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REDUCED HERBICIDE DOSES IN COMBINATION WITH ALLELOPATHIC PLANT EXTRACTS SUPPRESS WEEDS IN WHEAT

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Abstract

Allelopathy is gaining popularity worldwide probably for decreasing the cost of production and environment friendly weed suppressing approach. Repeated field studies conducted during 2011-12 and 2012-13 at Agricutural Research Institute Tarnab, Peshawar, Pakistan where allelopathic water extracts of *Oryza sativa*, *Parthenium hysterophorus*, *Phragmites australis* and *Datura alba* along with reduced doses of phenoxaprop-p-ethyl and bromoxinil+MCPA were tested for controlling weeds in wheat. It was observed that weed density was encouragly suppressed whereas spike length (cm), number of spikelets spike^{-1} and 1000 grain weight (g) of the wheat were improved when the allelopathic plant water extracts were used in combination with lower doses of herbicides. Thus, allelochemicals provide weed suppressing option in wheat. However, more studies are required to fully explore the possibility of weed management and isolation of the chemicals involved in weed suppression for environment friendly weed management in wheat. Such studies may decrease the cost of crop production and total use of herbicides.

Keywords: Allelopathy, Wheat, Reduced dose, Herbicides, Weeds.

Introduction

Weed infestation is a serious problem in wheat crop and uncontrolled weed can reduce wheat yield by 20-30% in Pakistan. Weed infestation negatively affect the growth of wheat due to competition. Weed management strategies like herbicide application and manual weeding are effect for weed control but in some cases it seems to be uneconomical because of higher costs and herbicide may also cause pollution (Cheema *et al.,* 2003).

In the recent past, the use of allelochemicals for weed control has been extensively investigated for sustainable crop production (Razzaq *et al.,* 2010). *Phenoxaprop-p-ethyl* is extensively used for grassy weeds and Buctril super (b*romoxinil+MCPA*) for controlling broad leaf weeds while Affinity (isoproturon + carfentrazone) are used as broad spectrum herbicide in wheat. The regular use of these herbicides in the same areas may cause weed resistance that will further create many related problems as the farmers in Pakistan are illiterate. Allelopathic plant water extracts of several plants have already shown ability to inhibit the density and dry biomass of weeds in wheat crop (Elahi *et al.,* 2011).

In order to decrease the use of herbicides, crops and weeds with potent allelopathic potential are helpful e.g., sorghum residues decreased normal weed population up to 95% (Anwar *et al.,* 2003). Use of allelopathic material in combination with reduced rates of herbicides is the major area of present research in Pakistan. Several studies conducted by Cheema and associates (Ahmad *et al.,* 2000; Cheema *et al.,* 2005; Jabran *et al.,* 2008) have reported that weed density was drastically decreased due to the application of sorgaab (sorghum water extracts). It was concluded that water extracts of the plants were effective to suppress the weeds that were in acceptable range.

Mahmood *et al.,* (2009) suggested the use of sorgaab weed management in wheat crop and stated that herbicidal treatments reduced weed density and biomass by 69% and 73%, respectively and it increased wheat yield by 40%.

Oryza sativa is grown as fodder crop while *Parthenium hysterophorus, Phragmites australis* and *Datura alba* are found in the different parts of the country and visual observation shows that these plant inhibit or suppress the growth of the nearby plants. Therefore these plants were collected to explore the possibility of these plants to use for weed suppression. As there is limited or no use of these plants therefore the infestaation and density of these weeds has tremendously increased. *P. hysterophorus* is already a serious threat to native plant species due to wide spread (Khan *et al.,* 2012) while *P. australis* is a great problem in aquatic bodies and cause huge losses in different ways. Many wild plants can be used for different purposes (Dastagir *et al.,* 2013) it has been communicated earlier that phytochemicals are usually water soluble, therefore the allelochemicals are released into the environment from any part of the allelopathic plants. Rain or irrigation can also cause release of allelochemicals and thus affect other plants (Rice, 1984). Effects of these chemicals depend upon species, concentration, their movement, fate and persistence in soil. These are also selective like synthetic herbicide. This characteristic could be used in weed management programmes and allelopathic plants may help in the development of biological herbicides. (Razzaq *et al.,* 2010). Due to wide range of allelopathic plants that are present in the agricultural lands, few plants were selected with the objectives to decipher their phytotoxic potential against winter weeds. Water extracts of allelopathic plants were tested in combination with low rates of herbicides for possible additive actions. Such studies are helpful to suppress the weeds with the benefits of low cost and protection of agri-food.

