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ALLELOPATHIC IMPACT OF SORGHUM AND SUNFLOWER ON GERMINATION AND SEEDLING GROWTH OF SUMMER BROADLEAF WEEDS

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ABSTRACT

Allelopathy is the releasing of certain compounds by one plant species which may suppress the germination and growth of neighbouring plants of another species. It offers a great potential for weed management. The laboratory bioassays were conducted for two consecutive years to assess the allelopathic potential of sorghum and sunflower during Kharif (summer) 2010 and 2011 under completely randomized design with three replications. The treatments comprised of control (check), sorghum and sunflower root/shoot powder applied @ 10 g kg^{-1} soil, and sorghum and sunflower root/shoot water extract applied @ 10 ml kg^{-1} soil. The data illustrated that water extracts and powders of allelopathic crops significantly reduced germination and growth of selected weeds: Waho (carpet weed: *Trianthema portulacastrum* L.), Lulur (false amaranth: *Digera arvensis* Forsk.) and Naro (field bindweed: *Convolvulus arvensis* L.). Sorghum and sunflower shoot water extracts exhibited strong allelopathic efficacy. These treatments conferred lowest and statistically equal ($P \geq 0.05$) values for germination, root length, shoot length, and fresh and dry biomass of tested weeds. The water extracts of sorghum and sunflower shoots and roots caused greater inhibitory effects on weeds as compared to powder treatments. Hence, the results suggest that sorghum and sunflower contain allelopathic effect with growth suppressing potential, and their herbage can be applied through water extract or soil incorporation for effective management of summer broadleaf weeds.

Keywords: Allelopathy, germination, growth, sorghum, sunflower, weeds.

INTRODUCTION

Weeds are one of the major biotic constraints in crop production system. The weeds interfere with crop plants through competition for moisture, nutrients, space, light and CO_2 through allelopathy. Allelopathic weeds cause adverse effects on crop plants by releasing phytotoxic compounds through root exudation,

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decomposition of residues, leachates and volatilization (Tanveer *et al*., 2010). Weeds reduce crop yield, deteriorate quality of produce and also increase the cost of production and harvesting (Cheema *et al*., 2010). One of the major causes of low yield of crops in our conditions is severe infestation by weeds. Narrow leaf weeds (Johnson grass, purple nutsedge, bermuda grass and jungle rice) cause heavy yield loss to narrow leaf crops (maize, rice and sugarcane) whereas, broadleaf weeds (carpet weed, field bindweed and false amaranth) have been causing heavy losses to broadleaf crops (cotton and cluster bean) due to similar leaf morphology and requirements for growth factors (Ali *et al.*, 2013). Many weeds infest summer crops, cotton, sugarcane, rice, maize, millet, sesame and cluster bean. Among broadleaf weeds, Waho (carpet weed: *Trianthema portulacastrum* L.), Lulur (false amaranth: *Digera arvensis* Forsk.) and Naro (field bindweed: *Convolvulus arvensis* L.) are considered noxious ones (Memon *et al*., 2014). Weeds are unintentionally sown plant species and their management is very essential for obtaining potential yield of any crop. Weed management through manual methods is a costly task (Hozayn *et al*., 2011). Unwise and excessive use of herbicides has been found one of the causes of environmental pollution (Jabran *et al*., 2010).

