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IMPACT OF SORGHUM EXTRACT TYPE, CONCENTRATION AND APPLICATION TIME ON WEEDS DENSITY AND WHEAT YIELD

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ABSTRACT

Traditional weed control methods are laborious, tedious and weather dependent. Weedicides causes contamination of environment, health threats and weed resistant development. Alternative weed management methods are needed to minimized environmental contamination. Therefore, the impact of sorghum water extract on weeds dynamics and wheat yield was evaluated at Agronomy Research Farm, University of Agriculture Peshawar, Pakistan during 2014-15. The experiment was composed of two sorghum extract types (stem and leaf extracts), three extract concentrations (1:3, 1:4 and 1:5 kg L^{-1}) and three application time (emergence, tillering and 50 % at emergence + 50 % at tillering). Herbicides treated, hand weeding and unweeded plots were included for comparison. Herbicides treated plots resulted in fewer weeds (39.0 m^{-2}), more leaf area tiller^{-1} (114.7 cm^2), taller plants (90.2 cm), longer spikes (10.57 cm) and more grain yield (3916.7 kg ha^{-1}) compared to sorghum water extract (SWE) sprayed plots. Among concentrations SWE applied with 1:3 concentration produced minimum weeds (84.4 m^{-2}), more leaf area tiller^{-1}(104.6 cm^2), taller plants (89.4 cm), longer spikes (9.95 cm) and more grain yield (3547.2 kg ha^{-1}). Among application time SWE applied at tillering gave lower weeds density (87.7 m^{-2}), higher leaf area tiller^{-1} (102.3 cm^2), taller plants (87.8 cm), longer spikes (9.85 cm) and higher grain yield (3308.9 kg ha^{-1}). Leaf water extract gave fewer weeds (91.4 m^{-2}), higher leaf area tiller^{-1} (101.9 cm^2), taller plants (87.6 cm), longer spikes (9.85 cm) and more grain yield (3263 kg ha^{-1}) compared to stem water extracts. It is concluded that leaf water extract sprayed at tillering with 1:3 concentration reduced weeds density and increased grain yield of wheat and is recommended for reducing weeds density and increasing grain yield of wheat in agro-climatic conditions of Peshawar, Pakistan.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most commonly cultivated food crop worldwide and its demand for human consumption in developing countries rises 1.6 % annually (Ortiz *et al.,* 2008). Pakistan is amongst the top ten wheat producing countries and ranks 5th in term of yield ha^{-1} and at 8th in terms of production (Hussain *et al*., 2010). However, wheat average yield ha^{-1} (2824 kg) is far below the yield of other wheat producing countries (MNFSR, 2014).

Amongst various factors limiting yield and productivity of wheat, weeds infestation has became a serious hazard in decreasing wheat yield in Pakistan. Weeds fight with wheat crop for moisture, space, light and other essential nutrients particularly NPK resulting in lower yield (Ozturk et al., 2012). Wild oat (*Avena fatua*), field bindweed (*Convolvulus arvensis*), annual bluegrass (*Poa annua*), canary grass (*Phalaris minor Retz*), Broad leaf dock (*Rumax dentatus*), Canada thistle (*Cirsium arvense*), lambsquarters (*Chenopodium album*), hausskn (*Fumaria indica*) and scarlet pimpernel (*Anagallis arvensis*) have emerged as main weeds infesting wheat fields in Pakistan (Hussain *et al.,* 2013). Losses due to weed infestation amount Rs. 120 billion whereas wheat alone accounts for Rs. 30 billion losses in Pakistan (Afridi *et al.,* 2014).

Weeds are controlled by different methods like chemical, mechanical and manual. Modern agriculture is yield intended and mainly depends on commercial herbicides to control weeds. Herbicides application is practical and most effective method used since long time to reduced weeds in different crops. However, excessive and injudicious use of commercial herbicides can lead to environmental, health, soil and water related problems (Farooq *et al*., 2011; Jabran *et al*., 2008). Use of the same type of herbicides for many years may develop resistant to weed biotype which is a serious issue to think about (Bhowmik and Inderjit, 2003). More than 295 biotypes of 177 weeds species have developed resistant to synthetic herbicides (Heap, 2005). Manual weed control is efficient method for weed control, but this method is time consuming, laborious and weather dependent. Due to unavailability of appropriate weed control machinery, mechanical weed control has also got less importance (Rao *et al*., 2007).

