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Research Article

Allelopathic effect of waste-land weeds on germination and growth of winter crops

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The authors declare that there is no conflict of interest regarding the publication of this manuscript.

HIGHLIGHTS

- Inhibitory effect was shown in germination and seedling growth of crops by the aqueous extracts of all weeds.
- Rhizospheric soils of parthenium and lantana reduced the germination and seedling growth of crops.
- *Parthenium hysterophorus* and *Lantana camara* exhibited the greatest allelopathic effect against oat and wheat.

ABSTRACT

Background: Waste-land weeds present around the fields exert their allelopathic influence on crops through their leaf leachates and rhizospheric soils.
Objective: A study was conducted to investigate the phytotoxic action of four common waste-land weeds *Parthenium hysterophorus* L., *Achyranthes aspera* L., *Lantana camara* L. and *Withania somnifera* L. through their aqueous extracts and rhizospheric soils against winter crops *Avena sativa* L., *Cicer arietinum* L., *Hordeum vulgare* L. and *Triticum aestivum* L.
Methods: Experiments were conducted in Agronomy laboratory in College of Agriculture at the University of Sargodha. In first experiment, 5% (w/v) water extract from entire plant of each weed was applied to germinating seeds of crops whereas in second experiment, crop seeds were subjected to the rhizospheric soil of each weed for germination test.
Results: Results revealed that aqueous extracts of weeds were more phyto-inhibitory compared to their rhizospheric soils. Minimum germination percentage (42.5%), germination index (7.4), seedling vigor index (665.3), root length (3.27 cm), seedling length (14.15 cm) and seedling biomass (74.2 mg) of crops were recorded in response to aqueous extract of *P. hysterophorus*. Root growth of the crops was affected more compared to the shoot growth. Minimum germination percentage was observed in *A. sativa* (13.3) by the action of *L. camara* aqueous extract. Rhizospheric soil of *L. camara* and *P. hysterophorus* resulted in minimum germination percentages (57.5 and 58.3, respectively) and seedling vigor indices (1472.5 and 2008.4, respectively) of crops. The lowest germination (30%) and germination index (3.7) was observed for *T. aestivum* seeds germinated in the rhizospheric soil of *W. somnifera*. Among crops, *A. sativa* and *C. arietinum* were more susceptible to the aqueous extracts whereas *T. aestivum* to rhizospheric

soils of weeds.
Conclusions: It can be concluded that waste-land weeds especially *P. hysterophorus* and *L. camara* negatively affect the crops by their allelopathy.

1 INTRODUCTION

Weed is a plant growing at a place where it is not wanted and not intentionally sown or a plant whose virtues have not yet discovered, plants that are competitive, pernicious, persistent and interfere negatively with crops production. They are primarily competing with crops for nutrient, light, space and water (Muzik, 1970). Allelopathy commonly refers to straight or circumlocutory, injurious or advantageous effect of a plant on nearby plant through during the production of chemical compounds that are released into the environment (Rice, 1984). Allelochemicals are plant's secondary metabolites that are unconfined into the environment through their leachates, volatile compounds, root exudates and decomposition products of plant residues in soil (Khalaj et al., 2013). Allelochemicals are synthesized by more or less all plants but do not have direct function in their development and reproduction (Bertin et al., 2003).

Waste-land weeds in contrast to crop-land weeds, do not interfere directly with crops but remain present in crop surroundings on field borders and water channels. Although they do not compete the crop plants but release allelochemicals into the environment adjacent to crops and therefore supposed to hamper crop growth and yield indirectly. During soil preparation, the soil underneath weeds at field border become mixed with crop field soil and inhibits the germination and growth of current and subsequent crop. Some of the commonly persistent waste-land weeds present in agro-ecological conditions of Sargodha, Pakistan are *Parthenium hysterophorus* L., *Achyranthes aspera* L., *Lantana camara* L. and *Withania somnifera* L.