Allelopathy has recently been recognized as cheap, eco-friendly and sustainable strategy for effective management of weeds, and it involves mostly farm produce materials (Iqbal and Cheema, 2009). Any direct or indirect inhibiting effect of one plant species on neighbouring plants of another species through release of phytotoxic compounds is termed as allelopathy (Weston *et al*., 2013). The allelopathic crops contain compounds with phytotoxic ability in their aerial and underground parts like leaves, flowers, seeds, stems and roots (Tesio and Ferrero, 2010) in varying concentrations. Sorghum and sunflower are reported to have high allelopathic potential, containing several allelochemicals such as sorgoleone, glycosides, terpenoids, flavonoids, alkaloids and phenolics (Anjum and Bajwa, 2008; Iqbal and Cheema, 2008). Allelochemicals reduce water and nutrients uptake by roots and inhibit photosynthesis, respiration, protein synthesis, cell division and thickness of seminal roots as well as cause slow maturation and delay or failure of reproduction (Jafariehyazdi and Javidfar, 2011). Sorgoleone is primarily an inhibitor of plant growth through inhibition of photosynthesis and respiration (Duke *et al*., 2007). Flavonoids and phenolics suppressed the germination and growth of several plants (Sadeghi *et al*., 2010). Allelopathic compounds secreted by sunflower suppressed the germination and growth by interruption of metabolic activities of wheat plant cells (Macias *et al*., 2002). Sunflower inhibited seed germination, growth and biomass of *Trianthema portulacastrum* (L.) (Mahmood *et al*., 2010) and *Digera arvensis* (Asgharipour, 2011). Sorghum reduced density and biomass of *Trianthema portulacastrum* (L.) and *Convolvulus arvensis* (L.) (Khalil *et al*., 2010). Laboratory experiments are considered very essential and helpful in evaluating the allelopathic properties of a plant (Sadeghi *et al*., 2010). The most common laboratory bioassays for phytotoxic compounds are conducting experiments on seed germination and growth. When sensitive plants are exposed to compounds with allelopathic properties, the germination and growth of these plants is depressed (Nouri *et al*., 2012). Allelopathic potential of different parts of plant may vary from each other

(Peng *et al*., 2004). Aquatic extract of various parts of allelopathic plants showed substantially inhibitory influences on weed growth (Ashraf and Akhlak, 2007). Narwal *et al*. (2005) reported that sorghum roots exudates (sorgoleone) decreased growth of chick weed, shepherd's purse and sesame.

Research has been done on utilizing allelopathic properties of crops and weeds to control different weeds in recent years under different agro-ecological conditions of the world including Pakistan. Research on weed control through sorghum and sunflower allelopathy has resulted in enhanced yield of crops (Khan *et al*., 2015). There is little or no information available on utilizing allelopathic properties of plants including sorghum and sunflower for weed management in crops under agro-ecological conditions of Sindh, Pakistan. The research on weed management in different crops in our province is being conducted through mechanical, manual and chemical methods (Chachar *et al*., 2009). Traditional methods i.e. hand pulling, hand hoeing and interculturing are mainly applied for weed control in cotton and other crops in Sindh. However, with the increased cost of manual labour, shifting of people from rural areas to urban areas, and the reluctance of younger labour to do this low profile job, it is becoming more expensive and difficult to control weeds in cotton. Similarly, the application of herbicides is causing environmental pollution and human health hazards (Cheema *et al*., 2010). Allelopathy offers a great potential for weed management. The allelopathic effects are species specific and concentration dependent (Duke *et al*., 2007). The implications of allelopathy for weed management need to be understood well again. Therefore, the present study was planned with the objectives, (1) to evaluate the allelopathic potential of sorghum and sunflower powder and water extract on broadleaf weeds, (2) to assess the allelopathic potential of sorghum and sunflower above ground and underground parts, and (3) to find out the germination and seedling growth of weeds in response to sorghum and sunflower allelopathy.

MATERIALS AND METHODS

The laboratory bioassays were conducted for two consecutive years (2010 and 2011) at Seed Testing Laboratory, Department of Agronomy, Faculty of Crop Production, Sindh Agriculture University, Tandojam, Pakistan during Kharif (summer). The experiment was laid out in a three replicated completely randomized design. The aluminum boxes (pots) having size of 30 cm x 15 cm x 15 cm were filled with 5 kg of soil and moistened with water. Propagatory material of weeds was sown on 1st May of each year. The boxes were placed at room temperature. The maximum, minimum and average temperature, and relative humidity during growth period of weeds was 43.2/42.6 ^{0}C, 24.3/26.7 ^{0}C and 33.7/34.6 ^{0}C, and 54.5/64.5% during 2010/2011, respectively. Three most common and noxious broadleaf weeds viz. Waho (*Trianthema portulacastrum* L.), Lulur (*Digera arvensis* Forsk.) and Naro (*Convolvulus arvensis* L.) of summer crops were evaluated against the allelopathic efficacy of sorghum and sunflower root / shoot powder and water extract. A control treatment (with no allelopathic material) was also included in the experiment. The treatments detail is given as under:

T1 = Control (check)
T2 = Sorghum root powder @ 10 g kg^{-1} soil
T3 = Sorghum shoot powder @ 10 g kg^{-1} soil
T4 = Sorghum root water extract @ 10 ml kg^{-1} soil
T5 = sorghum shoot water extract @ 10 ml kg^{-1} soil
T6 = Sunflower root powder @ 10 g kg^{-1} soil
T7 = Sunflower shoot powder @ 10 g kg^{-1} soil
T8 = Sunflower root water extract @ 10 ml kg^{-1} soil
T9 = Sunflower shoot water extract @ 10 ml kg^{-1} soil

Soil and herbage collection

The soil used for the experiment was collected from Latif farm, Sindh Agriculture University, Tandojam, Pakistan. The soil was sandy loam in texture. The herbage of allelopathic crops and propagatory materials of test weeds were collected from Students' Experimental Farm, Department of Agronomy, Sindh Agriculture University, Tandojam. Sorghum and sunflower plants were uprooted at maturity, separated as roots and shoots and dried under sun until fully dried.

Powder and water extract preparation

For preparing powder, the dried roots and shoots of sorghum and sunflower were chopped into 2 cm pieces and ground to a fine powder by grinder. For preparing water extracts, the powder of sorghum and sunflower roots and shoots was soaked in tap water for 24 hours at the ratio of 1:10 (w/v). The extracts were filtered through muslin cloth and concentrated to 20 times by boiling at 100 ^{0}C on a gas burner for easy handling and application, following the method developed by Cheema *et al*. (2002).

Powder incorporation and water extract application

In case of soil incorporation, the powders of root and shoot of sorghum and sunflower were mixed thoroughly with soil @ 10 g kg^{-1} soil (50 g box^{-1}) before sowing of weeds. For water extract application, the extracts prepared from root and shoot of sorghum and sunflower were sprayed on soil immediately after sowing of weeds @ 10 ml kg^{-1} soil (50 ml box^{-1}). Twenty five seeds / rhizomes of each weed species, Waho, Lulur and Naro were sown, maintaining five rows in a particular box. The boxes were irrigated regularly with canal water as and when needed.

Data collection

For recording data on germination (%), the sprouts were counted two times at 5 and 10 days after sowing (DAS) and averaged. The weed seedlings were uprooted on 31st May of each experimental year (30 DAS) from each box and kept separately. The root/shoot length (cm) and fresh biomass (g $seedling^{-1}$) was measured, placed in oven at 70 ^{0}C for 72 hours and after drying, the dry biomass (g $seedling^{-1}$) was recorded.

Statistical analysis

The collected data was subjected to statistical analysis using Statistix 8.1 computer software (Statistix, 2006). The LSD test was applied for statistical comparison of treatments at probability level 0.05.

RESULTS AND DISCUSSION

The experiments were conducted for two consecutive years during 2010 and 2011 for validity of results. The data was collected for each year on various parameters of tested weeds separately. However, the average data is presented as under:

Germination (%)

