World Applied Sciences Journal 26 (9): 1142-1149, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.26.09.13548

The Physiological Influence of Allelochemicals in Two Brassicaceae Plant Seeds on the Growth and Propagative Capacity of *Cyperus rotundus* and *Zea mays* L.

Nadia K. Messiha, S.A. Ahmed, Kowthar G. El-Rokiek, Mona G. Dawood and R.R. El-Masry

Botany Department, National Research Centre, Dokki, Giza, Egypt, P.O. Box, 12622

Submitted: Sep 24, 2013; **Accepted:** Nov 25, 2013; **Published:** Nov 30, 2013

Abstract: Two pot experiments were conducted during two successive summer seasons of 2010 and 2011 in the greenhouse of National Research Centre, Egypt to study the effect of incorporating seeds powder of *Eruca sativa* and *Brassica rapa* to the soil at the rate of 0, 25, 50 and 75 g/kg soil on the growth and propagative capacity of purple nutsedge as well as maize plants. At 45 days after sowing (DAS) all concentrations used of both *E. sativa* and *B. rapa* minimized to great extent the growth of foliage, underground organs as well as the dry weight of purple nutsedge that reached to complete control at 75 DAS, only with the higher concentrations (50 and 75g/kg soil) of *E. sativa* . On the other hand, low and middle concentrations used of both *E. sativa* and *B. rapa* caused significant increase in all growth characters and total carbohydrate contents of maize comparing to the corresponding controls. Results suggested that both *E. sativa* and *B. rapa* seeds powder could be used as a natural selective bioherbicide to control purple nutsedge weed and also improve maize growth.

Key words: Allelopathy · *Brassica rapa* · *Cyperus rotundus* L. · *Eruca sativa* · Glucosinolates content · Phenolic content · *Zea mays* L

INTRODUCTION

The allelopathic compounds (allelochemicals) released from plants into the environment, as a result of secondary plant metabolites, include a variety of compounds, often attract or repel, nourish or poison other organisms. Allelochemicals like phenolic compounds, flavonoides, terpenoids, alkaloids, amino acids and glucosinolates were found in different allelopathic plants [1-4]. Brassicaceae family has allelopathic potential on the growth of other plants [3,5-7]. They mainly produce glucosinolates that are not biologically active under normal conditions. When the plant tissues and cells are disrupted they are hydrolyzed by the enzyme myrosinase, resulting in several degradation products, including isothiocyanates, nitriles, thiocyanates, epithionitriles and oxazoliolines [8]. The main breakdown products are isothiocyanates which are phytotoxic [1, 5-7, 9, 10] and have pesticidal activities [3, 11]. Brassicacae plants have been reported to be higher in glucosinolate levels in the seeds than that in the leaves, stems and roots [1, 3].

The aim of this study was to investigate the allelopathic potential of two Brassicaceae plant seeds, watercress (*Eruca sativa*) and turnip (*Brassica rapa*) in controlling the growth and propagative capacity of purple nutsedge (*Cyperus rotundus* L.) which considered the most world's worst perennial weed and one of the main weed in maize (*Zea mays* L.) fields.

MATERIALS AND METHODS

Two pot experiments were carried out during two successive summer seasons of 2010 and 2011 in the greenhouse of National Research Centre, Dokki, Giza, Egypt. The stock of purple nutsedge (*Cyperus rotundus* L.) used as a source of tubers was collected from a dense stand at the National Research Centre Experimental Station. Maize (*Zea mays* L.) grains C.V. pioneer 30k 8 as well as the seeds of watercress (*Eruca sativa*) and turnip (*Brassica rapa*) were obtained from Agricultural Research Centre, Giza, Egypt. Clean seeds of *E. sativa* and *B. rapa* were grinded to fine powder, after that the powder was immediately incorporated in the soil surface before

Corresponding Author: S.A. Ahmed, Botany Department, National Research Centre, Dokki, Giza, Egypt.

sowing at the rate of 0, 25, 50 and 75g/kg soil. Dormant tubers of purple nutsedge and grains of maize were sown 2 cm deep in plastic pots filled with 2 kg of soil. The experiment consisted of 9 treatments including control, each treatment consist of 8 replicates.

