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STUDY OF CARAWAY AND PEA INTERCROPPING SYSTEMS IN TERMS OF GROWTH, PRODUCTIVITY AND COMPETITION INDICES UNDER DIFFERENT PHOSPHORUS FERTILIZATION LEVELS

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ABSTRACT: Due to the importance of intercropping as one of the methods of agricultural intensification, this research was conducted on caraway and pea crops at Experimental Farm, Fac. Agric., Zagazig Univ., Egypt during 2021/2022 and 2022/2023 seasons. The aim of this work was studying the influence of intercropping system (sole planting of each crop as control, 1: 1, 2: 2, 2: 3 and 3: 2 as ridge ratio of caraway: pea, respectively), phosphorus fertilization levels (0.00, 15.50, 31.00 and 46.50 kg P_2O_5/feddan) as well as their combination treatments on growth, productivity and competitive indices between caraway and pea plants. Results showed that, in most cases, alternating two ridges of caraway with two ridges of pea recorded the highest values in plant height, branches number per plant and total dry weight of both crops, fruits and volatile oil yield per caraway plant and pods yield per pea plant as well as total chlorophyll content and phosphorus percentage of both crops compared to the other intercropping systems. Additionally, the most of the measured parameters for the two crops showed a substantial rise at the maximum level of phosphorus fertilization. When compared to the other combinations, the 2: 2 intercropping system + 46.50 kg P_2O_5/feddan treatment was the most effective. Generally, land equivalent ratio referred to that using the intercropping system of 2: 2 and phosphorus fertilization at 46.5 kg P_2O_5/ feddan, one feddan may yield the same yield as 1.386 or 1.453 feddan of each crop grown separately.

Key words: Caraway, pea, intercropping, growth, productivity, competitive indices.

INTRODUCTION

Caraway (*Carium carvi* L.) is classified as an annual, aromatic herbaceous plant that is a member of the *Apiaceae* family (**Bailer *et al.*, 2001**). Caraway is believed to be a component in feed that enables cattle to produce more milk, improve their flavor, digestion, and gas production. When potatoes are stored, generally, volatile oil of caraway is used to prevent natural sprouting (**Kleinkopf *et al.*, 2003**). According to **Dyduch *et al.* (2006)**, caraway also has antibacterial, analgesic, antispasmodic, depletory and antioxidant properties. Another species that was examined in this study was *Pisum sativum* L., commonly known as pea. Pea is an annual crop classified under the *Leguminosae* family. Pea is one of the main winter crops farmed in Egypt for both domestic and international trade. Due to their high level of carbs, minerals, vitamins and proteins, pea seeds, whether fresh or dried, have a high nutritional value (**Smart**, **1990**).

The sowing of two or more agricultural crops in one field that are distinct from one another in terms of the length of their respective growing seasons as well as their biological and agronomic properties is known as intercropping (**Hiddink *et al.*, 2010**). The primary objective of the multi-cropping approach is to identify and leverage the synergistic interactions between distinct yet complementary plant species, wherein the combined cultivation of these plants yields superior outcomes compared to their individual cultivation (**Gill *et al.*, 2009;**

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Mahapatra, 2011). In order to increase resource usage and environmental conditions, intercropping is crucial for boosting productivity and yield stability (**Alizadeh *et al*., 2010**). Furthermore, **Khashaba *et al*. (2023)** pointed out that, in comparison to sole planting of caraway, two rows of caraway alternated with two rows of garlic dramatically boosted plant height, branch count, fresh weight, umbel count per plant and fruit output per plant. Additionally, compared to solitary garlic planting, the 1:2 intercropping system produced the highest values for plant fresh weight, plant height and bulb fresh weight.

With phosphorus accounting up roughly 0.2% of a plant's dry weight, it is thought to be a significant macronutrient for plants. It is a part of important compounds like ATPs, phospholipids, and nucleic acids. The modulation of enzyme reactions, metabolic pathway regulation, energy transmission, photosynthesis, transformation of carbohydrates, and production of oils are only a few of the activities it plays in plants (**Marschner, 1995**). Phosphorus is a very serious nutrient for plants, especially legumes. It is thought to be the second most important chemical for plants. Even though a lot of phosphorus is added to soil, the amount that plants can use is generally low (**Holford, 1997**). Moreover, significant increases were noticed in sweet fennel growth as well as yield and its attributes by increasing phosphorus fertilization levels (**Zaki *et al*., 2019**).

In addition, **Abdelkader and Hassan (2016)** reported that at a rate of 30 kg P_2O_5/feddan, the usage of P rates for both crops in a 1:2 intercropping system increased dill and fenugreek growth, yield, and active components while also maximizing land equivalent ratio and land utilization efficiency.

Therefore, the main objectives of this study was to i) evaluate the influence of intercropping systems on enhancing the growth and productivity of both caraway and pea plants, ii) notice the impact of phosphorus fertilization levels on improving the two crops productivity and iii) determined the impact of combination influence between intercropping system as well as phosphorus fertilization on competitive indices of caraway and pea yields.

MATERIALS AND METHODS

The present investigation was conducted in the Experimental Farm, Faculty of Agriculture, Zagazig University, Egypt, throughout the course of two consecutive winter seasons, specifically from 2021 to 2022 and 2022 to 2023. Aiming to evaluate the influence of intercropping system under different phosphorus fertilization levels on growth and yield components of caraway and pea as well as volatile oil production of caraway and some chemical constituents and competitive indices between both crops. According to **Chapman and Pratt (1978)**, the mechanical and chemical characteristics of the experimental soil (average of the two seasons) were provided in Table 1.

Experimental Units and Sowing

The experimental unit area was 36 m^2 (4.00 × 9.00 m) included fifteen ridges. Each ridge was 60 cm wide and 4 meters in length. Caraway fruits (about 4: 5 fruits) were sown in hills on one side of the ridge, and hills were spaced 30 cm, a part. After 20 days from sowing time, seedlings were thinned to be two plants/ hill. Whereas, pea (cv. Master B) seeds (about 1: 2 seeds) were sown in hills on both sides of the ridge, and hills were spaced 15 cm, a part. The sowing time was 24th and 28th October in 1st and 2nd seasons, respectively. The surface irrigation system was utilized in the current study.

Treatments

This experiment included 20 treatments. The experiment contained two main factors for the study; the first factor was 5 treatments of intercropping systems and 4 treatments of the level of phosphate fertilization. The phosphorus source was calcium superphosphate (15.5% P_2O_5). Each level (0.0, 15.5, 31.0 and 46.5 kg P_2O_5/ feddan) was applied during soil preparation. In addition, intercropping systems under study were as follows:

1. Sole planting of caraway and pea which were utilized as control.
2. By alternating 1 ridge of caraway with 1 ridge of pea, the 1:1 intercropping system was used.
3. By alternating 2 ridges of caraway with 2 ridges of pea, the 2: 2 intercropping system was used.
4. By alternating 2 ridges of caraway with 3 ridges of pea, the 2: 3 intercropping system was used.
5. By alternating 3 ridges of caraway with 2 ridges of pea, the 3: 2 intercropping system was used.

Table 1. Mechanical and chemical characteristics of experimental soil (average of two seasons)

Mechanical characteristics			Soil texture
Clay (%)	Silt (%)	Sand (%)	Clayey
55.16	29.72	15.12	

Chemical characteristics										
pH	E.C. dSm^{-1}	Organic matter (%)	$CaCO_3$ (%)	Soluble cations (meq./ L)				Soluble anions (meq. /L)		
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
8.04	2.32	0.56	0.47	11.93	9.26	4.32	5.06	8.75	5.65	16.17

Available nutrient (mg kg^{-1}soil)						
N	P	K	Fe	Zn	Cu	Mn
36.35	25.43	189	1.78	0.59	0.54	0.48

Experimental Design

The present work employed a split-plot experimental design, consisting of three repetitions and a total of 20 treatments. These treatments were formed by combining five different intercropping methods with four distinct amounts of phosphorus fertilization. The distribution of intercropping system treatments was randomized across the main plots, whereas the distribution of phosphorus levels was randomized across the sub-plots.

