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Allelopathic Potential of White Top and Syrian Sage on Vegetable Crops

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ABSTRACT

White top [*Cardaria draba* (L.) Desv.] and Syrian sage (*Salvia syriaca* L.) are noxious common weeds of field crops and orchards in Jordan. This study was conducted to investigate any allelopathic potential of volatiles, foliage leachates, root exudates, and shoot dried residues of both weed species on cabbage (*Brassica oleracea* L. var. *Capitata* cv. Pronzwik), carrot (*Daucus carota* L. cv. Natus), cucumber (*Cucumis sativus* L. cv. Beithalpha), squash (*Cucurbita pepo* L. cv. Byrouti), onion (*Allium cepa* L. cv. Texas Early Grana), pepper (*Capsicum annum* L. cv. Red Common), or tomato (*Lycopersicon esculentum* Mill cv. Special Back) through different laboratory and glasshouse experiments. Volatiles from Syrian sage fresh shoots reduced germination and inhibited seedling growth of most crops, and foliage leachates or root exudates of both weeds were toxic to different crops under laboratory conditions, with most effects on tomato and cabbage. In pot experiments, surface-placed shoot residues of both weeds significantly delayed seed germination and reduced seedling growth of all crops with carrot, onion, and tomato being the most affected. Decayed residues of white top were also toxic at 32 g kg^{-1}, but lower toxicity was obtained than when fresh materials were used. Foliage leachates or root exudates of both weed species added or released into the soil mixture reduced seedling growth of cabbage and tomato. Results showed that white top and Syrian sage are of great allelopathic potential against different vegetable crops; cabbage, onion, and tomato being the most sensitive crops.

MANY noxious annual and perennial weeds have been regarded as species with allelopathic potential and can severely affect crop survival and productivity (Putnam and Duke, 1978; Rice, 1979; Qasem, 1994). Allelochemicals produced by plants may be released into the surrounding environment in sufficient amounts with enough persistence to affect neighboring and succession species (Akram et al., 1990).

Different studies showed that some allelopathic agents are volatile, emanated from different plant parts (Oleszek, 1987; Bradow and Connick, 1988); others indicated that they exuded from roots to the root zone and interfere in root growth and functions (Rovira, 1969; Qasem and Hill, 1989) or inhibit seed germination (Rovira, 1969). Plant residues and their decomposition products are also implicated in virtually all biochemical processes (Patrick et al., 1963; Bhowmik and Doll, 1984). Some allelochemicals are water soluble leached from foliage parts by rain, mist, dew, or fog drip (Lovett and Lynch, 1979; Qasem, 1994), leading to the monospecies stands that several perennial weeds form in nature (Rice, 1984). However, the inhibitory materials may be autoinhibitory or heteroinhibitory (Kumari and Kohli, 1987), some can be highly selective (Stachon and Zimdahl, 1980; Sahid and Sugau, 1993), and their effect is concentration dependent (Qasem, 1993).

White top [*Cardaria draba* (L.) Desv.] and Syrian sage (*Salvia syriaca* L.) are perennial rhizomatous and root creeping weeds belonging to cruciferae and labiatae families, respectively. They are widespread in cultivated fields in Jordan and invade field crops as well as orchards. Their deep, penetrating, hard, and extensive creeping roots make them difficult to eradicate. If the weeds were left uncontrolled, they soon colonize a large area, choking the other plants present. Both are strong competitors for soil moisture in arid regions, and their growth increased with increasing water consumption (Al-Ahmed, 1982; Qasem and Abu-Irmaileh, 1983).

Furthermore, both weed species have been reported to possess high allelopathic activity against crops, including wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) (Qasem and Abu-Irmaileh, 1985; Qasem, 1993, 1994). When shoot and root extracts, water leachates, and dried residues of both weeds were added to the soil, all inhibited germination, growth, and development of these crops.

The objective of the present work was to investigate any possible role of allelopathy mechanism in the interference between these two common and noxious weed species (through their possible volatile materials, root exudates, foliage leachates, and shoot residues) on germination and growth of their associated vegetable crops.

