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Research Article

Effect of Intercropping by Flax, Radish and Fenugreek on Faba Bean, *Vicia faba* L., Production and Reduction of *Orobanche crenata* Forsk Seed Bank

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Abstract

Faba bean *Vicia faba* L. is a primary source of protein in the diet of masses in Egypt. Broom-rape, *Orobanche crenata* Forsk (Orobanchaceae), present great threat parasitic weed to some crops in Egypt including faba bean. Egyptian farmers were forced to abandon growing faba bean crops due to *O. crenata* heavy soil infestation. Several methods have been used for controlling this parasite, but without obvious success. Many researches have shown that intercropping has been more effective than monocropping in suppression of parasitic weeds. The effect of intercropping (fenugreek, radish and flax) using two resistant cultivars (Giza 843& Misr 3) on the emergence of the broomrape spikes and faba bean production were carried out. Intercropping flax or fenugreek among faba bean cultivars, caused a significant reduction in the infestation levels of *O. crenata* and increased the faba bean yield compared with sole treatments. Flax was more effective in the reducing infestation rate by *O. crenata* than fenugreek. This reduction appeared to be related to reduced seed germination which may have been as a result of allelochemicals released by fenugreek roots, though this was not confirmed in this study. The reduction in weed infestation was more pronounced in Giza 843, than in Misr 3. Flax treatment showed the lowest weed infestation compared with other intercropping treatments. Fenugreek intercropping treatment resulted in the highest pod yield for both Giza 843 and Misr 3. Using resistant cultivars intercropping with fenugreek or flax is very promising trend that generally combines both good yield and low number of emerged spikes that reduce broomrape seed bank in the infected soils, with variations depending on the cultivar and growing season.

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Keywords

Resistance Faba Bean Cultivars, Intercropping, Broomrape Infestation, Seed Bank

1. Introduction

Broomrapes (*Orobanche* spp.) are parasitic achlorophyllous weeds totally dependent on the host for organic carbon, water and nitrogen [1]. Various Orobanche species cause severe damage in the yields of many important crops. *Orobanche crenata* Forsk (broomrape) is a devastating weed parasitising legume and other crops such as pea, chick pea, faba bean, lentil, common vetch, and several crops [2-4]. The parasitic weed is widespread in Middle East, Southern Europe, and Mediterranean region]. In Egypt, *O. crenata*, is considered as a serious emerging problem where yield losses can reach more than 100% in faba bean [6, 4].

The seeds of these parasitic weeds may remain dormant in the soil for many years until germination is stimulated by root exudates from a host plant and the climatic conditions become favorable [7]. The continuous spread of *Orobanche* limits the choice of rotational crops and often force farmers to give up growing the most profitable host crops and many farmers in the infested areas abandon the cultivation of susceptible crops [8]. According to [9], faba bean roots release signaling molecules that induce the germination of the parasitic weed seeds in the root-soil interface. After germination, the parasite forms radicles and haustoria. The haustorium connects to host roots for penetrate it reaching the vascular tissues. The haustorium establishes a vascular connection with the xylem and/or xylem and phloem in order to absorb water and photosynthates from the host plant. Once a functional vascular connection is established, broomrape undergoes vegetative growth, followed by emergence from the soil. After weeks of vegetative growth, broomrape flowering, to form seeds [9].

Several strategies have been employed to control Orobanche spp. Physical, cultural, chemical and biological approaches have been explored but none has proven to be sufficiently effective, economical and as applicable as desired [1, 10]. The negative environmental effects of herbicides have encouraged researches to study sustainable approaches of weed control, including intercropping [11]. Intercropping host plants with inhibitory crops may be an interesting approach. Intercropping is regarded as an ecological method to manage pests, diseases and weeds and allow for more efficient resource utilization [12]. It has been demonstrated that intercrops with cereals, fenugreek (*Trigonella foenum*), berseem clover (*Trifolium alexandrinum* L.), or oats (*Avena sativa*) can reduce *O. crenata* infestation on faba bean and pea due to allelopathic interactions [13-15].

