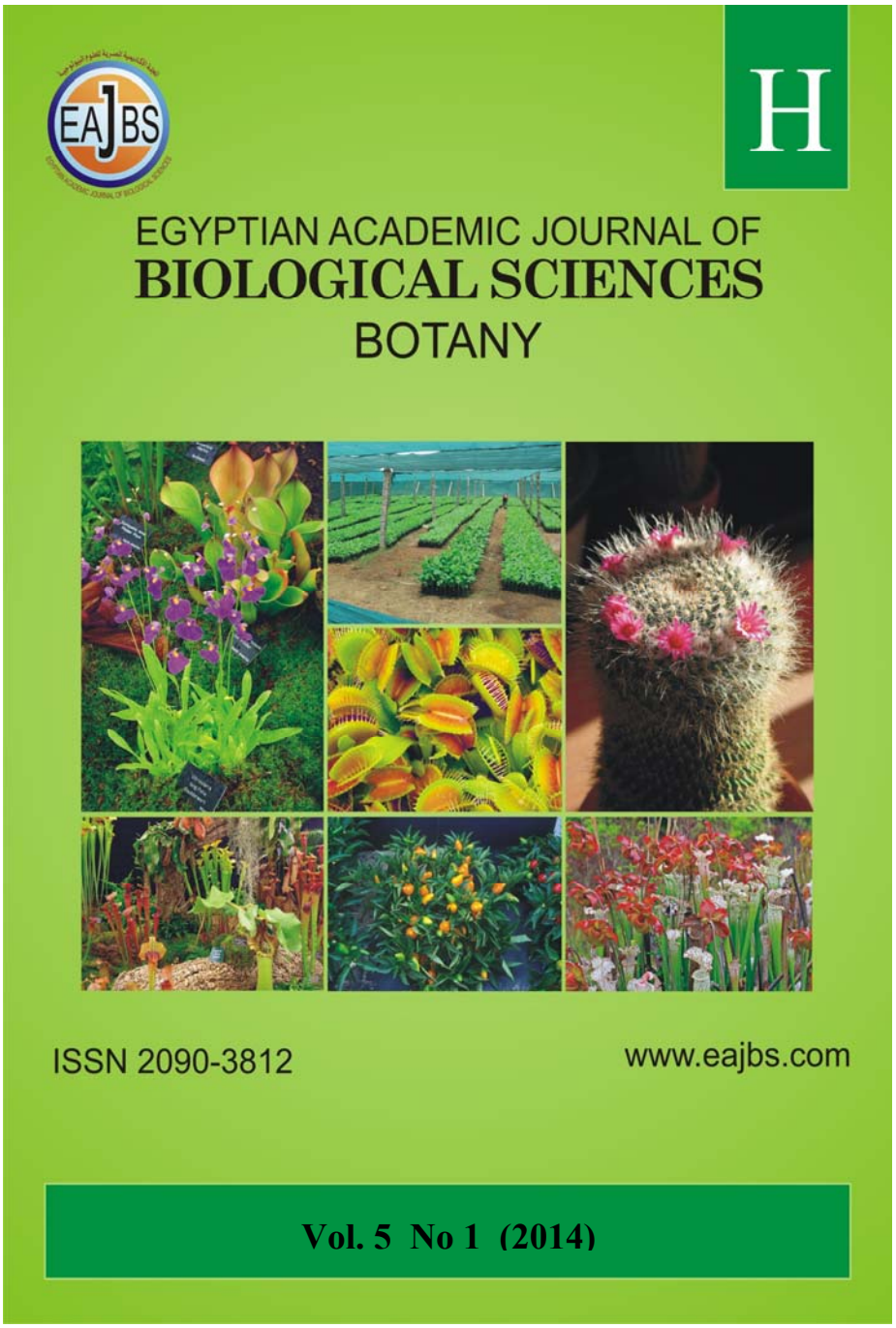

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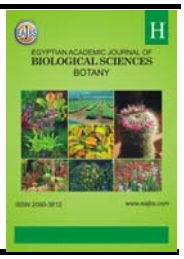

Allelopathic Effects of Some Botanical Extracts, Compared to the Herbicide Atrazine, against Germination of Selected Weeds

Sameeh A. Mansour [1*], Om Mohamed A. Khafagi [2], Abdel-Tawab H. Mossa [1], and Rasha M. El-Sanhoury [2]

1- Pesticides Chemistry Department, National Research Centre, Dokki, Giza, Egypt.
2- Department of Botany and Microbiology, Faculty of Science (Girls Branch), Al-Azhar University, Cairo, Egypt.

ABSTRACT

This study was conducted to evaluate the herbicidal activity of some plant extracts against three selected weeds (*Amaranthus retroflexus, Cichorium intybus* and *Echinochloa crus-galli.*) and also to be compared with the herbicide atrazine (gesaprim®, 80% WP). The plant extracts included: *Allium cepa* (Onion) lamina, *Allium sativum* (Garlic) lamina, *Cichorium intybus* (Chicory) (whole plant), *Citrus aurantium* (Sour orange) peel, *Conyza aegyptiaca* (Fleabane) (whole plant), *Oryza sativa* (Rice) straw, *Triticum aestivum* (Wheat) straw, and *Zea mays* (Corn) straw. Three sets of laboratory experiments were conducted. First, the plant species were water extracted and bioassayed using radish as a bioindicator plant. Then these plants were tested against the chosen weeds in six different concentrations (1%, 4%, 7%, 10%, 15%, and 20% w/v). Finally, weeds were subjected to the herbicide atrazine in four concentrations (3.75%, 1.875%, 0.9375%, and 0.46875% w/v). The results showed that the majority of screened plants inhibited germination of radish seeds in a percentage ca 40% or more. The concentration 25% of the recommended dose of atrazine (0.9375% w/v) was the most effective against germination of all target weeds. The herbicide atrazine was found to be more potent than all the tested plant extracts against all target weeds. As for the effect on *Amaranthus retroflexus* and *Cichorium intybus*, extracts of *Citrus aurantium* peel and *Cichorium* intybus, respectively were considered more promising since atrazine exceeded their potency with only 0.6 times. It was noticed also that the relative potency of atrazine and *Oryza sativa* extract (against *Cichorium intybus*) were nearly the same (1.1 time). Most the tested plant extracts were very weak as compared with atrazine against *Echinochloa crus-galli*.

Keywords: Botanical extracts; Weeds; Atrazine, Allelopathy, Seed germination.