Seed germination is referred as the most important stage particularly under stress environment. Many biochemical reactions take place during germination which provides the basic framework for succeeding growth and development of plant. The data (Table 1) revealed that application of water extracts and soil incorporation of powders prepared from roots and shoots of sorghum and sunflower caused substantial ($P \leq 0.05$) suppression of weeds germination in comparison with control. However, different treatments of water extracts and powder varied considerably in their allelopathic effect on germination of tested weeds. For *Trianthema portulacastrum* (L.) lowest and statistically equal ($P \geq 0.05$) germination of 50.0, 50.0 and 53.3% was observed in sorghum shoot water extract @ 10 ml kg^{-1} soil, sunflower shoot water extract @ 10 ml kg^{-1} soil and sorghum root water extract @ 10 ml kg^{-1} soil, respectively. In case of *Digera arvensis* (Forsk.), germination of 48.3, 50.0 and 51.7% with non-significant ($P \geq 0.05$) statistical differences between treatments was recorded in sorghum/sunflower shoot water extract @ 10 ml kg^{-1} soil and root water extract of each sorghum/ sunflower @ 10 ml kg^{-1} soil. Correspondingly, sorghum and sunflower shoot water extracts @ 10 ml kg^{-1} soil also conferred minimum, though statistical similar ($P \geq 0.05$), germination percentage (51.0 and 51.6%, respectively) for *Convolvulus arvensis* (L.). A critical review of the above data authenticated the suppressive allelopathic effects of sorghum and sunflower on germination of targeted weeds. Phytotoxic compounds in water extracts of allelopathic crops were probably solubilized and absorbed rapidly by the germinating seeds. The inhibitory effects originate through releasing of allelochemicals from application of water extract and powder incorporation (Kruidohf *et al*., 2010). When sensitive plants, either crops or weeds, are exposed to compounds with allelopathic properties, the germination of such plants is depressed markedly (Nouri *et al*., 2012). In this study, sorghum and sunflower water extracts application appeared to be most effective with highest inhibition in germination of weeds as compared to powder and control treatments. Mahmood *et al*. (2010) found that sorghum and sunflower water extract combination at higher concentration (100%) completely inhibited germination of *Trianthema portulacastrum*. In our study, inhibitory effects of sorghum and sunflower were variable and plant part and form specific. Shoot proved more allelopathic than root. Water extract performed well than powder in phytotoxic efficiency. Allelopathic potential of different parts of plant may vary from each other (Hozayn *et al*., 2011). The results are supported by those of Asgharipour (2011) who suggested that sunflower leaf extracts had more allelopathic effect on germination of *Digera arvensis* than did the root extracts and soil incorporation of sunflower residues.

Table 1. Effect of sorghum and sunflower powders and water extracts on germination (%) of summer broadleaf weeds.

Treatments	*Trianthema portulacastrum* (L.)	*Digera arvensis* (Forsk.)	*Convolvulus arvensis* (L.)
Control (check)	93.0 a	91.0 a	92.0 a
Sorghum root powder @ 10 g kg^{-1} soil	58.3 c	56.7 c	61.7 c
Sorghum shoot powder @ 10 g kg^{-1} soil	55.0 cd	53.3 cde	56.7 d
Sorghum root water extract @ 10 ml kg^{-1} soil	53.3 de	51.7 def	56.6 d
Sorghum shoot water extract @ 10 ml kg^{-1} soil	50.0 e	48.3 f	51.0 e
Sunflower root powder @ 10 g kg^{-1} soil	56.6 cd	63.3 b	61.7 c
Sunflower shoot powder @ 10 g kg^{-1} soil	58.3 c	51.7 def	68.3 b
Sunflower root water extract @ 10 ml kg^{-1} soil	63.3 b	55.0 cd	61.0 c
Sunflower shoot water extract @ 10 ml kg^{-1} soil	50.0 e	50.0 ef	51.6 e
S.E ±	1.92	2.07	2.22
$LSD_{0.05}$	4.04	4.36	4.66

Data in each column is average for two years (2010-2011)

Root and shoot length (cm)

Root and shoot length of *Trianthema portulacastrum*, *Digera arvensis* and *Convolvulus arvensis* were significantly ($P \leq 0.05$) decreased by water extracts and powder of sorghum and sunflower and their plant parts (Table 2) than control treatment. Lowest root length (4.0 and 4.6 cm) and shoot length (3.7 and 4.0 cm) of *Trianthema portulacastrum* with statistical similar ($P \geq 0.05$) values were recorded in sorghum shoot water extract @ 10 ml kg^{-1} soil and sunflower shoot water extract @ 10 ml kg^{-1} soil. For *Digera arvensis,* sorghum shoot water extract @ 10 ml kg^{-1} soil and sunflower shoot water extract @ 10 ml kg^{-1} soil demonstrated superiority in allelopathic effect and conferred statistically equal ($P \geq 0.05$) root length of 9.1 and 9.6 cm and shoot length of 6.5 and 7.0 cm, respectively. The least statistically non-different ($P \geq 0.05$) root length (7.7 and 8.3 cm) and shoot length (5.9 and 6.2 cm) of *Convolvulus arvensis* was also recorded in sorghum and sunflower shoot water extract @ 10 ml kg^{-1} soil. It is worth mentioning that root and shoot length of weeds was also substantially reduced by root water extract and shoot/ root powder of sorghum and sunflower in comparison with control. Inhibition in root and shoot length of tested weeds by water extracts and powders of sorghum and sunflower may be associated to presence of allelopathic compounds with phytotoxic effects.