The use of trap crops offers the advantage of stimulating broomrape germination without being parasitized. Flax, fenugreek and Egyptian clover are known trap crop for *O crenata* [16]. Allelopathy is a natural process in which plants interact with other plant species through releasing allelochemicals into the environment, hence affecting the growth of each other [17]. Many higher plant species contain chemicals with an allelopathic activity in different parts [18]. Under certain conditions, these allelochemicals are released into the environment, either as exudation or through decomposition of plant residues that affect the neighboring plants [19]. This effect may be positive or negative [20]. The objectives of this work were to investigate the effect of intercropping by flax, radish (*Raphanus sativus*) and fenugreek (*Trigonella foenum-graecum*) on faba bean, *Vicia faba* L., production and reduction of *O. crenata* Forsk seed bank. This was achieved through field trials.

2. Materials and Methods

Field experiments were conducted over two consecutive cropping seasons at the Nubaria Research Station's Agricultural Experimental. Egypt (2020/ 2021 and 2021/ 2022). Two faba bean cultivars, Giza 843 and Misr 3 were utilized, both are known for their resistance to *O. crenata* infestation. These cultivars were sown in rows within a naturally *O. crenata*-infested sandy loam soil field. The planting arrangement consisted of four rows, each 4 meters in length, with a row spacing of 0.5 meters, and 50 seeds were placed in each row. An optimal seeding ratio of three seeds of each Flax, fenugreek and radish were intercropped separately behind two faba seeds. Notably, no fertilizers or chemical treatments were administered throughout the duration of both seasons.

A Completely randomized block multifactor design (CRB) involving three blocks was adopted. Each treatment was replicated four times, with a plot area measuring 42 square meters. In each of the two seasons, observations were made at the crop's maturity stage. Specifically, the count of emerged Orobanche shoots and the pod yield of faba beans (measured in kilograms per plot) were recorded in the two central rows of each plot. Additionally, Orobanche characters such as the number of fruits and seeds per spike, along with the length of the spikes, were recorded. In addition, in each cropping seasons, nine random plants per plot/treatment were gently uprooted and the number of Broomrape fruits and seeds /shoot was recorded.

Statistical analysis

Where appropriate, data were subjected to one-way analysis of variance to determine differences between means. Student's t-test was used for statistical analyses. Data are presented as means of number of parasitized larvae ± SE.

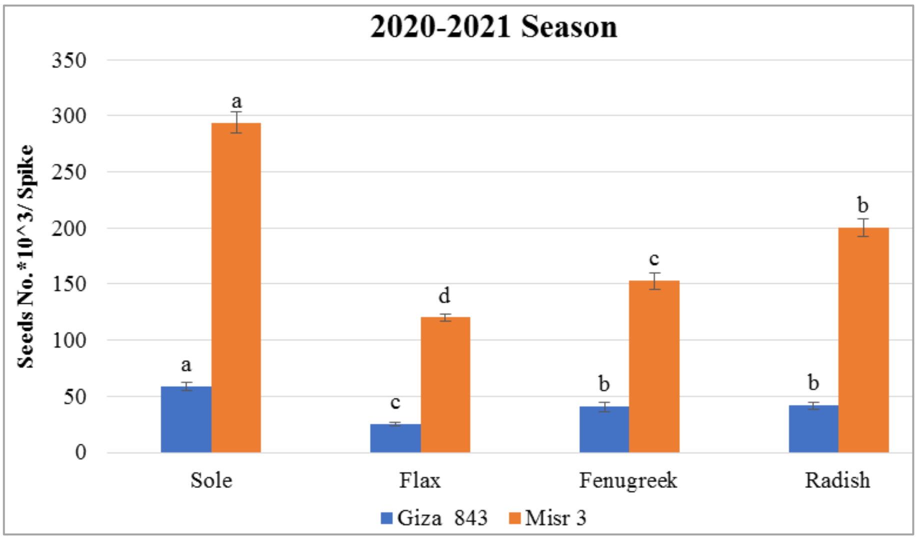
3. Results

Table 1 shows the effect of flax, fenugreek and radish intercropping with resistance two faba bean cultivars on *Orobanche* weed length, biomass and broomrape seed production (new seed bank) in 2020-2021 season. Sole faba bean Giza 843 had significant longer broomrape length (cm) (F 12.49; d.f. = 3, 11; P < 0. 05), higher broomrape biomass (g) (F = 137.29; d.f. = 3, 11; P < 0. 05) and capsules weight (g.) (F = 47.99; d.f. = 3, 11; P < 0. 05) /spike compared with those in faba bean cropping systems. In sole faba bean Misr 3, the same trend was observed. Where significant longer broomrape length (F = 12.93; d.f. = 3, 11; P < 0. 05), higher biomass (F = 231.42; d.f. = 3, 11; P < 0. 05), and casules weight/spike (F = 130.83; d.f. = 3, 11; P < 0. 05) were recoded.