MATERIALS AND METHODS

Laboratory Experiments

Experiment 1. Effect of Root Exudates

Ten-cm diameter plastic pots were filled with 500 g of soil mixture (clay/sand/peat, 3:1:1 of a pH 7.7) and planted with rhizomes of both weed species, separately. After emergence, seedlings were thinned to 10 per pot irrigated with tap water when needed and left to grow for 2 mo before being harvested. The soil was loosened, cleaned up from weed roots, and then mixed with an equal volume of distilled water and thoroughly shaken for 2 h on a shaker. The mixture was passed through filter paper and immediately assayed for phytotoxicity. For the control treatment, 500 g of weed-free soil was mixed with the same volume of distilled water and then similarly treated before used.

The effect of soil filtrate was studied by placing 20 seeds of cabbage (*Brassica oleracea* L. var. *Capitata* cv. Pronzwik), carrot (*Daucus carota* L. cv. Natus), cucumber (*Cucumis sativus* L. cv. Beithalpha), squash (*Cucurbita pepo* L. cv. Byrouti), onion (*Allium cepa* L. cv. Texas Early Grana), pepper (*Capsi-*

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cum annum L. cv. Red Common), or tomato (*Lycopersicon esculentum* Mill cv. Special Back) on a filter paper in each of four petri dishes at which 10 mL of the filtrate of either weed species was added per petri dish. In another treatment 10 mL of soil–weed-free filtrate was added per petri dish and treated as a control.

Dishes were incubated for germination in dark at 24°C for 2 to 3 wk, depending on crop species used, before the experiment was terminated. Data on germination and growth of different crops were recorded.

Experiment 2. Effect of Volatile Materials

Ten seeds of each crop species were placed separately in each of four sterilized (9 cm diam) petri dish lined with moistened filter paper. Thirty g of fresh, healthy, and clean shoots of white top or Syrian sage, were placed in the bottom of wide mouth 500-mL cups (11-cm diam), using four cups per weed species. Uncovered petri dishes (containing seeds) were placed over weed shoots inside the cups, which then tightly closed to eliminate any air diffusion. For the control treatment, dishes sown with crop seeds were placed in similar cups, without any weed materials added. All cups were incubated as in the previous experiments, for 1 to 2 wk, depending on crop tested. Data on germination and growth of different crops were recorded.

Glasshouse Experiments

Experiment 3. Effect of Surface Placed Residues

Dried shoots (oven-dried at 80°C for 48 h) of both weeds were ground to a fine powder, until they passed through 1.72-mm mesh. Plastic pots of 10-cm diameter filled with 500 g of the soil mixture were sown with 10 seeds of each vegetable crop. The ground, dried shoot materials were added at a rate of 16 g kg^{-1} soil on the soil surface. For the control treatment, seeds of each crop species were sown in the potted soil, but without any weed residue added.

Plants were grown in the glasshouse for 2 to 5 wk, depending on crop species used, then similar data as in the above experiments were taken at harvest.

Experiment 4. Effect of Root Exudates

Pots of 10-cm diameter were filled with 500 g of soil mixture and planted with rhizomes of white top or Syrian sage. After emergence, weed seedlings were thinned to 10 per pot, then irrigated with tap water when necessary. The weeds were grown for 2 mo, before being harvested from the above soil surface. The soil in each pot was loosened, weed roots and their parts were removed, and then all pots were sown again with seeds of the tested vegetable crops separately, using 10 seeds per pot. Fresh soil mixture (not used before) was sown by the same number of seeds of vegetable crops tested and regarded as controls. Irrigation with 100 mL of full-strength Hoagland nutrient solution (Hewitt, 1966) was carried out twice a week and with tap water when needed.

The experiment was terminated at 2 to 5 wk after emergence according to crop species used. Germination percentage was recorded at different intervals, then at harvest, data on stem length, and root and shoot dry masses were recorded.

Experiment 5. Effect of Foliage Leachates

One kg of fresh shoots of each weed species was sprinkled with tap water, then with distilled water, to remove dust and soil particles. Shoots were immersed in 1 L of distilled water for 5 min, then leached water were collected and filtered through Whatman no.1 filter paper. The filtrate was considered a full-strength leachate and immediately assayed.

Crop seeds were sown in plastic pots (10-cm diam) containing 500 g of the soil mixture. After emergence, seedling were thinned to one per pot, then, 150-mL leachates were applied to each of four pots grown by one vegetable species and at the cotyledon stage. Pots irrigated only with tap water were included and considered as control. The experiment was harvested at 2 to 4 wk after leachate application, depending on the treated crop species, when stem length and shoot and root dry masses of plants were determined.

