



Effect of Onion Intercropping Systems and Faba Bean Cultivars for Controlling Root-Knot Nematodes on Faba Bean (*Vicia faba* L.)



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THIS STUDY was conducted during 2022/2023 and 2023/2024 seasons at the Ismailia Experimental Research Station, Agricultural Research Center, Egypt to investigate the impact of intercropping patterns [two (IP1), three (IP2), and four rows (IP3) of onion intercropped] and cultivars of faba bean [Giza 843, Giza 716, and Sakha4] on root-knot nematode, *Meloidogyne* spp., management, yield of both crops, land equivalent ratio (LER), and farmer's income. The pots experiment under greenhouse conditions that inoculated with *M. incognita* showed that Giza 716 had the highest levels of total phenol content and enzyme activities of peroxidase, polyphenol oxidase, and phenylalanine. In the field, IP3 with Giza 716 significantly reduced numbers of galls, egg masses/root system, second-stage juveniles (j2s) in soil, gall index (GI), and egg mass index (EI) compared to control. Intercropping pattern IP3 increased yield and yield components / fed of faba bean, as well as onion yield / fed. Giza 716 had the highest values of yield and yield components. On the other hand, intercropped onion with Giza 843 produced the highest onion yield / fed. For interaction, IP3 with Giza 716 produced the highest values of yield and its components of faba bean. While the highest onion yield/fed obtained by IP3 with Giza 843. The highest values of LER (1.53 and 1.50), total and net return fed-1 were produced by IP3 with Giza 716. Therefore, we can recommend intercropping four rows of onion with faba bean Giza 716 to reduce E.I of nematodes and increase yield and gain pro-economic benefits.

Keywords: Faba bean, onion, root-knot nematode, LER, farmer's income.

Introduction

Faba bean (*Vicia faba* L.) is the primary legume crop in Egypt in terms of cultivation, production, and consumption. It forms a significant part of the daily diet due to its high nutritional value and protein content (Kambabazi *et al.*, 2022), which is more affordable compared to animal products. Its green and dry seeds are used for human consumption, while the peel and bean straw serve as fodder for livestock and poultry. Additionally, it plays an important part in improving the fertility of agricultural soil by fixing atmospheric nitrogen (Yuvaraj *et al.*, 2020). Despite extensive efforts to enhance faba bean yield in Egypt, there are still various biotic and abiotic constraints that significantly reduce its yield (Karkanis *et al.*, 2018).

There were significant differences between genetic variation of Faba bean genotypes (Abd EL-Mageed, 2018 and Ramadan *et al.*, 2025). Several faba bean cultivars are susceptible to plant-parasitic nematodes, in particular root-knot nematodes, *Meloidogyne* spp. that cause economic loss in yield especially in Egypt's newly reclaimed areas (Youssef and El-Nagdi, 2004; Hammam *et al.*, 2023). Globally, according to estimates, nematode damage to crops results in an annual economic loss

of around \$215 billion (Ferreira *et al.*, 2019). Even so, chemical nematicides were the most efficient method to manage root-knot nematodes, their toxicity to humans and environmental impact led to their removal from the market (Abad *et al.*, 2008). Now, safely and efficient strategies require for nematode management from available plant resources. Like nematode-resistant plants intercropping with host plants, which are practical ways to create unfavorable rhizosphere for developing, multiplying nematodes, and improving crop yield. Intercropping reduced nematode damage to the focal crop by 40% and disease incidence by 55% (Chadfield *et al.*, 2022). Intercropping supplies various exosystemic impacts, among these disease control. Therefore, numerous field experiments have demonstrated that intercropping generally results in higher crop yields than mono cropping, which is directly linked to a decrease in disease incidence (Lv *et al.*, 2020; El-Mehy *et al.*, 2022). Intercropping should be designed to minimize the damage caused by plant parasitic nematodes by choosing non-susceptible crops. Indeed, some plants can be releasing compounds that are repellents, attractants, nematotoxics, stimulants, or juvenile hatching eggs (Sikder and Vestergård, 2020). For instance, Allium species

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Received: 20/04/2025; Accepted: 22/07/2025

DOI: 10.21608/AGRO.2025.376999.1668

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including onion, leek, and garlic have sulfur amino-acid precursors in their cytoplasm, which upon cellular the enzyme allinase breaks down degradation to a new volatile organic compound, dimethyl disulfide (DMDS) (Sikder and Vestergård, 2020). Purified DMDS killed second stage juveniles, decreased egg masses, and galling formation of *M. incognita* on tomato plant (Silva *et al.*, 2018). Further, Li *et al.* (2018) confirmed that Welsh onion root exudates (4-hydroxy-benzeneethanol) are a naturally efficient nematicide, when grown onion as a companion plant, the roots of cucumber had 77.0% galls, and egg masses fewer than cucumber roots control. In addition to increasing systemic resistance to plant diseases, intercropping can also increase profitability, by lowering agricultural inputs while improving crop yield and land use efficiency (Abd-Allah, *et al.*, 2020; El-Mehy *et al.*, 2020). The desire to discover agroecological practices for nematode control has led researchers to study the effects of cultivars as an agricultural control method. The behavior of root-knot nematode varied greatly according to the cultivar type and the nematode species (Montasser *et al.*, 2017). Abdel-Baset *et al.* (2024) reported that Giza 843, and Sakha 4 cultivars were the most susceptible hosts, however, Giza 716 considered moderately resistant host to root-knot nematode, *M. incognita*. The benefits of intercropping differ with various cultivars of companion crops, indicating that specific goals, such as disease control and yield improvement, should be considered when selecting crop cultivars (De Long *et al.*, 2023). Therefore, the current study performed to test the effects of intercropping patterns and cultivar on the yield of faba bean and onion as well as the management of root-knot nematode, *Meloidogyne* spp. in intercropping versus sole planting.

Materials and Methods

2.1. Greenhouse experiment

Seeds of faba bean cultivars obtained from Field crops Research Institute, ARC, Egypt.

