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Assessment of some medicinal plants for their allelopathic potential against redroot pigweed (*Amaranthus retroflexus*)

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Abstract: The study was conducted to determine the allelopathic effects of *Crocus sativus* L., *Ricinus communis* L., *Nicotiana tabacum* L., *Datura inoxia* Mill., *Nerium oleander* L., and *Sorghum vulgare* L. on the germination and growth of *Amaranthus retroflexus* (redroot pigweed). Powder and aqueous extracts of these plants were used to run the experiment under laboratory and greenhouse conditions. In the laboratory, all aqueous extracts showed a significant inhibitory effect on the germination, seedling length and weight of redroot pigweed plants. The most allelopathic against the redroot pigweed were *R. communis*, *N. tabacum*, and *D. inoxia*. In the greenhouse experiment, extracts and the powder of these plants also showed significant inhibitory effects on pigweed dry weight, height, leaf area, number of survivor plants, and amount of chlorophyll. In the germination bioassay and application of powder, the inhibitory effect was dosage dependent – the higher the concentration, the strongest the inhibitory effect. From the obtained results, it can be concluded that the powder and extracts of the tested species have an herbicidal potential against redroot pigweed and could be used as natural herbicides and mulches.

Key words: allelopathy, *Amaranthus retroflexus*, natural herbicide, weeds

Introduction

Weeds have been, are, and will continue to be a major constraint to agriculture production throughout the world (National Research Council 1996). The introduction of pesticides in agriculture was an effective tool for controlling obnoxious weeds. The use of pesticides led to a reduction in yield loss. Continuous use of synthetic herbicides, though, creates environmental pollution and increases the number of herbicide resistant weeds. Hence, there is a need to find natural ways to control weeds which would minimize the dependency on synthetic herbicides (Bhadoria 2011). Allelopathic compounds, often considered plant-produced herbicides, can inhibit growth of nearby plants. These compounds could be an alternative weed management strategy for crop production and can offer environmental benefits (Colquhoun 2006). Since biosynthesized herbicides are easily biodegradable, they are believed to be much safer than synthesized herbicides (Machado 2007). Numerous plants have been screened for their herbicidal potential. These plants release allelochemicals which may help with weed control. Chung *et al*. (2001) assessed the allelopathic potential of 44 rice cultivars (*Oryza sativa* L.) on barnyard grass. All 44 cultivars exhibited marked differences in the inhibition of barnyard grass growth and development. Sunflower cultivars have been shown to be natural herbicides for weed control of *Chenopodium album* L., *Rumex dentatus* L., *Coronopus didymus* L., *Phalaris minor* Ketz., and *Medicago polymorpha* L. (Anjum and Bajwa 2008). Another practical way to use allelopathy in weed control is to apply residues of allelopathic plants as mulches. These residues can provide selective weed control through their physical presence on the soil surface and also through the release of allelochemicals (Bhowmik and Inderjit 2003). It was observed that *Tagetes minuta* L. leaf powder applied to rice field soil significantly reduced emergence and growth of *Echinochloa crus-galli* (L.) P. Beauv and *Cyperus rotundus* L. in pots under greenhouse and field conditions (Batish *et al*. 2007). Dhima *et al*. (2009) indicated that green manure of aromatic plants, such as anise, dill, oregano or lacy phacelia could be used for the suppression of barnyard grass and some broadleaf weeds in maize which consequently minimize herbicide usage.

Throughout the world, redroot pigweed, *Amaranthus retroflexus* L., is considered to be the most hazardous weed. Azizi and Fujji (2006) found that *Eucalyptus* sp. essential oils had a strong inhibitory effect on the germination of *A. retroflexus*. Incorporation of sunflower residues in the soil has been shown to reduce growth of redroot pigweed. Aqueous extracts of sunflower reduced germination and mean daily germination (Ghorbani *et al*. 2008). However, the effects of *Crocus sativus* L., *Ricinus communis* L., *Nicotiana tabacum* L., *Datura inoxia* Mill, *Nerium oleander* L., and *Sorghum vulgare* L. extracts and powders on the germination and growth of

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pigweed have not been well documented. The objectives of this research were to determine the phytotoxic effects of these medicinal plant extracts and powders on the germination and growth stages of pigweed.

