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Full Length Research Paper

Impact of crop residues on seed germination of native desert plants grown as weeds

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Allelopathy refers to an ecological phenomenon where there is plant-plant interference through release of organic chemicals (allelochemicals) in the surrounding soil environment as water leachates or root exudates. Crop residues produce allelochemicals that may inhibit seed germination of many weeds. In this study, I assessed the effect of aqueous extracts of three crop residues (radish, rocket and rhodes) on final germination percentage and germination rate of four desert plants recorded as weeds in the United Arab Emirates farms (*Coelachyrum piercei* (Benth.) Bor, *Plantago ovata* Forssk., *Sporobolus arabicus* Boiss. and *Tephrosia apollinea* (Delile) DC.). Residues of the two crucifers (radish and rocket) were more effective in inhibiting seed germination of the four species. Up to 4% of rhodes grass extracts showed insignificant effects on the seed germination. Both *C. piercei* and *P. ovate* were more sensitive to allelopathic effect (their germination was greatly inhibited), but *S. arabicus* and *T. apollinea* were more resistant to the extracts. The suppressive ability of the two crucifers' residues would be of environmental importance if integrated in weed management programmes.

Key words: Crop residues, radish, rhodes, rocket, seed germination, weeds.

INTRODUCTION

Allelopathy is an ecological phenomenon which refers to any direct or indirect positive or negative effect of one plant on the other through the release of chemicals into the environment (Rice, 1984). These organic chemicals (allelochemicals) can be directly and continuously released by the donor plants in their immediate environment as water leachates, volatiles in the air or root exudates in soil, or they can be the microbial degradation products of plant residues (Weston, 1996). Allelochemicals may interfere with survival and growth of neighboring plants, and may also discourage insects and pathogens infestation (Zeng et al., 2008).

Non-herbicidal innovations to manage weed populations are increasingly needed because of public concern about herbicide use, increased agricultural costs and the emergence of herbicide-resistant weed species (Wu et al., 1999). Allelopathy has been considered a natural and environment-friendly technique for weed control and thereby increases crop yields (Purvis et al., 1985). The application of allelopathy could be incur-porated into an integrated weed management package, thereby reducing the dependence on herbicides (Wu et al., 1999). Putnam and Duke (1974) indicated the possibility of utilizing allelopathic crops to suppress weed growth in agricultural sites. In addition, many investi-gations documented the feasibility of using cover crops and their residues for weed suppression (Weston, 2005).

Many cereals have shown allelopathic effects (Wu et al., 1998; Baghestani et al., 1999; Fujii, 2001; Zhao et al., 2005). For example, Wu et al. (1998) indicated that both germination and radicle growth of ryegrass were significantly inhibited by the aqueous shoot extracts of wheat cultivars. The inhibition for radicle elongation ranged from 19.2 to 98.7% and for seed germination from 4.2 to 73.2% (Wu et al., 1998). In addition, sorghum (*Sorghum bicolor*) is well recognized for its allelopathic effects on other crops (Putnam and DeFrank, 1983). Similarly, Brassicaceae family has received great attention with respect to its allelopathic effects and is known to contain glucosinolates, which suppress several weed species. Radish is the most popular allelopathic crop of this family (Uygur et al., 1990; Weston and Duke, 2003). Uygur et al. (1990) examined the effect of radish extracts on germination of 25 weed and 32 crop species and found that garden radish extracts totally inhibit the germination of 11 weeds and four crop species.

Resistance in plants evolves rapidly in response to particular chemical composition of neighboring plants (Ehlers and Thompson, 2004). Callaway et al. (2005) found that the survival of native grass speceis from North American communities that have experienced extensive invasion by *Centaurea maculosa* have higher tolerances to allelochemical exudates than individuals from communities that did not experience invasion. Similarly, weeds might evolve resistance to the natural allelopathic herbicides released or leached by some crop residues (Bewick, 1994). However, newly introduced weeds to the reclaimed farms in the deserts might have lower tolerance to allelochemicals of the crop residues, as compared to traditional old weeds that coevolved with the crops. Although, most of the studies were concerned with the traditional weeds associated with crop, none examined the impact of allelochemicals on the germination response of desert plants growing as weeds in farmlands reclaimed in the deserts. The aim of the present study was to determine the effects of leaf extracts of radish (*Raphanus sativus*), rocket (*Eruca sativa*) and rhodes grass (*Chlons gayana*) on the final seed germination and germination rate of four desert plants reported as weeds in many farms of the desert lands of United Arab Emirates (UAE): *Tephrosia apollinea, Coelachyrum piercei, Sporobolus arabicus* and *Plantago ovata*.