Sorghum (*Sorghum bicolor* L. Moench) is one of the potential allelopathic crops, which possesses a large number of allelochemicals that suppresses the growth of weeds. (Jabran *et al.,* 2010). Allelochemicals are found in roots, stems and leaves of plants (Wier *et al.,* 2004). Moreover, the allelopathic potential of various plant parts may vary (Chon and Kim, 2002; Economou *et al.,* 2002). Several essential secondary metabolites such as phenolic, alkaloids, flavonoids, and terpeniods were identified in sorghum plants (Jabran and Farooq, 2012; Anjum and Bajwa, 2008; Iqbal and Cheema, 2008). The phenolics present in sorghum comprised benzoic acid, caffeic acid, ferulic acid, gallic acid, syringic acid, coumaric acid and chlorogenic acid (Hassan *et al.,* 2012) which are phytotoxic to the growth of certain weeds and can reduced weeds density and growth (Tesio and Ferrero, 2010). Foliar application of sorghum water extract reduced weed density and dry weeds weight by 15 to 17 % and 19 t0 49 % respectively (Cheema and Khaliq, 2000).

The allelopathic function of sorghum is selective and depends on concentration of extract. (Kim *et al.,* 1993). Allelochemicals in low amount have stimulatory effect while in higher quantity exhibit inhibitory effects on growth and germination of weeds (Ghafarbi *et al.,* 2012, Jabeen and Ahmed, 2009; Ankita and Chabbi, 2012). The present study was therefore undertaken to investigate the effects of sorghum extract type, concentration and application time on weeds density and yield of wheat in agro-climatic conditions of Peshawar valley.

MATERIALS AND METHODS

Experimental Site

A field experiment was conducted at Agronomy Research Farm, University of Agriculture Peshawar, Pakistan during rabi season 2014-15. Peshawar lies at 17º, 35´ N and 35º, 41´ W with an altitude of 450 meters above the sea level. The experimental location has warm to hot, semi arid subtropical climate with less than 360 mm mean annual rainfall**.**

Experimental design and Experimental material

The experiment was carried out in randomized complete block (RCB) design having three replications. A plot size of 5.4 m^2 having six rows three meters long with 0.3 meters distant. Wheat variety "Atta Habib-2010" @ 120 kg ha^{-1} seed rate was sown on 27th November 2014. The crop was harvested on 15th May 2015. Nitrogen (N) and phosphorus (P) were applied @ 120 and 90 kg ha^{-1} respectively using Urea and DAP (di ammonium phosphate) as source. All P and half of N were applied at sowing and the remaining half of N was applied with first irrigation. The experiment was composed of two sorghum extract type (leaf and stem extracts), three extract concentrations (1:3, 1:4 and 1:5 kg L^{-1}) and three application time (emergence, tillering and 50 % at emergence + 50 % at tillering). Sorghum water extracts were applied as foliar spray with knapsack hand sprayer over weeds. No weeds check was performed and no spray was applied in control plots. Manual hand weeding was carried out by uprooting the weeds in hand weeded plots. Post emergence herbicides Buctril super 60EC (bromoxynil+MCPA) @ 1.5 L a.i ha^{-1} and Puma Super 75EW (fenoxaprop-P-ethyl) @ 1.25 L a.i ha^{-1} were applied 45 days after sowing in herbicides treated plots as broad leaf and narrow leaf weedicides respectively. Details of the sorghum water extract preparation were reported earlier (Rab *et al.,* 2016). All other agronomic practices such as irrigation and seedbed preparation were kept uniform for all the treatments. Treatments were applied as under. Control (No weed check and no spray), hand weeding (Manual hand weeding by uprooting weeds), herbicides application (Buctril @ 1.5 L ha^{-1} and Puma @ 1.25 L ha^{-1}), leaf water extract with 1:3 concentration applied at emergence (E), leaf water extract with 1:3 concentration applied at tillering (T), leaf water extract with 1:3 concentration applied 50 % at E + 50 % at T, leaf water extract with 1:4 concentration applied at emergence (E), leaf water extract with 1:4 concentration applied at tillering (T), leaf water extract with 1:4 concentration applied 50 % at E + 50 % at, leaf water extract with 1:5 concentration applied at emergence (E), leaf water extract with 1:5 concentration applied at tillering (T), leaf water extract with 1:5 concentration applied 50 % at E + 50 % at T, stem water extract with 1:3 concentration applied at emergence (E), stem water extract with 1:3 concentration applied at tillering (T), stem water extract with 1:3 concentration applied 50 % at E + 50 % at T, stem water extract with 1:4 concentration applied at emergence (E), stem water extract with 1:4 concentration applied at tillering (T), stem water extract with 1:4 concentration applied 50 % at E + 50 % at T, stem water extract with 1:5 concentration applied at emergence (E), stem water extract with 1:5 concentration applied at tillering (T), stem water extract with 1:5 concentration applied 50 % at E + 50 % at T.