When necessary, all suggested agricultural methods for cultivating caraway and pea plants were followed. During the soil preparation procedure, potassium fertilizer was added to the soil at a rate of 50 kg/feddan of potassium sulphate (50% K_2O). While three equal amounts of ammonium sulfate (20.5% N) nitrogen fertilizer in the form of 150 kg/feddan were applied to the soil 30, 60, and 90 days after sowing.

Measurements

Plant growth traits

After 90 days from the time of planting for caraway traits and 55 days for pea traits, plant height (cm), the number of branches per plant, and the total dry weight (g) of the plant were measured.

Yield components

At harvesting time, umbels number per plant, fruit yield per plant (g) and per feddan (kg) of caraway were recorded (at 150 days after sowing). Also, number of pods per plant, green pods yield per plant (g) and per feddan (ton), pod length (cm) and seeds number per pod of pea were listed (at 78-105 days after sowing).

Chemical constituents

The essential oils were ultimately extracted from air-dried caraway fruits by hydro distillation, which was utilized to separate the volatile oil (**Guenther, 1961**). The plant's volatile oil yield (ml) was calculated by multiplying that quantity by the percentage of volatile oils that were present in the fruit that the plant produced. We calculated the amount of volatile oil produced in each treatment by dividing the amount of volatile oil produced per caraway plant by the weight of the fruits produced per feddan (l). After 70 days from the planting date, the total chlorophyll content (SPAD unit) of fresh caraway and pea leaves (the upper 4 or 5 leaves in the plant) was assessed using a SPAD-502 meter, as described by **Markwell *et al.* (1995)**. In addition, **Hucker and Catroux (1980)** were used to calculate the total phosphorus percentage of pea seeds and caraway fruits.

Competitive Indices

Land equivalent ratio (LER)

This gives a general idea of how much acreage is needed for a single crop to generate the same amount as an intercropping system. The value one is most crucial for this goal. a method of intercropping that boosts component yields when the LER is higher than 1. However, intercropping has a negative impact on the growth and productivity of the two components being co-cultivated when LER is less than one. The following equation was used to determine the caraway and pea yield per feddan:

$$LER = Lc + Lp$$

$$Lc = \frac{Ycp}{Ycc}, \quad Lp = \frac{Ypc}{Ypp}$$

Where Ycc and Ypp are the yields per feddan of caraway and pea, respectively, as sole plantings and Ycp and Ypc are the yields of intercropping of caraway and pea, respectively, as intercrops (Mead and Willey, 1980). Lc is the relative yield of caraway, Lp is the relative yield of pea.

Area× Time Equivalent Ratio (ATER)

It was calculated according to the following equation:

$$ATER = \frac{Ycp/Ycc \times tc + Ypc/Ypp \times tp}{T}$$

Where: tc = the duration of caraway in days, tp = the duration period of pea in days, and T = the overall duration of the intercropping system in days (**Hiebsch and McCollum, 1987**). Ycp = Intercrop yield of caraway, Ycc = Sole yield of caraway, Ypc = Intercrop yield of pea, and Ypp = Sole yield of pea.

Land Utilization Efficiency percentages (LUE %)

The land utilization efficiency percentage (LUE %) was calculated by utilizing each LER and ATER values, according to **Mason *et al.* (1986**) equation as next:

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

Aggressivity (A)

Positive aggressivity values for any component indicate that this crop was the dominant species, while negative values for another component indicate that it was the dominated species. Moreover, Aggressivity value was calculated according to **Mc Gilchrist (1965)** equation as follows:

1. For combination of 1:1, 2:2 they were calculated according to the following equations:

$Acp = Lc - Lp$, $Apc = Lp - Lc$

2. For the other combination ratios (2: 3 and 3: 2), the equations used were:

$$Acp = \frac{Ycp}{Ycc \times Zcp} - \frac{Ypc}{Ypp \times Zpc}$$

$$Apc = \frac{Ypc}{Ypp \times Zpc} - \frac{Ycp}{Ycc \times Zcp}$$

Where: Acp= Aggressivity value for caraway against pea plants, Apc= Aggressivity value for pea against caraway plants, Ycp = Intercrop yield of caraway, Ypc = Intercrop yield of pea, Ycc = Sole yield of caraway, Ypp = Sole yield of pea, Zcp = Sowing proportion of caraway and Zpc = Sowing proportion of pea.

Statistical Analysis

Utilizing the computer application Statistix version 9 (**Analytical Software, 2008**), the data from the current study were statistically evaluated, and differences between the means of the treatments were deemed significant when they exceeded the least significant differences (LSD) at the 5% level.

RESULTS AND DISCUSSION

Influence of Intercropping System and Phosphorus Levels Treatments on Growth, Yield Components and Chemical Constituents of Caraway Plants

Intercropping system

Results presented in Table 2 show that in most cases intercropping systems between caraway and pea plants significantly increased caraway plant height, number of branches and total dry weight in both seasons (2021/2022 and 2022/ 2023)

Table 2. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A×B) on growth traits of caraway plant at 90 days after sowing during 2021/2022 and 2022/2023 seasons

Treatments		Growth Parameters					
		Plant height (cm)		Branches number		Total dry weight (branches+ leaves) (g)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)							
Sole caraway		115.08	112.08	8.33	9.42	44.36	44.23
1: 1		117.17	119.58	11.50	11.17	46.09	45.06
2: 2		129.08	128.67	12.00	12.58	48.31	48.69
2: 3		127.50	129.67	11.92	12.50	47.29	47.77
3: 2		121.92	119.75	11.00	10.92	44.18	44.79
L.S.D. at 5 %		**0.65**	**0.84**	**0.55**	**0.44**	**0.32**	**0.39**
Phosphorus fertilization level (kg P_2O_5/ fed.)							
Control (0.00)		118.87	115.60	9.47	9.73	44.02	43.29
15.50		120.33	120.87	10.67	10.87	45.86	44.89
31.00		123.60	123.87	11.47	12.13	46.45	46.88
46.50		125.80	127.47	12.20	12.53	48.13	49.36
L.S.D. at 5 %		**0.95**	**1.25**	**0.54**	**0.47**	**0.26**	**0.30**
Combination influence between intercropping systems and phosphorus fertilization							
Sole caraway	**0.00**	112.67	107.67	7.33	8.33	42.38	41.47
	15.50	114.33	109.33	7.67	8.33	44.08	42.84
	31.00	114.67	111.00	8.67	10.33	44.38	45.56
	46.50	118.67	120.33	9.67	10.67	46.59	47.05
1: 1	**0.00**	113.00	110.67	10.00	9.67	45.07	42.52
	15.50	115.33	119.67	11.67	10.67	45.81	43.26
	31.00	119.00	122.67	12.00	12.33	46.33	45.94
	46.50	121.33	125.33	12.33	12.00	47.15	48.51
2: 2	**0.00**	125.33	121.00	10.67	11.33	45.97	45.26
	15.50	127.67	129.67	11.67	12.33	47.92	48.12
	31.00	131.33	132.33	12.33	13.00	49.05	49.14
	46.50	132.00	131.67	13.33	13.67	50.30	52.23
2: 3	**0.00**	124.33	123.67	9.67	10.67	45.00	44.77
	15.50	125.67	129.33	11.67	12.33	46.78	46.06
	31.00	129.67	131.33	13.00	13.33	47.46	48.99
	46.50	130.33	134.33	13.33	13.67	49.90	51.26
3: 2	**0.00**	119.00	115.00	9.67	8.67	41.67	42.43
	15.50	118.67	116.33	10.67	10.67	43.33	44.19
	31.00	123.33	122.00	11.33	11.67	45.04	44.79
	46.50	126.67	125.67	12.33	12.67	46.70	47.76
L.S.D. at 5 %		**1.95**	**2.56**	**1.17**	**1.01**	**0.59**	**0.70**

