield components and volatile oil production were noticed with plot fertilized at 48 K_2O/feddan level compared to the lowest level under study in both seasons. Furthermore, the increases in fruit yield per plant were about 23.36 and 27.12% compared to control in 1st and 2nd seasons, respectively. Potassium is needful in young growing tissues for elongation of cell and probably for division of cell. It also helps in many physiological processes and improves quality and yield of spices (**Sadanandan *et al.*, 1993**). Furthermore, **Younis *et al*. (2010)** pointed out that fertilized fennel plants with 30 kg K_2O/feddan were effective on enhancing the yield of fruit yield and productivity of essential oil.

Regard the interaction effect between the two factors under study (intercropping system and potassium fertilization) proved that the highest values of number of umbels and fruit yield/ fennel plant were obtained when plants intercroped with onion at 1: 2 system combined with 48 kg K_2O/feddan (Table 3). Whenever, the highest values in fruit yield and volatile oil yield per feddan were recorded with the interaction treatment of sole crop fertilized with high level of potassium fertilization during both seasons (Tables 3 and 4). Generally, under each intercropping system increasing potassium fertilization levels gradually increased fruit yield components as well as volatile oil percentage and yield per plant and per feddan in the two seasons. Likewise, **Abdelkader *et al*. (2018)** reported that alternating 1 ridge of caraway with 2 ridges of onion combined with the highest rate of potassium (50 kg K_2O/feddan) significantly increased caraway fruits and volatile oil yield per plant compared to any combination treatments. These results also are in line with those stated by **Ahmed *et al*. (2020)** on maize–soybean intercropping system and fertilized with potassium at 60 kg ha^{-1}.

Yield Components of Onion Component

Data tabulated in Tables 5 and 6 show the influence of intercropping system, potassium fertilizer level and their interaction treatments on yield components of onion plant in both seasons. Sole onion planting had the highest values for each of yield grades 1, 2, 3 and 4, exportable yield, marketable and total bulbs yield which followed by 1: 2 intercropping system with significant differences with all intercropping systems under study in the two tested seasons. These decreasingly data may explicated as declared with that the highest onion plants population within large area unit (feddan) in sole onion as well as 1: 2 system could be recompensed the high of bulb average

Table 3. Effect of intercropping system, potassium fertilizer level and their combination treatments on yield components of fennel plant during the two seasons of 2019/2020 and 2020/2021

Treatments		Yield components					
		Number of umbels / plant		Fruit yield per plant (g)		Fruit yield per feddan (kg)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping systems (fennel: onion as row ratio)							
Sole fennel		51.63	54.06	28.52	29.51	1267.6	1311.6
1 : 1		68.57	71.87	35.86	38.97	796.8	866.0
1 : 2		71.49	74.69	38.27	42.70	561.3	626.3
2 : 1		67.76	70.74	36.91	40.45	1099.1	1204.4
2 : 2		68.08	66.82	38.44	41.27	854.3	917.1
LSD at 5 %		**1.21**	**0.82**	**0.49**	**0.55**	**8.98**	**13.82**
Potassium fertilization level (kg K_2O/ feddan)							
0.0		60.60	60.13	31.66	33.33	817.9	848.1
24		66.44	69.16	35.90	40.33	920.7	1029.0
48		69.47	73.62	39.25	42.08	1009.0	1078.1
LSD at 5 %		**0.76**	**0.56**	**0.27**	**0.46**	**8.61**	**11.73**
Intercropping	**K fertilizer levels**	**Intercropping systems × K fertilizer levels**					
	0.0	47.07	44.97	26.63	25.57	1183.7	1136.3
Sole fennel	**24**	51.53	53.33	28.03	30.20	1245.9	1342.2
	48	56.30	63.87	30.90	32.77	1373.4	1456.3
	0.0	61.53	60.53	31.17	31.43	692.6	698.5
1 : 1	**24**	69.77	76.20	36.10	41.83	802.2	929.7
	48	74.40	78.87	40.30	43.63	895.6	969.7
	0.0	64.53	66.43	34.47	38.53	505.5	565.2
1 : 2	**24**	73.87	77.77	38.40	44.03	563.2	645.8
	48	76.07	79.87	41.93	45.53	615.0	667.8
	0.0	65.43	67.83	31.83	34.50	947.9	1027.3
2 : 1	**24**	67.30	70.97	37.33	43.04	1111.7	1281.7
	48	70.53	73.43	41.57	43.80	1237.8	1304.2
	0.0	64.43	60.87	34.18	36.60	759.5	813.3
2 : 2	**24**	69.73	67.53	39.61	42.54	880.3	945.3
	48	70.07	72.07	41.55	44.67	923.3	992.7
LSD at 5 %		**1.84**	**1.31**	**0.69**	**1.00**	**18.09**	**25.46**

