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Herbicidal potential of *Aerva javanica* (Burm. f.) Juss. ex. Schult to control wild oat and its impact on wheat growth

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ABSTRACT

We investigated the phytotoxicity of desert cotton (*Aerva javanica)* extracts on wild oat and wheat. Aqueous extracts from *A. javanica* roots, leaves and inflorescences collected from Jeddah and Al-Baha regions, Saudi Arabia were used. Generally, the allelopathic potential of water extracts of *A. javanica* collected from Jeddah were more in inhibitory to wild oat germination and seedlings growth than those from Al-Baha. In both regions, root extracts were inhibitory to wild oat followed by leaves and inflorescences extracts. All test aqueous extracts of both regions did not inhibit the wheat germination or seedlings growth.Whreas, the wild oat germination was reduced by root extracts 58.62 %, 28.62 % leaves extracts : 32.72 %, 17.72 % and inflorescences extract 28.11 %, 12.13 % by in plants samples collected from Jeddah and Al-Baha, respectively. Wild oat radical length was inhibited by root extracts 53.27 %, 32.84 % leaves 42.35 %, 9.63 % and inflorescences extracts 22.64 %, 16.75 % in case of Jeddah and Al-Baha plants, respectively. In pot culture experiment, all treatments markedly reduced the plant dry weight and soluble carbohydrates, proteins and free amino acids contents in wild oat. The differences in the allelopathic potentials of studied *A. javanica* extracts were related to the qualitative variations in their phytochemicals constituents. Our results showed that *A. javanica* extracts could be safely used to control wild oat growth in wheat fields after more detsaled research..

Key words: Allopathic potential, *Aerva javanica*, *Avena fatua*, desert cotton, herbicide potential, seed germination, seedlings growth, *Triticum aestivum*, weeds management, wheat, wild oat.

INTRODUCTION

Weed management is a current need because annually weeds cause 9.7 % yield loss in agricultural crops (29). Weeds not only compete with crops for water, nutrients and sunlight but also suppress the crop plants by secreting some inhibitory chemicals known as allelochemicals, into the rhizosphere which reduces the crop growth and yield (5,52). In general, weeds are managed either manually or by using herbicides. However, manual weed management is not feasible because it is costly, time consuming and weeds may regenerate again (53). Weeds control using chemical herbicides has harmful effects directly or indirectly on soil environment, surface and ground water, natural flora and fauna and aquatic life, which adversely influences the human beings (43).

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Allelopathy as natural phenomenon, could be used for weed management by using the eco-friendly and inexpensive secondary products produced by plants, which offers a viable and pragmatic option for sustainable agriculture systems (16). Allelochemicals are from many chemical classes, these isolated from > 30 families of terrestrial and aquatic plants are used successfully for weed control (43). Allelochemicals production depends on the plant genotype and the environmental conditions during its growth (8,15). The stimulatory and/or inhibitory effects of allelochemicals depend on the plant and its organ (23). Furthermore, Gross (20) concluded that certain concentration of the same allelochemical that inhibit the growth of some species could stimulate the growth of others.

Wild oat (*Avena fatua* L.) is a common weed in Europe, Asia, North Africa, naturalized in Australia and the Americas (30). It is the 13th most important weed and has spread in irrigated areas worldwide (22). It is a major problem in cereals (wheat, barley, oat, etc.) and reduces their growth, yield and quality (9,34). It reduced the winter wheat production by 17 % to 62 % depending on the wheat variety (34). It is an annual grass and difficult to eradicate because its seeds shatter before crop maturity, hence, many seeds are ploughed into the soil and germinate in next crop season. The success of this weed is attributed to its adaptation to different biological and ecological conditions (36). Among several species of weeds in wheat field, wild oat is worst. The time of weed germination and emergence in the field is influenced by environmental factors, such as light, soil temperature, soil moisture and soil atmosphere (14). *Avena fatua* seedlings exceeds the wheat, barley and rye seedlings, in its ability to germinate from greater depths in the soil (11).

Although effective chemical weed control methods for wild oat are available, nonetheless, continuous use of the same type of herbicides have lead to the development of herbicide-resistant weed bio-types (6,46), which had lead to its increased population. Manea *et al*. (33) indicated that, application of some herbicides (Legato Plus EC, Stomp aqua, Pelican Delta 606 WG, Sekator Pogress EC) did not satisfactorily control the wild oat in wheat fields. In addition, using herbicides creates soil, water and air pollution and may enhance the disease risks (45). Hence, concern regarding use of herbicides is growing worldwide, so, demand for organically produced commodities in the world is also increasing (40). Scientists are looking for new ecological and natural approaches for weed management instead of chemical control. Srikrishnah and Begam (50), reported that numerous plant extracts are used to control different weeds in many parts of the world.