MATERIALS AND METHODS

Collections of plant materials and extract preparation

Fresh leaf samples of three crops were collected in October 2008 from mature plants of a farm around Al Fujairah, on the coast of the Gulf of Oman in the eastern region of UAE. Two of the crops are from crucifer family (Radish or *Raphanus sativus* and Rocket or *Eruca sativa*), and one is a forage grass (rhodes grass or *Chlons gayana*). All samples were oven dried at 50°C for five days and subsamples were ground to pass through a 3-mm sieve. As crop residues are usually used dry for suppressing the emergence of weeds, the dried plant materials were used in this experiment. Dried materials of each crop were extracted in distilled water at 25 g100 ml^{-1} for 24 h at 25°C. Following extraction, coarse plant materials were removed with a 2-mm sieve; extracts were passed through a Whatman filter paper and centrifuged at 12,000 rpm for 20 min. These 25% (w/v) extracts of dried materials were further diluted to obtain 1, 2, 3, 4 and 5% solutions.

Petri dishes bioassay

Seeds of four weedy plants (*Tephrosia apollinea*, *Coelachyrum piercei, Sporobolus arabicus* and *Plantago ovata*) were collected during May 2007 from a farm near Fujairah. Seeds were separated from the litters and stored dry in brown paper pages until their use in germination experiments in October 2008.

The germination was conducted in 9-cm Petri-dishes containing one disk of Whatman No. 1 filter paper, with 10 ml of test solution. Each dish was wrapped with parafilm as an added precaution against loss of water by evaporation. For each species, dishes were arranged in an incubator set at 15/25°C in 12 h dark/12 h light, with light coinciding with 25°C in a completely randomized design with three crop extracts (radish, rocket and rhodes) and five concentrations of each extract. Four replicate dishes were used for each treatment, each with 25 seeds. Sterile distilled water was used as a control. Radicle emergence was the criterion for germination. Germinated seedlings were counted and removed every second day for 20 days following seeds sowing.

Calculation and statistical analysis

The rate of germination was estimated using a modified Timson's index of germination velocity = $\Sigma G/t$, where, G is the percentage of seed germination at two days intervals and t is the total germination period (Khan and Ungar, 1984). The possible maximum value using this index with these data was 700/14 = 50. The higher the value, the more rapid the germination.

Two-way ANOVA was performed to evaluate the effects of extracted crop and extract concentration on final germination percentage and germination rate, seedling emergence and seedling dry weight. Tukey test (honestly significant differences, HSD) was used to estimate least significant range between means. The germination rate was log-transformed and germination percentages were arcsine-transformed to meet the assumptions of ANOVA. This transformation improved normality of the distribution of the data. All statistical methods were performed using SYSTAT, version 11.0.

RESULTS

Effects of crop extracts on seed germination of *T. apollinea*

Two-way ANOVA showed significant effects of the extracted crops ($P<0.05$) and extract concentration ($P< 0.001$) on the final germination of *T. apollinea* seeds. Regardless of the crop extract, there was no significant difference in final germination of *T. apollinea* seeds between control (non-treated seeds) and both 1 and 2%; all attained significantly greater values than the higher concentrations (3 to 5%). There was no significant difference between 4 and 5%. The extracts of both radish and rocket, but not that of rhodes, resulted in a significant decrease in final germination of *T. apollinea* seeds.