Materials and Methods

Preparation of extracts and powders

Arial parts of *C. sativus*, *R. communis*, *N. tabacum*, *D. inoxia*, *N. oleander*, and *S. vulgare* plants at the flowering stage were harvested from fields. Then, they were air dried and ground to a fine powder. One hundred ml of distilled water was added to 10 g of powder (10 g dry weight) for 24 h at 20°C and the obtained 10% (w/v) extract was filtered through filter paper and used as a source of phytotoxins. Sterile deionized water was used to dilute the extracts and to generate four extract concentrations: 2.5, 5.0, 7.5, and 10 g/l. The extracts were stored at 4°C when not in use.

Germination and seedling growth bioassay

Seeds of pigweed were obtained from the Research Field of Isfahan University of Technology. The pigweed seeds were kept at room temperature to break the dormancy of the seeds. Then healthy seeds were surface sterilized with 3% sodium hypochlorite and thoroughly rinsed with sterilized distilled water. The comparative assessment of the influence of various aqueous extract concentrations on seed germination and early growth of pigweed was carried out in Petri dishes. The dishes were 9 cm in diameter. Double-layered sterilized Whatman filter paper No. 1 was placed in sterilized Petri dishes. The filter paper was moistened with 5 ml of distilled water (the control), 2.5, 5.0, 7.5, and 10 g/l of extracts and placed in an illuminated (16 h light : 8 h dark) growth chamber at 25°C. Germination percentage and rate, seedling length, and dry weight (oven-dried at 75°C for 48 h) were investigated after 7 days of germination. The mean germination time was calculated to assess the rate of germination (*RG*) as follows:

$$RG = \sum(G/D),$$

where *G* is the number of newly germinated seeds on each day and *D* is the day of counting.

Pot experiment

Effect of plant extracts

Weeds were planted in plastic pots (30 cm deep, 15.5 cm wide) containing approximately 2 kg of 50% soil mixed with 20% commercial peat moss and 30% humus. Ten seeds of *A. retroflexus* were sown at a depth of one cm. After 7 to 10 days, when complete germination was achieved, the seedlings per pot were reduced by careful manual thinning, to five equally healthy seedlings. Three replicates were prepared for each treatment along with the control. The pots were arranged in a completely randomized design and were placed in a greenhouse under 25°C, with a 16 h day and an 8 h night. The pots were irrigated with tap water when required. The extracts (10 g/l) were applied as a foliar spray on weeds, 7 days after germination. Three applications of extracts were carried out at 1-week intervals. The control plant was similarly sprayed with distilled water. After 1 month, the plants were carefully uprooted and their height, dry weight (oven-dried at 75°C for 48 h), percent of survival weeds [(survivor weeds/total weeds) × 100], chlorophyll and carotenoid content, and leaf area were tested.

Effect of plant powders

Another experiment was performed to explore the effect of powder on the emergence and growth of the pigweed under the described conditions. Pots were irrigated with tap water and after a week, the dried powders of *C. sativus*, *R. communis*, *N. tabacum*, *D. inoxia*, *N. oleander*, and *S. vulgare* were added as mulch, at a dose of 100, 200, and 300 g/m^2 (1.9, 3.8, and 5.7 grams per pot). A parallel setup, but without mulch, served as the control. Three pots were maintained per treatment as replicates in a completely randomized manner. After 1 month, the plants were carefully uprooted and tested for their height, dry weight (oven-dried at 75°C for 48 h), percent of survival weeds ((survivor weeds/total weeds) × 100), chlorophyll and carotenoid content, and leaf area.

