J. Plant Production, Mansoura Univ., Vol. 8(2):195 - 203, 2017

Effect of Summer Crops Producing Allelopathic Compounds, Plant Density and Varieties of Faba Bean on Incidence of Broomrape

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ABSTRACT

Allelopathy is a natural which may prove to be a unique tool for weed control treatments and thereby increase some crop yields. Two experiments were conducted in naturally infested fields with broomrape (*Orobanche crenata* Forsk.) at Shandaweel Research Station, Sohag Governorate during 2013/14 and 2014/15 winter seasons. The aim of this work was to study the effect of crop sequences for producing allelopathic (cotton, sorghum and maize), two faba bean varieties (Giza-843 and Giza-40) and two plant densities (one side of the ridge and two sides of the ridge) in a split split-plot design were used to study the control of broomrape in faba bean. Results showed that sowing of maize before faba bean decreased significantly numbers and weight of broomrape spikes by 32.0 & 18.5% in the first season and by 37.7 & 37.5% in second season and lead to increase in number of days to broomrape emergence above soil surface by 18.5 & 16.6% in both seasons, respectively, compared to cotton and sorghum. Faba bean seed yield and components were increased by sowing faba bean after maize compared with faba bean after cotton and sorghum. While, faba bean after maize increased the seed yield of faba bean by 13.8 and 13.6 % in both seasons, respectively. Sowing of cotton before faba bean increased significantly the plant height, weight of pods/plant, weight of seeds/plant, 100-seed weight and seed yield (ardab/fed) by 3.9, 5.2, 4.9, 4.8 and 5.8% in 1st season, respectively, and by 9.1, 2.0, 3.5, 4.7 and 5.5% in 2nd season, receptively, compared with sowing of sorghum before faba bean. Number, weight and days emergence of broomrape above the soil surface were significantly affected with varieties of faba bean. Superiority of Giza 843 over Giza 40 was by 30.7 and 16.8% in the first season and by 39.7 and 37.5% in the second season. Late-onset broomrape above the surface of the soil with the cultivation of Giza 843 was by 16.8 and 22.5% in the first and second seasons, respectively. Varieties of (*vicia faba*) were significantly increased on yield (plant height, weight of pods/plant, weight of seeds/plant, 100-seed weight and seed yield/fed) in both seasons. Seed yield of faba bean was increased at cultivation of Giza 843 by 39.7 and 37.5% in the respective 1st and 2nd seasons, respectively, compared with Giza 40. Plant density showed significant effect on the number and weight of broomrape and days of number emergence of broomrape above the soil surface. Increasing plant density from 13 to 26 plants/m^2 increased the number and dry weight of broomrape/m^2 by (25.5 and 36.7%) and (29.3 and 28.6%) in both seasons, respectively. Faba plant height, weight of pods/plant, weight of seeds/plant, 100-seed weight and seed yield (ardab/fed) significantly affected was plant density in both seasons. The seed yield of faba bean cultivation was increased at the rate of 26 plants/m^2 by 5.58 and 4.91% in both seasons, respectively, compared to faba density of 13 plants/m^2. The interaction between crop sequences for producing allelopathic, faba varieties, and plant density were significant for the number and weight of broomrape spikes and also delayed the onset of broomrape above the soil surface, as well as increased faba bean yield and yield components in both seasons. This may be obtained in less number and weight of broomrape and the maximum number of days for the appearance of broomrape, as well as the higher weight of 100-seed and seed yield (ardab/fed) from the cultivation of maize crop earlier with the use of Giza 843 faba variety in the two seasons. Triple interaction between crop sequences for producing allelopathic, faba varieties and plant density was not significant for the number and weight of broomrape of spikes and faba yield and its components in the both seasons. HPLC analysis revealed that there were seven phenolic acids isolated from the foliage dry weight of cotton, sorghum and maize: (protocatechuic, caffic, p-hydroxy benzoic, vanillic, syringic, coumaric, and ferulic acid). However, the amounts of these phenols differ from plant to another. The highest values in maize are ferulic acid (325.5 µg) and coumaric acid (142.3µg), vanillic (95.5µg), *p*-hydroxy benzoic (53.6 µg) and caffic (36.5 µg). While, in sorghum are ferulic acid (249.9µg) and coumaric acid (120.2µg), and in cotton are ferulic acid (236.5µg) and syringic acid (204.4µg) and protocatechuic (44.4µg). From this study, it can be used the cotton, sorghum and maize as an Allelopathy influence plants in the agricultural cycle system through the cultivation of summer and winter crops relay in anti broomrape field in addition to the selection of resistant varieties and plant high density to reduce injury. Moreover, it can used these natural chemical compounds either as water extract of the shoots of plants with Allelopathy influence directly or mixed with soil in order to reduce the rate used of herbicides recommended, and increase the effectiveness of herbicides in weed control.

Keywords: Allelopathy, crop sequences, plant density, varieties, broomrape and faba bean.

INTRODUCTION

Allelopathy an important in the development of future integrated weed management strategies. Moreover, incorporating allelopathy into agriculture management may reduce the use of herbicides, which reduces pollution and diminish autotoxic hazards. In practice, the allelopathic properties of plants might be exploited by growing specific crop varieties, mixing certain crop residues with the soil and by using isolated allelochemicals as natural herbicides to reduce the impact of synthetic chemicals on the environment (Alam *et al.* 2001). In the future, there will be an increase in demand for worldwide better quality food and in large quantity due to the increasing of human population. Therefore, for sustainability of agriculture, we need to minimize the use of present pesticides, through the use of allelopathic for pests management. Gerald (1983) indicated that several crops showing promise are grain and forage species such as barley (*Hordeum sp*.), oat (*Avena sp*.), fescue (*Festuca sp*.) and sorghum (*Sorghum sp*.), and the agronomic species of corn (*Zea sp*.) and sunflower (*Helianthus sp*.). Parker and Riches (1993) indicated that sorghum (*Sorghum vulgare* Pers.), maize (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), mung bean (*Phaseolus aureus* Roxb.), and cucumber (*Cucumis sativus* L.) have been identified as trap crops for *Orobanche ramosa* and sweet pepper as a trap crop for Egyptian broomrape. Cardina (1995) mentioned that allelopathy has an adverse effect on plants caused by biochemicals that are produced by living plants. Blum (2004) reported that caffic, ferulic, *p*-coumaric, protocatechuic, sinopic, cyringic and

