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The allelopathic efficiency of two Brassicaceae plant seeds in controlling weeds associating sunflower plants

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ABSTRACT

Two pot experiments were performed in the greenhouse of the National Research Centre, Dokki, Giza, Egypt, during two successive summer seasons of 2014 and 2015 to study the Allelopathic potentiality of *Eruca sativa* (ESSP) and *Raphanus sativus* seed powder (RSSP) on the growth, yield of *Helianthus annuus* as well as associated narrow and broad-leaved weeds *Echinochloa crus-galli* and *Corchorus olitorius.* Treatments were applied by incorporating seed powder of *E. sativa* (ESSP) and *R. sativus* (RSSP) to the soil at (0, 15, 30, 45 and 60g/kg soil). All ESSP as well as RSSP concentrations used minimized to great extent the dry weight of the two weeds at 60 days after sowing (DAS) and at the harvest. The highest reduction recorded with the highest concentration (60g/kg soil) of both material used. On the other hand, *H. annuus* growth and yield, yield components as well as oil content percentage were significantly increased with the most ESSP and RSSP concentrations used as compared to their corresponding mixed controls. The best results were recorded with ESSP treatment at 45g/kg soil and with RSSP at 30 g/kg soil concentration; these treatments achieved maximum increases over their corresponding control free from weed (Healthy). The allelopathic effect of ESSP and RSSP due to the presence of the allelochemicals: glucosinolates and phenolic compounds which play an important role in controlling the two annual narrow and broad-leaved weeds associating *H. annuus* and also increasing its yield.

Keywords: Allelopathy, *Eruca sativa*, *Raphanus sativus,* Helianthus *annuus, Echinochloa crus- galli*, *Corchorus olitorius*, Glucosinolates content, Phenolic content

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INTRODUCTION

The practical importance of the allelopathic phenomenon is based upon the fact that plants produce numerous secondary bi-productions, when these compounds released in the environment either by leaching or by exudation or through decomposition processes, it could affect the growth of other plants either positively or negatively.

When Brassicaceae plant tissues are disrupted, glucosinolates are hydrolyzed to a number of products mainly isothiocyanates which are toxic (Fenwick *et al*., 1983; Fahey *et al*., 2001; Bennett *et al*., 2002; Kim and Ishii, 2006; Zaji and Majd, 2011 and Martinez-Ballesta *et al*., 2013). Our previous work at the National Research Centre of Egypt (Messiha *et al*., 2013) showed that both Eruca sativa and Brassica rapa seed powder gave good results in controlling the world worst perennial weed (Cyperus rotundus) associating corn plant and also improved the growth of corn.

Sunflower (Helianthus annuus L.) is one of the most important oil crops. It is considered as an economic and nutritious crop supplying man with oils which are very essential in his diet, especially in the developing countries. Sunflower seeds are the third largest source of vegetable oil worldwide. According to the statistical annual Report of Ministry of Agriculture and Land Reclamation in Egypt, it is grown in about 10497.5 ha. Increasing yield could be achieved through introducing high-yield producing cultivars and effective management of weeds, diseases and pests. Weeds are considered to be a serious problem because they compete for water, nutrients, light and space that reduce crop growth and yield (Hussein, 2001 and Lehoczky and Reisinger, 2003). Losses in million dollars are recorded all over the world due to weed competition ranges from 18 to 36% (Jat and Giri, 2000 , Singh and Giri, 2001 and Webster, 2004). Weed management is an important component of successful sunflower production.

The aim of the present work is to investigate the potentiality of using the seed powder of two Brassicaceae plants (Eruca sativa and Raphanus sativus) in controlling two weeds (Echinocloa crus –galli and Corchorus olitorius) associating sunflower plant.

