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# Searching for natural herbicides in methanol extracts of eight plant species

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## Abstract

**Background:** Plant extracts could turn out to be natural herbicides to be used in weed control. This study was conducted to study the phytotoxic effects of methanol extracts obtained from *Tamarix mannifera*, *Alhagi maurorum*, *Echinops spinosissimus*, *Haloxylon salicornicum*, *Lactuca virosa*, *Neurada procumbens*, *Ochradenus bacctus*, and *Cyperus conglomerates* plants on germination and growth of *Phalaris minor*, *Echinochloa crusgalli*, *Portulaca oleracea*, and *Lactuca sativa*.

**Results:** In laboratory trial, extracts of eight plants at 0, 5, 10, 20, and 40 g/L were evaluated on germination of seeds of four target species. The inhibitory effect of tested extracts varied among the examined seeds, and *P. minor* was the most sensitive. Extracts of *T. mannifera* and *L. virosa* showed the greatest effect on seed germination and seedling growth of studied seeds. Using the extract of *T. mannifera* at 40 g/L completely inhibited the germination and seedling growth of *P. minor* and shoot length of *P. oleracea* as well as root length of *E. crusgalli* and *L. sativa*. At this concentration, *L. virosa* nearly had a complete inhibition effect on germination and seedling growth of *P. minor* and *P. oleracea*. In the greenhouse trial, extracts from tested plants at four concentrations (0, 30, 60, and 90 g/L) were used in a phytotoxic bioassay against 6-week-old *L. sativa* and three target weeds. The growth of 6-week-old weeds tended to be less sensitive to the tested extracts than the weed germination. The significant injury effect was observed only when *T. mannifera* extract at 60 and 90 g/L was sprayed on *P. minor*, *E. crusgalli*, and *L. sativa* plants.

**Conclusions:** Among tested species, *T. mannifera* and *L. virosa* could be used for developing new natural herbicide.

**Keywords:** Allelopathy, Natural herbicide, Germination, *Tamarix mannifera*, *Lactuca virosa*

## Introduction

In an attempt to reduce the use of synthetic pesticides, extensive investigations into the possible exploitation of plant compounds as natural commercial products have been undertaken over the past two decades (Masum et al. 2016; Trezzi et al. 2016). Natural herbicides could offer new alternatives to synthetic herbicides. For many years, allelopathy research was conducted to study the effects of crude extracts on crop yields and weeds suppression under laboratory and field conditions (Putnam and Tang 1986). The use of plants with strong allelopathic properties for weed control has shown promising results. Bioassay has been used in the selection of plant species and extraction processes for the extracts in the search for a product with the highest phytotoxicity (Gomes et al. 2016; Rawat et al. 2017). Recently, crude extract of many plants

provided great inhibition on weed germination and growth (Al-Humaid and El-Mergawi 2014; Gomes et al. 2016; Rawat et al. 2017; Shah et al. 2018).

The Kingdom of Saudi Arabia exhibits a typical arid to semi-arid climate, and xerophytic vegetation makes up the prominent features of plant life (Zahran 1982). This vegetation is characterized by its unique biological diversity and species that have become acclimatized to grow under abiotic stress including hot temperatures and dry conditions. A number of native plants in this region have been reported to have allelopathic effects against different weed species (Al-Humaid and Warrag 1998; El-Mergawi and Al-Humaid 2017). In a previous study, we found that the extracts of seven native plants, *Pulicaria undulata*, *Prosopis juliflora*, *Rumex vesicarius*, *Teucrium baccatus*, *Anvillea garcinii*, *Artemisia monosperma*, and *Withania somnifera*, had the stronger inhibitory effect on germination of *Portulaca oleracea*, *Echinochloa crusgalli*, *Phalaris minor*, and *Lactuca sativa* seeds. Extracts of these

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plant species completely inhibited the germination of *P. minor* and *P. oleracea* at concentrations ranging from 10 to 40 g L<sup>-1</sup> (Al-Humaid and El-Mergawi 2014).

The discovery of plant species with high allelopathic potentials provided a possibility for decreasing inputs in agricultural crop growing and for producing organic foods (Bashir et al. 2012). This requires thorough study of the effects of individual plant extract or plant component against weeds. In this study, we tested the allelopathic effects of extracts obtained from eight native plants against four target plants—*Phalaris minor* Retz, *Echinochloa crusgalli* L. Beauv, *Portulaca oleracea* L., and *Lactuca sativa*, under laboratory and greenhouse conditions.