2.1.1. Experimental layout

In the pots experiment, faba bean seeds of cultivars (Giza 843, Giza 716 and Sakha 4) received surface sterilization and then sown into 30 cm-in diameter pots with sandy clay that had been steam-sterilized soil at one to four. A week after planting, the plants were thinned such that each pot contained only one seedling. Each seedling (one week-old) was inoculated with approximately 2000 newly hatched second-stage juveniles (J_2 s) of root-knot nematode, *Meloidogyne incognita* obtained from pure cultures maintained and propagated on tomato cv. Elissa. Each inoculated cultivar of faba bean was replicated three times. An equal number of pots as sole planting without nematode were included as a control. The experimental design was randomized

complete block design (RCBD) with three replications.

2.1.2. Biochemical characterization from roots of faba bean cultivars

After 15 days post-inoculation, the biochemical characterization from the roots of faba bean cultivars were determined as follows:

-Free phenolic compounds (mg g⁻¹ FW)

Free phenolic compounds evaluated according to (Saikia *et al.*, 2006).

Enzyme Activities (unit min⁻¹ mg protein⁻¹):

-The activity of polyphenol oxidase enzyme estimated according to Gaillard *et al.* (1993).

-The activity of peroxidase enzyme was determined according to (Hammerschmidt *et al.*, 1982).

-The activity of phenylalanine ammonia-lyase enzyme was determined by method suggested by (Cavalcanti *et al.*, 2007).

2.2. Field experiment:

2.2.1. -Study site

A field study was carried out during winter growing season of 2022/2023 and 2023/2024 at the Ismailia Experimental Research Station, Agricultural Research Center (ARC), Egypt. The climate in this region is arid with scarce rainfall, and experimental soil was classified as a sandy texture. Additional soil properties can be found in Table (1) was conducted by the Water and Soil Research Institute, A.C.R., utilizing the methodology outlined by Chapman and Pratt (1961).

Table 1. Soil physio-chemical properties of the Experimental site at (0–30cm depth).

Characteristics	Value	Unit
Sand	92.90	%
Silt	2.60	%
Clay	4.50	%
Organic matter	0.45	%
pH	7.15	
CaCO ₃	0.46	
N Available	12	(mg/kg)
P Available	9	(mg/kg)
K Available	86	(mg/kg)

2.2.2. Experimental layout

The experiment was planned as a split-plot arrangement in randomized complete block design (RCBD) and replicated three. Three onion (cv. Giza 20) intercropping patterns were allocated to the main plots, while three cultivars of faba bean (Giza 843, Giza 716 and Sakha 4) were assigned to the sub-plots. Net size of sub-plot was 24 m² (6 m x 4 m) having 5 beds of 1.2 m width and 4.0 m length.

2.2.3. Onion and faba bean intercropping patterns (IPs)

In all intercropping patterns, faba bean sowing on both sides of the bed in hills spaced at 20 cm apart, with left one plant/hill. Whereas onion plants were distributed in three patterns as follows.

IP1. Transplant onion plants in two rows in the middle of faba bean bed (100 % faba bean + 33.3% onion).

IP2. Transplant onion plants in three rows in the middle of faba bean bed (100 % faba bean + 50.0% onion).

IP3. Transplant onion plants in four rows in the middle of faba bean bed (100 % faba bean + 66.7% onion).

In addition, sole planting of both crops were implemented as recommended to calculate economic return and competitive relationships. Sole faba bean of three cultivars sowing on one side of the ridge (60 cm width) one plant/hill at 20 cm apart. Like, sole onion was also transplanting on the ridge (60 cm width) in three rows spacing at 15 x10 cm inter- and intra-row.

2.3. Agricultural Practices

Seeds of faba bean, and onion (*Allium cepa* L.) were obtained from Field crops Research Institute, ARC, Egypt. Sowing dates of three-faba bean cultivars were 2 and 5 November, while transplanting onion seedling (cv. Giza 20) was done on 5 and 9 December in first and second season, respectively. Calcium superphosphate (15.5% P₂O₅) and Potassium sulfate (48%K₂O) were applied during seedbed preparation at a rate of 200 and 50 kg/fed, respectively. Nitrogen fertilizer was added as a booster dose at a rate of 20 kg N/fed for faba bean. Later 15 days of transplanting onion, 90 kg N/fad applied (based on the plant density of onion) in five equal dosages in form of ammonium nitrate (33% N). Worth noting that, faba bean seeds was treated by *Rhizobium* spp. before sowing. Harvesting dates were done on 9 and 7 April for faba bean, and on 7 and 5 May for onion in first and second season, respectively. All other agricultural procedures were carried out according to the recommendations for both crops.

2.4. Nematode parameters assessment

The experiments performed in a field naturally infested with root-knot nematodes, *Meloidogyne* spp., over two successive seasons. The initial nematode population (Pi = ca 200 J2/ 250 g soil) was determined in soil sampled from each soil (Goodey, 1957). Upon harvest, the roots of ten plants from each treatment gently washed with tap water. Number of galls and egg masses/root system recorded. Egg-mass index (E.I.) and root gall index (G.I.) were determined using (Taylor and Sasser, 1978). The number of second stage juveniles (J2s) in each intercropping treatment were determined (Goodey, 1957). A comparison treatment with the nematicide Oxamyl (vydate®) 24% L, (N', N'-dimethyl-N-((methylcarbamoyl)oxy)-1-

thiooxamimidate) added at rate of 4 L/fad as recommended.

2.4.1 Crop characters

-Faba bean plants

From each treatment, samples of ten plants were randomly taken at harvest, and the following data were recorded: plant height (cm), number of pods plant⁻¹, number of seeds plant⁻¹, seed weight plant⁻¹ (g), and 100-seed weight (g). Seed yield (ardab fed⁻¹) was calculated based on the seed yield per subplot (kg) and subsequently converted to yield per fed (ardab).

-Onion plants

At harvest time, ten plants from each subplot were randomly selected to estimate the following data: plant height (cm), number of leaves plant⁻¹, bulb diameter (cm), and average bulb weight (g). The onion yield from the sub-plot was harvested and weighed (kg plot⁻¹) to estimate the yield ton per feddan.