Parthenium hysterophorus commonly known as parthenium is highly allelopathic in nature. Phytochemicals comes out from parthenium disturbing many plant species are phenolics, sesquiterpene and lectones (Swaminathan et al., 1990). Parthenin is the foremost sesquiterpene lactone while vanillic, caffeic, chlorogenic, anisic acids and ferulic are the chief phenolics (Batish et al., 2002; Singh et al., 2002). The phytotoxic influences on growth and germination of mungbean, soybean and maize by water extracts of parthenium were distinguished by Khan et al. (2011) and Safdar et al. (2014). *Achyranthes aspera* commonly known as prickly-chaff flower belongs to family Amaranthaceae. *A. aspera* plant has a diversity of allelochemicals like oleonolic acid, alkaloids, dihydroxy ketones, phenolics saponins, and long chain compounds which have been inaccessible from its different parts (Rameshwar and Akito, 2007; Srivastav et al., 2011). *Lantana camara* is also notorious as lanata, big sage, wild sage, red sage, white sage and tick berry. Lantana belongs to the family Verbenaceae and is one of the well-known allelopathic weed plants (Binggeli and Desalegn, 2002). Its roots, seed and leaf extracts release certain allelochemicals. Lantana can also hamper development of nearby plants by contending for soil nutrients (Dobhal et al., 2010) and subsequently change the microenvironment (e.g. light, temperature) by forming impenetrable thickets (Sharma and Raghubanshi, 2007). Allelopathic effects of *L. camara* on emergence and development of chickpea and rice was reported by Ahmed et al. (2007) and Bansal (1998). *Withania somnifera* L. belongs to family Solanaceae. It is a persistent plant also known as winter cherry or ashwagandha. Leaf extract of *W. somnifera* showed more inhibitory effect compared with stem and roots against emergence and plantlet growth of parthenium (Sherma and Puri, 2015).

Much of the attention of weed scientists remained on the crop-land weeds due to their direct interference with crops. However, very little research has yet been focused on waste-land weeds and the degree of their harmful effect on crops through leaf leachates and rhizospheric soils. To ascertain whether waste-land weeds (*P. hysterophorus*, *A. aspera, W. somnifera* and *L. camara*) exert their influence on nearby winter crops through various means, a trial was designed.

2 MATERIALS AND METHODS

Plant and soil bioassay experiments were performed to investigate the phyto-inhibitory influence of plant water extracts and soils from rhizosphere of four waste-land weeds *viz.*, parthenium (*Parthenium hysterophorus*), prickly chaff-flower (*Achyranthes aspera*), lantana (*Lantana camara*) and winter cherry (*Withania somnifera*) against four winter crops *viz.*, barley (*Hordium vulgare*), gram (*Cicer arietinum*), oat (*Avena sativa*) and wheat (*Triticum aestivum*). The study was conducted under controlled conditions in the Agronomy Laboratory of University College of

Agriculture, University of Sargodha, Pakistan during year 2015. In plant bioassay, 5% (w/v) aqueous extracts from whole plants of these weeds were applied to germinated seeds of crops whereas in soil bioassay, rhizospheric soils adjacent to roots of these weeds were used as germination media of crop seeds. Both experiments were repeated and results of the second repeat were considered and presented.

Preparation of aqueous extracts: *Parthenium hysterophorus, W. somnifera, L. camara* and *A. aspera* plants were uprooted near their maturity from the research area of University College of Agriculture, University of Sargodha, Sargodha (32.08° latitude, 72.67° longitude and 190 m altitude), Pakistan during month of March and plants specimens were brought to laboratory. They were exposed to preliminary room temperature drying and then whole plants were kept for oven-drying at 70 °C for 48 hours. Desiccated plants of each weed were chopped into small pieces (3-5 cm) and were dipped into distilled water with 1:20 (w/v) plant material: water ratio through 24 hours duration at room temperature (Hussain and Gadoon, 1981). After 24 hours they were shaken well. To obtain aqueous extract of each weed, its plant-water mixture was filtered through muslin cloth. The filtrate (aqueous extract) of each weed was preserved at room temperature.