About 21% of *T. apollinea* seeds germinated in distilled water (control). There was no significant difference between 1% extract of the different crops and the control. The 2% of radish and rhodes extracts did not affect the final germination, but the same concentration of rocket extract significantly reduced it. All higher concentrations (4 to 5%) of the different extracts resulted in significant reductions in the final germination; so, the effect was

Table 1. Effects of different concentrations of different crop extracts on final germination and germination rate of *T. apollinea* seeds.

Extracted crop	Concentration (%)	Final germination (%)		Germination rate	
		Mean	SE	Mean	SE
Control	0	21.3	2.7	43.4	2.3
Radish	1	20.0	2.3	39.1	2.1
	2	16.0	2.3	34.4	3.1
	3	10.7	1.3	27.8	2.8
	4	1.3	1.3	30.0	0.0
	5	2.7	1.3	18.7	6.2
Rhodes	1	21.3	1.3	40.6	2.9
	2	18.7	3.5	43.5	3.1
	3	10.7	2.7	33.3	7.5
	4	8.0	2.3	35.2	2.8
	5	12.0	2.3	35.4	7.5
Rocket		21.3	3.5	34.5	4.9
	2	13.3	1.3	37.5	2.4
	3	12.0	4.0	37.5	0.0
	4	6.7	1.3	37.5	0.0
	5	1.3	1.3	25.0	0.0

more pronounced in radish and rocket extracts. This result indicates that the suppression effect of the two crucifer species on the germination of *T. apollinea* was more obvious, as compared to the extracts of rhodes grass (Table 1).

The concentration of the extract had significant effect (P<0.05) on germination rate of *T. apollinea* seeds. However, the extract type had no significant effect (P>0.05). There was no significant difference between control and 1% extracts of radish, rocket and rhodes on the germination rate. In higher concentrations (2 to 5%), rhodes extracts did not affect the germination rate, but radish extracts significantly inhibited it. The effect of radish extracted was significantly greater than that of rocket at 3 and 5% (Table 1).

Effects of crop extracts on seed germination of *C. piercei*

Two-way ANOVA showed significant effects of the extracted crops and extract concentration (P<0.001) on the final germination of *C. piercei* seeds. Seed germination of *C. piercei* was very sensitive to the extracts of the different crops, as compared to those of *T. apollinea*. The non-treated seeds germinated to about 30%. However, the lowest concentration (1%) of both radish and rocket extracts resulted in significant reduction in final germination of *C. piercei* seeds. All higher concentrations of the extracts of these crops resulted in complete inhibition of the final germination. Seeds of *C. piercei* germinated in all concentrations of rhodes, so the germination level was significantly lower than that of the control. The reductions in final germination, as compared to the control, were 69% for both 1 and 2%, 86% for 3% and 82% for both 4 and 5%, respectively (Table 2).

The effects of extract type and concentration were significant on germination rate of *C. piercei* (P<0.001). The 1% concentration of both rhodes and rocket did not affect significantly the final germination rate of *C. piercei* seeds, but the same concentration of radish did. All higher concentrations of both radish and rocket (2 to 5%) inhibited the germination. There was no significant difference between germination rate of non-treated seeds, and those treated with 1 and 2% of rhodes extract. Higher levels of rhodes extracts (3 to 5%) significantly reduced germination rate of *C. piercei* (Table 2).

Effects of crop extracts on seed germination of *P. ovata*

The effects of the crop extract and extract concentration

Table 2. Effects of different concentrations of different crop extracts on final germination and germination rate of *C. piercei* seeds.

Extracted crop	Concentration (%)	Final germination (%)		Germination rate	
		Mean	SE	Mean	SE
Control	0	36.00	2.31	38.28	2.45
Radish	1	1.33	1.33	25.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
Rhodes	1	9.33	1.33	38.19	3.03
	2	9.33	1.33	37.50	0.00
	3	4.00	2.31	21.88	3.13
	4	5.33	1.33	16.67	4.17
	5	5.33	1.33	16.67	4.17
Rocket	1	5.33	1.33	41.67	4.17
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00

on the final germination of *P. ovata* were significant (P<0.001). Both radish and rocket extracts were more effective in germination inhibition of both *P. ovata* seeds. The lowest concentration (1%) of all crop extracts resulted in a significant increase in final germination of *P. ovata* seeds, as compared to the control. Seeds of *P. ovata* treated with 1% extracts of radish, rhodes and rocket germinated more than that of control by 47, 43.6 and 30%, respectively. All higher concentrations of radish and rocket resulted in significant reduction of the *P. ovata* germination. For rhodes extract, however, 2 and 3% resulted in significant increases, but 4 and 5% resulted in significant decreases in the final germination (Table 3).