2.4.2. Competitive relationships

Land Equivalent Ratio (LER)

In accordance with Willey (1979), LER is the area required for sole planting to achieve the same production under intercropping system at the same level of management. It was computed as follows:

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb})$$

Where:

Y_{aa} and Y_{bb} are the sole yield of crops a (faba bean) and b (onion), respectively; while Y_{ab} and Y_{ba} is the intercrop yield of faba bean crop (a) and onion crop (b).

Aggressivity (Ag)

To determine which of the two crops dominated in yield, according to Mc-Gilchrist, (1965).

$$Aab = Yab / (yaa \times zab) - Yba / (ybb \times zba).$$

Where, zab is planting proportion of faba bean, and zba is planting proportion of onion.

2.4.3. Farmer's benefit

Total return of intercropping cultures

Total return of intercropping pattern = Price of faba bean yield + price of onion yield. The average price of faba bean was 3000 and 3500 L.E. per ardab and for onion was 1000 and 7000 L.E. per ton in first and second season, to estimate the total return. The average of faba bean and onion were determined based on farm prices. Net return/fed= total return – total cost of intercropping.

where total cost was fixed cost of faba bean and variable cost of onion (price of transplanting, fertilizers, pest control and harvesting).

Statistical Analysis

Analysis of variance was done on the two-year data for a split-plot design according to Freed (1991). For the analysis, MSTAT-C software for statistical analysis was utilized. Means for all traits were compared by least significant differences (LSD) at a 0.05 probability level as developed by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Pots experiment

3.1.1. Biochemical characterization from roots of faba bean cultivars

Free phenolic compound

The effects of different faba bean cultivars on biochemical characteristics of the roots in control and infected faba bean cultivars with root-knot nematode, *Meloidogyne incognita*, revealed in Table 2. Data indicated that the content of free phenolic compounds in the roots varied depending on the cultivar. Among the three tested faba bean cultivars, the highest concentration of free phenolic compounds found in Giza 716, followed by Sakha 4, and Giza 843, which had the lowest concentration. A similar trend was noticed in the control and infected plants. This result was consistent with Faisal *et al.* (2023) found that resistant cultivars had high concentrations of phenolic contents, which gave them resistance against pathogens, while phenolic compounds were lower in susceptible genotypes. In response to pathogen attacks, plants create phenolic chemicals, regarded as components of their active defense mechanism.

- Enzyme Activities

As shown in Table (2) among all the tested cultivars, significantly higher polyphenol oxidase (PPO) activity was found in control cultivar Giza 716 (1.667 unit min⁻¹ mg protein⁻¹), followed by cv. Sakha 4 (1.242 unit min⁻¹ mg protein⁻¹), while, cv.

Giza 843 had lowest value (0.825 unit min⁻¹ mg protein⁻¹). In the same vein of infected plants, cultivar Giza 716 had (1.122 unit min⁻¹ mg protein⁻¹), followed by cv. Sakha 4 (0.985 unit min⁻¹ mg protein⁻¹), and cv. Giza 843 recorded the lowest value (0.825 unit min⁻¹ mg protein⁻¹). The activities of peroxidase enzyme, and phenylalanine ammonia-lyase enzyme behaved the same trend. A likely explanation for the resistance to nematode in Giza 716 may be due to its elevated levels of phenolic compounds, polyphenol oxidase, peroxidase, and phenylalanine ammonia-lyase enzymes, which were significantly lower in the susceptible faba bean cv. Giza 843. These results agree with Patel and Shukla (2018) who observed the presence of the highest total phenol content, peroxidase, polyphenol oxidase, Phenylalanine ammonia-lyase, total soluble protein, and total antioxidant activity in the resistant tomato cultivar compared with the susceptible ones. The observed results can be attributed to the pivotal role played by plant antioxidative enzymes in mediating the interactions between root-knot nematodes and plants. Antioxidative enzymes are integral to plants' physiological responses during pathogenic incursion and are critical for nematode endurance (Yang *et al.*, 2023). Several enzymes work together to enhance the tolerance and resistance in plants such as phenylalanine ammonia-lyase, and polyphenol oxidase enzyme. The primary enzyme that helps in triggering the synthesis of salicylic acid, which causes systemic resistance in many plants, is phenylalanine ammonia-lyase. Furthermore, it is necessary in forming phenolics and phytoalexins (Kim and Hwang, 2014). Polyphenol oxidase is key to the resistance mechanisms in host plants, catalyzing phenolic compounds, and synthesizing cell wall components like lignin and suberin (Singh *et al.*, 2021 and Zagorskina *et al.*, 2023). The lignification of cell walls contributes to defense responses against pathogens (Mouniga *et al.*, 2022). Peroxidase removal the toxic effects of hydrogen peroxide in plant tissues, supporting defense mechanisms. It also facilitates the synthesis of intermolecular bonds, strengthening cell walls against pathogen invasion (Abdel-Baset and Abdel-Monaim, 2020).

Table 2. Biochemical characterization from roots of faba bean cultivars infected with root-knot nematode, *Meloidogyne incognita*.

Cultivars	Free phenolic compounds (mg/ g FW)		Polyphenol oxidase enzyme (unit min ⁻¹ mg protein ⁻¹)		Peroxidase enzyme (unit min ⁻¹ mg protein ⁻¹)		Phenylalanine ammonia-lyase enzyme (unit min ⁻¹ mg protein ⁻¹)	
	Control plants	Infected plants	Control plants	Infected plants	Control plants	Infected plants	Control plants	Infected plants
Giza 716	4.436	3.670	1.667	1.122	1.902	1.232	5.225	4.777
Giza 843	3.157	2.220	1.146	0.825	11.294	0.872	3.455	2.252
Sakha 4	3.847	2.650	1.242	0.985	1.555	0.965	4.569	3.435
LSD 0.05	0.112	0.169	0.069	0.034	0.062	0.031	0.242	0.101

Means are the average of 3 replicates.