Photograph 1. *Aerva javanica* (Burm.f.) Juss. ex. Schult (21)

Desert cotton [*Aerva javanica* (Brum.f.) Juss. ex Shult. family Amaranthaceae is perennial herb (26,54)] and grows in Africa, Asia and extensively scattered worldwide (42). In Saudi Arabia, it is found in the western and southern regions (2,32). It has broad leaves with dense cover of hairs and its flowers have dense spikes (10 cm long) to protect from animal grazing (27). It grows on sandy sediments at different altitudes (49). The *Aerva* species bind the soil and control the soil erosion (39) and these could be also used for urban landscaping (19). These plants are also used to treat inflammatory diseases, kidney stones and as anti-plasmodial (17), anti-diarrheal, diuretic, anti-calculus and anti-diabetic drug (42). It has been traditionally used to treat wounds, cough, ulcers, toothache and hyperglycemia (26,47). The extracts of *A. javanica* are antibacterial, antifungal and insecticidal activity (38,51). This study aimed to evaluate the herbicidal potential of *A. javanica* extracts to control wild oat, identify its water soluble allelochemicals and determine their bioactivity which may lead to development of green herbicides for organic farming.

MATERIALS AND METHODS

I. Collection of soil samples and plant materials

Soil samples and *A. javanica* plants (flowering stage), were collected in April, 2017 from natural stands in Jeddah (22°31'N and 39°10'E, 53 m altitude) and Al-Baha (19° 20' N and 41° 42' E, 100 m altitude) cities, Saudi Arabia. Soil samples were used to determine the soil physio-chemical properties. The plants were gently washed with distilled water, dried between two paper towels and brought into the laboratory. *A. javanica* plants shoot and root length were measured and also its biomass was determined as per Wilde *et al*. (55). To prepare extracts, the plants were separated into roots, leaves and inflorescences, shade dried (for 3 weeks at 30 °C) and then powdered separately with electronic grinder.

II. Soil physiochemical properties

(i). Soil texture: Its components were determined using sieve method described by Al-Yamani and AL-Desoki (4). First, 100 g soil was weighed and sieved through mesh sizes 0.5, 0.1, 0.05 and 0.005 mm. The United States Department of Agriculture (USDA) classification of soil particle size was used to classify the soil texture: coarse sand (< 0.5 mm), fine sand (< 0.25 mm) silt (< 0.05 mm), or clay (< 0.002 mm). Next, the weighed soil sample was placed in the topmost sieve, and the sieves were shaken for 1.0 h using a sieve shaker. After this, the sieves were weighed separately and the relative percentage of coarse sand, fine sand, silt and clay was found.

(ii). Soil pH and electrical conductivity (EC): These were determined as per method of Conklin (10). Ten ml distilled water was poured into a flask with 10 g soil. The flask was shaken over night to mix its contents. The mixture was then filtered using a filter paper to separate the soil from the liquid. pH meter (Mettler Toledo AG) was used to determine the pH of solution. EC meter was used to determine the electrical conductivity of soil extract using uS/cm as concentration of soil anions.

(iii). Soil organic matter: It was determined as per Wilde *et al*. (55). Five g soil was put into an oven and heated at 110 °C for 2 h. The soil temperature was allowed to drop by placing the soil in desiccators, thereafter, it was weighed. Later soil was placed in furnace, and heated again at 500 °C for 3 h and left to cool overnight. Next day, the soil was placed in desiccator again and later weighed. The following formula was used to estimate the amount of organic matter in the soil sample:

$$\frac{\text{Dry soil (g) - incinerated soil (g)}}{\text{Dry soil (g)}} \times 100$$

(iv). Soil water content: It was measured according to Yousef (56) and Conklin (10). Soil samples (100 g) were dried in oven at 105 °C for 24 h. The samples were subsequently weighed before being placed in the oven again to dry further. The soil samples were repeatedly oven-dried until no further change in weight was observed. The following formula was used to calculate the amount of water in the soil sample:

$$\frac{\text{Wet sand (g) - Dry sand (g)}}{\text{Wet sand (g)}} \times 100$$

III. Aqueous extracts:

Aerva javanica aqueous extracts were prepared using shade dried roots, leaves and inflorescences collected from both sites. Ten g tissue sample was placed separately in sterile flasks containing 100 ml distilled water and shaken for one day at room temperature then, centrifuged at 1500 rpm for 30 min, the supernatant was filtered through one layer of filter paper (Whatman No. 1). After filtration, the extracts were stored at 4 °C until use for the lab bioassay and pot culture experiment.

IV. Petriplate Bioassay

Allelopathic potential of *A. javanica* roots, leaves and inflorescences extracts (100 g/L) were evaluated sowing 10 seeds of wild oat (*Avena fatua*L.) and wheat (*Triticum aestivum* L.) in sterilized Petri dishes (9 cm dia) lined with two layers of filter papers and moistened with 10 ml aqueous extracts/ distilled water as per treatments. Distilled water was used as a control treatment. Each treatment was replicated five times in completely randomized design. The petri dishes were kept in dark room at room temperature (30 °C) for one week until germination. Emergence of 2 mm radical was used as the criterion for germination. After seed germination, seedlings were grown for 10 days under 16-h-light period at 150 µmol m^{-2} s^{-1} supplied by cool white fluorescent lights at 30/22 °C day/night temperatures. At the end of the incubation period, radical and plumule length were measured.