### Materials and methods

All experiments were conducted at Qassim University, Buraydah city, Saudi Arabia, since October 2013.

#### Plant material and preparation

Aerial parts of eight plants (*Tamarix mannifera*, *Alhagi maurorum*, *Echinops spinosissimus*, *Haloxylon salicornicum*, *Lactuca virosa*, *Neurada procumbens*, *Ochradenus bacctus*, and *Cyperus conglomerates*) were collected at the flowering stage from Al-Qassim region, Saudi Arabia. These plant species are widespread as wild plants in El-Qassim, Saudi Arabia desert. Vegetative parts were immediately dried in open trays in a laboratory-drying oven at 60 °C and then ground into a powder and passed through a 40-mesh sieve with a particle diameter of less 0.35 mm. Dried materials were stored in tightly closed plastic containers to maintain dryness until extraction.

#### Extract preparation

Methanol extracts from ground vegetative parts were obtained by weighing 100 g of dried plant material into a flask containing 1.0 L of methanol. The flasks were shaken on an orbital shaker at 150-rpm agitation speed for 24 h at room temperature. The extracts were then filtered through a Whatman No. 1 filter paper. Methanol extracts were evaporated using a rotary evaporator at 40 °C using Rotavapor R-114 (Buchi, France), and the residues were weighed. Yields of extracts (%) were expressed as g residue/100 g dried plant material. The residues were dissolved in 1.0 L methanol to obtain a stock extract concentration equivalent to 100 g dried plant material/L of methanol. These original extracts were stored in a refrigerator at 4 °C until further dilution and bioassay.

#### Germination bioassay

A germination test was conducted using seeds of canary grass (*Phalaris minor* Retz), barnyard grass (*Echinochloa crusgalli* L. Beauv), and purslane (*Portulaca oleracea* L.) collected from agricultural fields. These target plants were chosen because they represent a range of grasses

and broadleaf weed species. In addition, *Lactuca sativa* plant has been commonly used in allelopathic studies. Seeds of *L. sativa* were purchased from Modesto Seed Co., INC, USA. Seeds were surface-sterilized with sodium hypochlorite (0.1%, w/v) for 2 min, washed under running tap water for 5 min followed by distilled water for 2 min, and stored for further use.

The stock methanol extract (100 g/L) was diluted with methanol to obtain final concentrations of 5, 10, 20, and 40 g/L (w/v). Methanol extract (4 mL) was placed in a 9-cm plastic Petri dish lined with a single Whatman No. 1 filter paper and evaporated to dryness for 24 h at 24 °C. Methanol (4 mL) was applied to a Petri dish to serve as a control. After evaporation, 4 mL of distilled water were added onto the filter paper. Twenty seeds were placed on the paper in the Petri dishes. Four replicate Petri dishes of each treatment were placed, in a completely randomized manner, in a growth chamber at 25 °C. After 7 days, germination percent, shoot length, and root length of germinated seeds were determined. Data were expressed in % of control for each treatment using the following equation:

$$\% \text{ of control} = (\text{Treatment/Control}) \times 100$$

#### Greenhouse bioassay

Another experiment was performed to study the effect of the eight plant extracts on 6-week-old *P. minor*, *E. crusgalli*, *P. oleracea*, and *L. sativa* plants raised under controlled conditions in an experimental greenhouse (25 ± 3 °C, 12 h photoperiod). Methanol extracts at four concentrations (0, 30, 60, and 90 g/L) were used in a phototoxic bioassay after evaporating the methanol and dissolving the residue in DMSO-water solution (1%, v/v). Plants were raised from the collected seeds in 12-cm diameter earthenware pots. The pots were filled with 750 g soil (sand: peat moss, 3:1, w/w), and 20 seeds of each plant species were sown per pot. Two weeks after emergence, pots were watered daily, and after 3 weeks, they were flushed with half-strength Hoagland solution. When plants were 6 weeks old, they were sprayed with plant extracts at 0, 3, 6, and 9% (w/v) concentrations using a common garden sprayer at the rate of 100 mL/m<sup>2</sup>. Four replicates of each treatment were placed in a completely randomized manner. Seven days after the extracts were sprayed onto the plants, the plants were examined for visible injury levels and the percent of chlorotic and necrotic areas were recorded.

#### Statistical analysis

Analyses were performed in triplicate. Analysis of variance and comparison of treatment means (LSD, 5% level) were performed using Stat graphics Plus Version 5.1.