The effect of extract type and concentration had significant effects on germination rate of *P. ovata* (P<0.01). The difference between control and 1% extracts of radish, rocket and rhodes with respect to the germination rate was insignificant. In the higher concentrations (2 to 5%), rhodes extracts did not affect the germination rate, but radish extracts significantly inhibited it. For rocket extracts, 2% did not affect the germination rate, but higher concentrations (3 to 5%) significantly inhibited it (Table 3).

Effects of crop extracts on seed germination of *S. arabicus*

The effects of the extracted crops and extract concentration on the final germination of *S. arabicus* seeds were significant (P< 0.001). Seed germination of *S. arabicus* was more tolerant to the extracts of the different crops, as compared to those of the other weedy plants. There was insignificant difference between control and all concentrations of rhodes and rocket, except 5% of rocket extract, with respect to the final germination. The final germination was reduced by about 35% with the application of 5% of rocket extract, as compared to the control. Radish extracts, however, did not affect germination rate at 1 and 2% levels, but significantly reduced it at 3% or higher levels. Concentrations of 4 and 5% almost inhibited the germination of *S. arabicus* seeds (Table 4).

Two way ANOVA showed that the effect of extract concentration, but not the extracted crop, was significant on germination rate of *S. arabicus* (P<0.05). The 4 and 5% concentrations of both radish and rocket resulted in a significant reduction in germination rate of *S. arabicus*, but lower concentrations (1 to 3%) did not affect it. All concentrations of rhodes grass, however, did not affect the germination rate of *S. arabicus* seeds (Table 4).

DISCUSSION

Crucifer family (Brassicaceae) is known to produce allelochemicals (Boydston and Hang, 1995; Eberlein et al., 1998; Kiemnec and McInnis, 2002). For example, the

Table 3. Effects of different concentrations of different crop extracts on final germination and germination rate of *P. ovata* seeds.

Extracted crop	Concentration (%)	Final germination (%)		Germination rate	
		Mean	SE	Mean	SE
Control	0	37.3	1.3	43.9	2.1
Radish	1	57.3	2.7	37.0	1.8
	2	1.3	1.3	12.5	0.0
	3	1.3	1.3	16.0	0.0
	4	2.7	1.3	12.5	0.0
	5	0.0	0.0	0.0	0.0
Rhodes	1	56.0	4.6	39.0	0.4
	2	52.0	4.0	37.5	0.0
	3	52.0	4.0	35.6	0.4
	4	21.3	2.7	37.5	3.2
	5	10.7	1.3	29.9	2.5
Rocket	1	50.7	3.5	37.2	0.3
	2	12.0	2.3	38.5	1.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
	5	0.0	0.0	0.0	0.0

incorporation of *Brassica* green manures into soil reduced weed emergence and biomass production without reducing yields of tolerant crops (Krishnan et al., 1998). In Nebraska, incorporating mustard species into soil reduced weed biomass in soybean by 49% at six weeks after emergence (Krishnan et al., 1998). Our results show significant inhibition for the aqueous extracts of the two members of the family Brassicaceae (radish and rocket), as compared to rhodes grass. A similar result was reported for the aqueous extract of wild radish; it significantly reduced germination and radicle growth of several weeds and crops (Norsworthy, 2003). In addition, the aqueous extract of leaves of *Parthenium hysterophorus* (Brassicaceae) suppressed seed germination and seedling growth of three cereal crops, three cultivated crucifers and two wild species of the family Asteraceae (Maharjan et al., 2007).