compared to sole planting. The highest values in this concern were achieved with 2: 2 and 2: 3 systems with significant differences when compared to control and the other two ones under study. In addition, the highest number of umbels number per plant (38.00 and 38.42 and 38.67 and 38.58 umbels/plant) and fruit yield per plant (19.77 and 18.58 and 18.72 and 18.39 g/plant) were recoded when 2 ridges of caraway plants alternating with 2 or 3 ridges of pea plants in 1st and 2nd seasons, respectively (Table 3). Moreover, all intercropping systems enhanced volatile oil percentage and yield per plant compared with sole planting system in the two consecutive seasons (Table 4). While, sole planting of caraway gave a significant increase in fruit and volatile oil yields per feddan compared to all intercropping systems under study in both seasons (Tables 3 and 4). In general, alternating 2 ridges of caraway with 2 ridges of pea significantly increased total chlorophyll content in leaves and total phosphorus percentage in fruits compared to sole caraway planting (Table 5).

This conclusion was in line with the widely held belief that plants benefit from the direct transfer of fixed N_2 in legume (pea) and non-legume (caraway) intercropping systems (**Graham and Vance, 2000**). Additionally, intercropping fennel with vegetables such as carrot, onion, and garlic had a significant impact on the growth parameters of fennel and increased plant height, dry matter accumulation, the number of branches per plant, and yield attributes when carrot was used in ratios of 1:1, 1:2 and 2:2 compared to onion and garlic (**Mehta *et al*., 2015**). According to **Gendy *et al.* (2017)**, when roselle plants were intercropped with cowpea, the greatest values of all recorded parameters (number of branches/plant, total dry weight, number of roselle fruits/plant, dry sepals yield/ plant, and anthocyanin content) were recorded. Also, **Mohammadzadeh *et al.* (2022)**, intercropping marjoram with mung bean had a considerable positive influence on the plant's productivity and the quality of its essential oil.

Phosphorus level

The results obtained are shown in Table 2, which demonstrates that plant height, branch count per plant, and total dry weight of caraway plants rose with increasing phosphorus levels at 90 days after sowing time compared to control in both seasons. Fertilized caraway plants with 46.5 kg P_2O_5/feddan significantly increased number of umbels per plant as well as fruit yield per plant and per feddan compared to the other levels under study (Table 3). Generally, all phosphorus fertilization levels under study recorded a significant improve in volatile oil production of caraway compared to control in the two tested seasons (Table 4). Likewise, total chlorophyll content as SPAD unit and total phosphorus percentage significantly increased by using 46.5 kg P_2O_5/feddan compared to the other ones under study (Table 5). The increase in total chlorophyll content was about 2.31 and 2.38 (SPAD) for P fertilizer at 46.50 kg P_2O_5/feddan over the control in the 1st and 2nd seasons, respectively.

The superior effects of P fertilizer application on growth indices of dill and fenugreek plants can be attributed to P's role in the molecular structure of crucial molecules like DNA and RNA. Additionally, it is crucial for meristem tissues, cell division, and photosynthesis (**Marshner, 1995**). Moreover, **Sonmez (2018)** indicated that the 60 kg ha^{-1} phosphorus application produced the largest number of 1000-seed weight, seeds per umbel and essential oil content of anise plant.

Combination influence between intercropping system and phosphorus level

At 90 days after sowing time in both seasons, the intercropping system and phosphorus levels significantly affected the height, number of branches per plant, and total dry weight per plant of caraway (Table 2). In addition, the combination between intercropping systems 2: 2 as well as 2: 3 (2 ridges caraway: 2 or 3 ridges pea) and phosphorus fertilization at 46.50 kg P_2O_5/feddan increased umbels number per plant, fruit and volatile oil yield per plant (Table 3 and 4) and both of total chlorophyll content in leaves and phosphorus percentage in fruits (Table 5).

The simulative effect of intercropping systems 2: 2 and 2: 3 (50 and 40% caraway: 50 and 60% pea) and 46.50 kg P_2O_5/feddan on yield components may be due to that this treatment increased number of branches/ plant and total dry weight. Caraway growth traits were improved by phosphorus

Table 3. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A×B) on yield components of caraway plant during 2021/2022 and 2022/ 2023 seasons

Treatments		Yield components					
		Number of umbels per plant		Fruit yield per plant (g)		Fruit yield per feddan (kg)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)							
Sole caraway		33.09	33.58	14.82	13.35	658.86	593.12
1: 1		34.50	35.00	16.80	16.43	373.38	365.09
2: 2		38.00	38.42	19.77	18.58	439.29	412.88
2: 3		38.67	38.58	18.72	18.39	332.72	327.01
3: 2		35.17	35.58	16.87	16.86	374.83	374.77
L.S.D. at 5 %		**0.79**	**0.57**	**0.25**	**0.21**	**6.55**	**4.91**
Phosphorus fertilization level (kg P_2O_5/ fed.)							
Control (0.00)		32.73	32.73	16.23	15.49	406.36	385.65
15.50		35.40	35.13	16.69	15.90	419.17	394.69
31.00		36.67	37.47	17.57	17.04	441.36	421.42
46.50		38.73	39.60	19.09	18.46	476.37	456.55
L.S.D. at 5 %		**0.53**	**0.43**	**0.24**	**0.22**	**7.91**	**5.29**
Combination influence between intercropping systems and phosphorus fertilization							
Sole caraway	**0.00**	28.67	30.33	13.77	12.66	612.16	562.52
	15.50	33.00	31.33	14.37	12.79	638.82	568.31
	31.00	34.33	35.33	15.17	13.43	674.08	596.90
	46.50	36.33	37.33	15.98	14.51	710.38	644.75
1: 1	**0.00**	32.33	31.67	15.99	15.37	355.35	341.64
	15.50	34.00	33.67	16.59	15.75	368.61	349.94
	31.00	34.67	36.33	16.71	16.73	371.27	371.79
	46.50	37.00	38.33	17.92	17.86	398.31	396.97
2: 2	**0.00**	35.00	33.67	17.84	17.15	396.46	381.12
	15.50	36.67	37.67	18.53	17.32	411.72	384.98
	31.00	38.67	39.67	20.38	18.56	452.98	412.39
	46.50	41.67	42.67	22.32	21.29	496.01	473.05
2: 3	**0.00**	34.33	35.33	17.36	16.64	308.57	295.89
	15.50	38.67	38.33	17.53	17.47	311.65	310.58
	31.00	40.33	39.33	18.65	19.00	331.56	337.84
	46.50	41.33	41.33	21.32	20.46	379.09	363.74
3: 2	**0.00**	33.33	32.67	16.17	15.62	359.27	347.05
	15.50	34.67	34.67	16.43	16.18	365.05	359.64
	31.00	35.33	36.67	16.96	17.47	376.90	388.16
	46.50	37.33	38.33	17.91	18.19	398.09	404.24
L.S.D. at 5 %		**1.29**	**1.01**	**0.52**	**0.48**	**16.64**	**11.35**

Table 4. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A × B) on volatile oil production of caraway plant during 2021/2022 and 2022/2023 seasons