vanillic are phenolic acids that had primary allelopathic effects on plant process by reducing rates of photosynthesis, carbon allocation to root. Uludag *et al*. (2006) found that allelopathic compounds which were produced from tobacco, sunflower, chickpea, lentil, wheat, maize and cotton decreased the number of *Orobanche ramosa* tubercles up to 68 % on tomato plants. Kocacaliskan *et al.* (2009) stated that the chemical interactions that occur among living organisms including plants, insects and microorganisms are called allelopathy, and the organic compounds involved in allelopathy are called allelochemicals. Ghotbi *et al*. (2012) indicated that the most significant reduction in broomrape shoot and capsule number was demonstrated in those pots that contained corn (53.00%), cotton (36.33%) and sorghum (51.33%). Yongqing *et al*. (2013) indicated that intercropping with non-host plants that induce "suicidal germination" and are allelopathic to root parasites is a promising approach that warrants continued efforts to identify potential trap crops and improve their efficacy.

Varieties differ in vegetation according to growth, as differ in stem, leave size, branches, continued to grow after flowering, and thus lead to different forms of plant. Hassanein et al. (1998) indicated that (Giza-843) had medium tolerance in pot experiments based on the Orobanche incidence while other varieties were highly susceptible. In artificial and natural infestations in the field at Giza- 3, it was found that both Giza- 843 and Giza- 429 were partially tolerant. Khalil et al. (2004) found that development of resistant faba cultivars (Giza 674, Giza 429, Giza 402, Giza 843, Misr-3 and Misr-1) that are being utilized in crosses to breed for Orobanche resistance. Magdi et al. (2010) indicated that the results obtained represent supportive evidence on the positive relationship between salt-tolerance and Orobance-tolerance in the three cultivars (G429, G843, and M1). Gadalla et al. (2010) proved that Giza 3 was the susceptible cultivar and G.843 was tolerant, which had the lowest Orobanche tubercles/plant. Spectrophotometer was used to assess total protein, peroxidase and polyphenoloxidase activity extracted from faba bean roots and shoots. Amer et al. (2012) found that significant differences for the varieties of bean based on percentage of growth, plant height, branches/plant, pod length and number of seeds/pod, with average values of 94.8%, 35.8 cm, 87.5 cm, and 10.4 cm, respectively. Ismail (2013) revealed that faba bean variety (Misr1) caused decreased number and dry weight of Orobanche spikes by 17.3, 17.0 and 13.1%, respectively, in both seasons as compared with variety (Giza 40). Nagwa et al. (2015) showed that faba beans variety Giza- 843 rats of 40 % (16 kg /fed) of sole led to a decline in O. crenata increasing of seed yield ardab/fed on faba bean and protein% Compared to monoculture.

(Rafiei, 2009) found that plant density defines the number of plants/m^2, which in turn determines the area available to each individual plant. Abou Salama and Dawood (1994) revealed that seed yield was increased by increasing plant density up to 26.7 plants/m^2. Sharaan *et al.* (1998) indicated that sowing faba Giza 2 or Giza 429 with density of 112 or 140.000 plants/faddan resulted in highest seed yield with acceptable quality. Ismail and Fakkar (2008) reported that increasing plant density from 13 to 27 plants per m^2 increased number and dry weight of *Orobanche* spikes/m^2 by (13.2, 10.8%, 24.0 and 10.7%) and increased seed yield of faba bean by (60.7 and 50.0 %) in first and second seasons, respectively. Talal (2010) stated that highest value of faba were obtained at the highest plant density (60 plants/plot) for all the parameters like stem and leaf dry weight, the total dry matter, seed dry weight and stem height. Bakry *et al*. (2011) According to the literature, the optimum plant density to obtain high productivity for different faba bean crop varieties can range from 10 to 100 plants/m^2. Nasr *et al*. (2013) showed that total dry weight/plant was gradually increased with increasing plant density up to 8 plants/faba dripper and significantly decreased with 10 and 12 plants/dripper, however, increasing plant density increased the plant height and decreased the number of branches/plant.

The aim of this work was to estimate allelopathy impact in reducing the incidence of broomrape and increased faba yield in ways that safe the environment following agricultural crops and effect of the summer crop for producing allelopathic, faba varieties and plant density on control broomrape in faba bean.

MATERIALS AND METHODS

Two field experiments were conducted at Shandaweel Agricultural Research Station in Sohag Governorate during 2013/14 and 2014/15 winter seasons to study the effect of the summer crops preceding faba bean for producing allelopathic compounds and effect of faba bean varieties and plant density on control of broomrape in faba bean. The two experiments were conducted in naturally infested fields with broomrape (*Orobanche crenata* Forsk.). Use of a split split-plot experiment, using randomized complete block design (RCBD) with three replications as follows:

A- Main plots (crop for producing allelopathic compounds):

1- Cotton (*Gossypium barbadense* L.). The variety was Giza-90.

2- Sorghum (*Sorghum bicolor* L). The variety was Shandaweel-6.

3- Maize (*Zea mays* L.). Single cross-10 (SC10).

B-Sub plots (varieties of faba bean):

1- Giza-843 (resistant to broomrape).

2- Giza-40 (susceptible to broomrape).

C-Sub-sub plots (plant density):

The sub sub-plot area was 10.5 m^2 containing five ridges, 3.5 cm in length and 60 cm apart

1-Seeds were planted on one side of the ridge (60 cm), 25 cm between hills and thinned to two plants/hill. Density of faba bean was 13 plants/m^2.