3.2. Field experiment

3.2.1. Nematode parameters

Effect of intercropping patterns

Results in Table 3 revealed that intercropping onion with faba bean cultivars at different patterns significantly reduced root-knot nematodes populations under field conditions, in the two successive seasons. Intercropping pattern IP3 (four rows of onion) decreased number of galls/root, egg masses/root, and number of second stage juveniles (j_2s) in soil compared to IP1 (2 rows of onion) by 23.0, 40.1 and 25.7% and by 12.6, 23.6 and 14.0% over IP2 (3 rows of onion), as average of the two seasons. These results were confirmed with Abd Allah *et al.* (2020) who reported that intercropping 4 rows of onion with sugar beet was more effective in reduced galls, egg masses numbers, and second-stage juveniles (J_2s) in soil of root-knot nematodes, *Meloidogyne* spp. Disease reduction in intercropping might be related to the suppression of pathogens owing to allelopathic effects, and the induction of plant systematic resistance against a pathogen, owing to non-host plants of the component crop (Silva *et al.*, 2018). Numerous plants secrete allelochemicals with strong antimicrobial potential through root exudation or volatilization, these compounds may have a complex interrelationship on resistance against root-knot nematodes (Li *et al.*, 2018). Some plants can release substances that serve as repellents, attractants, nematotoxics, stimulants, or inhibitors of juvenile nematode hatching (Sikder and Vestergård, 2020).

Effect of faba bean cultivars

Nematode parameters significantly affect by different faba bean cultivars as presented in Table 3. Among the tested cultivars of faba bean, there were notable differences in nematode parameters, Giza 843 cultivar recorded the highest number of second-stages juveniles (j_2s) in soil, number of gall and egg masses/ root system, as well as gall and egg mass indexes. Followed by cultivar Sakha 4, and cultivar Giza 716. This result agreed with the work of Abdel-Baset *et al.* (2024).

Interaction effect

In general, the parameters of nematode negatively influenced by intercropping onion in different patterns with all faba bean cultivars compared to control treatments (sole faba bean without

nematicide), as shown in Table 3). The most efficient treatment in reducing the population of root-knot nematodes, *Meloidogyne* spp., was intercropping four rows of onion (IP3) with faba bean cultivar Giza 716 followed by Sakha 4, and Giza 834, respectively. Contrary, intercropping pattern two rows of onion (IP1) with Giza 843 was the lowest effective intercropping treatment in reducing the population of root-knot nematodes (*Meloidogyne* spp.). However, this pattern (IP1) with the three faba bean cultivars outperformed on control treatments in lowering the population of root-knot nematodes, in two successive seasons. It is worth noting that, the nematicide treatments oxamyl 24 % with three cultivars was superior to all intercropping treatments in reducing the number of galls or egg masses per root system, root gall index (RGI) or egg masses index (EI), as well as, number of second stage juveniles (j_2s) in soil.

3.2.2. Faba bean characters

Effect of intercropping patterns

As shown in Table (4) intercropping patterns of onion had asignificant effect on the faba bean, except for plant height. Increasing plant population of onion intercropped with faba bean from two rows (IP1) up to four rows (IP3) significantly increased number of pods plant⁻¹, number of seeds plant⁻¹, seed weight plant⁻¹, 100-seed weight and seed yield fed⁻¹ of faba bean. The increases in seed weight plant⁻¹, by IP3 compared with IP2 and IP1 were 5.2 and 16.4% for first season and by 10.0 and 22.9% for second once, respectively. Likewise, seed yield fed⁻¹ increased under IP3 by 2.1 and 12.3% in 2022/2023 season and by 3.7 and 11.3% in 2023/2024 season, in that order. Interpretation of these results may be attributed to IP3 more effective in controlling nematode infestations than other patterns, as shown in Table (3). These results are in accordance with those obtained by Abd Allah *et al.* (2020) who reported that intercropping 4 rows of onion with sugar beet reduced RKNs *Meloidogyne* spp., and increased yield of sugar beet compared to intercropping two rows of onion. Chadfield *et al.* (2022) reported that intercropping reduced nematode damage to the focal crop by 40% compared to monocrop planting. Additionally, intercropping enhanced the absorption of nutrients and photosynthesis, which encouraged the growth of faba bean, thus decreasing the development of soil-borne disease (Yang *et al.*, 2024).

Table 3. Effect of onion intercropping patterns, faba bean cultivars and their interaction on root-knot nematodes, *Meloidogyne* spp., in two successive seasons.

Character 		No. of galls /root system		No. of egg masses/ root system		No. of j ₂ s/ 250g soil		Gall mass index (G.I)		Egg mass index (E.I)	
		2022/ 23	2023/ 24	2022/ 23	2023/ 24	2022/ 23	2023/ 24	2022 /23	2023 /24	2022 /23	2023 /24
Treatment											
Intercropping patterns											
IP1		63.33	65.00	26.33	27.77	235.55	244.44	4	4	3.00	3.11
IP2		55.44	57.55	20.66	21.77	201.11	213.33	4	4	2.66	2.66
IP3		48.66	50.11	15.77	16.66	170.00	186.66	4	4	2.11	2.33
LSD at 0.05		1.25	1.94	1.36	1.3	7.66	5.23	-	-	0.20	0.20
Faba bean cultivars											
Giza 843		67.11	68.33	27.22	28.77	255.55	270.00	4	4	3.33	3.33
Giza 716		45.33	47.11	12.55	13.55	163.33	175.55	4	4	1.77	2.00
Sakha 4		55.00	57.22	23.00	23.88	187.77	198.88	4	4	2.66	2.77
LSD at 0.05		1.3	1.77	0.79	0.95	12.42	11.78	-	-	0.20	0.20
Interaction effect											
IP1	G. 843	77.33	79.33	35.00	37.66	306.66	316.66	4	4	4.00	4.00
	G. 716	50.66	52.66	15.00	15.66	190.00	196.66	4	4	2.00	2.00
	Sak. 4	62.00	63.00	29.00	30.00	210.00	220.00	4	4	3.00	3.33
IP2	G. 843	66.66	68.00	25.33	27.00	253.33	270.00	4	4	3.00	3.00
	G. 716	45.66	47.00	12.33	13.33	166.66	176.66	4	4	2.00	2.00
	Sak. 4	54.00	57.66	24.33	25.00	183.33	193.33	4	4	3.00	3.00
IP3	G. 843	57.33	57.66	21.33	21.66	206.66	223.33	4	4	3.00	3.00
	G. 716	39.66	41.66	10.33	11.66	133.33	153.33	4	4	1.33	2.00
	Sak. 4	49.00	51.00	15.66	16.66	170.00	183.33	4	4	2.00	2.00
LSD at 0.05		2.25	3.06	1.37	1.64	21.52	20.4	-	-	0.34	0.34
Control G.843		97.67	104.00	43.67	47.33	373.33	386.67	4.67	5.00	4.00	4.00
Control G.716		57.67	58.00	18.33	21.00	203.33	220.00	4.00	4.00	2.00	2.67
Control Sak.4		74.33	76.00	32.67	35.33	243.33	260.00	4.00	4.00	4.00	4.00
Sole G. 843 with Oxamyl		35	38	10	11	120	120	4	4	1	2
Sole G. 716 with Oxamyl		30	30	8	9	100	110	3	3	1	1
Sole Sakha 4 with Oxamyl		32	36	9	10	110	120	4	4	1	1