Materials and Methods

Field experiments were conducted during rabi 2011 and was repeated in 2012 at experimental field of Agricultural Research Institute Tarnab, Peshawar, KPK, Pakistan which is located between 33° 44′ and 34° 15′ north latitude and 71° 22′ and 71° 42′ east longitude.

Meteorological data: The mean maximum temperature in summer is over 40°C and the mean minimum temperature is 25°C. The mean minimum temperature during winter is 4°C and maximum is 18.35°C.

The average winter rainfall is higher in winter than that of the summer. Based on a 30 year record, the average annual precipitation has been recorded as 400 millimeters where Wind speeds vary during the year from 5 knots in December to 24 knots in June. The relative humidity varies from 46% in June to 76% in August.

Physico-chemical properties of the experimental field: Samples of the soil were collected few days before sowing to a depth of 10 cm for its various physico-chemical properties analysis at soil science lab of Agricultural Research Institute Tarnab Peshawar. Percentage of clay, silt and sand of the soil samples was determined with the help of hydrometer method where textural class was analyzed by using international Textural Triangle. Soil was analyzed for its various chemical properties (Table 1).

Table. 1. Physico-chemical characteristics of soil.

Characteristics	Units	Readings
Textural class		Silty clay loam
Clay	%	37.0
Silt	%	60.0
Sand	%	3.0
$Caco_3$	%	18.50
Organic matter	%	0.41
Nitrogen	%	0.020
Phosphorus	%	7.1
Potassium	%	300
pH		8.2

Land preparation: After the harvesting of maize crop, experimental field was irrigated about 15 days before planting of wheat seeds. It was ploughed at desirable field condition and followed by single planking. Finally two more ploughing and planking were done to a proper tilth for wheat planting.

Collection of test plants for extracts: Water extract of *Oryza sativa* L., *Parthenium hysterophorus* L., *Phragmites australis* Cav. and *Datura alba* L. were collected from the fields in Peshawar and were harvested at maturity stage. These test plants were harvested at the base above ground with the help of a sickle. After collection, these plants were cleaned from dust and other particles.

Procedure adopted: The test plants were chopped into small pieces of 3 cm with the help of electric fodder cutter. Wheat variety "Pirsabak-2008" was planted in 25 cm spaced rows with single row hand drill on 15th November, 2011 and was repeated on same date in 2012 at recommended seed rate of 120 kg ha^{-1}. There were eight rows of wheat crop in each plot, 3 m long. Recommended rate of nitrogen and phosphorus (N:P) at the rate of 120: 60 kg ha^{-1} was applied. Half nitrogen and full phosphorus were applied at sowing time while the remaining nitrogen was applied during 2nd irrigation. Nitrogen and phosphorus were applied in the form of Urea and DAP, respectively. Moreover, the crop was irrigated as per requirement of the wheat crop. The experiments were performed in a Randomized Complete Block Design (RCBD) with sixteen treatments, replicated four times. The detail of the treatments during the study was as follows:

Treatments

T_1 = *Oryza sativa* L. extract alone @ 500 kg ha^{-1}
T_2 = *Parthenium hysterophorus* L. extract alone @ 500 kg ha^{-1}
T_3 = *Phragmites australis* Cav. extract alone @ 500 kg ha^{-1}
T_4 = *Datura alba* L. extract alone @ 500 kg ha^{-1}
T_5 = *Oryza sativa* L. extract + ½ Puma Super 750EW
T_6 = *Oryza sativa* L. extract + ½ Buctril Super 600 EC
T_7 = *Parthenium hysterophorus* L. extract+½ Puma Super 750EW
T_8 = *Parthenium hysterophorus* L. extract+ ½ Buctril Super 600EC
T_9 = *Phragmites australis* Cav. extract + ½ Puma Super 750EW
T_{10} = *Phragmites australis* Cav. extract + ½ Buctril Super 600EC
T_{11} = *Datura alba* L. extract + ½ Puma Super 750EW
T_{12} = *Datura alba* L. extract + ½ Buctril Super 600EC
T_{13} = ½ Puma Super 750EW (Grass leaf killer) @ 625 ml ha^{-1}
T_{14} = ½ Buctril Super 600 EC (Broad leaf killer) @ 375 ml ha^{-1}
T_{15} = Hand weeding
T_{16} = Control (Weedy check)

Extract preparation: The above mentioned 3 cm small chopped pieces of plants were dried in an oven for 72 hours at 65^{o}C and then the plants materials were soaked in distilled water @ 150 g L^{-1} for 48 hrs and finally were filtered to collect the respective water extracts. The treatments mentioned above were sprayed as post-emergence in the concerned treatments with knapsack sprayer fitted with flat fan nozzle at 30 days after sowing (DAS). Hand weeding was practiced at 30 days after sowing of wheat crop as per treatment design. A weedy check was maintained as control treatment for comparison.