The allelopathic of sorghum and sunflower was plant parts and application form specific. Shoot was found more allelopathic than root. Hozayn *et al*. (2011) reported that allelopathic potential of plant parts vary from each other. Water extract of allelopathic crops showed their superiority in phytotoxic activity over powder. The inhibitory effect of allelopathic crops water extracts on weeds growth was possibly due to their readily available and solubilized form which perhaps adversely affected radicle and reduced water and nutrients uptake, chlorophyll and photosynthesis. The results are congruent with the findings of Asgharipour (2011) who reported that most inhibitory effect of sunflower was produced by leaf extracts as compared to residues incorporation. Foliar application of sorghum and sunflower water extract combination at higher concentration (100%) in pot experiment greatly suppressed root and shoot length of horse purslane seedlings (Mahmood *et al*., 2010).

Table 2. Effect of sorghum and sunflower powders and water extracts on root and shoot length (cm) of summer broadleaf weeds.

Treatments	*Trianthema portulacastrum* (L.)		*Digera arvensis* (Forsk.)		*Convolvulus arvensis* (L.)	
	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)
Control (check)	10.6 a	8.6 a	18.0 a	12.4 a	15.6 a	13.1 a
Sorghum root powder @ 10 g kg^{-1} soil	7.1 c	5.9 b	12.7 c	8.4 cd	9.5 cd	8.3 c
Sorghum shoot powder @ 10 g kg^{-1} soil	6.1 d	5.1 cd	10.7 d	8.0 de	9.2 d	7.5 d
Sorghum root water extract @ 10 ml kg^{-1} soil	5.3 e	4.7 d	10.0 e	7.6 ef	8.5 e	6.7 e
Sorghum shoot water extract @ 10 ml kg^{-1} soil	4.0 f	3.7 e	9.1 f	6.5 g	7.7 f	5.9 f
Sunflower root powder @ 10 g kg^{-1} soil	8.1 b	5.8 b	13.5 b	9.2 b	10.7 b	9.3 b
Sunflower shoot powder @ 10 g kg^{-1} soil	7.4 c	5.2 c	11.2 d	8.9 bc	10.1 bc	8.5 c
Sunflower root water extract @ 10 ml kg^{-1} soil	6.3 d	4.9 cd	10.9 d	8.5 cd	9.4 d	7.7 d
Sunflower shoot water extract @ 10 ml kg^{-1} soil	4.6 ef	4.0 e	9.6 ef	7.0 fg	8.3 ef	6.2 ef
S.E ±	0.32	0.18	0.23	0.28	0.31	0.28
$LSD_{0.05}$	0.67	0.39	0.50	0.58	0.65	0.59

Data in each column is average for two years (2010-2011)

Table 3. Effect of sorghum and sunflower powders and water extracts on fresh and dry biomass (g seedling^{-1}) of summer broadleaf weeds.

