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EFFECTS OF SORGHUM LEAVES, ROOTS AND STEMS WATER EXTRACT, HAND WEEDING AND HERBICIDE ON WEEDS SUPPRESSION AND YIELD OF WHEAT

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ABSTRACT

To compare allelopathic effects of sorghum plant parts water extract (WE) with hand weeding and herbicide on suppression of weeds in wheat and wheat yield under rain fed conditions, an experiment was conducted at the research farm, University of Arid Agriculture, Rawalpindi during Rabi 2001-02.Treatments used were: Control (un-weeded check), hand weeding 60 DAS, herbicide spray (Logron) @ 250 g ha^{-1} 60 DAS, sorghum root WE spray @ 5 L ha^{-1}, sorghum stem WE spray @ 5 L ha^{-1}, sorghum leaf WE spray @ 5 L ha^{-1}, sorghum stem + root WE spray @ 5 L ha^{-1}, sorghum stem + leaf WE spray @ 5 L ha^{-1}, sorghum root + leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS. Among separate spray of sorghum roots, stem and leaf WE, root WE was found to be the most effective treatment and reduced weed density by 20.7 and 22.23%, weeds fresh weight by 19.97 and 22.97% and weeds dry weight by 15.7 and 21.37% compared to control recorded at 80 and 105 DAS, respectively. Among combination of sorghum plant parts WE , stem + root WE had greater influence than stem + leaf or root + leaf treatments and decreased weed density by 23.42 and 33.42%, weeds fresh weight by 25.64 and 33.78% and weeds dry weight by 21.7 and 33.70% compared to control measured at 80 and 105 DAS, respectively. Hand weeding caused reduction of 46.19 and 41.09% in weed density, 46.34 and 41.5% in fresh weight, 44.98 and 37.59% in dry weight over control and herbicide caused reduction of 77.08 and 72.11% in weed density, 78.59 and 70.7% in fresh weight, 74.59 and 67.51% in dry weight compared to control recorded at 80 and 105 DAS, respectively. Sorghum plant parts WE spray significantly reduced plant population, fresh and dry weight *Anagalis arvensis* L.(Pimpernel), *Chenopodium album*L. (Lambs quarter), *Fumaria indica*L. (Fumitory). All sorghum plant parts WE treatments suppressed plant height. Longer spikes, more grain $spike^{-1}$ and heavier grain were found in stem + root WE treatment. Separate spray of root WE increased wheat yield by 12 % compared to control. An increase of about 20% over control was recorded in stem + root or stem + leaf treatment which was statistically at par with hand weeding. Logron application resulted in 25.52% yield increase over control.

INTRODUCTION

Wheat is a main winter crop in Pothowar region of the Punjab and is mainly grown on residual soil moisture received during monsoon. Weeds infestation is major cause of low yields in rain fed areas of the Punjab. Weeds can reduce wheat yield by 25-30% (Nayyar, *et al*. 1994) and research finings indicated that wheat yield could be increased by 37% if weeds are properly controlled (Baloch, 1993). Winter rains encourage weeds growth and weeds compete vigorously with main crop for light, nutrients, space and moisture. Weed management is an important aspect of successful crop production. Traditional weed control methods are time consuming, weather dependent and labor intensive. Herbicides use is expensive and injudicious use can create environmental hazards (Blair, *et al*. 1992) and can also affect the nutritive value of many crops (Nazarko, *et al*. 2003). Moreover, researchers have reported herbicide resistance in many weeds (Doug, *et al*. 2002) due to excessive use of herbicides. Allelopathy is a natural, inexpensive, environmentally safe and an organic approach to control weeds and increase crop yields while conserving the ecosystem. Ahmad, *et al*. (1991) concluded that sorghum is highly allelopathic and sorghum residue could be effectively used to manage some of the important weeds in irrigated wheat crop without affecting crop in semi-arid environment.