**Results**

**Germination bioassay**

The effects of methanol extract of eight native plants on germination percentage and seedling growth of *P. minor*, *E. crusgalli*, *P. oleracea* and *L. sativa* plants were determined at 5, 10, 20 and 40 g/L (Tables 1, 2, and 3).

**Effect of plant extracts on germination percentage**

The germination of *P. minor* was inhibited by the extracts in all test concentrations, and the degree of inhibition increased with increased extract concentrations (Table 1). At the highest concentration (40 g/L), germination of *P. minor* exhibited great inhibition as affected by the extracts of *T. mannifera* (100%), *A. maurorum* (65%), *E. spinosissimus* (85%), *H. salicornicum* (67%), *L. virosa* (95%), *N. procumbens* (71%), and *O. bacctus* (73%). With less extent, the effects of different plant extracts on germination of *P. oleracea* were similar to those seen on the germination of *P. minor*. The highest reduction effect on germination of *P. oleracea* was obtained with *T. mannifera* and *L. virosa* at 40 g/L (reached 87% and 94%, respectively).

Germination of *E. crusgalli* and *L. sativa* seeds possessed the least inhibitory effect (Table 1). The most inhibition effect on *E. crusgalli* germination was obtained by *L. virosa* and *C. conglomerates* extracts at 20 g/L and 40 g/L. As for *L. sativa*, using different extracts at low

**Table 1** Effect of plant extracts (% of control) on germination percentage of *P. minor*, *P. oleracea*, *E. crusgalli*, and *L. sativa*

Plant species	Extract concentration (g/L)							
	5	10	20	40	5	10	20	40
	<i>P. minor</i>				<i>P. oleracea</i>			
<i>T. mannifera</i>	68*	55*	42*	0*	77*	68*	40*	13*
<i>A. maurorum</i>	50*	44*	38*	35*	73*	71*	70*	62*
<i>E. spinosissimus</i>	56*	41*	27*	15*	93	82*	78*	67*
<i>H. salicornicum</i>	87*	71*	47*	33*	89	85*	87	49*
<i>L. virosa</i>	98	91	67*	5*	100	97	97	6*
<i>N. procumbens</i>	68*	44*	38*	29*	96	80*	80*	76*
<i>O. bacctus</i>	87*	70*	67*	27*	92	88	80*	74*
<i>C. conglomerates</i>	98	91	81*	81*	100	100	100	67*
	<i>E. crusgalli</i>				<i>L. sativa</i>			
<i>T. mannifera</i>	100	100	85*	7 <sup>8</sup> *	100	89	24*	21*
<i>A. maurorum</i>	100	92	89	81*	100	94	87	84*
<i>E. spinosissimus</i>	100	87	89	81*	100	96	100	88
<i>H. salicornicum</i>	97	80*	80*	70*	99	100	93	54*
<i>L. virosa</i>	100	98	60*	57*	100	97	100	100
<i>N. procumbens</i>	100	100	84*	78*	100	100	100	99
<i>O. bacctus</i>	88	70*	73*	68*	100	100	100	97
<i>C. conglomerates</i>	83*	81*	62*	57*	98	99	95	62*

\*Values significantly less than the respective control ( $p \leq 0.05$ )

**Table 2** Effect of plant extracts (% of control) on shoot length of *P. minor*, *P. oleracea*, *E. crusgalli*, and *L. sativa*

Plant species	Extract concentration (g/L)							
	5	10	20	40	5	10	20	40
	<i>P. minor</i>				<i>P. oleracea</i>			
<i>T. mannifera</i>	99	46*	10*	0*	80*	66*	35*	0*
<i>A. maurorum</i>	35*	27*	13*	0*	65*	50*	48*	46*
<i>E. spinosissimus</i>	53*	25*	8*	0*	86	66*	61*	59*
<i>H. salicornicum</i>	73*	30*	24*	0*	92	90	75*	28*
<i>L. virosa</i>	64*	36*	37*	0*	100	96	66*	0*
<i>N. procumbens</i>	12*	10*	10*	0*	87	71*	65*	52*
<i>O. bacctus</i>	71*	70*	46*	21*	128*	124*	121*	121*
<i>C. conglomerates</i>	94	78*	69*	36*	143*	128*	97	47*
	<i>E. crusgalli</i>				<i>L. sativa</i>			
<i>T. mannifera</i>	71*	42*	35*	25*	119*	104	39*	24*
<i>A. maurorum</i>	96	88	68*	47*	118*	110	96	88
<i>E. spinosissimus</i>	91	90	84*	69*	118*	102	96	89
<i>H. salicornicum</i>	67*	56*	40*	36*	148*	159*	115*	75*
<i>L. virosa</i>	96	86*	44*	36*	143*	127*	112	87
<i>N. procumbens</i>	110	87*	89	41*	119*	107	90	83*
<i>O. bacctus</i>	75*	73*	61*	49*	120*	118*	110	108
<i>C. conglomerates</i>	97	73*	72*	37*	130*	143*	140*	93

