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The dual allelopathic capacity of two Brassicaceae plants' seed powder in controlling *Orobanche crenata* infesting *Pisum sativum* as well as stimulating its growth and yield

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Abstract

Background: It is well known that legume and other crops such as pea, faba bean, lentil, chick pea, and several other crops are susceptible to *Orobanche crenata* (broomrape) infestation. There is a direct relationship between *O. crenata* infestation and yield losses depending on the severity of infestation, the crop sensitivity, the planting date, and the different prevailing environmental factors. So, the present investigation aims to evaluate the allelopathic potentiality of the seed powder of the Brassicaceae plants (*Eruca sativa* and *Sinapis alba*) in controlling *O. crenata* infesting *Pisum sativum* plants.

Materials/methods: Two greenhouse experiments were held during two consecutive winter seasons to study the allelopathic effect of *Eruca sativa* (Essp) and *Sinapis alba* (Sasp) seed powder and compare it with recommended Basamid (Dazomet) herbicide treatment in controlling *O. crenata* infesting *Pisum sativum* as well as their effect on *P. sativum* growth, yield, and yield attributes. The treatments were conducted by mixing the seed powder of *E. sativa* (Essp) or *S. alba* (Sasp) to the soil at 12.5, 25.0, 37.5, and 50 g/kg soil as well as Basamid herbicide at 0.2 g/pot.

Results: The recorded results show that both Essp and Sasp at successive rates as well as Basamid treatment scored a great inhibition in dry weight of *O. crenata* tubercles infesting *P. sativum* plants at 55 days after sowing (DAS) and at harvest. The highest rate (50 g/kg) of both applied seed powder achieved the highest level of controlling *O. crenata* investigated weed. Growth as well as yield and yield attributes of *P. sativum* increased by the application of Essp and Sasp especially at the lowest rates in comparison with infected control.

Conclusion: The lowest rates (12.5 and 25 g/kg soil) of both Essp and Sasp were the optimum applied treatments that suppressed *O. crenata* weed with the highest yield of *P. sativum* as compared with the healthy control. Glucosinolates and phenolic compounds in both seed powder may be the main active allelochemical which could be considered as a natural bioherbicide for controlling the *O. crenata* parasitic weed that infests *P. sativum* and reflected in turn on the plant yield by increase.

Keywords: Allelopathy, *Eruca sativa*, *Sinapis alba*, Glucosinolates, Phenolic contents, *Pisum sativum*, *Orobanche crenata*

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Background

Orobanche crenata (broomrape) is a parasitic weed on legume and other crops such as pea, chick pea, faba bean, lentil, common vetch, and several crops (Messiha et al. 2004; Hershenhorn et al. 2009). *O. crenata* parasitic weed is widespread in Middle East, Southern Europe, and Mediterranean region (Kandil et al. 2015). The leguminous yield losses due to *O. crenata* infestation depend on variation of dominant environmental factors, brutality of infection, and sowing date (Rubiales et al. 2009; Kandil et al. 2015). The difficulty in controlling *Orobanche* spp. in leguminous is related to several agents such as its location from the soil surface, host plant roots penetration, complicated mechanisms of seed dispersion, germination, and permanence (Linke and Saxena 1991). Recently, many strategies have been developed aiming to control *O. crenata* parasitic weed either chemically or biologically beside the cultural practices (Rubiales et al. 2009; Fernandez-Aparicio et al. 2011; Messiha et al. 2018; El-Dabaa et al. 2019; El-Masry et al. 2019).

Pea (*Pisum sativum* L.) is a well-known vegetable and belongs to the family Leguminosae. It is a major ingredient of vegetarian diets and meets the food requirements of people all over the world. It contains most essential nutrients like starch, protein, and fiber and has significant amounts of vitamins and minerals and is characterized by a relatively high antioxidant activity (Han and Baik 2008). Pea is one of leguminous plants which infested by *O. crenata* that causes severe loss of the plant yield.

