



## Plant Production Science

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## THE ROLE OF INTERCROPPING CARAWAY (*Carum carvi* L.) AND GARLIC (*Allium sativum* L.) ON THE GROWTH AND YIELD UNDER DIFFERENT RATES OF POTASSIUM FERTILIZATION

Norhan M.E.M. Khashaba\*, Dalia A.S. Nawar and M.A.I. Abdelkader

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

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**ABSTRACT:** A field experiment was conducted at a private farm in Taha El-Marg Village, Diarb Negm District, Al Sharqia Governorate, Egypt during the two consecutive winter seasons of 2020/2021 and 2021/2022. This experiment was done to study the effect of intercropping systems between caraway: garlic at different row ratio (sole crop of each as control, 1: 2, 2: 1 and 2: 2, respectively), different potassium rates (0, 25, 50 and 75 kg K<sub>2</sub>O/feddan) and their combination on growth and yield of caraway and garlic plants. Main plots consisted in the intercropping systems and the subplots were constituted by the potassium fertilization rates. Alternating two rows of caraway with two rows of garlic significantly increased plant height, number of branches per plant, plant fresh weight, number of umbels per plant and fruit yield per plant compared to sole caraway planting. Also, using 1: 2 intercropping system gave the highest values regard plant height, plant fresh weight and bulb fresh weight compared to sole garlic planting. Moreover, the highest potassium fertilization rate (75 kg K<sub>2</sub>O /feddan) gave the highest values in growth traits and yield components of caraway and garlic crops compared to control. Sole crop of caraway and garlic significantly recorded the highest values of fruits and bulbs yield per feddan compared to intercropping systems under study. In general, the combination between intercropping system and potassium affected growth and yield components of both crops and the best treatment in this regard was 2: 2 system for caraway and 1: 2 for garlic and 75 kg K<sub>2</sub>O/feddan.

**Key words:** Caraway, garlic, intercropping, potassium, growth, yield.

### INTRODUCTION

Caraway (*Carum carvi*, L.) is a perennial plant that is a member of the Apiaceae family. Many species of this family are used as dried or fresh herbs or as ingredients in medicines. Caraway fruits, which are usually called seeds, have a volatile oil with a lot of terpenoid parts (Kocourkova *et al.*, 1999). Caraway is thought to be a feed ingredient that helps cattle make more milk, taste better, digest better and have less gas. Caraway volatile oil is used to keep potatoes from sprouting naturally, mostly when stored (Kleinkopf *et al.*, 2003). It is also an antiseptic, a painkiller, an antispasmodic, a depletor, and an antioxidant (Sembratowicz and Czech, 2005; Dyduch *et al.*, 2006). In

addition, garlic (*Allium sativum* L.), which is a member of the Alliaceae family, is one of the oldest vegetables that people have been growing for a long time. After onion, it is the second most important crop grown and used from the allium genus. Garlic cloves are often used as a spice or condiment, but they are also good for your health in many ways (contains Allicin in di allyle di sulphide form). Increasing garlic production is very important to keep up with the growing demand for exports and local use (El-Hifny, 2010).

Intercropping can help you get a higher yield than just planting one crop at a time (Mandal *et al.*, 1986). So, it's important to choose a combination of crops that work well together if you want to use more growth resources, like

\* Corresponding author: Tel. : +201150683700  
 E-mail address: nm782126@gmail.com

solar energy and water per unit area per unit time, and keep the soil in good shape while improving yield components. So, the different crops in intercropping systems need to be chosen in a way that takes advantage of how they work together to make the best use of resources and increase overall productivity (Mucheru-Muna *et al.*, 2010). The main idea behind the intercropping system is to get more total yield and productivity from the same amount of space and time. Different indices have been made to show how intercropping affects competition and how it might be beneficial (Ghosh, 2004; Alizadeh *et al.*, 2010).

Potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes that affect plant growth and metabolism. It also helps plants survive when they are stressed by both living and nonliving things. Also, it is very important for normal cell division, the movement of carbs and the breakdown of nitrates. On, potassium doesn't seem to be a permanent part of the structure, but playing a role in metabolism (Black, 1960). Potassium had significant effect on grain yield, straw weight and umbels number per black caraway plant (Zabihi and Nourihoseini, 2019). Also, the most vegetative traits, yield and its components of garlic were significantly increased with increasing potassium fertilization levels compared to control (El-Sayed and El Morsy, 2012; Jiku *et al.*, 2020).

Therefore, the main aim of this study was to evaluate the role of intercropping systems on enhancing the growth traits as well as yield components of both caraway and garlic plants under different potassium fertilization rates.

## MATERIALS AND METHODS

A field experiment was conducted at a private farm in Taha El-Marg Village, Diarb Negm District, Al Sharqia Governorate, Egypt during the two consecutive winter seasons of 2020/2021 and 2021/2022. This experiment was done to study the effect of intercropping systems at different row ratio (sole crop of each as control, 1: 2, 2: 1 and 2: 2 of caraway: garlic, respectively), different potassium rates (0, 25, 50 and 75 kg K<sub>2</sub>O/feddan) and their combination

on growth and yield of caraway and garlic plants. Randomized soil sample was collected before sowing to determine the physical and chemical properties of the experimental soil according to the standard method as described by Chapman and Pratt (1978) in Table 1.

### Plant Material

The caraway fruits were obtained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza. Also, garlic bulbs (cv. Balady) were obtained from privet Farm in Diarb Negm District, Al Sharqia Governorate, Egypt. Caraway fruits and garlic cloves were sowed in the experimental plots on 11<sup>th</sup> and 7<sup>th</sup> October during the 1<sup>st</sup> and 2<sup>nd</sup> seasons, respectively.

### Cultivation

The experimental unit area was 21.60 m<sup>2</sup> (3 m × 7.20 m) contained 12 ridges 60 cm apart and 50 cm between caraway plants (two plants/hill) and 10 cm between garlic (plant/hill) plants. Therefore, the number of caraway plants in a feddan (4200 m<sup>2</sup>) for sole crop were about 44445 plants/feddan as well as the number of garlic plants were 133,334 plants/feddan and the number of plants under different intercropping systems shown in Table 2.

### Fertilization

The NP fertilization rates were 60 and 31 kg of N and P<sub>2</sub>O<sub>5</sub> /feddan, respectively. The source of nitrogen was ammonium sulphate (20.5% N), while the source of phosphorus was calcium superphosphate (15.5% P<sub>2</sub>O<sub>5</sub>). Furthermore, potassium fertilization rates (0.0, 25, 50 and 75 kg K<sub>2</sub>O/feddan) were added as potassium sulphate (48 % K<sub>2</sub>O). All amount of P fertilizer was added during soil preparation. Whereas, N and K fertilizers were divided into 5 equal rates and were applied to the soil at 30, 55, 80, 105 and 130 days after sowing date. The irrigation system was surface irrigation.

### Experimental Design

This experiment was set up in a split-plot design with three replicates. The main plots were occupied by four intercropping systems. While the sub plots were entitled to four potassium fertilization rates. The combination treatments between intercropping systems and potassium fertilization rates were 20 treatments.

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

Physical analysis				Soil texture									
Clay (%)		Silt (%)		Sand (%)		Clay							
53.26		34.72		12.02									
Chemical analysis													
pH	E.C. dSm <sup>-1</sup>	Organic matter (%)	CaCO <sub>3</sub> (%)	Soluble cations (meq./L)				Soluble anions (meq./L)					
				Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	CO <sub>3</sub> <sup>--</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>--</sup>		
8.13	3.17	0.63	0.56	12.23	11.72	2.87	4.18	0.00	9.86	3.91	17.23		
Available nutrient (mg kg <sup>-1</sup> soil)													
N		P		K		Fe		Zn		Cu		Mn	
45.22		18.49		263		1.87		0.77		0.65		0.50	

**Table 2. Number of caraway and garlic plants per feddan under intercropping systems**

Intercropping systems (Caraway: garlic)	Number of plants/feddan	
	Caraway	garlic
Sole crop	44445	133334
1 row of caraway: 2 rows of garlic	14801	88801
2 row of caraway: 1 row of garlic	29601	44401
2 rows of caraway: 2 rows of garlic	22223	66667