\*Values significantly less than the respective control ( $p \leq 0.05$ )

**Table 3** Effect of plant extracts (% of control) on root length of *P. minor*, *P. oleracea*, *E. crusgalli*, and *L. sativa*

Plant species	Extract concentration (g/L)							
	5	10	20	40	5	10	20	40
	<i>P. minor</i>				<i>P. oleracea</i>			
<i>T. mannifera</i>	89	25*	3*	0*	80*	84*	29*	10*
<i>A. maurorum</i>	37*	25*	10*	0*	41*	40*	36*	33*
<i>E. spinosissimus</i>	52*	26*	8*	0*	90	57*	50*	50*
<i>H. salicornicum</i>	26*	12*	7*	0*	109	80*	57*	7*
<i>L. virosa</i>	63*	25*	26*	0*	113	73*	72*	0*
<i>N. procumbens</i>	5*	5*	3*	0*	80*	75*	55*	55*
<i>O. bacctus</i>	59*	48*	39*	10*	145*	108	108	108
<i>C. conglomerates</i>	71*	58*	39*	37*	135*	127*	90	45*
	<i>E. crusgalli</i>				<i>L. sativa</i>			
<i>T. mannifera</i>	43*	23*	8*	0*	85*	57*	10*	0*
<i>A. maurorum</i>	79*	43*	21*	19*	88	75*	65*	33*
<i>E. spinosissimus</i>	70*	55*	48*	46*	83*	95	73*	70*
<i>H. salicornicum</i>	22*	18*	12*	7*	107	105	91	26*
<i>L. virosa</i>	89	71*	19*	6*	91	68*	15*	11*
<i>N. procumbens</i>	72*	61*	52*	16*	47*	43*	53*	16*
<i>O. bacctus</i>	47*	26*	22*	14*	124*	107	103	101
<i>C. conglomerates</i>	99	71*	52*	12*	85*	58*	66*	37*

\*Values significantly less than the respective control ( $p \leq 0.05$ )

concentrations (5–20 g/L) did not produce any significant effect on germination percentage, except the inhibition effect of *T. mannifera* extract at 20 g/L. However, at the highest concentration, *T. mannifera*, *H. salicornicum*, and *C. conglomerates* reduced germination of *L. sativa* by 79%, 46%, and 38%, respectively.

#### Effect of plant extracts on shoot length

Data in Table 2 indicated that shoot growth of target seeds varied greatly in their response to examine extracts, and *P. minor* achieved the greatest sensitivity. All plant extracts resulted in remarkable reduction in shoot length of *P. minor*, and the degree of reduction increased as the extract concentration increased. The inhibition effects ranged between 22 and 90% at 10 g/L as well as between 31 and 92% at 20 g/L. By increasing the concentration to 40 g/L, extracts of *T. mannifera*, *A. maurorum*, *E. spinosissimus*, *H. salicornicum*, *L. virosa*, and *N. procumbens* completely inhibited shoot growth of *P. minor*. The inhibition effect on shoot length of *P. oleracea* was somewhat lower than that observed for *P. minor*. Except the consistent stimulation effects obtained by *O. bacctus* and *C. conglomerates*, all plant extracts reduced shoot length of *P. oleracea* at all tested concentrations. However, a complete inhibition was obtained by using extracts of *T. mannifera* and *L. virosa* at 40 g/L.

As for *E. crusgalli* seeds, the extracts inhibited shoot elongation at all test concentrations and the degree of inhibition increased by increasing the extract concentration (Table 2). At the highest concentration (40 g/L), the greatest inhibition effects on shoot length of *E. crusgalli* were recorded at 40 g/L for all tested extracts, especially *T. mannifera* (75%). Data in Table 2 indicated that *L. sativa* seeds possessed the least inhibitory as compared with other examine seeds. Whereas, all extracts stimulated the shoot growth of *L. sativa* at 5 and 10 g/L, ranging between 2% and 59% when compared with the control. With increasing concentration to 20 g/L, many of plant extracts continued to cause a stimulatory effect. However, the greatest inhibitory effect on shoot growth of *L. sativa* was obtained by *T. mannifera* at 20 g/L (61%) and at 40 g/L (76%).