Chlorophyll determination

One gram of leaf material from the weed of each treatment was ground with liquid nitrogen, then 15 ml of extraction solution (80% acetone) was added. Next, the slurry was centrifuged at 7,000 rpm. The supernatant was measured at 645 nm, 662 nm, and 470 using 80% aqueous acetone as the blank, to calibrate the spectrophotometer (U-1800 Hitachi, Japan). The amounts of chlorophyll *a* (C_a), chlorophyll *b* (C_b), total chlorophyll (C_{a+b}) and carotenoids (C_d) content were determined according to Lichtenthaler and Buschmann (2001) as follows:

$$C_a = 11.24 \times A_{661.6} - 2.04 \times A_{644.8} \text{ (mg/ml)},$$

$$C_b = 20.13 \times A_{644.8} - 4.19 \times A_{661.6} \text{ (mg/ml)},$$

$$C_{a+b} = 4.0 \times A_{661.6} + 18.09 \times A_{644.8} \text{ (mg/ml)},$$

$$C_d = (1000 \times A_{470} - 1.90\, C_a - 63.14\, C_b)/214 \text{ (mg/ml)},$$

where A is absorbance at wavelength of, respectively, 644.8 nm, 661.6 nm, 644.8 nm, and 470 nm.

In addition, the chlorophyll content was also determined using a chlorophyll meter (SPAD-502 Plus, Konica Minolta, Japan).

Leaf area measurement

All the leaves from each treatment were cut and leaf area was measured in cm^2 using a green leaf area meter (OSK--Model GA-5, Japan).

Statistical analysis

A completely randomized design (CRD) with three replications was used for the experiments. For the bioassay and the powder experiment, six types of extracts from different plant species, and four and three levels of extract concentrations were consequently combined in a complete factorial arrangement. Data of germination and growth parameters were subjected to the analysis of variance (ANOVA) using SAS Statistical Program. A comparison of the control and the means was performed using the Least Significant Difference (LSD). Inhibition percentage (%) was calculated as:

[(the control value − treatment value)/the control value] × 100.

Results

Germination and seedling growth bioassays

Pigweed germination and seedling growth inhibition were increased when the extract concentration was increased (Table 1). Pigweed germination was affected more by the plant extracts than seedling growth. The concentrations which caused the greatest inhibition of pigweed germination, seedling elongation, and seedling dry weight were *R. communis*, *N. tabacum*, *D. inoxia*, and *N. oleander*. The concentrations which caused the least inhibition of pigweed germination, seedling elongation, and seedling dry weight were *C. sativus* and *S. vulgare*. From the four extract concentrations, *N. tabacum* extract inhibited 100% of pigweed germination. Inhibition caused by *C. sativus* extract (four concentrations) was 34.5%, 40.5%, 46.5%, and 58.3%, respectively (Table 1).

Pot experiment

Effect of plant extracts

In early germination bioassays, a 10 g/l extract was the most effective against the pigweed, so it was selected for the pot experiment. The weeds exposed to foliar sprays with different extracts showed stunted growth, as was also true of the early germination bioassays. The survival weed percentage was reduced up to 40%. The total weight and biomass of the tested weeds declined significantly ($p < 0.01$). On a dry weight basis, the most reduction (27.4%) was recorded when pigweed was sprayed with an extract of *D. inoxia*. The lowest pigweed height was observed in pots treated with *S. vulgare* extract. Application of plant extracts decreased pigweed leaf area when compared to the control but there was no significant difference between the extracts. Chlorophyll contents of pigweed in both measurements (SPAD and spectrophotometer) decreased with the application of extracts while carotenoid contents were not affected by phytotoxins (Table 2).