### Sampling and Collecting Data

After 108 days from sowing, 3 plants were randomly chosen from each plot to determine the following parameters:

#### Plant growth parameters

- 1- Plant height (cm);
- 2- Number of branches / caraway plant;
- 3- Number of leaves / garlic plant and
- 4- Plant fresh weight / (g)

#### Yield components

- 1- Number of umbels/caraway plant;
- 2- Number of cloves /bulb of garlic plant;
- 3- Fruit yield per plant (g) and per feddan (kg) and
- 4- Bulb fresh weight and bulb yield/feddan (ton).

### Statistical Analysis

The statistical layout of this experiment was split-plot experiment in completely randomized block design. 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

### Effect of Intercropping Systems, Potassium Fertilization and Their Combination Treatments of Caraway Plant Growth

Results tabulated in Tables 3, 4 and 5 reveal that, alternating 2 rows of caraway with 2 rows of garlic recorded the highest values of plant height (128.75 and 130.75 cm), number of branches per plant (12.29 and 13.33) and plant fresh weight (274.45 and 272.98 g) in 1<sup>st</sup> and 2<sup>nd</sup>

**Table 3. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on plant height (cm) of caraway during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole caraway	108.33	106.67	111.33	114.67	<b>110.25</b>
1 : 2	113.67	123.33	126.00	128.67	<b>122.92</b>
2 : 1	120.33	123.00	125.00	129.00	<b>124.33</b>
2 : 2	121.67	126.67	131.67	135.00	<b>128.75</b>
Mean (K)	<b>116.00</b>	<b>119.92</b>	<b>123.50</b>	<b>126.83</b>	
L.S.D. at 5 %	For (I)= 1.56		For (K)= 1.18	For (I×K)= 2.56	
<b>Second season</b>					
Sole caraway	110.33	114.00	121.67	124.00	<b>117.50</b>
1 : 2	114.00	120.00	123.00	127.00	<b>121.00</b>
2 : 1	118.00	126.67	128.67	131.67	<b>126.25</b>
2 : 2	126.67	129.00	132.33	135.00	<b>130.75</b>
Mean (K)	<b>117.25</b>	<b>122.42</b>	<b>126.42</b>	<b>129.42</b>	
L.S.D. at 5 %	For (I)= 0.59		For (K)= 0.39	For (I×K)= 0.90	

**Table 4. Effect of intercropping system (I), potassium fertilization level (k) and their interaction treatments on number of branches per plant of caraway during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole caraway	10.33	10.43	11.00	11.33	<b>10.78</b>
1 : 2	10.00	12.00	11.00	13.00	<b>11.50</b>
2 : 1	10.33	10.50	13.00	12.00	<b>11.55</b>
2 : 2	11.00	11.90	12.03	14.23	<b>12.29</b>
Mean (K)	<b>10.42</b>	<b>11.21</b>	<b>11.76</b>	<b>12.64</b>	
L.S.D. at 5 %	For (I)= 0.42		For (K)= 0.19	For (I×K)= 0.53	
<b>Second season</b>					
Sole caraway	10.33	10.00	12.00	11.33	<b>10.92</b>
1 : 2	10.43	13.00	13.00	13.00	<b>12.36</b>
2 : 1	10.43	13.00	14.00	14.00	<b>12.86</b>
2 : 2	12.00	13.33	14.00	14.00	<b>13.33</b>
Mean (K)	<b>10.80</b>	<b>12.33</b>	<b>13.25</b>	<b>13.08</b>	
L.S.D. at 5 %	For (I)= 0.43		For (K)= 0.46	For (I×K)= 0.90	