Experiment 6. Effect of Decayed Residues

Ground, dried shoots of white top or Syrian sage were added and mixed thoroughly with the potted soil mixture at a rate of 32 g kg^{-1}. The soil shoot residue mixture was placed in pots of 10-cm diameter, and frequently irrigated with tap water for 1 mo to allow natural decay of weed residues. The soil was then loosened, and each pot was sown with 10 seeds of one crop species. There were four pots per crop species. Pots filled with the same soil mixture, without any residue added and sown with 10 seeds of the same crop species, were included and considered as a control.

All pots were irrigated with tap water when required. The experiment was continued for 2 to 5 wk (depending on crop species used), then plants were harvested from the above soil surface and their stem length, fresh and dry weights, and root dry weights were determined.

Statistics and Data Analysis

Treatments in all experiments were laid out in a randomized complete block design with four replicates. Data were taken on germination percentage, stem and total root lengths, and shoot and root dry weights after being oven-dried at 80°C for 48 h. All data were statistically analyzed by ANOVA, and treatments means were compared using the least significant differences (LSD) at $p = 0.05$.

RESULTS AND DISCUSSION

Laboratory Experiments

Experiment 1. Effect of Root Exudates

No significant reduction in germination of cabbage was detected with root exudates of either weed species added to petri dishes (Fig. 1). However, white top exudates significantly reduced total root length of this crop. Phytotoxicity of root exudates showed great variation between both weeds, and the effect was highly depending on crop species tested. Certain crops were not affected by these exudates, indicating that allelopathic compounds may be highly selective, less toxins released from weed roots to the growing medium or varying crop tolerance to allelopathic agents. Stachon and Zimdahl (1980), indicated that much higher rates of root exudates and subsequently higher rates of exuded biologically active compounds were required to reduce plant growth. Furthermore, Patterson (1981) observed that long-term release of toxic compounds of living plants into the soil caused strong, harmful effects that would otherwise not appear in short-term experiments. When root exudates were added to the growth medium, growth of crops tested was reduced (Fig. 1) and their roots were clearly affected. Exuded chemicals from roots of both weed