Data were recorded for weed density, leaf area $tiller^{-1}$, plant height, spike length and grain yield. For weeds density data weeds were counted in one meter row at two different places in each plot. Weeds density m^{-2} was then calculated by using the given equation. Weeds density data was recorded two times (i.e. 70 and 90 days after sowing) in each plot.

$$\text{Weed density } (m^{-2}) = \frac{\text{Weeds number in one meter row}}{0.3 \text{ m} \times 1 \text{ m} \times 1}$$

For leaf area tiller^{-1} data, five representative tillers were randomly selected from each plot. The length and width of each tiller's leaves were measured with ruler and then average leaf length (A.L.L) and average leaf width (A.L.W) was recorded. Number of leaves of all the five tillers was also counted. Leaf area tiller^{-1} was then calculated using the given equation. The correction factor (C.F) used was 0.75 according to Khalil *et al.,* 2002.

$$\text{Leaf area tiller}^{-1} = \frac{\text{Total no. of leaves x A.L.L (cm) x A.L.W (cm) x C.F}}{\text{Number of tillers}}$$

For plant height data ten representative plants from each plot were selected randomly and their height was measured with help of a meter rod and then averaged to record individual plant height for further analysis. For recording spike length data ten representative spikes were selected at random from each plot and their length was measured with the help of ruler from the initial joint to the spike tip excluding awn. Spike length data was then averaged to record individual spike length for further analysis. For grain yield data three central rows were harvested manually from each plot and then bundled and placed in field for sun drying for some days. Each bundle was threshed separately with electronic wheat thresher machine. Grains of each threshed bundle were collected and weigh with digital balance. Grain yield was then converted into kg ha^{-1} using the given equation.

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Three middle rows grain yield (kg) x 10000}}{\text{0.3 m x 3m x 3}}$$

Statistical analysis

To determine analysis of variance for each parameter collected data were analyzed according to techniques appropriate for randomized completely block design (RCBD). Means were evaluated by Least Significant Differences (LSD) test when F values were significant at $P \leq 0.05$ probability level (Steel *et al.,* 1997).

RESULTS AND DISCUSSION

Weeds density (m^{-2})

Sorghum extract type, concentration, application time and stages significantly affected weeds density of wheat, whereas all the interactions were non significant (Table 1). More weeds (105.6) were recorded 90 days after sowing (DAS) compared with 83.9 weeds recorded 70 DAS. Herbicides sprayed plots resulted in fewer weeds (39.0) over sorghum water extract (SWE) sprayed plots (94.7). Similarly, hand weeded plots and SWE sprayed plots gave lower weed density (56.5) compared with control plots (154.7). Mean values for sorghum extract type showed that leaf extract gave fewer weeds (91.4), whereas stem extract produced more weeds (98.1). Mean values for concentration showed that fewer weeds (84.8) were noted with 1:3 concentration. Weed density increased with each increase in concentration and more weeds (103.1) were produced with 1:5 concentration. Application time showed that SWE applied at tillering resulted in minimum weeds (87.7), while SWE applied 50 % at emergence + 50 % at tillering gave maximum weeds (102.4). Reduction in weeds density with herbicides treatment and hand weeding plots may be due to fewer weeds recorded in herbicides treated and hand weeded plots. These results are in line with (Santos, 2009) who reported that weeds were effectively controlled with herbicides. More suppression of weeds with concentrated extract might be due to the fact that allelochemicals in low amount works as hormones and in high quantity acts as herbicides (Anwar *et al.,* 2003). These results are in line with (Nikneshan *et al.,* 2011) who reported that as water extract concentration increased from 25 to 100 %, the inhibitory effect on germination indices also increased. Our results are also in line with (Farooq *et al.,* 2011, Awan *et al.,* 2012) who reported significant decrease in weeds density with allelopathic crop water extract. The suppression of weed density with leaf and stem water extracts suggested the presence and effectiveness of allelochemicals in both of these materials. These results are in line with (Ashraf and Akhlaq, 2007) who reported significant reduction in weeds density with foliar application of both leaf and stem water extract of sorghum. Similarly, Rashid et al. (2008) reported that plant extract significantly affect the growth of other plants due to allelopathy.