Table 1. *Effect of flax, fenugreek and radish intercropping through with two faba bean cultivars on Orobanche weed length, biomass and seed production (2020-2021 season).*

Cultivar	Intercropped plant	*Orobanche*		Capsules Weight(g)/Spike	Infestation by *P. orobanchia* (%)	Seeds weight (mg)/Spike
		Length (cm)	Biomass (g)			
Giza 843	Sole	68.44a ±3.57	42.10a±1.78	19.59a ±0.88	47.33a ±0.84	385.69a ±26.26
	Flax	54.78b ±3.08	21.58c ±0.86	11.37c ±0.64	55.15b ±1.75	176.9b ±18.22
	Fenugreek	51.94b ±3.88	40.75b ±1.33	11.18c ±0.74	50.48b ±1.80	125.69c ±26.26
	Radish	56.09b ±3.72	48.38a ±2.45	14.85b ±1.33	48.70b ±1.37	210.61b ±21.78
Misr 3	Sole	65.89a ±2.67	52.63a ±0.33	28.92a ±0.81	20.92d ±0.84	1186.17a ±133.83
	Flax	50.29b ±2.40	36.54c ±0.77	12.41c ±0.58	49.37a ±1.27	424.85b±45.92
	Fenugreek	50.11b ±7.87	40.07b ±0.46	11.37c ±0.60	39.41c ±1.48	304.18b±78.06
	Radish	52.20b ±3.09	53.47a ±1.72	20.67b ±2.19	46.07 b±0.96	1005.82a±109.19

For each cultivar, means in each column followed by the same letter are not significantly different (P < 0.05; ANOVA).



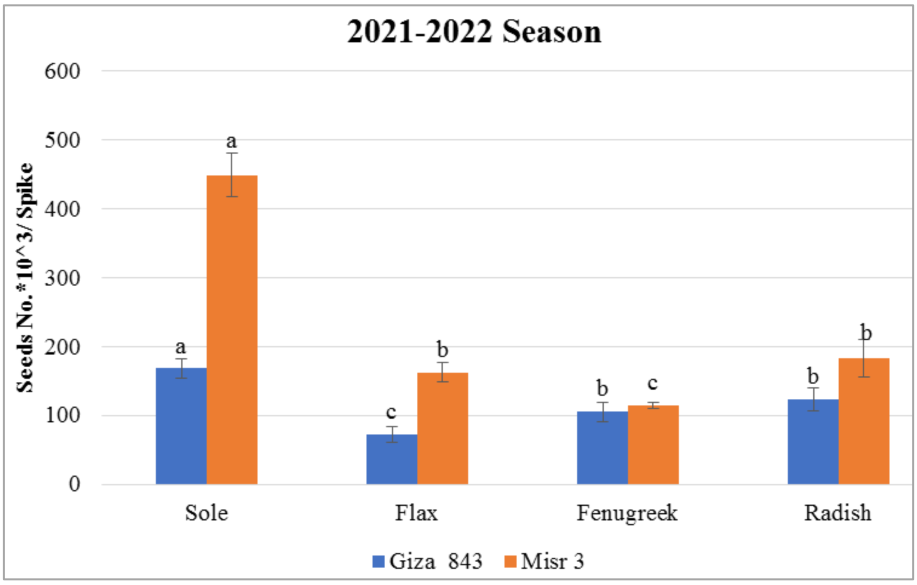


Figure 1. *Effect of flax, fenugreek and radish intercropping in two faba bean cultivars on Orobanche seeds number per spike. For each cultivar, bars bearing the same letter are not significantly different (P < 0.05; ANOVA).*

