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EVALUATION OF YIELD COMPONENTS AND SOME COMPETITIVE INDICES BETWEEN CARAWAY AND ONION PLANTS AS AFFECTED BY INTERCROPPING SYSTEM UNDER DIFFERENT POTASSIUM FERTILIZER RATES

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ABSTRACT: A two-years (2016/2017 and 2017/2018) field experiments were carried out at Experimental Farm, Agriculture Faculty, Zagazig University, Egypt to evaluate yield components, potassium content and some competitive indices between caraway and onion at different ridge ratios (sole crop of each components, 1:1, 1:2 and 2:2 of caraway: onion, respectively) under different potassium fertilization rates (0.0, 25 and 50 kg K_2O/fad. A split-plot experiment based on randomized complete block design with three replications was planned. Results indicated that yield components (different grades of yield and exportable, marketable and total yield of onion as well as umbel number/plant, fruit and oil yield/plant and/faddan of caraway), potassium content/plant of each crop and competitive indices between them were affected by experimental factors. In most cases, onion sole crop recorded the highest values in yield components compared to intercropping systems under all potassium fertilization rates. In the same trend, the highest value in each of fruit and volatile oil yield /faddan of caraway was recorded with sole caraway crop. Also, the highest rate of potassium recorded significant increase in these parameters compared to control. Competition indices, *i.e.,* land equivalent ratio (LER), area time equivalent ratio (ATER), land utilization efficiency (LUE%) and relative crowding coefficient (RCC) revealed that, applied intercropping system (1:2) was more efficient than sole cropping and other ones under study when combined with potassium fertilization rate at 50 kg K_2O/faddan, in most cases. Aggressivity (A) estimation indicated that caraway was dominant while onion was dominated. Generally, this mixture seems promising in the development of sustainable crop yield advantages with a limited use of external inputs under Sharkia Governorate conditions.

Key words: Onion, caraway, intercropping system, potassium, yield, LER, ATER, LUE, RCC, aggressivity

INTRODUCTION

Crops diversification with intercropping can give higher yield than sole planting (**Mandal *et al.*, 1986**). Thus selecting compatible combination of components is necessary for increasing utilization of gridgeth resources, *viz.*, solar energy and water unit area per unit time that will also keep the soil in good physical condition with improvement in yield components. Hence, choice of the different crops in intercropping systems needs to be suitably maneuvered to harvest the synergism among them towards efficient utilization of resource base and to maximizing overall productivity (**Mucheru-Muna *et al.*, 2010**). The main concept of intercropping system is to get increased total yield and productivity per unit area and time. Various indices have been developed to indicate the competition and possible advantage in intercropping (**Ghosh, 2004; Alizadeh *et al.*, 2010**).

Potassium (K) in enzyme activation, plays a role to aid substrate binding by lowering energy barriers in the ground and/or transition states rather than being the agents of causing catalysis

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(**Page and Di Cera, 2006**). Minerals such as potassium (K) may affect the gridgeth and essential oil synthesis in aromatic plants and are used by plants to build many processes. This mineral affects the function and levels of enzymes involved in the terpenoides biosynthesis (**Hafsi *et al.,* 2014**).

Over the past 15 years, the total surface area dedicated to the onion crop in the world has doubled reaching its present figure of 2.74 million ha. (**Pelter *et al.*, 1992; FAO, 2002**). In addition, **Shedeed *et al.* (2015)** reported that, 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. Onion contemplated a high monetary value crop for Egyptian farmers. However, Egyptian dry, fresh and processed onions are demanded by the international market.

Caraway (*Carum carvi*, L.) plants is a perennial plant, belongs to family Apiaceae, many species of this family usually used in dried state or as fresh herb, as a house hold remedies or as medicinal ingredients. Caraway fruits, commonly called seeds, contain volatile oil, with many terpenoid components **(Kocourkova *et al*., 1999)**. Caraway is considered a feed stuff that increases milk production, improves taste and digestibility and reduces flatulence of cattle. Caraway volatile oil is used as a natural inhibitor of sprouting, mainly in stored potatoes (**Kleinkopf *et al*., 2003)**. It has also antiseptic, pain sedative, antispasmodic, depletive and antioxidant properties **(Sembratowicz and Czech, 2005; Dyduch *et al*., 2006)**.

The most important aim of this study is maximizing onion and caraway plants productivity by using different intercropping systems combined with potassium fertilization rate represented as potassium sulphate under Sharkia Governorate conditions.

MATERIALS AND METHODS

The present work was conducted at the Experimental Farm (Ghazala), Fac. Agric. Zagazig Univ., Egypt, during two consecutive seasons of 2016/2017 and 2017/2018. Intercropping systems (caraway: onion at different ridge ratios; 1:1, 1:2 and 2 : 2 in comparison with sole crop of each specie), different potassium fertilization rate (0.0, 25 and 50 kg K_2O/fad.) and their combinations were used to evaluated yield components, potassium content/plant and some competitive indices of caraway and onion. These treatments were arranged in a split-plot in randomized complete blocks design with 3 replicates. Intercropping systems were randomly arranged in the main plots and potassium fertilization rates were distributed randomly in the sub plots. The physical and chemical properties of the experimental soil site are shown in Table 1, according to **Chapman and Pratt (1978)**.