Collection of rhizospheric soils: Soils adjacent to roots of uprooted plants of *P. hysterophorus, W. somnifera, L. camara* and *A. aspera* were collected from the investigate area of University College of Agriculture, University of Sargodha, Sargodha, Pakistan during march, 2015. The rhizospheric soil of each weed was put in separate plastic bags and kept in laboratory. Before using, soils were sieved. The 300 grams of soil was filled in each plastic pot (12 cm diameter and 6 cm depth) which was used as germination medium for crop seeds.

Germination and growth conditions: In Petri plate experiment, ten seeds, each of oat, wheat, barley and gram were sown in 9 cm diameter Petri plates with dual layer of filter paper at bottom and moistened with 3 mL of aqueous extracts of weeds. In case of control, distilled water with a same quantity was used instead of aqueous extract. In pot-based soil bioassay experiment, crop seeds were sown in rhizopheric soils of waste-land weeds filled in plastic pots with 6 cm depth and 12 cm diameter. The completely randomized design with a factorial arrangement was used for both experiments. Petri plates and pots were placed in germinator at 25 °C for 12 days.

Data recording and calculations: In both the plant and soil bioassay experiments, day by day count was performed regarding germination/emergence for the period of 12 days. After complete emergence, shoot and root lengths of crop seedlings were taken. Seedling roots and shoots were weighed after oven drying at 70 °C for 24 h. Data of daily germination/ emergence count were used to calculate a variety of vigor parameters as detailed below:

Germination/emergence percentage (GP/EP) was worked out by following formula:

$$GP/EP = [N_T \times 100]/N \qquad \text{(eq. 1)}$$

where N_T: proportion of germinated/emerged seeds in each treatment for the final measurement, and N: Number of seeds used in bioassay.

The germination/emergence index (GI/EI) was worked out by formula as described by as described by Scott et al. (1984):

$$GI/EI = N1/D1 + \cdots \ldots .. + NL/DL \qquad \text{(eq. 2)}$$

where N_1: number of seeds germinated/emerged on 1st count, D_1: days to 1st count, N_L: number of seeds germinated/emerged on last count, and D_L: days to last count.

Mean germination/emergence time (MGT/MET) was worked out by equation as given by Dezfuli et al. (2008):

$$MGT/MET = \sum Dn/\sum n \qquad \text{(eq. 3)}$$

where n: Number of seeds which were germinated/ emerged on day D, D: Number of days counted from the beginning of germination/ emergence.

Time to 50% germination/emergence (T_{50}) was worked out according to the formula modified by Farooq et al. (2005):

$$T50 = ti + \{(N/2) - ni\}(tj - ti)/nj - ni \qquad \text{(eq. 4)}$$

where N: final number of germination/emergence, n_i, n_j: cumulative number of seeds germinated/emerged by adjacent counts at times t_i and t_j when $n_i < N/2 < n_j$.

Seedling vigor index (SVI)was worked out by the formula as described by Orchard (1977):

$$SVI = \text{seedling length (cm)} \times \text{germination percentage}$$

Data Analysis: Recorded data were analyzed statistically by using Fisher's analysis of variance technique by Statistix 8.1 software program on computer. The least significant difference test was used for mean separation at 0.05 (5%) probability level (Steel et al., 1997).