Treatments		Volatile oil production					
		Volatile oil (%)		Volatile oil yield/ plant (ml)		Volatile oil yield/ feddan (l)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)							
Sole caraway		2.49	2.48	0.369	0.331	16.43	14.72
1: 1		2.50	2.50	0.421	0.410	9.34	9.14
2: 2		2.66	2.61	0.528	0.488	11.72	10.82
2: 3		2.62	2.63	0.490	0.483	8.73	8.60
3: 2		2.51	2.49	0.422	0.422	9.40	9.35
L.S.D. at 5 %		**0.01**	**0.01**	**0.007**	**0.006**	**0.18**	**0.11**
Phosphorus fertilization level (kg P_2O_5/ fed.)							
Control (0.00)		2.50	2.49	0.406	0.385	10.13	9.57
15.50		2.54	2.53	0.424	0.403	10.63	9.96
31.00		2.57	2.56	0.453	0.437	11.32	10.75
46.50		2.61	2.60	0.501	0.481	12.41	11.82
L.S.D. at 5 %		**0.01**	**0.01**	**0.006**	**0.006**	**0.19**	**0.14**
Combination influence between intercropping systems and phosphorus fertilization							
Sole caraway	**0.00**	2.47	2.46	0.340	0.310	15.09	13.82
	15.50	2.49	2.48	0.357	0.320	15.89	14.09
	31.00	2.51	2.49	0.380	0.333	16.92	14.88
	46.50	2.51	2.49	0.400	0.360	17.81	16.07
1: 1	**0.00**	2.47	2.47	0.397	0.380	8.77	8.44
	15.50	2.49	2.50	0.410	0.390	9.17	8.74
	31.00	2.51	2.52	0.423	0.420	9.33	9.36
	46.50	2.53	2.52	0.453	0.450	10.08	10.02
2: 2	**0.00**	2.56	2.49	0.457	0.427	10.15	9.50
	15.50	2.65	2.58	0.493	0.447	10.90	9.93
	31.00	2.67	2.63	0.543	0.490	10.08	10.84
	46.50	2.77	2.75	0.620	0.587	13.76	13.01
2: 3	**0.00**	2.52	2.56	0.440	0.423	7.79	7.56
	15.50	2.58	2.61	0.450	0.457	8.05	8.11
	31.00	2.63	2.65	0.490	0.503	8.73	8.95
	46.50	2.73	2.69	0.580	0.550	10.34	9.80
3: 2	**0.00**	2.46	2.46	0.397	0.387	8.84	8.54
	15.50	2.50	2.48	0.410	0.403	9.14	8.93
	31.00	2.53	2.50	0.430	0.437	9.52	9.72
	46.50	2.53	2.52	0.450	0.460	10.09	10.20
L.S.D. at 5 %		**0.02**	**0.02**	**0.014**	**0.014**	**0.41**	**0.28**

Table 5. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A×B) on total chlorophyll content (SPAD) in leaves and total phosphorus percentage in fruits of caraway plant during 2021/2022 and 2022/2023 seasons

Treatments		Chemical constituents			
		Total chlorophyll content (SPAD unit)		Total phosphorus percentage	
		Seasons		Seasons	
		1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)					
Sole caraway		32.50	32.01	0.535	0.519
1: 1		32.84	32.83	0.537	0.544
2: 2		35.01	34.60	0.636	0.637
2: 3		34.56	33.74	0.633	0.615
3: 2		33.37	32.89	0.537	0.549
L.S.D. at 5 %		**0.17**	**0.44**	**0.010**	**0.006**
Phosphorus fertilization level (kg P_2O_5/ fed.)					
Control (0.00)		32.61	31.96	0.529	0.522
15.50		33.27	32.90	0.551	0.560
31.00		33.83	33.65	0.590	0.583
46.50		34.92	34.34	0.632	0.626
L.S.D. at 5 %		**0.21**	**0.33**	**0.008**	**0.005**
Combination influence between intercropping systems and phosphorus fertilization					
Sole caraway	**0.00**	32.45	31.45	0.514	0.501
	15.50	32.63	31.70	0.529	0.511
	31.00	31.86	32.16	0.539	0.519
	46.50	33.05	32.74	0.559	0.543
1: 1	**0.00**	32.08	31.76	0.522	0.515
	15.50	32.84	32.58	0.524	0.543
	31.00	33.26	33.52	0.533	0.553
	46.50	33.17	33.44	0.569	0.566
2: 2	**0.00**	33.22	32.63	0.540	0.543
	15.50	34.19	33.64	0.604	0.617
	31.00	35.30	35.62	0.653	0.650
	46.50	37.34	36.49	0.747	0.736
2: 3	**0.00**	33.07	32.01	0.555	0.538
	15.50	34.14	33.54	0.579	0.586
	31.00	34.67	33.95	0.690	0.640
	46.50	36.38	35.45	0.707	0.695
3: 2	**0.00**	32.21	31.96	0.514	0.514
	15.50	32.55	33.04	0.520	0.542
	31.00	34.07	32.97	0.537	0.553
	46.50	34.66	33.57	0.577	0.588
L.S.D. at 5 %		**0.43**	**0.77**	**0.018**	**0.013**

fertilization treatments as well as the intercropping method (each separately). They may therefore exert more of an effect when grown together, boosting the fruit and volatile oil yields of caraway intercropped with pea. These findings are consistent with those made by **Abdelkader *et al.* (2019)**, who found that coriander intercropped with pea at a 1: 2 system and fertilized with 90 kg N/feddan was the best combination treatment for enhancing plant growth, yield components, and volatile oil production.

Influence of Intercropping System and Phosphorus Levels Treatments on Growth, Yield Components and Chemical Constituents of Pea Plants

Intercropping system

Results in Table 6 indicate that, in most cases, plant height, number of branches and total dry weight per pea plant significantly increased when 2 ridges of caraway intercropped with 3 ridges of pea compared to sole crop in both seasons. All intercropping systems under study significantly increased pods number per plant, pods yield per plant, pod length and number of seeds per pod compared to sole pea planting during the two seasons (7 and 8). Furthermore, alternating two ridges of caraway with two ridges of pea (2: 2 system) recorded higher increase in total chlorophyll in leaf tissues of pea as well as total phosphorus percentage in pea seeds compared to sole pea planting (Table 9).

In addition, **Mohamed (2013)** demonstrated that compared to other intercropping treatments and solitary pea, intercropping pea with *Carium carvi* enhanced pea fresh and dry weight as well as the weight of 100 seeds for both seasons. On the other hand, the intercropping with *Cuminum cyminum* and *Nigella sativa*, had the lowest results. In contrast, **Abou-El-Hassan *et al.* (2018)** revealed that the highest values of all vegetative growth traits (plant length, leaf number/plant and plant fresh weight), nutritional status (total phosphorus %) and yield (diameter and weight of pea pod and total yield per feddan) of pea and green onion were recorded with sole planting (control).

Phosphorus level

Table 6's findings demonstrate that increasing phosphorus fertilization levels gradually enhanced plant height, branch count, and overall dry weight of the pea plant. Compared to the other levels under study in both seasons, the level of 46.5 kg P_2O_5/feddan yielded the highest mean results in this regard. Moreover, the highest mean values of number of pods per plant, green pods yield per plant and per feddan (24.20 and 25.96 pods/ plant and 36.91 and 37.29 pods yield/ plant as g and 1.993 and 2.005 pods yield/ feddan as ton) were achieved when pea plants fertilized with 46.5 kg P_2O_5/feddan level in the first and second seasons, respectively, compared to control and the other levels under study (Table 7). Using any phosphorus fertilization level significantly increased pod length and seeds number per pod compared to control (Table 8). Total chlorophyll content in pea leaves and total phosphorus percentage in pea seeds increased gradually as phosphorus fertilization levels increased in both seasons (Table 9).