Parameters: During the experimentation the data on the following parameters were recorded.

Weed density (m^{-2}): Weed density in all the above-mentioned treatments was recorded at 45 days after sowing. Quadrate having size of 33 x 33 cm was randomly thrown five times in each treatment and the weeds inside the quadrate were counted. The mean of the five quadrates was subsequently converted to density m^{-2}.

Spike length (cm): Length of ten representative randomly selected spikes was measured in each treatment and average was recorded.

Number of spikelets spike^{-1}: The number of spikelets spike^{-1} was counted by randomly selecting ten spikes in each treatment and counting the spikelets on each spike and then mean was calculated.

1000 grain weight (g): The 1000 grain weight was recorded by selecting a random sample of 1000 grains from each treatment and then weighing by electronic balance in grams (g).

Statistical analysis: Collected data were analyzed according to procedure appropriate for RCBD and means were compared using LSD test when F-values are significant (Steel & Torrie, 1984).

Results and Discussion

Weed density (m^{-2}): Analyzed data showed that allelochemicals alone and in combination with synthetic herbicide had significant effect on weed density at forty five days after sowing (Table 2). Maximum weed reduction was noted in plots treated with *P. hysterophorus* + ½ B. Super and *P. hysterophorus* + ½ Puma super which gave (43.50 and 43.00 weeds m^{-2}) followed by 54.75 and 52.00 weeds m^{-2} observed in *D. alba* + ½ B. Super and *D. alba* + ½ P. Super, respectively. Moreover weed density of (63.25 and 67.00 m^{-2}) was recorded in *P. australis* + ½ Puma super and *P. australis* + ½ Buctril super, respectively over weedy check. Half dose of the synthetic herbicide suppressed weeds by 121.38 by ½ Puma super followed by half Buctril super 600 (127.75) as compared to untreated plots. Interestingly extract alone showed promising weed control when compared with untreated plots. Earlier reports have shown that higher plant releases a diversity of allelochemicals into the environment, which include phenolics, alkaloids, long - chain fatty acids, terpenoids and flavanoids (Rice, 1984). The compounds exhibit a wide range of mechanisms of action; affect on DNA (alkaloids), photosynthetic and mitochondrial function (quinines), phytohormone activity, ion uptake and water balance. In addition, the allelochemicals are an important defense for certain plants against the interference of other plants of the same or different species, which can affect their growth and development (Uremis *et al.,* 2009; Gupta & Mittal, 2012). Extracts of the allelopathic plants probably acted synergistically when combined with herbicides. Elahi *et al*., (2011) observed that sunfaab +riceaab and1/3 dose of phenoxaprop-p-ethyl resulted in best control of narrow leaf weed population and dry matter which was statistically equal to the label dose. The plant water extracts such as *P. hysterophorus, D. alba, P. australis* and *O. sativa* in combination with herbicides can be used to reduce the full dose of herbicides which is dangerous for human, animal health and harmful for flora and fauna. During the instant studies, the extract combinations enhanced the effectiveness of certain herbicides. These results were supported by Cheema *et al.,* (2003; 2009) who reported that allelopathy may be manipulated to reduce herbicide dose. Due to successfulness of the use of allelochemicals in agriculture, it has been communicated that the dose of herbicide can be decreased if allelopathic water extracts and herbicides were used in mixture (Cheema *et al.,* 2003; 2002a,b). They reported that water extracts of sorghum showed very good results in cotton as weeds were controlled by such treatments. It is concluded from the instant studies that allelopathic plant water extracts with reduced dose of herbicide can suppress the weed density by inhibiting the germination of weed seeds. Current research is focused on the effects of weeds on crops, crops on weeds and crops on crops. These findings further support the idea that there are chances to use plant derived chemical compounds as growth promoters for different crops and herbicides for weed control (Chen *et al.,* 2008). As weeds should be controlled before 40 days after emergence of the crop (Shehzad *et al.,* 2013) therefore the instant results are encouraging for the scientists to explore weed management through allelopathy.