Control G. 843, G.716 and Sak.4, were sole planting of three faba bean cultivars that had not tread with nematicide.

IP1: 2 rows of onion intercropping with faba bean (100% faba bean+33.3% onion).

IP2:3 rows of onion intercropping with faba bean (100% faba bean+50.0% onion).

IP2:4 rows of onion intercropping with faba bean (100% faba bean+66.7% onion).

Effect of faba bean cultivars

Results of Table 4 showed that faba bean cultivars had a significant effect on plant height, number of pods plant⁻¹, number of seeds plant⁻¹, seed weight plant⁻¹, 100-seed weight and seed yield per fed of faba bean in both seasons. Faba bean Giza 716 cultivar had the highest values for the above mentioned traits, except plant height, Sakha 4 had the highest plant height. Notably, the differences between Giza 716 and Sakha 4 did not reach a significant level in most cases. On contrary, the lowest values were achieved by Giza 843 cultivar in both growing seasons. Intercropping faba bean Giza 716 with onion increased seed yield plant⁻¹ by 13.2 and 3.4% in the 2022/23 season and by 20.0 and 3.3% in the 2023/24 season compared to Giza 843 and Sakha 4 cultivar, respectively. Likewise, when sowing faba bean cultivar Giza 716 the increases in seed yield fed⁻¹ compared to Giza 843 and Sakha 4 were 11.9 and 3.5% in 1st season, and 19.9 and 5.5% in 2nd season, respectively. A probable reason for superiority of Giza 716 in growth and seed yield on the other cultivars, Giza716 is considered a moderately resistant host to root-knot nematode, *M. incognita*, followed by Sakha 4 cultivar, while Giza 843 was the most susceptible host. This result is in line with Abdel-Baset *et al.* (2024). As a rule, variations in the genetic composition of the studied faba bean cultivars may explain the disparities in growth, seed yield, and their components (Abdelaal 2023). As results were obtained by El-Mehyet *et al.* (2020) they found that Giza 843 had the lowest seed yield and its components compared with Giza 716 and Sakha1.

Interaction effect

Results illustrated in Table 4 indicated that the interaction between intercropping patterns and faba bean cultivars had a significant effect on number of pods plant⁻¹, and seed weight plant⁻¹ in the second

season, while number of seeds plant⁻¹, and seed yield per fed of faba bean were significantly affected in both seasons. Data also in the same table cleared that intercropping onion with Giza 716 under pattern IP3 (four rows of onion) gave the maximum values of all the previously noted traits in both seasons. Whereas the minimum values of these parameters were obtained by intercropping two rows of onion (IP1) with faba bean Giza 843. These results could be attributed to increasing systematic plant resistance to root-knot nematodes infection and improved yield and its components of faba bean by intercropping onion with the faba bean Giza 716 cultivar under the IP3 pattern. Where high concentration of phenolic contents and antioxidative enzymes in Giza 716 give it resistance against root-knot nematodes (*Meloidogyne* spp.). Further, intercropped onion plants secrete allelochemicals with strong nematicide potential, which inhibit root-knot nematode activity and egg hatchability. The findings presented here are corroborated by Abd-Allah *et al.* (2020); Chadfield *et al.* (2022); Faisal *et al.* (2023) and Abdel-Baset *et al.* (2024).

3.2.3. Onion characters

Effect of intercropping patterns

Intercropping onion with faba bean at different intercropping pattern, significantly affected plant height, number of leaves plant⁻¹, bulb diameter, average bulb weight and onion yield fed⁻¹ in both seasons (Table 5). Results herein show significant increases in plant height and yield fed⁻¹ of onion by increasing plant density in IP3 up to four rows onion compared with IP1 (two rows onion) and IP2 (three rows onion) across the two seasons. However, sole planting of onion had the highest bulb yield over than all intercropping patterns. This increase may be due to an increase in plant density per unit area. Meanwhile, number of leaves plant⁻¹, bulb diameter, and the average bulb weight decreased.

Table 4. Effect of intercropping patterns, faba bean cultivars and their interaction on faba bean parameters in the two seasons.