INTRODUCTION

Weeds are the most abundant plant species which do not only compete with crop plants for nutrients, water, space and light but also give refuge to pests and diseases; and occasionally interfere with crop growth by releasing allelopathic substances into the rhizosphere of the crop plants (Rice, 1984). There are several methods used for weed control which include prevention, cultural, mechanical,

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biological, and chemical means. Herbicides offer promising increase in crop yield through effective weed control. Although herbicides are very effective in controlling weeds, yet certain risks such as environmental pollution and human health problems are involved in herbicides use. Improper use of herbicides may lead to crop injury, health hazards, soil and water pollution, and in certain cases, target weeds are not controlled because of low doses used by farmers. Herbicide resistance in weeds due to continuous use of the same herbicide for several years is also an emerging problem (Cheema *et al.,* 2005). Although the use of herbicides cannot be eliminated, their use can be reduced by exploiting allelopathy as an alternate weed management tool for crop production (Cheema and Khaliq, 2000; and Jabran *et al.*, 2008). Allelopathy provides natural weed control either by: mulching the soil, the use of allelopathic crops as cover crops, preparing water extracts of allelopathic crops and then sprayed over crops and weeds, the use of allelopathic crop as an intercrop, selection of allelopathic crop varieties or identification of new herbicide chemistry. The harmful effects of allelopathic substances include: inhibition and delays in germination, seed darkening and turgidity, deformation of seedling, declines in roots, radical, stem, and coleoptiles development, swelling and necrosis of root or radical, paleness, lack of root hair, and decreasing in total dry matter (Jackulski and Rudnic, 1994). However, this can be managed in light of accurate screening before use.

The present study aimed at: (1) Investigating the allelopathic potential of some botanical extracts using radish (*Raphanus sativum*) as a bioindicator plant. (2) Studying the allelopathic activity of these botanical extracts on three selected weeds; *Amaranthus retroflexus, Cichorium intybus*, and *Echinochloa crus-galli.* (3) Studying the biological activity of the herbicide atrazine (gesaprim®, 80% WP) against these weeds.

MATERIALS AND METHODS

A set of laboratory experiments were conducted in Pesticide Chemistry Laboratory, National Research Centre, Dokki, Cairo, Egypt. Their details are given below.

Plant Materials

The plant species used in the allelopathic investigation were divided into: (a) donor species (sources of plant extracts), (b) receiver species (target weeds) and (c) a bioindicator plant. The scientific and common names, families, as well as the used parts of the plants investigated for their biological and allelopathic activities are listed in Table 1.

Donor plants were collected from fields located in Shobrakheet, El- Behera Governorate at ripening stage. All the used parts of donor species were rinsed with water, shade dried, ground and finally stored in airtight jars until use. While seeds of the target weeds and the bioindicator plant were purchased from a local shop in Cairo. Before use, seeds were sterilized with 5% sodium hypochlorite for 10 min. and thoroughly rinsed with distilled water and then soaked in tap water for 24 hours. Floated seeds were removed.

Table1: Plants investigated for their biological and allelopathic activities

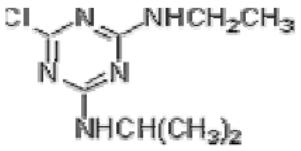
No.	Scientific name	Family	Common name	Used part
	(a) Donor species (Sources of plant extracts)			
1	***Allium cepa*, L. cv. Brand Giza red**	Alliaceae	Onion	Lamina
2	***Allium sativum*, L. cv. Balady**	Alliaceae	Garlic	Lamina
3	***Cichorium intybus*, L.**	Asteraceae	Chicory	Whole plant
4	***Citrus aurantium*, L.**	Rutaceae	Sour orange	Peel
5	***Conyza aegyptiaca*, (L.) Aiton**	Asteraceae	Fleabane	Whole plant
6	***Oryza sativa*, L. cv. Giza 177**	Poaceae	Rice	Straw
7	***Triticum aestivum*, L. cv. Sakha 94**	Poaceae	Wheat	Straw
8	***Zea mays*, L. cv. Signal cross 10**	Poaceae	Corn	Straw
	(b) Receiver species (Target species)			
9	***Amaranthus retroflexus*, L.**	Amaranthaceae	Redroot pigweed	Seeds
10	***Cichorium intybus*, L.**	Asteraceae	Chicory	Seeds
11	***Echinochloa crus-galli*, (L.) P. Beauv.**	Poaceae	Barnyardgrass	Seeds
	c) Bioindicator plant			
12	***Raphanus sativum*, L.**	Brassicaceae	Radish	Seeds

Herbicides

Atrazine (gesaprim®) herbicide was selected to be tested against the studied weeds. It was purchased from a local shop in Cairo. Atrazine is described in the **Pesticide Manual (2003)** as follows:

Chemical Name (IUPAC): 6-chloro-N2-ethyl-N4-isopropyl-1,3,5-triazine-2,4-diamine.

Trade name: Gesaprim.



Formulation used: (80% wettable powder "WP").

Manufacturer: Syngenta**.**

Recommended application dose: 750 g/feddan.

Pre-harvest interval (PHI): 28 days.

Experimental Work

Preparation of Aqueous Extracts of Plant Materials

With a slight modification of the method used by Chung *et al.* (2003), the aqueous extracts were prepared as follow: 20 g of ground plant material were soaked in 1 liter of distilled water for 24 h at room temperature. The solutions were filtered through four layers of cheese cloth to remove debris and then centrifuged at 3000 rpm for ½ h. The supernatant was filtered through one layer of Whatman no. 42 filter paper to prevent microorganisms' growth. A series of dilutions were made to prepare the different tested concentrations.

Preparation of Herbicide Stock Solutions

The stock solution was prepared according to the recommended dose of the herbicide, i.e. 3.75 g of the wettable powder were dissolved in 1 liter of distilled water. Four sets of concentrations were prepared (3.75%, 1.875%, 0.9375%, and 0.46875% w/v) which represent the same recommended dose, and 50%, 25%, and 12.5% of the recommended dose, respectively.

Test Procedures

The study comprised three sets of laboratory experiments. All experiments were conducted under laboratory conditions at 25 ± 2°C. All experiments were left for 7 days before recording data using three replicates for each treatment. Seeds of the target weeds or those of the bioindicator plant were sowed in a Petri dish (9 - cm diameter), lined with filter paper, and 10 ml of the aqueous extracts were added to these dishes. Controls received only distilled water and were carried out along with each patch of treatments. Germination test was performed according to rules of the International seed testing association (I.S.T.A., 1996). The actual length of root and shoot was measured using a straightedge while the fresh weight of seedlings was

measured using an electric balance. Details of each experiment are separately given below:

Experiment 1: Preliminary Screening Test

The aim of this test was to investigate the allelopathic potential of different parts of screened plants on germination of radish seeds. Radish was used as the test plant in this experiment because it is strongly sensitive to allelochemicals at low concentration (Tsuzuki *et al*., 1995). To make such test, three concentrations (1%, 5% and 10%; w/v) were prepared from each plant extract. After 7 days, number of germinated seeds was counted to determine germination percentage of radish seeds in all treatments. Germination was deemed to occur only after the radical had protruded beyond the seed coat by at least 1 mm. Germination percentage was calculated using this formula: Germination % = No of germinated seeds / 20 ×100. The inhibition percentage was calculated as follows: Inhibition (%) of germination = [(control - treatment)/control] × 100. Extracts caused ca 40 % inhibition of radish seeds germination were chosen to be tested against target weeds in details.