2-Seeds were planted on two sides of the ridge (60 cm), 25 cm between hills and thinned to two plants/hill. Density of faba bean was 26 plants/m^2.

Faba bean was planted on 20th and 24th November in the first and second seasons, respectively. In both seasons, soil texture was sandy clay loam (Table 1).

Table 1. Mechanical and chemical analysis of the soil in the two seasons.

Chemical analysis / seasons	Soil texture	Sand %	Silt %	Clay %	O. M %	pH	$CaCo_3$ %	Available nutrients (ppm) N	P	K
2013/14	Sandy	54.11	29.81	16.08	0.8	7.8	7.5	54.11	29.81	16.08
2014/15	Clay loam	52.85	28.68	18.47	0.9	7.7	7.6	52.85	28.68	18.47

Data recorded:

1-Broomrape:

The following data were recorded:

I- Broomrape spikes/faba bean plant.

1- Number of broomrape spikes/m^2.

2- Dry weight of broomrape spikes/m^2 (g).

$$\text{3- Broomrape incidence \%} = \frac{\text{No. of infested host plants by broomrape}}{\text{Total number of host plant/m}^2} \times 100$$

4-Broomrape severity=Average number of spikes/host plant(Table 2).

II- Faba bean yield and its components

The number and weight of broomrape spikes/plant correlation with the faba bean seed yield/plant were determined.

Counted date of germination of spikes (days), number of broomrape spike/m^2 and dry weight of broomrape/m^2 was calculated also.

Table 2. The suggested scale of broomrape infestation in host plants to broomrape (adopted from Hassanein *et al*. 1998).

Host susceptibility to broomrape infestation	Score: Broomrape Incidence (%)	Broomrape severity No. of spikes/host plant	Yield losses %
Highly susceptible (HS)	100	10	100
Moderately susceptible (MS)	60 - 90	7- 9	60- 90
Moderately tolerant (MT)	40 - 60	4-7	40- 60
Tolerant (T)	0 - 30	1- 3	10- 30
Resistant (R)	>10	1> 2	No effect
Immune (I)	0	0	No effect

2-Yield and its components:

At harvest, (mid-April), samples of ten faba bean plants were collected at random from the central ridges of each plot to study the following traits: plant height (cm), number of pods/plant, weight of pods/plant (g), 100-seed weight/plant and seed yield/feddan.

Identification of phenolic acids in donor plant species:

Vanillic, syrungic, ferulic,, *p*-coumaric, *p*-hydroxypenzoic, protocatoic and caffic were subsequently checked for purity by high pressure liquid chromatography (HPLC). HPLC grade water and MeOH were used for all analyses. Phosphoric acid buffer was made using H_3PO_4 and HPLC grade $NH_4H_2PO_4$.

Phenolic extraction and hydrolysis: Water extract of each donor plant shoot was prepared, then phenolic extraction of phenolics in the water extract which found in glycon form was extracted as described by Mckeehen *et al*. (1999). Approximately, 15 ml of 4 N NaOH was added for 200ml of each concentration of water extract in 50 ml Pyrex centrifuge tube purged with nitrogen and shaken for 2 h in dark.

Statistical analysis:

Results were analyzed as split-split plot design by Gomez and Gomiz (1984). Least significant difference (LSD) method was used to test the differences between treatments means at 5 % level of probability as described by Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

1-Effect of preceding summer crops for producing allelopathic compounds:

A- Broomrape

Data in Tables 3 and 4 showed that the effect of preceding crops for producing allelopathic compounds on broomrape characters in 2013/2014 and 2014/2015 seasons.

Sowing of maize before faba bean decreased significantly the number of plant infestation of spikes broomrape/m^2, weight of spikes broomrape (g), incidence %, spike height and spike diameter (cm) by 32.0, 18.5, 44.7, 18.4 and 67.7% in 2013/14 season and by 37.7, 37.6, 16.6, 17.5 and 38.3% in 2014/15 season, respectively, as compared with sowing of sorghum before faba bean. Sowing of faba bean after maize lead to delay in days to broomrape emergence by 18.5% (122.37 days) and 16.6% (154.27 days) in the first and second seasons, respectively, as compared with sowing of faba bean after sorghum (84.56 and 132.29 days), in 2013/14 and 2014/15 seasons, respectively.

Table 3. Effect of preceding summer crops for producing allelopathic compounds, faba bean varieties and plant density on broomrape incidence in the first season.

Characters / Treatments	No. of plants /plot	No. of plant infestation	No. of spikes broomrape/m^2	Dry weight of spikes broomrape (g/m^2)	Incidenc %	Severity	days to broomrape emergence	spike height (cm)	spike diameter (cm)
A - Preceding summer crops									
- Cotton	174.83	28.92	23.58	99.05	16.84	0.152	102.37	26.64	2.01
- Sorghum	166.67	35.92	25.92	108.85	23.28	0.181	84.56	29.57	2.80
- Maize	184.42	22.50	18.58	78.05	12.54	0.112	122.37	25.03	1.67
LSD at 0.05	4.63	3.48	4.12	17.30	2.24	0.03	4.93	2.00	0.14
B – Varieties									
- Giza 843	178.11	26.00	19.89	83.53	15.22	0.128	103.37	21.95	2.16
- Giza 40	172.50	32.22	25.50	107.10	19.89	0.169	101.12	32.57	2.41
F test	*	*	*	*	*	*	*	*	*
C - Plant density									
- One side of ridge	228.78	23.83	20.28	85.17	15.14	0.089	108.37	30.25	2.41
- Two side of ridge	121.83	34.39	25.11	105.47	19.97	0.207	98.12	23.91	2.16
F test	*	*	*	*	*	*	*	*	*
Interactions:									
- A * B	ns	ns	*	*	*	*	*	ns	ns
- A * C	ns	ns	*	*	*	*	*	ns	ns
- B * C	ns	ns	ns	ns	*	*	*	ns	ns
- A * B * C	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 4. Effect of preceding summer crops for producing allelopathic compounds, faba bean varieties and plant density on broomrape incidence in the second season.