Data presented in Table 3 demonstrated that, in the first season, sole faba bean cultivar of Giza 843 had significant lower weed infestation rate (16.04%) compared to sole Misr 3 (24.02%). Moreover, when faba bean intercropped with flax, fenugreek, or radish, both cultivars showed significantly higher reduction in weed infestation compared to sole cultivars. The reduction was more pronounced in Giza 843, than in Misr 3. Among the intercropped system, flax treatment showed the lowest weed infestation (8.78% in Giza 843 and 8.73% in Misr 3) compared with other intercropping treatments. Theses significant figures affected the broomrape seed load freshly added to the Giza 843 soil (for seed number $F = 50.04$; d.f. = 3, 11; $P < 0.05$ and for seed weight ($F = 69.82$; d.f. = 3, 11; $P < 0.05$)); and Misr 3 soil (For seed number, $F = 305.99$, d.f. = 3, 11; $P < 0.05$; for seed weight, $F = 58.75$; d.f. = 3, 11; $P < 0.05$), respectively. The reduction of broomrape seeds in Giza 843 intercropped by flax, fenugreek and radish treatments reached up 57.61, 31.46 and 29.48% compared to sole soil vs.95.11, 48.01 and 31.77 % in Misr 3 soil, respectively (Figure 1).

Table 2. *Effect of flax, fenugreek and radish intercropping with two faba bean cultivars on Orobanche weed length, biomass and seed production (2021-2022 season).*

Cultivar	**Intercropped plant**	***Orobanche*** Length (cm)	Biomass (g)	**Capsules Weight(g)/ Spike**	**Infestation by *P. orobanchia* (%)**	**Seeds weight (mg)/ Spike**
Giza 843	Sole	61.33a ±2.70	11.40a ±0.81	16.50a ±0.04	65.47c ±2.58	26.13a ±2.39
	Flax	40.00b ±3.67	6.17a ±0.51	11.00c ±0.05	77.17ab ±3.80	11.19c ±1.13
	Fenugreek	40.34b ±4.92	10.94b ±0.31	11.10c ±0.06	71.92b ±4.53	12.8c ±0.65
	Radish	42.26b ±3.35	12. 08a±0.12	12.70b ±0.13	80.86bc ±2.76	18.77b ±2.25
Misr 3	Sole	58.11a ±2.11	19.08a ±1.28	11.56b ±0.08	40.12c ±3.20	58.45a ±1.25
	Flax	45.99bc ±3.60	13.58b ±1.24	10.50c ±0.07	92.39a ±0.54	18.04c ±0.61
	Fenugreek	41.65c ±2.40	12.65b ±1.04	9.30d ±0.09	79.63b ±3.46	20.41c ±2.77
	Radish	50.11b±3.45	11.17b ±1.06	14.79a ±0.03	83.86b ±1.24	42.62b ±2.76

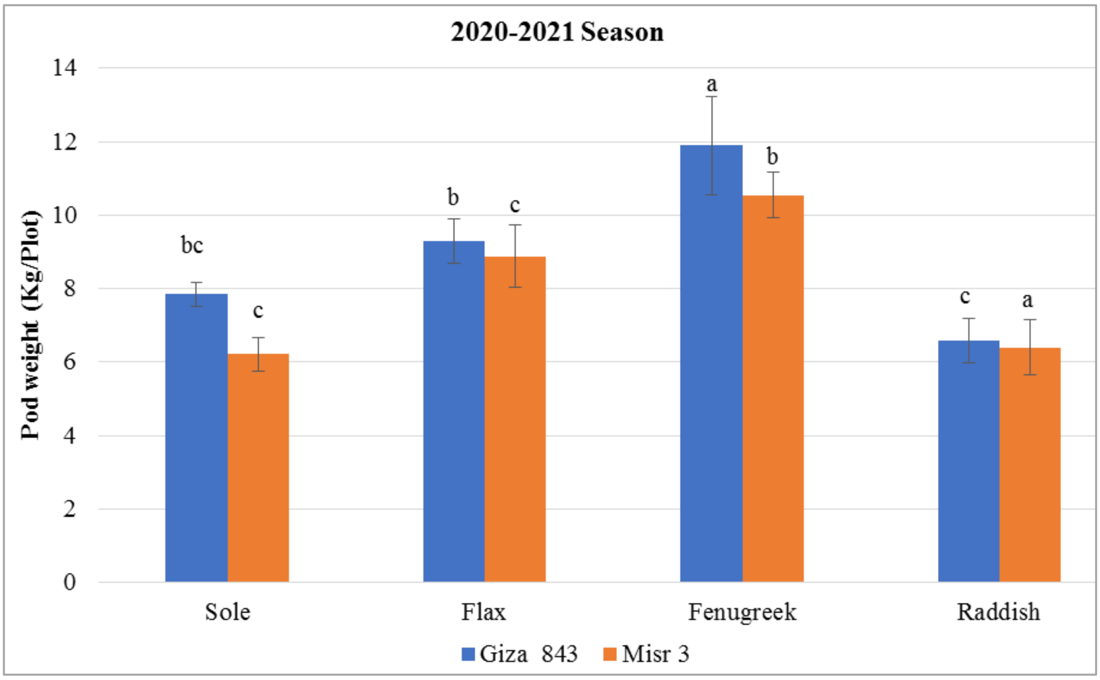
For each cultivar, means in each column followed by the same letter are not significantly different (P < 0.05; ANOVA).