Mature sorghum plants possess nine water soluble chemicals which are phytotoxic to certain weeds such as *Phalaris minor* Retz., *Chenopodium album* L., *Rumex dentatus* L., and *Convolvulus arvensis* L. (Cheema, 1988). Water extract of matured sorghum plants was used by Cheema and Khaliq (2000) and reported that water extract spray reduced weed biomass by 35-40% and increased wheat yield by 10-21%. Literature review indicated that water extract of different plant parts of potential allelopathic crops had significantly different suppressive effects on the growth of weeds. Sunflower leaf leachate had more phytotoxic effects on growth of weeds than that of stem and roots exudates (Wilson and Rice, 1968). Barley leaves were the most phytotoxic plant part and were also the major source of allelopathic substances (Ben-Hammouda, *et al*. 2001). The inhibitory effects of rice straw water extract on the growth of *Echinochloa crus-galli* L.P.Beauv. were more pronounced than that of water extract of rice hull or leaves (Chung, *et al*. 2003). Sorghum roots exudates reduced growth of various weed species at very low concentration (Roth, *et al*. 2000). It has also been documented that production of allelochemicals in plants is influenced by environmental factors and greater quantities of allelochemicals have been found in plants grown under drought and mineral stress (Roth, *et al*. 2000, Suthep, *et al*. 2001).

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The specific objective of this study was to evaluate the effects of sorghum plant parts water extract prepared from matured sorghum plants grown under rain fed conditions in semiarid environment on suppression of growth of various weed species, yield and yield related traits of wheat under rain fed conditions. The information may be useful for weed management and for researchers investigating to prepare natural herbicides.

MATERIALS AND METHODS

To study allelopathic effects of sorghum plant parts water extract (WE) on suppression of weeds in wheat and grain yield under rain fed conditions, an experiment was conducted at the research farm, University of Arid Agriculture, Rawalpindi during Rabi 2001-2002. The soil was clay loam having 0.75% organic matter. The pH and ECe of saturated soil extract were 7.40 and 30 dSm^{-1}, respectively.

Sorghum plants were uprooted at maturity and separated into roots, stem and leaves. The sorghum roots, stem and leaves herbage was sun-dried and chaffed with fodder cutter into 2 cm pieces. Chaffed herbage of roots, stem and leaves was separately soaked in deionized water in 1:10 (1 kg each of roots, stem and leaves herbage in 10 L of water) in separate containers for 24 h at room temperature. The WE from respective container was thoroughly agitated and the mixture was filtered through a screen. The volume of respective filtrate was reduced twenty times by continuously boiling to prepare sorghum root, stem and leaf WE.

Seedbed was prepared by giving four cultivations each followed by planking. Fertilizer @ 125 kg N ha^{-1} and 80 kg P ha^{-1} in the form of urea and diammonium phosphate was applied at the time of seedbed preparation. Wheat cv. 'Inqilab-91' at the seed rate of 125 kg ha^{-1} was sown on Nov. 22, 2001 with a single row hand drill in rows 30 cm apart. Only one irrigation was applied 30 days after sowing (DAS) during the crop season.. The experiment was laid out in randomized complete block design with four replications. Seven rows 30 cm apart per treatment were maintained in plot size of 7 x 2.4 m. Treatments such as control (un-weeded check), hand weeding 60 DAS and Logron Extra 64 WG. (Terbutryn + Triasulfuron) spray @ 250 g ha^{-1} 60 DAS were included for comparison. Sorghum plant parts WE treatments were as under:

Sorghum root WE spray @ 5 L ha^{-1} 60 and 80 DAS
Sorghum stem WE spray @ 5 L ha^{-1} 60 and 80 DAS
Sorghum leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS
Sorghum stem + root WE spray @ 5 L ha^{-1} 60 and 80 DAS
Sorghum stem +leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS
Sorghum root + leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS

Data on weed density and weed biomass were recorded at 80 and 105 days after sowing from two randomly selected $1m^2$ quadrat from each experimental plot. Weeds fresh weight was recorded just after removing weeds from the experimental plots. Weeds dry weight was recorded after drying at 70^oC for 72 h in an oven. The experimental area was free of noxious and perennial grass weed species. Weed species viz. *Anagallis arvensis* L. (Blue pimfernal), *Chenopodium album* L. (Lambs quarter), *Fumaria indica* L. (Fumitory), *Medicago polymorpha* L. (Bur clover) were found in the experimental area.