Characters / Treatments	No. of plants /plot	No. of plant infestation	No. of spikes broomrape/m^2	Dry weight of spikes broomrape (g/m^2)	Incidenc %	Severity	days to broomrape emergence	spike height (cm)	spike diameter (cm)
A - Preceding summer crops									
- Cotton	171.08	28.00	20.67	86.80	16.62	0.139	144.35	25.14	1.96
- Sorghum	163.75	36.50	24.42	102.55	24.03	0.176	132.29	27.45	2.74
- Maize	180.00	22.75	16.41	68.95	12.91	0.104	154.27	23.36	1.55
LSD at 0.05	4.75	3.75	5.35	22.47	2.36	0.04	3.01	1.65	0.12
B – Varieties									
- Giza 843	174.00	25.22	17.33	72.80	15.11	0.118	96.22	20.84	2.05
- Giza 40	169.22	33.94	23.67	99.40	20.59	0.162	78.56	30.25	2.12
F test	*	*	*	*	*	*	*	*	*
C - Plant density									
- One side of ridge	224.89	23.33	17.89	75.13	15.59	0.081	96.89	27.54	2.33
- Two side of ridge	118.33	35.83	23.11	97.07	20.11	0.198	87.89	22.4	2.09
F test	*	*	*	*	*	*	*	*	*
Interactions:									
- A * B	ns	ns	*	*	*	*	*	ns	ns
- A * C	ns	ns	*	*	*	*	*	ns	ns
- B * C	ns	ns	ns	ns	*	*	*	ns	ns
- A * B * C	ns	ns	ns	ns	ns	ns	ns	ns	ns

Sowing faba bean after cotton decreased the number of broomrape spikes/m^2, weight of spikes broomrape, incidence %, spike height and spikes diameter by 9.6, 12.3, 21.1, 6.4 and 20.4% in 2013/14 and by 25.9, 25.8, 9.1, 7.6 and 20.9% in 2014/15 season, respectively, as compared with sowing of faba bean after sowing sorghum. Sowing faba bean after cotton lead to increase days of broomrape emergence by 12.2 and 9.1% in both seasons, respectively, compared to sowing of faba bean after sorghum. Growing maize before faba bean gave the lowest broomrape severity in both seasons (0.112 and 0.104) as compared with cotton and sorghum. These results may be explained by Allelochemicals which caused inhibition of germination and growth has been identified (Wu *et al.* 1999).

B- Yield and yield components of faba beans:

Tables 5 and 6 indicated that the effect of preceding summer crops for producing allelopathic compounds on faba yield was significant in both seasons.

Sowing of maize before faba bean increased significantly plant height, weight of pods/plant, weight of seeds/plant, 100-seed weight and seed yield (ardab/fed) by 13.3, 33.5, 24.7, 14.0 and 13.8 % in 2013/14 season and by 16.6, 7.4, 8.7, 9.9 and 13.8% in 2014/15 season, respectively, as compared with sowing of sorghum before faba bean.

Sowing of cotton before faba bean increased significantly plant height, weight of pods/plant, weight of seeds/plant, 100-seed weight and seed yield (ardab/fed) by 3.9, 5.2, 4.9, 4.8 and 5.8% in first season and by 9.1, 2.0, 3.5, 4.7 and 5.5% in second season, respectively, as compared with sowing of cotton before faba bean.

These results are in harmony with those obtained by Hamayun *et al.* (2005) they mentioned that extracts of shoots and rhizomes from *Cyperus rotundus* and *Echinochloa crus-galli* were evaluated for allelopathic effect on seed germination.

A- Broomrape

Data in Tables 3 and 4 showed that varieties of faba bean affected significantly the broomrape growth characters in both seasons.

Sowing of variety Giza 843 decreased significantly number of spikes broomrape/m2, weight of spikes broomrape (g), spikes height and spikes diameter (cm) by 30.7, 16.8, 32.6 and 17.6 % in 2013/14 season and by 39.7, 37.5, 31.1 and 3.4% in 2014/15 season, respectively, as compared with variety Giza 40.

Variety of Giza 843 led to increase days of broomrape emergence by 16.8% (103.37 days) and 22.54% (96.22 days) compared with variety Giza 40 (101.12 78.56 days) in 2013/14 and 2014/15 seasons respectively. Cultivar Giza843 gave the lowest values (0.128 and 0.118) of broomrape severity in both seasons compared with Giza 40 (0.169 and 0.162). The obtained results are in agreement with those of Ismail (2013) and Nagwa et al. (2015).

Table 5. Effect of preceding summer crops for producing allelopathic compounds, faba bean varieties and plant density on faba bean yield and its components in the 2013/14 season.

Characters Treatments	Plant height (cm)	Weight of pods/ Plant (g)	Seed weight / plant(g)	100-seed Weight (g)	Seed yield (ardab /fed)
A - Preceding summer crops					
- Cotton	100.30	45.84	40.65	71.64	5.51
- Sorghum	96.53	43.56	38.75	68.30	5.19
- Maize	109.14	58.17	48.32	77.87	5.89
LSD at 0.05	7.32	5.33	7.62	1.91	0.23
B – Varieties					
- Giza 843	99.78	55.26	48.32	83.96	6.72
- Giza 40	104.20	43.12	38.75	61.25	4.34
F test	*	*	*	*	*
C - Plant density					
- One side of ridge	99.78	48.85	41.95	75.99	5.38
- Two side of ridge	104.2	49.53	45.12	69.21	6.68
F test	*	*	*	*	*
Interactions:					
- A * B	ns	*	*	*	*
- A * C	ns	*	*	*	*
- B * C	ns	ns	*	*	*
- A * B * C	ns	ns	ns	ns	ns

2-Effect of faba bean varieties:

B- Yield and its components:

Data in Tables 5 and 6 showed that the variety Giza 843 was significantly higher in plant height, weight of pods/plant, weight of seeds/plant, weight of 100-seed and seed yield (ardab/fed) by 4. 24, 28.15, 24.70, 37.08 and 54.84 % in first season and by 16.17,

7.98, 10.65, 8.12 and 14.86% in sacond season, respectively, compared to Giza 40. These findings are reported by Amer et al. (2012), Girma and Haile (2014) and Nagwa et al. (2015).