Leaf area tiller^{-1} (cm^{2})

Sorghum extract type, concentration and application time significantly influenced leaf area tiller^{-1} of wheat, while all the interactions were non significant (Table 2). Herbicides sprayed plots gave more leaf area tiller^{-1} (114.7 cm^{2}) compared with SWE (101.3 cm^{2}). Likewise, hand weeded plots and SWE plots resulted in higher leaf area tiller^{-1} (110 cm^{2}) compared with control plots (74 cm^{2}). Mean values for concentration showed that more leaf area tiller^{-1} (104.6 cm^{2}) was generated with 1:3 concentration. Leaf area tiller^{-1} decreased with each increase in concentration and smaller leaf area tiller^{-1} (98.1 cm^{2}) was produced with 1:5 concentration. Application time indicated that SWE sprayed at tillering resulted in more leaf area tiller^{-1} (101.4), whereas SWE applied 50 % at emergence + 50 % at tillering gave lower leaf area tiller^{-1} (100.2 cm^{2}). Leaf water extract produced more leaf area tiller^{-1} (101.9 cm^{2}) compared with stem water extract (100.7 cm^{2}). Increase in leaf area tiller^{-1} may due to reduction in weed density. Reduction in weed density might boosted wheat plants development and growth and thus generated taller plants with vigorous leaves. These results are in line with (Anwar, 2002) who reported more leaf area with herbicides application followed by hand weeding. Our results are also in line with (Cheema *et al.,* 2000) who reported significant increased in leaf area with concentrated sorghum water extracts application.

Plant height (cm)

Sorghum extract type, concentration and application time significantly affected plant height of wheat, whereas all the interactions were non significant (Table 3). Herbicides sprayed plots produced taller plants (92 cm) compared with SWE sprayed plots (87.1 cm). Likewise, hand weeded plots and SWE plots generated longer plants (91 cm) compared with control plots (84.2 cm). Mean values for concentration showed that smaller plants (85.4 cm) were observed with 1:5 concentration. Plant height enlarged with each decrease in concentration and heighted plants (89.4 cm) were recorded with 1:3 concentration. Application time revealed that SWE sprayed at tillering produced longer plants (87.8 cm), while SWE sprayed 50 % at emergence + 50 % at tillering resulted in shorter plants (86.7 cm) which was statistically at par with SWE applied at tillering gave (86.8 cm) plant height of wheat. Leaf water extract gave taller plants (87.6 cm) compared with stem water extract (86.6 cm). Increase in plant height with herbicides, hand weeding and SWE over control might be due to the fewer weeds recorded in these plots. Reduced weed density may resulted in less competition of wheat with weeds for nutrients mainly nitrogen, phosphorus and potash and other resources like space, light and water which are needed in ample quantity for proper growth and development and hence produced taller plants of wheat. These results are in line with (Ahmad *et al.,* 2000, Cheema *et al.,* 2000, Cheema *et al.,* 2001) who reported more weeds suppressed with herbicides application, which ultimately gave taller plants of wheat compared with hand weeding and SWE sprays. Our results are also in line with (Khan *et al.,* 2015, Elahi *et al.,* 2011) who reported significant increase in plant height of wheat with allelopathic crop water extracts foliar sprays.

Spike length (cm)

Sorghum extract type, concentration and application time significantly influenced spike length of wheat, while all the interactions were non significant (Table 4). Herbicides sprayed plots produced longer spikes (10.57 cm) compared with SWE sprayed plots (9.78 cm). Similarly, lengthy spikes (10.27 cm) were noted in hand weeded plots and SWE sprayed plots compared with control plots (9.00 cm). Mean values for concentration showed that shorter spikes (9.62 cm) were noticed with 1:5 concentration. Spike length increased with each decrease in concentration and longer spikes (9.94 cm) were noted with 1:3 concentration. Application time showed that SWE sprayed at tillering gave longer spikes (9.85 cm), which was statistically at par with SWE applied at emergence resulted in (9.78 cm) spike length of wheat, whereas SWE applied 50 % at emergence + 50 % at tillering showed shorter spikes (9.71 cm), which was statistically similar with SWE applied at emergence resulted in (9.77 cm) spike length of wheat. Leaf water extract gave lengthy spikes (9.84 cm) compared with stem water extract (9.71 cm). These results are in line with (Javaid *et al.,* 2009) who reported longer spikes with water extract of allelopathic crops. Our results are in line with (Afridi *et al.,* 2014, Mehmood *et al.,* 2013) who reported significant increase in spike length with water extracts of allelopathic crops and (Khan *et al.,* 2013) who reported longer spikes with herbicides application compared with water extracts sprays.