The recent approaches in agricultural production are trying to use natural and safe substances to compete weeds, insects, nematodes, etc., to decrease the harmful effects of synthetic chemicals (like herbicides, insecticides, nematicides, and fungicides) and at the same time improve the quality and increase the production of different crops. Allelopathy is the phenomenon where natural compounds are released from the different parts of the plant such as roots, shoots, leaves, or flowers which affect other plants (Rice 1995) and can be used as a safe approach for controlling some weeds. Many higher plant species have been approved to have chemicals accompanied with the allelopathic properties; these allelochemicals are released into surrounding areas either by exudation or leaching or through decomposition of plant residues that affect the neighboring plants (Einhellig 2004). These neighboring receptor plants are positively or negatively affected by the allelochemicals (Zhou et al. 2011). In different allelopathic plants, allelochemicals such as flavonoids, terpenoids, alkaloids, glucosinolates, phenolic compounds, and amino acids were found (Fahey et al. 2001; Velasco et al. 2008).

Brassicaceae family is reported to have allelochemicals that improved its inhibitory effect on weed growth and hence received great attention to be applied as a safe controlling method (Fenwick et al. 1983; Velasco et al. 2008; Zaji and Majd 2011; Martinez-Ballesta et al. 2013; El-Wakeel et al. 2019). The allelochemicals that are produced in abundant amount in *Brassica* sp. tissues are known as glucosinolates. As the plant tissues are disrupted, the myrosinase enzyme acts to hydrolyze glucosinolates to several degradable products, i.e., nitriles, isothiocyanates, thiocyanates, oxazoliolines, and epithionitriles (Bones and Rossiter 2006). Isothiocyanates are the main degradable products that are phytotoxic (Fenwick et al. 1983; Fahey et al. 2001; Zaji and Majd 2011; Martinez-Ballesta et al. 2013) and have pesticidal activities (Velasco et al. 2008). Many scientists have been improved that seeds of Brassicaceae contain an abundant amount of glucosinolates that are higher than any other part of plants (Fahey et al. 2001; Velasco et al. 2008).

So, the present investigation is applied to evaluate the allelopathic potentiality of two seed powder of the Brassicaceae plants (*Eruca sativa* and *Sinapis alba*) in controlling *Orobanche crenata* infesting *Pisum sativum* plants.

Materials and methods

Two pot experiments were carried out during two successive winter seasons of 2016/2017 and 2017/2018 at the greenhouse of the National Research Centre, Dokki, Giza, Egypt. Pea (*Pisum sativum*) seeds (cv. Master B) and seeds of both watercress (*Eruca sativa*) and white mustard (*Sinapis alba*) were obtained from the Agricultural Research Centre, Giza, while parasitic weed seeds of *Orobanche crenata* (broomrape) were obtained from the Weed Control Section, Ministry of Agric., Giza, Egypt. Clean seeds of both *E. sativa* and *S. alba* were grinded to fine powder and immediately incorporated to the soil surface before sowing at the rate of 0, 12.5, 25.0, 37.5, and 50 g/kg soil. The experiment consisted of 11 treatments, including two controls (healthy and infected). Each treatment is represented by nine pots. All treatments, except healthy control, were infected with *O. crenata* seeds (0.2 g/pot) at 5-cm depth from the soil surface. The experiment also includes herbicidal treatment with Basamid (Dazomet) for comparison with the allelopathic effect of both *E. sativa* and *S. alba* treatments. Basamid granules (tetrahydro-3, 5-dimethyl-2H-1, 3, 5-thiadiazine 2-thione) were mixed in the soil infected with *O. crenata* seeds (0.2 g/pot) at 5-cm depth from the soil surface. After 2 weeks, *P. sativum* seeds (8 seeds/pot) were sown on November 27 and 26 in the first and second seasons, respectively, 3 cm deep in pots with a 30-cm diameter (0.07 m^2) filled with 5 kg clay and sandy soil (2,1). Two weeks later, the *P. sativum* plants were thinned to 4 plants/pot. All treatments were distributed in a complete randomized design. The normal cultural practices of growing *P. sativum* plants were followed especially fertilization and irrigation.