**Table 5. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on plant fresh weight (g) of caraway during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole caraway	240.00	266.89	271.94	292.06	<b>267.72</b>
1 : 2	217.35	237.95	240.38	251.84	<b>236.88</b>
2: 1	253.62	260.90	281.54	281.12	<b>269.29</b>
2: 2	262.78	269.26	283.39	282.37	<b>274.45</b>
Mean (K)	<b>243.44</b>	<b>258.75</b>	<b>269.31</b>	<b>276.85</b>	
L.S.D. at 5 %	For (I)= 5.03		For (K)= 4.90	For (I×K)= 9.84	
<b>Second season</b>					
Sole caraway	241.50	251.22	240.58	233.33	<b>241.66</b>
1 : 2	251.97	260.66	279.22	282.14	<b>268.50</b>
2: 1	268.95	265.25	257.38	276.77	<b>267.09</b>
2: 2	265.56	261.60	287.30	277.46	<b>272.98</b>
Mean (K)	<b>257.00</b>	<b>259.68</b>	<b>266.12</b>	<b>267.42</b>	
L.S.D. at 5 %	For (I)= 0.85		For (K)= 0.49	For (I×K)= 1.20	

seasons, respectively. Generally, increasing rows number of garlic under two rows of caraway gradually increased caraway growth in both seasons. Moreover, using any potassium fertilization rate significantly increased caraway growth traits compared to control in both seasons. The highest values in this regard were obtained from 75 kg K<sub>2</sub>O/ feddan. There was an increase regard the combination treatments between the intercropping systems and potassium fertilization rates for plant height, branches number per plant and total fresh weight of plant compared to control (sole caraway without potassium application) in most cases in both seasons.

In addition, **Abdelkader and Mohsen (2016)** pointed out that, alternating one row of each of coriander or fennel with three rows of onion gave the highest values of plant height, number of branches per plant and total dry weight of apiaceous crops. **Massoud et al. (2019)** found that, potassium fertilization significantly increased plant height and number of branches per plant of caraway plant compared to control. Furthermore, as mentioned just before, both intercropping

system and K fertilization treatments (each alone) increased caraway growth, in turn, they together might maximize their effects leading to tallest plant, more branches per plant as well as heaviest fresh weight per plant.

#### **Effect of Intercropping Systems, Potassium Fertilization and Their Combination Treatments of Caraway Yield Components**

Data of both seasons in Tables 6, 7 and 8 show that, number of umbels and fruit yield per caraway plant were increased and recorded the highest values by using 2 : 2 intercropping system compared to sole crop and the others systems under study. Sole crop of caraway gave the highest values in fruit yield per feddan compared to intercropping systems (1: 2, 2: 1 and 2 : 2 systems) under study. Increasing potassium fertilization rates gradually increased number of umbels per plant as well as fruit yield per plant (g) and per feddan (kg) in both seasons. Fertilized caraway plants by 75 kg K<sub>2</sub>O/feddan significantly increased caraway yield components compared to control. Using 2: 2 intercropping system combined with 75 kg

**Table 6. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on number of umbels/plant of caraway during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole caraway	56.00	58.33	58.33	60.00	<b>58.17</b>
1 : 2	72.00	73.00	78.00	79.00	<b>75.50</b>
2: 1	83.33	82.33	92.00	96.00	<b>88.42</b>
2: 2	88.00	93.00	95.00	97.00	<b>93.25</b>
Mean (K)	<b>74.83</b>	<b>76.67</b>	<b>80.83</b>	<b>83.00</b>	
L.S.D. at 5 %	For (I)= 0.42		For (K)= 0.38	For (I×K)= 0.77	
<b>Second season</b>					
Sole caraway	80.00	103.33	76.67	110.67	<b>92.67</b>
1 : 2	94.00	100.00	106.33	100.00	<b>100.08</b>
2: 1	108.33	106.00	133.33	93.33	<b>110.25</b>
2: 2	116.67	100.00	111.67	133.00	<b>115.33</b>
Mean (K)	<b>99.75</b>	<b>102.33</b>	<b>107.00</b>	<b>109.25</b>	
L.S.D. at 5 %	For (I)=14.84		For (K)=8.82	For (I×K)=21.22	