Grain yield (kg ha^{-1})

Sorghum extract type, concentration and application time significantly influenced grain yield of wheat, whereas all the interactions were non significant (Table 5). Herbicides sprayed plots produced higher grain yield (3916.7 kg ha^{-1}) compared with SWE sprayed plots (3222.4 kg ha^{-1}). Similarly, hand weeded plots and SWE sprayed plots gave more grain yield (3683.3 kg ha^{-1}) compared with control plots (2346.7 kg ha^{-1}). Mean values for concentration showed that higher grain yield (3547.2 kg ha^{-1}) was noticed with 1:3 concentration. Grain yield of wheat decreased with each increase in concentration and lower grain yield (2997.8 kg ha^{-1}) was recorded with 1:5 concentration. Application time showed that SWE sprayed at tillering gave higher grain yield (3308.9 kg ha^{-1}), whereas SWE sprayed 50 % at emergence + 50 % tillering gave lower grain yield (3161.1 kg ha^{-1}), which is statistically at par with SWE applied at emergence resulted in (3197.2 kg ha^{-1}) grain yield of wheat. Leaf water extract gave more grain yield (3263 kg ha^{-1}) compared with stem water extract (3181.9 kg ha^{-1}). Significant increase in grain yield with herbicides application, hand weeding and SWE sprays may due to more weed reduction in these plots, due to which the competition for resources was reduced, which allow more flow of nutrients towards seed and more photosynthates were translocated to reproductive parts. These results are in line with (Hossain *et al.,* 2008, Khan *et al.,* 2013, Cheema *et al.,* 2002, Arif *et al.,* (2015, Iqbal *et al*., 2010) who reported maximum grain yield with herbicides treated plots compared with SWE plots. Our results are also in line with (Awan *et al.,* 2012, Khan *et al.,* 2015, Arif *et al.,* 2015) who reported more grain yield with foliar application of water extract of allelopathic crops.

CONCLUSION

It is concluded that sorghum leaf water extract applied with 1:3 concentration sprayed at tillering gave fewer weeds, more leaf area tiller^{-1}, taller plants, longer spikes and higher grain yield of wheat.

Table-1. Weed density (m^{-2}) of wheat as affected by sorghum extract type, concentration, application time and stages.

Sorghum Extract Type (SET)	Stages 70 DAS	90 DAS	Mean
Leaf water extract	80.8	102.0	91.4
Stem water extract	86.9	109.2	98.1
Mean	83.9	105.6	
Extract Concentration (C) (kg L^{-1})			
1:3	74.1	95.6	84.8 c
1:4	84.9	107.6	96.3 b
1:5	92.6	113.6	103.1 a
Application time (AT)			
Emergence (E)	83.4	104.9	94.2 b
Tillering (T)	77.3	98.0	87.7 c
50% at E + 50% at T	90.9	113.8	102.4 a
Planned Mean Comparison			
Control	143.3	166.0	154.7
Sorghum Water Extract	83.9	105.6	94.7
Hand Weeding	45.0	68.0	56.5
Herbicides Application	28.7	49.3	39.0
Interactions			
SET x C	NS	C x AT	NS
SET x C x AT	NS	SET x AT	NS

Means of same group having similar letters are non-significant using LSD test at P≤0.05
LSD for concentration and application time at p ≤ 0.05 = 6.42
NS = Non Significant

Table-2. Leaf area tiller^{-1} (cm^{2}) of wheat as affected by sorghum extracts type, concentration and application time.

Extract Concentration (C) (kg L^{-1})	Sorghum Extract type (SET) Leaf extract	Stem extract	Mean
1:3	105.11	104.11	104.61 a
1:4	102.00	100.44	101.22 b
1:5	98.67	97.56	98.11 c
Application Time (AT)			
Emergence (E)	101.89	100.89	101.39 a
Tillering (T)	103.11	101.56	102.33 a
50 % at E + 50 % at T	100.78	99.67	100.22 b
Mean	101.93	100.70	
Planned Mean Comparison		Interactions	
Control	74.00	SET x C	NS
Sorghum water extract	101.31	SET x AT	NS
Hand weeding	110.00	C x AT	NS
Herbicides application	114.67	SET x C x AT	NS

Means of same group having similar letters are non-significant using LSD test at P≤0.05
LSD for concentration and application time at p ≤ 0.05 = 1.10
NS = Non Significant

Table-3. Plant height (cm) of wheat as affected by sorghum extracts type, concentration and application time.

Extract Concentration (C) (kg L^{-1})	Sorghum Extract Type (SET) Leaf extract	Stem extract	Mean
1:3	89.9	89.0	89.4 a
1:4	87.0	85.8	86.4 b
1:5	86.0	84.9	85.4 c
Application Time (AT)			
Emergence (E)	87.2	86.4	86.8 b
Tillering (T)	88.4	87.3	87.8 a
50 % at E + 50 % at T	87.4	86.0	86.7 b
Mean	87.6	86.6	
Planned Mean Comparison		Interactions	
Control	84.2	SET x C	NS
Sorghum water extract	87.1	SET x AT	NS
Hand weeding	91.0	C x AT	NS
Herbicides application	92.0	SET x C x AT	NS

Means of same group having similar letters are non-significant using LSD test at P≤0.05
LSD for concentration and application time at p ≤ 0.05 = 0.76
NS = Non Significant

Table-4. Spike length (cm) of wheat as affected by sorghum extracts type, concentration and application time.