Table 2. The inhibitory potential of mixed allelopathic synthetic herbicide on weed density m^{-2}.

S. No.	Extract/herbicide	Rate (kg ha^{-1})	Weed density (m^{-2}) 45 DAS
1.	*O. sativa* (alone)	500	140.88 c
2.	*P. hysterophorus* (alone)	500	87.00 f
3.	*P. australis* (alone)	500	127.25 d
4.	*D. alba* (alone)	500	115.25 e
5.	*O. sativa* + ½ P. Super 750 EW	500 + 625 ml	75.75 gh
6.	*O. sativa* + ½ B. Super 600 EC	500 + 375 ml	78.00 fg
7.	*P. hysterophorus* + ½ P. Super 750EW	500 + 625 ml	43.00 l
8.	*P. hysterophorus* + ½ B. Super 600EC	500 + 375 ml	43.50 l
9.	*P. australis* + ½ P. Super 750EW	500 + 625 ml	63.25 ij
10.	*P. australis* + ½ B. Super 600EC	500 + 375 ml	67.00 hi
11.	*D. alba* + ½ P. Super 750EW	500 + 625 ml	52.00 kl
12.	*D. alba* + ½ B. Super 600EC	500 + 375 ml	54.75 jk
13.	½ P. Super 750EW	500 ml	121.38 de
14.	½ B. Super 600 EC	300 ml	127.75 d
15.	Hand weeding	-	154.13 b
16.	Control	-	178.75 a
	Mean		**95.61**

LSD $_{0.05}$ for weed density m^{-2} (45 DAS) = 10.34

Table 3. The inhibitory potential of mixed allelopathic synthetic herbicide on yield parameters of wheat crop.

S. No	Extracts/herbicides	Rate (kg ha^{-1})	Spike length (cm)	No. of spikelets $spike^{-1}$	1000 grain weight (g)
1.	*O. sativa* (alone)	500	9.06 ghi	18.30 gh	39.05 def
2.	*P. hysterophorus* (alone)	500	9.84 e	19.40 de	40.35 cd
3.	*P. australis* (alone)	500	9.20 fgh	18.82 fg	39.75 de
4.	*D. alba* (alone)	500	9.44 efg	18.88 ef	39.45 de
5.	*O. sativa* + ½ P. Super 750 EW	500 + 625 ml	10.63 cd	19.85 cd	42.35 bc
6.	*O. sativa* + ½ B. Super 600 EC	500 + 375 ml	10.40 d	19.48 cd	42.05 bc
7.	*P. hysterophorus* + ½ P. Super 750EW	500 + 625 ml	10.86 bc	20.02 bc	43.85 ab
8.	*P. hysterophorus* + ½ B. Super 600EC	500 + 375 ml	10.86 bc	19.98 bc	43.65 ab
9.	*P. australis* + ½ P. Super 750EW	500 + 625 ml	11.48 a	20.90 a	44.45 a
10.	*P. australis* + ½ B. Super 600EC	500 + 375 ml	11.10 ab	20.83 a	44.05 ab
11.	*D. alba* + ½ P. Super 750EW	500 + 625 ml	11.06 abc	20.67 a	43.25 ab
12.	*D. alba* + ½ B. Super 600EC	500 + 375 ml	10.98 bc	20.43 ab	42.85 ab
13.	½ P. Super 750EW	625 ml	9.54 ef	18.92 ef	39.55 de
14.	½ B. Super 600 EC	375 ml	9.33 fg	18.82 fg	39.25 def
15.	Hand weeding	-	8.82 hi	18.22 h	37.95 ef
16.	Control	-	8.66 i	18.18 h	37.25 f
	Mean		**10.075**	**19.48**	**41.20**

$LSD_{0.05}$ for spike length (cm) = 0.45, for No. of spikelets $spike^{-1}$ = 0.56, for 1000 grain weight (g) = 2.04