The availability of mineral phosphorus to the roots of pea plants supplemented with phosphorus fertilizer may have improved root growth and increased mineral absorption, which in turn led to an increase in the number of pods/plant and an increase in the overall yield of pods per feddan. According to **El-Abd *et al.* (2013)**, fertilizing Master B pea plants with mineral phosphorus at a rate of 50 kg P_2O_5/feddan led to the most pronounced increases in vegetative growth, green pod output, and quality. According to **Khan *et al.* (2021)**, plants treated with 90 kg ha^{-1} of phosphorus showed the highest absolute growth rate, pods $plant^{-1}$, pod length, 100 seed weight, and yield ha^{-1}.

Combination influence between intercropping system and phosphorus level

Results of both seasons under discussion in Tables 6 and 7 indicates that, the combination between intercropping systems of 2: 2 and 2: 3 and phosphorus fertilization levels of 31.0 and 46.50 kg P_2O_5/feddan increased growth traits of pea plants, number of pods/ plant and pods yield per plant compared to control in both seasons. The longest pods and more seeds per pod were recorded under the combination treatment of 2: 2 intercropping system with 46.50 kg P_2O_5/ feddan level compared to the other combination treatments under study (Table 8). In the same time, the best combination treatment between intercropping system and phosphorus fertilization regard total chlorophyll content and total phosphorus

Table 6. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A × B) on growth traits of pea plant at 55 days after sowing during 2021/ 2022 and 2022/2023 seasons

Treatments		Growth Parameters					
		Plant height (cm)		Branches number		Total dry weight (g)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)							
Sole pea		51.75	53.25	3.36	3.36	14.47	14.26
1: 1		54.33	56.17	3.47	3.69	15.10	14.87
2: 2		54.58	58.33	4.06	3.97	18.94	19.90
2: 3		59.58	58.17	4.06	4.22	19.38	20.27
3: 2		55.33	54.25	3.75	4.06	16.04	15.25
L.S.D. at 5 %		**0.80**	**0.75**	**0.13**	**0.07**	**0.34**	**0.67**
Phosphorus fertilization level (kg P_2O_5/ fed.)							
Control (0.00)		50.93	51.80	3.42	3.42	14.40	14.87
15.50		53.73	54.27	3.62	3.80	15.93	16.10
31.00		56.60	57.60	3.84	3.91	17.88	17.47
46.50		59.20	60.47	4.07	4.31	19.94	19.20
L.S.D. at 5 %		**0.80**	**0.61**	**0.10**	**0.15**	**0.33**	**0.30**
Combination influence between intercropping systems and phosphorus fertilization							
Sole pea	**0.00**	47.00	48.33	3.22	3.22	12.76	12.68
	15.50	50.67	51.33	3.33	3.44	13.63	13.75
	31.00	53.00	54.00	3.44	3.22	14.95	14.46
	46.50	56.33	59.33	3.44	3.56	16.54	16.15
1: 1	**0.00**	50.67	53.33	3.11	3.56	13.32	13.28
	15.50	52.67	53.67	3.44	3.44	14.02	13.58
	31.00	56.33	57.67	3.44	3.56	16.19	15.12
	46.50	57.67	60.00	3.89	4.22	16.87	17.48
2: 2	**0.00**	51.33	54.00	3.89	3.56	15.18	17.11
	15.50	53.33	56.00	4.00	4.11	18.15	19.40
	31.00	55.67	59.67	4.11	3.89	20.98	21.03
	46.50	58.00	63.67	4.22	4.33	21.45	22.07
2: 3	**0.00**	54.33	53.67	3.78	3.22	17.20	18.16
	15.50	58.67	57.00	3.89	4.22	18.48	19.52
	31.00	60.67	60.33	4.33	4.56	20.19	21.19
	46.50	64.67	61.67	4.22	4.89	21.67	22.19
3: 2	**0.00**	51.33	49.67	3.11	3.56	13.52	13.12
	15.50	53.33	53.33	3.44	3.78	15.38	14.22
	31.00	57.33	56.33	3.89	4.33	17.07	15.55
	46.50	59.33	57.67	4.56	4.56	18.18	18.12
L.S.D. at 5 %		**1.74**	**1.40**	**0.23**	**0.29**	**0.72**	**0.89**

Table 7. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A × B) on yield components of pea plant during 2021/2022 and 2022/ 2023 seasons

Treatments		Yield components					
		Pods number/ plant		Pods yield per plant (g)		Pods yield per feddan (ton)	
		Seasons		Seasons		Seasons	
		1st	2nd	1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)							
Sole pea		18.05	19.42	29.37	28.81	2.611	2.561
1: 1		20.22	23.25	31.40	31.96	1.396	1.421
2: 2		24.00	24.58	37.64	39.50	1.673	1.756
2: 3		24.17	24.92	34.69	35.76	1.850	1.907
3: 2		19.47	18.75	30.22	31.21	1.343	1.387
L.S.D. at 5 %		**0.49**	**0.61**	**0.78**	**0.46**	**0.066**	**0.023**
Phosphorus fertilization level (kg P_2O_5/ fed.)							
Control (0.00)		18.47	18.80	29.12	29.61	1.588	1.601
15.50		19.91	20.91	31.00	32.20	1.685	1.743
31.00		22.16	23.33	33.62	34.70	1.831	1.876
46.50		24.20	25.69	36.91	37.29	1.993	2.005
L.S.D. at 5 %		**0.27**	**0.31**	**0.35**	**0.49**	**0.021**	**0.026**
Combination influence between intercropping systems and phosphorus fertilization							
Sole pea	**0.00**	16.22	17.44	26.87	26.08	2.388	2.318
	15.50	16.67	17.56	28.10	28.28	2.498	2.514
	31.00	18.78	19.78	31.04	31.11	2.760	2.676
	46.50	20.55	22.89	31.46	30.77	2.796	2.735
1: 1	**0.00**	17.44	18.78	27.98	29.33	1.243	1.304
	15.50	17.78	22.11	31.43	31.30	1.397	1.391
	31.00	20.89	24.67	31.58	32.48	1.404	1.443
	46.50	24.78	27.44	34.61	34.73	1.538	1.543
2: 2	**0.00**	21.22	20.11	32.03	34.63	1.423	1.539
	15.50	23.22	24.22	35.23	38.04	1.566	1.691
	31.00	24.44	26.11	40.02	41.03	1.779	1.823
	46.50	27.11	27.89	43.27	44.30	1.923	1.969
2: 3	**0.00**	20.56	22.56	30.83	29.75	1.644	1.587
	15.50	23.78	24.22	32.57	34.28	1.737	1.828
	31.00	25.89	25.22	34.28	37.13	1.828	1.980
	46.50	26.44	27.67	41.08	41.87	2.191	2.233
3: 2	**0.00**	16.89	15.11	27.91	28.23	1.240	1.255
	15.50	18.11	16.44	27.66	29.07	1.229	1.292
	31.00	20.78	20.89	31.19	32.77	1.386	1.456
	46.50	22.11	22.56	34.13	34.77	1.517	1.545
L.S.D. at 5 %		**0.71**	**0.86**	**1.03**	**1.06**	**0.077**	**0.056**

Table 8. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A×B) on fruit quality of pea plant during 2021/2022 and 2022/2023 seasons