Table 4. Effect of intercropping system, potassium fertilizer level and their combination treatments on volatile oil production of fennel plant during the two seasons of 2019/2020 and 2020/2021

Treatments		Volatile oil production					
		Volatile oil percentage		Volatile oil yield per plant (ml)		Volatile oil yield per feddan (l)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping systems (fennel: onion as row ratio)							
Sole fennel		2.71	2.62	0.78	0.78	34.48	34.62
1 : 1		2.88	2.81	1.03	1.11	22.94	24.57
1 : 2		2.93	2.96	1.13	1.27	16.50	18.58
2 : 1		2.87	2.99	1.06	1.21	31.60	36.11
2 : 2		3.02	2.96	1.17	1.22	25.95	27.19
LSD at 5 %		**0.07**	**0.12**	**0.03**	**0.04**	**0.60**	**1.15**
Potassium fertilization level (kg K_2O/ feddan)							
0.0		2.75	2.68	0.87	0.90	22.19	22.63
24		2.90	2.87	1.04	1.16	26.61	29.43
48		3.00	3.05	1.18	1.29	30.10	32.58
LSD at 5 %		**0.05**	**0.06**	**0.02**	**0.03**	**0.60**	**0.79**
Intercropping	**K fertilizer levels**	**Intercropping systems × K fertilizer levels**					
	0.0	2.50	2.40	0.67	0.61	29.59	27.30
Sole fennel	**24**	2.77	2.67	0.78	0.81	34.48	35.77
	48	2.87	2.80	0.89	0.92	39.37	40.78
	0.0	2.83	2.57	0.88	0.81	19.62	17.93
1 : 1	**24**	2.93	2.80	1.06	1.17	23.53	26.04
	48	2.87	3.07	1.16	1.34	25.67	29.74
	0.0	2.87	2.73	0.99	1.05	14.49	15.45
1 : 2	**24**	2.87	3.00	1.10	1.32	16.15	19.38
	48	3.07	3.13	1.29	1.43	18.86	20.92
	0.0	2.77	2.87	0.88	0.99	26.22	29.45
2 : 1	**24**	2.87	3.03	1.07	1.31	31.87	38.88
	48	2.97	3.07	1.23	1.34	36.72	40.00
	0.0	2.77	2.83	0.94	1.04	21.01	23.04
2 : 2	**24**	3.07	2.87	1.21	1.22	27.00	27.10
	48	3.23	3.17	1.34	1.42	29.85	31.44
LSD at 5 %		**0.11**	**0.17**	**0.05**	**0.08**	**1.25**	**1.85**

Table 5. Effect of intercropping system, potassium fertilizer level and their combination treatments on yield grades (ton/feddan) of onion plant during the two seasons of 2019/2020 and 2020/2021

Treatments		Yield grades (ton/feddan)							
		Grade 1		Grade 2		Grade 3		Grade 4	
		Seasons		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Intercropping systems (fennel: onion as row ratio)									
Sole onion		4.18	3.96	1.81	1.78	0.39	0.41	0.19	0.19
1 : 1		2.41	2.40	1.02	0.98	0.23	0.23	0.07	0.07
1 : 2		3.47	3.33	1.37	1.44	0.35	0.29	0.12	0.12
2 : 1		1.90	1.88	0.52	0.69	0.29	0.21	0.07	0.08
2 : 2		2.89	2.67	1.06	1.07	0.32	0.27	0.09	0.13
LSD at 5 %		**0.05**	**0.04**	**0..02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Potassium fertilization level (kg K_2O/ feddan)									
0.0		2.72	2.64	1.08	1.09	0.30	0.27	0.10	0.11
24		3.08	2.91	1.18	1.24	0.31	0.29	0.11	0.12
48		3.11	3.00	1.20	1.24	0.34	0.29	0.11	0.13
LSD at 5 %		**0.03**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Intercropping	**K fertilizer levels**	**Intercropping systems × K fertilizer levels**							
	0.0	4.03	3.73	1.73	1.68	0.37	0.38	0.19	0.17
Sole onion	**24**	4.19	3.94	1.83	1.77	0.39	0.43	0.19	0.20
	48	4.32	4.22	1.86	1.87	0.40	0.41	0.19	0,19
	0.0	2.11	2.25	0.93	0.82	0.22	0.22	0.07	0.06
1 : 1	**24**	2.54	2.46	1.04	1.09	0.23	0.24	0.07	0.07
	48	2.58	2.51	1.09	1.03	0.25	0.23	0.06	0.08
	0.0	3.12	3.00	1.31	1.40	0.31	0.27	0.11	0.12
1 : 2	**24**	3.60	3.44	1.34	1.42	0.34	0.31	0.11	0.12
	48	3.69	3.54	1.45	1.49	0.39	0.29	0.12	0.13
	0.0	1.71	1.76	0.46	0.62	0.28	0.22	0.05	0.05
2 : 1	**24**	1.99	1.93	0.56	0.75	0.29	0.21	0.08	0.09
	48	2.01	1.96	0.52	0.71	0.30	0.20	0.07	0.10
	0.0	2.62	2.45	0.97	0.94	0.31	0.24	0.09	0.13
2 : 2	**24**	3.09	2.78	1.13	1.15	0.31	0.27	0.08	0.13
	48	2.96	2.77	1.08	1.10	0.34	0.31	0.10	0.15
LSD at 5 %		**0.07**	**0.05**	**0.03**	**0.03**	**0.02**	**0.02**	**0.02**	**0.02**