V. Pot Culture

The pot experiment was done during winter season in January in 2018 in screen house under natural conditions (minimum/maximum temperature was around 15/30º C), February (21/38 ºC). To study the effects of *A. javanica* roots, leaves and inflorescences on wheat and wild oat growth under field conditions, wheat and wild oat seeds were primed in the previously prepared *A. javanica* aqueous extracts for 4 h. Seeds primed in distilled water were used as control. Then, five primed seeds of wild oat and wheat were sown in

plastic pots (30 cm dia and 30 cm depth) filled with 3 Kg homogenously mixed sand: clay soil (2:1). All pots were irrigated with tap water every three days for one month and maintained at 95 % field capacity. The experiment was done in completely randomized design with 5 replicates. At the end of the experimental period (Jan, 15 - Feb, 15, 2018), wild oat and wheat plants were dried at 70 °C for 48 h and their dry weight was recorded.

Response index (RI): It was calculated using the formula of Richardson and Williamson (45) to observe the magnitude of inhibition of various extracts treatment on seed germination, radicle and plumule length from bioassay experiment and plant dry weight from pot experiment.

$$\text{Response Index (RI)} = (T/C - 1) \times 100$$

Where, T: Treatment, C: Control

VI. Biochemical analysis

Primary metabolites (soluble carbohydrates, proteins and amino acids) were determined in wild oat and wheat plants collected from the pot culture experiment. Soluble carbohydrates were determined according to the methods of Fales (13) and Schlegel (48). Soluble proteins contents were determined according to Lowry *et al*. (31) by Folin reagent. Free amino acids were determined in tissue samples following the method of Moore and Stein (37).

Secondary metabolites in aqueous *A. javanica* extracts were analyzed by GC-Mass spectroscopy (GC/MS) in the Analytical Chemistry Unit (ACAL), Assiut University.

Statistical Analysis

Data obtained were subjected to Student's t-test (α- 5%) for analyzing the significance of the difference between both studied regions. In bioassay and pot experiment, control and treatments results were compared using one-way analysis of variance (ANOVA), using the SPSS statistical package followed by Duncan's multiple range test ($p < 0.05$).

RESULTS AND DISCUSSION

Ecology of *A. javanica* collecting regions:

There was remarkable difference in physico-chemical properties of soil in studied regions (Table 1). Jeddah soil consisted mainly of coarse sand (73.62 %) and fine sand (25.77 %), however, in Al-Baha soil fine sand was most dominant (70.76 %) than coarse sand (29.18 %). The percentages of silt and clay soil in both regions were small. The silt and clay (%) soil of Jeddah were higher than Al-Baha. Jeddah soil had lower pH, soil organic matter, water content and electrical conductivity compared to Al-Baha. In accordance with our results, Arshad *et al.* (3) reported that *A. javanica* grows in low saline soil with high organic matter content and low soil moisture content. Likewise, Soliman (49) also showed that *A. javanica* grows in sandy soil.

Table 1. Soil physical and chemical properties of Jeddah and Al-Baha regions

Soil Property		Jeddah	Al-Baha
Physical	Coarse sand (%)	73.62 ± 3.24**	29.18 ±7.40
	Fine sand (%)	25.77 ± 0.31	70.757 ± 7.41**
	Silt (%)	0.377 ± 0.05**	0.067 ± 0.00
	Clay (%)	0.237 ± 0.02**	0.001 ± 0.00
Chemical	pH	7.63 ± 0.01	7.73 ± 0.02*
	Organic matter (%)	7.29 ± 0.12	9.19 ± 0.04*
	Water content (%)	8.62 ± 0.05	9.08 ± 0.04*
	Electrical conductivity (uS/cm)	0.13 ± 0.00	0.14 ± 0.06*

Each point is mean of five replications ± standard error. Asterisks show significant differences between the two regions (*p < 0.05; **p < 0.01; ***p < 0.001) by t-test.

The effects of different habitats in Jeddah and Al-Baha on *A. javanica* growth were given in Figs. 1 and 2. Shoot and root length of *A. javanica* plants collected form Jeddah were significantly higher than those collected from Al-Baha (Fig. 1). The dry matter (%) in *A. javanica* roots collected from Jeddah was higher than that in Al-Baha plants (Fig. 2). Contrarily dry matter (%) of *A. javanica* shoots collected from Al-Baha was significantly higher than those collected from Jeddah city. These results suggested that *A. javanica* grows better in coarse sand soil with higher silt and clay content better than fine sand.

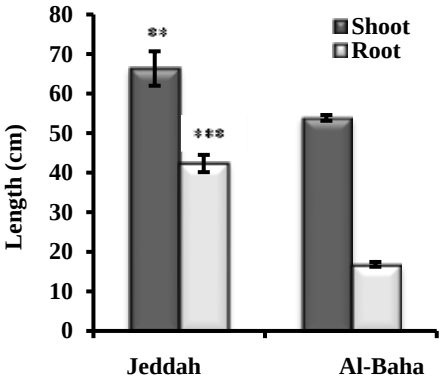

Figure 1. Shoot and root length of *A. javanica* plant collected from Jeddah and Al-Baha regions. Each point is a mean of five replicates ± standard error. Asterisks show significant differences between the two regions (*p < 0.05; **p < 0.01; ***p < 0.001) by t-test.