Table 3. Effect of flax, fenugreek and radish intercropping with two faba bean cultivars on number & infestation rate of O. crenata and pod yield (dry weight kg. /plot) of faba bean.

Season	Intercropped plant	Cultivar					
		Giza 843			Misr 3		
		Weed no./plot	% Weed infestation ± SE	Pod weight (kg) / Plot ± SE	Weed no./plot	% Weed in-festation ± SE	Pod weight (kg) / Plot ± SE
2020-2021	Sole	No data	16.04a ± 1.59	7.84bc ± 0.33	No data	24.02a ± 1.03	6.21c ± 0.45
	Flax	No data	8.78b ± 1.46	9.29b ± 0.59	No data	8.73b ± 2.87	8.88b ± 0.84
	Fenugreek	No data	9.93b ± 1.67	11.99a ± 1.34	No data	10.49b ± 1.67	10.54a ± 0.62
	Radish	No data	11.76b ± 0.41	6.59c ± 0.61	No data	21.56a ± 6.93	6.40c ± 0.76
2021-2022	Sole	96.67a ± 4.40	18.52a ± 2.62	5.30c ± 0.08	185.18a ± 5.61	44.44a ± 4.54	4.75c ± 0.17
	Flax	65.00b ± 3.54	5.56d ± 0.26	8.39a ± 0.59	41.50d ± 4.44	13.80c ± 0.46	7.14b ± 0.20
	Fenugreek	51.50c ± 4.79	9.11c ± 0.00	8.92a ± 0.52	52.50c ± 0.89	13.89c ± 0.46	9.19a ± 0.76
	Radish	60.00b ± 0.91	13.89b ± 0.46	6.86b ± 0.67	70.00b ± 0.41	25.00b ± 1.94	5.62c ± 0.55

For each season, means in each column followed by the same letter are not significantly different ($P < 0.05$; ANOVA).

Data in Table 3 showed that the intensity of weed infestation significantly affected the faba bean pod yield (kg)/ plot. When weed infestation increased significantly in sole cutivars of both Giza 843 plots ($F = 16.00$; d.f. = 3, 11; $P < 0.05$) and Misr3 plots ($F = 23.67$; d.f. = 3, 11; $P < 0.05$). So, intercropping significantly affected pod yield in both Giza 843 ($F = 24.62$; d.f. = 3, 11; $P < 0.05$) and Misr 3 ($F = 23.67$; d.f. = 3, 11; $P < 0.05$). Fenugreek intercropping treatments resulted in the highest pod yield for both Giza 843 and Misr 3, (11.99 and 10.54 kg / Plot, respectively, Figure 2).