Table 6. Effect of preceding summer crops for producing allelopathic compounds, faba bean varieties and plant density on faba bean yield and its components in 2014/15 season.

Characters Treatments	Plant height (cm)	Weight of pods/ plant(g)	Seed weight / plant(g)	100-seed Weight (g)	Seedyield (ardab /fed)
A - Preceding summer crops					
- Cotton	144.35	75.51	69.37	74.27	6.88
- Sorghum	132.29	73.99	67.02	70.96	6.52
- Maize	154.27	79.50	72.85	77.98	7.42
LSD at 0.05	9.21	1.63	1.80	0.48	0.24
B – Varieties					
- Giza 843	154.38	79.4	73.27	77.31	7.42
- Giza 40	132.89	73.53	66.22	71.50	6.46
F test	*	*	*	*	*
C - Plant density					
- One side of ridge	142.54	66.84	61.6	80.35	6.77
- Two side of ridge	144.73	85.83	77.88	68.46	7.12
F test	*	*	*	*	*
Interactions:					
- A * B	ns	*	*	*	*
- A * C	ns	*	*	*	*
- B * C	ns	ns	*	*	*
- A * B * C	ns	ns	ns	ns	Ns

3-Effect of plant density:

A-Broomrape

Sowing of faba bean on two sides of ridge increased significantly the number of spikes broomrape and spikes weight broomrape, while decreased the spikes height and spikes diameter by 25.5, 36.8, 25.9 and 11.57% in first season and by 29.3, 28.6, 18.7 and 11.5% in second season, respectively, to compared with sowing of faba bean on one side of ridge (Tables 3 and 4).

Plant density at 26 plants/m2 led to decrease days broomrape emergence by 10.5% (98.12 days) and 12.1% (87.89 days) in 2013/14 and 2014/15 seasons, respectively, as compared with plant density at 13 plants/m2 (108.37 and 86.89 days). Plant density at 13 plants/m2 gave the lowest values of broomrape severity in both seasons (0.089 and 0.081) as compared with plant density at 26 plants/m2 (0.207 and 0.198). These findings are in harmony with those reported by Ismail and Fakkar (2008) reported that increasing plant density from 13 to 26 plants per m2 increased number and dry weight of broomrape spikes/m2 by (13.2, 10.8%, 24.0 and 10.7%) .

B- Yield and yield components of faba bean:

Data in Tables 5 and 6 showed that plant density at 26 plants/m2 on two sides of ridge increased significantly plant height, weight of pods/plant, weight of seeds/plant, and seed yield (ardab/fed) by 4.24, 1.39, 7.56 and 5.58 % in 2013/14 season and by 1.51, 22.12, 20.90 and 4.91% in 2014/15 season, respectively, as compared with plant density at 13 plants /m2 on one side of ridge. The 100-seed weight decreased significantly by 9.72 and 17.41% under sowing faba bean at 26 plants/m2 in the first and second seasons, respectively.

4-Effect of the interaction between preceding summer crops and faba varieties:

A-Broomrape

Table 7 demonstrated that effect of the interaction between preceding summer crops and faba varieties was significant on broomrape growth in 2013/14 and 2014/15 seasons.

Table 7. Effect of the interactions between preceding summer crops and faba bean varieties on broomrape characters in 2013/14 and 2014/15 seasons.

preceding Summer crops (A)	Varieties (B)	No. of spikes broomrape/m^2		Dry weight of spikes broomrape (g/m^2)		Incidence %		Severity		days to broomrape emergence	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Cotton	Giza 843	19.33	16.67	81.2	70	14.48	13.62	0.122	0.11	104.12	99.83
	Giza 40	27.83	24.67	116.9	103.6	19.2	19.62	0.183	0.168	101.5	79.67
Sorghum	Giza 843	22.83	20.83	95.9	87.5	19.43	20.07	0.158	0.152	79.0	81.5
	Giza 40	29.0	28.0	121.8	117.6	27.13	28.0	0.203	0.2	89.12	72.0
Maize	Giza 843	17.5	14.5	73.5	60.9	11.73	11.65	0.103	0.092	127	107.33
	Giza 40	19.67	18.33	82.6	77.0	13.35	14.17	0.12	0.117	118.12	87.0
LSD at 0.05		3.19	2.69	13.41	11.29	1.87	1.59	0.03	0.02	5.3	4.75

Sowing of maize before faba bean decreased the number of spikes broomrape, spikes height and spikes diameter by 29.3, 19.3, 32.1 and 20.9% in 1st season and by 45.1, 45.3, 32.1 and 22.9% in 2nd season under sowing variety Giza 40 as compared with sowing of sorghum before faba bean under variety of Giza 40 in both seasons.

B-Yield and its components

Data in Table 8 indicated that the interaction between preceding summer crops and faba varieties significantly affected yield in the two seasons. Sowing faba bean after sowing maize increased weight of pods/ plant, weight of seeds/plant, 100- seed weight and seed yield (ardab/fed) by 23.5, 12.6, 25.6 and 49.9% in first season and by 31.4, 28.3, 25.1 and 18.7% in second season, respectively, under sowing variety Giza 843 as compared with sowing Giza 40 faba bean after sowing sorghum.