Onion transplants (cv. Giza 6) of nearly 40 days old were transplanted on 18^{th} and 22^{th} October in first and second seasons, respectively, and fruits of caraway component were sown in the same time. Onion was transplanted at space of 10 cm between hills, on the two sides of the ridge, but fruits of caraway were sown at space of 30 cm in one side of the ridge just after irrigation. After three weeks from planting, germinated plants were thinned to two plants/hill for caraway plant. Experimental plot was 21.6 m^2 (3 × 7.20 m) included 12 ridges; each ridge was 60 cm apart and 3 m in length.

All plants received normal agricultural practices whenever they needed. All plants were fertilized with nitrogen and phosphorus fertilization at the rate of 200 kg/fad., of ammonium sulphate (20.5%N) and 200 kg/fad., of calcium super phosphate (15.5% P_2O_5). Phosphorus fertilizer was added during soil preparation as a soil dressing application. While, nitrogen and potassium fertilizers were divided into three equal portions and were added to the soil after 30, 55 and 80 days from transplanting and sowing.

Data Recorded

Yield and its components

At maturity, onion plants (150 days after transplanting) 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

Table 1: Physical and chemical properties of experimental soil

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Clay
56.36	9.26	17.62	16.76	

Chemical analysis											
pH	E C m.mohs/cm	Organic mater (%)	Soluble cations (meq./L)			Soluble anions (meq./L)			Available (ppm)		
			Mg^{++}	Ca^{++}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.82	0.98	0.58	2.7	1.6	4.1	4.5	1.7	3.5	18	20	71

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). For caraway plant (130 days after sowing), umbel number/plant and fruit yield per plant (g) were determined, then total fruit yield per faddan (kg) was calculated. The essential oil from air-dried fruits of caraway plants was isolated by hydro distillation for 3 hr., in order to extract the essential oils according to **Guenther (1961)** and the volatile oil yield per plant and per faddan was calculated.

Potassium content per plant (g)

Samples of dry bulbs of onion and caraway fruits were randomly taken from each treatment for these propose. Furthermore, potassium percentage was determined by using flame photometer according to the method described by **Bridgen and Lilleland (1946)** and K content per plant was calculated.

Competitive Indices

Land equivalent ratio (LER)

This parameter was determined for onion and caraway yield recorded per faddan according to **Mead and Willey (1980)** equation as follows:

LER = Lc + Lo,

$$\text{Lcaraway (Lc)} = \frac{Yco}{Ycc}$$

$$\text{Lonion (Lo)} = \frac{Yoc}{Yoo}$$

Where Lc and Lo are the relative yield of caraway and onion, respectively, as well as Ycc and Yoo are the yields per faddan of caraway and onion, respectively, as sole crops and Yco and Yoc are the yields of caraway and onion, respectively, as intercrop yields of each components.

Area time equivalent ratio (ATER)

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

$$\text{ATER} = \frac{Yco/Ycc \times tc + Yoc/Yoo \times to}{T}$$

Where: Yco = intercropped yield of caraway, Ycc = sole yield of caraway, Yoc = intercropped yield of onion, Yoo = sole yield of onion, tc = the duration of caraway in days, to= the duration of onion in days and T= the total duration of intercropping system in days.

Land utilization efficiency (LUE%)

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

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

Relative crowding coefficient (RCC)

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

K = (K caraway × K onion),

$$K_{onion \times caraway} = \frac{Yoc \times Zco}{(Yoo - Yoc)\, Zoc}$$ and

$$K_{caraway \times onion} = \frac{Yco \times Zoc}{(Ycc - Yco)\, Zco}$$

Where Zco is the planting proportion of caraway intercropped with onion and Zoc is the planting proportion of onion intercropped with caraway. When the product of the two coefficients (K caraway × K onion) 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 crops. The CR gives a better measure of competitive ability of the species and is also advantageous as an index over K and aggressivity (**Willey and Rao, 1980**). The CR is calculated according to the following formula:

$$CR_{caraway \times onion} = \frac{LER_{caraway}}{LER_{onion}} \left(\frac{Zoc}{Zco}\right)$$ and

$$CR_{onion \times caraway} = \frac{LER_{onion}}{LER_{caraway}} \left(\frac{Zco}{Zoc}\right)$$

Aggrissivity (A)

Mc Gilchrist (1965) equation was used to calculate aggrissivity value as follows:

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

$$Aco = Lc - Lo$$ and $$Aoc = Lo - Lc$$

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

$$Aco = \frac{Yco}{Ycc \times Zco} - \frac{Yoc}{Yoo \times Zoc}$$ and

$$Aoc = \frac{Yoc}{Yoo \times Zoc} - \frac{Yco}{Ycc \times Zco}$$

Where: Yco = intercropped yield of caraway, Yoc = yield of onion intercropped with caraway, Ycc = sole yield of caraway, Yoo = sole yield of onion, Zco = sowing proportion of caraway. Zoc = sowing proportion of onion.