Spike length (cm): All the combinations of allelopathic plant water extracts with reduced dose of herbicides significantly improved spike length as compared to control. It can be seen from the data (Table 3) that lengthy (11.48 cm) spike was observed in *P. australis* + ½ Puma super treated plots which was statistically at par with *D. alba* + ½ P. Super (11.06 cm). While spike length of 10.86 cm was noted in both treatments of *P. hysterophorus* + ½ Puma super as well as *P. hysterophorus* + ½ Buctril super. The allelopathic plant water extracts alone and half dose of herbicide alone showed similar results as compared to control (8.66 cm). Reduced dose of synthetic herbicide showed equal effect with higher dose of allelopathic plant water extracts. The higher rate of allelopathic plant water extracts compensated the lower rates of herbicide. This study further indicated that in most cases pure form of allelpathic plant water extracts were more effective and can reduce the dose of herbicide up to 75% (Iqbal & Cheema, 2007). It has been noted that grassy weeds like *A. fatua* and broadleaf weeds like *R. dentatus* are harmful for all the winter crops including wheat. Due to strong competitive ability of these weeds with wheat crops, the management of these weeds need to be addressed to avoid the grain yield losses (Tauseef *et al.,* 2013). Allelochemicals of *P. hysterophorus* can be exploited as a source of natural herbicides to control other invasive species (Mulatu *et al.,* 2009). The dose of phenoxoprop p-ethyl and pendimethalin can be decreased upto great extent when water extracts of allelopathic plants like sorghum and sunflower water extracts were used in wheat and canola, respectively. The weed control was acceptable and below threshold level due to use of these allelopatic plant extracts (Mahmood *et al.,* 2009; Jabran *et al.,* 2010). It is believed that change in spike length in a field trial was due to weed suppression that resultantly favoured the crops plants to use the resources (Irshad & Cheema, 2004). Javaid *et al.,* (2009) found that allelochemicals increased the spike length due to weed suppression. Allelopathy in field condition is always due to join action of mixture of various allelochemicals rather than to one allelochemical. Cheema *et al.,* (2003) conducted field experiments to test the water extracts of sorghum, sunflower and eucalyptus alone and in mixtures with one another at various doses. The combination of the allelopathic water extracts reduced the weed density and dry biomass whereas of these extracts individually had no suppression or minimum inhibition. Plant derived compounds are released into the soil and thus the neighboring plants' capacity to absorb water and minerals and other physiological process in the plants are disturbed. Due to these negative effects on the surrounding plants, the receiver plants are adversely affected by the allelochemicals. There are several reports that show the positive effects of allelochemicals on crop plants. However, during the present study, the allelopathic plants showed negative effects on other plants. Synthetic herbicide with high and minimum doses in cultivated and non cultivated land for various activities is a type of serious risk in developing countries. In Pakistan and our neighboring countries, there is no awareness about the safe use of chemicals thus; bioherbicides provide best weed management option as well as also environment friendly technique.

Number of spikelets $spike^{-1}$: Results revealed that there was increase in number of spikelets $spike^{-1}$ in all the treatments over control. Maximum (20.90) number of spikelets $spike^{-1}$ was recorded in *P. australis* + ½ Puma super treated plots while minimum (18.18) number of spikelets $spike^{-1}$ was noted in control. *P. australis* + ½ Buctril super produced 20.83 followed by *D. alba* + ½ P. Super and B Super (20.67 & 20.43, respectively). *P. hysterophorus* + ½ Puma super and Buctril super gave

20.02 & 19.98 while *O.sativa* + ½ Puma super and Buctril super produced 10.63 & 10.40 spikelets spike^{-1} (Table 3). The reduced dose of herbicides when used in combination with water extracts of allelopathic plant improved spikelets almost equal to the herbicides used as a full dose. Improvement in spikelets spike^{-1} might be due to the best weed control or might be due to the positive effect of combination of allelochemicals and reduced doses of herbicides. Cheema *et al.,* (2003) observed that more fertile tillers were observed in the plots in which two sprays of allelopathic extracts as foliar were used with low rate of herbicides. Thus it is assumed that the presence of *P. australis* for long time may have affected the soil seed bank of various weed species in soil. These findings are further supported by Khan & Khan (2012) who found that the application of *Phragmites australis* and *Helianthus annuus* gave 68 and 65% weed control, respectively. These allelopathic plants could be successfully incorporated in weed management approaches in wheat. The findings of this research is relevant to the findings of Elahi *et al.,* (2011) who found that crops/plants are allelopathic to different weeds and possibility exist to reduce herbicidal dosage by combining the allelopathic water extracts for controlling weeds in wheat. Lower rate of herbicide application with water extracts of allelopathic plant will probably decrease the total herbicidal use that will subsequently increase the farm income and will be less toxic to the environment (Razzaq *et al.,* 2010).