**Table 7. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on fruit yield/plant (g) of caraway during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole caraway	8.77	9.300	12.37	13.60	<b>11.01</b>
1 : 2	11.24	13.600	10.50	19.31	<b>13.65</b>
2: 1	10.12	11.590	13.57	14.40	<b>12.42</b>
2: 2	10.51	10.433	15.42	17.48	<b>13.46</b>
Mean (K)	<b>10.16</b>	<b>11.22</b>	<b>12.96</b>	<b>16.20</b>	
L.S.D. at 5 %	For (I)= 0.82		For (K)= 0.49	For (I×K)= 1.18	
<b>Second season</b>					
Sole caraway	8.10	11.80	13.57	14.70	<b>12.04</b>
1 : 2	11.45	12.37	16.37	20.69	<b>15.22</b>
2: 1	10.28	12.13	16.60	18.27	<b>14.32</b>
2: 2	11.30	15.27	16.59	19.33	<b>15.63</b>
Mean (K)	<b>10.28</b>	<b>12.90</b>	<b>15.78</b>	<b>18.25</b>	
L.S.D. at 5 %	For (I)= 1.15		For (K)= 0.32	For (I×K)= 1.27	

**Table 8. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on fruit yield/feddan (kg) of caraway during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole caraway	389.64	413.35	549.65	604.47	<b>489.28</b>
1 : 2	166.41	200.41	155.41	285.81	<b>202.01</b>
2: 1	299.66	343.08	401.59	426.25	<b>367.64</b>
2: 2	233.56	231.86	342.75	388.53	<b>299.18</b>
Mean (K)	<b>272.32</b>	<b>297.17</b>	<b>362.35</b>	<b>426.26</b>	
L.S.D. at 5 %	For (I)=17.40		For (K)=19.87		For (I×K)=38.48
<b>Second season</b>					
Sole caraway	360.01	524.46	602.98	653.36	<b>535.20</b>
1 : 2	169.52	183.14	242.24	306.18	<b>225.27</b>
2: 1	304.20	359.16	491.38	540.71	<b>423.86</b>
2: 2	251.12	339.49	368.75	429.57	<b>347.23</b>
Mean (K)	<b>271.21</b>	<b>351.56</b>	<b>426.34</b>	<b>482.46</b>	
L.S.D. at 5 %	For (I)=22.81		For (K)=9.51		For (I×K)=28.04

K<sub>2</sub>O/feddan gave the highest values in number of fruits per plant (97 and 133 umbels) in the 1<sup>st</sup> and 2<sup>nd</sup> seasons, respectively. These results are in line with those found by **Abdelkader *et al.* (2018)** on caraway intercropped with garlic whose reported that alternating 1 row of caraway with 2 rows of onion combined with the highest rate of potassium (50 kg K<sub>2</sub>O/feddan) was significantly increased number of umbels and fruit yield per caraway plant compared to the other combination treatments.

#### **Effect of Intercropping Systems, Potassium Fertilization and Their Combination Treatments of Garlic Plant Growth**

Data recorded in Tables 9, 10 and 11 indicate that, using 1 row of caraway: 2 rows of garlic produced the highest values in plant height and plant fresh weight compared to sole garlic crop and the other intercropping systems under study in both seasons. The highest number of leaves per garlic plant (8.42 and 8.29 leaves) was obtained with 2: 2 intercropping system in the first and second seasons. Fertilized garlic plants

with 75 kg K<sub>2</sub>O/feddan significantly increased plant height, number of leaves per plant and plant fresh weight compared to control. Generally, the best combination treatment was intercropping caraway with garlic at 1: 2 system combined with 75 kg K<sub>2</sub>O/feddan rate in both seasons.

This may be attributed to 3 factors. i) The high population of garlic plants within area unit which increased the above mentioned parameters. ii) The low competition between the shorter component crop (garlic) and taller one (caraway) on sunlight which might be happened with decreasing the row ratio of garlic plants resulting in low growth of garlic. iii) The low competition between caraway and garlic plants on available nutrients as reported by **El-Shamy *et al.* (2008)** on guar when intercropped with sunflower. Moreover, **Mohammed *et al.* (2021)** indicated that intercropping systems and lithovit rates influenced the plant height, number of leaves per plant and total dry weight per plant of roselle and cluster bean compared to control.