MATERIALS AND METHODS

Two pot experiments were carried out during two successive seasons of 2014 and 2015 in the greenhouse of the National Research Centre, Dokki, Giza, Egypt. Sunflower (*Helianthus annuus*) seeds as well as seeds of watercress (*Eruca sativa*), raddish (*Raphanus sativus*), Barnyard grass (*Echinochloa crus-galli*) and Jews mallow (*Corchorus olitorius*) were obtained from Agricultural Research Centre, Giza, Egypt. Clean seeds of *E. sativa* and *R. sativus* were grinded to fine powder, after that the powder was immediately incorporated in the soil surface before sowing at the rate of 0, 15, 30, 45 and 60g/kg soil. The seeds of *H. annuus*, *E. crus-galli* and *C.olitorius* were sown 2cm deep in pots filled with 7kg of soil. The experiment consisted of 20 treatments including control; each treatment consisted of 8 replicates.

Characters studied

Weeds

Four replicates were collected from each treatment, 60 days after sowing (DAS) and at harvest, dry weight of both E. crus-galli and C. olitorius (g/pot) were recorded.

Helianthus annuus plants

Plant growth

In both seasons, at 60 DAS, samples of Helianthus annuus plants were collected from each treatment to determine plant height (cm), number of leaves/plant and dry weight of plant (g).

Yield, yield components and oil content of *Helianthus annuus* plants

At harvest, samples of Helianthus annuus plants were taken from each treatment to determine: -head diameter (cm), fresh and dry weight of head (g), weight of seeds/head (g) and weight of 100 seeds (g), as well as the oil content of dried seeds.

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Chemical analysis

Total glucosinolates (µ mol/g DW)

Total glucosinolates were extracted from dry samples of seed powder of both E. sativa and R. sativus. Glucosinolates were measured by determining the liberated glucose which released during hydrolysis by myrosinase enzyme defined by Nasirullah and Krishnamurthy, 1996.

Total phenolic contents (mg/g DW)

Total phenolic contents of both E. sativa and R. sativus seed were determined colorimetrically using Folin and Ciocalteu phenol reagent according to the method defined by Snell and Snell, 1953.

Total oil content of *H. annuus* seeds

Oil content of the plant seeds was determined according to the procedure reported by A.O.A.C., 1990. A known weight of the ground seeds was imbedded in petrol ether and allowed to extract using Soxhlet apparatus.

Statistical analysis

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

RESULTS

Weed growth characters

Data recorded in Table (1) show that, different seed powder concentrations (15 to 60g/kg soil) of both *Eruca sativa* (ESSP) and *Raphanus sativus* (RSSP) incorporated to the soil significantly reduced the dry weight of both weeds *Echinochloa crus-galli* and *Corchorus olitorius* at the two ages of growth 60 DAS and at harvest as compared to the corresponding controls. The rate of reduction of each weed increased by increasing the applied concentration used. At harvest, the maximum reduction in weed dry weight was recorded with the highest concentration (60g/kg soil) of both (ESSP) and (RSSP), which reached to about 87.0 and 89.0 % with *E. crus-galli* and to about 88.0 and 89.0 % with *C. olitorius*, respectively as compared to the corresponding controls.

Table (1): Effect of different concentrations of seed powder of *Eruca sativa* or *Raphanus sativus* on dry weight of *Echinocloa crus –galli* as well as *Corchorus olitorius* (g/pot).

Treatments		Weed dry weight (g/pot)	
Plants	Rate (g/kg soil)	60 days	At harvest
Echinocloa crus –galli	…………..	29.30	95.90
Echinocloa crus –galli + Helianthus annuus	…………..	21.90	73.20
Corchorus olitorius	…………..	26.25	91.20
Corchorus olitorius + Helianthus annuus	…………..	17.80	62.60
Echinocloa crus –galli + Helianthus annuus + Eruca sativa	15	20.30	39.60
	30	15.70	23.35
	45	11.05	16.05
	60	7.50	9.45
Corchorus olitorius + Helianthus annuus + Eruca sativa	15	16.20	37.60
	30	13.95	22.49
	45	7.05	11.60
	60	3.20	7.50
Echinocloa crus –galli + Helianthus annuus + Raphanus sativus	15	19.02	33.90
	30	14.45	17.85
	45	8.45	11.25
	60	6.30	8.20
Corchorus olitorius + Helianthus annuus + Raphanus sativus	15	15.95	31.35
	30	11.10	16.15
	45	5.55	10.60