Table 6. Effect of intercropping system, potassium fertilizer level and their combination treatments on yield components (ton/feddan) of onion plant during the two seasons of 2019/2020 and 2020/2021

Treatments		Yield components (ton/feddan)					
		Exportable yield (grade 1 + grade 2)		Marketable yield (grade 1 + grade 2 + grade 3)		Total yield (grade 1 + grade 2 + grade 3 + grade 4)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping systems (fennel: onion as row ratio)							
Sole onion		5.988	5.739	6.375	6.147	6.567	6.334
1 : 1		3.866	3.562	3.659	3.611	3.726	3.678
1 : 2		4.836	4.763	5.182	5.050	5.299	5.170
2 : 1		2.417	2.577	2.703	2.787	2.770	2.868
2 : 2		3.950	3.730	4.271	4.001	4.359	4.136
LSD at 5 %		**0.053**	**0.049**	**0.058**	**0.040**	**0.059**	**0.038**
Potassium fertilization level (kg K_2O/ feddan)							
0.0		4.063	3.728	4.096	3.995	4.199	4.101
24		4.260	4.156	4.569	4.435	4.676	4.556
48		4.311	4.338	4.649	4.527	4.758	4.654
LSD at 5 %		**0.033**	**0.026**	**0.036**	**0.025**	**0.037**	**0.025**
Intercropping	**K fertilizer levels**	**Intercropping systems × K fertilizer levels**					
	0.0	5.763	5.408	6.133	5.788	6.326	5.962
Sole onion	**24**	6.020	5.718	6.408	6.144	6.599	6.347
	48	6.180	6.094	6.583	6.507	6.770	6.692
	0.0	4.358	3.071	3.257	3.290	3.325	3.350
1 : 1	**24**	3.578	3.592	3.805	3.781	3.877	3.847
	48	3.662	4.023	3.915	3.761	3.976	3.838
	0.0	4.431	4.393	4.741	4.665	4.854	4.783
1 : 2	**24**	4.941	4.860	5.277	5.165	5.391	5.281
	48	5.136	5.034	5.529	5.319	5.652	5.445
	0.0	2.170	2.379	2.447	2.600	2.500	2.654
2 : 1	**24**	2.549	2.682	2.835	2.891	2.912	2.977
	48	2.531	2.669	2.828	2.870	2.898	2.973
	0.0	3.590	3.389	3.903	3.631	3.990	3.758
2 : 2	**24**	4.214	3.931	4.521	4.196	4.601	4.326
	48	4.047	3.868	4.390	4.177	4.486	4.323
LSD at 5 %		**0.080**	**0.069**	**0.087**	**0.061**	**0.090**	**0.059**

weight in this regard compared with other intercropping systems under study. In this concern, **Abdelkader and Mohsen (2016)** indicated that solid planting of onion recorded the highest bulb yield per feddan when onion intercropped with coriander or fennel crops. **Moghbeli *et al*. (2019)** suggested that the highest onion total bulb yield was obtained with intercropped with fenugreek plants and sown at 30 plant m^{-2} density.

