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Effects of African purslane (*Zaleya pentandra* L.) on germination and seedling growth of maize

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ABSTRACT

African purslane (*Zaleya pentandra* L. Aizoaceae family) significantly affects the germination and growth of other plants. We determined the effects of aqueous extract and plant residues of African purslane on the seed germination and growth of maize in the laboratory and pot culture. In preliminary experiments, roots and leaves exhibited the positive and negative phytotoxic effects on maize. Hence the extracts of root and leaves were diluted to 1,2,3,4% concentrations. The lower concentrations of soil incorporated residues of African purslane were stimulatory to the growth of maize, whereas at the higher concentrations were inhibitory. Residues incorporated at 1% significantly increased the root, shoot length, fresh and dry biomass and seedling vigour of maize, 4% dose decreased all these parameters. In laboratory bioassay, the higher concentration of root extract (5%) stimulated the seedling growth, while leaves and whole plant extracts reduced the growth indices of maize. Chemical analysis of weed extract was done to identify the allelochemicals responsible for our results. The chemical analysis showed the presence of significant amount of water-soluble phenolics in extracts of African purslane. The content of total phenolic acids was higher in the leaf extract than other parts. The high phytotoxic ability of African purslane suggests that this species may cause more problems in future, if not managed well.

Keyword: African purslane, allelopathy, germination, maize, seedling growth, stimulation, weed residues, *Zaleya pentandra* L.

INTRODUCTION

Allelopathy is a phenomenon, in which plants release chemical compounds called "allelochemicals" in the soil through various modes viz., root exudation, volatilization, leaching and decomposition of plant residues (4,21,22,25). These allelochemicals have the potential to modify the plant growth and community structure (3,15,24,27). Decomposing plant residues, plant extracts and leachates have been not investigated for allelopathy in agriculture as crop management tool. Toxins released from the plant residues inhibits the seed germination and seedling growth of many plants (24,36). Plant leachates affect the seed germination and early seedling growth (3,4,6,19,31,34) and decrease radicle growth (5,7). The allelochemicals at lower conc can promote the growth of neighboring species.

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The cultivated plant's yield is decreased by weed-crop interference either in the form of competition or through allelopathic interactions. Each weed affects the germination, seedling emergence, vegetative growth and yield of crops (4,9,16,23,24,27, 28,34,38). African Purslane (Family Aizoaceae, native to Africa) is major invasive weed species in agricultural lands in Arabian Peninsula, Palestine, Iran, India, Pakistan (35) Zambia, Zimbabwe, Madagascar and South Africa (13). It has about 127 genera and 2500 species (32,36). No research has been done on its residual phytotoxic effects on germination, seedling emergence and vegetative growth of many crops (30,26). Much research has been done on weeds allelopathy, but no work has been done on the phytotoxicity of African purslane against cereals. This study aimed to determine the influence (either stimulatory or inhibitory) of allelochemicals present in African purslane on the germination and seedling establishment of maize.

MATERIAL AND METHODS

The greenhouse study was conducted at the Islamia University of Bahawalpur, Bahawalpur [29.3956° N, 71.6836° E and 116 msl, temp. 32 ºC], Pakistan during 2014. The greenhouse received natural solar light. The Plastic pots (15 x 12 cms) were filled with sieved, air dried and well-mixed soil [0.726-2.10% organic matter and soil nitrogen about 0.040%] from our Research Farm. The fully mature plants (5 kg) of African purslane and sample soils and the weeds were collected in April 2014. The plant samples were collected at maturity from 10-random sites from the Islamia University of Bahawalpur, Bahawalpur. Whole plants were dug up carefully using a digging fork to loosen the nearby soil. Plants were shade dried and chopped into 2-4 cm pieces and promptly mixed with the soil in situ at 1, 2, 3, and 4% (w/w) to prevent volatilization of allelochemicals.

Pot culture

The pot culture was done during September 2014. Maize 'hybrid 3062' developed by Pioneer seeds (Ltd.) was used as a test crop. The uniform and healthy seeds were surface sterilized with sodium hypochlorite solution (10% ratio) for 15 min and rinsed thrice with sterile distilled water. Ten seeds were sown per Pot, after the complete decomposition of residues (2 months after soil incorporation). The soil and plant biomass was mixed thoroughly with 10-days interval. Water was regularly applied to enhance the microbial activity. After two months, complete decomposition was confirmed when plants pieces become part of the soil. The seeds were sown in pots (1.3 kg soil per pot) at 2.5 cm distance from plant to plant. Control pot was without any residues. The pots were placed in the greenhouse (mean temp 32 ºC $\pm$ 4) for 40 days. To keep the pots moist, necessary irrigation was insured to maintain field capacity in pots during the study period. The experiment was laid out in Completely Randomized Design (CRD) with four replications. The speed of germination, germination (%), seedling vigour index, emergence %, root and shoot length, fresh and dry weight of maize were recorded. Root and shoot length was manually determined using a measuring tape, while fresh and dry weight was determined using electronic weight balance.