Character Treatment	Plant height		No. pods/plant		No. seeds/plant		Seed weight/plant		100-seed weight		Seed yield(ardab /fed)		
	2022/23	2023/24	2022/23	2023/24	2022/23	2023/24	2022/23	2023/24	2022/23	2023/24	2022/23	2023/24	
Intercropping patterns													
IP1	91.57	98.97	11.37	11.71	42.09	42.87	38.04	37.17	79.93	79.86	8.33	8.39	
IP2	91.69	99.59	12.50	13.18	47.33	48.59	42.07	41.53	80.61	80.58	8.72	8.87	
IP3	90.30	101.04	12.96	13.44	49.20	50.41	44.27	45.68	81.56	80.87	8.97	9.04	
LSD at 0.05	N.S	N.S	0.28	0.69	1.00	1.18	1.52	1.07	0.30	0.20	0.17	0.21	
Faba bean cultivars													
G843	83.97	94.21	11.66	11.43	44.90	44.83	38.54	37.01	78.76	77.54	7.69	7.57	
G 716	93.66	99.54	12.63	13.63	47.88	49.41	43.64	44.40	81.68	82.14	9.37	9.60	
Sakha 4	95.93	105.84	12.53	13.27	45.84	47.62	42.19	42.97	81.67	81.61	8.97	9.13	
LSD at 0.05	3.5	3.29	0.4	0.31	1.06	0.73	1.15	0.65	0.36	0.23	0.25	0.15	
Interaction effect													
IP1	G843	85.33	93.57	10.37	10.20	39.60	40.60	34.52	31.50	78.13	77.20	7.41	7.23
	G 716	92.57	99.10	11.87	12.57	43.47	45.17	40.77	41.00	80.80	81.57	8.93	9.12
	Sakha 4	96.80	104.23	11.87	12.37	43.20	42.83	38.83	39.00	80.86	80.80	8.66	8.81
IP2	G843	83.60	94.47	12.27	11.43	47.47	45.10	39.00	35.20	78.70	77.63	7.76	7.61
	G 716	95.23	98.97	12.63	14.10	48.57	50.90	44.43	45.23	81.47	82.23	9.45	9.76
	Sakha 4	96.23	105.33	12.60	14.00	45.97	49.77	42.77	44.17	81.67	81.87	8.95	9.24
IP3	G843	82.97	94.60	12.33	12.67	47.63	48.80	42.10	44.33	79.43	77.80	7.89	7.87
	G 716	93.17	100.57	13.40	14.23	51.60	52.17	45.73	46.97	82.77	82.63	9.74	9.92
	Sakha 4	94.77	107.97	13.13	13.43	48.37	50.27	44.97	45.73	82.47	82.17	9.29	9.34
LSD at 0.05	N.S	N.S	N.S	0.54	1.83	1.27	N.S	1.12	N.S	N.S	0.43	0.25	
Sole G843	95.50	104.00	10.00	10.10	36.20	38.70	36.20	30.60	78.40	77.00	7.41	7.57	
Sole G 716	102.40	109.50	11.30	12.3	41.50	43.00	38.70	40.00	80.0	80.40	8.57	9.05	
Sole Sakha 4	110.00	115.70	12.00	12.00	39.70	41.80	41.50	37.40	80.1	80.10	8.25	8.61	

IP1: 2 rows of onion intercropping with faba bean (100% faba bean+33.3% onion).

IP2:3 rows of onion intercropping with faba bean (100% faba bean+50.0% onion).

IP2:4 rows of onion intercropping with faba bean (100% faba bean+66.7% onion).

This could be attributed to increased intra- and interspecific competition on environmental resources under high plant densities of both crops. Same results were obtained by Abd-Allah *et al.*, (2020) increasing onion plant density up to four rows intercropping with sugar beet significantly increased plant height and onion yield/fed.

Effect of faba bean cultivars

The results displayed in Table 5 show that three cultivars of faba bean were significantly affected by onion yield and yield components in both growing seasons. The highest value for plant height was produced by intercropping onion with cultivar Sakha4, followed by Giza 716 without significant differences between them. Meanwhile number of leaves plant⁻¹, bulb diameter, average bulb weight and yield (ton fed⁻¹) increased by intercropping onion with faba bean cultivar Giza 843 in both growing seasons, whereas intercropping onion with faba bean Sakha4 gave the lowest values of these parameters for onion in both seasons. Reduction in onion yield intercropped with cultivar Sakha 4 were 17 and 25% and by 12 and 18% with cultivar Giza 716, compared to cultivar G.843 in first and second seasons, respectively Table (5). Faba bean Sakha4 had tallest plants compared with Giza 843 and Giza 716 cultivars Table (4). This increased the shadow effect around onion plants and heightened interspecific competition, which reduced onion parameters compared with other cultivars. Faba bean cultivars significantly influenced the growth and yield of companion crops, as noted by El-Mehy *et al.* (2020) they reported that faba bean Giza 843 intercropped with sugar beet produce the highest root yield of sugar beet and yield components comparable to Giza-716 and Sakha-4 cultivars. Faba bean cultivars that are shorter can generate less interspecific light competition (Nelson *et al.*, 2021).

Interaction effect

Results in Table5 showed that onion characters were not significantly affected by the interaction of onion intercropping patterns and faba bean cultivars, except average bulb weight, and onion yield fed⁻¹, in both seasons. The highest average bulb weight was produced by intercropping two rows of onion plants (IP1) with Giza 843. Contrary, the lowest values of average bulb weight were obtained by intercropped four rows of onion, IP3 pattern, with cultivar Sakha 4. This indicates that the increase in plant density of onion that intercropped with the tallest cultivars resulted in an increase in competition between plants and reduce yield and its components. However, the highest onion yield fed⁻¹ was obtained with intercropping four rows of onion with Giza 843, while lowest values obtained by intercropping two rows of onion (IP1) with Sakha 4 cultivar. These results may be attributed to yield fed⁻¹ depending on plant density per unit area, rather than average weight of bulb. In addition, the faba bean Giza 843 cultivar is the shortest, effectively reducing

shadowing effects on onion plants compared to other cultivars. These results in line with the findings of Abd Allah *et al.* (2020) they found that substantial gains in onion yield per fed were observed with an increase of plant density of onion intercropped with sugar beet from two to four rows. Nelson *et al.* (2021) faba bean cultivars that are shorter can generate less interspecific light competition.

Competitive ratio

Land equivalent ratio

Interaction between intercropping patterns and faba bean cultivars affected LER, as shown in Table 6. Relative yield of faba bean (L faba bean) was ever higher than those of the onion were, indicated that a positive correlation between relative yield and plant density per unit area. The increase in LER values over 1.0 in all intercropping treatments confirming the advantageous yield of intercropped onion with faba bean. Results confirmed that LER of pattern IP3 (four rows onion) with faba bean surpassed the other two intercropping patterns IP1 and IP2 of onion in both seasons. The highest values of LER (1.53 and 1.50) were produced by intercropping pattern IP3 with faba bean Giza 716 in 2022/2023 and 20223/2024 season, respectively. While, the lowest LER values (1.30 and 1.24) were achieved by IP1 with faba bean Sakha 4 cultivar, respectively in first and second seasons. These results confirm that the optimum intercropping pattern and faba bean cultivars offered unfavorable conditions for development root-knot nematodes, thus improved yield of faba bean compared to sole faba bean. These results are in harmony with those obtained by Abd-Allah *et al.* (2020) who found that increasing onion density up to four rows most effective treatment to reduced nematodes and increased yield of sugar beet and LER.