Treatments		Fruits quality			
		Pod length (cm)		Seeds number/ pod	
		Seasons		Seasons	
		1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)					
Sole pea		6.47	6.61	7.05	7.23
1: 1		6.92	7.00	7.41	7.29
2: 2		7.97	7.39	8.40	8.51
2: 3		7.54	7.65	8.04	8.41
3: 2		7.29	7.05	7.69	7.60
L.S.D. at 5 %		**0.13**	**0.018**	**0.017**	**0.11**
Phosphorus fertilization level (kg P_2O_5/ fed.)					
Control (0.00)		6.74	6.71	7.20	7.18
15.50		7.10	6.99	7.57	7.76
31.00		7.38	7.29	7.88	7.99
46.50		7.73	7.57	8.22	8.30
L.S.D. at 5 %		**0.10**	**0.014**	**0.15**	**0.16**
Combination influence between intercropping systems and phosphorus fertilization					
Sole pea	**0.00**	5.86	6.18	6.67	6.55
	15.50	6.49	6.38	7.03	7.26
	31.00	6.59	6.88	7.17	7.43
	46.50	6.92	7.01	7.33	7.68
1: 1	**0.00**	6.49	6.61	7.03	6.65
	15.50	6.91	6.98	7.23	7.23
	31.00	7.04	7.05	7.47	7.50
	46.50	7.21	7.35	7.90	7.76
2: 2	**0.00**	7.33	6.98	7.83	7.70
	15.50	7.73	7.15	8.07	8.36
	31.00	8.17	7.45	8.50	8.56
	46.50	8.63	7.98	9.20	9.43
2: 3	**0.00**	7.09	7.19	7.37	8.03
	15.50	7.24	7.48	8.11	8.30
	31.00	7.74	7.92	8.28	8.50
	46.50	8.09	7.02	8.40	8.80
3: 2	**0.00**	6.91	6.58	7.10	7.00
	15.50	7.11	6.98	7.40	7.63
	31.00	7.35	7.15	8.00	7.96
	46.50	7.78	7.48	8.27	7.82
L.S.D. at 5 %		**0.24**	**0.33**	**0.34**	**0.33**

Table 9. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A×B) on total chlorophyll content (SPAD) in leaves and total phosphorus percentage in seeds of pea plant during 2021/2022 and 2022/2023 seasons

Treatments		Chemical constituents			
		Total chlorophyll content (SPAD unit)		Total phosphorus percentage	
		Seasons		Seasons	
		1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)					
Sole pea		39.24	39.86	0.416	0.458
1: 1		41.04	40.38	0.430	0.475
2: 2		43.91	43.33	0.480	0.534
2: 3		41.24	41.68	0.443	0.493
3: 2		41.65	41.80	0.440	0.468
L.S.D. at 5 %		**0.13**	**0.18**	**0.008**	**0.005**
Phosphorus fertilization level (kg P_2O_5/ fed.)					
Control (0.00)		39.81	39.54	0.415	0.460
15.50		40.97	40.93	0.433	0.482
31.00		42.11	42.30	0.455	0.493
46.50		42.77	42.87	0.464	0.507
L.S.D. at 5 %		**0.15**	**0.09**	**0.005**	**0.005**
Combination influence between intercropping systems and phosphorus fertilization					
Sole pea	**0.00**	38.93	38.27	0.389	0.445
	15.50	39.09	40.11	0.405	0.455
	31.00	39.36	39.91	0.422	0.465
	46.50	39.59	41.14	0.449	0.465
1: 1	**0.00**	39.26	39.27	0.405	0.455
	15.50	40.36	39.41	0.425	0.469
	31.00	42.03	41.87	0.435	0.485
	46.50	42.53	40.97	0.455	0.489
2: 2	**0.00**	41.13	40.14	0.445	0.502
	15.50	43.39	43.84	0.459	0.529
	31.00	44.99	44.24	0.509	0.539
	46.50	46.13	45.11	0.509	0.565
2: 3	**0.00**	39.73	40.61	0.425	0.469
	15.50	40.43	40.97	0.439	0.489
	31.00	42.93	41.77	0.449	0.499
	46.50	41.86	43.37	0.459	0.515
3: 2	**0.00**	40.03	39.41	0.412	0.429
	15.50	41.56	40.31	0.439	0.469
	31.00	41.26	43.71	0.459	0.475
	46.50	43.76	43.77	0.449	0.499
L.S.D. at 5 %		**0.32**	**0.25**	**0.013**	**0.011**

percentage was 2: 2 system + 46.50 kg P_2O_5/ feddan (Table 9). Likewise, according to **Abdelkader *et al*. (2020)**, intercropping systems significantly impacted the yield components of dill or onions. In comparison to intercropping systems, the sole crop produced the greatest values for the onion yield components (grade 1, grade 2, exportable yield, marketable yield, and total yield).

Influence of Intercropping System and Phosphorus Levels Treatments on competitive indices between caraway and Pea Plants

Intercropping system

Results tabulated in Table 10 indicate that, the maximum mean values in LER (1.305 and 1.379), ATER (1.113 and 1.174) and LUE % (120.92 and 127.68) was obtained from the treatment at alternating 2 ridges of caraway with 2 ridges of pea in the 1st and 2nd seasons, respectively. This shows the efficiency of this system (2: 2) in benefiting from the environmental resources surrounding the plants and water and minerals in the soil by 120.92% and 127.68% in the 1st and 2nd seasons, respectively. Concerning aggressivity values as shown in Table 11, it is clear that caraway component crop under 1: 1, 2: 2 and 2: 3 intercropping systems as well as pea component crop under 3: 2 intercropping system was the dominant, whereas pea was the dominated one under all intercropping systems except that of 3: 2 system. According to **Abou-El-Hassan *et al.* (2018)**, all treatments had LER values more than 1, which is a solid predictor of the land productivity of pea and green onion crops. Also, **Mohamed *et al*. (2020)**, the intercropping system of 2: 2 ridges of cow pea and pearl millet crops, respectively, recorded the highest mean values of land equivalent ratio (LER) for both seasons. At all intercropping systems during the two seasons, cow pea and pearl millet were the dominant crops.

Phosphorus level

According to Table 10 analysis of the impact of phosphorus levels on the competitive indices of the two crops, the level of P_2O_5 (46.50 kg/fed.) significantly increased during both seasons in terms of the land equivalent ratio (LER), area-time equivalent ratio (ATER), and land utilization efficiency percentage (LUE%) when compared to the control. Moreover, intercropping systems was a positive sign for pea and negative for caraway thereby that pea was dominant while caraway was dominated. Additionally, the benefit of cultivating species (such as caraway and pea) together largely depends on the level of inter versus intra crop competition. When companion crops require different amounts of plant growth resources (such as light, water, and nutrients), there is less inter-crop competition compared to intra-crop competition. In the same time, the competitive indices (LER, ATER, and LUE) were considerably impacted by phosphorus rates, according to **Abdelkader *et al*. (2020).** It is clear from the aggressivity values that, in contrast to the dill component crop, the onion component crop were dominated by varying phosphorus levels.

Combination influence between intercropping system and phosphorus level

Data described in Table 10 show that, the combination between intercropping systems of 2: 2 followed by 2: 3 and phosphorus fertilization level at 46.50 kg P_2O_5/feddan recorded the highest values of LER, ATER and LUE % compared to 1: 1 system combined with 0.00 kg P_2O_5/feddan in both seasons. Generally, land equivalent ratio referred to that using the intercropping system of 2: 2 and phosphorus fertilization at 46.50 kg P_2O_5/feddan, one feddan may yield the same yield as 1.386 or 1.453 feddan of each crop grown solely. Except for the combination between the 3: 2 system and any phosphorus fertilization levels in the two seasons, all combination treatments between the intercropping system and phosphorus fertilization levels demonstrated that the caraway component crop was the dominating. These results are in accordance with those stated by **Abdelkader and Hassan (2016)** on dill when intercropped with fenugreek and fertilized with phosphorus and **Abdelkader *et al*. (2020)** on dill when intercropped with onion and fertilized with phosphorus.