Emergence (%) : Emerged seedlings/total seedlings/ 100.

Seedling vigour index (SVI) was determined as under (1):

SVI = Radicle length (cm) × Emergence (%)

Aqueous extracts of African purslane

The plants were first dried at room temperature (25 ºC ±4) for seven days and then in an oven at 70 ºC for 48 h. The dried parts (roots, leaves, and whole plant) of the A. purslane plant were separated, weighed and immersed separately in tap water in 1:20 ratio (w/v) at room temperature for 24 h (14). Then filtered through 10- and 60-mesh sieves to obtain water extracts. Water was used because most allelochemicals are water soluble (29).

Detection of phytotoxins in water extracts

The water extracts were chemically analyzed on a Shimadzu HPLC system (Model SCL-10A, Tokyo, Japan) for identification and quantification of phytotoxins. The conditions of separation include column dimension-25 cm length×4.6 mm diameter, particle size of 5 µm, Diatomite- Supleco wax 10, Attenuation- 0.01 ppm, Rate of recorder-10 mm min^{-1}, Detector- SPD-10A vp-detector, Detection - UV, 280 nm, Flow rate -0.25 mL min^{-1}, Volume injection sample-50 µL, Type of column- Shim-pack CLC-Octadeyl Silicate (ODS), Mobile phase- Isocrartic;100% methanol and temperature of 25^0C. The peaks were detected by a UV detector. Standards of suspected phytotoxins (Aldrich, St Louis, USA) were run similarly for identification and quantification.

Statistical analysis

The collected data were analyzed through Analysis of Variance (ANOVA) techniques, and means of treatments were analyzed for their significance (35). Least significant difference (LSD) at ($P \leq 0.05$) was applied to those treatments where means were found significant. The data from the repeated experiments were combined because there was no time-by-treatment interaction.

RESULTS AND DISCUSSION

Lab Bioassay

Both leaf and whole plant water extracts reduced the primary root length, adventitious root length and coleoptile length. Contrarily the root extracts stimulated all parameters than control (Figure 1, 2). Our results are in accordance with findings of Shahrokhi *et al*. who showed that *Convolvulus arvensis* water extracts from leaf and stem reduced the germination of barley seeds (33). The coleoptiles length followed the increasing order: leaf < whole plant < control < root extract i.e. coleoptiles length was maximum under root extract application and minimum in leaves extract. The highest concentrations of both root and leaf extract showed the highest allelopathic effect.

The diluted extracts of leaves and roots revealed that higher concentration of leaf extract was inhibitory, while the lowest concentration (1%) increased the root and coleoptiles length (Figure 1, 2). A significant amount of water-soluble phenolics were found both in root and leaf extracts of African purslane including quericitin, frolic acid,

sinapic acid and quericitin, caffeic acid, 4-hydroxy3-methoxy benzoic acid respectively (Table 1). Root extracts proved stimulatory, showing maximum lengths at 4% concentration. While, it decreased linearly when diluted extracts (1, 2, and 3%) were applied and was minimum in control. GI and MGT showed a little significant effect at different concentrations.

Table 1. Chemical analysis of African purslane extracts

Chemical component	Concentration ($Mg\ ml^{-1}$)	Retention time (Min)
Leaves		
Quericetin	2.673	0.68
Caffeic acid	12.69	4.27
4-hydroxybenzoic acid	14.89	28.93
M-coumaric acid	20.053	0.82
Quericetin	2.673	0.68
Roots		
Quercetin	3.28	2.993
Ferulic acid	6.48	22.453
Sinapic acid	1.43	25.927

The influence of allelochemicals is manifested in germination inhibition, but can be more pronounced on the seedlings growth (22). When comparing extracts from different plant parts, the leaf extract was more inhibitory to germination and shoot length, while both whole plant and leaf extract were equally inhibited the root length and coleoptiles length of maize seedling. Differences in the allelopathic potential of various plant parts of *C. arvensis* have been observed (33) and are caused by the different concentration of allelochemicals in plant organs. The highest concentration of extracts was most inhibitory to germination and all growth parameters, while lower concentration was stimulatory. Tanveer *et al*. and Marinov-Serafimov also reported inhibitory effects of higher and stimulatory effect of lower concentrations of weed water extracts (22,36).