Statistical Analysis

The statistical layout of this experiment was split-plot experiment in completely randomized block design. Where, intercropping systems were randomly distributed in the main plots, while bio-potassium rates were randomly arranged in sub-plots. Each treatment was included three replicates. Data were analyzed according to **Gomez and Gomez (1984)**. The means were compared using computer program of Statistix version 9 (**Analytical software, 2008**).

RESULTS AND DISCUSSION

Yield Components and Potassium Content of Onion

Effect of intercropping systems:

Results exhibited in Tables 2 and 3 reveal the effect of intercropping systems, potassium fertilization rate and their combinations on yield components and potassium content per bulb (g) in the two seasons (2016/2017 and 2017/2018). Sole onion crop had the highest value for each of yield grade 1 and 2, exportable yield, marketable and total yield with significant differences with all intercropping systems under study during both seasons. These paradoxical results may interpreted in the light of that the highest population of onion plants within area unit (faddan) in sole onion could be compensated the high of average bulb weight in this treatment compared with intercropping system treatments.

Abdelkader and Mohsen (2016) found that pure stand of onion gave the highest yield per faddan when onion intercropped with fennel and coriander plants. Moreover, alternating two ridges of caraway with two ridges of onion treatment (2:2 system) recorded significant increase in potassium content per plant compared with the other ones under study. These results are in harmony with those reported by **Singh *et al.* (2002)** on intercropped mint species within sugarcane.

Table 2. Effect of intercropping system and potassium rate and their combinations on different grades of onion yield (ton/fad.) during 2016/2017 and 2017/2018 seasons

Intercropping system (caraway: onion) (I)	Potassium rate (kg K_2O/faddan) (K)							
	0.0	25	50	Mean (I)	0.0	25	50	Mean (I)
	2016/2017 season				2017/2018 season			
				Yield of grade 1				
Sole onion	3.526	3.806	3.967	3.766	3.491	3.708	3.967	3.722
1 ridge: 1 ridge	1.488	1.534	1.578	1.533	1.536	1.571	1.645	1.584
1 ridge: 2 ridges	2.268	2.349	2.581	2.400	2.292	2.437	2.599	2.443
2 ridges: 2 ridges	1.532	1.563	1.621	1.572	1.536	1.563	1.628	1.576
Mean (K)	2.204	2.313	2.437		2.214	2.320	2.460	
LSD at 5%	(I) = 0.038	(K) = 0.033	(I×K) = 0.065		(I) = 0.028	(K) = 0.033	(I×K) = 0.061	
				Yield of grade 2				
Sole onion	1.822	1.953	2.082	1.953	1.911	1.978	2.125	2.005
1 ridge: 1 ridge	1.324	1.381	1.423	1.376	1.323	1.404	1.433	1.387
1 ridge: 2 ridges	1.571	1.710	1.851	1.711	1.621	1.735	1.837	1.731
2 ridges: 2 ridges	0.991	1.050	1.116	1.052	0.976	1.017	1.119	1.038
Mean (K)	1.427	1.523	1.618		1.458	1.534	1.629	
LSD at 5%	(I) = 0.023	(K) = 0.035	(I×K) = 0.061		(I) = 0.039	(K) = 0.014	(I×K) = 0.045	
				Yield of grade 3				
Sole onion	0.210	0.269	0.280	0.253	0.202	0.274	0.286	0.254
1 ridge: 1 ridge	0.432	0.386	0.296	0.371	0.387	0.434	0.441	0.420
1 ridge: 2 ridges	0.208	0.259	0.213	0.226	0.182	0.274	0.212	0.222
2 ridges: 2 ridges	0.250	0.176	0.147	0.191	0.138	0.176	0.221	0.178
Mean (K)	0.275	0.272	0.234		0.227	0.289	0.290	
LSD at 5%	(I) = 0.017	(K) = 0.016	(I×K) = 0.031		(I) = 0.024	(K) = 0.036	(I×K) = 0.063	
				Yield of grade 4				
Sole onion	0.180	0.168	0.181	0.176	0.175	0.159	0.173	0.169
1 ridge: 1 ridge	0.057	0.074	0.072	0.068	0.091	0.062	0.024	0.059
1 ridge: 2 ridges	0.056	0.065	0.086	0.069	0.079	0.063	0.070	0.070
2 ridges: 2 ridges	0.195	0.205	0.178	0.193	0.249	0.211	0.202	0.220
Mean (K)	0.122	0.128	0.129		0.148	0.123	0.117	
LSD at 5%	(I) = 0.006	(K) = 0.009	(I×K) = 0.016		(I) = 0.005	(K) = 0.006	(I×K) = 0.011	

Table 3. Effect of intercropping system and potassium rate and their combination on yield components (ton/fad.) and K content/bulb (g) of onion during 2016/2017 and 2017/2018 seasons