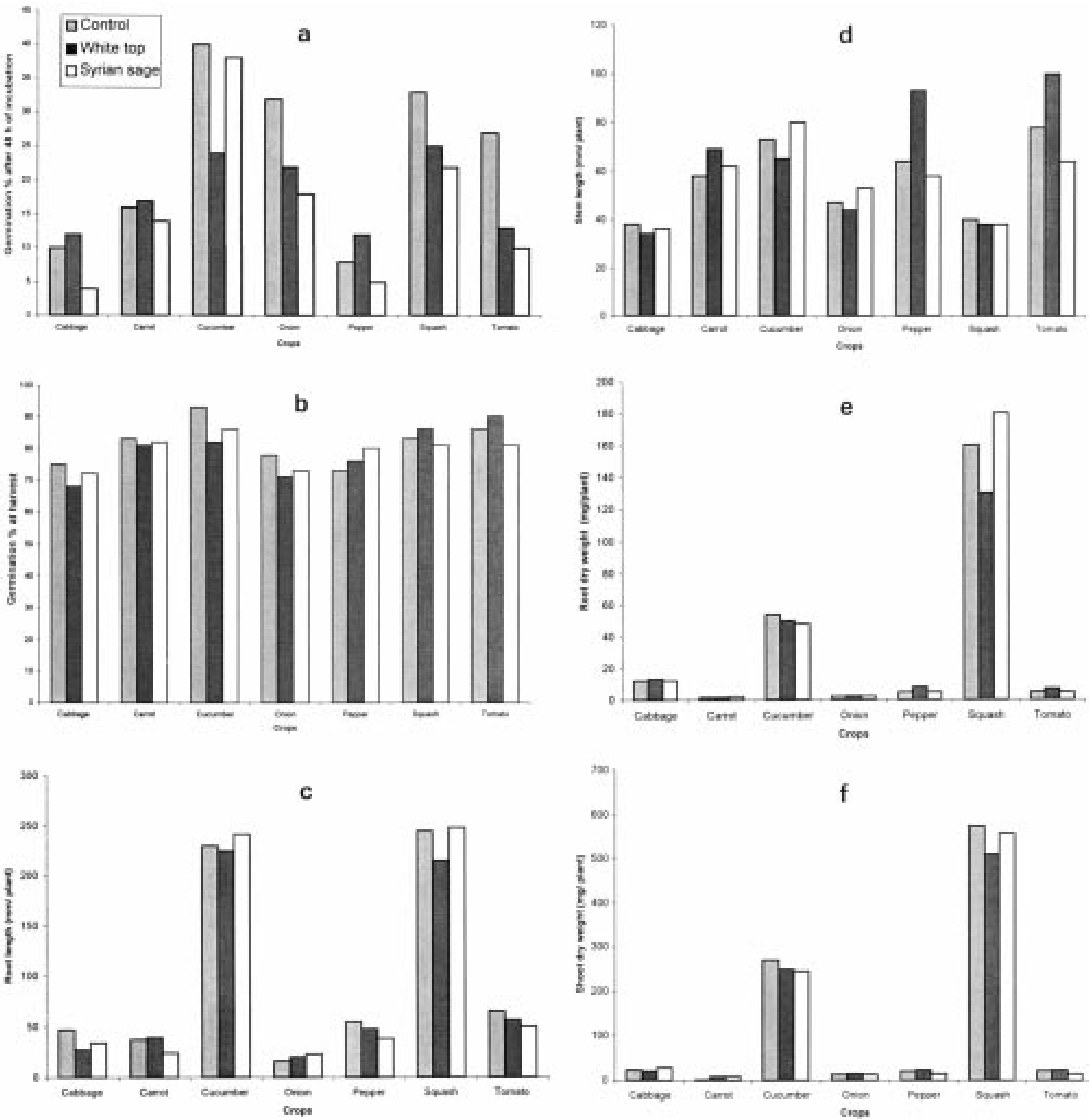

Fig. 1. Effect of root exudates of white top and Syrian sage on (*a*) germination at 48 h of incubation, (*b*) germination at harvest, (*c*) root length, (*d*) stem length, (*e*) root dry weight, and (*f*) shoot dry weight of selected vegetable crops grown under laboratory conditions.

species may interfere with nutrient availability and thus reduced growth.

Root exudates of Syrian sage reduced total root length of carrot seedlings and severely affected tomato growth, although germination and stem length of tomato were not significantly affected. Neither squash nor carrot was affected by exudates of either weed species.

Experiment 2. Effect of Volatile Materials

All crops were affected by volatiles of Syrian sage shoots, but the degree of inhibition varied between crops (Table 1). Results showed that volatile from Syrian sage fresh shoots inhibited growth of all crops except pepper, but the degree of phytotoxicity varied between crops. Oleszek (1987) concluded that the toxicity of compounds from crucifers was species dependent, and the acceptor species react in different ways to volatiles of different donor species. Allelopathic activity of released compounds of different *Salvia* species have been well established and suggested that volatiles are localized in the leaves of purple sage (*Salvia leucophylla* Greene) (Muller et al., 1964); and terpenoids could be released from both *S. leucophylla* and lance-leaf sage (*Salvia reflexa* Hornem.) (Muller et al., 1964; Lovett and Lynch, 1979). Similarly, chemical compounds may be released from Syrian sage shoots, since it belongs to the same genus. In addition, inhibitory growth patterns of the affected crop species can be clearly observed in the vicinity and around patches of this weed in nature (Qasem and Abu-Irmaileh, 1985).

The exact nature of volatiles released from the donor plant is not yet known. These results suggest chemical characterization of these volatiles needs to be done.

Results showed that germination, root length, and root and shoot dry weights of carrot and squash were inhibited, while only dry mass of cabbage was reduced by volatility of this weed species.

Glasshouse Experiments

Experiment 3. Effect of Surface Placed Residues

Crops responded differently to the soil-applied shoot residues of both weed species (Table 2). Shoot residues of white top, when used as a soil mulch, delayed emergence, reduced the number of final emerged seedlings, and stem length and shoot and root dry weights of cabbage, onion, pepper and tomato. Grinding of plant tissues may not represent the exact situation occurring in nature and may enhance release of allelochemicals. This procedure, however, is followed in the present experiment to allow better coverage of pot surface with the relatively small amount of weed residue used. In nature, amount of plant residues is expected to be higher and the decay process of these residues may take place faster than that under glasshouse conditions due to different environmental factors, better prevailing under field conditions, leading to fast release of allelochemicals. However, dried residues of both weeds delayed seedling emergence of carrot and tomato and affected growth of carrot plants. Syrian sage shoot residues significantly reduced stem length and dry weight of cucumber and squash.