Pot culture

Germination: African purslane residues proved phytotoxic to the emergence of maize seeds. The seeds germination was 100% in control pots. T_1, T_2, T_3 showed 90% germination. Minimum emergence was observed in T_4**.** The maximum seedling vigour index was in T_1 (1% incorporated residues) followed by T_0 (control), whereas the least seedling vigour index was observed in 4%. The use of germination indices helps in testing the effects on the physiological processes during the germination (8). The high speed of germination leads to higher vigour. The treatments exhibited different responses to germination index. The germination index in treatment T_4 was less than all other treatments; the least value was observed in treatment T_4 when analyzed statistically (Table 2).

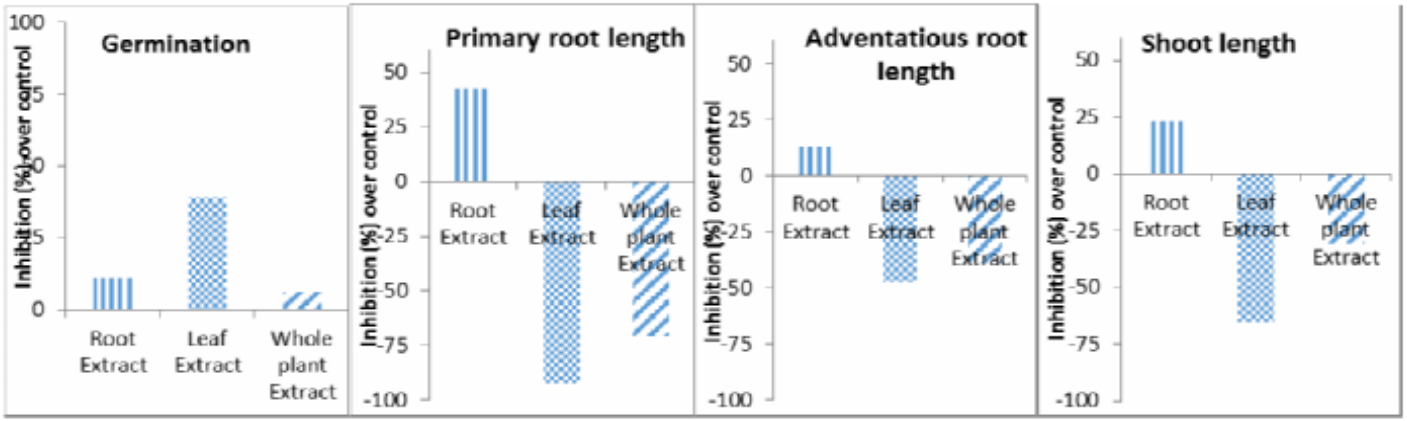

Figure 1. Effects of aqueous extract (5%) of African purslane on the growth indices of maize

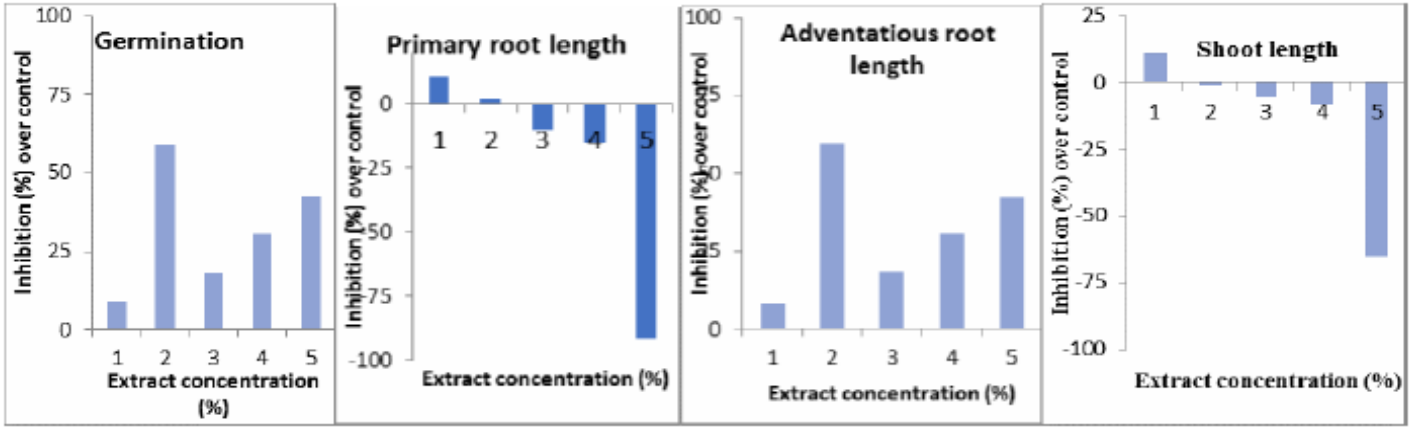

Figure 2. Effects of African purslane leaf extracts on the germination and seedling growth of maize