1000 grain weight (g): Application of plant water extracts in combinations with low herbicide rates significantly improved 1000 grain weight as compared to untreated plot (Table 3). The maximum (44.45 & 44.05 g) 1000 grain weight were recorded for *P. australis* + ½ Puma super and *P. australis* + ½ Buctril super followed by 43.85 & 43.65 g of 1000 grain weight observed in *P. hysterophorus* + ½ P. Super and *P. hysterophorus* + ½ Buctril super. While minimum (37.25 g) 1000 grain weight was noted in untreated plot. *P. hysterophorus* alone produced 40.35 g of 1000 grain weight as compared to reduced dose of Puma super (39.55 g) and Buctril super (39.25 g). Heavier 1000 grain weight was produced where allelopathic plant water extracts alone and ½ dose of synthetic herbicide in combination were applied. Application of reduced doses of herbicides mixed with allelopathic water extracts produced higher grain yield compared with the application of reduced doses of herbicides (Khan *et al.,* 2012). Highest grain weight might be due to successful weed control in treated plots. It could be due to the action of various types of allelochemicals present in allelopathic plants that were used in the form of water extracts. Extracts and residues of tested species might have the potential to use for pre-emergence and post-emergence weed control (Nekonam *et al.,* 2013). Several processes are considered to play important role in the allelopathy. Studies have shown that fresh plants of allelopathic plant like *P. hysterophorus* were more toxic to other plants as compared to decomposed plants of the same plant species (Mulatu *et al.,* 2009). Thus there is possibility to use allelopathic plants as compost. However, more scientific studies are needed to fully explore the use of allelopathic plants as fresh and decomposed. These results are similar to the finding of Khan *et al.,* (2012) who studied that half dose of atrazine tank mixed with water extracts of sorghum, brassica, sunflower and mulberry applied provided an edge to maize plants to extract more water and nutrients from the soil resulting in vigorous growth which produced larger sized cobs with more grains. Earlier research (Khaliq *et al.,* 2002; Jabran *et al.,* 2008; Mahmood *et al.,* 2009; Razzaq *et al.,* 2010, 2012) findings have shown that the use of reduced doses of herbicides with allelopathic plant water extracts has increased the desirable characters of crop plants. The present findings depicted that the aqueous extracts of allelopathic plants with reduced dose of herbicide are effective against different weeds in wheat.

Conclusion

Allelopathic potential of several plants was investigated in combination with low dose of herbicides. It was noted that water extracts of the allelopathic plants in combination with reduced dose of herbicides were effective to suppress weeds which ultimately improved the yield related parameters of wheat.

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References

Ahmad, A., Z.A. Cheema and R. Ahmad. 2000. Evaluation of sorgaab as natural weed inhibitor in Maize. *J. Animal Plant Sci*., 10: 141-146.

Anwar, S., W.A. Shah, M. Shafi, J. Bakht and M.A. Khan. 2003. Efficiency of sorgaab (sorghum water extract) and herbicide for weed control in wheat (*Triticum aestivum* L.) crop. *Pak. J. Weed Sci. Res*., 9(3&4):161-170.

Cheema, Z.A., A. Khaliq and M. Mubeen. 2003. Response of wheat and winter weeds to foliar application of different plant water extracts of sorghum (*S. bicolor*). *Pak. J. Weed Sci. Res*., 9(1-2): 89-97.

Cheema, Z.A., A. Khaliq and M. Tariq. 2002b. Evaluation of concentrated Sorgaab alone and in combination with reduced rates of three pre-emergence herbicides for weed control in cotton (*G. hirsutum* L.). *Int. J. Agric. Biol*., 4(4): 549-552.

Cheema, Z.A., A.H. Khichi and A. Khaliq. 2005. Feasibility of reducing herbicide dose in combination with sorgaab for weed control in transplanted fine rice (*Oryza sativa* L.). *Int. J. Agric. Biol*., 7: 892-894.

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

Cheema, Z.A., M.N. Mushtaq, M. Farooq, A. Hussain and I.U. Din. 2009. Purple nutsedge management with allelopathic sorghum. *Allelopathy J*., 23: 305-312.

Chen, X.H., F. Hu and C.H. Kong. 2008. Varietal improvement in rice allelopathy. *Allelopathy J*., 22: 379-384.