Characters studied

Weed growth characters

In each season, three replicates were collected from each treatment at 55 days after sowing (DAS) and at harvest. The numbers as well as fresh and dry weight of *O. crenata* tubercles/pot (g) were recorded at the two growth ages, while *O. crenata* tubercles length (cm) was recorded at harvest only.

Plant growth

In both seasons, samples of *P. sativum* plants were collected from each treatment at 30, 55, and 90 days after sowing (DAS) to determine the shoot height (cm), root length (cm), number of leaves/plant, number of branches/plant, and fresh and dry weight of plant (g).

Yield and yield attributes

At harvest, samples of *P. sativum* plants were taken from each treatment to determine the number of pods/plant, fresh weight of pods/plant (g), dry weight of pods/plant, and number of seeds/pod.

Chemical analysis

Total glucosinolates (μmol/g DW)

Total glucosinolates were extracted from dry samples of seed powder of both *E. sativa* and *S. alba*. Glucosinolates were measured by determining the liberated glucose which was released during hydrolysis by myrosinase enzyme (Rauchberger et al. 1979). The resulting glucose was determined colorimetrically according to the methods defined by Nasirullah (1996).

Total phenolic contents (mg/g DW)

Total phenolic contents of both *E. sativa* and *S. alba* seeds were determined colorimetrically using Folin and Ciocalteu phenol reagent according to the method defined by Snell and Snell (1953).

Statistical analysis

All data were statistically analyzed according to Snedecor and Cochran (1980), and the treatment means were compared by using LSD at 5% level of probability.

The data obtained were subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1980) using the CoStat Software Program Version 6.303 (2004), and LSD at 0.05 level of significance was used for the comparison 140 between means.

Results

Characteristics of weed growth

The results in Table 1 appeared the efficiency of the investigated *Eruca sativa* (Essp) and *Sinapis alba* (Sasp) seed powder at successive rates (12.5 to 50 g/kg soil), and Basamid herbicide at 0.2 g/kg soil scored a significant inhibitory effect on *Orobanche crenata* infesting *Pisum sativum* plants. This inhibitory effect could be represented in the number and fresh and dry weight of *O. crenata* tubercles/pot at both ages (55 DAS and at harvest) comparing with their corresponding infected control. The reduction

Table 1 Effect of different rates of both *Eruca sativa* and *Sinapis alba* seed powder and herbicide Basamid on *Orobanche crenata* tubercles at 55 days after sowing and at harvest of *Pisum sativum* (combined analysis of two seasons)

Treatments	At 55 days after sowing			At harvest			
	No. of *O. crenata* tubercles/pot	Fresh weight of *O. crenata*/pot (g)	Dry weight of *O. crenata*/pot (g)	No. of *O. crenata* tubercles/pot	Fresh weight of *O. crenata*/pot (g)	Dry weight of *O. crenata*/pot (g)	Length of *O. crenata* tubercles (cm)
Pisum sativum (*P.*) + *Orobanche crenata* (*O.*)	58.5	21.30	4.15	62.0	40.50	5.90	7.50
P. + *O.* + Basamid at 0.2 g/pot	19.0	7.55	1.47	6.5	5.50	0.54	3.25
P. + *O.* + *Eruca sativa* (*E.*) at 12.5 g/kg soil	28.0	7.70	1.50	4.0	3.85	0.37	3.62
P. + *O.* + *E.* at 25 g/kg soil	4.0	0.65	0.11	3.0	2.50	0.32	2.83
P. + *O.* + *E.* at 37.5 g/kg soil	3. 0	0.42	0.09	2.0	2.40	0.16	2.00
P. + *O.* + *E.* at 50 g/kg soil	1. 0	0.08	0.02	1.0	2.05	0.10	1.00
P. + *O.* + *Sinapis alba* (*S.*) at 12.5 g/kg soil	31.0	13.85	2.70	6.0	7.40	0.72	3.68
P. + *O.* + *S.* at 25 g/kg soil	25.0	6.60	1.29	5.0	4.60	0.45	3.18
P. + *O.* + *S.* at 37.5 g/kg soil	2.5	1.95	0.38	3.0	1.20	0.20	3.00
P. + *O.* + *S.* at 50 g/kg soil	1.0	0.12	0.02	1.0	0.30	0.10	1.67
LSD at 5%	1.8	0.78	0.33	1.5	0.85	0.21	0.79