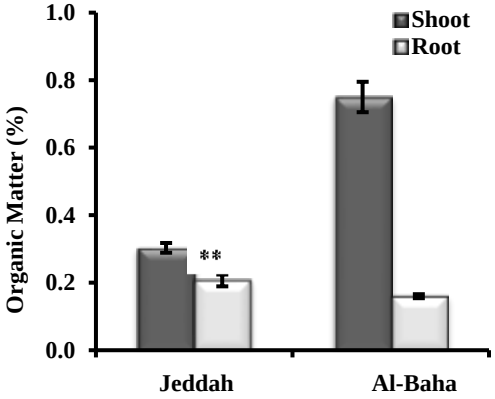

Figure 2. Shoot and root dry matter (g) of *A. javanica* plant collected from Jeddah and Al-Baha regions. Each point is a mean of five replicates ± standard error. Asterisks show significant differences between the two regions (*p < 0.05; **p < 0.01; ***p < 0.001) by t-test.

Petriplate Bioassay:

A. javanica aqueous extracts had significant effects on the growth parameters (response index of seed germination, radical length, plumule length and plant dry weight) of wheat plants and wild oat. However, for easy comparison the mean values were subjected to response index (inhibitory and stimulatory) for these parameters (Figs. 3, 4, 5 and 6).

I. Wheat: All aqueous extracts of both regions slightly stimulated the seeds germination of wheat (Fig. 3). Inflorescence water extract of both regions showed the highest germination percentage than control, (12.74 %) in case of Jeddah and (15.64 %) in case of Al-Baha. Leaves and root extracts of low concentrations slightly stimulated the wheat germination. (4.49 %). The root water extract of *A. javanica* collected from Jeddah only inhibited (4.49 %) the wheat radical length. However, all other extracts slightly stimulated the wheat radical length (Fig. 4). All studied extracts did not influence the wheat plumule length (Fig. 5).

II. Wild oat: All aqueous extracts of both regions markedly inhibited the germination (%) of wild oat (Fig. 3). In both regions, root extract was most inhibitory followed by leaves and inflorescences. However, water extracts of *A. javanica* plants collected from Jeddah inhibited the seeds germinations of wild oat markedly more than plants collected from Al-Baha. Root water extract inhibited wild oat germination by about 58.62 % and 28.62 % lower than control in case of Jeddah and Al-Baha, respectively. Leaves water extracts inhibited the wild oat seeds germination by 32.72 % and 17.72 % than control in case of samples from Jeddah and Al-Baha respectively. While the inflorescences water extracts inhibited the wild oat seeds germination by 28.11 % and 12.13 % than control in case of Jeddah and Al-Baha respectively. In wild oat seedlings, the radical length (Fig. 4) was more responsive to aqueous extracts treatments compared to plumule (Fig. 5). The water extracts of *A. javanica* collected from Jeddah inhibited the radical length of wild oat more effectively compared to those collected from Al-Baha (Fig. 4). The *A. javanica* root extracts inhibited the wild oat racial length by 53.27 % and 32.83 % in Jeddah and Al-Baha samples, respectively. *A. javanica* leaves extracts inhibited the wild oat radical length by 42.35 % and 9.76 % in Jeddah and Al-Baha samples, respectively. While the inflorescences extracts inhibited the wild oat racial length by 22.64 % and 16.75 % in Jeddah and Al-Baha samples, correspondingly. Similar trend was observed in the response of plumule length to the studied water extracts, the aqueous extracts of *A. javanica* collected from Jeddah were more inhibitory than plants collected from Al-Baha. Root water extract was most effective followed by leaves and inflorescences (Fig. 5).

Pot Culture

I. Wheat: In pot experiments, all tested water extracts did not affect the wheat seedlings dry weight (Fig. 6). Furthermore, the studied water extracts did not influence the contents of soluble carbohydrates, proteins and free amino acid in wheat seedlings (Table 2).

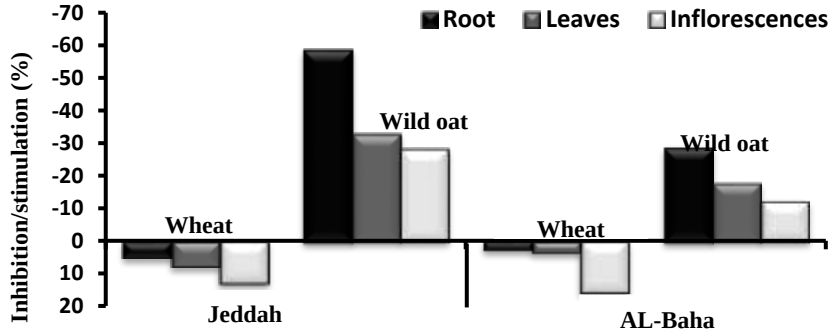

Figure 3. Response index of seed germination RI (%) of wheat and wild oat seedlings as affected by water extracts of *A. javanica* plant collected from Jeddah and Al-Baha regions.