Data Recorded

Purple Nutsedge: Four replicates were collected from each treatment at ages of 45 and 75 DAS and the following growth characters were taken:

- Number of mother shoots/tuber.
- Number of leaves of mother shoots/tuber.
- Length of mother leaves (cm).
- Number of daughter shoots/tuber.
- Number of leaves of daughter shoots/tuber.
- Number of propagative organs (basal bulbs and tubers)/plant).
- Number of rhizomes/plant.
- Length of rhizomes/plant (cm).
- Dry weight of foliage (g/plant).
- Dry weight of underground organs (g/plant).
- Total dry weight (g/plant).

Maize Plants: In both seasons, samples of maize plants were collected at 45 and 75 DAS to determine:

- Plant length (cm).
- Number of leaves /plant.
- Root length (cm).
- Fresh weight of plant (g).
- Fresh weight of root (g).
- Fresh weight of total plant (g).
- Dry weight of plant (g).
- Dry weight of root (g).
- Dry weight of total plant (g).

Chemical Analysis:

Total Glucosinolates (µmol/g DW): Total glucosinolates were extracted from dry samples of seeds powder of both *E. sativa* and *B. rapa*. Glucosinolates were measured by determining the liberated glucose which released during hydrolysis by myrosinase enzyme [12]. The resulting glucose was determined colorimetrically according to the methods defined by Nasirullah and Krishnamurthy [13].

Total Phenolic Contents (mg/g DW): Total phenolic contents of both *E. sativa* and *B. rapa* seeds were determined colorimetrically using Folin and Ciocalteu phenol reagent according to the method defined by Snell and Snell [14].

Total Carbohydrate Contents (mg/g DW): Total carbohydrate contents in maize leaves were estimated colorimetrically by the phenol-sulphuric method [13].

Statistical Analysis: All data were statistically analyzed according to Snedecor and Cochran [15] and the treatment means were compared by using LSD at 5% probability.

RESULTS

Purple Nutsedge Growth

Purple Nutsedge Foliage

Growth Characters of Mother Shoots: Generally all growth characters of purple nutsedge increased by increasing the plant age (Table 1), while when purple nutsedge growing with maize the growth criteria of purple nutsedge were significantly decreased as compared to corresponding control, except the number of mother shoots/tuber at 45 DAS. Treatments with the seeds powder of *E. sativa* caused complete control in the number of mother shoots/tuber of purple nutsedge with the highest concentration (75g/kg soil) at 45 DAS, while at 75 DAS the same results were recorded with 50 and 75 g/kg soil of *E. sativa.* Significant reduction in the number of mother shoots/tuber of purple nutsedge was also recorded with different concentrations of *B. rapa* at 45 and 75 DAS, except the low concentration (25g/kg soil) at 45 DAS comparing to the corresponding control. Low concentration (25g/kg soil) of *E. sativa* caused highly significant reduction in the number and length of leaves of mother shoots/tuber at 45 and 75 DAS as compared to their corresponding controls, while the highest concentration (75g/kg soil) caused complete control in the same mother characters. Different concentrations of *B. rapa* treatments in both growth ages showed high significant reduction in the number and length of mother leaves/tuber. The rate of reduction increased by increasing the concentration and the age comparing to their corresponding controls.