Experiment 2: Studying the Biological Activity of Aqueous Plant Extracts against Target Weeds (*Amaranthus retroflexus, Cichorium intybus*, and *Echinochloa crus-galli*)

The purpose of this experiment was to study the biological activity of different parts of screened plants on germination, root length and shoot length of target weeds. To conduct this experiment, six concentrations (1%, 4%, 7%, 10%, 15% and 20%; w/v) were prepared for each plant extract. At the end of the seventh day, germination was recorded as mentioned before and the actual length of root and shoot was also determined as described before. Inhibition percentage of germination, root length and shoot length were calculated using the previously mentioned equation.

Experiment 3: Studying the Biological Activity of Herbicide Atrazine (Gesaprim®) Against Target Weeds (*Amaranthus retroflexus, Cichorium intybus*, *and Echinochloa crus-galli*)

This experiment was designed to test the biological activity of the herbicide atrazine (gesaprim ®, 80% WP) at the concentrations mentioned before against *Amaranthus retroflexus*, *Cichorium intybus* and *Echinochloa crus-galli*. In the same manner, germination percentage, root length, and shoot length of seedlings in all treatments were recorded.

Estimation of Relative Potency

Relative potency is used to compare the activity of plant extracts on germination as compared with a specific herbicide and expressed as X folds potentiation. Relative potency was calculated using this equation: Relative potency= LC_{50} of plant extract/LC_{50} of herbicide. N.B. LC_{50} was calculated using LD-P line software (a program devoted to calculate probit analyses according to **Finney, 1971**) which refers to concentration causing 50% inhibition of germination.

Statistical Analysis

The data obtained were subjected to statistical analysis according to Snedecor and Cochran (1981). Statistical analysis was performed using Statistical Package for Social Sciences, Version 16.0 (SPSS, Inc., Chicago, III., USA) for Windows. Continuous variables were analyzed as mean values ± standard deviation (SD). Differences among continuous variables with normal distribution were analyzed by Student's t-test. Values followed by * or ** which indicate significant or highly significant as compared with control at a probability level of 0.05 and 0.01, respectively.

RESULTS

Preliminary Screening Test

The first effort of this study was to evaluate the allelopathic potential of different parts of screened plants on germination of radish seeds, using three different concentrations (1%, 5%, and 10% w/v) for each plant extract. The results of this screening (Table 2) showed a reduction in germination percentage along with increase of concentration in all plant extracts. At concentration of 1%, some plant extracts showed stimulation of germination of radish seeds including *Allium cepa* lamina, *Allium sativum* lamina and *Zea mays* straw. At the same time, *Zea mays* straw continued stimulating germination at 5% concentration and had no effect on germination at 10% concentration. Some plant extracts completely inhibited germination at 5% concentration including *Cichorium intybus* and *Citrus aurantium.* At 10% concentration, the majority of screened plants inhibited germination in a percentage ca 40% or more (except a few cases), so these plant extracts were suggested to be tested against target weeds in details. Although extracts of *Oryza sativa* straw, *Triticum aestivum* straw, and *Zea mays* straw did not reach this percentage, they were excepted since it was reviewed in several researches that they have allelopathic activity (e.g.; Jung *et al*., 2003; Kugler, 2006 and Almezory, 1996), and so they might be supposed to have a biological effect on the target weeds.

Table 2: Effects of aqueous extracts of different plants on germination of radish (*Raphanus sativum*) seeds.

plant	Conc. %	Germination %	
		Mean	I%
***Allium cepa* lamina**	**0**	90.00 ±1.15	-
	1	91.67±0.58	-1.85
	5	63.33±1.15	29.63
	10	0.0±0.0	100
***Allium sativum* lamina**	**0**	77.27±1.00	-
	1	85.00±2.00	-9.99
	5	50.00±6.24	35.29
	10	3.33±0.58	95.67
***Cichorium intybus* (whole plant)**	**0**	93.33±2.15	-
	1	86.67±2.52	7.14
	5	0.0±0.0	100
	10	0.0±0.0	100
***Citrus aurantium* peel**	**0**	90.00±2.00	-
	1	85.00±2.00	5.55
	5	0.0±0.0	100
	10	0.0±0.0	100
***Conyza aegyptiaca* (whole plant)**	**0**	98.31±2.00	-
	1	88.33±0.58	10.16
	5	7.33±3.06	25.42
	10	8.33±1.15	91.52
***Oryza sativa* straw**	**0**	98.33±1.15	-
	1	93.33±0.58	5.08
	5	85.00±0.0	13.55
	10	60.00±2.00	38.98
***Triticum aestivum* straw**	**0**	98.30±1.00	-
	1	91.67±1.53	6.74
	5	90.00±1.0	8.44
	10	81.67±0.58	16.91
***Zea mays* straw**	**0**	91.66±0.15	-
	1	98.33±1.15	-7.27
	5	96.66±0.58	-5.45
	10	91.66±1.15	0

Biological Activity of Aqueous Plant Extracts against *Amaranthus retroflexus*

In this experiment, the biological activity of different parts of screened plants were evaluated against germination, root length, and shoot length of *Amaranthus retroflexus*, using six concentrations (1%, 4%, 7%, 10%, 15%, and 20% w/v). The results showed a significant increase in inhibition percentage of the recorded parameters and the inhibition percentage was directly proportional with concentration increase (Table 3); except a few cases in which a slight drop in the inhibition sequence was observed.