#### Effect of plant extracts on root length

The results indicated that the effects of plant extracts on the root length of target seeds were concentration and species-dependent (Table 3). The inhibitory effect of the test extracts varied among the four seed species examined. Methanol extract of tested plants inhibited root growth of *P. minor* at all concentrations when compared with control. Extracts of *T. mannifera*, *A. maurorum*, *E. spinosissimus*, *H. salicornicum*, *L. virosa*, and *N. procumbens* caused more than 70% reduction in root length of *P. minor* when applied at 10 or 20 g/L. By increasing

concentration to 40 g/L, these extracts resulted in a complete inhibition on root growth of *P. minor*. The response of *E. crusgalli* to test extracts was similar to that of *P. minor*. Root growth of *E. crusgalli* was greatly affected by different plant extracts at all tested concentrations. At high concentrations (20 and 40 g/L), *T. mannifera* inhibited the root growth of *E. crusgalli* with 92% and 100%, respectively.

The root growth of *P. oleracea* and *L. sativa* was exhibited less sensitive to the extracts than *P. minor* and *E. crusgalli* (Table 3). At low doses, plant extracts had inhibitory and stimulatory effects on root length of *P. oleracea* and *L. sativa*. The extracts of *O. bacctus* continued to stimulate root elongation of two seeds at all tested concentrations. Except for *O. bacctus*, all examined extracts reduced root length of *P. oleracea* and *L. sativa* at 20 g/L, particularly *T. mannifera* extract (71% and 90%, respectively). Whereas maximum inhibition effect on root length of *P. oleracea* and *L. sativa* was obtained at 40 g/L, especially for extracts of *T. mannifera* (90% and 100%, respectively), *H. salicornicum* (93% and 74%, respectively), and *L. virosa* (100% and 89%, respectively).

#### Greenhouse bioassay

The inhibitory activity of methanol extract from eight native plants on growth of 6-week old of *P. minor*, *E. crusgalli*, *P. oleracea*, and *L. sativa* was determined at 30, 60, and 90 g/L (Table 4). In general, the growth of 6-week-old plants was less sensitive to the test extracts than the seed germination. Except for *T. mannifera*, foliar spray of tested extracts at all examined concentrations did not produce any significant reduction on growth of four target plants, whereas using *T. mannifera* extract at 60 g/L or 90 g/L inhibited growth of *P. minor*, *E. crusgalli*, and *Lactuca sativa* between 13 and 25%.

#### Discussion

Methanol extract of eight plants had the ability to affect germination percent and seedling growth of both monocotyledonous species (*P. minor* and *E. crusgalli*) and dicotyledonous species (*P. oleracea* and *L. sativa*), under laboratory condition. The inhibitory effect of the test extracts varied among the four seed species examined, and *P. minor* was more sensitive to tested extracts than *P. oleracea*, *E. crusgalli*, and *L. sativa*. Similar observation was reported by Al-Humaid and El-Mergawi (2014). Moreover, we found that the effectiveness of extracts on the root growth was apparently greater than that on the germination percent or shoot growth of the same tested seeds. This is in agreement with Turk and Tawaha (2002), in which they reported that extracts of allelopathic plants generally have more pronounced effects on root, rather than shoot, growth. This may be attributed to the fact that roots are the first to absorb the



**Table 4** Effect of plant extracts (% of control) on growth of 6-week-old *P. minor*, *P. oleracea*, *E. crusgalli*, and *L. sativa*

Plant species	Extract concentration (g/L)					
	30	60	90	30	60	90
	<i>P. minor</i>			<i>P. oleracea</i>		
<i>T. mannifera</i>	87	85*	75*	92	95	92
<i>A. maurorum</i>	95	92	92	97	97	96
<i>E. spinosissimus</i>	95	94	92	97	99	94
<i>H. salicornicum</i>	93	94	92	98	98	96
<i>L. virosa</i>	94	96	94	96	96	95
<i>N. procumbens</i>	95	93	95	97	96	97
<i>O. bacctus</i>	95	96	96	96	97	97
<i>C. conglomerates</i>	97	94	95	99	97	98
	<i>E. crusgalli</i>			<i>L. sativa</i>		
<i>T. mannifera</i>	90	87*	82*	90	87*	82*
<i>A. maurorum</i>	99	95	95	97	97	96
<i>E. spinosissimus</i>	92	94	92	96	96	92
<i>H. salicornicum</i>	95	95	95	94	95	93
<i>L. virosa</i>	97	98	97	98	96	97
<i>N. procumbens</i>	95	95	96	95	95	95
<i>O. bacctus</i>	95	95	94	96	95	94
<i>C. conglomerates</i>	95	94	94	97	97	94

\*Values significantly less than the respective control ( $p \leq 0.05$ )

allelochemicals or autotoxic compounds from the environment.