P. Pisum sativum, O. Orobanche crenata, E. Eruca sativa, S. Sinapis alba in *O. crenata* characteristics at the two ages was rate dependent. Optimum reduction in growth parameters of *O. crenata* tubercles/pot was recorded with the highest Essp and Sasp rates (50 g/kg soil) at the two ages of growth in comparison with their corresponding infected control. The highest decrease of *O. crenata* tubercles dry weight at harvest was found with 50 g/kg soil rate of Essp and Sasp, reached to 98.31%, for both materials as compared with their corresponding infected control. These superior treatments achieved better results than Basamid treatment at 0.2 g/pot in controlling *O. crenata* parasitizing *P. sativum.*

Growth of *Pisum sativum*

The recorded results in Tables 2, 3, and 4 indicated that most growth characters of *P. sativum* such as shoot height (cm), root length (cm), number of leaves/plant, number of branches/plant, and fresh and dry weight of plant (g) at 30, 55, and 90 DAS were significantly stimulated by treating with all Essp and Sasp successive rates (12.5 to 50 g/kg soil) and Basamid treatment at 0.2 g/pot at the three growth ages, i.e., 30, 55, and 90 DAS as compared with their corresponding infected control. The lowest rate (12.5 g/kg soil) of both incorporated materials (Essp and Sasp) recorded the highest significant increases in the investigated growth parameters as compared with healthy control and recommended the herbicidal Basamid treatment at different growth ages. At 90 DAS, both Essp and Sasp at 12.5 g/kg soil rate recorded maximum increases in the total dry weight of the *P. sativum* plant which amounted to 9.25 and 7.71% respectively more than the corresponding healthy control, whereas the infestation with *O. crenata* caused reduction in the *P. sativum* dry weight which reached to 55.27% at the same growth age compared with the healthy control.

Pisum sativum yield

The results of yield and yield attributes of *P. sativum* at harvest such as the number of pods/plant, fresh and dry weight of pods/plant, and number of seeds/pod are recorded in Table 5. All these yield parameters significantly increased by the application of Essp and Sasp at successive rates (12.5 to 50 g/kg soil) and Basamid treatment at 0.2 g/pot as compared with untreated infected controls. Incorporating the soil with Essp and Sasp at 12.5 and 25 g/kg soil rates as well as 0.2 g/pot soil Basamid herbicide was the superior treatments in developing *P. sativum* yield and yield attributes.

Not only the lowest applied treatment (12.5 g/kg soil) of both Essp and Sasp alleviated the harmful effect of *O. crenata* infesting *P. sativum* which amounted to 74.27% as shown in the dry weight of pods/plant, but also increased this character to reach to 30.58 and 14.08%, respectively, over the corresponding healthy control. It is clear from the results of Essp at 12.5 g/kg soil rate induced increase in the dry weight of pods/plant amounted to more than the double of that recorded with the same rate of Sasp in the same yield parameters (30.58, 14.08). It should be noted that the use of both Essp and Sasp at 12.5 g/kg soil rate induced increases which exceed that caused by the herbicidal effect of Basamid herbicide (0.2 g/pot) in all *P. sativum* yield and yield attributes.

Table 2 Effect of different rates of both *Eruca sativa* and *Sinapis alba* seed powder and herbicide Basamid on growth parameters of *Pisum sativum* at 30 days after sowing (combined analysis of two seasons)