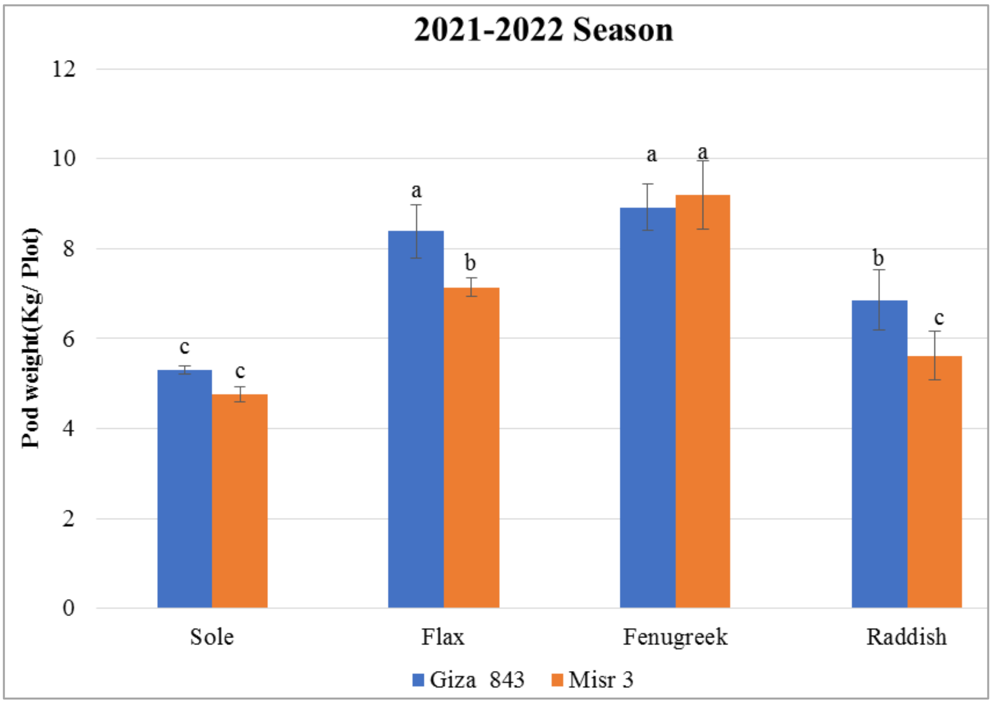


Figure 2. *Effect of flax, fenugreek and radish intercropping in two faba bean cultivars on faba bean production (Pod weight Kg/plot). For each cultivar, bars bearing the same letter are not significantly different (P < 0.05; ANOVA).*

In the second season, *Orobanche* weed length, biomass, and seeds production were measured (Table 2). Sole cropping of Giza 843 had the highest values for these parameters (weed length F = 66.32; d.f. = 3, 11; P < 0. 05); weed biomass (F = 22.57; d.f. = 3, 11; P < 0. 05; seeds production (F = 356.92; d.f. = 3, 11; P < 0. 05), resulted in highest seeds production. So, intercropping with flax, fenugreek, or radish reduced *Orobanche* weed characteristics. Among the intercropping plots, flax intercropping had the most significant reduction in *Orobanche* seed production (F = 356.92; d.f. = 3, 11; P < 0. 05). For Misr 3 cultivar the same trend was observed. In Misr 3 sole soil, longest weed length (F = 1011.66; d.f. = 3, 11; P < 0. 05) greatest biomass (F = 16.8; d.f. = 3, 11; P < 0. 05) greatest seeds production (F = 268.7; d.f. = 3, 11; P < 0. 05), While fenugreek had the greatest reduction (F = 268.7; d.f. = 3, 11; P < 0. 05) in freshly added seeds comparing to other cropping systems.

Intercropping affected the broomrape seed load freshly added to the Giza 843 soil (for seed number F = 356.92; d.f. = 3, 11; P < 0. 05 and for seed weight (F = 305.99; d.f. = 3, 11; P < 0. 05)); and Misr 3 soil (For seed number, F = 265.7, d.f. = 3, 11; P < 0. 05; for seed weight, F = 138.84; d.f. = 3, 11; P < 0. 05), respectively. The reduction of broomrape seeds in Giza 843 intercropped by flax, fenugreek and radish treatments reached up 57.03, 37.56 and 26.89% compared to sole soil vs.63.82, 74.41 and 59.16% in Misr 3 soil, respectively (Figure 1).