Data on plant height (cm), spike length (cm), spikelets $spike^{-1}$ and grains $spike^{-1}$ were recorded in 10 randomly selected samples taken from each plot. Fertile tillers m^{-2} was counted from two randomly selected $1m^2$ quadrats in each plot. A random sample was obtained from each plot to take 1000-grain weight. Grain yield was measured on plot basis and was converted into kg ha^{-1}. The data were subjected to analysis of variance technique. F-statistic was based on residual mean square error. The LSD at 5% level of probability was used for comparison of treatment means (Montgomery, 2001).

RESULTS AND DISCUSSION

Weed Density and Weed Biomass

The separate spray of sorghum root, stem and leaf WE reduced weeds population significantly (Table I). The root WE treatment reduced weed population more than stem WE or leaf WE. The root WE spray reduced weed density by 20.7 and 22.23% compared to control recorded at 80 and 105 DAS, respectively. The spray of stem + root WE decreased weeds population more than that of stem + leaf WE or root + leaf WE. The spray of stem + root WE suppressed weed population by 23.42 and 33.42% relative to control recorded at 80 and 105 DAS, respectively. Hand weeding decreased weeds population by 46.19 and 41.09% compared to control recorded at 80 and 105 DAS, respectively. Herbicide logron application was the most effective treatment and decreased weeds population by 77.08 and 72.11% relative to control recorded at 80 and 105 DAS, respectively (TableII).

The effect of treatments on weeds fresh weight was significantly different (Table I). Sorghum root WE spray was the most effective treatment among the separate spray of plant parts WE treatments and reduced fresh weight by 19.69 and 22.97% recorded at 80 and 105 DAS, respectively. The stem + root WE spray was found more effective treatment than that of stem + leaf WE or root + leaf WE treatments and reduced weeds fresh weight by 25.64 and

33.78% over control recorded at 80 and 105 DAS, respectively. The effect of treatments on weeds dry weight was similar to that of their effect on fresh weight (Table I). Among the separate spray of sorghum plant parts WE treatments, sorghum root WE spray was more effective treatment than that of stem or leaf WE treatments. The spray of root WE reduced weeds dry weight by 15.7 and 21.37% compared to control measured at 80 and 105 DAS, respectively. The stem + root WE treatment had greater influence on weeds dry weight than that of stem + leaf WE or root + leaf WE treatments and caused reduction in weeds dry weight of 21.7 and 33.70% relative to control recorded at 80 and 105 DAS, respectively. Hand weeding caused reduction of 46.34 and 41.5% in fresh weight, 44.98 and 37.59% in dry weight over control recorded at 80 and 105 DAS, respectively. Herbicide effects were more pronounced and caused reduction of 78.59 and 70.7% in fresh weight, 74.59 and 67.51% in dry weight compared to control recorded at 80 and 105 DAS, respectively (Table II).

Data about weeds density, fresh and dry weight of weeds in this experiment indicated that sorghum root and stem + root WE spray decreased weeds population and suppressed weeds growth significantly. These results are supported by findings of Cheema, *et al*. (1997). They reported that sorghum WE influence was selective on germination and growth of weeds. Einhelling and Rasmussen (1989) had pointed out that suppressive effects of sorghum were primarily on broad-leaved weeds. The more pronounced effect of root WE and stem + root WE treatments than that of other sorghum treatments may be due to the chief phytotoxin viz. sorgoleone (p-benzoquinine) that was found in exudates of sorghum roots (Nimbal, *et al*. 1996, Roth, *et al*. 2000). The effectiveness of stem + root WE treatment may be probably due to an additive effect of each group of toxins present in root and stem, thus accentuating the allelopathic effects. This interpretation is supported by the findings of Wilson and Rice (1968) who reported that phytotoxins of sunflower leaf leachate, root exudates and soil extract were not the same compounds.

Density and Biomass of Individual Weed Species

The response of weed species to treatments was further examined by discussing weed population and growth of individual weed species found in experimental area.