3 RESULTS AND DISCUSSION

Plant bioassay: Data presented in Table 1 indicated that different germination parameters including germination percentage (GP), germination index (GI), mean germination time (MGT) and time to 50% germination (T_{50}) of crops were affected significantly by water extracts of weeds. Among weeds, *P. hysterophorus* and *L. camara* imparted the highest inhibitory effect as aqueous extracts of these weeds resulted in significantly lower GP (42.5 and 50.8%) and GI (7.4 and 9.5), respectively in crops. The GP of these treatments was reduced to 52 and 34% compared to the distilled water (control). The weed-specific crop germination response as revealed by the weed × crop interaction means showed *A. sativa* to be the most sensitive crop regarding germination percentage to all weeds. This is manifested by its lowest GP (13.3 to 23.3%) and GI (5.0) beneath the influence of aqueous extracts of weeds. The GP of *C. arietinum* by the application of *P. hysterophorus* extract remained statistically at par with these values. Among crops, *A. sativa* and *C. arietinum* were proved to be the most susceptible to phytotoxic inhibitory effect of weeds as seeds of these crops showed the maximum values of MGT (3.9 and 3.7 d, respectively) and T_{50} (3.3 d) that were significantly different from those of other crops. Data concerning growth of crops as affected by water extracts of weeds are shown in Table 2. All the weeds except *W. somnifera* expressed significant inhibitory effect in seedling biomass of crops by producing their lowest seedling biomasses (63.33, 74.17 and 81.67 g) in response to *A. aspera*, *P. hysterophorus* and *L. camara*, respectively. However, the values of crop seedling lengths remained 14.2, 16.5 and

Table 1 - Germination of winter crops as affected by aqueous extract of waste-land weeds

Treatment	Crop	GP (%)	GI	MGT	T50
Distilled water (Control)	*T. aestivum*	96.6 a	19.8	2.5	2.1
	H. vulgare	96.6 a	19.6	2.5	2.0
	A. sativa	86.6 abc	11.2	4.9	4.3
	C. arietinum	80.0 abcd	10.4	4.9	4.2
P. hysterophorus	*T. aestivum*	63.3 cdef	11.5	2.8	2.5
	H. vulgare	60.0 def	10.1	3.3	2.8
	A. sativa	23.3 gh	4.1	3.2	2.9
	C. arietinum	23.3 gh	3.9	2.8	2.7
W. somnifera.	*T. aestivum*	86.6 abc	17.3	2.4	2.2
	H. vulgare	93.3 a	15.7	2.9	2.7
	A. sativa	20.2 gh	4.4	3.0	1.9
	C. arietinum	66.6 bcde	11.3	2.9	2.7
L. camara.	*T. aestivum*	90.9 ab	18.5	2.3	2.1
	H. vulgare	50.0 ef	11.1	2.9	2.7
	A. sativa	13.3 h	1.3	5.2	5.0
	C. arietinum	50.0 ef	7.2	4.1	3.9
A. aspera	*T. aestivum*	93.3 a	15.5	3.1	2.4
	H. vulgare	93.3 a	16.6	3.1	2.4
	A. sativa	23.3 gh	3.9	2.8	2.5
	C. arietinum	40.0 fg	5.9	3.6	3.0
LSD		24.84	NS	NS	NS
Weed means		GP (%)	GI	MGT	T50
Distilled water (Control)		90.0 a	15.3 a	3.7	3.2
P. hysterophorus		42.5 d	7.4 d	3.0	2.7
W. somnifera		66.6 b	12.2 b	2.8	2.3
L. camara.		50.8 cd	9.5 cd	3.6	3.4
A. aspera		62.5 bc	10.5 bc	3.1	2.6
LSD		12.42	2.5	NS	NS
Crop means		GP (%)	GI	MGT	T50
T. aestivum		86.0 a	16.5 a	2.6 c	2.3 b
H. vulgare		78.6 a	14.6 a	2.9 bc	2.5 b
A. sativa		33.3 c	5.0 c	3.9 a	3.3 a
C. arietinum		52.0 b	7.7 b	3.7 ab	3.3 a
LSD		11.11	2.23	0.79	0.74

In a column, values not sharing same letter(s) are significantly different at $P \leq 0.05$, GP = germination percentage, GI = germination index, MGT = mean germination time, T_{50} = time to 50% germination, NS = Non-significant.