Table 2: Effect of different rates (%) of soil incorporated residues of African purslane on the emergence indices of maize

African purslane residues rate (%)	Seedling Vigour Index	Emergence (%)	Germination Index
Control	2046 *a	100 a	3.17 a
1%	2090 a	92 b	3.01 a
2%	1696 b	95 ab	2.82 a
3%	1869 ab	95 ab	3.01a
4%	1394 c	82 c	2.82 a
LSD	281.15	7.2803	0.38

*Means not sharing the same letter within a column differ significantly from each other at probability *p 0.05.*

Seedling growth: The allelopathic effects of soil incorporated residues of African purslane significantly affected the growth indices of maize. The lower concentration (1%) of residues stimulated all growth indices of maize. The root/shoot length and root/shoot dry weight of maize were stimulated at 1% dose soil incorporated residues than control. However, the higher doses (2%, 3%, and 4%) of soil incorporated residues suppressed the growth of maize and a linear increase in suppression was observed with increase in residues dose. The minimum values of all growth indices of maize were found at 4% dose of soil incorporated residues of African purslane (Table 3,4).

Table 3. Effects of soil incorporated residues of African purslane on the growth of maize

African purslane residues rate (%)	Root		Shoot	
	Length (cm)	Dry weight (mg)	Length (cm)	Dry weight (mg)
Control	20.47* ab	110 a	21.19 b	90 c
1%	22.62 a	80 b	24.16 a	120 a
2%	17.85 bc	50 c	21.86 ab	110 b
3%	19.74 abc	40 c	18.85 c	80 d
4%	16.88 c	30 d	15.69 d	60 e
LSD at 5 %	2.884	0.014	2.299	0.007

*Means not sharing the same letter within a column differ significantly from each other at probability *p 0.05.*

These results agree with Al-Wakeel, who reported that allelochemicals suppressed the root, shoot lengths preventing the cell division or may be due to decrease in growth stimulation (2). Results are also supported by the findings of (17) who reported the suppressive effects of extracts of sorghum and sunflower on root length of *C. intybus* as compared with control. Reduction in root length by application of African purslane might be due to inhibitory effects of allelopathic compounds present in African purslane. These findings are similar to (4,20) who proved that allelopathy may stimulate growth at low concentrations but become detrimental at higher concentration. It is known that roots are

Table 4. Effect of African purslane root extracts on the germination traits and seedling growth of maize

Treatment	Germination		Root		Shoot
	GI	MGT	Primary root (cm)	Adventitious root (cm)	Coleoptile length (cm)
Control	8.6950 bc	1.3500 b	3.3400 c*	1.0600 cd	1.7250 cd
1%	10.200 a	1.1525 b	3.0575 c	0.9775 d	1.1750 e
2%	9.3325 ab	1.1500 b	3.7800 c	1.0725 cd	1.5125 d
3%	8.4000 bc	1.3450 b	5.2250 b	1.3900 b	1.9225 bc
4%	8.9000 b	1.2500 b	9.2975 a	1.7250 a	2.4500 a
5%	7.7475 c	1.7500 a	4.7800 b	1.1975 c	2.1150 b
LSD	1.0664	0.2613	0.9970	0.1903	0.3279

*Means not sharing the same letter within a column differ significantly from each other at probability *p 0.05.*

more sensitive to allelochemicals than aerial parts of seedlings (10,28,37) presumably because they are present near decomposing residues that release allelochemicals. Impeded vegetative growth of seedling due to the phytotoxic activity of allelochemicals released by residues of swine cress resulted in lower fresh and dry weight of wheat seedlings (18). They concluded that aqueous extracts of different parts of swine-cress were inhibitory to wheat germination and seedling growth, suggesting a possible allelopathic interference under field conditions.

CONCLUSIONS

The phytotoxic effects of African purslane against maize were concentration dependent. Lower concentrations of soil incorporated residues of African purslane promoted the growth of maize, while, higher concentrations inhibited the germination and growth of maize. This study suggests that a series of experiments under controlled as well as field conditions should be conducted to determine the phytotoxic effects of this weed against other associated weeds of maize.

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