Table 3: Allelopathic effects of aqueous extract of selected plants on germination, root length, and shoot length of *Amaranthus retroflexus*

Plant	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
Allium cepa lamina	**0%**	83.33±1.52	-	3.28±1.24	-	1.91±0.44	
	1%	75.00±1.73	10	2.41±0.54**	26.39	2.30±0.46**	-20.55
	4%	46.66±0.57**	44	0.59±0.48**	82.03	1.48±0.66*	22.47
	7%	40.00±1.00**	52	0.13±0.13**	96.04	0.65±0.50**	66.02
	10%	43.33±6.65	48Δ	0.06±0.06**	98.17	0.61±0.52**	68.11
	15%	5.00±0.0**	94	0.0±0.0**	100	0.04±0.12**	97.9
	20%	3.33±0.57*	96	0.0±0.01**	99.89Δ	0.03±0.12**	98.25
Allium sativum lamina	**0%**	88.33±0.57	-	2.34±0.96	-	2.58±0.42	-
	1%	70.00±2.64	20.75	1.99±0.76	14.81	3.26±0.55**	-26.28
	4%	53.33±0.57**	39.62	0.23±0.33**	90.17	1.19±1.01**	53.73
	7%	45.00±2.00*	49.05	0.03±0.06**	98.43	0.74±1.01**	71.39
	10%	13.33±1.52**	84.9	0.01±0.03**	99.43	0.19±0.50**	92.52
	15%	1.66±0.57**	98.11	0.0±0.0**	100	0.01±0.09**	99.35
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
Cichorium intybus (whole plant)	**0%**	86.66±0.57	-	2.88±1.16	-	2.22±0.52	-
	1%	60.00±1.73*	30.76	0.66±0.97**	76.96	1.77±1.05*	20.27
	4%	15.00±1.73**	82.69	0.0±0.0**	100	0.11±0.19**	95.04
	7%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
Citrus aurantium peel	**0%**	90.00±1.00	-	2.44±1.12	-	1.96±0.43	-
	1%	56.66±2.08*	37.03	0.19±0.26**	92.09	0.92±0.49**	52.8
	4%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	7%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100

Inhibition (%) = [(control -treatment) / control] × 100. Numbers with negative (-) value indicate stimulation over control. Δ refers to unexpected value. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001, respectively.

Table 3: (continued)

Plant	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
***Conyza aegyptiaca* (whole plant)**	**0%**	93.33±0.57	-	3.78±1.21	-	1.75±0.21	─
	1%	78.33±0.57*	16.07	3.76±1.02	0.44	2.23±0.28**	-27.18
	4%	70.00±3.00	25	2.18±0.65**	42.37	2.14±0.41**	-22.43
	7%	16.66±2.08**	82.14	0.10±0.34**	97.18	0.26±0.46**	85.17
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
***Oryza sativa* straw**	**0%**	86.66±0.57	-	3.16±1.09	-	2.54±0.54	─
	1%	78.33±1.52	9.61	2.15±0.90**	31.92	3.04±0.98*	-19.9
	4%	61.66±0.57**	28.84	0.10±0.22**	96.62	0.64±0.76**	74.8
	7%	15.00±2.00**	82.69	0.0±0.0**	100	0.03±0.05**	98.68
	10%	1.66±0.57**	98.07	0.0±0.0**	100	0.003±0.01**	99.86
	15%	1.66±0.57**	98.07	0.0±0.0**	100	0.003±0.01**	99.86
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
***Triticum aestivum* Straw**	**0%**	88.33±0.57	-	2.69±1.09	-	1.73±0.26	─
	1%	75.00±1.00*	15.09	2.38±1.51	11.38	2.70±1.01**	-56.15
	4%	66.66±2.30*	24.52	2.12±1.31	21.28	2.84±0.48**	-63.84Δ
	7%	70.00±3.00	20.75Δ	1.29±0.59**	51.98	2.60±0.76**	-50.19
	10%	58.33±4.16	33.96	0.64±0.40**	75.99	1.93±0.94	-11.34
	15%	33.33±3.51*	62.26	0.07±0.16**	97.4	0.55±0.69**	68.07
	20%	6.66±0.57**	92.45	0.02±0.08*	99	0.17±0.50**	90
***Zea mays* straw**	**0%**	81.66±2.30	-	2.33±1.06	-	2.45±0.72	─
	1%	75.00±3.46	8.16	1.69±0.62*	27.67	3.31±0.81**	-35.05
	4%	58.33±1.52*	28.57	0.27±0.31**	88.44	1.32±0.94**	46.19
	7%	46.66±4.04	42.85	0.10±0.17**	95.43	0.80±0.89**	67.39
	10%	18.33±0.57**	77.55	0.003±0.01**	99.85	0.13±0.29**	94.7
	15%	3.33±0.57**	95.91	0.0±0.0**	100	0.01±0.04**	99.59
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100

Inhibition (%) = [(control -treatment) / control] × 100. Numbers with negative (-) value indicate stimulation over control. Δ refers to unexpected value. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001, respectively.

For more accuracy, the experiment was repeated again and the same result was obtained, this in addition that they were still significant as compared with the control which may need further studies to interpret such cases. Such examples of the same manner were always remarked with a (Δ) mark in all succeeding tables. Comparing different measured parameters revealed that root length is much sensitive to all tested plants. The first appearance of a complete inhibition of any of the recorded parameters was observed at 4% concentration. It is worth mentioning that the aqueous extracts of *Citrus aurantium* peel caused a significant complete inhibition of all tested biological cursors of *Amaranthus retroflexus* at this concentration.

Biological Activity of Aqueous Plant Extracts against *Cichorium intybus*

In the same manner, selected plants were tested against *Cichorium intybus* at six different concentrations (1%, 4%, 7%, 10%, 15%, and 20% w/v). The results showed

that with increase in the concentration of plant extracts from 1 to 20%, the germination percentage, root length, and shoot length decreased significantly (Table 4). It was noticed again that root length is more sensitive to all tested plants than other tested parameters. Significantly extract of *Cichorium intybus* completely inhibited all biological cursors of *Cichorium intybus* at 4% concentration.