Anagallis Arvensis

Among the separate spray of sorghum plant parts, root WE was the most effective treatment and decreased density of *Anagallis arvensis* by 27.6 and 31.69%, fresh weight by 26.64 and 30.72% and dry weight by 27 and 24% over control recorded at 80 and 105 DAS, respectively (Table II). Among the combination of sorghum plant parts WE treatments, the foliar spray of stem + root WE had more pronounced effects and reduced *Anagallis arvensis* L. density by 38 and 40.85%, fresh weight by 36.71 and 43% and dry weight by 38 and 47% compared to control recorded at 80 and 105 DAS, respectively. (Table II). The spray of leaf or stem WE alone did not show any pronounced effect on population, fresh and dry weight of *Anagallis arvensis* (Table II).

Chenopodium album L

The spray of root WE alone decreased density of *Chenopodium album* by 23.6 and 32.5% compared to control recorded at 80 and 105 DAS, respectively (Table II). Among the other sorghum plant parts WE treatments, stem + root WE reduced weed population of this weed by 34.83 and 47.75% compared to control recorded at 80 and 105 DAS, respectively. The effect of stem + leaf WE treatment on population of this weed was almost similar to stem + root WE treatment and reduced weed density by 33.71 and 43.75% compared to control recorded at 80 and 105 DAS, respectively. Fresh and dry weight of *Chenopodium album* was significantly influenced by sorghum plant parts WE treatments (Table II). The combination of stem + leaf and root + leaf WE treatments significantly reduced fresh and dry weight of this weed species but the notable effect was of stem + root WE treatment that caused reduction of 37.83 and 49% in fresh weight and 33.33 and 52.06 % in dry weight over control recorded at 80 and 105 DAS, respectively.

Fumaria indica L

Among the separate WE of root, stem and leaf, the influence of root WE on density of this weed was greater than that of stem or leaf WE (Table III). The root WE treatment decreased population by about 27.32 and 28.9%, fresh weight by 26.28 and 23.53% and dry weight by 25.32 and 31.72% over control recorded at 80 and 105 DAS, respectively (Table III). Although stem + leaf and root + leaf WE treatments significantly reduced population of this weed species but more reduction of 36.08 and 39.88% over control was found in stem + root WE treatment recorded at 80 and 105 DAS, respectively. Fresh and dry weight of *Fumaria indica* was significantly influenced by sorghum plant parts WE treatments (Table III). Sorghum stem + root WE treatment caused reduction in fresh weight by 37 and 40% and about 36 and 44%in dry weight over control recorded at 80 and 105 DAS, respectively (Table III).

Medicago polymorhha L

The separate spray of sorghum plant parts WE or different combination of sorghum plant parts WE treatments did not show any appreciable influence on population except sorghum stem WE treatment that reduced density of *Medicago polymorhha* by about 11.18 and 20.45% over control recorded at 80 and 105 DAS, respectively. The magnitude of effects of separate spray of sorghum plant parts WE or combination of different plant parts WE treatments on fresh and dry weight was similar to the treatments effects on its density measured at 80 and 105 DAS. However, stem WE spray reduced fresh weight by 20.11% and 18.93%over control recorded at 105 DAS (Table III).

Yield and Yield Components

All sorghum WE treatments suppressed plant height (Table IV). The shortest plants were observed in stem + root WE treatment followed by stem + leaf and root + leaf. Relatively longer plants were founding in hand weeding and herbicide treatments. Tillering, in general was proliferate in this experiment because of one irrigation at the time of tillering. There was no statistically significant difference in number of tillers m^{-2} where sorghum root, stem and leaf WE was sprayed. Among the other sorghum WE treatments the highest number of tillers m^{-2} was recorded in stem + leaf WE treatment that followed by root + leaf WE treatment. There were significantly more tillers m^{-2} in hand weeding and herbicide application treatments relative to control. Similar effects of sorghum WE spray and sorghum herbage mulch were reported by Cheema and Khaliq (2000) on tillers per unit area.