Table 8. Effect of the interactions between preceding summer crops and faba bean varieties on yield and yield components in 2013/14 and 2014/15 seasons.

preceding Summer crops (A)	Varieties (B)	Weight of pods / plant (g)		Seed weight / plant(g)		100-seed weight (g)		Seed yield ardab/fed	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Cotton	Giza 843	54.39	88.82	48.51	76.13	84.46	79.9	6.35	7.33
	Giza 40	37.29	70.8	32.79	57.92	58.81	68.65	4.04	6.43
Sorghum	Giza 843	47.16	84.63	42.37	75.92	79.51	76.73	6.75	6.88
	Giza 40	39.96	66.38	35.49	63.1	57.09	65.8	4.27	6.17
Maize	Giza 843	64.34	84.03	54.06	81.88	87.9	84.42	7.06	8.05
	Giza 40	52.11	63.95	47.99	63.82	67.84	71.55	4.71	6.78
LSD at 0.05		3.68	2.45	7.37	1.84	4.11	1.84	0.2	0.2

5-Effect of the interaction between preceding summer crops and plant density:

A-Broomrape

Table 9 demonstrated that effect of interaction between preceding summer crops and plant density of faba bean was significant on broomrape growth in both 2013/14 and 2014/15 seasons.

Sowing of maize before faba bean decreased the number of spikes broomrape, spikes height and spikes diameter by 18.6, 20.5, 17.2 and 25.1% in first season and by 38.4, 38.3, 22.7 and 20.1% in second season with sowing faba bean on one side of ridge as compared with sowing sorghum before faba bean under sowing on the two sides of ridge in both seasons. Maize sowing before faba bean led to delay emergence of broomrape 7.3% and 8.7 % with sowing faba bean on two sides of ridge in first and second seasons, respectively, as compared to sowing faba bean on one side of ridge.

B-Yield and yield components

Data in Table 10 indicated that the interaction between preceding summer crops and plant density was significantly affected on yield and yield components in the two seasons.

Sowing of faba bean after sowing maize increased the weight of pods/ plant, weight of seeds/plant, 100- seed weight and seed yield (ardab/fed) by 54.5, 23.5, 29.6 and 49.9% and by 23.6, 31.4, 25.1 and 18.7% , in first and second season, respectively, under plant density at 26 plants/m^2 as compared to sowing faba bean after sowing sorghum under plant density at 13 plants/m^2.

Table 9. Effect of interactions between preceding summer crops and faba bean plant density on broomrape in 2013/14 and 2014/15 seasons.

Preceding Summer crops (A)	Plant density (C)	No. of spikes broomrape/m^2		Dry weight of spikes broomrape (g/m^2)		Incidence %		Severity		days of broomrape emergence	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Cotton	One side of ridge	21	18	88.2	75.6	16	16.02	0.092	0.082	105.9	87
	Two side of ridge	26.17	23.33	109.9	98	17.7	17.22	0.213	0.197	99.7	92.5
Sorghum	One side of ridge	22.17	20.17	93.1	84.7	18	18.67	0.102	0.093	92.4	82.3
	Two side of ridge	29.67	28.67	124.6	120.4	28.6	29.4	0.26	0.258	76.4	71.2
Maize	One side of ridge	17.67	15.5	74.2	65.1	11.4	12.1	0.075	0.068	126.9	91.3
	Two side of ridge	19.5	17.33	81.9	72.8	13.7	13.72	0.148	0.14	118.3	100
LSD at 0.05		3.2	3.09	13.5	13	2.1	1.91	0.02	0.02	4.58	3.47

Table 10. Effect of the interactions between preceding summer crops and faba bean plant density on yield and its components in 2013/14 and 2014/15 seasons.

Preceding Summer crops (A)	Plant density (C)	Weight of pods / plant (g)		Seed weight / plant(g)		100-seed weight (g)		Seed yield ardab/fed	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Cotton	One side of ridge	48.99	79.37	44.42	73.98	71.56	74.28	5.21	6.67
	Two side of ridge	42.69	71.65	36.87	64.75	65.04	67.63	5.17	7.1
Sorghum	One side of ridge	44.37	75.87	39.76	69.2	76.26	77.12	5.76	6.3
	Two side of ridge	42.75	72.12	38.1	64.85	67.01	71.44	5.26	6.17
Maize	One side of ridge	55.24	82.8	51.16	76.63	80.15	80.53	6.07	7.33
	Two side of ridge	61.11	76.82	50.89	69.07	75.59	75.43	5.7	7.5
LSD at 0.05		4.25	3.26	3.62	2.22	2.48	1.98	1.11	0.86

6-Effect of the interaction between faba varieties and plant density on:

A –Broomrape

Table 11 demonstrated that the effect of interaction between faba varieties and plant density was significant on days of emergence of broomrape only in 2013/14 and 2014/15 seasons.

Sowing variety Giza 843 faba bean led to increase days of emergence of broomrape by 7.3% and 8.7 % with sowing faba bean on two sides of ridge in first and second seasons respectively compared with sowing variety Giza 40 faba bean on one side of ridge.

Table 11. Effect of the interactions between faba bean varieties and plant density on broomrape in 2013/14 and 2014/15 seasons.

Preceding Summer crops (A)	Plant density (C)	Incidence %		Severity		days of broomrape emergence	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Cotton	One side of ridge	16	16.02	0.092	0.082	105.9	87
	Two side of ridge	17.7	17.22	0.213	0.197	99.7	92.5
Sorghum	One side of ridge	18	18.67	0.102	0.093	92.4	82.3
	Two side of ridge	28.6	29.4	0.26	0.258	76.4	71.2
Maize	One side of ridge	11.4	12.1	0.075	0.068	126.9	91.3
	Two side of ridge	13.7	13.72	0.148	0.14	118.3	100
LSD at 0.05		2.1	1.91	0.02	0.02	4.58	3.47

B- Yield and its components of faba bean

Data in Table 12 noted that the interaction between faba varieties and plant density was significantly affected on yield and its components in both seasons.