Data in Table 3 showed that the higher intensity of weed infestation in sole treatments significantly affected the faba bean pod yield (kg)/plot. When weed infestation increased significantly in sole cultivars of both Giza 843 plots (F = 51.03; d.f. = 3, 11; P < 0. 05) and Misr3 plots (F = 100.47; d.f. = 3, 11; P < 0. 05); intercropping significantly affected pod yield in both Giza 843(F = 39 76; d.f. = 3, 11; P < 0. 05) and Misr 3(F = 47.88; d.f. = 3, 11; P < 0. 05). Fenugreek intercropping treatments resulted in the highest pod yield for both Giza 843 and Misr 3, (8.92 and 9.19kg / Plot, respectively, Figure 2).

During the second season (2021-2022) weed infestation (Table 3) followed similar trend of the previous season. Where, Giza 843 had a lower weed infestation rate than Misr 3 in sole cropping (18.52% and 44.44%, respectively). Flax intercropping treatment significantly reduced weed infestation in both Giza 843 and Misr 3 faba bean cultivars (5.56% and 13.80%, respectively), while fenugreek and radish also had positive effects. Also, in this season, the effect of intercropping on faba bean pod yield was significant. Flax and Fenugreek intercropping increased significantly pod yield of both Giza 843 (8.39 ± 0.59) and 8.92 ± 0.52 kg) and Misr 3 (7.14 ± 0.20 and 9.19 ± 0.76kg) cultivars, respectively.

The reduction in weed infestation was more pronounced in Giza 843, than in Misr 3. Among the intercropped system, flax treatment showed the lowest weed infestation (8.78% in Giza 843 and 7.73% in Misr 3) compared with other intercropping treatments.

Fenugreek intercropping treatment resulted in the highest pod yield for both Giza 843 and Misr 3, (11.99 and 10.54 kg/ Plot, respectively). Among the intercropping plots, flax intercropping had the most significant reduction in *Orobanche* seed production (F = 356.92; d.f. = 3, 11; P < 0. 05).

4. Discussion

Broomrape (*Orobanche crenata* Forsk.) is a major threat to faba bean and an important danger parasite. Intercropping is defined as an agronomic practice of growing two or more crops in the same field at the same time [21]. An intercropping is a necessity to control the spread and progress of the parasite before it leads to great economic losses. Understanding the impact of intercropping on *Orobanche* capsules number and seeds is crucial for developing sustainable agricultural practices in faba bean fields. The advantage of intercropping in controlling crop diseases has been reported in numerous intercropping systems [22-24]. The present results showed that intercropping faba bean cultivars with flax, fenugreek, or radish had positive effects on reducing *Orobanche* infestation and improving pod yield in two growing seasons. Fenugreek or flax + faba bean decreased number of spikes per plot and pod weight (kg.)/plot increased compared with sole faba bean. On the other hand, fenugreek, flax or radish + faba bean had a lower number of parasitic seedes/spike compared with sole faba bean but radish + faba bean had a higher parasitic seeds/ spike than the others treatments in plots soil infested with broomrape. This may suggest that allelochemicals released by roots of intercropping plants differ in their amounts or effectiveness. Results of [25] showed that growing fenugreek with faba bean cultivars Giza 843 and Misr 3 reduced seed germination of broomrape by almost 30% than their sole cultures, meanwhile this percentage reached 73% by growing radish with Misr 3 only. Present study suggested that flax and fenugreek intercropping, in particular, appeared to be highly effective in reducing weed infestation and increasing pod yield compared with intercropping by radish. The results suggest that intercropping by Flax and fenugree can be a valuable strategy for managing *Orobanche* infestation and enhancing faba bean production, with variations depending on the cultivar and growing season.

5. Conclusion

Intercropping faba bean cultivars with flax, fenugreek, or radish had positive effects on reducing *Orobanche* infestation and improving pod yield in both growing seasons. Flax and fenugree intercropping, in particular, appeared to be highly effective in reducing weed infestation and increasing pod yield compared with intercropping by radish. The results suggest that intercropping by Flax and fenugreek can be a valuable strategy for managing *Orobanche* infestation and enhancing faba bean production, with variations depending on the cultivar and growing season. Reduced *Orobanche* seed production and capsule formation seed production can lead to lower weed infestation and subsequently improve faba bean yields. Farmers can potentially use this information to make informed decisions about intercropping practices based on the present data.

Abbreviations

CRB: Completely Randomized Block Multifactor Design

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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