Treatments	Growth parameters					
	Shoot height of plant (cm)	Root length (cm)	No. of leaves/plant	No. of branches/plant	F.W. of plant (g)	D.W. of plant (g)
Pisum sativum (*P.*)	44.6	10.8	8.8	1.27	5.68	1.15
Pisum sativum (*P.*) + *Orobanche crenata* (*O.*)	27.8	6.4	6.8	1.01	2.34	0.46
P. + *O.* + Basamid at 0.2 g/pot	43.5	10.6	8.4	1.24	5.56	1.11
P. + *O.* + *Eruca sativa* (*E.*) at 12.5 g/kg soil	63.0	15.3	10.2	1.39	8.64	1.61
P. + *O.* + *E.* at 25 g/kg soil	51.8	13.3	9.7	1.32	6.88	1.34
P. + *O.* + *E.* at 37.5 g/kg soil	43.0	10.2	8.2	1.22	5.39	1.10
P. + *O.* + *E.* at 50 g/kg soil	37.2	9.8	8.0	1.18	5.26	1.03
P. + *O.* + *Sinapis alba* (*S.*) at 12.5 g/kg soil	53.0	13.3	9.8	1.35	8.08	1.53
P. + *O.* + *S.* at 25 g/kg soil	48.3	13.0	9.3	1.30	6.62	1.31
P. + *O.* + *S.* at 37.5 g/kg soil	33.2	8.7	7.7	1.15	4.55	0.91
P. + *O.* + *S.* at 50 g/kg soil	32.2	6.9	7.6	1.11	3.82	0.77
LSD at 5%	2.14	1.38	1.06	0.15	1.10	0.12

P. Pisum sativum, *O. Orobanche crenata*, *E. Eruca sativa*, *S. Sinapis alba*

Table 3 Effect of different rates of both *Eruca sativa* and *Sinapis alba* seed powder and herbicide Basamid on growth parameters of *Pisum sativum* at 55 days after sowing (combined analysis of two seasons)

Treatments	Growth parameters					
	Shoot height of plant (cm)	Root length (cm)	No. of leaves/plant	No. of branches/plant	F.W. of plant (g)	D.W. of plant (g)
Pisum sativum (*P.*)	57.8	13.3	13.2	1.55	9.20	4.03
Pisum sativum (*P.*) + *Orobanche crenata* (*O.*)	45.0	8.8	10.1	1.11	5.65	1.59
P. + *O.* + Basamid at 0.2 g/pot	57.3	12.3	13.0	1.53	9.02	3.69
P. + *O.* + *Eruca sativa* (*E.*) at 12.5 g/kg soil	69.3	17.5	14.7	1.74	13.68	5.05
P. + *O.* + *E.* at 25 g/kg soil	63.3	14.2	14.0	1.65	11.04	4.79
P. + *O.* + *E.* at 37.5 g/kg soil	55.3	11.5	12.8	1.35	8.68	3.52
P. + *O.* + *E.* at 50 g/kg soil	54.5	11.2	12.5	1.29	8.32	3.46
P. + *O.* + *Sinapis alba* (*S.*) at 12.5 g/kg soil	63.8	16.0	14.6	1.69	12.79	4.90
P. + *O.* + *S.* at 25 g/kg soil	59.7	14.0	13.7	1.58	9.54	4.60
P. + *O.* + *S.* at 37.5 g/kg soil	50.5	9.8	12.1	1.21	7.15	2.94
P. + *O.* + *S.* at 50 g/kg soil	45.8	9.0	11.5	1.19	7.02	2.90
LSD at 5%	1.71	1.52	1.14	0.17	1.44	0.86

P. Pisum sativum, O. Orobanche crenata, E. Eruca sativa, S. Sinapis alba

Quantitative estimation of total glucosinolates and total phenolic contents in *Eruca sativa* and *Sinapis alba* seed powder

Table 6 shows the quantity of total glucosinolates (316.03 and 288.59 μmol/g dry weight) and total phenolic contents (35.62 and 43.62 mg/g dry weight) in the seed powder of *E. sativa* and *S. alba*, respectively.

Discussion

Modern researches seek to apply the allelopathic approach as a nonchemical safe method to suppress the competitor weeds. Our previous studies ensured allelopathic efficiency of seed powder of some Brassicaceae plants such as *Raphanus sativus*, *Sinapis alba*, *Eruca sativa*, and *Brassica rapa* in controlling some annual and perennial weeds (Messiha et al. 2013; Ahmed et al.