Conclusion

According to the aforementioned findings, using a combination treatment of 46.50 kg P_2O_5/ feddan as calcium super phosphate and a 2: 2 system (caraway: pea) is preferable to other treatments and appears promising in the development of sustainable both crops production with a limited use of external inputs. The benefit of competitive indices (LER, ATER, and LUE %) between caraway and pea plants supported these treatment.

Table 10. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A×B) on competitive indices between caraway and pea crops during 2021/ 2022 and 2022/2023 seasons

Treatments		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 system (Caraway: pea as ridge ratio)							
1: 1		1.103	1.171	0.942	1.004	102.25	108.72
2: 2		1.305	1.379	1.113	1.174	120.92	127.68
2: 3		1.212	1.293	1.000	1.070	110.64	118.15
3: 2		1.084	1.173	0.930	1.011	100.71	109.19
L.S.D. at 5 %		**0.012**	**0.011**	**0.010**	**0.010**	**1.07**	**1.04**
Phosphorus fertilization level (kg P_2O_5/ fed.)							
Control (0.00)		1.162	1.220	0.988	1.036	107.47	112.84
15.50		1.164	1.235	0.986	1.050	107.51	114.25
31.00		1.149	1.259	0.975	1.071	106.18	116.50
46.50		1.230	1.302	1.037	1.102	113.35	120.16
L.S.D. at 5 %		**0.022**	**0.021**	**0.020**	**0.017**	**2.11**	**1.91**
Combination influence between intercropping systems and phosphorus fertilization							
1: 1	**0.00**	1.102	1.170	0.946	1.001	102.41	108.57
	15.50	1.137	1.169	0.969	1.003	105.31	108.62
	31.00	1.060	1.163	0.908	1.000	98.40	108.17
	46.50	1.111	1.180	0.946	1.011	102.87	109.55
2: 2	**0.00**	1.245	1.342	1.066	1.143	115.53	124.21
	15.50	1.272	1.350	1.084	1.148	117.76	124.91
	31.00	1.317	1.372	1.124	1.168	122.05	127.02
	46.50	1.386	1.453	1.180	1.238	128.35	134.56
2: 3	**0.00**	1.194	1.211	0.987	1.006	109.04	110.83
	15.50	1.184	1.274	0.975	1.056	107.95	116.47
	31.00	1.155	1.306	0.956	1.084	105.57	119.51
	46.50	1.318	1.381	1.083	1.135	120.02	125.82
3: 2	**0.00**	1.107	1.159	0.951	0.996	102.92	107.73
	15.50	1.064	1.147	0.916	0.993	99.04	106.99
	31.00	1.062	1.195	0.911	1.031	98.69	111.30
	46.50	1.103	1.192	0.940	1.023	102.17	110.72
L.S.D. at 5 %		**0.040**	**0.038**	**0.036**	**0.031**	**3.80**	**3.46**

Table 11. Influence of intercropping system (A), phosphorus fertilization level (B) and their combinations (A × B) on Aggressivity values between caraway and pea crops during 2021/2022 and 2022/2023 seasons

Treatments		Aggressivity			
		Aggressivity caraway for pea values		Aggressivity pea for caraway values	
		Seasons		Seasons	
		1st	2nd	1st	2nd
Intercropping system (Caraway: pea as ridge ratio)					
1: 1		+ 0.032	+ 0.060	- 0.032	- 0.060
2: 2		+ 0.027	+ 0.010	- 0.027	- 0.010
2: 3		+ 0.081	+ 0.140	- 0.081	- 0.140
3: 2		- 0.337	- 0.300	+ 0.337	+ 0.300
L.S.D. at 5 %		**0.034**	**0.024**	**0.034**	**0.024**
Phosphorus fertilization level (kg P_2O_5/ fed.)					
Control (0.00)		- 0.023	- 0.024	+ 0.023	+ 0.024
15.50		- 0.046	- 0.002	+ 0.046	+ 0.002
31.00		- 0.033	- 0.001	+ 0.033	+ 0.001
46.50		- 0.094	- 0.063	+ 0.094	+ 0.063
L.S.D. at 5 %		**0.026**	**0.030**	**0.026**	**0.030**
Combination influence between intercropping systems and phosphorus fertilization					
1: 1	**0.00**	+ 0.060	+ 0.045	- 0.060	- 0.045
	15.50	+ 0.017	+ 0.062	- 0.017	- 0.062
	31.00	+ 0.041	+ 0.083	- 0.041	- 0.083
	46.50	+ 0.010	+ 0.052	- 0.010	- 0.052
2: 2	**0.00**	+ 0.052	+ 0.013	- 0.052	- 0.013
	15.50	+ 0.017	+ 0.005	- 0.017	- 0.005
	31.00	+ 0.027	+ 0.009	- 0.027	- 0.009
	46.50	+ 0.010	+ 0.014	- 0.010	- 0.014
2: 3	**0.00**	+ 0.114	+ 0.173	- 0.114	- 0.173
	15.50	+ 0.060	+ 0.154	- 0.060	- 0.154
	31.00	+ 0.124	+ 0.182	- 0.124	- 0.182
	46.50	+ 0.027	+ 0.050	- 0.027	- 0.050
3: 2	**0.00**	- 0.319	- 0.325	+ 0.319	+ 0.325
	15.50	- 0.280	- 0.230	+ 0.280	+ 0.230
	31.00	- 0.325	- 0.277	+ 0.325	+ 0.277
	46.50	- 0.423	- 0.367	+ 0.423	+ 0.367
L.S.D. at 5 %		**0.056**	**0.057**	**0.056**	**0.057**

REFERENCES

Abdelkader, M.A.I. and H.M. S. Hassan (2016). Effects of intercropping pattern and phosphorus fertilizer rate on growth, yield, active ingredients and some competitive indices of dill and fenugreek plants. Minufiya J. Agric. Res., 41(1): 141-160.

Abdelkader, M.A.I., A.A. Fahmy and S.A. Bardisi (2020). Improving yield components and competitive indices of dill and onion components as influenced by intercropping system and phosphorus fertilization level. J. of Plant Production, Mansoura Univ., 11 (10): 885-892.

Abou-El-Hassan, S., M.M.H. Gad El-Moula and H.H. Abotaleb (2018). Response of pea and green onion to bacterial and mycorrhizal inoculation with low rate of mineral fertilizers under intercropping. Mid. East J. Appl. Sci., 8 (2): 612-624.

Alizadeh, Y., A. Koocheki and M.N. Mahallati (2010). Yield, yield components and potential weed control of intercropping bean (*Phaseolus vulgaris* L.) with sweet basil (*Ocimum basilicum* L.). Iranian J. Field Crops Res., 7 (2): 541-553.

Analytical Software (2008). Statistix Version 9, Analytical Software, Tallahassee, Florida, USA.

Bailer, J., T. Aichinger, G. Hackl, K. D. Hueber and M. Dachler (2001). Essential oil content and composition in commercially available dill cultivars in comparison to caraway. Industrial Crop and Prod., 14: 229-239.

Chapman, D.H. and R.F. Pratt (1978). Methods of Analysis for Soils, Plants and Waters. Div. Agric. Sci. Univ. Calif. USA, 16-38.

Dyduch, J., A. Najda and N. Brzozowski (2006). Gridgeth and chemical content of caraway (*Carum carvi*, L.) in the first year of cultivation. Folia. Hort., 1:108-112.

El-abd, S.O., M.F. Zaki, R.S.R El-Mohamedy and G.S. Riad (2013). Improving growth, fresh pod yield and quality, and controlling root rot and damping off of pea grown in sandy soil by integration effect of phosphorus fertilizer with biological seed treatments. Mid. East J. Agric. Res., 2 (1): 8-15.