**Table 9. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on plant height (cm) of garlic during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole garlic	81.27	87.00	90.40	92.17	<b>87.71</b>
1 : 2	88.50	92.33	95.33	97.28	<b>93.36</b>
2: 1	82.83	83.83	88.17	89.17	<b>86.00</b>
2: 2	83.50	85.67	90.00	91.00	<b>87.45</b>
Mean (K)	<b>84.02</b>	<b>87.20</b>	<b>90.98</b>	<b>92.40</b>	
L.S.D. at 5 %	For (I)= 2.74		For (K)= 3.90	For (I× K)= 7.27	
<b>Second season</b>					
Sole garlic	74.00	74.67	85.00	85.67	<b>79.83</b>
1 : 2	84.33	88.33	88.67	89.67	<b>87.75</b>
2: 1	73.67	83.67	86.67	87.67	<b>82.92</b>
2: 2	78.00	85.00	86.00	91.00	<b>85.00</b>
Mean (K)	<b>77.50</b>	<b>82.92</b>	<b>86.58</b>	<b>88.50</b>	
L.S.D. at 5 %	For (I)= 1.32		For (K)= 0.71	For (I× K)= 1.80	

**Table 10. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on number of leaves/ plant of garlic during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole garlic	7.00	8.00	8.00	7.67	<b>7.67</b>
1 : 2	8.00	7.67	8.00	9.00	<b>8.17</b>
2: 1	8.00	7.67	8.00	9.00	<b>8.17</b>
2: 2	8.00	7.67	9.00	9.00	<b>8.42</b>
Mean (K)	<b>7.75</b>	<b>7.75</b>	<b>8.25</b>	<b>8.67</b>	
L.S.D. at 5 %	For (I)= 0.12		For (K)= 0.33	For (I× K)= 0.58	
<b>Second season</b>					
Sole garlic	7.00	8.00	8.00	7.67	<b>7.67</b>
1 : 2	8.00	8.00	8.00	9.00	<b>8.25</b>
2: 1	7.00	8.00	8.00	8.00	<b>7.75</b>
2: 2	7.00	8.00	9.00	9.17	<b>8.29</b>
Mean (K)	<b>7.25</b>	<b>8.00</b>	<b>8.25</b>	<b>8.46</b>	
L.S.D. at 5 %	For (I)= 0.27		For (K)= 0.24	For (I× K)= 0.50	



**Table 11. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on plant fresh weight (g) of garlic during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole garlic	78.20	81.50	81.09	85.00	<b>81.45</b>
1 : 2	75.84	82.46	84.00	92.24	<b>83.64</b>
2: 1	76.50	81.50	84.96	88.86	<b>82.96</b>
2: 2	65.15	74.77	76.49	77.017	<b>73.36</b>
Mean (K)	<b>73.92</b>	<b>80.06</b>	<b>81.64</b>	<b>85.78</b>	
L.S.D. at 5 %	For (I)= 1.35		For (K)= 1.35		For (I× K)= 2.93
<b>Second season</b>					
Sole garlic	79.54	79.85	80.48	82.51	<b>80.59</b>
1 : 2	85.64	90.00	91.35	94.11	<b>90.27</b>
2: 1	83.29	86.36	87.43	90.06	<b>86.79</b>
2: 2	69.49	73.56	74.74	83.00	<b>75.20</b>
Mean (K)	<b>79.49</b>	<b>82.44</b>	<b>83.50</b>	<b>87.42</b>	
L.S.D. at 5 %	For (I)= 1.45		For (K)= 0.54		For (I× K)= 1.72