Table 4: Allelopathic effects of aqueous extracts of selected plants on germination, root length, and shoot length of *Cichorium intybus.*

plant	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
Allium cepa **lamina**	**0%**	96.66±0.57	–	4.71±1.01	–	1.89±0.30	–
	1%	83.33±1.52*	13.79	1.30±0.30**	72.41	1.93±0.22	-2.46
	4%	83.33±2.08	13.79	0.51±0.25**	89.17	1.63±0.31*	13.4
	7%	48.33±2.51*	50	0.11±0.16**	97.52	0.60±0.41**	68.07
	10%	48.33±0.57**	50	0.15±0.16**	96.81Δ	0.49±0.24**	73.89
	15%	30.00±1.00**	68.96	0.01±0.04**	99.71	0.18±0.20**	90.47
	20%	3.33±0.57**	96.55	0.0±0.0**	100	0.01±0.07**	99.11
Allium sativum **lamina**	**0%**	88.33±1.52	–	4.12±0.90	–	1.77±0.24	–
	1%	80.00±1.00	9.43	3.51±0.79*	14.86	2.30±0.32**	-29.83
	4%	61.66±2.08*	30.18	0.55±0.42**	86.59	1.30±0.42**	26.45
	7%	31.66±1.52**	64.15	0.12±0.21**	97.01	0.48±0.56**	72.79
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
Cichorium intybus **(whole plant)**	**0%**	90.00±1.00	-	4.33±0.96	–	1.97±0.26	–
	1%	46.66±1.15**	48.14	0.34±0.40**	91.99	1.31±0.75**	33.27
	4%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	7%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
Citrus aurantium **peel**	**0%**	90.00±1.00	–	3.91±1.25	–	1.64±0.37	–
	1%	90.00±2.00	0	2.26±0.64**	42.29	1.71±0.54	-4.67
	4%	51.66±0.57**	42.59	0.0±0.0**	100	0.03±0.07**	97.76
	7%	15.00±1.73**	83.33	0.0±0.0**	100	0.0±0.0**	100
	10%	6.66±1.52**	92.59	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100

Inhibition (%) = [(control -treatment)/control] × 100. Numbers with negative (-) value indicate stimulation over control. Δ refers to unexpected value. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001, respectively.

Table 4 (continued)

plant	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
Conyza aegyptiaca (whole plant)	**0%**	80.00±2.00	–	2.57±1.31	–	1.59±0.36	–
	1%	81.66±1.15	-2.08	2.43±1.21	5.43	2.63±0.55**	-65.4
	4%	43.33±2.88*	45.83	0.81±0.71**	68.56	1.57±1.07	1.04
	7%	23.33±1.52**	70.83	0.01±0.06**	99.35	0.14±0.22**	90.98
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
Oryza sativa straw	**0%**	91.66±1.52	–	3.83±1.38	–	2.10±0.45	–
	1%	60.00±1.00*	34.54	2.26±1.33**	41	2.04±1.05	3.01
	4%	38.33±4.50*	58.18	0.51±0.85**	86.62	0.64±0.81**	69.17
	7%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
Triticum aestivum straw	**0%**	95.00±1.00	–	3.31±1.15	–	2.00±0.25	–
	1%	90.00±1.00	5.26	3.90±1.18	-17.7	2.39±0.38**	-19.43
	4%	73.33±3.51	22.8	3.26±0.66	-1.4	2.26±0.42**	-12.62
	7%	65.00±2.64*	31.57	1.67±1.16**	49.39	1.82±0.61**	9.3
	10%	71.66±4.04**	24.56Δ	0.89±0.72**	72.93	1.24±0.72**	37.87
	15%	58.33±2.08*	38.59	0.16±0.26**	94.96	0.49±0.46**	75.41
	20%	56.66±1.52*	40.4	0.08±0.16**	97.38	0.46±0.34**	76.91
Zea mays straw	**0%**	95.00±0.0	–	3.31±1.19	–	1.88±0.33	–
	1%	81.66±0.57**	14.03	3.23±0.67	2.41	2.37±0.31**	-25.97
	4%	61.66±2.30*	35.08	0.24±0.32**	92.65	0.92±0.71**	51.23
	7%	40.00±4.58*	57.89	0.03±0.10**	98.89	0.23±0.37**	87.63
	10%	18.33±2.30**	80.7	0.0±0.0**	100	0.03±0.04**	98.05
	15%	10.00±1.73**	89.47	0.0±0.0**	100	0.02±0.05**	98.76
	20%	0.0±0.0	100	0.0±0.0**	100	0.0±0.0**	100

Inhibition (%) = [(control - treatment) / control] × 100. Numbers with negative (-) value indicate stimulation over control. Δ refers to unexpected value. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001, respectively.

Biological Activity of Aqueous Plant Extracts against *Echinochloa crus-galli*

The effect of plant extracts on germination of *Echinochloa crus-galli* (Table 5) was not obvious and had no specific trend; for example, *Conyza aegyptiaca* extract at 1% concentration stimulated germination by -2% followed by less stimulation (-4% and -8%) at 4% and 7% concentration, then returned to -4% stimulation at 10% and finally inhibited germination by 8% and 18% at 15% and 20% concentration, respectively. Similar cases were recorded in extracts of *Allium cepa* leaves, *Oryza sativa* straw, *Triticum aestivum* straw, and *Zea mays* straw. In spite of that, inhibition of germination by other plant extracts was concentration dependent (i.e., direct proportion). This experiment also illustrated that root length was more sensitive than

the other tested parameters to all tested plants. Significantly extract of *Cichorium intybus* completely inhibited all biological cursors of *Echinochloa crus-galli* at 7% concentration.

Table 5: Allelopathic effects of aqueous extract of selected plants on germination, root length, and shoot length of *Echinochloa crus-galli*.

plant	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
***Allium cepa* lamina**	**0%**	96.66±1.15	–	3.36±1.45	–	5.09±0.82	–
	1%	83.33±0.57	13.79Δ	3.84±1.31	-14.25	5.71±0.76*	-12.1
	4%	93.33±1.15	3.44	1.14±0.59**	66.13	4.63±0.86*	9.06
	7%	90.00±1.00	6.89	0.45±0.21**	86.53	2.75±0.58**	45.94
	10%	88.33±0.57	8.62	0.30±0.08**	90.99	2.12±0.55**	58.31
	15%	78.33±2.08	18.96	0.23±0.11**	93.16	1.26±0.45**	75.26
	20%	58.33±0.57**	39.65	0.12±0.10**	96.33	0.95±0.48**	81.21
***Allium sativum* lamina**	**0%**	88.33±1.52	–	3.31±1.31	–	5.35±1.03	–
	1%	96.66±0.57	-9.43	3.00±0.93	9.34	6.45±0.90**	-20.47
	4%	95.00±0.00	-7.54	1.00±0.59**	69.64	5.89±0.97*	-9.95
	7%	90.00±2.00	-1.88	0.45±0.37**	86.43	5.83±0.94	-8.89
	10%	80.00±1.00	9.43	0.15±0.15**	95.47	4.37±1.18**	18.29
	15%	58.33±2.08	33.96	0.0±0.0**	100	3.22±0.91**	39.82
	20%	40.00±4.35*	54.7	0.0±0.0**	100	1.56±1.24**	70.75
***Cichorium intybus* (whole plant)**	**0%**	80.00±1.00	–	4.11±1.00	–	5.00±0.91	–
	1%	91.66±0.57*	-14.58	1.50±0.80**	63.45	5.04±1.09	-0.66
	4%	23.33±1.52**	70.83	0.0±0.0**	100	0.60±0.82**	87.94
	7%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	10%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
***Citrus aurantium* peel**	**0%**	90.00±1.00	–	3.43±1.31	–	5.11±1.15	–
	1%	90.00±2.00	0	0.59±0.96**	82.79	4.10±1.07**	19.75
	4%	51.66±0.57**	42.59	0.0±0.0**	100	1.70±0.74**	66.68
	7%	15.00±1.73**	83.33	0.0±0.0**	100	0.33±0.60**	93.41
	10%	6.66±1.52**	92.59	0.0±0.0**	100	0.09±0.23**	98.23
	15%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100
	20%	0.0±0.0**	100	0.0±0.0**	100	0.0±0.0**	100

Inhibition (%) = [(control - treatment) / control] × 100. Numbers with negative (-) value indicate stimulation over control. Δ refers to unexpected value. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001, respectively.