Growth Characters of Daughter Shoots: Complete control to daughter shoots of purple nutsedge was obtained due to the application of *E. sativa* (25, 50 and 75g/kg soil) at two ages. Different concentrations of

Table 1: Effect of different concentrations of *Eruca sativa* and *Brassica rapa* seeds on the growth parameters of *Cyprus rotundus* foliage (Average of the two seasons)

		Growth characters									
		Mother shoots						Daughter shoots			
		No. of shoots/tuber		No. of leaves /tuber		Leaves length (cm)		No. of shoots/tuber		No. of leaves of shoots/tuber	
Treatments	Rate (g/kg soil)	45 days	75 days	45 days	75 days	45 days	75 days	45 days	75 days	45 days	75 days
C. rotundus	--	2.0	3.0	21.8	25.0	46.0	57.5	4.0	5.4	12.0	15.6
C. rotundus + Z. mays	--	2.0	2.0	17.5	21.0	42.0	32.3	3.0	2.1	8.0	5.9
C. rotundus + Z. mays + E. sativa	25	1.0	0.5	3.0	2.6	19.0	15.0	0.0	0.0	0.0	0.0
	50	0.3	0.0	1.5	0.0	11.0	0.0	0.0	0.0	0.0	0.0
	75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. rotundus + Z. mays + B. rapa	25	2.0	1.0	9.0	8.0	39.0	27.0	1.5	0.0	4.0	0.0
	50	1.0	1.0	8.0	5.3	28.0	22.0	1.0	0.0	3.0	0.0
	75	1.0	0.7	5.0	3.8	25.0	12.0	0.5	0.0	2.0	0.0
LSD 0.05		0.3	0.2	0.96	1.1	2.27	1.82	0.3	0.2	0.9	0.3

Table 2: Effect of different concentrations of *Eruca sativa* and *Brassica rapa* seeds on the growth parameters of *Cyprus rotundus* L underground organs (Average of the two seasons)

		Growth characters					
		No. of basal bulbs and tubers /plant		No. rhizomes /plant		Length of rhizomes (cm)	
Treatments	Rate (g/kg soil)	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
C. rotundus	--	4.20	6.0	3.9	5.4	12.50	13.9
C. rotundus + Z. mays	--	2.40	2.6	2.8	1.9	10.70	6.8
C. rotundus + Z. mays + E. sativa	25	0.00	0.0	0.0	0.0	0.00	0.0
	50	0.00	0.0	0.0	0.0	0.00	0.0
	75	0.00	0.0	0.0	0.0	0.00	0.0
C. rotundus + Z. mays + B. rapa	25	2.00	0.5	1.5	0.5	6.00	5.4
	50	1.33	0.0	1.3	0.0	3.25	0.0
	75	1.0	0.0	1.0	0.0	0.50	0.0
LSD 0.05		0.25	0.34	0.36	0.17	0.84	0.27

B. rapa seeds powder in the 1st age showed significant reduction in both daughter characters, the rate of reduction significantly increased by increasing the concentration rate used. Maximum reduction was recorded with the highest concentration (75g/kg soil) of *B. rapa* which reached to 83.3 and 75.0 % in the number of daughter shoots/tuber and number of leaves of daughter shoots/tuber, respectively comparing to their corresponding mixed control. At the 2nd age, all *B. Rapa* treatments resulted in complete control to daughter characters.

Uunderground Organs: All concentrations of *E. sativa* caused complete control of all underground organs criteria at both growth ages. Significant reduction was also recorded (45 DAS) on the number of basal bulbs and tubers/plant, number of rhizomes/plant and length of rhizomes with all concentrations of *B. rapa*. The rate of reduction, increased by increasing the rate of concentration used as compared to the corresponding controls at 75 DAS, the low concentration (25 g/kg soil) of *B. rapa* caused pronounced and significant reduction in the different growth parameters values of underground organs comparing to their corresponding controls. The rate of control in the number of basal bulbs and tuber/tuber reached to 91.7 and 80.8 %, respectively when compared to the corresponding controls, while the higher concentrations (50 and 75g/kg soil) used of *B. rapa* caused complete control of all growth characters of underground organs of purple nutsedge (Table 2).