Extract Concentration (C) (kg L^{-1})	Sorghum Extract Type (SET) Leaf extract	Stem extract	Mean
1:3	10.01	9.89	9.95 a
1:4	9.84	9.71	9.78 b
1:5	9.70	9.57	9.63 c
Application Time (AT)			
Emergence (E)	9.84	9.72	9.78 ab
Tillering (T)	9.92	9.78	9.85 a
50 % at E + 50 % at T	9.79	9.67	9.73 b
Mean	9.85	9.72	
Planned Mean Comparison		Interactions	
Control	9.00	SET x C	NS
Sorghum water extract	9.79	SET x AT	NS
Hand weeding	10.27	C x AT	NS
Herbicides application	10.57	SET x C x AT	NS

Means of same group having similar letters are non-significant using LSD test at P≤0.05
LSD for concentration and application time at p ≤ 0.05 = 0.082
NS = Non Significant

Table-5. Grain yield (kg ha^{-1}) of wheat as affected by sorghum extracts type, concentration and application time.

Extract Concentration (kg L^{-1})	Sorghum Extract Type (SET)		
	Leaf extract	Stem extract	Mean
1:3	3566.7	3527.8	3547.2 a
1:4	3166.7	3077.8	3122.2 b
1:5	3055.6	2940.0	2997.8 c
Application Time			
Emergence (E)	3227.8	3166.7	3197.2 b
Tillering (T)	3366.7	3251.1	3308.9 a
50 % at E + 50 % at T	3194.4	3127.8	3161.1 b
Mean	3263.0	3181.9	
Planned Mean Comparison		Interactions	
Control	2346.7	SET x C	NS
Sorghum Water Extract	3222.4	SET x AT	NS
Hand Weeding	3683.3	C x AT	NS
Herbicides Application	3916.7	SET x C x AT	NS

Means of same group having similar letters are non-significant using LSD test at $P \leq 0.05$
LSD for concentration and application time at $p \leq 0.05$ = 52.26
NS = Non Significant

REFERENCES CITED

Afridi, R.A., M.A. Khan, H. Gul and M.K. Daud. 2014. Allelopathic influence of rice extracts on phenology of various crops and weeds. Pak. J. Bot. 46(4): 1211-1215.

Ahmad, A., Z.A. Cheema and R. Ahmad. 2000. Evaluation of sorgab as natural weed inhibitor in maize. J. Anim. Plant Sci. 10:141-146.

Anjum, T. and R. Bajwa. 2008. Screening of sunflower varieties for their herbicidal potential against common weeds of wheat. J. Sustain. Agri. 32(2): 213-229.

Ankita, G. and M. Chabbi. 2012. Effect of allelopathic leaf extract of some selected weed flora of Ajmer district on seed germination of Triticum aestivum. Sci. Res. Rept. 2: 311-315.

Anwar, S. 2002. Effect of sorghum extract and other weed control methods on wheat. M.Sc (Hons) Thesis, Dept. of Agronomy, the University of Agriculture Peshawar, Pakistan.

Anwar, S., W. A. Shah, M. Shafi, J. Bakht and M. A. Khan. 2003. Efficacy of sorgaab (sorghum water extract) and herbicide for weed control in wheat (*Triticum aestivum* L.) crop. Pak. J. Weed Sci. Res. 9: 161-170.

Arif, M., Z. A. Cheema, A. Khaliq and A. Hassan. 2015. Organic weed management in wheat through allelopathy. Int. J. Agric. Biol. 17(1); 127-134.

Ashraf, M. and M. Akhlaq. 2007. Effects of sorghum leaves, roots and stems water extract, hand weeding and herbicide on weeds suppression and yield of wheat. Sarhad J. Agri. 23: 321-328.

Awan, F. K., M. Rasheed, M. Ashraf and M. Y. Khurshid. 2012. Efficacy of brassica sorghum and sunflower aqueous extracts to control wheat weeds under rainfed conditions of Pothwar, Pak. J. Anim. Pl. Sci. 22: 715-721.

Cheema, Z. A., A. Khaliq and S. Akhtar. 2001. Use of sorgaab (sorghum water extract) as a natural weed inhibitor in spring mungbean. Int. J. Agric. Biol. 3: 515-518.