As for yield components of onion bulbs Tables 5 and 6 cleared that, in most cases, 48 kg K_2O/feddan gave the highest values of yield grades 1, 2, 3 and 4, exportable yield, marketable and total bulbs yield with significant difference between this treatment and the lowest level in both seasons. Habitually, the two levels under study increased onion yield components compared to control in both seasons. Generally, increasing potassium fertilizer levels from 24 to 48 kg /feddan gradually increased exportable yield, marketable and total bulbs yield of onion crop. Potassium (K) is also considered as a quality element as it improves yield parameters of numerous crops including onion (**Nasreen and Hossain, 2000**). In this connection, **Aftab *et al*. (2017)** that highest yield was achieved in plots fertilized with potassium at the level of 120 kg ha^{-1}, While, the lowest onion yield was recorded with control. **Marrocos *et al*. (2018)** revealed that potassium fertilization enhanced a raise in commercial and total bulb yield of onion, with the maximum obtained in the level of 180 kg ha^{-1} of K_2O.

Results illustrated in Tables 5 and 6 show that, the highest yields of exportable yield, marketable and total bulbs yield of onion were recorded when the sole onion was fertilized with high potassium fertilization level compared with the other interaction treatments under study in both seasons. Also, increasing potassium fertilizer level under intercropping systems (2: 1 and 2: 2) significantly reduced total bulb yield of onion per feddan. Moreover, **Abdelkader *et al*. (2018)** pointed out that alternating 1 row of caraway with 2 rows of onion combined with 50 kg K_2O/feddan was significantly increased onion yield components than any combinations in the two seasons. Also, **Abd-Elsamed *et al*. (2020)** suggested that level of 75 kg of potassium fertilization/feddan enhanced maize yield when intercropped with soybean plants. In addition, the sole planting of *Dracocephalum moldavica* as well as *Vigna radiata* fertilized with NPK gave the highest seed yields for both components compared to intercropping pattern between them (**Faridvand *et al*., 2021**).

Competitive Indices between Fennel and Onion

Data presented in Tables 7 reveal the effect of intercropping system, potassium fertilizer level and their interaction treatments on competitive indices (LER, ATER and LUE%) which related with relative fruits yield of fennel per feddan and relative bulb yield of onion per feddan in both seasons. The LER, ATER, LUE% values revealed that 33.7 and 37.1, 27.0 and 27.9 as well as 30.32 and 32.52 % more land would require to cultivated the sole crops to give the same quantities of intercropped yield of fennel and onion recorded by utilizing 2: 2 and 1:2 intercropping systems during 1st and 2nd seasons, respectively. In addition, all intercropping systems (1: 1, 1: 2, 2: 1 and 2: 2) produced higher competitive indices than sole planting (>1) which suggested the intercropping superiority over sole planting system of the two components. From aggressivity indice, the two crops had the same numerical value by + for the dominant crop and - for the dominated one (Table 8). Furthermore, there was a positive sign for fennel and a negative sign for onion, indicating that fennel was dominant while onion was dominated one in both seasons. However, in all intercropping systems under study the values of competitive ratio for fennel were greater than for onion showing the dominance of fennel. In addition, **Boori (2014)** in fennel intercropped with fenugreek, **Mehta *et al*. (2015)** in fennel intercropped with onion, garlic or carrot and **Yadav *et al*. (2017)** in fennel intercropped with carrot, cabbage, cauliflower or cauliflower had reported similar results.

The highest values (1.310 and 1.356, 1.242 and 1.285 and 127.59 and 132.04 %) of competitive indices (LER, ATER and LUE%) were observed when fennel and onion fertilized with potassium at 24 kg K_2O/feddan, respectivily, in the two seasons (Table 7). In most cases, all potassium fertilization levels produced higher competitive indices compared to control (without potassium fertilization) in both seasons. It is known that an aggressivity value of zero shows that the component plants are equally competitive. For any other values, two crops will have the same numerical value by positive for the dominant crop and negative for the dominated one as presented in Table 8. Fennel had higher competitive ratios in all potassium fertilization,

Table 7. Effect of intercropping system, potassium fertilizer level and their combination treatments on LER, ATER and LUE% between fennel and onion during the two seasons of 2019/2020- 2020/2021