### Effect of Intercropping Systems, Potassium Fertilization and Their Combination Treatments of Garlic Yield Components

The data illustrated in Tables 12, 13 and 14 indicate that, average of bulb fresh weight and number of cloves per bulb recorded the highest values when garlic intercropped with caraway under 1: 2 system compared to sole crop and the other systems under study in both seasons. Using any intercropping significantly decreased bulb yield per feddan compared to sole crop. These paradoxical results may interpreted in the light of that the highest population of garlic plants within area unit (feddan) in sole garlic could be compensated the high of average bulb fresh weight in this treatment compared with intercropping systems. Also, **Abdelkader and Mohsen (2016)** reported that solid planting of onion gave the highest yield per feddan when onion intercropped plus fennel or coriander plants. Likewise, alternating 2 rows of caraway with 2 rows of onion treatment (2:2 system) recorded significant enhance in bulb fresh weight compared with solid planting. The best

values in garlic yield components were achieved by the highest potassium fertilization rate compared to the lowest rates under study and control in 2020/2021 and 2021/2022 seasons. In addition, **Wang *et al.* (2022)** pointed out that the application of potassium fertilizer improved the cloves number, the cloves and bulbs diameters and reduced variations in bulb size. In general, 1: 2 intercropping system combined with 75 kg K<sub>2</sub>O/feddan gave the highest values regard number of cloves per garlic plant and bulb fresh weight compared to the other ones under study in the two consecutive seasons.

### Conclusion

This study suggests that, caraway/garlic association should be utilized by farmers instead of caraway sole crop, especially at 2: 2 cropping system, and garlic 1: 2 under Al Sharqia Governorate conditions. The use of the potassium rates for both crops, in the intercropping system of 2: 2 or 1:2, resulted in increases in caraway and garlic growth and yield components at the rate of 75 K<sub>2</sub>O/feddan.

Table 12. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on number of cloves/bulb of garlic during 2020/2021 and 2021/2022 seasons

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole garlic	36.00	41.00	47.00	46.33	<b>42.58</b>
1 : 2	50.00	48.00	46.00	49.00	<b>48.25</b>
2: 1	45.00	44.67	47.00	48.00	<b>46.17</b>
2: 2	44.00	43.00	46.00	49.00	<b>45.50</b>
Mean (K)	<b>43.75</b>	<b>44.17</b>	<b>46.50</b>	<b>48.08</b>	
L.S.D. at 5 %	For (I)= 0.19		For (K)= 0.17	For (I×K)= 0.35	
<b>Second season</b>					
Sole garlic	41.00	43.00	45.00	41.00	<b>42.50</b>
1 : 2	44.00	45.00	47.00	49.00	<b>46.25</b>
2: 1	45.00	44.00	46.00	47.00	<b>45.50</b>
2: 2	39.00	40.00	44.67	47.00	<b>42.67</b>
Mean (K)	<b>42.25</b>	<b>43.00</b>	<b>45.67</b>	<b>46.00</b>	
L.S.D. at 5 %	For (I)= 0.14		For (K)= 0.12	For (I×K)= 0.25	

Table 13. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on bulb fresh weight (g) of garlic during 2020/2021 and 2021/2022 seasons

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole garlic	32.14	36.91	36.90	39.30	<b>36.31</b>
1 : 2	34.40	38.32	40.13	42.53	<b>38.85</b>
2: 1	31.77	38.00	39.37	40.26	<b>37.35</b>
2: 2	27.87	32.06	32.68	36.00	<b>32.15</b>
Mean (K)	<b>31.54</b>	<b>36.32</b>	<b>37.27</b>	<b>39.52</b>	
L.S.D. at 5 %	For (I)= 0.49		For (K)= 0.45	For (I× K)= 0.92	
<b>Second season</b>					
Sole garlic	29.67	31.13	32.23	31.96	<b>31.25</b>
1 : 2	24.87	30.70	31.53	36.00	<b>30.78</b>
2: 1	25.93	27.48	34.03	34.97	<b>30.61</b>
2: 2	23.41	28.30	30.20	33.40	<b>28.83</b>
Mean (K)	25.97	29.40	32.00	34.08	
L.S.D. at 5 %	For (I)= 0.78		For (K)= 0.71	For (I×K)= 1.45	

**Table 14. Effect of intercropping system (I), potassium fertilization level (K) and their interaction treatments on bulb yield/feddan (ton) of garlic during 2020/2021 and 2021/2022 seasons**