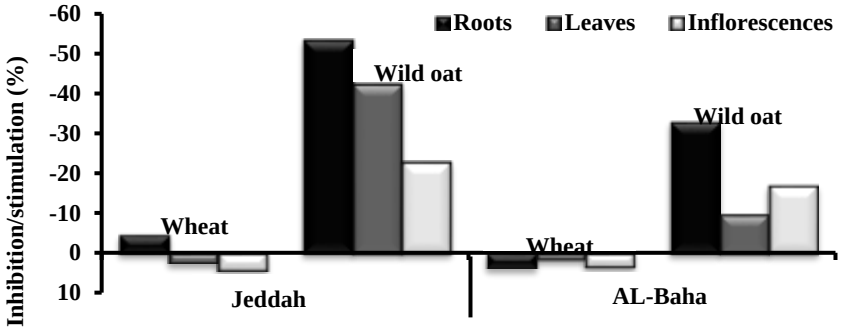

Figure 4. Respnse indext of radical lengths RI of wheat and wild oat seedlings as affected by water extracts of *A. javanica* plant collected from Jeddah and Al-Baha regions.

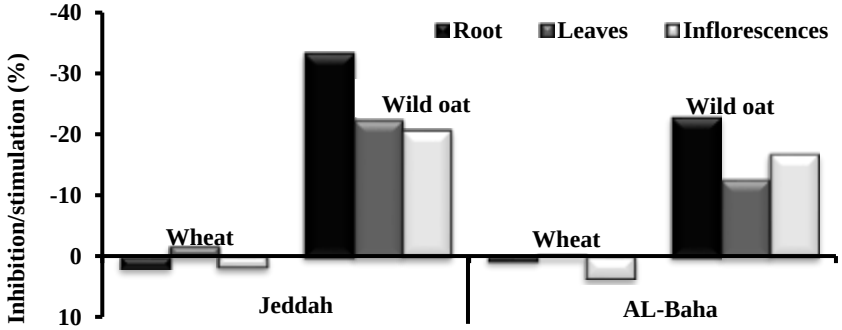

Figure 5. Respnse indext of Plumule lengths RI of wheat and wild oat seedlings as affected by water extracts of *A. javanica* plant collected from Jeddah and Al-Baha regions.

Table 2. Effects of *A. javanica* water extracts on carbohydrate (mg/g DW), proteins (mg/g DW) and amino acids (mg/g DW) contents in wheat and wild oat seedlings

Site	Wheat				Wild Oat			
	Control	Root	Leaves	Infl.	Control	Root	Leaves	Infl.
				Carbohydrates				
Jeddah	5.62 ± 0.12 [a]	5.73 ± 0.85 [a]	5.18 ± 0.31 [a]	5.89 ± 0.04 [a]	7.34±1.2 [d]	3.68± 0.012[a]	5.73 ± 0.09 [b]	6.18± 0.21 [c]
Al-Baha	4.62 ± 0.13 [b]	4.52 ± 0.10 [a]	4.89 ± 0.20 [b]	5.12 ± 0.24 [b]	6.97 ±1.2 [d]	5.53± 0.13 [a]	5.98 ± 0.25 [b]	6.94± 0.31 [c]
				Proteins				
Jeddah	12.54±0.24 [a]	11.34± 0.54 [a]	12.87 ± 1.1 [a]	13.27 ± 1.3 [b]	19.52 ± 1.4 [c]	12.9± 0.51 [a]	15.63± 0.92 [b]	15.03± 1.2 [b]
Al-Baha	10.54±0.21 [a]	9.73 ± 0.59 [a]	10.86 ± 1.2 [a]	11.21± 1.4 [a]	21.52 ± 1.4 [d]	16.2±1.3 [a]	19.73± 0.56 [c]	18.93± 1.0 [b]
				Amino acids				
Jeddah	0.83 ± 0.04 [c]	0.62 ± 0.02 [a]	0.78 ± 0.06 [b]	0.88 ± 0.12 [d]	0.56 ± 0.02 [c]	0.44± 0.00 [a]	0.59 ± 0.01 [d]	0.52 ± 0.02 [b]
Al-Baha	0.63 ± 0.02 [b]	0.55 ± 0.03 [a]	0.66 ± 0.09 [c]	0.73 ± 0.08 [d]	0.62±0.02 [c]	0.58 ± 0.02 [a]	0.57 ± 0.00 [b]	0.66 ± 0.03 [d]

Infl: Infloresence, Each value is mean of 5 replications ± standard error. different letters in same row for each plant meant significant difference at $P \leq 0.05$ by Duncan's multiple range test.

Carbohydrates content in wheat did not change significantly due to all water extracts of samples obtained from Jeddah, while, it was significantly enhanced by leaves and inflorescences extract of samples collected from Al-Baha by about 5.84 and 10.34 % respectively. The wheat seed priming with inflorescences extract of samples obtained from Jeddah significantly increased the proteins content (5.82 %) over the control. Lowest Amino acid content in wheat seedlings was recorded due to the seed priming with water extracts of roots collected from both regions. However, inflorescences extracts significantly enhanced the amino acid content in wheat by 6.02 and 15.87 % than controls in case of Jeddah and El-Baha plants respectively.