Significantly longer spikes were found in stem + root, stem + leaf and root + leaf WE treatments compared to control. Spike length in hand weeding and herbicide treatments was statistically same as was found in combination of sorghum plant parts WE treatments. Although the hand weeding effects, herbicide application and sorghum WE treatments on spikelets $spike^{-1}$remained statistically non significant but slightly more spikelets $spike^{-1}$ were recorded in root or leaf WE treatments. Significantly more grains $spike^{-1}$ was recorded in all treatments compared to control. Grains $spike^{-1}$ in sorghum WE treatments were almost same as in hand weeding and herbicidal treatment. The 1000-grain weight was significantly higher in sorghum root, stem + root and root + leaf WE treatments than that in control, hand weeding and herbicide application treatments. The reason seemed to be less tillers m^{-2} in these treatments relative to hand weeding and herbicide application treatments. Nauman (1997) has also reported significantly positive effects of sorghum WE spray on 1000-grain weight and non significant effects on spikelets $spike^{-1}$.

Grain yield varied significantly among the treatments (Table IV). Grain yield in herbicide treatment was 25.52% higher than that in control. Among the separate spray of sorghum plant parts WE treatments, sorghum root WE spray increased grain yield by about 11.98% compared to control. An increase of about 19.87 and 18.75% over control was recorded where sorghum stem + root and stem + leaf WE was sprayed, respectively and this increase was statistically at par with the increase in hand weeding over control. These results confirmed the findings of Nauman (1997) and Ashraf and Iqbal (2006) who reported higher grain yield in plots treated with sorghum WE. The increase in grain yield may be probably due to suppressive allelopathic effects of sorghum plant parts WE at an early stage on weed population and weed biomass, which ultimately resulted in healthier wheat plants and favored higher wheat grain yield. The suppressed plant height by inhibitory effects of sorghum plant parts WE treatments may also have resulted in stronger stems and have induced dwarfing characteristic of wheat plants and consequently have produced longer spikes, more grains $spike^{-1}$ and heavier grains.

CONCLUSION

The comparison of the magnitude of effects of sorghum plant parts WE treatments with hand weeding and herbicide application treatments showed that stem + root WE treatment caused reduction in weed density, fresh and dry weight by about 33%, hand weeding by about 40% and herbicide application by about 70%. The increase in grain yield in stem + root and stem + leaf WE treatments were statistically same as in hand weeding and herbicide application. The comparison of the magnitude of effects of treatments on weed density, fresh and dry weight, and grain yield generated many hypotheses for future investigations. The application rate/concentration of water extracts of individual plant parts or sorghum plant herbage need to be determined experimentally. The allelochemicals present in each part of sorghum plant need to be identified. It can also be further postulated that low dose of herbicide along with concentrated water extract of sorghum herbage can be exploited as means of weed control to control broad-leaved weeds in field crops.

Table I. ***Effect of sorghum plant parts water extract on weed density, fresh and dry weight of weeds in wheat during 2001 -02***

Treatments	Weed density (m^{-2})		Weeds fresh weight		Weeds dry weight ($g\ m^{-2}$)	
	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS
Control (un-weeded check)	147.3 a	131.8 a	139.6 a	155.4 a	21.65 a	27.0 a
Hand weeding 60 DAS	79.2 d (46.19)	77.7 f (41.09)	74.90 f (46.34)	90.9 e (41.5)	11.93 e (44.98)	16.85 e (37.59)
Herbicide (Logron) @ 250 g ha^{-1} 60 DAS	33.7 e (77.08)	36.7 g (72.11)	29.88 g (78.59)	45.50 f (70.7)	5.5 f (74.59)	8.77 f (67.51)
Sorghum root WE spray @ 5 L ha^{-1} 60 and 80 DAS	116.8 c (20.70)	102.5 c (22.23)	112.1 cd (19.69)	119.7 c (22.97)	18.25 cd (15.7)	21.23 c (21.37)
Sorghum stem WE spray @ 5 L ha^{-1} 60 and 80 DAS	129.0 b (12.42)	112.0 b (15.02)	122.8 b (12.03)	132.3 b (14.86)	19.98 b (7.71)	23.95 b (11.29)
Sorghum leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS	127.3 b (13.57)	113.5 b (13.88)	120.8 b ((13.46)	133.1 b (14.35)	20.0 b (7.62)	23.27 b (13.81)
Sorghum stem + root WE @ 5 L ha^{-1} 60 and 80 DAS	112.8 c (23.42)	87.7 e (33.42)	103.8 e (25.64)	102.9 d (33.78)	16.95 d (21.7)	17.90 e (33.7)
Sorghum stem + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	111.5 c (24.3)	93.7 de (28.86)	108.3 de (22.42)	106.8 d (31.27)	17.33 cd (19.95)	19.60 d (27.4)
Sorghum root + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	121.0 bc (17.85)	102.0 cd (22.61)	117.3 bc (15.97)	123.6 bc (20.46)	18.60 bc (14.08)	21.6 c (20.0)
Significance Level	* **	**	**	**	**	**
LSD (0.05)	10.41	8.52	8.30	11.73	1.54	1.57