Intercropping system (caraway: onion) (I)	Potassium rate (kg K_2O/faddan) (K)							
	0.0	25	50	Mean (I)	0.0	25	50	Mean (I)
	2016/2017 season				2017/2018 season			
	Exportable yield (grade 1 + grade 2)							
Sole onion	5.348	5.759	6.049	5.719	5.401	5.686	6.092	5.726
1 ridge: 1 ridge	2.813	2.915	3.001	2.910	2.859	2.975	3.078	2.971
1 ridge: 2 ridges	3.840	4.059	4.432	4.110	3.913	4.172	4.436	4.174
2 ridges: 2 ridges	2.523	2.613	2.737	2.624	2.513	2.581	2.748	2.614
Mean (K)	3.631	3.837	4.055		3.671	3.854	4.089	
LSD at 5%	(I) = 0.027	(K) = 0.048	(I×K) = 0.083		(I) = 0.032	(K) = 0.036	(I×K) = 0.068	
	Marketable yield (grade 1 + grade 2+ grade 3)							
Sole onion	5.558	6.028	6.330	5.972	5.603	5.960	6.378	5.980
1 ridge: 1 ridge	3.245	3.301	3.297	3.281	3.246	3.409	3.519	3.391
1 ridge: 2 ridges	4.047	4.318	4.644	4.336	4.094	4.446	4.648	4.396
2 ridges: 2 ridges	2.773	2.789	2.884	2.815	2.650	2.756	2.969	2.792
Mean (K)	3.906	4.109	4.289		3.898	4.143	4.378	
LSD at 5%	(I) = 0.034	(K) = 0.051	(I×K) = 0.090		(I) = 0.041	(K) = 0.053	(I×K) = 0.097	
	Total yield (grade 1 + grade 2+ grade 3+ grade 4)							
Sole onion	5.738	6.196	6.511	6.148	5.778	6.118	6.551	6.149
1 ridge: 1 ridge	3.302	3.375	3.369	3.348	3.337	3.471	3.543	3.450
1 ridge: 2 ridges	4.103	4.383	4.730	4.405	4.173	4.509	4.718	4.467
2 ridges: 2 ridges	2.969	2.994	3.063	3.008	2.899	2.967	3.171	3.012
Mean (K)	4.028	4.237	4.418		4.047	4.266	4.496	
LSD at 5%	(I) = 0.034	(K) = 0.052	(I×K) = 0.092		(I) = 0.044	(K) = 0.055	(I×K) = 0.100	
	Potassium content/bulb (g)							
Sole onion	2.906	3.046	3.220	3.057	2.875	3.062	3.216	3.051
1 ridge: 1 ridge	2.798	3.075	3.267	3.033	2.696	3.104	3.229	3.010
1 ridge: 2 ridges	2.863	3.008	3.159	3.010	2.945	3.131	3.207	3.094
2 ridges: 2 ridges	3.084	3.131	3.264	3.160	3.053	3.177	3.235	3.155
Mean (K)	2.913	3.065	3.217		2.892	3.118	3.221	
LSD at 5%	(I) = 0.064	(K) = 0.076	(I×K) = 0.140		(I) = 0.039	(K) = 0.045	(I×K) = 0.084	

Effect of potassium fertilization rates

Results averaged in Tables 2 and 3 show that the highest values of most yield components of onion and potassium content per bulb (g) were significantly increased by potassium fertilization rates compared to control (unfertilized plants) in both seasons. Furthermore, in most cases potassium fertilization rate at (50 kg K_2O/fad.), significantly increased onion yield grades especially grades 1, 2 and 3, exportable yield, marketable yield, total yield and potassium content compared to control during the two seasons.

Effect of combination between intercropping system and potassium rates

The combination between intercropping system and potassium fertilization rate showed that the highest values of onion yield components were recorded when the highest potassium fertilization rate (50 kg/fad.) was combined with sole crop (Tables 2 and 3). On the other side, in most cases, the highest potassium content per bulb was achieved with the highest potassium rate when applied to 2:2 intercropping system in both seasons.

Yield Components and Potassium Content of Caraway

Effect of intercropping systems

Results illustrated in Tables 4 and 5 show that, alternating one ridge of caraway with two ridges of onion treatment (1 : 2 system) recorded significant increase in number of umbels and fruit yield per caraway plant (g), volatile oil percentage and yield per plant (ml) as well as potassium content/plant (g) compared with the other ones under study in the two tested seasons (Tables 4 and 5). Also, all intercropping systems under study significantly increased above mentioned parameters of caraway plant compared to sole crop of caraway in both seasons. **Gendy *et al.* (2018)** on black cumin when intercropped with fenugreek had reported similar results.

Caraway fruit and volatile oil yield per faddan was decreased with intercropping systems compared to caraway sole cropping (Tables 4 and 5). Such decrease was significant in the first and second seasons. Generally, sole crop system increased fruit and volatile oil yield per faddan compared with the other intercropping planting systems under study. These paradoxical results can be interpreted in the light of that the higher population of caraway plants within area unit (faddan) in sole caraway or onion planting could be compensated the lack of fruit and volatile oil yield per plant in these treatments compared with 1:1, 1:2 or 2:2 ratios. Similar results were found by **Nurbakhsh *et al.* (2013)** on sesame intercropped with bean, **Singh *et al.* (2014)** on mustard intercropped with lentil and **Padma *et al.* (2018)** on coconut intercropped with *Cymbopogon martini*.