Aggressivity

Aggressivity estimated the variation in competitiveness of the component crops in intercropping patterns. The higher aggressive value indicates a greater difference in the ability to compete, as well as a greater disparity among expected and actual yield in both crops. It was clear from the data in Table 6 that the aggressivity values of the faba bean were (+). In contrast, its values were (-) for onion, meaning that faba bean was dominant and onion was dominated. The most unfavorable aggressivity values (0.97 and 0.93) were obtained with dense planting of onion (IP3) along with faba bean Sakha 4 cultivar in first and second seasons, respectively. This indicated that the highest plant density per unit area with the tallest cultivar increased competition between intercrop components. These results agree with those obtained by El-Mehy *et al.* (2020) also reported that values of aggressivity under intercrop showed that faba bean was a higher competitive and dominant crop over sugar beet.

Table 5. Effect of intercropping patterns, faba bean cultivars and their interaction on onion parameters in the two seasons.

the two seasons.											
Character		Plant height (cm)		No. leaves/plant		Bulb diameter (cm)		Average bulb weight (g)		Onion yield (ton /fed)	
Treatment		2022/23	2023/ 24	2022/ 23	2023/ 24	2022/ 23	2023/24	2022/ 23	2023/24	2022/23	2023/ 24
Intercropping patterns											
IP1		49.95	46.45	8.56	7.38	5.52	5.33	77.17	74.17	3.81	3.75
IP2		52.03	49.15	7.45	6.50	5.15	4.85	71.88	67.03	5.00	4.95
IP3		55.06	52.08	7.14	5.57	4.73	4.51	61.52	62.11	5.60	5.72
LSD at 0.05		1.10	1.64	0.50	0.21	0.15	0.14	1.91	3.07	0.14	0.12
Faba bean cultivars											
G843		50.88	47.52	8.24	7.04	5.63	5.25	83.34	74.20	5.22	5.54
G 716		52.36	50.08	7.58	6.12	5.04	4.80	65.67	64.60	4.77	4.72
Sakha 4		53.80	50.08	7.33	6.30	4.73	4.64	61.56	64.52	4.42	4.22
LSD at 0.05		1.47	1.07	0.33	0.36	0.17	0.15	1.88	1.67	0.15	0.14
Interaction effect											
IP1	G843	47.23	44.70	9.13	8.03	5.96	5.56	92.70	82.23	4.37	4.67
	G 716	50.53	46.46	8.50	7.10	5.33	5.30	70.00	69.33	3.49	3.52
	Sakha 4	52.10	48.20	8.06	7.10	5.26	5.13	68.83	70.96	3.57	3.25
IP2	G843	51.33	47.03	7.90	7.16	5.70	5.23	88.73	72.03	5.57	5.86
	G 716	51.70	50.23	7.23	6.03	5.10	4.73	65.96	64.73	4.89	4.67
	Sakha 4	53.06	50.20	7.23	6.30	4.66	4.60	60.96	64.33	4.55	4.32
IP3	G843	54.10	50.83	7.70	5.93	5.23	4.96	68.60	68.33	6.02	6.38
	G 716	54.86	53.56	7.03	5.30	4.70	4.36	61.06	59.73	5.64	5.68
	Sakha 4	56.23	51.86	6.70	5.50	4.26	4.20	54.90	58.26	5.13	5.11
LSD at 0.05		N.S	N.S	N.S	N.S	N.S	N.S	3.26	2.9	0.26	0.24
Sole onion		42.80	40.30	10.30	8.90	6.40	6.10	105.2	98.60	14.16	14.53

Table 6. Interaction effect of intercropping patterns and faba bean cultivars on land equivalent ratio (LER) and aggressivity (Ag) in the two seasons.

Pattern	Cultivar	L faba	L onion	LER	Ag faba	Ag onion	L faba	L onion	LER	Ag faba	Ag onion
		2022/2023 season					2023/2024 season				
IP1	Giza 843	1.03	0.29	1.32	0.22	-0.22	0.96	0.30	1.26	0.07	-0.07
	Giza 716	1.04	0.27	1.31	0.32	-0.32	1.01	0.25	1.26	0.35	-0.35
	Sakha 4	1.05	0.25	1.30	0.39	-0.39	1.02	0.22	1.24	0.47	-0.47
IP2	Giza 843	1.08	0.39	1.47	0.42	-0.42	1.01	0.40	1.41	0.28	-0.28
	Giza 716	1.10	0.35	1.45	0.60	-0.60	1.08	0.32	1.40	0.64	-0.64
	Sakha 4	1.08	0.32	1.40	0.65	-0.65	1.07	0.30	1.37	0.70	-0.70
IP3	Giza 843	1.10	0.42	1.52	0.76	-0.76	1.04	0.44	1.48	0.63	-0.63
	Giza 716	1.13	0.40	1.53	0.90	-0.90	1.10	0.40	1.50	0.82	-0.82
	Sakha 4	1.13	0.36	1.49	0.97	-0.97	1.08	0.35	1.43	0.93	-0.93

IP1: 2 rows of onion intercropping with faba bean (100% faba bean+33.3% onion).

IP2:3 rows of onion intercropping with faba bean (100% faba bean+50.0% onion).

IP2:4 rows of onion intercropping with faba bean (100% faba bean+66.7% onion).