Means in columns followed by same letter are not significantly different by Fisher's protected Least Significant Difference at 5% probability level.
** = Significant at 1% probability level. DAS = days after sowing. WE = water extract. In parenthesis % decrease compare to control.

Table II ***Effect of sorghum plant parts water extract on weed density, fresh and dry weight of Anagallis arvensis and Chenopodium album***

Treatments	Anagallis arvensis						Chenopodium album					
	Weed Density (m^{-2})		Fresh weight ($g\ m^{-2}$)		Dry weight ($g\ m^{-2}$)		Weed Density (m^{-2})		Fresh weight ($g\ m^{-2}$)		Dry weight ($g\ m^{-2}$)	
	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS
Control (un-weeded check)	40.75 a	35.5 a	32.55 a	34.83 a	4.92 a	6.75 a	22.25 a	20.0 a	26.7 a	25.98 a	5.1 a	5.75 a
Hand weeding 60 DAS	23.75 d (41.71)	24.75 bcd (30.28)	18.98 c (41.69)	24.08 bc (30.86)	2.8 c (43.08)	4.67 cde (30.81)	13.0 d (41.57)	15.75 bc (21.25)	15.67 d (41.31)	20.4 bc (21.48)	2.97 d (41.76)	4.3 b (22.8)
Herbicide (Logron) @ 250 g ha^{-1} 60 DAS	11.75 e (71.16)	9.50 e (73.24)	9.23 d (71.64)	10.35 d (70.28)	1.95 d (60.36)	2.15 f (68.15)	4.75 e (78.65)	8.25 f (58.75)	5.8 e (71.28)	10.35 f (60.16)	1.22 e (76.08)	2.1 f (62.3)
Sorghum root WE spray @ 5 L ha^{-1} 60 and 80 DAS	29.50 c (27.6)	24.25 cd (31.69)	23.88 b (26.64)	24.13 bc (30.72)	3.57 b (27.43)	5.15 bcd (23.7)	17.0 bcd (23.6)	13.5 cd (32.5)	21.38 abc (19.93)	17.15 cd (33.99)	4.05 bc (20.59)	3.72 c (33.57)
Sorghum stem WE spray @ 5 L ha^{-1} 60 and 80 DAS	36.0 b (11.65)	30.75 bc (13.38)	29.20 a (10.29)	31.05 a (10.85)	4.37 a (11.17)	6.12 ab (9.33)	19.25 ab (13.48)	16.25 b (18.75)	23.7 ab (11.24)	21.1 b (18.78)	4.40 ab (13.73)	4.35 b (21.9)
Sorghum leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS	36.5 ab (10.42)	29.0 bc (18.31)	29.60 a (9.06)	28.27 ab (18.83)	4.62 a (6.09)	5.67 abc (16.0)	18.0 abc (19.1)	16.75 b (16.25)	18.45 bcd (30.9)	21.55 b (17.05)	3.65 bcd (28.43)	4.25 b (23.7)
Sorghum stem + root WE @ 5 L ha^{-1} 60 and 80 DAS	25.25 cd (38.05)	21.0 d (40.85)	20.60 bc (36.71)	19.85 c (43.01)	3.05 bc (38.0)	3.57 e (47.11)	14.5 cd (34.83)	10.5 ef (47.75)	16.6 cd (37.83)	13.25 ef (49.0)	3.4 cd (33.33)	2.67 e (52.06)
Sorghum stem + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	28.0 cd (31.28)	24.25 cd (31.69)	21.77 bc (33.12)	24.0 bc (31.09)	3.52 b (28.45)	4.40 cde (34.81)	14.75 bcd (33.71)	11.25 de (43.75)	18.98 bcd (28.91)	15.43 de (40.61)	3.5 cd (31.37)	3.07 d (44.88)
Sorghum root + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	28.75 c (29.44)	24.75 bcd (30.28)	23.67 b (27.28)	29.20 ab (16.16)	3.4 bc (30.89)	4.57 cde (32.3)	16.25 bcd (26.97)	14.75 bc (26.25)	19.7 bcd (26.22)	19.08 bcd (26.56)	3.75 bcd (26.47)	4.0 bc (28.19)
Significance Level	**	**	**	**	**	**	**	**	**		**	**
LSD (0.05)	4.53	6.05	3.83	6.65	0.69	1.16	4.66	2.49	5.6	3.86	0.84	0.37