Intercropping system (caraway: garlic) As row ratio	Potassium fertilization level (Kg K <sub>2</sub> O/feddan)				Mean (I)
	0.0	25	50	75	
<b>First season</b>					
Sole garlic	7.03	7.54	7.81	5.50	<b>6.970</b>
1 : 2	3.99	4.11	4.20	4.20	<b>4.124</b>
2: 1	1.92	1.84	2.01	2.17	<b>1.99</b>
2: 2	2.31	2.55	2.69	2.86	<b>2.60</b>
Mean (K)	<b>3.82</b>	<b>4.01</b>	<b>4.18</b>	<b>3.68</b>	
L.S.D. at 5 %	For (I)= 0.17		For (K)= 0.04	For (I×K)= 0.18	
<b>Second season</b>					
Sole garlic	6.06	7.51	7.96	8.17	<b>7.42</b>
1 : 2	3.55	4.00	4.29	5.30	<b>4.28</b>
2: 1	1.39	1.79	2.14	2.27	<b>1.90</b>
2: 2	2.29	2.48	2.56	2.96	<b>2.57</b>
Mean (K)	<b>3.32</b>	<b>3.94</b>	<b>4.24</b>	<b>4.67</b>	
L.S.D. at 5 %	For (I)= 0.09		For (K)= 0.02	For (I×K)= 0.09	

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## دور تحميل الكراوية والثوم على النمو والمحصول تحت مستويات مختلفة من التسميد البوتاسي

نورهان محمد السعيد منصور خشبة، داليا أحمد سامي نوار، محمد أحمد إبراهيم عبد القادر

قسم البساتين – كلية الزراعة – جامعة الزقازيق – مصر.

أجريت تجربة حقلية في مزرعة خاصة بقريّة طحا المرج، مركز ديرب نجم، محافظة الشرقية، مصر خلال موسمي الشتاء المتتاليين لأعوام 2021/2020 و 2022/2021. أجريت هذه التجربة لدراسة تأثير نظم التحميل بين الكراوية: الثوم بنسب خطوط مختلفة (المحصول المنفرد لكل منها ككنترول، 1: 2 ، 2: 1 و 2: 2، على التوالي)، معدلات البوتاسيوم المختلفة (صفر، 25 ، 50 و 75 كجم من بوزر/أفدان) والتداخل بينهما على النمو والمحصول لنباتات الكراوية والثوم. وزعت نظم التحميل في قطع الأرض الرئيسية ووزعت معدلات التسميد بالبوتاسيوم في القطع الفرعية. أدى تبادل صفين من الكراوية مع صفين من الثوم إلى زيادة معنوية في طول النبات، وعدد الأفرع لكل نبات، والوزن الطازج للنبات، وعدد الثورات لكل نبات، ومحصول الثمار لكل نبات مقارنة بزراعة الكراوية المنفردة. كذلك فإن استخدام نظام التحميل 1: 2 أعطى أعلى القيم لكل من طول النبات والوزن الطازج للنبات والوزن الطازج للأبصال مقارنة بزراعة الثوم منفرداً. علاوة على ذلك، فإن أعلى معدل من التسميد البوتاسي (75 كجم من بوزر/أفدان) اعطي أعلى القيم في صفات النمو ومكونات المحصول لنباتات الكراوية والثوم مقارنة بالكنترول. سجل المحصول المنفرد من الكراوية والثوم أعلى قيم محصول الثمار والأبصال للفدان مقارنة بنظم التحميل الأخرى قيد الدراسة. عموماً، فإن معاملات التداخل بين نظم التحميل والتسميد البوتاسي أثرت على النمو ومكونات المحصول لكلا المحصولين وكانت أفضل معاملة تداخل في هذا الصدد 2: 2 للكراوية و 1: 2 للثوم مع التسميد البوتاسي بمعدل 75 كجم بوزر/أفدان.

### المحكمون:

1- أستاذ نباتات الزينة والطبية والعطرية- كلية الزراعة بأسسيوط – جامعة الأزهر.  
2- أستاذ الخضر- كلية الزراعة – جامعة الزقازيق.

1- أ.د. السيد حماد عامر حماد  
2- أ.د. أحمد عبدالله محمود محسن