Table 4 Effect of different rates of both *Eruca sativa* and *Sinapis alba* seed powder and herbicide Basamid on growth parameters of *Pisum sativum* at 90 days after sowing (combined analysis of two seasons)

Treatments	Growth parameters					
	Shoot height of plant (cm)	Root length (cm)	No. of leaves/plant	No. of branches/plant	F.W. of plant (g)	D.W. of plant (g)
Pisum sativum (*P.*)	60.8	13.7	13.7	2.32	6.86	3.89
Pisum sativum (*P.*) + *Orobanche crenata* (*O.*)	48.3	9.2	10.6	1.18	3.52	1.74
P. + *O.* + Basamid at 0.2 g/pot	60.7	12.9	13.4	2.29	6.64	3.55
P. + *O.* + *Eruca sativa* (*E.*) at 12.5 g/kg soil	72.8	18.8	16.3	2.56	7.48	4.25
P. + *O.* + *E.* at 25 g/kg soil	66.0	15.3	14.3	2.46	7.11	4.13
P. + *O.* + *E.* at 37.5 g/kg soil	58.6	12.6	13.1	1.93	6.51	3.46
P. + *O.* + *E.* at 50 g/kg soil	57.2	12.0	12.8	1.74	6.26	3.32
P. + *O.* + *Sinapis alba* (*S.*) at 12.5 g/kg soil	66.5	16.5	15.2	2.53	7.24	4.19
P. + *O.* + *S.* at 25 g/kg soil	61.8	14.5	14.0	2.40	7.02	4.08
P. + *O.* + *S.* at 37.5 g/kg soil	53.0	11.0	12.2	1.57	5.84	3.15
P. + *O.* + *S.* at 50 g/kg soil	51.4	9.7	11.4	1.33	5.71	2.94
LSD at 5%	1.82	1.37	1.34	0.18	1.09	0.36

P. Pisum sativum, O. Orobanche crenata, E. Eruca sativa, S. Sinapis alba

Table 5 Effect of different rates of both *Eruca sativa* and *Sinapis alba* seed powder on yield and yield attributes of *Pisum sativum* at harvest (combined analysis of two seasons)

Treatments	Yield and yield components of *Pisum sativum*			
	Number of pods/plant	Fresh weight of pods/plant (g)	Dry weight of pods/plant (g)	Number of seeds/pod
Pisum sativum (*P.*)	4.16	9.49	2.06	5.25
Pisum sativum (*P.*) + *Orobanche crenata* (*O.*)	1.59	2.21	0.53	2.17
P. + *O.* + Basamid at 0.2 g/pot	4.00	8.94	1.97	4.69
P. + *O.* + *Eruca sativa* (*E.*) at 12.5 g/kg soil	5.90	12.37	2.69	5.84
P. + *O.* + *E.* at 25 g/kg soil	4.70	10.06	2.30	5.41
P. + *O.* + *E.* at 37.5 g/kg soil	3.97	8.27	1.83	4.27
P. + *O.* + *E.* at 50 g/kg soil	3.94	6.74	1.48	4.08
P. + *O.* + *Sinapis alba* (*S.*) at 12.5 g/kg soil	5.53	10.18	2.35	5.64
P. + *O.* + *S.* at 25 g/kg soil	5.40	9.84	2.22	5.16
P. + *O.* + *S.* at 37.5 g/kg soil	3.90	4.15	0.93	3.78
P. + *O.* + *S.* at 50 g/kg soil	2.78	3.23	0.71	3.49
LSD at 5%	0.99	1.02	0.31	0.85

P. Pisum sativum, *O. Orobanche crenata*, *E. Eruca sativa*, *S. Sinapis alba*

2014, 2016; El-Masry et al. 2015; El-Rokiek et al. 2017) as well as parasitic weeds as some *Orobanche* species (*O. crenata* and *O. ramosa*) parasitizing faba bean and tomato plants (Messiha et al. 2018; El-Dabaa et al. 2019; El-Masry et al. 2019).