Table 1. Effects of the extracts from 6 plant species on pigweed germination, germination rate, seedling length, and dry weight

Species	Concentration [g/l]	Germination [%]	Germination rate	Length [cm]	Dry weight [g]
The control	0	56.00 a*	42.42 a	2.49 a	0.53 a
C. sativus	2.5	36.67 b (34.5)**	39.29 ab (7.4)	2.41 a (2.8)	0.27 bc (49.1)
	5.0	33.33 b (40.5)	33.36 bc (23.4)	2.42 a (2.8)	0.27 bc (49.1)
	7.5	30.00 cd (46.4)	32.48 c (21.3)	2.42 a (2.8)	0.27 bc (49.1)
	10.0	23.33 bc (58.3)	25.81 d (39.1)	2.37 a (4.8)	0.26 bc (50.9)
R. communis	2.5	16.67 d (70.2)	5.83 ef (86.2)	1.72 b (30.9)	0.04 e (92.5)
	5.0	2.00 e (96.4)	0.74 ef (98.2)	0.62 de (75.1)	0.02 e (96.2)
	7.5	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	10.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
N. tabacum	2.5	1.33 e (97.6)	1.04 ef (97.5)	0.33 ef (86.7)	0.04 e (92.5)
	5.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	7.5	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	10.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
D. inoxia	2.5	15.33 d (72.6)	2.15 ef (94.9)	1.23 c (50.6)	0.27 bc (49.1)
	5.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	7.5	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	10.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
N. oleander	2.5	6.67 e (88.1)	1.79 ef (95.8)	1.04 cd (58.2)	0.20 cd (62.3)
	5.0	1.33 e (97.6)	0.74 ef (98.2)	1.00 cd (59.8)	0.16 d (69.8)
	7.5	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	10.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
S. vulgare	2.5	53.33 a (4.8)	22.57 d (46.8)	1.09 cd (56.2)	0.26 bc (50.9)
	5.0	20.00 d (64.3)	6.80 e (83.9)	1.01 cd (59.4)	0.30 b (43.4)
	7.5	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)
	10.0	0.00 e (100)	0.00 f (100)	0.00 f (100)	0.00 e (100)

*means with the same letters in a column are not significantly different at $p < 0.05$ using the LSD test

**numbers in parentheses are the inhibition percentage (%) compared with the control

Table 2. Effects of extracts (with a concentration of 10 g/l) from 6 plant species on pigweed dry weight (DW), height (H), SPAD, leaf area (LA), % survival weed (SW), chlorophyll *a* (C_a), chlorophyll *b* (C_b), total chlorophyll (C_{a+b}), and carotenoid (C_d)

Species	DW [g]	H [cm]	SPAD	LA [cm²]	SW [%]
The control	3.65 a*	30.25 a	49.20 a	77.59 a	100.00 a
C. sativus	3.22 b (11.8)**	26.00 ab (14.0)	41.57 bc (15.5)	46.77 b (39.7)	53.40 b (46.6)
R. communis	3.45 a (5.5)	21.00 bc (30.6)	45.30 ab (7.9)	57.17 b (26.3)	53.00 b (47.0)
N. tabacum	2.86 c (21.6)	20.33 c (32.8)	38.87 c (21.0)	45.23 b (41.7)	40.00 b (60.0)
D. inoxia	2.65 c (27.4)	22.58 bc (25.3)	37.02 c (24.7)	40.60 b (47.6)	40.00 b (60.0)
N. oleander	2.89 c (20.8)	23.00 bc (23.9)	42.67 bc (13.3)	46.08 b (40.6)	46.60 b (53.4)
S. vulgare	3.24 b (11.2)	17.83 c (41.0)	41.13 bc (16.4)	53.73 b (30.7)	40.00 b (60.0)

Species	C_a [mg/ml]	C_b [mg/ml]	C_{a+b} [mg/ml]	C_d [mg/ml]
The control	30.00 a	17.01 a	38.07 a	6.68 a
C. sativus	29.77 ab (0.7)	14.99 a (11.9)	35.93 ab (5.6)	6.66 a (0.3)
R. communis	27.53 abc (8.2)	12.31 b (27.6)	31.72 bc (16.7)	6.40 a (4.2)
N. tabacum	25.72 c (14.3)	10.98 b (35.4)	29.79 c (21.7)	6.51 a (2.5)
D. inoxia	27.56 abc (8.1)	11.27 b (33.7)	30.74 c (19.2)	6.61 a (1.0)
N. oleander	26.63 bc (11.2)	10.13 b (40.4)	28.31 c (25.6)	6.67 a (0.1)
S. vulgare	27.56 abc (8.1)	11.98 b (29.6)	31.42 c (17.5)	6.51 a (2.5)