The inhibitory effect of the aqueous extract of radish and rocket on seed germination of the different plants in the present study could be attributed to the presence of some allelochemicals in the extracts. For example, other members of Brassicaceae, such as *Brassica* sp., contain high amounts of glucosinolates (Fenwick et al., 1983). Although, the biological activity of these secondary plant metabolites is very low, they play a key role in weed suppression (Fenwick et al., 1983). In addition, Vaughn and Berhow (1999) isolated several phytotoxic chemicals, mainly allyl isothiocyanate and benzyl isothiocyanate from garlic mustard, another member of Brassicaceae.

Several studies have reported the allelopathic effects of grasses family. Wheat, oat, corn and sorghum residues, for example, contain water-soluble materials that are toxic to the growth of wheat seedlings (Guenzi et al., 1967; Li et al., 2005; Zuo et al., 2005). In addition, the aqueous shoot extracts of wheat cultivars significantly inhibited both germination and radicle growth of ryegrass (Wu et al., 1998). Phytotoxicity was found to correlate with the total phenolic contents in the extract (Wu et al., 1998). Our results show little or no allelopathic inhibition for the rhodes grass extract on the germination of the different studied species. Caswell et al. (1991) examined the allelopathic effect of rhodes grass on the Hawaiian populations of *Rotylenchulus reniformis*, the reniform nematode, and found no effect. Similarly, rhodes grass hydrophobic root exudates did not reduce the rate of hatching of *Rotylenchulus renqonnis*. However, no other studies are available on the impact of rhodes grass on the germination of weedy species.

The results show that seeds of *S. arabicus* were the most resistant to the extract of the three crops: only 4% of radish extract was effective in inhibiting their germination. Seeds of *P. ovata* were less tolerant than those of *S. arabicus*, but more resistant, as compared to *T. apollinea* and *C. piercei* extracts. Despite the fact that all four weeds were native desert plants, both *T. apollinea* and *C. piercei* had higher frequency around the farms, as

Table 4. Effects of different concentrations of different crop extracts on final germination and germination rate of *S. arabicus* seeds.

Extracted crop	**Concentration (%)**	**Final germination (%)**		**Germination rate**	
		Mean	**SE**	**Mean**	**SE**
Control	0	77.33	5.33	43.75	0.40
Radish	1	70.67	3.53	41.29	0.26
	2	66.67	2.67	47.28	0.38
	3	45.33	2.67	41.53	0.14
	4	5.33	1.33	37.50	0.00
	5	1.33	1.33	37.50	0.00
Rhodes	1	58.67	1.33	44.01	0.62
	2	66.67	2.67	42.77	0.20
	3	66.67	3.53	40.24	0.13
	4	62.67	2.67	42.30	0.20
	5	69.33	4.81	42.79	0.94
Rocket	1	90.67	5.33	44.03	0.85
	2	85.33	1.33	43.98	1.29
	3	77.33	3.53	42.32	0.93
	4	77.33	2.67	39.49	1.31
	5	50.67	3.53	40.56	2.04

compared to *P. ovata* and *S. arabicus* (Ali El-Keblawy, personal observation). The lack of coevolved tolerance of *P. ovata* and *S. arabicus* to allelopathic chemicals of the crop residues would explain their resistance, as compared to the other two species. It has been documented that plants can evolve resistance to chemical substances produced by their neighbor plants (Ehlers and Thompson, 2004; Callaway et al., 2005). Callaway et al. (2005) found that the survival of the native grass species from North American communities that have experienced extensive invasion by *Centaurea maculosa* have higher tolerances to allelochemical exudates than individuals from communities that did not experience invasion.

Weed management systems often seek biological solutions to minimize the environmental impacts related to the use of herbicides in agricultural systems (Tesio and Ferrero, 2011). In recent years, allelochemicals are considered as an important tool for sustainable weed and pest management (Singha et al., 2001). The plant residues that are left in the fields after the harvest of crops represent a waste problem. However, if properly managed, these residues could be used for controlling weeds and pests. The results of the present study show the incorporation of the two crucifers' residues into soil for reducing emergence of the desert plants that are growing as weeds in the desert agroecosystems.

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