Effect of potassium fertilization rates

Results tabulated in Tables 4 and 5 show that, any potassium rates significantly enhanced the number of umbels/plant, fruit yield per plant and per faddan, volatile oil percentage and yield per plant and per faddan as well as potassium content per plant of caraway compared with control in both seasons. The highest values of yield components of caraway were recorded with the highest rate of potassium fertilization during both seasons. These results are in line with those found by **Meena *et al.* (2015)** on cowpea plants. Potassium fertilizers proved its role in plant metabolism, carbohydrate synthesis, water transport in xylem, cell elongation. **Pal *et al.* (2016)** reported that addition of K resulted with higher herb yields of *Thymus serphyllum*.

Effect of combination between intercropping system and potassium rates

As for yield components of fruits and volatile oil of caraway Tables 4 and 5 cleared that alternating 1 ridge of caraway with 2 ridges of onion combined with the highest rate of potassium (50 kg K_2O/faddan) was significantly higher than any combination treatments in the two consecutive seasons. Also, increasing potassium fertilization rate under intercropping systems significantly increased potassium content per plant. The highest yields per faddan of fruits or volatile oil were recorded when the sole caraway was fertilized with the highest potassium rate. These results are in line with those reported by **Sherawat and Singh (2009)** on bean intercropped with potato and fertilized with potassium and **Gendy *et al.* (2018)** on black cumin when intercropped with fenugreek and fertilized with NPK rates.

Table 4. Effect of intercropping system and potassium rate and their combinations on yield components of caraway during 2016/2017 and 2017/2018 seasons

Intercropping system (caraway: onion) (I)	Potassium rate (kg K_2O/faddan) (K)							
	0.0	25	50	Mean (I)	0.0	25	50	Mean (I)
	2016/2017 season				2017/2018 season			
	Umbel number / plant							
Sole caraway	27.67	33.67	39.00	33.44	30.33	35.00	40.00	35.11
1 ridge: 1 ridge	36.33	45.00	50.33	43.89	35.67	45.00	49.33	43.33
1 ridge: 2 ridges	41.00	46.33	52.00	46.44	41.67	45.00	52.67	46.78
2 ridges: 2 ridges	35.67	41.67	49.00	42.11	35.33	42.33	49.33	42.33
Mean (K)	35.17	41.67	47.58		35.75	42.08	47.83	
LSD at 5%	(I) = 0.94	(K) = 0.72	(I×K) = 1.50		(I) = 1.04	(K) = 0.87	(I×K) = 1.76	
	Fruit yield / plant (g)							
Sole caraway	11.08	12.87	14.12	12.69	11.87	13.23	14.18	13.09
1 ridge: 1 ridge	13.54	16.12	18.09	15.92	14.12	15.93	17.93	15.99
1 ridge: 2 ridges	14.70	16.33	20.64	17.22	14.73	15.96	20.69	17.12
2 ridges: 2 ridges	13.60	14.81	17.36	15.26	13.36	14.98	17.95	15.43
Mean (K)	13.23	15.03	17.55		13.52	15.03	17.69	
LSD at 5%	(I) = 0.70	(K) = 0.37	(I×K) = 0.92		(I) = 0.14	(K) = 0.42	(I×K) = 0.71	
	Fruit yield/faddan (kg)							
Sole caraway	517.24	600.77	658.80	592.27	554.10	617.42	661.75	611.09
1 ridge: 1 ridge	315.86	376.14	422.19	371.40	329.48	371.79	418.38	373.21
1 ridge: 2 ridges	228.62	254.08	321.02	267.91	229.09	248.22	321.80	266.37
2 ridges: 2 ridges	317.42	345.58	405.16	356.05	311.66	349.62	418.85	360.04
Mean (K)	334.79	394.14	451.79		356.08	396.76	455.19	
LSD at 5%	(I) = 17.29	(K) = 10.34	(I×K) = 24.11		(I) = 7.72	(K) = 10.68	(I×K) = 19.05	

Table 5. Effect of intercropping system and potassium rate and their combinations on volatile oil yield components and K content /plant (g) of caraway during 2016/2017 and 2017/2018 seasons