*means with the same letters in a column are not significantly different at $p < 0.05$ using the LSD test
**numbers in parentheses are the inhibition percentage (%) compared with the control

Table 3. Effects of the powder of 6 plant species on pigweed dry weight (DW), height (H), SPAD, leaf area (LA) and % survival weed (SW)

Species	Concentration [g/m²]	DW [g]	H [cm]	SPAD	LA [cm²]	SW [%]
The control	The control	4.93 a*	27.39 ab	35.69 ab	79.21 a	100.00 a
C. sativus	100	2.47 ab (49.9)**	23.21 abc (15.3)	29.39 abc (17.6)	66.01 b (16.7)	72.22 ab (27.8)
	200	0.86 b (82.5)	10.83 c (60.5)	27.40 abc (23.2)	62.24 bc (21.4)	66.67 ab (33.3)
	300	0.70 b (85.8)	12.17 c (55.6)	18.32 c (48.7)	60.35 bc (23.8)	33.33 b (66.7)
R. communis	100	4.63 a (6.1)	28.94 ab (–5.6)	36.00 a (–0.9)	67.90 b (14.3)	77.78 ab (22.2)
	200	4.23 a (14.2)	27.78 a (–1.4)	35.88 abc (–0.5)	67.90 b (14.3)	61.11 ab (38.9)
	300	2.42 ab (50.9)	25.49 ab (6.9)	33.01 a (7.5)	64.12 b (19.0)	51.23 ab (48.7)
N. tabacum	100	2.14 ab (56.6)	22.17 abc (19.0)	18.32 c (48.7)	62.24 bc (21.4)	42.11 b (57.9)
	200	0.78 b (84.2)	10.83 c (60.4)	15.44 c (56.7)	56.58 c (28.6)	25.63 b (74.4)
	300	0.56 b (88.6)	8.22 c (70.0)	11.14 c (68.8)	60.35 bc (23.8)	23.97 b (76.0)
D. inoxia	100	2.47 ab (49.9)	15.23 bc (44.4)	21.50 bc (39.7)	64.12 b (19.0)	54.86 ab (45.1)
	200	0.86 b (82.5)	11.57 c (57.7)	18.33 c (48.6)	64.12 b (19.0)	47.11 b (52.9)
	300	0.70 b (85.8)	10.85 c (60.4)	17.81 c (50.1)	62.24 bc (21.4)	41.01 b (59.0)
N. oleander	100	3.61 ab (26.8)	22.21 abc (18.9)	20.26 bc (43.2)	67.90 b (14.2)	55.56 ab (44.4)
	200	2.99 ab (39.3)	16.61 bc (39.3)	19.49 bc (45.4)	60.35 bc (23.8)	44.44 ab (55.6)
	300	1.71 ab (65.3)	14.79 bc (46.0)	19.30 bc (45.9)	62.24 bc (21.4)	33.33 b (66.7)
S. vulgare	100	3.50 ab (29.0)	19.81 abc (27.7)	30.71 abc (13.9)	67.90 b (14.3)	61.11 ab (38.9)
	200	3.03 ab (38.5)	19.79 abc (27.7)	28.51 abc (20.1)	67.90 b (14.3)	50.00 ab (50.0)
	300	1.86 ab (62.3)	18.95 abc (30.8)	26.17 abc (26.7)	64.12 b (19.0)	50.00 ab (50.0)

*means with the same letters in a column are not significantly different at $p < 0.05$ using the LSD test
**numbers in parentheses are the inhibition percentage (%) compared with the control