Total and net return (L.E/fed)

The total return and net return of intercropped onion with faba bean as compared to sole faba bean in both seasons are shown in Table 7. Results indicated that returns of faba bean or onion varied by different intercropping patterns and cultivars. Intercropping onion with faba bean clearly increased total and net return in both seasons compared to sole faba bean. Intercropping four rows onion (IP3) with faba bean Giza 716 gave the highest total return, namely 85620 and 75880 L.E/fed compared to sole faba bean 25710 and 30609 L.E/fed in 2022/2023 and 2023/2024 season, respectively. Likewise, the maximum net return 42591 and 30587 L.E/fed recorded with Giza 716 under IP3 intercropping

pattern in first and second season, respectively. On the contrary, intercropping pattern IP1, 2 rows of onion, along with Sakha 4 cultivar had lowest total return and net return in both seasons. However, these treatments produce values of net and total returns higher than sole faba bean cultivar. Where sole planting of faba bean has resulted in losses in net income. These losses may be attributed to nematode effect on yield of faba bean in sole planting. These results supported by Ferreira *et al.* (2019) Root knot nematodes result in substantial economic loss exceeding 215 billion US\$ a year. : 114-151.

Table 7. Interaction effect of intercropping patterns and faba bean cultivars on total and net return (L.E/fed) in the two seasons.

Pattern	Cultivar	Faba return	Onion return	Total return	Cost	Net return	Faba return	Onion return	Total return	cost	Net return
		2022/2023 season					2023/2024 season				
IP1	Giza843	22230	40700	62930	36809	26121	25305	30590	55895	38747	17148
	Giza716	26790	37900	64690	36809	27881	31920	25340	57260	38747	18513
	Sakha 4	25980	35700	61680	36809	24871	30835	22750	53585	38747	14838
IP2	Giza843	23280	55700	78980	39919	39061	26635	41020	67655	42020	25635
	Giza716	28350	48900	77250	39919	37331	34160	32690	66850	42020	24830
	Sakha 4	26850	45500	72350	39919	32431	32340	30240	62580	42020	20560
IP3	Giza843	23670	60200	83870	43029	40841	27545	44660	72205	45293	26912
	Giza716	29220	56400	85620	43029	42591	34720	41160	75880	45293	30587
	Sakha 4	27870	51300	79170	43029	36141	32690	35770	68460	45293	23167
Sole Giza 843		21600	-	21600	30609	-9009	26495	-	26495	32220	-5725
Sole Giza 716		25710	-	25710	30609	-4899	31675	-	31675	32220	-545
Sole Sakha 4		24750	-	24750	30609	-5859	30135	-	30135	32220	-2085

IP1: 2 rows of onion intercropping with faba bean (100% faba bean+33.3% onion).

IP2:3 rows of onion intercropping with faba bean (100% faba bean+50.0% onion).

IP2:4 rows of onion intercropping with faba bean (100% faba bean+66.7% onion).

Consent for publication:

All authors declare their consent for publication.

Author contribution:

The manuscript was edited and revised by all authors.

Conflicts of Interest:

The author declares no conflict of interest.

Acknowledgments:

The authors thank the members of Crop Intensification Research Department, Field Crops Res. Inst., Agric. Res. Center, Giza, Egypt. And so Food Legumes Research Department, Field Crops Res. Inst., Agric. Res. Center, Giza, Egypt.as well as Department of Nematode Diseases Research,

Plant Pathol. Res. Inst., Agric. Res. Center, Giza, Egypt. Agricultural Research Center (ARC), Egypt for supporting this work.

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تأثير أنظمة تحميل البصل وأصناف الفول على مكافحة نيماتودا تعقد الجذور في الفول البلدي

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أجريت هذه الدراسة خلال موسمي 2023/2022 و 2024/2023 بمحطة البحوث الزراعية بالإسماعيلية، مركز البحوث الزراعية، محافظة الإسماعيلية، مصر. تهدف هذه التجربة لدراسة تأثير أنظمة تحميل البصل في (صفي، 3 صفوف، و 4 صفوف) ولدراسة أصناف الفول البلدي (جيزة 843، جيزة 716، وسخا 4) على مكافحة نيماتودا تعقد الجذور في الفول، على إنتاجية كلا المحصولين، المكافئ الأرضي، ودخل المزارع. أوضحت تجربة الأخص أن الصنف جيزة 716 يحتوي على أعلى مستويات من محتوى الفينول الكلي ونشاط إنزيم البيروكسيداز وأوكسيداز البولي فينول والفينيل ألانين، مما أدى إلى تعزيز مكافحته للإصابة بنيماتودا تعقد الجذور. كما أوضحت تجربة الحقل أن تحميل 4 صفوف من البصل مع الصنف جيزة 716 أدى إلى تقليل أعداد العقد النيماتودية وكثل البيض على الجذر وكذلك أعداد الطور المعدي (اليرقي الثاني) في التربة بشكل ملحوظ لنيماتودا تعقد الجذور. مقارنة بالمعاملات الأخرى. أدى نظام التحميل إلى زيادة محصول الفول ومكوناته، وكذلك محصول البصل للفدان. تفوق صنف الفول جيزة 716 في قيم المحصول ومكوناته، يليه سخا 4. ومع ذلك، تحقق أعلى محصول للفدان من البصل المحمل مع الصنف جيزة 843. بالنسبة للتفاعل، حققت زراعة 4 صفوف من البصل مع الصنف جيزة 716 أعلى قيم للمحصول ومكوناته من الفول. بينما تم الحصول على أعلى محصول بصل/فدان من النظام IP3 مع الصنف جيزة 843. سجلت أعلى قيمة للمكافئ الأرضي (LER 1.53 و 1.50) بتحميل 4 سطور بصل IP3 مع الفول صنف جيزة 716 وكان الفول هو السائد عندما كانت القيم موجبة ومحصول البصل هو المسود عندما كانت القيم سالبة. تم تسجيل أعلى عائد إجمالي وصافي دخل للفدان بتحميل 4 سطور بصل مع الصنف جيزة 716. بينما أدت الزراعة المنفردة للفول إلى خسائر في صافي الدخل. لذلك، يمكننا التوصية بزراعة 4 صفوف من البصل مع الفول صنف جيزة 716 لتقليل مؤشر العقد النيماتودية بنسبة 13% وزيادة الغلة بنسبة 12%، وتحقيق ميزة اقتصادية

الكلمات الدالة: الفول البلدي - البصل - نيماتودا تعقد الجذور - المكافئ الأرضي - الدخل النقدي للمزارع.