Cheema, Z. A., and A. Khaliq. 2000. Use of sorghum allelopathic properties to control weeds in irrigated wheat in a semi arid region of Punjab. Agric. Ecos. Environ. 79: 105-112.

Cheema, Z. A., H. M. I. Sadiq and A. Khaliq. 2000. Efficacy of sorgaab (sorghum water extract) as a natural weed inhibitor in wheat. Int. J. Agric. Biol. 2:144-146.

Cheema, Z. A., M. Iqbal and R. Ahmad. 2002. Response of wheat varieties and some Rabbi weeds to allelopathic effects of sorghum water extract. Int. J. Agri. Biol. 52-55.

Chon, S. U. and J. D. Kim. 2002. Biological Activity and Quantification of Suspected Allelochemicals from Alfalfa Plant Parts. J Agron Crop Sci., 188 (4): 281-285.

Economou, G., O. Tzakou, A. Gani, A. Yannitsaro and D. Bilalis. 2002. Allelopathic effect of *Conyza albida*. Ecology. 17: 2021-2034.

Elahi, M., Z. A. Cheema, S. M. A. Basra, M. Akram and Q. Ali. 2011. Use of allelopathic water extract of field crops for weed control in wheat. Int. Res. J. Plant Sci. 2(9): 262-270.

Farooq, M., K. Jabran, Z.A. Cheema, A. Wahid and K. H. M. Siddique. 2011. The role of allelopathy in agricultural pest management. Pest Manage. Sci. 67(5): 493-506.

Ghafarbi, S. P., S. Hassannejad and R. Lotfi. 2012. Allelopathic effects of wheat seed extracts on seed and seedling growth of eight selected weed species. Int. J. Agric. Crop Sci. 4(19):1452-57.

Hassan, M.M., H. M. Daffalla, S. O. Yagoub, M.G. Osman, A. M. E Gani, and A. G. E. Babiker. 2012. Allelopathic effects of some botanical extracts on germination and seedling growth of *Sorghum bicolor* L. Int. J. Agric. Technol. 8(4): 1423-1469.

Heap, I. 2005. The international survey of herbicide resistant weeds. Online, Internet, March 2, 2005. http:// www.weedscience.com.

Hossain, M. I., D. Barma, M. R. Islam, M. Z. Uddin and M. Rahman. 2008. Effect of newly developed herbicides on the growth and yield of wheat. Int. J. Sustainable Crop Prod. 4(1): 1-4.

Hussain, M., L. H. Akhtar, M. Rafiq, M. Z. Aslam, A. H. Tariq, M. Aslam, M. Arshad and S. Ahmad. 2010. Mairar-08: New wheat (*Triticum aestivum* L) variety released for general cultivation under normal and late planting in Punjab province (Pakistan). Int. J. Agric. Biol. 12(3): 341-347.

Hussain, Z., K. B. Marwat, F. Munsif, A. Samad and K. Ali. 2013. Evaluation of various herbicides and their combinations for weed control in wheat crop. Pak. J. Bot. 45(1): 55-59.

Iqbal, J. and Z. A. Cheema. 2008. Purple nutsedge (*Cyprus rotundus* L.) management in cotton with combined application of sorgaab and S. metolachlor. Pak. J. Bot. 40(16): 2383-2391.

Iqbal, J., F. Karim and S. Hussain. 2010. Response of the wheat crop (*Triticum aestivum* L.) and its weeds to allelopathic crop water extracts in combination with reduced herbicides rates. Pak. J. Agri. Sci. 47: 309-316.

Jabeen, N. and M. Ahmed. 2009. Possible allelopathic effects of three different weeds on germination and growth of maize (*Zea mays*) cultivars. Pak. J. Bot. 41: 1677-1683.

Jabran, K. and M. Farooq. 2012. Implications of potential allelopathic crops in agricultural systems. In: Allelopathy: Current Trends and Future Applications, pp: 349–385. Cheema, Z.A., M. Farooq and A. Wahid. Springer: Verlag Berlin Heidelberg, Germany.

Jabran, K., Z. A. Cheema, M. Farooq and M. Hussain. 2010. Lower doses of pendimethalin mixed with allelopathic crop water extracts for weed management in canola (*Brassica napus*). Int. J. Agric. Biol. 12: 335-340.

Jabran, K., Z. A. Cheema, M. Farooq, S. M. A. Basra, M. Hussain and H. Rehman. 2008. Tank mixing of allelopathic crop water extracts with pendimethalin helps in the management of weeds in canola (*B. napus*) field. Int. J. Agric. Biol. 10 (3): 293-296.