Table 2 - Growth parameter of crops as influenced by the aqueous extract of different weeds

Treatment	Crop	SL	RL	SDW	RDW	SDL	SB	SVI
Distilled water (Control)	*T. aestivum*	11.7	11.3 bc	83.3 abc	56.7 abc	23.9 bcd	140.0	2306.8 bc
	H. vulgare	17.4	18.5 a	90.0 ab	73.3 a	34.1 a	163.3	3300.7 a
	A. sativa	13.6	10.8 bcd	60.0 abcde	26.7 defg	25.7 abc	86.7	2211.7 bc
	C. arietinum	1.5	1.7 g	23.3 ef	33.3 cdef	3.2 h	56.7	259.7 g
P. hysterophorus	*T. aestivum*	13.3	4.5 efg	66.7 abcde	50.0 abcd	19.8 cde	116.7	1256.6 e
	H. vulgare	16.0	4.0 efg	63.3 abcde	30.0 defg	19.0 cdef	93.3	1026.6 ef
	A. sativa	10.0	3.1 fg	23.3 ef	6.7 g	15.0 def	30.0	314.0 ef
	C. arietinum	0.85	1.5 g	46.7 bcdef	10.0 fg	2.7 h	56.7	64.0 g
W. somnifera.	*T. aestivum*	14.3	10.0 bcd	70.0 abcd	43.3 bcd	23.8 bcd	113.3	2057.2 cd
	H. vulgare	18.5	6.9 def	103.3 a	40.0 bcde	26.9 abc	143.3	2325.5 bc
	A. sativa	8.2	1.8 g	10.0 f	16.7 efg	10.0 fgh	26.7	203.6 g
	C. arietinum	2.5	3.1 fg	40.0 cdef	36.7 bcde	5.3 gh	76.7	348.2 fg
L. camara.	*T. aestivum*	16.8	10.8 bcd	103.3 a	60.0 ab	29.1 ab	163.3	2599.2 abc
	H. vulgare	19.3	12.2 b	73.3 abcd	26.7 defg	29.5 ab	100.0	1417.7 de
	A. sativa	6.3	4.3 efg	6.7 f	6.7 g	10.6 fgh	13.33	105.7 g
	C. arietinum	2.1	2.5 g	33.3 def	16.7 efg	5.4 gh	50.0	281.5 fg
A. aspera	*T. aestivum*	15.9	8.6 bcd	63.3 abcde	46.7 bcd	25.3 abc	110.0	2943.5 ab
	H. vulgare	13.8	7.9 cde	50.0 bcdef	33.3 cdef	22.1 bcde	83.3	2045.2 cd
	A. sativa	9.2	3.4 fg	13.3 f	6.7 g	14.0 efg	20.0	350.4 fg
	C. arietinum	1.3	1.9 g	23.3 ef	16.7 efg	3.3 h	40.0	123.4 g
LSD		NS	4.02	46.3	23.6	N.S	NS	750.3
Weed means		SL	RL	SDW	RDW	SDL	SB	SVI
Distilled water (Control)		11.0	10.6 a	64.2 a	47.5 a	21.7 a	111.67 a	2019.7 a
P. hysterophorus		10.0	3.3 c	50.0 ab	24.2 b	14.2 b	74.17 b	665.3 c
W. somnifera		11.0	5.5 b	55.8 ab	34.2 b	16.5 b	90.00 ab	1233.6 b
L. camara.		11.1	7.4 b	54.2 ab	27.5 b	18.7 ab	81.67 b	1101.0 b
A. aspera		10.0	5.4 b	37.5 b	25.8 b	16.2 b	63.33 b	1365.6 b
LSD		NS	2.01	23.2	11.8	4.5	28.30	375.2
Crop means		SL	RL	SDW	RDW	SDL	SB	SVI
T. aestivum		14.5 a	9.0 a	77.3 a	51.3 a	24.4 a	128.67 a	2232.6 a
H. vulgare		17.0 a	9.9 a	76.0 a	40.7 b	26.3 a	116.67 a	2023.2 a
A. sativa		9.5 b	4.7 b	22.7 b	12.7 c	15.0 b	35.33 b	637.1 b
C. arietinum		1.6 c	2.1 c	33.3 b	22.7 c	4.0 c	56.00 b	215.4 c
LSD		2.73	1.79	20.7	10.6	4.1	25.31	335.5

Value having different letters show significant difference ($P \leq 0.05$), SL=shoot length, RL=root lenght, SFW=shoot fresh weight, RFW=root fresh weight, SDW=shoot dry weight, RDW=root dry weight, SDL=seedling length, SVI=seedling vigor index, SB=seedling biomass, NS= Non-significant.