Gendy, A.S.H., W.S. Nosir and D.A.S. Nawar (2017). Growth, yield components and some chemical constituents of roselle and cowpea as influenced by intercropping system and bio-fertilization type. Mid. East J. Appl. Sci., 7 (1): 195-205.

Gill, S., M. Abid and F. Azam (2009). Mixed cropping effects on growth of wheat (*Triticum aestivum* L.) and chickpea (*Cicer arietenum* L.). Pak. J. Bot., 41 (3):1029- 1036.

Graham, P.H. and C.P. Vance (2000). Nitrogen fixation in perspective: an overview of research and extension needs. Field crops Res., 65: 93-106.

Guenther, E. (1961). The Essential Oils. Vol. (1): D.von. Nostrand Comp., New York, 236.

Hiddink, G.A., A.J. Termorshuizen and A.H.C. Van Bruggen (2010). Mixed Cropping and Suppression of Soilborne Diseases. In Genetic Engineering, Bio-fertilization, Soil Quality and Organic Farming; Lichtfouse, E., Ed.; Sustainable Agriculture Reviews; Springer: Dordrecht, The Netherlands, 119–146.

Hiebsch, C.K. and R.E. McCollum (1987). Area×time equivalency ratio: a method for evaluating the productivity of intercrops. Agron. J., 79: 15–22.

Holford, I.C.R. (1997). Soil phosphorus: its measurement, and its uptake by plants. Aust. J. Soil Res., 35: 227-239.

Hucker, T.W.G. and G. Catroux (1980). Phosphorus in sewage ridge and animal waster slurries. Proceeding of the EEC Seminar, Haren (Gr); Groningen Netherlands 12, 13 June.

Khan, S., F. Aman, M, Ismaeel, Z. Ali, M. Alam, S. Iqbal and T. Khan (2021). Growth and yield response of pea (*Pisum sativum* L.) cultivars to phosphorus fertilization. Sarhad J. Agric., 37 (2): 369-376.

Khashaba, N. M.E.M., D.A.S. Nawar and M.A.I. Abdelkader (2023). The role of intercropping caraway (*Carum carvi* L.) and garlic (*Allium sativum* L.) on the growth and

yield under different rates of potassium fertilization. Zagazig J. Agric. Res., 50 (2): 167-179.

Kleinkopf, G.E., N.A. Oberg and N.L. Olsen (2003). Sprout inhibition in storage: Current status, new chemistries and natural compounds. Ame. J. Potato Res., 80 (5): 317-327.

Mahapatra, S.C. (2011). Study of grass-legume intercropping system in terms of competition indices and monetary advantage index under acid lateritic soil of India. Am. J. Exp. Agric., 1 (1): 1-6.

Markwell, J.; J. C. Osterman and J. L. Mitchell (1995). Calibration of the Minolta SPAD-502 leaf chlorophyll meter. Photosynthesis Research 46: 467-472.

Marschner, H. (1995). Mineral nutrition of higher plants. 2nd Ed., Academic Press, London, New York.

Mason, S. C.; D. E. Leihner and J. J. Vorst (1986). Cassava-cowpea and cassava-peanut intercropping. 1. Yield and land use efficiency. Agron. J., 78: 43-46.

Mc Gilchrist, C.A. (1965). Analysis of competition experiments. Biometrics, 21: 975- 985.

Mead, R. and R.W. Willey (1980). The concept of a 'land equivalent ratio' and advantages in yields from intercropping. Exp. Agric., 16: 217–228.

Mehta, R.S., B. Singh, S.S. Meena, G. Lal, R. Singh and O.P. Aishwath (2015). Fennel (*Foeniculum vulgare* Mill.) based intercropping for higher system productivity. Int. J. Seed Spices, 5 (1): 56-62.

Mohamed, A.M.E., M. M. Ibrahim, M.A.A. El-Said and A.Y. Mahdy (2020). Effect of intercropping cow pea with pearl millet on forage yield and competitive relationships. Archives of Agriculture Sciences Journal, 3 (3): 101-116.

Mohamed, G.M. (2013). Effect of intercropping of pea with some medicinal plants on microbial community of soil, damping-off and downy mildew diseases, under Beheira Governorate conditions. J. Plant Prot. and Path., Mansoura Univ., 4 (7): 625-641.

Mohammadzadeh, V., E.l Rezaei-Chiyaneh, H. Mahdavikia, A. Rahimi, M. Gheshlaghi, M. L. Battaglia and M. T. Harrison (2022). Effect of intercropping and bio-fertilizer application on the nutrient uptake and productivity of mung bean and marjoram. Land, 11 (10): 1-16.

Smart, J. (1990). Grain legumes. Evolution and genetic resources. Camb. Univ. Press, Camb., U.K., 200.

Sonmez, C. (2018). Effect of phosphorus fertilizer on some yield components and quality of different anise (*Pimpinella anisum* L.) populations. Turk. J. Field Crops, 23(2): 100-106.

Zaki, M.F., S.A. Abou Sedera, H.A.A. Mahdy and M.M. Abou El Magd (2019). Effect of bio-and mineral phosphorus fertilization on vegetative growth, nutrients content, yield and quality of sweet fennel plants cultivated under newly reclaimed soil. Current Sci. Int., 8 (1): 147-160.

دراسة نظم تحميل الكراوية والبسلة على النمو والإنتاجية ومؤشرات التنافس تحت مستويات التسميد الفوسفاتي المختلفة

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أجري هذا البحث على محصولي الكراوية والبسلة في المزرعة التجريبية، كلية الزراعة ، جامعة الزقازيق ، مصر خلال موسمي 2021/ 2022 و 2022/ 2023 وذلك لأهمية التحميل كإحدى طرق التكثيف الزراعي. كان الهدف من هذا العمل هو دراسة تأثير نظم التحميل (الزراعة المنفردة لكل محصول ككنترول ، 1: 1 ، 2: 2 ، 2: 3 و 3: 2 كنسبة خطوط من الكراوية: البازلاء، على الترتيب)، مستويات التسميد الفوسفاتي (صفر، 15,50، 31,00، 46,50 كجم فو$_2$أ$_5$ / فدان) ومعاملات التداخل بينهما على النمو ومكونات المحصول وبعض المكونات الكيميائية ومؤشرات التنافس بين نباتات الكراوية والبسلة. أوضحت النتائج أنه في معظم الحالات، أن تبادل خطين من الكراوية مع خطين من البسلة سجلت أعلى القيم لطول النبات وعدد الأفرع لكل نبات والوزن الجاف الكلي لكلا المحصولين بالإضافة إلى محصول الثمار ومحصول الزيت العطري لنبات الكراوية ومحصول القرون لنبات البازلاء وكذلك محتوى الكلوروفيل الكلي ونسبة الفسفور لكلا المحصولين مقارنة بنظم التحميل الأخرى. بالإضافة إلى ذلك، أظهرت معظم الصفات المدروسة للمحصولين زيادة معنوية عند التسميد بمستوى التسميد الفوسفاتي المرتفع. بالمقارنة مع معاملات التداخل تحت الدراسة، فإن استخدام نظام التحميل (2: 2) + 46,50 كجم فو$_2$أ$_5$/فدان كانت المعاملة الأفضل تأثيراً. بشكل عام ، أوضحت نسبة المكافئ الأرضي، أن باستخدام نظام التحميل 2: 2 والتسميد الفوسفاتي بمعدل 46.50 كجم فو$_2$أ$_5$ / فدان، يمكن للفدان الواحد تحت تلك المعاملة أن ينتج نفس إنتاج 1,386 أو 1,453 فدان عند زراعة كل محصول منهما منفرداً.

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