Table 4. Effects of the powder of 6 plant species on pigweed chlorophyll *a* (C_a), chlorophyll *b* (C_b), total chlorophyll (C_{a+b}), and carotenoid (C_d) content

Species	Concentration [g/m^2]	C_a [mg/ml]	C_b [mg/ml]	C_{a+b} [mg/ml]	C_d [mg/ml]
The control	The control	16.35 ab*	6.61 ab	18.16 ab	5.20 a
C. sativus	100	14.70 ab (10.1)**	4.86 ab (26.5)	15.28 ab (17.8)	4.22 ab (18.8)
	200	13.96 ab (14.6)	4.84 ab (26.8)	14.72 ab (20.9)	3.37 ab (35.2)
	300	12.58 ab (23.0)	4.79 ab (27.5)	13.68 ab (26.4)	3.04 ab (41.5)
R. communis	100	19.59 a (–19.8)	8.85 a (–33.9)	22.66 a (–21.8)	4.18 ab (19.6)
	200	18.76 ab (–14.7)	7.48 ab (–13.2)	20.73 ab (–11.4)	3.55 ab (31.7)
	300	16.61 ab (–1.6)	6.17 ab (6.6)	17.92 ab (3.6)	3.23 ab (37.9)
N. tabacum	100	12.52 ab (23.4)	4.65 ab (29.6)	14.25 ab (23.4)	2.89 b (44.4)
	200	11.21 ab (31.4)	3.66 ab (44.6)	13.22 ab (28.9)	2.55 b (51.0)
	300	10.23 b (37.4)	3.02 b (54.3)	11.28 b (39.3)	2.06 b (60.4)
D. inoxia	100	16.45 ab (–0.6)	4.98 ab (24.6)	14.58 ab (21.6)	3.50 ab (32.7)
	200	15.55 ab (4.9)	4.66 ab (29.5)	13.65 ab (26.6)	3.21 ab (38.3)
	300	13.78 ab (15.7)	4.72 ab (28.6)	12.63 ab (32.1)	3.04 ab (41.5)
N. oleander	100	15.83 ab (3.2)	6.14 ab (7.1)	17.33 ab (6.8)	4.22 ab (18.8)
	200	9.06 b (44.6)	3.55 b (46.3)	9.95 b (46.5)	2.54 b (51.1)
	300	8.88 b (45.7)	3.45 b (47.8)	9.73 b (47.7)	2.33 b (55.2)
S. vulgare	100	16.00 ab (2.1)	5.55 ab (16.0)	15.82 ab (14.9)	4.58 ab (11.9)
	200	14.13 ab (13.6)	4.46 ab (32.5)	15.54 ab (16.4)	3.91 ab (24.8)
	300	10.83 ab (33.8)	4.05 ab (38.7)	11.71 ab (37.0)	3.03 ab (41.7)

*means with the same letters in a column are not significantly different at $p < 0.05$ using the LSD test

**numbers in parentheses are the inhibition percentage (%) compared with the control

Effect of plant powders

The growth of redroot pigweed was reduced when plant mulches were added to the soil. This reduction depended on the amount of the applied plant residue (Table 3). At the highest value of residues (300 g/m^2), we recorded 80, 45, and 21% reductions in dry weight, height, and leaf area, respectively. Pigweed leaf area was less affected than pigweed weight and height. The results revealed that plant residue effects depended on the type of species. Residues of *C. sativus*, *N. tabacum*, and *D. inoxia* were more potent in reducing dry weight and height of pigweed but there was no significant difference in the leaf areas of pigweed that were treated with different species (Table 3). The total chlorophyll and carotenoid content of pigweed was also significantly affected after using plant residues (Table 4).