16.2 mm by growing their seeds in aqueous extracts of *P. hysterophorus, W. sominfera and A. aspera*, respectively that were significantly lower than the distilled water treated control. The root growth of crop seedlings was more suppressed than their shoot growth by the phytotoxic effect of weeds. Seedling vigor index of crop was also significantly reduced in response to the aqueous extracts of all weeds in comparison to control. Among crops, seedling growth of *C. arietinum* and *A. sativa* were proved to be more susceptible to phytotoxic action of weeds aqueous extracts.

The higher deleterious effect of *P. hysterophorus* and *L. camara* on germination and seedling growth of crops was probably due to the strong allelopathic potential caused by their aqueous extracts. Rashid et al. (2008) also reported a decline in the seed germination of barley due to the application of parthenium extract. Safdar et al. (2014) also reported significant phytotoxic action of various parts of parthenium plant against emergence and seedling growth of maize. In addition, the strong allelopathic effect of water extracts of all parts of plant *L. camara* on the emergence of *Pennisetum americanum*, *Lactuca sativa*, *Setaria italica* and *Vigna radiata* has also been demonstrated by Hussain et al. (2011) and Maiti et al. (2010).

Soil bioassay: Data showing the effect of rhizospheric soils of wasteland weeds on emergence and growth of crops have been presented in Tables 3 and 4, respectively. Data indicated that significant reductions in GP of crops was observed in seeds sown in rhizospheric soils of *L. camara* and *P. hysterophorus* that were 32.35 and 31.4% lower than the control (Table 3). However, crops germination speed in terms of MGT and T_{50} was significantly enhanced in rhizospheric soils of all weeds compared to the control soil. Whereas, there was no effect of rhizopheric soils of wasteland weeds on GI of crop seeds. Among crops,

Table 3 - Germination of crops as influenced by rhizospheric soil of different weeds

Treatment	Crop	GP (%)	GI	MGT	T50
Distilled water (Control)	*T. aestivum*	83.3	11.2	4.6	3.7
	H. vulgare	96.7	15.2	3.2	2.8
	A. sativa	76.7	10.1	4.9	4.2
	C. arietinum	83.3	9.9	5.1	4.4
W. somnifera	*T. aestivum*	30.0	3.7	4.3	4.2
	H. vulgare	96.7	17.0	2.8	2.4
	A. sativa	96.7	16.5	3.0	2.5
	C. arietinum	73.3	12.7	2.9	2.3
A. aspera.	*T. aestivum*	50.0	9.8	2.9	2.1
	H. vulgare	80.0	14.2	2.9	2.8
	A. sativa	86.7	14.8	3.2	2.8
	C. arietinum	43.3	9.7	3.3	2.9
L. camara.	*T. aestivum*	33.3	4.8	2.4	2.3
	H. vulgare	73.3	10.5	3.8	3.5
	A. sativa	80.0	12.6	3.7	3.5
	C. arietinum	43.3	8.5	2.5	2.2
P. hysterophorus	*T. aestivum*	46.7	7.3	3.3	2.9
	H. vulgare	40.0	13.1	2.8	2.6
	A. sativa	90.0	14.9	3.1	2.7
	C. arietinum	56.7	9.5	3.2	2.9
LSD		NS	NS	NS	NS
Weed means		**GP (%)**	**GI**	**MGT**	**T50**
Distilled water (Control)		85.0 a	11.6	4.4 a	3.8 a
W. somnifera		74.2 ab	12.5	3.3 b	2.8 b
A. aspera		70.0 abc	12.1	3.1 b	2.7 b
L. camara.		57.5 c	9.1	3.1 b	2.8 b
P. hysterophorus		58.3 bc	11.2	3.1 b	2.8 b
LSD		16.4	NS	0.78	0.83
Crop means		**GP (%)**	**GI**	**MGT**	**T50**
T. aestivum		48.7 c	7.4 b	3.5	3.0
H. vulgare		77.3 ab	14.0 a	3.1	2.8
A. sativa		86.0 a	13.8 a	3.6	3.1
C. arietinum		64.0 b	10.1 b	3.4	2.9
LSD		14.6	3.21	NS	NS