Intercropping system (caraway: onion) (I)	Potassium rate (kg K_2O/faddan) (K)							
	0.0	25	50	Mean (I)	0.0	25	50	Mean (I)
	2016/2017 season				2017/2018 season			
	Volatile oil percentage							
Sole caraway	1.220	1.223	1.333	1.259	1.240	1.297	1.377	1.304
1 ridge: 1 ridge	1.237	1.300	1.387	1.308	1.290	1.340	1.393	1.341
1 ridge: 2 ridges	1.303	1.367	1.417	1.362	1.303	1.390	1.430	1.374
2 ridges: 2 ridges	1.243	1.320	1.383	1.316	1.303	1.353	1.400	1.352
Mean (K)	1.251	1.302	1.380		1.284	1.345	1.400	
LSD at 5 %	(I) = 0.017	(K) = 0.012	(I×K) = 0.026		(I) = 0.011	(K) = 0.014	(I×K) = 0.025	
	Volatile oil yield/plant (ml)							
Sole caraway	0.135	0.157	0.188	0.160	0.147	0.171	0.195	0.171
1 ridge: 1 ridge	0.167	0.210	0.251	0.209	0.182	0.213	0.250	0.215
1 ridge: 2 ridges	0.192	0.223	0.292	0.236	0.192	0.222	0.296	0.237
2 ridges: 2 ridges	0.169	0.195	0.240	0.201	0.174	0.203	0.251	0.209
Mean (K)	0.166	0.196	0.243		0.174	0.202	0.248	
LSD at 5 %	(I) = 0.008	(K) = 0.005	(I×K) = 0.012		(I) = 0.002	(K) = 0.006	(I×K) = 0.010	
	Volatile oil yield/faddan (l)							
Sole caraway	6.312	7.350	8.785	7.483	6.874	8.006	9.110	7.997
1 ridge: 1 ridge	3.907	4.889	5.855	4.884	4.250	4.982	5.830	5.021
1 ridge: 2 ridges	2.978	3.474	4.547	3.666	2.985	3.451	4.602	3.679
2 ridges: 2 ridges	3.947	4.564	5.604	4.705	4.062	4.732	5.863	4.886
Mean (K)	4.286	5.069	6.198		4.543	5.292	6.351	
LSD at 5%	(I) = 0.231	(K) = 0.133	(I×K) = 0.316		(I) = 0.125	(K) = 0.156	(I×K) = 0.284	
	Potassium content / plant (g)							
Sole caraway	0.488	0.580	0.640	0.569	0.527	0.596	0.665	0.596
1 ridge: 1 ridge	0.594	0.758	0.932	0.762	0.651	0.785	0.924	0.787
1 ridge: 2 ridges	0.688	0.852	1.087	0.876	0.692	0.835	1.085	0.871
2 ridges: 2 ridges	0.595	0.654	0.890	0.713	0.586	0.701	0.922	0.736
Mean (K)	0.591	0.711	0.887		0.614	0.729	0.899	
LSD at 5 %	(I) = 0.033	(K) = 0.018	(I×K) = 0.043		(I) = 0.030	(K) = 0.029	(I×K) = 0.056	

Competitive Indices Between Onion and Caraway

Effect of intercropping systems

Total land productivity in terms of LER, ATER, LUE(%) and RCC of relative bulb yield of onion per faddan and relative fruits yield of caraway per faddan as influenced by intercropping system, potassium fertilization rate and their combinations are recorded in Table 6. The highest values of above competitive indices (except that of LER) were observed in 33.33% onion + 66.67% caraway (1: 2 system) in the two seasons. In general, all intercropping systems had higher LER, ATER, LUE% and RCC than sole crop (>1) which indicated the superiority of intercropping over solid planting system. These LER, ATER, LUE% values indicated that 16.7 to 16.1%, 10.7% to 10.3% and 113.70 to 113.17% more land would require to plant the sole crops to produce the same quantities of intercropped yield of caraway and onion produced by using 1:2 intercropping system during the first and second seasons, respectively. Based on definitions, a relative crowding coefficient (RCC) indicates the advantage of intercropping over sole crop. Therefore, it can be concluded that the 1: 2 system due to the highest relative crowding coefficient among different planting proportions, is the best intercropping proportion of caraway and onion. Regardless of the planting systems, aggrissivity or dominance index (Ag), based on the results, there was a positive sign for caraway and a negative sign for the intercropped onion, indicating that caraway was dominant while onion was dominated (Table 7). It is known that an aggrissivity 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.

Competitive ratio (CR) is only used as a measure of intercrop competition (inter-specific competition) (**Dhima *et al.* (2006)**. CR for each of caraway and onion plants was significantly influenced by intercropping systems (Table 7). Furthermore, intercropped caraway had higher competitive ratios in all proportions with onion, indicating that *Carum carvi* plants was more competitive (CR caraway > one) than onion (CR onion < one). However, in all intercropping systems the values of CR for caraway were greater than for onion indicating the dominance of caraway.

The enhancing effect of intercropping on competitive indices was previously reported by **Marer *et al.* (2007)** in maize intercropped with pigeon pea, **Abdelkader and Mohsen (2016)** in onion intercropped with fennel and coriander plants and **Gendy *et al.* (2017)** on roselle when intercropped with cowpea.

Effect of potassium fertilization rates

In most cases there was significant difference between different potassium fertilization rates. This means that increasing potassium fertilization rate had effect on LER, ATER, LUE% and RCC values (Table 6). Generally, the highest potassium fertilization rate (50 kg K_2O/fad.) significantly increased all competitive indices during the two seasons. All above mentioned indices were greater than unity, thus demonstrating yield advantages for potassium fertilization compared to control (unfertilized plants).

However, the highest rate of potassium (50 kg/faddan) significantly increased competitive ratio and aggrissivity compared to the other rates in both seasons.