	60	3.05	6.90
LSD at 5%		2.34	1.88

***Helianthus annuus* growth**

The results in Table (2) illustrate that different *Helianthus annuus* growth parameters, as plant height (cm), number of leaves/plant as well as dry weight of plant (g) at 60 DAS and at harvest were significantly increased with all applied seed powder concentrations of *E. sativa* (ESSP) or *R. sativus* (RSSP) when compared to the corresponding mixed controls. The highest significant results on the different *Helianthus annuus* parameters were recorded with both 45g/kg soil of ESSP concentration and 30 g/kg soil of RSSP concentration. At harvest, ESSP at 45g/kg soil concentration induced maximum increase in dry weight of *H. annuus* associated with *E. crus-galli* as well as *C. olitorius*, that reached to about 14.0 and 29.0%, respectively over the corresponding control free from weed. While, RSSP at 30 g/kg soil concentration achieved maximum increase in the same character of plant associated with *E. crus-galli* and C. *olitorius*, reached to about 11.0 and 21.0%, respectively over the corresponding control free from weed.

Table (2): Effect of seed powder of *Eruca sativa* or *Raphanus sativus* on some growth parameters of *Helianthus annuus.*

Treatments		Plant height (cm)		No. of leaves/plant		Dry weight of plant (g)	
Plants	Rate (g/kg soil)	60 days	At harvest	60 days	At harvest	60 days	At harvest
***Helianthus annuus* only**	………….	108.0	160.0	16.5	22.5	11.90	21.35
Helianthus annuus* + *Echinocloa crus –galli	………….	83.0	119.8	10.5	13.0	4.00	10.86
Helianthus annuus* + *Corchorus olitorius	………….	85.0	123.8	11.5	14.0	4.50	12.02
Helianthus annuus* + *Echinocloa crus –galli* + *Eruca sativa	15	86.5	125.0	12.5	16.5	6.90	15.00
	30	96.5	150.0	14.5	21.0	10.85	19.88
	45	117.5	170.0	18.0	23.0	14.30	24.36
	60	105.0	155.0	15.0	19.4	11.70	19.00
Helianthus annuus* + *Corchorus olitorius*+ *Eruca sativa	15	91.5	132.5	12.8	17.5	9.20	16.10
	30	107.5	167.0	17.5	22.0	12.85	22.50
	45	120.0	180.0	19.0	24.5	17.25	27.55
	60	105.5	157.0	16.0	21.5	12.05	20.10
Helianthus annuus* + *Echinocloa crus –galli* + *Raphanus sativus	15	90.0	128.0	12.6	16.7	7.00	16.05
	30	115.0	168.0	17.0	22.8	14.00	23.70
	45	100.0	151.0	15.0	19.6	11.15	19.80
	60	94.0	135.0	13.5	17.0	9.25	16.44
Helianthus annuus* + *Corchorus olitorius* + *Raphanus sativus	15	94.5	140.0	13.0	18.0	9.65	24.36
	30	135.5	178.0	20.5	25.0	14.60	25.90
	45	106.0	163.0	16.0	20.0	12.70	20.65
	60	95.5	149.0	14.0	19.2	10.10	18.10
LSD at 5%		4.0	6.6	1.7	2.1	0.68	1.59