Treatments		Some competitive indices					
		Land equivalent ratio (LER)		Area time equivalent ratio (ATER)		Land utilization efficiency (LUE%)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping systems (fennel: onion as row ratio)							
1 : 1		1.194	1.238	1.131	1.173	116.27	120.55
1 : 2		1.249	1.295	1.204	1.247	122.64	127.12
2 : 1		1.286	1.371	1.200	1.279	124.31	132.52
2 : 2		1.337	1.353	1.270	1.283	130.32	131.83
LSD at 5 %		**0.009**	**0.012**	**0.009**	**0.011**	**0.910**	**1.175**
Potassium fertilization level (kg K_2O/ feddan)							
0.0		1.193	1.293	1.132	1.225	116.27	125.87
24		1.310	1.356	1.242	1.285	127.59	132.04
48		1.296	1.295	1.229	1.227	126.27	126.10
LSD at 5 %		**0.013**	**0.019**	**0.012**	**0.017**	**1.266**	**1.800**
Intercropping	**K fertilizer levels**	**Intercropping systems × K fertilizer levels**					
	0.0	1.111	1.177	1.052	1.115	108.15	114.60
1 : 1	**24**	1.232	1.299	1.167	1.230	119.94	126.46
	48	1.239	1.239	1.174	1.173	120.64	120.60
	0.0	1.194	1.300	1.152	1.250	117.30	127.47
1 : 2	**24**	1.269	1.314	1.224	1.265	124.65	128.95
	48	1.282	1.272	1.237	1.226	125.97	124.93
	0.0	1.196	1.349	1.116	1.259	115.60	130.39
2 : 1	**24**	1.334	1.424	1.245	1.329	128.91	137.67
	48	1.329	1.340	1.239	1.250	128.40	129.50
	0.0	1.272	1.346	1.208	1.275	124.03	131.03
2 : 2	**24**	1.404	1.386	1.333	1.316	136.86	135.10
	48	1.334	1.328	1.267	1.260	130.08	129.36
LSD at 5 %		**0.023**	**0.033**	**0.022**	**0.030**	**2.256**	**3.162**

Table 8. Effect of intercropping system, potassium fertilizer level and their combination treatments on aggressivity values and competitive ratio between fennel and onion during the two seasons of 2019/2020 and 2020/2021

Treatments		Some competitive indices							
		Aggressivity values (Ag)				Competitive ratio (CR)			
		For fennel (Ag_{fo})		For onion (Ag_{of})		For fennel (CRf)		For onion (CRo)	
		Seasons		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Intercropping systems (fennel: onion as row ratio)									
1 : 1		+0.06	+0.08	- 0.06	- 0.08	1.11	1.13	0.90	0.88
1 : 2		+0.12	+0.21	- 0.12	- 0.21	1.10	1.17	0.91	0.85
2 : 1		+0.03	+0.02	- 0.03	- 0.02	1.03	1.01	0.98	0.99
2 : 2		+0.01	+0.05	- 0.01	- 0.05	1.02	1.07	0.98	0.93
LSD at 5 %		**0.023**	**0.015**	**0.023**	**0.015**	**0.030**	**0.022**	**0.025**	**0.017**
Potassium fertilization level (kg K_2O/ feddan)									
0.0		+0.05	+0.11	- 0.05	- 0.11	1.06	1.12	0.94	0.90
24		+0.05	+0.08	- 0.05	- 0.08	1.06	1.09	0.95	0.92
48		+0.06	+0.07	- 0.06	- 0.07	1.06	1.09	0.94	0.92
LSD at 5 %		**N.S.**	**0.021**	**N.S.**	**0.021**	**N.S.**	**0.022**	**N.S.**	**0.017**
Intercropping	**K fertilizer levels**	**Intercropping systems × K fertilizer levels**							
	0.0	+0.06	+0.05	- 0.06	- 0.05	1.11	1.09	0.90	0.91
1 : 1	**24**	+0.06	+0.09	- 0.06	- 0.09	1.10	1.14	0.91	0.88
	48	+0.07	+0.09	- 0.07	- 0.09	1.11	1.16	0.90	0.86
	0.0	+0.13	+0.29	- 0.13	- 0.29	1.11	1.24	0.90	0.81
1 : 2	**24**	+0.13	+0.20	- 0.13	- 0.20	1.11	1.16	0.90	0.86
	48	+0.09	+0.16	- 0.09	- 0.16	1.07	1.13	0.93	0.89
	0.0	+0.02	+0.02	- 0.02	- 0.02	1.01	1.02	0.99	0.99
2 : 1	**24**	+0.01	+0.03	- 0.01	- 0.03	1.01	1.02	0.99	0.98
	48	+0.07	+0.01	- 0.07	- 0.01	1.05	1.01	0.95	0.99
	0.0	+0.01	+0.09	- 0.01	- 0.09	1.02	1.14	0.98	0.88
2 : 2	**24**	+0.01	+0.02	- 0.01	- 0.02	1.01	1.03	0.99	0.97
	48	+0.01	+0.04	- 0.01	- 0.04	1.02	1.06	0.98	0.95
LSD at 5 %		**0.039**	**0.037**	**0.039**	**0.037**	**0.043**	**0.041**	**0.035**	**0.033**

indicating that fennel plants was more competitive (CR fennel > one) than onion (CR onion < one). **Abdelkader *et al*. (2018)** found that the highest potassium fertilization rate (50 kg K_2O/fed.) significantly increased all competitive indices (LER, ATER and LUE %) between caraway and onion in intercropping systems.