Means in columns followed by same letter are not significantly different by Fisher's protected Least Significant Difference at 5% probability level. ** = Significant at 1% probability level. DAS = days after sowing. WE = water extract. In parenthesis % decrease compare to control.

Table III. ***Effect of sorghum plant parts water extract on weed density, fresh and dry weight of Fumaria indica and Medicago polymorpha***

Treatments	Fumaria indica						Medicago polymorpha					
	Weed Density (m^{-2})		Fresh weight ($g\ m^{-2}$)		Dry weight ($g\ m^{-2}$)		Weed Density (m^{-2})		Fresh weight ($g\ m^{-2}$)		Dry weight ($g\ m^{-2}$)	
	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS	80 DAS	105 DAS
Control (un-weeded check)	48.5 a	43.25 a	45.58 a	55.58 a	5.45 a	7.25 a	35.75 a	33.0 a	37.70 a	38.97 a	6.90 a	7.92 a
Hand weeding 60 DAS	23.75 f (51.03)	21.0 e (51.44)	20.2 f (55.68)	27.15 e (51.15)	2.60 f (52.29)	3.82 d (47.31)	18.75 b (47.55)	16.25 c (50.75)	18.28 b (48.79)	19.27 d (50.55)	3.55 c (48.5)	4.05 d (48.86)
Herbicide (Logron) @ 250 g ha^{-1} 60 DAS	11.25 g (76.8)	10.25 f (76.3)	10.55 g (76.85)	13.05 f (76.52)	1.47 g (73.03)	1.92 e (73.51)	6.0 c (83.20)	7.75 d (76.51)	4.30 c (87.95)	11.75 e (69.84)	0.85 d (87.68)	2.6 e (67.17)
Sorghum root WE spray @ 5 L ha^{-1} 60 and 80 DAS	35.25 d (27.32)	30.75 c (28.9)	33.6 d (26.28)	42.5 bc (23.53)	4.07 cde (25.32)	4.95 c (31.72)	35.0 a (2.09)	31.25 a (5.3)	34.63 a (2.99)	35.88 abc (7.92)	6.57 ab (4.78)	7.4 abc (6.56)
Sorghum stem WE spray @ 5 L ha^{-1} 60 and 80 DAS	42.0 bc (13.14)	38.25 b (11.56)	38.53 bc (15.47)	48.92 ab (11.98)	4.65 bc (14.68)	6.05 a (14.06)	31.75 a (11.18)	26.25 b (20.45)	33.03 a (7.47)	31.13 c (20.11)	6.52 ab (5.5)	6.42 c (18.93)
Sorghum leaf WE spray @ 5 L ha^{-1} 60 and 80 DAS	42.75 b (11.86)	37.75 b (12.71)	40.67 b (10.77)	48.15 b (13.36)	4.87 ab (10.64)	5.85 b (19.31)	34.75 a (2.79)	30.0 ab (9.09)	35.03 a (1.87)	35.08 abc (9.98)	6.85 ab (0.72)	7.5 abc (5.3)
Sorghum stem + root WE @ 5 L ha^{-1} 60 and 80 DAS	31.0 e (36.08)	26.0 d (39.88)	28.63 e (37.19)	33.25 de (40.17)	3.5 e (35.78)	4.07 d (43.86)	33.0 a (7.69)	31.50 a (4.54)	34.4 a (3.64)	31.53 c (12.96)	6.22 ab (9.85)	7.52 abc (5.05)
Sorghum stem + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	34.0 de (29.9)	28.75 cd (33.52)	32.78 de (28.08)	36.67 cd (34.02)	3.92 de (28.07)	5.55 bc (23.44)	34.75 a (2.79)	28.75 ab (12.87)	34.5 a (3.36)	32.7 bc (16.08)	6.37 ab (7.68)	6.57 bc (17.04)
Sorghum root + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	38.0 cd (30.28)	30.0 cd (30.63)	35.28 cd (22.6)	41.2 c (25.87)	4.3 bcd (21.1)	5.42 bc (25.24)	35.0 a (2.09)	32.50 a (1.51)	33.63 a (5.79)	37.6 ab (3.51)	6.15 b (10.86)	7.6 ab (4.04)
Significance Level	**	**	**	**	**	**	**	**	**	**	**	**
LSD (0.05)	4.19	4.08	4.58	6.83	0.71	0.67	4.75	4.56	5.9	5.83	0.7	1.12