Effect of combination between intercropping system and potassium rates

Results tabulated in Tables 6 and 7 reveal that, concerning the interaction treatments, all combinations between intercropping system and potassium fertilization rate produced higher LER, ATER, LUE% and RCC values (more than one unit). In all the combinations treatments, ATER values were smaller than LER values (Table 6), indicating the over estimation of resource utilization in the latter. Thus contrary to LER, ATER is free from problems of over estimation of resource utilization. In addition, the best treatment in this parameters as well as aggrissivity was the combination between 1: 2 intercropping system with 50 kg/fad., of potassium fertilization rate. However, the highest values of competitive ratio for caraway (CR caraway) were achieved by combination between 1: 2 system and 25 kg/fad., potassium

Table 6. Effect of intercropping system and potassium rate and their combinations on LER, ATER, LUE(%) and RCC indices between caraway and onion components during 2016/2017 and 2017/2018 seasons

Intercropping system (caraway: onion) (I)	Potassium rate (kg K_2O/faddan) (K)							
	0.0	25	50	Mean (I)	0.0	25	50	Mean (I)
	2016/2017 season				2017/2018 season			
	Land equivalent ratio (LER)							
1 ridge: 1 ridge	1.187	1.172	1.158	1.172	1.172	1.170	1.173	1.171
1 ridge: 2 ridges	1.157	1.130	1.214	1.167	1.137	1.139	1.207	1.161
2 ridges: 2 ridges	1.133	1.059	1.085	1.092	1.066	1.051	1.117	1.078
Mean (K)	1.159	1.120	1.152		1.125	1.120	1.166	
LSD at 5 %	(I) = 0.035	(K) = 0.031	(I×K) = 0.055		(I) = 0.012	(K) = 0.017	(I×K) = 0.031	
	Area time equivalent ratio (ATER)							
1 ridge: 1 ridge	1.106	1.088	1.073	1.089	1.093	1.089	1.089	1.090
1 ridge: 2 ridges	1.098	1.074	1.149	1.107	1.081	1.085	1.142	1.103
2 ridges: 2 ridges	1.051	0.982	1.003	1.012	0.991	0.976	1.032	0.999
Mean (K)	1.085	1.048	1.075		1.054	1.050	1.088	
LSD at 5 %	(I) = 0.031	(K) = 0.027	(I×K) = 0.049		(I) = 0.012	(K) = 0.017	(I×K) = 0.027	
	Land utilization efficiency (LUE%)							
1 ridge: 1 ridge	114.63	113.00	111.57	113.07	113.26	112.93	113.09	113.09
1 ridge: 2 ridges	112.80	110.22	118.13	113.72	110.89	111.21	117.42	113.17
2 ridges: 2 ridges	109.20	102.03	104.43	105.22	102.80	101.36	107.47	103.88
Mean (K)	112.21	108.42	111.37		108.99	108.50	112.66	
LSD at 5 %	(I) = 3.304	(K) = 2.885	(I×K) = 5.215		(I) = 1.219	(K) = 1.886	(I×K) = 2.922	
	Relative crowding coefficient (RCC)							
1 ridge: 1 ridge	2.137	2.031	1.918	2.029	2.007	1.986	2.027	2.007
1 ridge: 2 ridges	7.973	7.152	10.123	8.416	7.387	7.567	9.771	8.241
2 ridges: 2 ridges	1.751	1.270	1.424	1.482	1.308	1.231	1.622	1.386
Mean (K)	3.954	3.484	4.488		3.567	3.594	4.473	
LSD at 5 %	(I) = 0.790	(K) = 0.466	(I×K) = 1.022		(I) = 0.397	(K) = 0.512	(I×K) = 0.822	

Table 7. Effect of intercropping system and potassium rate and their combination on competitive ratio (CR) and aggrissivity values (Ag) indices between caraway and onion components during 2016/2017 and 2017/2018 seasons

Intercropping system (caraway: onion) (I)	Potassium rate (kg K_2O/faddan) (K)							
	0.0	25	50	Mean (I)	0.0	25	50	Mean (I)
	2016/2017 season				2017/2018 season			
	Competitive ratio for caraway (CRc)							
1 ridge: 1 ridge	1.063	1.152	1.239	1.151	1.030	1.062	1.169	1.087
1 ridge: 2 ridges	1.238	1.196	1.342	1.258	1.903	1.906	1.893	1.901
2 ridges: 2 ridges	1.190	1.191	1.307	1.229	1.125	1.168	1.308	1.200
Mean (K)	1.164	1.179	1.296		1.353	1.379	1.456	
LSD at 5 %	(I) = 0.060	(K) = 0.063	(I×K) = 0.107		(I) = 0.012	(K) = 0.054	(I×K) = 0.077	
	Competitive ratio for onion (CRo)							
1 ridge: 1 ridge	0.943	0.870	0.808	0.874	0.971	0.942	0.856	0.923
1 ridge: 2 ridges	0.808	0.838	0.746	0.797	0.525	0.524	0.528	0.526
2 ridges: 2 ridges	0.844	0.840	0.766	0.817	0.893	0.858	0.765	0.839
Mean (K)	0.865	0.849	0.773		0.796	0.775	0.716	
LSD at 5 %	(I) = 0.046	(K) = 0.045	(I×K) = 0.078		(I) = 0.011	(K) = 0.041	(I×K) = 0.058	
	Aggrissivity values for caraway (Ag_{co})							
1 ridge: 1 ridge	+ 0.036	+ 0.082	+ 0.123	+ 0.080	+ 0.017	+ 0.035	+ 0.091	+ 0.048
1 ridge: 2 ridges	+ 0.255	+ 0.208	+ 0.372	+ 0.278	+ 0.159	+ 0.101	+ 0.379	+ 0.213
2 ridges: 2 ridges	+ 0.098	+ 0.092	+ 0.144	+ 0.112	+ 0.062	+ 0.081	+ 0.149	+ 0.097
Mean (K)	+ 0.130	+ 0.128	+ 0.213		+ 0.079	+ 0.072	+ 0.206	
LSD at 5 %	(I) = 0.045	(K) = 0.043	(I×K) = 0.075		(I) = 0.016	(K) = 0.049	(I×K) = 0.071	
	Aggrissivity values for onion (Ag_{oc})							
1 ridge: 1 ridge	- 0.036	- 0.082	- 0.123	- 0.080	- 0.017	- 0.035	- 0.091	- 0.048
1 ridge: 2 ridges	- 0.255	- 0.208	- 0.372	- 0.278	- 0.159	- 0.101	- 0.379	- 0.213
2 ridges: 2 ridges	- 0.098	- 0.092	- 0.144	- 0.112	- 0.062	- 0.081	- 0.149	- 0.097
Mean (K)	- 0.130	- 0.128	- 0.213		- 0.079	- 0.072	- 0.206	
LSD at 5 %	(I) = 0.045	(K) = 0.043	(I×K) = 0.075		(I) = 0.016	(K) = 0.049	(I×K) = 0.071	