Table 5 (continued)

plant	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
Conyza aegyptiaca (whole plant)	**0%**	83.33±1.52	–	3.14±1.08	–	6.31±0.97	–
	1%	85.00±1.73	-2	4.82±2.01**	-53.23	7.01±0.91*	-11.15
	4%	86.66±2.30	-4Δ	2.31±0.89**	26.5	6.76±1.22	-7.06
	7%	90.00±1.00	-8Δ	1.36±0.53**	56.8	4.05±1.63**	35.77
	10%	86.66±1.15	-4Δ	0.64±0.54**	79.67	2.29±1.45**	63.62
	15%	76.66±1.15	8	0.0±0.0**	100	0.99±0.24**	84.21
	20%	68.33±0.57*	18	0.0±0.0**	100	0.64±0.16**	89.86
Oryza sativa straw	**0%**	75.00±1.00	–	1.56±0.58	–	1.47±0.46	–
	1%	65.00±2.64	13.33	1.63±0.77	-4.7	1.36±0.56	7.23
	4%	65.00±2.64	13.33	0.77±0.41**	50.18	1.09±0.53*	25.79
	7%	81.66±1.15	-8.88Δ	0.37±0.39**	75.92	0.80±0.44**	45.47
	10%	63.33±1.52	15.55	0.14±0.11**	90.62	0.59±0.31**	59.5
	15%	53.33±4.93	28.88	0.073±0.078**	95.31	0.22±0.16**	84.61
	20%	45.00±2.64*	40	0.0±0.0**	100	0.15±0.10**	89.59
Triticum aestivum straw	**0%**	76.66±2.08	–	2.02±0.65	–	2.00±0.45	–
	1%	73.33±2.51	4.34	2.64±0.75**	-30.47	1.94±0.56	3.32
	4%	75.00±0.00	2.17Δ	1.88±0.86	6.91	1.89±0.68	5.48
	7%	68.33±1.52	10.86	1.10±0.55**	45.63	1.68±0.70*	16.11
	10%	71.66±1.52	6.52Δ	0.72±0.49**	64.41	1.21±0.56**	39.53
	15%	65.00±1.00	15.21	0.08±0.10**	95.71	0.44±0.24**	78.07
	20%	46.66±1.15*	39.13	0.04±0.05**	97.85	0.41±0.32**	79.23
Zea mays straw	**0%**	88.33±2.08	–	4.03±1.25	–	5.39±0.83	–
	1%	80.00±2.00	9.43	5.67±1.15**	-40.64	5.79±1.02	-7.54
	4%	91.66±2.08	-3.77Δ	4.34±1.24	-7.6	4.42±0.96**	17.99
	7%	88.33±1.15	0Δ	3.16±0.66*	21.74	4.31±0.85**	19.97
	10%	81.66±2.30	7.54Δ	2.02±0.57**	49.89	3.97±0.90**	26.28
	15%	71.66±2.51	18.86	0.35±0.29**	91.24	2.92±0.68**	45.82
	20%	60.00±1.00*	32.07	0.0±0.0**	100	1.69±0.51**	68.64

Inhibition (%) = [(control - treatment) / control] × 100. Numbers with negative (-) value indicate stimulation over control. Δ refers to unexpected value. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001, respectively.

Biological Activity of Atrazine (Gesaprim®) against Target Weeds (*Amaranthus retroflexus*, *Cichorium intybus*, and *Echinochloa crus-galli*)

A series of four concentrations were prepared for the herbicide Atrazine (gesaprim ®, 80% WP) including the recommended dose (R.D, 3.75% w/v), 50% of R.D, (1.875% w/v), 25% of R.D (0.9375% w/v), and 12.5% of R.D (0.46875%; w/v). They were tested against germination, root length, and shoot length of the target weeds; *Amaranthus retroflexus, Cichorium intybus*, and *Echinochloa crus-galli* (Table 6). As for the effect on germination, the concentration 25% of R.D. was the most effective against germination of all target weeds. The same R.D was more effective than the other tested doses against root length of both *Amaranthus retroflexus* and *Cichorium intybus.* The concentration 12.5% of R.D was the best dose in inhibiting root and shoot length of *Echinochloa crus-gall.*

Table 6: The biological activity of Gesaprim (80% WP) on germination, root length, and shoot length of the target weeds (*Amaranthus retroflexus, Cichorium intybus, and Echinochloa crus-galli*).

Target weeds	Conc.	Germination %		Root length		Shoot length	
		Mean	I%	Mean	I%	Mean	I%
Amaranthus retroflexus	**Control**	16.00 ± 2.00	-	0.45 ± 0.18	-	0.94 ± 0.17	-
	the same R.D	13.33 ± 2.31**	16.67	0.23 ± 0.05**	48.15	0.69 ± 0.19**	26.3
	50% of R.D	11.67 ± 1.53*	27.08	0.48 ± 0.52	-5.93	0.78 ± 0.33	16.7
	25% of R.D	11.67 ± 2.08**	27.08	0.67 ± 0.46*	-48.15	0.94 ± 0.41	0
	12.5% of R.D	13.00 ± 2.65**	18.75	0.61 ± 0.45	-36.3	0.88 ± 0.21	6.41
Cichorium intybus	**Control**	18.67 ± 1.53	-	1.49 ± 0.69	-	1.64 ± 0.78	-
	the same R.D	18.67 ± 0.58	0	1.00 ± 0.33**	32.51	2.36 ± 0.45**	-43.8
	50% of R.D	18.33 ± 1.53	1.79	1.03 ± 0.39*	30.72	2.26 ± 0.47**	-37.5
	25% of R.D	18.00 ± 1.73	3.57	1.12 ± 0.54*	24.44	2.10 ± 0.60*	-27.6
	12.5% of R.D	18.33 ± 1.53	1.79	1.93 ± 0.50*	-30.04	2.24 ± 0.45**	-36.3
Echinochloa crus-galli	**Control**	5.33 ± 2.08	-	1.05 ± 1.71	-	2.18 ± 3.01	-
	the same R.D	5.33 ± 2.52	0	0.73 ± 0.98	31.01	0.64 ± 0.93*	70.7
	50% of R.D	4.67 ± 0.58	12.5	1.31 ± 1.62	-24.05	1.01 ± 1.35	53.7
	25% of R.D	3.00 ± 2.65*	43.75	0.19 ± 0.42*	81.65	0.15 ± 0.25*	93
	12.5% of R.D	3.67 ± 2.08*	31.25	0.14 ± 0.47*	86.71	0.11 ± 0.18*	94.8