II. Wild oat: All tested water extracts reduced the dry weight in wild oat (Fig. 6), which confirmed the results of our lab. bioassay. Wild oat dry weight was severely reduced by seed priming with water extracts of *A. javanica* samples collected from Jeddah than from Al-Baha. In case of Jeddah plants, root water extract was most effective (31.27 %), followed by leaves (22.35 %) and inflorescences (15.64 %). The water extracts of different plant parts collected from Al-Baha were slightly inhibitory (about 10 %). While the water extracts significantly reduced the soluble carbohydrates, proteins and free amino acid contents in the wild oats than control (Table 2). The water extract of root samples collected from both regions decreased the studied metabolites content in wild oat seedlings. However, Jeddah root samples were more effective compared to Al-Baha samples. The seeds priming with root extract of samples obtained from Jeddah significantly reduced the soluble carbohydrates, proteins and free amino acid contents by 49.86, 33.76 and 21.42 % than control respectively. However, the seeds priming with Al-Baha root extract were less inhibitory to soluble carbohydrates, proteins and free amino acid contents by 20.66, 24.44 and 6.45 % than control, respectively. Leaves and inflorescences water extracts also reduced the secondary metabolites contents than controls in samples from Jeddah and were more effective compared to Al-Baha.

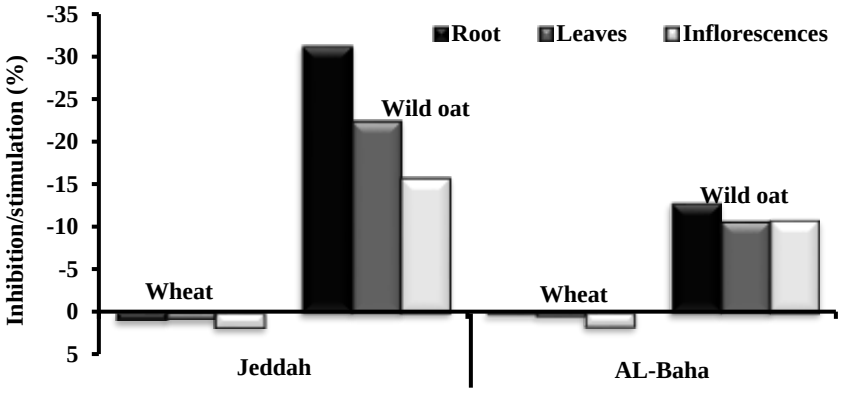

Figure 6. Respnse index of Dry weight RI of wheat and wild oat plants as affected by water extracts of *A. javanica* plant collected from Jeddah and Al-Baha regions.

Inhibition of wild oat seed germination and plant growth with *A. javanica* water extracts is significant finding of this study. Wheat growth was little affected with the test water extracts. Similar results have been recorded in field experiment for sorghum and sunflower water extracts, where the wild oat growth was reduced, but the wheat growth was enhanced (24). Similarly, wild oat germination and seedling growth were suppressed by rice hull extracts (28). The phytotoxic properties of *A. javanica* leaf extracts were also recorded by Gilani *et al*. (18), they observed that inhibitory effects were enhanced with increasing concentration of leaves extracts. Similar findings were also recorded elsewhere regarding the allelopathic potential of barley, sunflower and parthenium supported the use of plant allelopathy for biological control of weeds (7,25,35). The greater inhibition of wild oat growth rather than wheat is possibly due to the concentration of allelopathic chemicals in the studied extracts.

The response of wild oat to *A. javanica* water extracts varied based on the source of allelochemicals and the plant habitat. The suppression of wild oat due to root extracts was more than leaves and inflorescence extracts for both studied regions, while extracts of *A. javanica* plant samples collected from Jeddah were more effective compared to Al-Baha.

Chemical composition of *A. javanica* water extracts:

The identification and characterization of chemical compounds in water extracts, according to their elution order on GC-MS column, are shown in Table (3) and Fig. (7).

Table 3. Biologically active chemical compounds of water extracts from different organs of *A. javanica* plant collected from Al-Baha and Jeddah regions

No.	Chemical Class	Compound	Area **(%)**					
			Root		Leaves		Inflorescences	
			Jeddah	Al-Baha	Jeddah	Al-Baha	Jeddah	Al-Baha
1	Alkaloid	5-Oxo-6-phenyl-1,2,3,5,6,7-hexahydroimidazo[1,2-a]pyridine-8-carbonitrile	3.11	-		-	-	-
2	Alkaloid	3-Cyano-5,7-dimethoxy-1-methylcarbazole	-	-	-	-	-	2.72
3	Alkaloid	N(1),3-Dimethyl-2-chloro-4,5-dihydropyrrole	-	-	-	-	-	3.60
4	Alkaloid	2-Methyl-1H-indole	-	5.26	-	-	-	2.36
5	Alkaloid	Methyl 1-anthraquinonesulfenate	-	1.50		-	-	-
6	Alkaloid	N-Trichloroacetyl-tryptamine	-	-	3.47	-	-	-
7	Alkaloid	Pristane	-	-	5.60	-	-	-