Concerning the interaction treatments, all interaction between intercropping system and potassium fertilizer level gave higher LER, ATER and LUE% values were more than one unit in both seasons (Table 7). Also, the highest values (1.404 and 1.424, 1.333 and 1.329 as well as 136.86 and 137.67%) in these indices was the interaction between 2: 2 or 1: 2 intercropping system with 24 kg K_2O/fed., of potassium fertilization rate in 1^{st} and 2^{nd} seasons, respectively. In general, under all interaction treatments, fennel crop had a positive sign and onion crop had a negative, indicating that fennel was dominant whilst onion was dominated (Table 8). In the same line, competitive ratio was greater than one with fennel while it was lower one in onion, clearing the fennel was more competitive than onion under all interaction treatments during the two consecutive seasons. In addition, **Gendy *et al*. (2018)** demonstrated that competitive ratio, indicating that black cumin was more competitive (CR > one) than fenugreek (CR < one) in all intercropping systems with fenugreek under NPK fertilization. Also, **Ahmed *et al*. (2020)** reported that potassium application levels in developing a potential soybean/maize intercropping systems for obtaining higher productivity as well as LER.

Conclusion

Cultivated fennel and onion crops with each other led to yield improvement under potassium fertilization application. Competitive indices between fennel and onion in all intercropping systems were > 1 and the highest value was obtained in 2: 2 or 1: 2 systems fertilized with 24 kg K_2O/feddan. Generally, this work reveals that fennel intercropped with onion, especially at these cropping systems with moderate potassium fertilization could be applied under Sharkia Governorate condition.

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استخدام نظم التحميل للحصول على محصول عالي ومؤشرات تنافس جيدة من الشمر والبصل تحت مستويات مختلفة من السماد البوتاسي

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استخدمت نظم تحميل مختلفة (المحصول المنفرد لكل مكون، 1:1 ، 1: 2، 2: 1 و 2: 2 من الشمر: البصل، على الترتيب) تحت مستويات مختلفة من السماد البوتاسي (صفر، 24 و 48 كجم بو$_2$أ/فدان) للحصول على أعلى مكونات محصولية وأفضل مؤشرات تنافس للشمر والبصل. أجريت تجربة حقلية في المزرعة التجريبية (مزرعة غزالة) كلية الزراعة، جامعة الزقازيق، مصر خلال الموسمين المتتاليين لعامي 2020/2019 و 2021/2020. أظهرت النتائج المحققة أن نظم التحميل أدت إلى نقص معنوي في محصول الثمار أو الأبصال /فدان من الشمر والبصل، على التوالي، مقارنة بالزراعة المنفردة لكل منهما. من خلال البيانات المتحصل عليها لوحظ أن معدلي 24 و48 كجم بو$_2$أ/فدان من مستويات البوتاسيوم أعطت زيادة معنوية في المكونات المحصولية لكل من الشمر أو البصل. علاوة على ذلك، أشارت قيم العدوانية ونسبة التنافس إلى أن الشمر كان المكون السائد، بينما كان البصل هو المكون المسود علية في نظم التحميل المختلفة. تم الحصول على أعلى القيم للنسبة المئوية لكفاءة استخدام الأرض (128.91 و 137.67 وكذلك 136.86 و135.10) عند زراعة الشمر مع البصل تحت نظامي التحميل 2: 1 وكذلك 2: 2 مع التسميد البوتاسي بمستوى 24 بو$_2$أ/ فدان في الموسمين الأول والثاني، على التوالى. لذلك، أدي استخدام نظم التحميل 2: 1 و 2: 2 إلى إعطاء ميزة محصولية مقارنة بالزراعة المنفردة على مستوى وحدة المساحة كما يتضح من أعلى نسبة مكافئ أرضي، ونسبة مكافئ الأرض لوحدة الزمن والنسبة المئوية لكفاءة استخدام الأرض.

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