"R.D" refers to the recommended dose of Gesaprim, and "I" represents the inhibition %.
Inhibition (%) = [(control -treatment)/control] × 100.
Numbers with negative (-) value indicate stimulation over control. Values followed by * or ** are significant or highly significant as compared with control at a probability level of 0.05 and 0.001 respectively.

Relative Potency of Atrazine (gesaprim®, 80% WP) as compared with Plant Extracts

The herbicide atrazine was found to be more potent than the all tested plant extracts against the target weeds. As for the effect on *Amaranthus retroflexus* and *Cichorium intybus*, extracts of *Citrus aurantium* peel and *Cichorium* intybus, respectively were considered more promising since atrazine exceeded their potency with only 0.6 times (Tables 7 and 8). Also, it was noticed that the relative potencies of atrazine and *Oryza sativa* extract (against *Cichorium intybus*) were nearly the same (1.1 times; Table 8). Most of the tested plant extracts were very weak as compared with atrazine against *Echinochloa crus-galli* (Table 9).

Table 7: Relative potency of plant extracts as compared with herbicide atrazine (at the level of LC_{50}) against *Amaranthus retroflexus*.

Plant	LC_{50} of plant extract (g/L)	Relative potency (X-Times)
***Allium cepa* lamina**	3.55	1.9
***Allium sativum* lamina**	2.99	1.6
***Cichorium intybus* (whole plant)**	1.3	0.7
***Citrus aurantium* peel**	1.07	0.6
***Conyza aegyptiaca* (whole plant)**	3.04	1.6
***Oryza sativa* straw**	2.88	1.5
***Triticum aestivum* straw**	7.33	3.9
***Zea mays* straw**	3.52	1.9
Atrazine (g/L)	1.89	1.0

N.B.: Relative potency= LC_{50} of plant extract/LC_{50} of herbicide.

Table 8: Relative potency of plant extracts as compared with herbicide atrazine (at the level of LC_{50}) against *Cichorium intybus*

Plant	LC_{50} of plant extract (g/L)	Relative potency (X-Times)
***Allium cepa* lamina**	6.67	4.5
***Allium sativum* lamina**	3.24	2.2
***Cichorium intybus* (whole plant)**	0.96	0.6
***Citrus aurantium* peel**	3.3	2.2
***Conyza aegyptiaca* (whole plant)**	2.73	1.8
***Oryza sativa* straw**	1.58	1.1
***Triticum aestivum* straw**	30.82	20.7
***Zea mays* straw**	3.98	2.7
Atrazine (g/L)	1.49	1.0

N.B.: Relative potency= LC_{50} of plant extract/LC_{50} of herbicide.

Table 9: Relative potency of plant extracts as compared with herbicide atrazine (at the level of LC_{50}) against *Echinochloa crus-galli*.

Plant	LC_{50} of plant extract (g/L)	Relative potency (X-Times)
***Allium cepa* lamina**	OE	950.2
***Allium sativum* lamina**	19.68	48.0
***Cichorium intybus* (whole plant)**	2.35	5.7
***Citrus aurantium* peel**	3.3	8.0
***Conyza aegyptiaca* (whole plant)**	OE	3971.1
***Oryza sativa* straw**	58. 78	143.4
***Triticum aestivum* straw**	77.77	189.7
***Zea mays* straw**	OE	940.9
Atrazine (g/L)	0.41	1.0

N.B.: Relative potency= LC_{50} of plant extract/LC_{50} of herbicide, OE refers to out of estimation values due to very low inhibition percentage at the tested concentrations.

DISCUSSION

Laboratory bioassays constitute a significant part of allelopathic research, and various bioassays have been proposed to demonstrate allelopathy under controlled laboratory conditions. Laboratory bioassays allow researchers to eliminate all possible alternative interferences through perfectly controlled experimental designs and manipulation of nearly all parameters (Inderjit and Dakshini, 1995). Radish (*Raphanus sativum*) was used as a bioindicator plant in the preliminary screening for two reasons; first, it is so sensitive to chemicals at low concentrations, that sometimes they may overestimate the actual allelopathic activity of tested plants (Olofsdotter, 2001). Second, radish was the most sensitive test species when grown on filter paper in transparent boxes at a 45° angle (Haugland and Brandsaeter, 1996).

Extracting allelochemicals using water depended on a recommendation by avoiding using organic solvents as extractants in allelopathic bioassays (Inderjit and Dakshini, 1995) since this may lead to the release of certain compounds which may not be released under natural circumstances. In addition, Whitehead *et al.* (1981) suggested that the amounts of phenolic compounds can be best extracted with water as an extractant in comparison to $Ca(OH)_2$ or 2M NOH. Depending on measuring more than one growth parameter (such as germination percentage, root length, shoot length and seedling weight) also matched suggestions of Inderjit and Dakshini (1995) for allelopathic bioassays.

Allium spp. had a stimulatory effect at low concentrations (less than 10%) for example promotion of radish germination; promotion of *Amaranthus* shoot length; stimulation of *Cichorium intybus* shoot length and also promotion of *Echinochloa crus-galli* germination, root length, and shoot length. Such stimulatory effects were

also observed by garlic (*Allium sativum*) against root length of Chinese cabbage; melon; root length of tomato; and root length and fresh weight of lettuce (Zhou *et al.*, 2007; ZuoFei, 2007; Han *et al.*, 2013). The major allelochemicals in garlic straw aqueous extracts were preliminarily determined to be the ester like compounds such as dimethyl 2-methoxyhexane-1,6-dioate and dibutyl phthalate, the organic acid like compounds such as 4-hydroxy-3-methoxy benzoic acid and 4-hydroxy-benzoic acid, and the phenol like compounds such as mequinol (ZuoFei, 2007). The possible mechanism of the allelopathy in garlic may be that allicin inhibits both the growth of microorganisms and seed germination. It also protects the damaged garlic from microorganisms and competition from other monocots for nutrients (Sharangi, 2011). The author also stated that crops like *Allium* spp. (onion, garlic, and leek), may be tried as possible donor plants towards contributing allelochemicals to the unwanted weeds resulting in the desired shift of competition favoring the target crop of interest. This is based on the fact that these crops contain certain biologically active sulphur compounds which have proven insecticidal, fungicidal, acaricidal, and nematicidal activities, if not demonstrable herbicidal activity (Auger *et al.*, 2004).