8	Organic acid	Fumaric acid, 4-cyanophenyl dodecyl ester	2.94	-		-	-	-
9	Organic acid	Fumaric acid, decyl 4-heptyl ester	2.48	-	2.10	-	-	-
10	Organic acid	Fumaric acid, hexadecyl 2-methylallyl ester	5.81	-				
11	Organic acid	2-Ethylbutyric acid, eicosyl ester	-	1.18		-	-	-
12	Organic acid	Carbamic acid, N-aminocarbonylmethyl-, isobutyl(ester)	-	-	2.81	-	-	-
13	Organic acid	Dimethyl ester of pentylurofuranoic acid isomer	-	-	3.37	-	-	-
14	Organic acid	Dimethyl ester of pentylurofuranoic acid isomer	-	-	-	2.45	2.72	-
15	Organic acid	Octadecanoic acid, 2,3-dihydroxypropyl ester	-	-	-	-	3.35	-
16	Organic acid	15-Hydroxypentadecanoic acid	-	-	-	-	-	4.33
17	Terpene	Phytane	0.66	1.11	-	2.40	5.79	-
18	Terpene	Squalane	-	2.42		-	-	-
19	Flavonoid	7-Ethoxy-6-chloro-2,2-dimethyl-4-chromanone	-	-	-	4.55	4.94	
20	Glycoside	Deoxycelidoniol	-	-	-	4.77	10.48	5.23
21	Amino acid	L-Tryptophanol	-	-	-	2.28	-	-

I. Roots: The most abundant five allelochemicals in root extracts of Jeddah region were (i). 5-Oxo-6-phenyl-1,2,3,5,6,7-hexahydroimidazo[1,2-a]pyridine-8-carbonitrile (3.11 %), (ii). Fumaric acid, 4-cyanophenyl dodecyl ester (2.94 %), (iii). Fumaric acid, decyl 4-heptyl ester (2.48%), (iv). Fumaric acid, hexadecyl 2-methylallyl ester (5.81 %) and Phytane (0.66 %). While in root extracts from Al-Baha the major compounds were: (i). 2-Methyl-1H-indole (5.26 %), (ii). 2-Ethylbutyric acid, eicosyl ester (1.18 %), (iii). Methyl 1-anthraquinonesulfenate (1.50 %), (iv). Phytane (1.11 %) and (v). Squalane (2.42 %).

II. Leaves: The major chemical constituents in leaves water extract of samples from Jeddah (Fig. 7 and Table 3) were (i). carbamic acid, (ii). N-aminocarbonylmethyl-isobutyl(ester) (2.81 %), (iii). cimethyl ester of pentylurofuranoic acid isomer (3.37 %), (iv). fumaric acid, decyl 4-heptyl ester (2.10 %), (v). N-Trichloroacetyl-tryptamine (3.47 %) and (vi). pristane (5.60 %). While, the most abundant chemicals identified in the leaves collected from Al-Baha were (i). 7-Ethoxy-6-chloro-2,2-dimethyl-4-chromanone (4.55 %),