In a column, value with different letters show significant difference ($P \leq 0.05$), GP= germination percentage, GI= germination index, MGT= mean germination time, T_{50} = time to 50% germination.

T. aestivum and *C. arietinum* were proved to be sensitive to allelopathic effect of rhizospheric soils of weeds as these crops gave significantly lower GP (48.7 and 64%, respectively) than other crops. However, these crops hastened their germination by showing significantly the lower GI (7.4 and 10) compared to the rest of crops. Regarding seedling growth, shoot length of crops was significantly reduced by sowing their seeds in rhizospheric soils of *A. aspera* (16.9 mm), *L. camara* (18.6 mm) and *P. hysterophorus* (18.1 mm) (Table 4). However, significantly lower root lengths (6.6 and 10.8 mm) and seedling lengths (25.2 and 27.7 mm) were measured from seeds sown in rhizospheric soils of *L. camara* and *A. aspera,* respectively. While, the seedlings germinated in rhizospheric soil of *L. camara* showed the lowest seedling vigor index (1472.5) that varied significantly among weeds. It is also obvious from the data that phytotoxic inhibitory effect of rhizospheric soils of weeds was more pronounced against shoot growth than root growth of crop seedlings.

The decrease in germination percentage and seedling length of crops in response to rhizospheric soils of weeds seems to be the deleterious effect of allelochemicals present in those soils. However, phytotoxic substances present in minute concentration in soils could be responsible for the little inhibitory or triggering effect on germination parameters like MGT and T_{50}.Safdar et al. (2014) found the presence of total and individual phenolic concentrations in rhizospheric soils of *P. hysterophorus* considerably lower than those detected in the water extracts of different plant parts. The reduction in germination percentage and seedling growth in maize due to the toxic effect of rhizospheric soil of *P. hysterophorus* has also been noticed by Safdar et al. (2014). Biswas et al. (2010) reported that emergence of rice seedlings was significantly reduced by different concentrations of

Table 4 - Growth parameters of crops as influenced by the rhizospheric soils of different waste-land weeds