Means in columns followed by same letter are not significantly different by Fisher's protected Least Significant Difference at 5% probability level. ** = Significant at 1% probability level. DAS = days after sowing. WE = water extract. In parenthesis % decrease compare to control..

Table IV ***Effect of sorghum plant parts water extract on yield components and grain yield of wheat***

Treatments	Plant height (cm)	Tillers (m^{-2})	Spike length (cm)	Spikelets $spike^{-1}$	Grain $spike^{-1}$	1000-grain weight (g)	Grain yield ($kg\ ha^{-1}$)
Control (un-weeded check)	88.05 abc	345.5 e	9.02 e	20.70	41.7 c	32.53 e	2762 f
Hand weeding 60 DAS	89.53 ab	396.5 b	10.31 abcd	21.00	47.30 ab	33.70 d	3252 bc (17.74)
Herbicide (Logron) @ 250 g ha^{-1} 60 DAS	90.1 a	427 a	11.20 a	20.90	49.38 a	34.63 bc	3467 a (25.52)
Sorghum root WE @ 5 L ha^{-1} 60 and 80 DAS	84.22 bcd	365.3 cde	10.05 bcde	21.10	48.83 ab	35. 65 a	3093 cde (11.98)
Sorghum stem WE @ 5 L ha^{-1} 60 and 80 DAS	85.0 abcd	352.8 de	9.51 de	20.55	47.33 ab	33.65 d	2982 de (7.96)
Sorghum leaf WE @ 5 L ha^{-1} 60 and 80 DAS	87.1 abc	349.3 e	9.80 cde	21.10	46.10 b	33.15 de	2933 ef (6.19)
Sorghum stem + root WE @ 5 L ha^{-1} 60 and 80 DAS	79.68 d	357.8 de	10.91 ab	20.23	49.00 ab	36.00 a	3311 ab (19.87)
Sorghum stem + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	82.5 cd	384.8 bc	10.57 abc	21.00	48.05 ab	33.90 cd	3280 abc (18.75)
Sorghum root + leaf WE @ 5 L ha^{-1} 60 and 80 DAS	83.07 cd	375.8 bcd	10.7 abc	20.20	48.05 ab	35.22 ab	3164 bcd (14.55)
Significance Level	**	**	**	NS	**	**	**
LSD (0.05)	5.18	54.45	1.03	-	3.04	0.90	213.2

Means in columns followed by same letter are not significantly different by Fisher's protected Least Significant Difference at 5% probability level.
** = Significant at 1% probability level. DAS = days after sowing. WE = water extract. In parenthesis % increase compare to control.

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