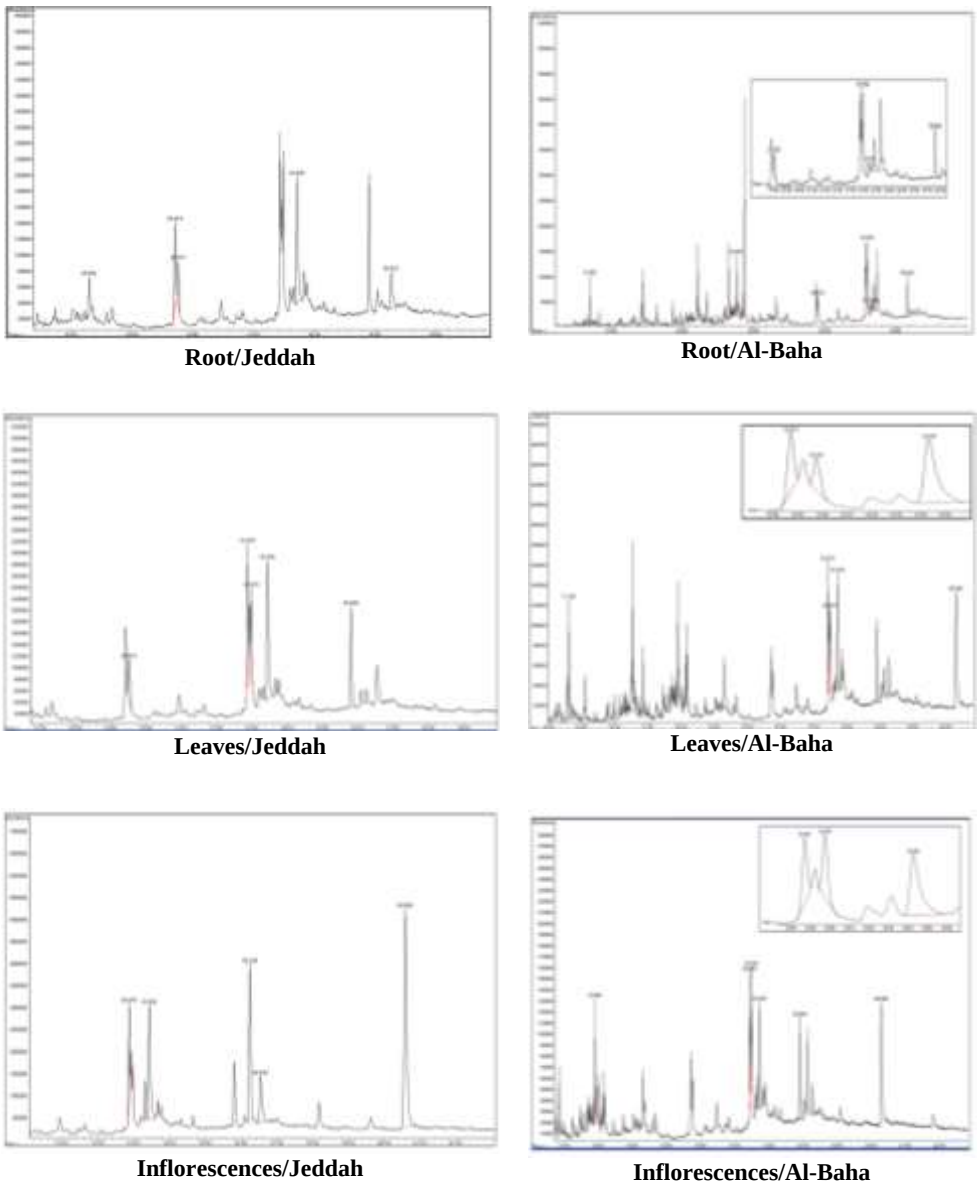

Figure 7. Gas chromatograms for the chemical constituents of *A. javanica* water extracts.

(ii). deoxycelidoniol (4.77 %), (iii). dimethyl ester of pentylurofuranoic acid isomer (2.45 %), (iv). L-Tryptophanol (2.28 %) and (v). L-Tryptophanol (2.40 %).

III. Inflorescence: The major chemical constituents in inflorescence water extract of samples from Jeddah (Fig. 7 and Table 3) were (i). 7-Ethoxy-6-chloro-2,2-dimethyl-4-

chromanone (4.94 %), (ii). deoxycelidoniol (10.48 %), (iii). dimethyl ester of pentylurofuranoic acid isomer (2.72 %), (iv). octadecanoic acid, 2,3-dihydroxypropyl ester (3.35 %) and (v). phytane (5.79 %). The major chemicals identified in inflorescences extract of Al-Baha samples were: (i). 15-Hydroxypentadecanoic acid (4.33 %), (ii). 2-Methyl-1H-indole (2.36 %), (iii). 3-Cyano-5,7-dimethoxy-1-methylcarbazole (2.72 %), (iv). deoxycelidoniol (5.23 %) and (v). N(1),3-Dimethyl-2-chloro-4,5-dihydropyrrole (3.60 %).

The most abundant five secondary compounds found in the leaves, infloroscence and roots of *A. javanica* are given in Table (3). These indicated that there were clear variations in the chemical compounds contents in relation to plant organ or habitat. These results are in accordance with previous studies on *Salvadora persica* and *Heliotropium bacciferum* (1,12). The variability in the allelopathic potentials in this study were attributed to the different chemicals in the test extracts rather than the concentration of same chemical, as the various plant parts show different profiles in the chemicals identified by GC-MS analysis. In general, the allelopathic influence of various secondary metabolites, (which reacted with one another) produced by shikimic acid or acetate pathways differ (28). In this study 21 allelochemicals (9 organic acids, 7 alkaloids, 2 terpenes, 1 flavonoid, 1 glycoside and 1 amino acid) were identified. A variety of chemical compounds including alkaloids, steroids, lipids, flavonoids, tannins, saponins, essential oils and carbohydrates are identified from *A. javanica* (44,47). According to Putnam (41), the best expression to illustrate the chemical nature of allelochemicals is the diversity. They vary from simple hydrocarbon, to complex polycyclic compounds with molecular weights of hundreds. Almost all secondary metabolites classes were involved, and in some cases major intermediates, e.g., organic acids, in plant metabolism also seems to be implicated.

CONCLUSIONS

Water extracts from *A. javanica* roots, leaves and inflorescences collected from Jeddah and Al-Baha regions, Saudi Arabia showed variable effects on wheat and wild oat growth. The test extracts markedly inhibited the wild oat growth but did not affect the wheat. The water extracts of *A. javanica* collected from Jeddah were more inhibitory to wild oat seed germination and seedlings growth than those from Al-Baha. Thus the allelopathic compounds present in *A. javanica* might be developed as natural herbicide to control wild oat in wheat fields. Further studies are required to explore the bioactivity of *A. javanica* allelochemicals under field conditions.

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