***Helianthus annuus* yield, yield components and oil content**

The results of yield and yield components of *H. annuus*, as head diameter (cm), fresh and dry weight of head (g), weight of seeds/head (g) and weight of 100 seeds (g) recorded in Table (3) show that, the effect of most applied concentrations of ESSP or RSSP (15 to 60 g/kg soil) on the plant associated with *E. crus-galli* or *C. olitorius* significantly increased *H. annuus* yield parameters as compared to the corresponding controls. The best results of *H. annuus* yield parameters resulted with 45g/kg soil ESSP concentration as well as with 30 g/kg soil RSSP concentration. Not only, both these two applied concentrations (45g/kg soil ESSP and 30 g/kg soil RSSP) alleviated the harmful effect of the two weeds, *E. crus-galli* and *C.olitorius*, but also, increased the plant yield over than that of the corresponding control free from weed. Maximum increase in the weight of seeds/head of plant associated with *E. crus-galli* or *C. olitorius* recorded with 45g/kg soil ESSP, reached to about 19.8 and 29.8% respectively over the corresponding control free from weed. The corresponding result was recorded with 30 g/kg soil RSSP concentration achieved increase in the weight of seeds/head of plant accompanied with *E. crus-galli* or *C. olitorius* reached to about 11.3 and 21.9% respectively over than that of the corresponding control free from weed.

The pattern of change in oil content percentage of *H. annuus* seeds showed the same tendency in the weight of seeds/head of the plant (Table 3). The most effective treatments in increasing plant oil content, associating with *E. crus-galli* or *C.olitorius,* were recorded with 45g/kg soil ESSP as well as with 30 g/kg soil RSSP concentration. These increases reached to about 9.8 and 12.9 %, respectively when treated with 45g/kg soil ESSP, while with 30 g/kg soil RSSP concentration reached to about 7.3 and 11.7%, respectively over their corresponding control free from weed.

Table (3): Effect of seed powder of *Eruca sativa* or *Raphanus sativus* on *Helianthus annuus* yield, yield components and oil content

Treatments		Yield/plant					Oil content %
Plants	Rate (g/kg soil)	Head diameter (cm)	Fresh weight of head (g)	Dry weight of head (g)	Weight of seeds/head	Weight of 100 seeds	
***Helianthus annuus* only**	………	9.4	67.85	16.33	9.12	2.55	30.19
Helianthus annuus* + *Echinocloa crus –galli	………	4.0	31.65	6.42	3.24	1.14	19.87
Helianthus annuus* + *Corchorus olitorius	………	4.4	35.00	7. 02	3.79	1.19	20.46
Helianthus annuus* + *Echinocloa crus –galli* + *Eruca sativa	15	4.5	36.00	7.32	3.85	1.31	22.76
	30	7.7	60.22	13.51	6.42	2.06	25.36
	45	10.3	81.50	16.62	10.93	3.31	33.15
	60	6.3	50.54	9.96	5.53	1.82	30.44
Helianthus annuus* + *Corchorus olitorius*+ *Eruca sativa	15	5.5	42.70	8.93	4.26	1.46	25.37
	30	8.5	62.41	15.08	9.05	2.58	29.74
	45	10.5	88.21	17.61	11.84	3.98	34.08
	60	8.0	61.25	14.31	6.83	2.18	30.01
Helianthus annuus* + *Echinocloa crus –galli* + *Raphanus sativus	15	5.0	40.50	7.52	4.09	1.42	24.32
	30	10.0	79.80	16.55	10.15	2.95	32.38
	45	6.0	54.74	10.46	6.37	1.75	29.76
	60	5.1	45.50	8.85	4.49	1.60	26.17
Helianthus annuus* + *Corchorus olitorius* + *Raphanus sativus	15	5.8	46.96	9.02	4.83	1.63	25.44
	30	11.0	98.50	19.34	11.12	4.18	33.71
	45	7.4	61.00	11.85	8.87	2.20	29.79
	60	6.5	47.80	9.05	5.21	1.87	26.24
LSD at 5%		0.7	3.10	1.05	1.33	0.22	1.02

Changes in Total Glucosinolates and Total Phenolic Contents in *Eruca sativa* and *Raphanus sativus*:

The results in Table (4) illustrated clearly that total Glucosinolates and total Phenolic contents in RSSP are higher than that present in ESSP.