Experiment 4. Effect of Root Exudates

Germination of the different crops was not significantly affected by root exudates. However, stem length and root and shoot dry weights of all crops tested were reduced by root exudates of both weed species (Fig. 2). The degree of inhibition was species-dependent. Qasem (1995) reported that root exudates of redroot pigweed (*Amaranthus retroflexus* L.) and nettle-leaved goosefoot (*Chenopodium murale* L.) released to the soil affected growth of squash seedlings showing as mineral deficiency symptoms compared with the control. In the present experiment, nonsterilized root exudates were used since this treatment may change the chemical nature of soil-extracted exudates. Therefore, association of fungal spores or other soil microorganisms with root systems of studied weeds is not to be excluded. However, no

Table 1. Effect of volatiles from shoots of white top and Syrian sage on germination (G), total root length (TRL), shoot dry weight (SHDWt.), and root dry weight (RDWt.) per plant of certain vegetable crops grown in petri dishes at 24°C.

Weed species	Cabbage				Carrot				Cucumber				Onion				Pepper				Squash				Tomato			
	G	TRL	SHD wt.	RD wt.	G	TRL	SHD wt.	RD wt.	G	TRL	SHD wt.	RD wt.	G	TRL	SHD wt.	RD wt.	G	TRL	SHD wt.	RD wt.	G	TRL	SHD wt.	RD wt.	G	TRL	SHD wt.	RD wt.
	%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —	
Control	80	53	23	9	82	30	13	4	88	171	145	23	70	17	11	4	80	15	5	2	85	144	193	44	80	59	12	4
White top	70	52	21	8	70	31	13	4	78	179	143	22	70	15	10	3	75	15	5	1	80	113	402	41	63	58	12	4
Syrian sage	75	49	16	6	50	4	5	0	60	106	104	13	68	8	6	1	58	8	4	1	53	24	120	19	50	30	8	4
LSD $P = 0.05$	16	8	2	2	12	5	2	1	15	26	20	4	12	3	2	1	10	4	1	1	15	24	34	3	11	6	2	1

Table 2. Effect of surface placed shoot residue of white top and Syrian sage on germination (G), stem length (SL) per plant, shoot dry weight (SHDWt.), and root dry weight (RDWt.) per pot of certain vegetable crops grown under glasshouse conditions.

Weed species	Cabbage				Carrot				Cucumber				Onion				Pepper				Squash				Tomato			
	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.
	%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —		%	mm	— mg —	
Control	85	58	600	341	90	76	312	148	88	109	858	205	70	171	267	111	80	67	687	272	73	135	1888	326	90	66	875	255
White top	65	42	288	122	70	24	241	133	88	110	785	204	65	139	221	86	75	53	529	150	75	145	1665	283	65	32	308	161
Syrian Sage	83	61	600	251	75	71	251	137	73	95	525	146	78	155	269	121	68	60	512	167	70	122	1635	323	75	55	508	223
LSD $P = 0.05$	12	8	89	40	15	9	30	28	16	13	102	38	17	20	42	20	14	8	71	34	17	25	273	31	16	10	100	29

fungal contamination or growth of any disease was observed in the whole study period. Evidences are accumulating and showing that root exudates of certain plant species are toxic to the roots of neighboring plants, and inhibited germination of some other species (Tukey, 1969; Rovira, 1969; Brown et al., 1983).

Root exudates of Syrian sage inhibited growth of cabbage, cucumber, and tomato seedlings and the harmful effect on these crops was more pronounced than on other crop species tested. In comparison, white top root exudates were less toxic to the same crops.

Experiment 5. Effect of Foliage Leachates

Crops were different in their responses to foliage leachates of these weeds. Leached water from foliage parts of white top significantly reduced shoot and root dry weights of pepper, squash and tomato, whereas leached water of Syrian sage reduced shoot and root dry weight of cucumber seedlings (Table 3). Persistent rainfall for a period may leach chemicals from aerial parts of the plants under field conditions. However, allelopathic effects of the leached materials depend on the transfer of chemicals from weed to crop foliage or roots and may depend on both donor and acceptor species. Seedlings growth of different lines of wheat and barley was severely inhibited with white top leachates (Qasem, 1994), and the allelopathic effect of dried shoot residues of the weed species on both crops is well established under field conditions (Qasem, 1994). Inhibitory growth patterns of the affected species are clearly noticed in the vicinity of this weed under field conditions and affected crop plants appeared short in stature with abnormal growth of root systems.