Sowing variety of Giza 843 faba bean increased the weight of seeds/plant, 100- seed weight and seed yield (ardab/fed) by 23.5, 29.6 and 49.9% in first season and by 31.4, 25.1 and 18.7% in the second season, respectively, compared with Giza 40 faba bean on two sides of ridge in the both seasons.

Table 12. Effect of the interactions between faba bean varieties and plant density on yield and yield components in 2013/14 and 2014/15 seasons.

Varieties (B)	Plant density (C)	Seed weight / plant (g)		100-seed weight (g)		Seed yield ardab/fed	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Giza 843	One side of ridge	49.22	79.44	85.68	82.4	6.56	7.22
	Two side of ridge	47.42	76.32	82.23	78.3	6.88	7.62
Giza 40	One side of ridge	41.02	67.1	66.3	72.22	4.81	6.3
	Two side of ridge	36.49	64.12	56.19	64.7	3.87	6.75
LSD at 0.05		2.47	3.56	2.03	2.06	0.29	0.23

7-Effect of the interaction among preceding summer crops, faba bean varieties and plant density on:

A –Broomrape

The interaction among preceding summer crops, faba bean varieties and plant density was not significant on broomrape growth in 2013/14 and 2014/15 seasons.

B- Yield and yield components of faba bean

The interaction brtween preceding summer crops, varieties and plant density was no significant on yield in the two seasons.

The growing demand for sustainable agricultural systems requires that the researchers reevaluate current production methods and inputs. To ensure continued productivity and potentially reduce synthetic herbicide requirements, allelopathy has become a focal point for research in the agricultural community. Although, many questions have yet to be resolved, the utilization of allelochemicals for weed suppression remains a promising avenue for reducing herbicide usage. Whether through the development of natural herbicides from isolated allelochemicals or through the application of cover crops with allelopathic properties, allelopathy will most likely be a factor in providing sustainable systems in the future.

Biochemical analysis for allelopathic compounds from preceding summer crops

Table 13 shows that the chemical analysis of cotton, maize and sorghum shoots revealed that the total phenolic aglycones was 100 µg/g dry weight respectively.

HPLC analysis revealed that there were seven phenolic acids isolated from the foliage dry weight of cotton, sorghum and maize, i.e. protocatechuic, caffic, p-hydroxy benzoic, vanillic, syringic, coumaric, and ferulic acids. However, the amounts of these phenols differ from one plant to another. The highest values in maize are ferulic acid (325.5 µg) and coumaric acid (142.3 µg), vanillic (95.5 µg), *p*-hydroxy benzoic (53.6 µg) and caffic (36.5 µg). While, in sorghum are ferulic acid (249.9µg) and coumaric acid (120.2 µg), and in cotton are ferulic acid (236.5 µg) and syringic acid (204.4 µg) and protocatechuic (44.4 µg).

Table 13. Phenolic acids in shoots of cotton, maize and sorghum plants.

NO	Plants of allelopathic donors	HPLC analysis :Phenolic acids (concentration µg/100 mg)						
	Scientific name	protocatoic	caffic	*p*-hydroxypenzoic	*p*-coumaric	syrungic	ferulic	Vanillic
1	Cotton	44.4	21.1	45.2	102.2	204.4	236.5	83.5
2	Maize	42.2	36.5	53.6	142.3	196.6	325.5	95.5
3	Sorghum	25.4	19.8	32.9	120.2	164.7	249.9	78.8

On the contrary, the least phenols values in rice are caffic acid (5.89 µg) and vanillic acid (18.5 µg), in alfalfa are protocatechuic acid (1.26 µg), caffic acid (0.44µg), in *Cyperus rotundus* are caffic acid (0.52 µg) and vanillic acid (1.52 µg) and in *Xanthium strumarium* are coumaric acid (8.49 µg) and caffic acid (13.42 µg).

Finally, it could be concluded that the allelopathic effect was found in cotton maize and sorghum against broomrape in faba bean. There is possibility of using the previous plants as allelopathic donors in agriculture rotation system and/or in the sequence summer and winter crops in the field.

Moreover, these natural allelochemical products either as water extracts from foliage of donor plants or incorporation directly into the soil may reduce the rate of the recommended herbicides and increase the efficiency of the herbicides to control broomrape in faba bean.

However, it is still needed to evaluate the previous results under field conditions to inter-act and contribute the natural allelochemical products with biotic and abiotic environmental factors.

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تأثير المحاصيل الصيفية المنتجة للأليلوباثي والكثافة النباتية وأصناف الفول البلدي علي مكافحة الهالوك

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[1]قسم بحوث البقوليات معهد بحوث المحاصيل الحقلية ، مركز البحوث الزراعية - الجيزة- مصر .

[2] المعمل المركزي لبحوث الحشائش ، مركز البحوث الزراعية - الجيزة- مصر .