All species affect germination percentage and seedling growth of target seeds, in a dose-response relationship. It is evident that the most promising plants were *T. mannifera* and *L. virosa* due to their remarkable potency and their regularity in inhibiting both seed germination and seedling growth of target seeds. Using *T. mannifera* extract at 40 g/L completely inhibited the germination and seedling growth of *P. minor*, shoot length of *P. oleracea*, and root length of *E. crusgalli* and *L. sativa* seeds. Moreover, at 40 g/L, *L. virosa* nearly had a complete inhibition on germination and seedling growth of *P. minor* and *P. oleracea* and caused a great inhibition on seedling growth of *E. crusgalli* and *L. sativa* seeds. Inhibition of plant extracts on the seed germination process is thought to be related to osmotic effects on the rate of imbibition, which then inhibits the initiation of germination and, especially, the cell elongation (Black 1989). Such inhibitory effects led to suggest that extracts of these plants likely contain allelochemicals as phenolics and terpenoids (Wesołowska et al. 2006; Stojakowska et al. 2012). On the contrary, at low concentration, many of plant extracts caused a remarkable stimulation effect on root and shoot growth of *P. oleracea* and *L. sativa* seeds, particularly at low concentration. The extract of *O. bacctus* stimulated shoot and root elongation of *L.*

*sativa* at all tested concentrations. In line of these results, Narwal (1994) mentioned that allelochemicals that inhibit the growth of some species at certain concentration might stimulate the growth of the same or different species at different concentrations. Generally, allelopathic effects are not totally inhibitory; they depend on the developmental stages or target species (Otusanya et al. 2008) or the concentration of the extract (He et al. 2009). Not all allelochemical substances are inhibitors; they can be stimulants, like mineral nutrients, organic acids, carbohydrates, and growth regulators (Tukey Junior 1969). It is essential to identify the concentration of which each specific response occurs if allelopathic interaction is to be used in weed management program.

The greenhouse experiment provided further evidence for the great allelopathic potential, observed in laboratory, for *T. mannifera* extract. Using this extract at 60 g/L and 90 g/L significantly reduced growth of 6-week-old *P. minor*, *E. crusgalli*, and *L. sativa* plants. The inhibition effect may occur through a variety of mechanisms including suppressed hormone activity, reduced rate of ion uptake, inhibition of some physiological process (as photosynthesis, respiration, and protein formation), decreased permeability of cell membranes, and/or inhibition of enzyme action (Rice 1974). In general, the growth of 6-week-old weeds (Table 4) tended to be less sensitive to the test extracts than the weed germination (Tables 1, 2, 3, and 4). Inderjit and Weston (2000) reported that greenhouse bioassays do not adequately predict the responses observed in laboratory bioassay. Thus, the seedling stage and the more mature stage of target plants vary in their sensitivities to plant extracts (Reigosa et al. 1999). Hence, weed germination might be the most sensitive index with which to judge allelopathy of tested extracts under natural conditions (Coree et al. 2008).

### Conclusions

We examined the allelopathic effects of eight native plants from the Al-Qassim region of Saudi Arabia on seed germination and growth of 6-week-old plants of *P. minor*, *E. crusgalli*, *P. oleracea*, and *L. sativa*. The effectiveness of extracts depended on the target plants, extract concentrations, and test plant species. Extracts of *T. mannifera* and *L. virosa* were capable of inhibiting seed germination and seedling growth of target species, especially at high concentrations. In general, the growth of 6-week-old plants was less sensitive to the test extracts than the seed germination. The only significant reduction in growth of target plants was obtained by *T. mannifera* extract. Generally, the extracts of *T. mannifera* and *L. virosa* could yield pure, active compounds with potencies sufficient to the development of new herbicidal substances.

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### Availability of data and materials

The datasets generated during and/or analysed during the current study are included in this manuscript.

### Authors' contributions

RAEI-M performed the laboratory analysis and wrote the paper and AAI-H performed the data coordinated the data collection. Both authors read and approved the final manuscript.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

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