Table (4): Total glucosinolates (μmol/g DW) and Total phenolic contents (mg/g DW) in *Eruca sativa* and *Raphanus sativus* seeds

Materials	Total glucosinolates (μmol/g DW)	Total phenolic contents (mg/g DW)
Eruca sativa	316.03	35.62
Raphanus sativus	688.54	69.50

DISCUSSION

The current approaches in agriculture production are to find a suitable biological solution to decrease the harmful effects of the use of herbicides and pesticides and increasing the crop production (Khanh, *et al*. 2005). Plant Allelopathy offers a great possibility to resolve this critical issue and could be used in different methods to solve this problem (Narwal, 2000; Duke *et al*. 2001; Javaid *et al*. 2006; Ma *et al*. 2006 and Iqbal *et al*. 2007). Brassicaceae plants among many allelopathic plants contain many allelochemicals which are useful and effective to manage weeds in many crops (Biswas *et al*.2014).

The results of the present investigation reveal, to great extent, significant growth reduction on narrow and broad-leaved weeds, E.crus-galli and C.olitorius, after the incorporation of ESSP as well as RSSP to the soil at the two growth ages 60 DAS and at harvest. The maximum reduction of both weeds recorded by the highest concentration (60 g/kg soil) of each seed powder E. sativa and R. sativus (Table 1). Many previous researches showed that Brassicaceae plants have allelopathic potential on the growth of other plants (Petersen *et al*. 2001; Norsworthy 2003; Turk and Tawaha 2003; Messiha *et al*. 2013; Ahmed *et al*. 2014; Baeshen 2014 and El-Masry *et al*. 2015). The reducing effect of Brassicaceae plant seed powder (ESSP and RSSP) on the weed growth attributed to their natural allelochemicals, mainly glucosinolates and polyphenols (Table 4). Glucosinolates hydrolyzed by endogenous enzyme myrosinase into many products mainly isothiocyanates (Fenwick *et al*. 1983), have different biological function including anti- cancer, anti- bacterial, anti- fungal, anti- oxidative, allelopathic properties (Higdon *et al*. 2007; Traka and Mithen, 2009 and Latte *et al*. 2011) and can also be used as an alternative to synthetic pesticides for pest and disease control (Sarwar and Kirkegaard, 1998) and as bioherbicides for weed control (Messiha *et al*. 2013; Ahmed *et al*. 2014 and El-Masry *et al*. 2015), Since the mode of action of the synthetic herbicide Basamid is the production of isothiocyanates (Messiha *et al*. 1993 and 2013 ; Khalaf *et al*. 1994 and Sharara *et al.* 2011).

On the other side, ESSP and RSSP treatments not only achieved good results in controlling narrow and broad- leaved weeds, E. crus-galli (C4 plant) and C. olitorius (C3 plant) but also improved and increased H. annuus growth and yield (Tables 2 and 3). Several workers found that weed growth inhibition by chemical or biological means increased the competitive ability of the plant and consequently the growth and yield improved (Abdelhamid and El-Metwally, 2008; El-Rokiek *et al*. 2012 and 2013; Ahmed *et al*. 2012 and 2014; Messiha *et al*. 2013; El-Masry *et al*. 2015; Jursik *et al*. 2015 and Seshadri *et al*. 2015). It is worthy to mention that ESSP at 45g/kg soil and RSSP at 30g/kg soil were the best treatments in improving the growth and yield components of H. annuus as compared to their corresponding controls, this may be due to the selectivity of allelochemicals in their action and the responsibility of the plants (Einhellig, 1995). Allelochemicals which inhibit the growth of some species at certain concentrations could stimulate the growth of same or different species at different concentrations (Narwal, 1994; Ahmed *et al*. 2012 and 2014; Messiha *et al*. 2013; Baeshen 2014 and El-Masry *et al*. 2015).

The results of this study as well as our previous work indicate the possibility of using the allelopathic activity of some Brassicaceae plant seed powder as Eruca sativa, Raphanus sativus and Brassica rapa as a selective bioherbicide for controlling annual and perennial weeds accompanied different crop plants.

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