Treatments	*Trianthema portulacastrum* (L.)		*Digera arvensis* (Forsk.)		*Convolvulus arvensis* (L.)	
	Fresh biomass	Dry biomass	Fresh biomass	Dry biomass	Fresh biomass	Dry biomass
	(g seedling^{-1})					
Control (check)	7.5 a	3.2 a	18.7 a	8.6 a	5.9 a	2.3 a
Sorghum root powder @ 10 g kg^{-1} soil	4.1 bc	1.9 b	13.7 c	6.4 c	4.1 bc	1.7 b
Sorghum shoot powder @ 10 g kg^{-1} soil	3.9 cd	1.7 bc	12.3 e	5.8 def	3.6 c	1.5 b
Sorghum root water extract @ 10 ml kg^{-1} soil	3.4 ef	1.5 de	12.1 e	5.7 ef	2.9 d	1.2 c
Sorghum shoot water extract @ 10 ml kg^{-1} soil	2.9 g	1.3 f	10.9 f	4.9 f	2.7 d	1.1 c
Sunflower root powder @ 10 g kg^{-1} soil	4.4 b	1.9 b	14.6 b	7.1 b	4.4 b	1.7 b
Sunflower shoot powder @ 10 g kg^{-1} soil	4.1 bc	1.9 b	13.2 d	6.3 cd	3.9 bc	1.6 b
Sunflower root water extract @ 10 ml kg^{-1} soil	3.7 de	1.6 cd	13.0 d	6.3 cd	3.0 d	1.3 c
Sunflower shoot water extract @ 10 ml kg^{-1} soil	3.1 fg	1.4 ef	11.3 f	5.6 f	2.8 d	1.1 c
S.E ±	0.17	0.08	0.19	0.29	0.28	0.11
$LSD_{0.05}$	0.36	0.17	0.41	0.61	0.59	0.23

Data in each column is average for two years (2010-2011)

Fresh and dry biomass (g seedling^{-1})

It is evident from the data (Table 3) that sorghum and sunflower water extracts and powders caused marked ($P<0.05$) inhibition in fresh and dry biomass of tested weeds. For *T. portulacastrum,* the minimum fresh biomass (2.9 and 3.1 g seedling^{-1}) and dry biomass (1.3 and 1.4 g seedling^{-1}) with non-significant ($P\geq0.05$) statistical difference to each other were noticed in sorghum and sunflower shoot water extract @ 10 ml kg^{-1} soil, respectively. In case of *D. arvensis*, application of sorghum and sunflower shoot water extract @ 10 ml kg^{-1} soil differed non-significantly ($P\geq0.05$) with each other in allelopathic inhibitory efficacy and produced statistically equal 10.9 and 11.3 g seedling^{-1} fresh biomass, and 4.9 and 5.6 g seedling^{-1} dry biomass. As far as the allelopathic effects of sorghum and sunflower on *C. arvensis* are concerned, maximum suppression with statistical similar (P≥0.05) values of fresh biomass (2.7, 2.8, 2.9 and 3.0 g seedling^{-1}) and dry biomass (1.1, 1.1, 1.2 and 1.3 g seedling^{-1}) were observed in sorghum/sunflower shoot water extract @ 10 ml kg^{-1} soil and sorghum/sunflower root water extract @ 10 ml kg^{-1} soil. The decrease in fresh and dry biomass of tested weeds may be linked to reduced root and shoot length caused by allelopathic compounds present in water extracts and powders of sorghum and sunflower. Allelopathic compounds suppress water and nutrients uptake by roots, reduce photosynthesis and biomass accumulation (Jafariehyazdi and Javidfar, 2011). Kamal (2011) reported that phytotoxic compounds present in sunflower decreased chlorophyll contents, root and shoot length, and ultimately biomass of wheat seedlings. The results of this study showed that allelopathic effects of sorghum and sunflower were form and plant part specific. Water extract of sorghum and sunflower caused more negative allelopathic effects as compared to powder. Shoots of both crops demonstrated higher inhibitory effects than roots. Sunflower leaf extracts caused highest reduction in dry weight of false amaranth over root extracts as well as residues soil incorporation (Asgharipour, 2011). Similarly, Mahmood *et al*. (2010) reported that application of sorghum and sunflower water extracts reduced shoot dry weight of horse purslane by 66% over control. The results of this study are closely in association with Khan *et al*. (2015) who revealed that allelopathic chemicals in leaf water extracts of sorghum and sunflower significantly suppressed fresh and dry biomass of weeds.

CONCLUSION

It is concluded from the results that water extract and powder of sorghum and sunflower markedly inhibited germination and growth of weeds over control. Sorghum and sunflower shoot water extracts @ 10 ml kg^{-1} soil caused highest allelopathic influence where lowest germination, root/shoot length and fresh/dry biomass of targeted weeds was recorded. Shoot appeared higher in phytotoxic activity than root. Water extract proved most effective in allelopathic efficacy over powder. Hence, it can be concluded that sorghum and sunflower possess allelopathic properties which can be used for effective weed management.

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