Table 3: Effect of different concentrations of *Eruca sativa* and *Brassica rapa* seeds on the dry weight of foliage, underground organs and total dry weight (g/plant) of *Cyperus rotundus* (Average of the two seasons)

		Dry weight g/plant					
		Foliage		Underground organs		Total dry weight (g/plant)	
Treatments	Rate (g/kg soil)	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
C. rotundus	--	0.90	1.50	1.40	1.60	2.30	3.10
C. rotundus + *Z. mays*	--	0.36	0.31	0.33	0.25	0.69	0.56
C. rotundus + *Z. mays* + *E. sativa*	25	0.13	0.10	0.00	0.00	0.13	0.10
	50	0.05	0.00	0.00	0.00	0.05	0.00
	75	0.00	0.00	0.00	0.00	0.00	0.00
C. rotundus + *Z. mays* + *B. rapa*	25	0.30	0.25	0.20	0.10	0.50	0.35
	50	0.15	0.10	0.15	0.00	0.30	0.10
	75	0.10	0.05	0.05	0.00	0.15	0.05
LSD at 5%		0.09	0.09	0.08	0.07	0.16	0.13

Table 4: Effect of different concentrations of *Eruca sativa* and *Brassica rapa* seeds on growth characters of *Zea mays* plants at 45 and 75 days after sowing (Average of the two seasons)

		Growth characters					
		Plant length (cm)		No. of leaves/plant		Root length (cm)	
Treatments	Rate (g/kgsoil)	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
Z. mays	--	58.1	62.8	5.0	6.2	34.5	53.5
Z. mays+ *C. rotundus*	--	51.6	60.7	4.2	5.3	31.4	51.2
Z. mays + *C. rotundus* + *E. sativa*	25	69.7	84.0	6.0	7.5	40.0	61.1
	50	83.0	101.5	7.6	8.5	50.7	66.0
	75	46.0	82.6	3.8	7.2	27.1	59.6
Z. mays + *C. rotundus* + *B. rapa*	25	63.4	77.6	5.6	7.1	37.0	57.4
	50	75.0	94.2	7.2	8.0	42.7	62.0
	75	35.9	39.1	3.2	4.0	20.6	32.6
LSD at 5%		0.78	1.60	0.51	0.19	1.08	1.84

Dry Weight: Dry weight of foliage, underground organs as well as total dry weight of purple nutsedge alone (Table 3) increased by increasing plant age, while mixed stand of purple nutsedge + maize recorded significant decrease in both ages of growth (45 and 75 DAS) in these characters as compared to their corresponding control (purple nutsedge alone). Different concentrations of *E. sativa* as well as *B. rapa* induced high significant reduction in the dry weight of foliage of purple nutsedge at 45 DAS comparing to the corresponding controls except the highest concentration (75g/kg soil) of *E. sativa* that caused complete control. After 75 days, low concentration (25 g/kg soil) of *E. sativa* and the three concentrations of *B. rapa* caused significant reduction in the foliage dry weight comparing to the corresponding controls, while both higher concentrations (50 and 75g/kg soil) of *E. sativa* caused complete control of foliage dry weight of purple nutsedge. The underground organs are the main storage parts of purple nutsedge plants. All treatments of *E. sativa* in both ages of growth induced complete control of underground organs growth, while different concentrations of *B. rapa* after 45 days of growth caused significant reduction. The rate of reduction significantly increased by increasing the concentration rate used until it reached to 96.4 and 84.8%, respectively as compared to corresponding controls. After 75 days of growth (75 DAS) the higher concentration used of *B. rapa* recorded complete control. The pattern of change in the total dry weight of purple nutsedge (foliage + underground organs) showed the same tendency in the dry weight of foliage (Table 3) in the two ages of growth (45 and 75 DAS) comparing to the corresponding controls.

Maize Growth: Results presented in Tables 4 and 5 illustrated that 25 and 50 g/kg soil of both *E. sativa* and *B. rapa* caused significant increase in all growth characters of maize in the two ages of growth as compared to their corresponding controls. The middle concentration (50g/kg soil) of *E. sativa* achieved the maximum increase in all these growth characters in both growth ages comparing to the corresponding controls. The maximum increase in the total dry weight of maize at 75 DAS was recorded with 50g/kg soil of both *E. sativa* and *B. rapa* reached to 144.4 and 125.9%, respectively as compared to corresponding

Table 5: Effect of different concentrations of Eruca sativa and Brassica rapa seeds on growth characters of Zea mays plants at 45 and 75 days after sowing (Average of the two seasons).