Javaid, I., Z. A. Cheema and M. M. Naeem. 2009. Allelopathic crop water extracts reduce the herbicide dose for weed control in cotton (*Gossypium hirsutum*). Int. J. Agric. Biol. 4: 360-366.

Khalil, S. K., K. Zeb and A. Z. Khan. 2002. Changes in leaf area assimilate accumulation and partitioning of wheat varieties planted on different dates. Pak. J. Soil Sci. 21: 15-19.

Khan, A.A., I. Ullah, M. Mansoor, E.A. Khan, A.A. Khakwani and M.S. Baloch. 2013. Efficacy and economic analysis of plant aqueous exudates on physiological parameters of wheat. Pak. J. Weed Sci. Res. 17(4): 417-424.

Khan, E.A., A.Z. Khakhwani, M. Munir and G. Ullah. 2015. Effect of allelopathic chemicals extracted from various plant leaves on weed control and wheat crop productivity. Pak. J. Bot. 47(2): 735-740.

Kim, S.Y., S.K. Datta, R.P. Robles, K.U. Kim, S.C. Lee and D.H. Shin. 1993. Allelopathic effect of sorghum extract and residues on selected crops and weeds. Korean J. Weed Sci. 14: 34-41.

Mahmood, A., A. Rashid, M.A. Ali and M.Q. Waqar. 2013. Efficacy of aqueous extracts of different allelopathic plants combined with reduced herbicides for weed control in wheat. J. Agric. Res. 51(4): 399-410.

MNFSR. 2014. Ministry of National Food Security and Research, Agricultural Statistics, Economic Wing, Government of Pakistan, Islamabad. Available at: http://www.mnfsr.gov.pk.

Nikneshan, P., H. Karimmojeni, M. Moghanibashi and N.A.S. Hosseini. 2011. Allelopathic potential of sunflower on weed management in safflower and wheat. Aust. J. Crop Sci. 5: 1434-1440.

Ortiz R, K.D. Sayre, B. Govaerts, R. Gupta, G.V. Subbarao, T. Ban, D. Hodson, J.M. Dixon, J.I. Ortiz-Monasterio and M. Reynolds. 2008. Climate change: Can wheat beat the heat? Agriculture, Ecosystems and Environment. 126:46-58.

Ozturk, M., U. Kebapci, S. Gucel, E. Cetin and E. Altundag. 2012. Biodiversity and land degradation in the lower Euphrates sub region of Turkey. J. Environ. Biol. 33: 311-323.

Putnam, A.R. and W.O. Duke. 1974. Biological suppression of weeds: evidence for allelopathy in accessions of cucumber. Science, 185: 370-372.

Rab, A., S.K. Khalil, M. Asim, N. Mehmood, H. Fayyaz, I. Khan, S. Zahid and H. Nawaz. 2016. Response of sorghum (*Sorghum bicolor* L.) extract type, concentration and application time to weeds weight, grain and biomass yield of wheat**.** Pure Appl. Biol. 5(4): 850-558. http://dx.doi.org/10.19045/bspab.2016.50106.

Rashid, H., M.A. Khan, A. Amin, K. Nawab, N. Hussain and P.K. Bhowmik. 2008. Effect of *Parhtenium hysterophorus* L. root extracts on seed germination and growth of maize and barley. The Americ. J. Plant Sci. Biotech. 2(2): 51-55.

Rao, A.N., D.E. Johnson, B. Sivaprasad, J.K. Ladha, A.M. Mortimer. 2007. Weed Management in Direct-Seeded Rice. Adv Agron. 93: 153-255.

Rueda, A.V.P., J. Rasmussen, R. Gerhards and N.E. Fournaise. 2011. The influence of post-emergence weed harrowing on selectivity, crop recovery and crop yield in different growth stages of winter wheat. Weed Res. 51: 478-488.

Santos, B.M. 2009. Drip applied metal potassium and herbicides as methyl bromide alternatives for cyperus control in tomato. Crop Prot. 28: 68-71.

Steel, R.G.D., J.H. Torrie and D.A. Deekey. 1997. Principles and Procedure of Statistics: A Biometrical Approach, 3rd edition, pp: 400-428. McGraw Hill Book Co. Inc. New York, USA.

Tesio, F. and A. Ferrero. 2010. Allelopathy a chance for sustainable weed management. Int. J. Sustain. Develop. World Ecol. 17 (5): 377-389.

Weir, T.L., S.W. Park and J.M. Vivanco. 2004. Biochemical and physiological mechanisms mediated by allelochemicals. Current Opin. Plant Biol. 7: 472-479.