The allelopathic potential of *Cichorium intybus* (chicory) may be due to the phenolic contents (e.g., monocaffeoyl tartaric acid, chlorogenic acid, and chicoric acid) which were detected in the fresh aerial parts (Innocenti *et al.*, 2005) and also sesquiterpenoids (8a-angeloyloxycichoralexin and guaianolides such as cichoralexin and 10a-hydroxycichopumilide) which were identified in the root (Nishimura and Satoh, 2006). *Cichorium intybus* extract was found to be the most effective against germination of its seeds which may reveal autotoxicity. Autotoxicity is a phenomenon of intraspecific allelopathy that occur when a plant species releases chemical substances which inhibit or delay germination and growth of the same plant species (Putnam, 1985; Singh *et al.*, 1999). Autotoxicity is known for example in *Triticum aestivum* (wheat), *Zea mays* (corn), and *Oryza sativa* (rice) (Wu *et al.*, 2012; Singh *et al.* 2010; Ghahari and Miransari, 2009). This phenomenon can be relied on for the management of this weed. Extracts of *Cichorium intybus* were significantly more potent than those of *Conyza aegyptiaca* against target weeds although they are species of the same family Asteraceae which reveal that the allelopathic potentiality may differ among species within the same family.

Citrus aurantium (sour orange) peel completely inhibited all recorded parameters of *Amaranthus retroflexus*, this may be due to the presence of terpenes and phenolic inhibitors which caused also reduction of seed germination and/or seedling growth of *Amaranthus retroflexus* (Al Saadawi *et al.*, 1985). The concentrations of abscisic acid-b-D-glucopyranosyl ester (ABA-GE) in peel was found to be one of the main growth inhibitors in *Citrus junos* fruit. The concentration was greatest in the peel, followed by the inside and seeds (Kato-Noguchi and Tanaka, 2004).

The allelopathic activity of *Conyza aegyptiaca* may be due to the presence of the phloroglucinol glucoside derivative [2, 4-*dihydroxy*-6-(beta-D-glucopyranosyloxy) phenyl]-butan-1-one and roseoside in addition to kaempferol-3-O-beta-D-glucopyranoside which were isolated from aerial parts (Mahmoud *et al.*, 2009). At 10% concentration, *Conyza aegyptiaca* extract completely inhibited all recorded parameters of both *Amaranthus retroflexus* and *Cichorium intybus,* so it is recommended that this economical concentration should be subjected to further field studies for the management of these weeds.

The allelopathic activity of *Oryza sativa* (rice) straw is well known. In Sri Lanka, farmers use rice straw as an organic amendment to rice fields. Hassan *et al.* (1994) reported that some rice varieties suppress the growth of *Echinochloa crus-*

galli. Moody (1995) reported that weed populations could be managed with phytotoxic crop residues. Straw of allelopathic rice varieties has inhibited the growth of *Heteranthera limosa* (Dilday *et al.*, 1990) and *Cyperus iria* (Lin *et al.*, 1993). It is also well known that rice straw releases phenolic acids that can act as allelopathic agents. Kuwatsuka and Shindo (1973) isolated 13 different phenolic acids in decomposition of rice straw; benzoic acid, 4-hydroxybenzoic acid, protocatechuic acid, gallic acid, vanillic acid, syringic acid, salicylic acid, gentisic acid, β-resorcylic acid, *p*-coumaric acid, caffeic acid, ferulic acid and sinapinic acid. The inhibitory activities of momilactone B against the germination and growth of several plant species had been reported. A 5 μM solution of momilactone B inhibited the germination of *Amaranthus lividus* by 50 %. Judging from its inhibitory activity, momilactone B was considered to be a candidate for a rice allelochemical (Rimando and Duke 2003).

Triticum aestivum (wheat) straw possessed allelopathic effect although it was weak as compared with other plant extracts due to the presence of at least five phenolic acids, which had been previously identified as the toxic principles involved in the phytotoxicity of the straw (Jobidon *et al.*, 1989). According to Nie *et al.* (2004) in *Zea mays* (corn), there are structural diversity of cyclic hydroxamic acids and related benzoxazolinones. DIMBOA (1,4-benzoxazin-3(4H)-ones) is the most abundant derivative in *Zea mays*. The content of cyclic hydroxamic acids is strongly cultivar-dependent in *Zea mays*. After germination, the level of DIMBOA increases, and the maximum level occurs in young seedlings a few days after germination. DIMBOA exists in all parts of plants, and its concentration is generally higher in shoots than in roots. Because of their phototoxic properties, cyclic hydroxamic acids show a great variety of biological activities. They are the defensive agents against plant diseases, pests, nematodes and other plants.

In all cases, root length was always the most sensitive indicator than the other tested parameters. This matched the findings of Jafariehyazdi1 and Javidfar (2011) when they studied the allelopathic effect of *Brassica* spp. on sunflower. Also, roots were inhibited more strongly than seedling height at the same concentrations when extracts of *Conyza Canadensis* were applied (Xing Xiang *et al.,* 2009). It may be due to the fact that the root, which develops first, is affected by tested extracts for a longer period of time than the hypocotyls (Jasicka-Misiak *et al.*, 2005).

The susceptibility of a certain target weed to atrazine (gesaprim®, 80% WP) depends on being more tolerant or sensitive to the herbicide. In plants tolerant to atrazine, it is readily metabolised to hydroxyatrazine and amino acid conjugates, with further decomposition of hydroxyatrazine by degradation of the side-chains and hydrolysis of the resulting amino acids on the ring, together with evolution of CO_2. While in atrazine sensitive plants, unaltered atrazine accumulates, leading to chlorosis and death (Pesticide Manual, 2003).

Comparing the potency of the herbicide atrazine with that of the tested plant extracts revealed that atrazine was found to be more potent than all the tested plant extracts against all target weeds. In spite of that, plant extracts which had similar potency (such as *Oryza sativa* straw) or slightly less potent (such as *Citrus aurantium* peel and *Cichorium intybus*) could be considered more promising plants and require further studies to detect the suitable form of application in weed control management.

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