		45 days after sowing						75 days after sowing					
		Fresh weight (g//plant)			Dry weight (g//plant)			Fresh weight (g//plant)			Dry weight (g//plant)		
Treatments	Rate (g/kg soil)	Plant	Root	Total	Plant	Root	Total	Plant	Root	Total	Plant	Root	Total
Z. mays	--	7.7	2.7	10.4	1.26	0.86	2.12	12.4	8.3	20.7	2.14	2.24	4.38
Z. may s+ C. rotundus	--	6.6	2.0	8.6	1.00	0.63	1.63	9.8	6.7	16.5	1.38	1.55	2.93
Z. mays + C. rotundus + E. sativa	25	13.1	4.9	18.0	1.75	1.37	3.12	20.2	14.9	35.1	2.81	2.97	5.78
	50	13.9	5.6	19.5	2.10	1.52	3.62	29.2	17.9	47.1	3.90	3.26	7.16
	75	5.1	1.4	6.5	0.90	0.49	1.39	14.8	12.5	27.3	2.60	2.62	5.22
Z. mays + C .rotundus + B.rapa	25	10.0	3.2	13.2	1.48	1.0	2.48	18.0	13.7	31.7	2.73	2.71	5.44
	50	12.7	3.7	16.4	1.71	1.20	2.91	21.7	16.2	37.9	3.50	3.12	6.62
	75	4.0	1.1	5.1	0.63	0.35	0.98	5.4	4.1	9.5	0.97	0.93	1.90
LSD 0.05	--	0.23	0.21	0.61	0.13	0.08	0.22	1.12	0.81	1.05	0.15	0.06	0.09

Table 6: Effect of different concentrations of Eruca sativa and Brassica rapa seeds on total carbohydrate contents (mg/g DW) of Zea mays Leaves.

		Days after sowing (DAS)	
Treatments	Rate (g/kg soil)	45 days	75 days
Z. mays	--	136.90	149.30
Z. may+ C. rotundus	--	92.40	138.60
Z. mays + C. rotundus + E. sativa	25	296.41	376.05
	50	394.83	460.49
	75	90.20	274.21
Z. mays + C. rotundus + B. rapa	25	207.15	322.31
	50	249.97	370.17
	75	83.32	107.43
LSD 0.05	--	3.74	3.60

Table 7: Total glucosinolates (µmol/g DW) and Total phenolic contents (mg/g DW) in *Eruca sativa* and *Brassica rapa* seeds

Materials	Total glucosinolates (µmol/g DW)	Total phenolic contents (mg/g DW)
E. sativa	316.03	35.62
B. rapa	252.70	28.41

mixed control (maize+ purple nutsedge). It is worthy to mention that the highest concentration of *E. sativa* at 45 days showed significant reduction in different growth parameters in maize comparing to corresponding control. However, by increasing plant age (75 DAS) a recovery lead to significant increase in these characters. Applying the highest concentration of *B. rapa* significantly inhibited to high extent all maize characters at both growth ages when compared to corresponding controls.

Changes in Total Carbohydrate Contents: Total carbohydrate contents of maize leaves significantly increased when treated with the low and middle concentrations (25 and 50 g/kg soil) of both materials used (*E. sativa* and *B. rapa*) in the two ages of growth (45 and 75 DAS) comparing to corresponding control. The highest total carbohydrate contents in maize leaves in the two growth ages was recorded with the middle concentration (50 g/kg soil) of *E. sativa* (394.83 and 460.49) as compared to corresponding mixed control (92.4 and 138.6) at 45 and 75 DAS, respectively (Table 6).