الأليلوباثي هي مواد تنتج طبيعيا من النباتات وتؤثر إما سلباً أوإيجاباً علي نباتات أخري. فقد وجد كثير من الباحثين تأثير الذرة الشامية والقطن والذرة الرفيعة المثبط لنمو وانتشار الهالوك. لذلك أقيمت تجربتان حقليتان في حقول مصابة طبيعيا بالهالوك بمحطة البحوث الزراعية بشندويل - سوهاج خلال موسمي النمو الشتوي 2014/2013 و2015/2014م فى تصميم القطع المنشقة مرتين بهدف دراسة تأثير المحاصيل السابقة المنتجة للأليلوباثى (قطن ، ذرة رفيعة وذرة شامية) وصنفين من الفول البلدى (جيزة 843 وجيزة 40) وكثافتين نباتيتين (13 و 26 نبات/م^2) علي مكافحة الهالوك. أدى زراعة الذرة الشامية كمحصول منتج للاليلوباثي في إنقاص عدد ووزن شماريخ الهالوك بنسبة 32 و18.5٪ في الموسم الاول وبنسبة 37.7 و37.6 ٪ في الموسم الثاني وتأخير ظهور نباتات الهالوك فوق سطح التربة بنسبة 18.5 و16.6٪ في الموسمين الأول والثاني بالمقارنة بالقطن والذرة الرفيعة. تفوقت زراعة الفول البلدي عقب الذرة الشامية في محصول البذور/ف ومكوناته في كلا الموسمين مقارنة بزراعة الفول البلدي عقب قطن أو ذرة رفيعة مما يوضح أن الذرة الشامية أكثر المحاصيل إنتاجا للمواد الاليلوباثية عن باقي المحاصيل. حيث زاد محصول البذور للفول البلدي المنزرع عقب ذرة شامية بنسبة 13.8 و13.6 ٪ في الموسمين الأول والثاني بالمقارنة بزراعته عقب ذرة رفيعة. أدى زراعة القطن قبل الفول البلدى إلى زيادة معنوية فى كل من ارتفاع النبات ، وزن القرون/نبات ، وزن البذور/نبات ، وزن 100-بذرة ومحصول البذور (أردب/فدان) بقيم 3.9 ، 5.2 ، 4.9 ، 4.8 و 5.8% فى الموسم الأول وبقيم 9.1 ، 2 ، 3.5 ، 4.7 و 5.5% فى الموسم الثانى بالمقارنة بزراعة الذرة الرفيعة قبل الفول البلدى. كان لأصناف الفول البلدي تأثيراً معنوياً علي عدد ووزن شماريخ الهالوك وعدد الأيام اللازمة لظهورالهالوك فوق سطح التربة حيث تفوق الصنف جيزة 843 عن الصنف جيزة 40 بنسبة 30.7 و16.8 ٪ في الموسم الاول وبنسبة 39.7 و37.5 % في الموسم الثاني كما تأخر ظهور الهالوك فوق سطح التربة مع زراعة الصنف جيزة 843 بنسبة 16.8و22.5٪ في الموسمين الأول والثاني علي التوالي . كما أثرت أصناف الفول البلدي معنوياً علي طول النبات ، وزن قرون النبات ووزن بذورالنبات ووزن الـ100 بذرة ومحصول البذور/ف في الموسمين . حيث زاد المحصول البذري للفول البلدي بزراعة الصنف جيزة 843 بنسبة 39.7 و37.5 ٪ في الموسمين الأول والثاني علي التوالي مقارنةً بالصنف جيزة 40. أثرت الكثافة النباتية تأثيراً معنوياً علي عدد ووزن شماريخ الهالوك وعدد الأيام اللازمة لظهور الهالوك فوق سطح التربة .أشارت النتائج إلى أن زيادة الكثافة النباتية من 13 الى 26 نبات/م^2 أدت إلى زيادة العدد والوزن الجاف للهالوك/م^2 بمقدار (25.5 و36.7٪) و(29.3 و28.6٪) فى الموسمين الأول و الثاني على التوالي.أثرت الكثافة النباتية معنوياً علي طول النبات للفول البلدى ، وزن قرون النبات و وزن بذور النبات ووزن الـ100 بذرة ومحصول البذور/ف في الموسمين . حيث زاد المحصول البذري للفول البلدي بزراعة الفول البلدي بمعدل 26 نبات/م2 بنسبة5.58 و4.91٪ في الموسمين الأول والثاني علي التوالي مقارن بزراعة الفول البلدي بمعدل 13 نبات/م^2. كان التفاعل بين المحصول السابق والأصناف وبين المحصول السابق والكثافة النباتية وبين الأصناف والكثافة النباتية معنوياً علي عدد ووزن شماريخ الهالوك وكذلك تأخير ظهور الهالوك فوق سطح التربة وكذلك علي المحصول ومكوناته في الموسمين. أمكن الحصول علي أقل عدد ووزن للهالوك وأقصي عدد أيام لظهور الهالوك وكذلك أعلي وزن من الـ 100 بذرة والمحصول البذري (أردب/ف) من زراعة الذرة الشامية كمحصول سابق مع استخدام الصنف جيزة 843 والزراعة علي ريشتين. كان التفاعل الثلاثي بين المحصول السابق والأصناف والكثافة النباتية غير معنوي علي عدد ووزن شماريخ الهالوك والمحصول ومكوناته في كلا الموسمين. بين التحليل باستخدام جهاز الـ HPLC أنه يوجد سبعة أحماض فينولية ذات التاثير الاليلوباثي تم عزلها من المجموع الخضرى الجاف للذرة الشامية والقطن والذرة الرفيعة. الأحماض الفينولية المثبطة لنمو وانتشار الهالوك هي حمض الفانيلك (95.5-83.5- 78.8 ميكروجرام) وحمض الفيروليك (325.5 - 236.5 - 249.9 ميكروجرام) والسيرنجك (196.6 -204.4 - 164.7 ميكروجرام) والكيوماريك (142.3- 102.2- 120.2 ميكروجرام) الهيدروكسي بنزويك (53.6-45.2- 32.9 ميكروجرام) والكافيك (36.5-21.1- 19.8 ميكروجرام) والبروتوكاتويك (42.2- 44.4- 25.4 ميكروجرام) تفوقت الذرة الشامية تلاها القطن ثم الذرة الرفيعة. نستخلص من هذه الدراسة أنه يمكن استخدام الذرة الشامية والذرة الرفيعة والقطن كنباتات ذات تأثير أليلوباثى فى نظام الدورة الزراعية من خلال تتابع زراعة المحاصيل الصيفية والشتوية فى الحقل لمكافحة الهالوك بهدف تقليل معدل استخدام مبيدات الحشائش الموصى بها بالإضافة إلي إختيار الأصناف المقاومة والكثافة النباتية العالية لتخفيف الإصابة.