In this study, the effect of leachates applied to the soil was less phytotoxic than other treatments. The concentration of leached material and the effect of microorganisms may have been important factors in determining the stimulatory or the inhibitory action of the leached compounds (Patterson, 1981). In this experiment, weed shoots were immersed in water for only a short period of time and low amount of shoots in large volume of water was used.

Pepper, cabbage, squash, and tomato seedlings were notably affected by foliage leachates of both weeds; onion and carrot were less so. Higher phytotoxicity was found on tomato than squash and cucumber seedlings and by leachates of both weeds. Leachates of white top were more inhibitory to cabbage, squash, and tomato crops than those of Syrian sage.

Experiment 6. Effect of Decayed Residues

Results of this experiment showed that cucumber, squash, and tomato suffered more than other crops from decayed residues of white top (Table 4). However, seed germination of most crops was not affected by decaying residues from any of the weeds. Similar results were obtained with the decayed residues of Syrian sage on growth of these crops. Decayed residues of white top, however, reduced root dry weight of cucumber and tomato and seedlings growth of squash. Although decayed

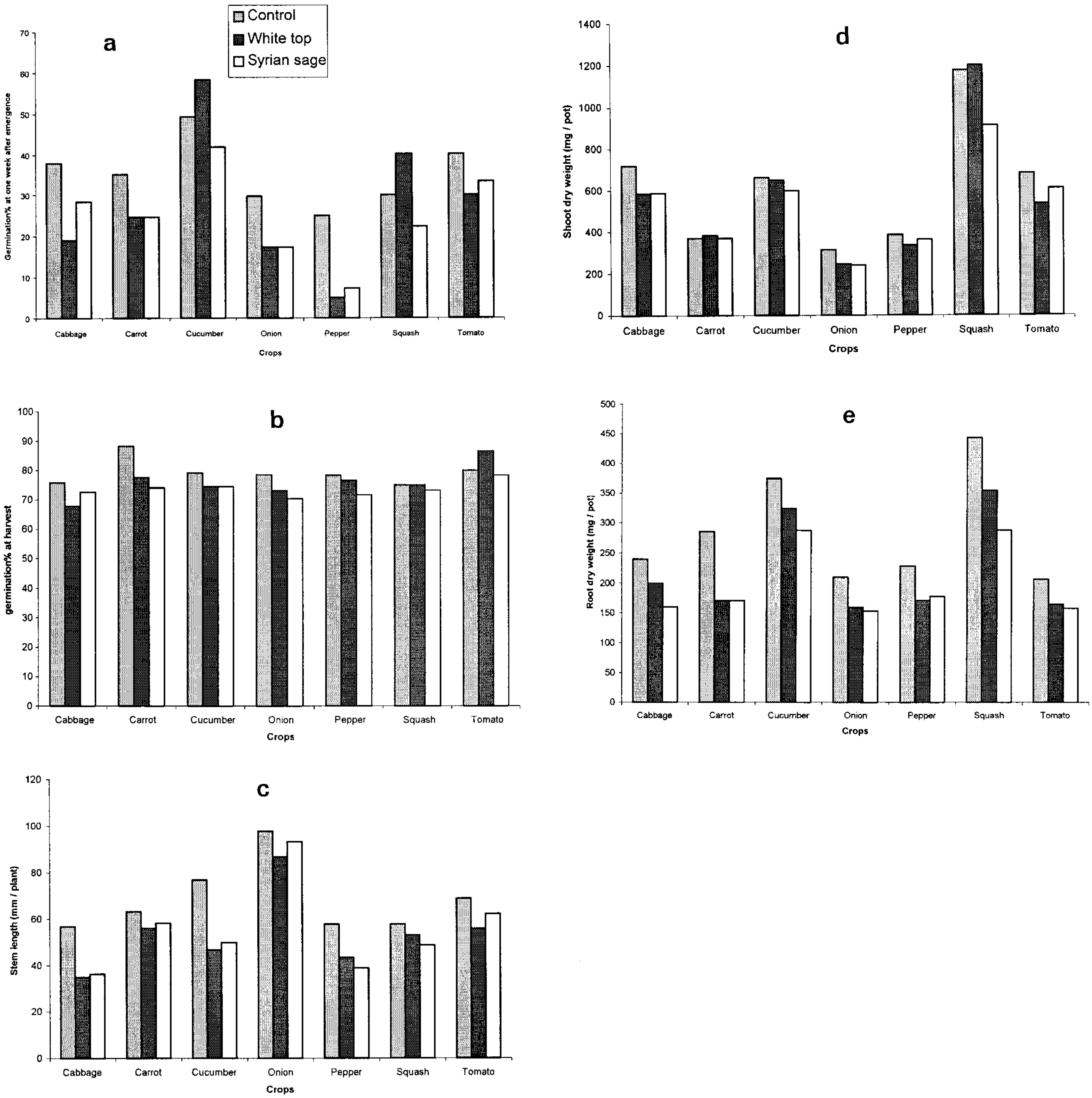

Fig. 2. Effect of root exudates of white top and Syrian sage on (*a*) germination at 1 wk after emergence, (*b*) germination at harvest, (*c*) stem length, (*d*) shoot dry weight, and (*e*) root dry weight of selected vegetable crops grown under glasshouse conditions.

residues enhanced growth of certain crop species, the effect of such treatment on sensitive crops was pronounced.

CONCLUSIONS

White top and Syrian sage are perennial weeds widely spread in cultivated land in Jordan. Using different experimental techniques revealed that both have allelopathic potential against different vegetable crops. The effect of root exudates, foliage leachates, volatile materials, and dried shoot residues of both weeds on germination and growth of different crop species varied.