Changes in Total Glucosinolates and Total Phenolic Contents in *Eruca sativa* and *Brassica rapa* Seeds Powder: The results in Table 7 indicated that total glucosinolates in *E. sativa* seeds are higher than that present in *B. rapa* by about 20%. The same tendency was recorded with total phenolic contents of two Brassicaceae plant seeds, *E. sativa* and *B. rapa*.

DISCUSSION

Research efforts in the past have concentrated on the discovery and use of herbicides for weed control. Recently, there have been considerable efforts in designing weed management strategies of allelopathic compounds as bioherbicides to suppress weeds in crops

[3, 6, 16, 17]. The allelopathic potential of residues of some Brassicaceae plants were investigated under both laboratory and field conditions to determine the possibility of using them as natural pesticides for controlling weeds [3, 6, 11, 16, 17]. Secondary plant metabolites include a variety of compounds that could be released into the environment by means of four ecological processes, volatilization, leaching, decomposition of plant residues in soil and root exudation [18]. When Brassicaceae plant tissues are disrupted, glucosinolates are hydrolyzed to a number of products. The main breakdown products are isothiocyanates, which are phytotoxic and achieved good results in controlling weeds [1, 6, 7, 9-11, 17, 19-23]. The results of this study reveal that all different treatments of both *E. sativa* and *B. rapa* seeds powder minimized to a great extent, all growth characters of foliage and underground organs, as well as the dry weight of purple nutsedge until it reached to complete control with the higher concentrations of *E. sativa* seeds at the second growth age (Tables 1, 2 and 3). Similar results were reported by allelochemicals present in the other plants powder [4, 24-30]. On the other hand, the results of the present research reveal that the low and middle concentrations (25 and 50g/kg soil) of both *E. sativa* and *B. rapa* have a stimulatory effect (negative allelopathic effects) on different maize growth characters and carbohydrate contents in the two growth ages as compared to the corresponding controls. Best results achieved by the middle concentration of *E. sativa.* Similar results were also reported by allelochemicals present in the powder of other plants [4, 31, 32]. Both Brassicaceae plants seeds *E. sativa* and *B. rapa* achieved to great extent good results in controlling the perennial weed, purple nutsedge and also improved the growth of maize plants, this may be due to the selectivity of allelochemicals in their action and plants in their responses [33]. Allelochemicals which inhibit the growth of some species at certain concentrations may stimulate the growth of same or different species at different concentrations [4, 34].

It is worthy to mention that, the increase in both allelochemicals (glucosinolates and total phenolic contents) in *E. sativa* seeds was more than those occur in *B. rapa* seeds which lead to increase in its allelopathic potentiality in controlling purple nutsedge weed. Finally, both *E. sativa* and *B. rapa* seeds powder could be used as bioherbicide similar to the synthetic herbicide Basamid, since the mode of action of both is the production of isothiocyanates, which effectively control the growth and propagative capacity of purple nutsedge and other weeds [35-37].

CONCLUSION

The results of this study indicate the possibility of using the allelopathic activity of *Eruca sativa* and *Brassica rapa* seeds powder as a selective bioherbicide for controlling purple nutsedge in maize cultivation. Therefore, further studies are still needed under field conditions.