The results of the present study revealed that *E. sativa* and *S. alba* seed powder possess allelopathic inhibitory effect that can be utilized in controlling *O. crenata* infesting *P. sativum* plants. Incorporating Essp and Sasp to the soil at rates from 12.5 to 50 g/kg soil negatively affected all growth parameters of *O. crenata* tubercles. The maximum rate of both materials (50 g/kg soil) scored the maximum reduction in all *O. crenata* parameters. Although Brassicaceae plants have the same mode of action of Basamid synthetic herbicide, both investigated Brassica species were more effective than Basamid in controlling *O. crenata* parasitic weed (Table 1). The mode of action depends on the induction of isothiocyanates, which recently proved its effectiveness in controlling the growth of parasitic and nonparasitic weeds (Messiha et al. 1993; Sharara et al. 2011).

It is worthy to mention that the allelopathic reducing effect of the two used materials, i.e., Essp and Sasp, on *O. crenata* growth parameters could be attributed to the natural allelochemicals mainly glucosinolates and phenolic compounds which by chemical analysis were estimated in abundant amount in both investigated plant materials (Table 5). The endogenous active myrosinase enzyme acts in hydrolyzing glucosinolates into other products mainly isothiocyanates (Fenwick et al. 1983). Isothiocyanates have been applied as pesticides for pest and disease control (Sarwar and Kirkegaard 1998) and as bioherbicides for weed control (Messiha et al. 2013, 2018; Ahmed et al. 2014, 2016; El-Masry et al. 2015; El-Rokiek et al. 2017; El-Dabaa et al. 2019; El-Wakeel et al. 2019). The results of the present study indicate also that most growth parameters and yield attributes of *P. sativum* significantly increased by the application of Essp and Sasp at successive rates and the herbicidal Basamid applied at 0.2 g/pot (Tables 2, 3, 4, and 5). However, both 12.5 and 25 g/kg soil Essp and Sasp and 0.2 g/pot Basamid treatments were the effective superior treatments in controlling *O. crenata* parasitic weed.

Table 6 Total glucosinolates (μmol/g dry weight) and total phenolic contents (mg/g dry weight) in the seed powder of both *Eruca sativa* and *Sinapis alba*

Materials	Total glucosinolates (μmol/g dry weight)	Total phenolic contents (mg/g dry weight)
Eruca sativa seed extract	316.03	35.62
Sinapis alba seed extract	288.59	43.62

It should be noted that the limitation of competitive agent between *O. crenata* weed and *P. sativum* plants induced growth parameters and consequently *P. sativum* yield (Ahmed et al. 2014; El-Rokiek et al. 2013; El-Masry et al. 2015, 2019; Jursik et al. 2015; Seshadri et al. 2015; Messiha et al. 2018). In addition, the stimulatory response of *P. sativum* plants probably related to the selective properties of the allelochemicals in their mode of action (Einhellig 1995). Allelochemicals have a selective effect that inhibits the growth of some species at a certain rate and stimulates the growth of other species at the same rate (Messiha et al. 2013, 2018; Ahmed et al. 2014; Baeshen 2014; El-Masry et al. 2015, 2019; El-Dabaa et al. 2019).

Conclusion

Incorporating *Eruca sativa* or *Sinapis alba* seed powder to the soil is considered a safe and effective method to control *Orobanche crenata* parasitizing *Pisum sativum* and also significantly increasing the growth and yield of the plants. The most effective rates of both seed powder (12.5 and 25 g/kg soil) are recommended to be investigated through the field level to manage *Orobanche crenata* infecting *Pisum sativum* plants.

Abbreviations

DAS: Days after sowing; Essp: *Eruca sativa* seed powder; *O. crenata*: *Orobanche crenata*; *P. sativum*: *Pisum sativum*; Sasp: *Sinapis alba* seed powder

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Authors' contributions

SAA participated in putting the research idea and the design of the study, participated in assembling scientific research literature, participated in practical cultivation and collecting data, performed the statistical analysis, and participated in writing and reviewing the manuscript. NKM and RRE participated in putting the research idea and the design of the study, participated in assembling scientific research literature, participated in practical cultivation and collecting data, and participated in writing and reviewing the manuscript. MATE participated in putting the research idea and the design of the study, participated in assembling scientific research literature, participated in practical cultivation and collecting data, participated in writing and reviewing the manuscript, and submitted the manuscript for publication as the corresponding author. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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