Using closed container technique, volatile materials from Syrian sage fresh shoots significantly inhibited germination and growth of all crops except pepper, while foliage leachates of both weed species were highly toxic. Root exudates of both weed species resulted in various inhibitory actions, which were donor and receiver dependent. Allelopathic effects of both weed species on vegetable crops under field conditions merit further research.

Table 3. Effect of foliage leachates of white top and Syrian sage on stem length (SL) per plant, shoot dry weight (SHDWt.), and root dry weight (RDWt.) per pot of certain vegetable crops grown in pots.

	Cabbage			Carrot			Cucumber			Onion			Pepper			Squash			Tomato		
Weed species	SL	SHD wt.	RD wt.	SL	SHD wt.	RD wt.	SL	SHD wt.	RD wt.	SL	SHD wt.	RD wt.	SL	SHD wt.	RD wt.	SL	SHD wt.	RD wt.	SL	SHD wt.	RD wt.
	mm	mg		mm	mg		mm	mg		mm	mg		mm	mg		mm	mg		mm	mg	
Control	115	288	132	88	33	25	99	428	158	135	44	26	82	152	104	177	1093	371	167	378	105
White top	94	247	80	67	31	30	88	425	124	142	50	26	66	88	75	171	735	305	113	218	59
Syrian sage	99	247	122	81	31	23	85	273	78	131	41	23	67	74	55	154	880	309	162	288	77
LSD $P = 0.05$	14	62	23	15	6	7	10	93	22	17	11	5	11	23	24	17	142	53	13	71	17

Table 4. Effect of decayed incorporated shoot residue of white top and Syrian sage on germination (G), stem length (SL) per plant, shoot dry weight (SHDWt.), and root dry weight (RDWt.) per pot of certain vegetable crops grown under glasshouse conditions.

	Cabbage				Carrot				Cucumber				Onion				Pepper				Squash				Tomato			
Weed species	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.	G	SL	SHD wt.	RD wt.
	%	mm	mg		%	mm	mg		%	mm	mg		%	mm	mg		%	mm	mg		%	mm	mg		%	mm	mg	
Control	73	34	427	149	80	43	233	150	75	60	654	371	85	107	318	176	80	36	266	108	73	80	1287	304	70	49	284	158
White top	70	37	399	145	65	22	324	148	90	53	374	82	70	72	241	136	70	35	310	107	80	54	1131	236	75	50	231	127
Syrian sage	70	41	439	144	67	41	332	169	75	68	533	537	63	117	340	174	80	39	331	120	75	89	1461	338	80	50	236	166
LSD $P = 0.05$	13	5	74	30	12	8	61	31	15	6	70	36	11	24	60	20	11	6	36	21	11	12	211	54	12	8	25	23

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