REFERENCES

1. Fahey, J.W., A.T. Zalcmann and P. Talalay, 2001. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. Photochemistry, 56: 5 -51.
2. Einhellig, F.A., 2002. The Physiology of Allelochemical Action: Clues and Views. pp: 1-23. In: Allelopathy, from Molecules to Ecosystems, M.J. Reigosa and N. Pedrol Eds. Science Publishers, Enfield, New Hampshire.
3. Velasco, P., P. Soengas, M. Vilar and M.E. Cartea, 2008. Comparison of glucosinolate profiles in leaf and seed tissues of different *Brassica napus* crops. J. Amer. Soc. Hort. Sci., 133(4): 551-558.
4. Ahmed, S.A., N.K. Messiha, R.R. El-Masry and K.G. EL-Rokiek, 2012. Allelopathic potentiality of the leaf powder of *Morus alba* and *Vitis vinifera* on the growth and propagative capacity of purple nutsedge (*Cyperus rotundus* L.) and maize (*Zea mays* L.). J. of Appl. Sci. Res., 8(8): 4744 -4751.
5. Fenwick, G.R., N.M. Griffiths and R.K. Heaney, 1983. Bitterness in Brussels sprouts (*Brassica oleracea* L. var. gemmifera): the role of glucosinolates and their breakdown products. J. of the Sci. of Food and Agric., 34: 73-80.
6. Zaji, B. and A. Majd, 2011. Allelopathic potential of canola (*Brassica napus* L.) residues on weed suppression and yield response of maize (*Zea mays* L.). International Conference on Chemical, Ecology and Environmental Sciences IICCEES, 2011) Pattaya. December, pp: 457-460.
7. Martinez-Ballesta, M.D.C., D.A. Moreno and M. Carvajal, 2013. The physiological importance of glucosinolates on plant response to a biotic stress in Brassica. Int. J. Mol. Sci., 14: 11607-11625.
8. Bones, A.M. and J.T. Rossiter, 2006. The enzymic and chemically induced decomposition of glucosinolates. Phytochemistry, 67: 1053 -1067.

9. Bennett, R.N., F.A. Mellon, N.P. Botting, J. Eagles, E.A.S. Rosa and G. Williamson, 2002. Identification of the major glucosinolate (4-mercaptobutyl glucosinolate) in leaves of *Eruca sativa* L. (rocket salad). Phytochemistry, 61: 25-30.
10. Kim, S.J. and G. Ishii, 2006. Glucosinolate profiles in the seeds, leaves and roots of rocket salad (*Eruca sativa* Mill.) and anti-oxidative activities of intact plant powder and purified 4-methoxyglucobrassicin. Soil Sci. and Plant Nutrition, 52: 394-400.
11. Borek, V., M.J. Morra, P.D. Brown and J.P. McCaffrey, 1994. Allelochemicals produced during Sinigrin decomposition in soil. J. Agric. Food Chem., 42: 1030-1034.
12. Rauchberger, Y., S. Mokady and U. Cogan, 1979. The effect of aqueous leaching of glucosinolates on the nutritive quality of rapeseed meal. J. Food Agric., 30: 31-39.
13. Nasirullah and M.N. Krishnamurthy, 1996. A method for estimating glucosinolates in mustard/rapeseeds and cake. J. Food Sci. Technol., 33(6): 498-500.
14. Snell, F.D. and C.T. Snell, 1953. Colorimetric Methods. pp: 606 Volume 111. Organic, D. Van Nostrand Company, Inc. Toronto, New York, London.
15. Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 7th Ed. pp: 507. The Iowa State Univ. Press, Ames, Iowa.
16. Malik, S.M., J.K. Norsworthy, A.S. Culpepper, M.B. Riley and W. Bridges Jr, 2008. Use of wild radish (*Raphanus raphanistrum*) and rye cover crops for weed suppression in sweet corn. Weed Sci., 56(4): 588-595.
17. Uremis, I., M. Arslan, A. Uludag and M. Sangum, 2009. Allelopathic potentials of residues of 6 Brassica species on Johnsongrass [*Sorghum halepense* (L.) Pers.]. African J. of Biotechnology, 8(15): 3497 -3501.
18. Chou, C.H., 1999. Roles of allelopathy in plant biodiversity and sustainable agriculture. Critical Reviews in Plant Sci., 18: 609-636.