Treatment	Crop	SL	RL	SDW	RDW	SDL	SB	SVI
Distilled water (Control)	*T. aestivum*	13.9	7.4 efg	90.0	20.0	21.3	110.0	1767.6
	H. vulgare	19.2	10.5 cdefg	116.7	100.0	29.7	216.7	2854.7
	A. sativa	12.8	8.8 defg	80.0	80.0	21.5	160.0	1643.1
	C. arietinum	21.3	16.4 bc	296.7	483.3	38.3	780.0	3276.7
W. somnifera	*T. aestivum*	16.4	10.4 cdefg	16.7	10.0	26.8	26.7	830.6
	H. vulgare	20.2	18.9 b	120.0	283.3	39.1	403.3	3790.7
	A. sativa	14.9	10.4 cdefg	66.7	143.3	25.3	210.0	2440.1
	C. arietinum	26.0	14.7 bcd	456.7	710.0	40.6	1166.7	3105.7
A. aspera.	*T. aestivum*	19.4	12.4 bcdef	63.3	110.0	31.8	173.3	1590.3
	H. vulgare	19.9	13.0 bcdef	200.0	163.3	32.9	363.3	2689.7
	A. sativa	17.8	6.1 fg	63.3	66.7	23.9	130.0	2114.0
	C. arietinum	35.8	26.7 a	290.0	443.3	62.4	733.3	3809.7
L. camara.	*T. aestivum*	14.4	7.4 efg	46.7	23.3	21.8	70.0	1095.6
	H. vulgare	14.5	4.5 g	73.3	96.7	19.0	170.0	1444.5
	A. sativa	15.3	4.4 g	70.0	180.0	19.7	250.0	1589.7
	C. arietinum	30.2	10.2 cdefg	316.7	730.0	40.5	1046.7	1760.2
P. hysterophorus	*T. aestivum*	14.4	14.5 bcde	33.3	80.0	30.3	113.3	1504.5
	H. vulgare	18.3	14.8 bcd	63.3	70.0	33.1	133.3	2232.0
	A. sativa	14.4	6.4 fg	196.7	20.0	20.9	216.7	1883.1
	C. arietinum	23.9	19.5 ab	290.0	600.0	43.4	890.0	2414.0
LSD		NS	7.23	NS	NS	NS	NS	NS
Crop means		SL	RL	SDW	RDW	SDL	SB	SVI
T. aestivum		16.0 b	10.4 bc	50.0 b	48.7 b	26.4 bc	98.7 b	1357.7 b
H. vulgare		18.4 b	12.4 b	114.7 b	142.7 b	30.8 b	257.3 b	2602.3 a
A. sativa		15.0 b	7.2 c	95.3 b	98.0 b	22.3 c	193.3 b	1934.0 b
C. arietinum		27.5 a	17.5 a	330.0 a	593.3 a	45.1 a	923.3 a	2873.3 a
LSD		3.85	3.23	88.25	191.02	6.44	234.07	655.24
Weed means		SL	RL	SDW	RDW	SDL	SB	SVI
Distilled water (Control)		23.2 a	14.6 a	154.1	195.8	37.8 a	350.0	2550.9 a
W. somnifera		19.4 ab	13.6 ab	165.0	286.7	32.3 ab	451.7	2541.8 a
A. aspera		16.9 b	10.8 b	145.8	170.8	27.7 bc	316.7	2385.5 a
L. camara.		18.6 b	6.6 c	126.6	257.5	25.2 c	384.2	1472.5 b
P. hysterophorus		18.1 b	13.8 ab	145.8	192.5	31.9 abc	338.3	2008.4 ab
LSD		4.31	3.61	NS	NS	7.20	NS	732.58

Value having different letters show significant difference ($P \leq 0.05$), SL=shoot length, RL=root length, SFW=shoot fresh weight, RFW=root fresh weight, SDW=shoot dry weight, RDW=root dry weight, SDL=seedling length, SVI=seedling vigor index, SB=seedling biomass.

P. hysterophorus weed debris. Enyew and Raja (2015) reported that *L. camara* leaf powder mixed in soil with 2.5, 5.0 and 7.5% (w/v) ratios significantly inhibited the germination index, stem thickness, seedling biomass, shoot and root lengths, and germination percentage of wheat and maize crops owing to its strong allelopathic nature. Previous studies also showed that rhizospheric soils of weeds due to their enrichment with allelochemicals caused growth inhibition by reduction in cell division (Hussain et al., 1984; Rice, 1984; Putnam and Chung-Shih, 1986).

4 Conclusions

In terms of germination and seedling growth inhibition among winter crops, *P. hysterophorus* and *L. camara* could be ranked first. However, *P. hysterophorus* imparted the maximum phyto-inhibition through its aqueous plant extract whereas *L. camara* through its rhizospheric soil. The overall inhibitory effect of aqueous plant extracts of weeds was more pronounced than their rhizospheric soils. Similarly, crops showed a higher suppression in their root growths in response to weed aqueous extracts whereas shoot growths in response to their rhizospheric soils. Among crops, *A. sativa, C. arietinum* and *T. aestivum* were more susceptible to allelopathicity of weeds.

5 Contributions

MSH: performed the experiments, data collection, analyzed the data, MES: designed the experiments, manuscript writing, MA: revised the manuscript, AT: final reading and approval, RQ and LA: interpreted the results, HHA, NF, HMRJ and ZHT: literature review and literature search.

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