fertilization rate, in contrary, the highest values of competitive ratio for onion (CR onion) were achieved by combination between 1: 1 system without potassium fertilization application in both seasons. These results are in line with those reported by **Gendy *et al.* (2018)** on black cumin when intercropped with fenugreek and fertilized with NPK rates.

Conclusion

In general, the results showed that the yield components and potassium content of onion and caraway were significantly affected by the treatments under study. Ridge planting of onion and caraway led to yield improvement in intercropping system fertilized by potassium. LER, ATER, LUE% and RCC values in all intercropping systems was > 1 and the highest value was obtained in 1: 2 system fertilized with 50 kg K_2O/fad., of potassium fertilization rate. Also, with respect to the aggression power, the caraway was determined as the dominant component. This study suggests that caraway/ onion association should be used by farmers instead of onion or caraway sole crops, especially at 1:2 cropping system with 50 kg/fad., of potassium fertilization, under Sharkia Governorate condition.

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تقييم المساهمات المحصولية وبعض مؤشرات التنافس بين نباتات الكراوية والبصل باستخدام نظم التحميل تحت معدلات السماد البوتاسي المختلفة

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أُجريت تجربتان حقليتان خلال عامي (٢٠١٦/٢٠١٧ و ٢٠١٧/٢٠١٨) بالمزرعة التجريبية بغزالة، كلية الزراعة، جامعة الزقازيق، مصر لتقييم المساهمات المحصولية والمحتوى من البوتاسيوم وبعض مؤشرات التنافس بين الكراوية والبصل بنسب زراعة مختلفة (المحصول المنفرد لكل محصول، ١:١ ، ١: ٢ و ٢: ٢ من الكراوية: البصل، على الترتيب) تحت معدلات مختلفة من السماد البوتاسي (صفر، ٢٥ و ٥٠ كجم بو٢أ/فدان)، صممت التجربة كقطع منشقة مرة واحدة في قطاعات كاملة العشوائية في ثلاث مكررات، أوضحت النتائج، أن عوامل الدراسة قد أثرت على المساهمات المحصولية (الدرجات المختلفة لمحصول البصل، والمحصول المصدر والمحصول المسوق والمحصول الكلي كذلك، عدد النورات/ نبات ومحصول الثمار والزيت العطري/نبات و/فدان للكراوية) ومحتوى البوتاسيوم/نبات لكل مكون ومؤشرات التنافس بينهما، في معظم الحالات، سجل المحصول المنفرد من البصل أعلى القيم للمساهمات المحصولية مقارنة بنظم التحميل تحت جميع معدلات التسميد البوتاسي، في نفس الصدد، سجلت أعلى القيم من محصول الثمار والزيت العطري/فدان مع المحصول المنفرد من الكراوية، أيضاُ، أدي استخدام أعلى معدل من البوتاسيوم إلى زيادة معنوية في تلك الصفات مقارنة بالكنترول، أظهرت مؤشرات التنافس لكل من نسبة المكافئ الأرضي ونسبة المكافئ الأرضي لوحدة الزمن وكفاءة استخدام الأرض ومعامل الحشد النسبي، أن استخدام نظام التحميل ١: ٢ كان أفضل من الزراعة المنفردة ومعاملات التحميل الأخرى تحت الدراسة عند تداخله مع معدل التسميد البوتاسي ٥٠ كجم بو٢أ/فدان في معظم الحالات، أوضح مقياس العدوانية أن الكراوية كان المحصول السائد بينما البصل كان المحصول المسود عليه، عموماً، تبدو هذه المعاملة ملائمة لتحسين إنتاجية تلك المحاصيل مع تقليل استخدام المعاملات الإضافية تحت ظروف محافظة الشرقية.

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