19. Cerny, M.S., E. Taube and R. Battaglia, 1996. Identification of bis (4-isothiocyanatobutyl) disulfide and its precursor from rocket salad (*Eruca sativa*). J. Agric. Food Chem., 44: 3835-3839.
20. Peterson, J., R. Belz, F. Walker and K. Hurle, 2001. Weed suppression by release of isothiocyanates from turnip-rape mulch. Agron. J., 93: 37-42.
21. Weckerle, B., K. Michel, B. Balazs, P. Schreier and G. Toth, 2001. Quercetin 3, 3, 4-tri-O-B-D-glucopyranosides from leaves of *Eruca sativa* (Mill.). Phytochemistry, 57: 547-551.
22. Jirovetz, L., D. Smith and G. Buchbauer, 2002. Aroma compound analysis of *Eruca* sativa (Brassicaceae) SPME headspace leaf samples using GC, GC-MS and olfactometry. J. Agric. Food Chem., 50: 4643-4646.
23. Miyazawa, M., T. Maehara and K. Kurose, 2002. Composition of the essential oil from the leaves of *Eruca sativa*. Flavour Fragr. J., 17: 187-190.
24. Duke, S.O., F.E. Dayan and A.M. Rimando, 1998. Natural products as tools for weed management. Weed Res., 40(1): 99-111.
25. Olofsdotter, M., L.B. Jensen and B. Courtois, 2002. Improving crop competitive ability using allelopathy -an example from rice. Plant Breeding, 121(1): 1-9.
26. James, J.F. and R. Bala, 2003. Allelopathy: How Plant Suppress Other Plants. The Hort. Sci. Dept. Inst. Food Agric. Sci. Univ. Florida. (Available at: http://edis.Ufl.Edu).
27. Padmanaban, B. and M. Daniel, 2003. Biology and bionomies of palm white grub, *Leucopholis burmeisteri*. Indian J. Entom., 65(4): 444-452.
28. Rudramuni, M.S., V.K. Rao and V. Ravindra, 2006. Allelopathic Potential of Neem Extract in Horticultural Crops. 8th World Congress of Soil Sci., July 9-15. Philadelphia, Pennsylvania, USA.
29. El-Rokiek, K.G., R.R. EL-Masry, N.K. Messiha and S.A. Ahmed, 2010. The Allelopathic effect of mango leaves on the growth and propagative capacity of purple nutsedge (*Cyperus rotundus* L.). J. of Am. Sci., 6(9): 151-159.
30. El-Rokiek, K.G., N.K. Messiha, R.R. EL-Masry and S.A. Saad El-Din, 2011. Evaluating the leaf residues of *Eucalyptus globules* and *Mangifera indica* on growth of *Cynodon dactylon* and *Echinochloa colonum*. J. of Applied Sci. Res., 7(12): 1793-1799.
31. Minorsky, P.V., 2002. Allelopathy and grain crop production. Plant Physiol., 130: 1745-1746.
32. Stephanie, R.D., D.J. Anita, L.B. Eric, L.R. David and A.S. Scott, 2004. Common sunflower (*Helianthus annuus*) and shattercane (*Sorghum bicolor*) interference in corn. Weed Sci., 52: 976-983.

33. Einhellig, F.A., 1995. Mechanism of Action of Allelochemical in Allelopathy. In: Allelopathy Organisms, Processes and Application. Am. Chem. Soc., Washington, USA, pp: 96-116.
34. Narwal, S.S., 1994. Allelopathy in Crop Production. Production Publ. Scientific Publishers Jodhpur (India) pp: 288.
35. Messiha, N.K., S.H. El Gayar and S.A.R. Mohamed, 1993. The efficiency of Basamid (dazomet) in controlling purple nutsedge (*Cyperus rotundus* L.) in two different Egyptian soils. Egypt. J. Appl. Sci., 8(1): 369-380.
36. Khalaf, K.A., R.R. EL-Masry and N.K. Messiha, 1994. The effect of soil treatment with Basamid (dazomet) on *Orobanche crenata* and *Cuscuta planiflora*. Proc. 3th Inter. Workshop on *Orobanche* and related *Striga* Res. Amsterdam, pp: 576-579.
37. Sharara, F.A., K.G. El-Rokiek and S.S. Gaweesh, 2011. Effect of soil fumigation on growth, development, yield of wheat (*Triticum aestivum* L) and associated weeds. Int. J. Acad. Res., 3(2): 781-786.