Dastagir, G., F. Hussain, F. Khattak and Khanzadi. 2013. Proximate analysis of plants of family zygophyllaceae and euphorbiaceae during winter. *Sarhad J. Agric*., 29(3): 395-400.

Elahi, M., Z.A. Cheema., S.M.A. Basra., M. Akrm 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.

Gupta, A. and C. Mittal. 2012. Effect of allelopathic leaf extract of some selected weed flora of Ajmer district on seed germination of *Triticum aestivum* L. *Sci. Res. Rep.*, 2(3): 311-315.

Iqbal, J. and Z.A. Cheema. 2007. Effect of allelopathic crop water extracts on glyphosate dose for weed control in cotton (*Gossypium hirsutum*). *Allelopathy J.*, 19: 403-410.

Irshad, A. and Z.A. Cheema. 2004. Effect of sorghum extract on management of barnyard grass in rice crop. *Allelopath. J.* 14: 205-212.

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* L.). *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 (*Brassica napus*) field. *Int. J. Agric. Biol*., 10: 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.

Khaliq, A., Z. Aslam and Z.A. Cheema. 2002. Efficacy of different weeds management strategies in mungbean (*Vigna radiata* L.). *Int. J. Agric. Biol.*, 4: 237-239.

Khan, H., K.B. Marwat, G. Hassan and M.A. Khan. 2012. Chemical control of *Parthenium hysterophorus* at different growth stages in non-cropped area. *Pak. J. Bot.*, 44(5): 1721-1726.

Khan, M. B., M. Ahmad, M. Hussain, K. Jabran, S. Farooq, and H. M. Waqas. 2012. Allelopathic plant water extracts tank mixed with reduced doses of atrazine efficiently control *Trianthema portulacastrum* L. in *Zea mays* L. *The J. Anim. Plant Sci.*, 22(2): 339-346.

Khan, R. and M.A. Khan. 2012. Weed control efficiency of bioherbicides and their impact on grain yield of wheat (*Triticum aestivum* L.) *European J. Appl. Sci.*, 4(5): 216-219.

Mahmood, K., M.B. Khan, M. Hussain and M.A. Gorchani. 2009. Weed Management in Wheat Field (*Triticum aestivum*) using allelopathic crop water extracts. *Int. J. Agric. Biol.*, 11-6: 751-755.

Mulatu, W., B. Gezahegn and T. Solomon. 2009. Allelopathic effects of an invasive alien weed Parthenium hysterophorus L. compost on lettuce germination and growth. *African J. Agric. Res.*, 4(11): 1325-1330.

Nekonam, M. S., J. Razmjoo, B. Sharifnabi and K. Hassan. 2013. Assessment of allelopathic plants for their herbicidal potential against field bindweed (*Convolvulus arvensis*). *Aust. J. Crop Sci.*, 7(11): 1654-1660.

Razzaq, A., Z.A. Cheema, K. Jabran, M. Farooq, A. Khaliq, G. Haider and S.M.A. Basra. 2010. Weed management in wheat through combination of allelopathic water extract with reduced doses of herbicides. *Pak. J. Weed Sci. Res.*, 16(3): 247-256.

Razzaq, A., Z.A. Cheema, K. Jabran, M. Hussain, M. Farooq and M. Zafar. 2012. Reduced herbicide doses used together with allelopathic sorghum and sunflower water extracts for weed control in wheat. *J. Plant Prot. Res*., 52: 281-285.

Rice, E.L. 1984. Allelopathy. Academic Press Inc., New York.

Shehzad, M., A. Tanveer1, M. Ayub, K. Mubeen, M. Ibrahim, I. Qadir and N. Sarwar. 2013. Effect of weed-crop competition on growth and yield of garden cress. *Sarhad J. Agric.*, 29(1): 79-82.

Steel, R.G.D. and J.H. Torrie. 1984. Principles and procedures of statistics (2nd Ed.). MC Graw Hill Book Co; Singhapore. pp. 172-177.

Tauseef, A., S. Khalid, Y. Arafat, S. Sadia, and S. Riaz. 2013. Allelopathic suppression of *Avena fatua* and *Rumex dentatus* in associated crops. *Pak. J. Weed Sci. Res*., 19(1): 31-43.

Uremis, I., M. Ahmet, A. Uludag and M. Sangun. 2009. Allelopathic potentials of residues of 6 brassica species on johnsongrass (*Sorghum halepense*). *Afr. J. Biotech*., 8: 3497-3501.

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