Discussion

The results clearly demonstrated that most of the tested plant species inhibited seed germination. and root and shoot growth of redroot pigweed in the bioassay. These extracts may have potential for preemergence weed control. There are various modes of action or physiological target sites for allelochemicals. Inhibition of cell division and elongation, prevention of gibberellins and/or indoleacetic acid-induced growth, reduction of mitotic activity, inhibition of protein formation, inhibition of respiration, and decrease in cell membranes permeability, among others, as suggested by Rice (1984), could be the reason for the inhibition of redroot pigweed germination and seedling growth by the plant extracts. Furthermore, the impacts of the extracts were almost proportional to the applied doses. The duration of weed germination was also increased due to the extracts. Thus, allelochemicals may reduce weed competition with crops by delaying weed germination (Jeffersona and Pennacchio 2003). There was a clearly observed variation in the allelopathic potential among the selected species as concerns their aqueous extract bioassay against redroot pigweed. *Datura inoxia* caused the greatest reduction in seed germination and dry weight of weed seedlings, whereas *C. sativus* had the least effect. Variation has also been reported by various early workers. Fujii (2001) assessed 53 cover crop plant species (including 26 leguminous, 19 graminaceous, and 8 others) for their allelopathic activity. It was found that leguminous cover crops such as hairy vetch and velvetbean, and graminaceous cover crops, such as oat (*Avena sativa* L.) and rye (*Secale cereale* L.) as well as certain cultivars of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) showed high allelopathic potential. Similar results were also reported by Machado (2007) who screened 42 species and showed that species had different allelopathic effects. He showed that meadowfoam seed meal (*Limnanthes alba* Benth.), yard-long bean (*Vigna sesquipedalis* (L.) Fruw.), blue spruce (*Picea pungens* Engelm.), and pine (*Pinus* spp.) extracts completely inhibited the germination of downy brome seed and have a potential for use in the control of downy brome in wheat-based cropping systems. Variability in allelopathic expression in plants

might be due to the different nature of allelochemicals released by these species. The phytotoxic effect of sorghum was reported to be due to the exudation of sorgoleone, a group of lipophilic benzoquinones (Czarnota *et al*. 2001). The result of phytochemical studies for *N. tabacum* revealed the presence of alkaloids, flavonoids, phytosterols, triterpinoids, tannins, and carbohydrates (Sunil *et al*. 2011). The phytochemical screening of *D. innoxia* extract was reported to contain atropine, scopolamine, essential oils, saponins, flavonoids, phenols, and cardiac glycosides (Ayuba *et al*. 2011). *Nerium oleander* extract was reported to have rutin, quercetin (flavonoids), oleandrin, neriine (cardiac glycosides), rosagenin, folinerin, neritaloside and other compounds (Rajyalakshmi *et al*. 2011).

In the pot experiment, similar observations were recorded. Plant extracts decreased the biomass of redroot pigweed and exhibit a phytotoxic effect on the growth parameters of pigweed. Several studies have shown that various allelopathic plants suppressed the growth of the tested species. Xuan *et al*. (2004) reported that aqueous extract of neem (*Azadirachta indica* A. Juss.) had phytotoxic potential and inhibited growth of *E. crus-galli, Monochoria vaginalis* (Burm. f.), and *Aeschynomene indica* L. Similarly, Anjum and Bajwa (2008) while studying the allelopathy influence of the sunflower on some weeds indicated the strong suppressive potential of this plant on some growth and physiological parameters of the tested plants. Our results demonstrated that application of the powder of these plants also reduced growth of pigweed and reductions showed a concentration-dependent mechanism. In addition, some species have a more inhibitory effect on the growth of weeds when applied as mulch, since the inhibitory effect of *C. sativus* powder was higher than the extract of this plant. This may be associated with the fact that aqueous extraction could not completely extract allelochemicals from this plant.

In conclusion, the present study indicates that all tested species residues and extracts had potent herbicidal activity on seedling growth and biomass of redroot pigweed. All the tested species residues and extracts may be favorably incorporated into agricultural systems for weed management and the tested species may be used as natural bioherbicides. Given the fact that environmental conditions in the field can be different from those in the laboratory and greenhouse, additional work is required to check the herbicidal activity of these species, under different field conditions.

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