

EFFICACY OF AQUEOUS EXTRACTS OF DIFFERENT ALLELOPATHIC PLANTS COMBINED WITH REDUCED HERBICIDE DOSES FOR WEED CONTROL IN WHEAT

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ABSTRACT

Allelopathic crop water extracts with reduced herbicide doses were tested for weed control in wheat at Adaptive Research Farm, Sheikhpura, Pakistan during the year 2010-11. Aqueous extracts of sorghum (*Sorghum bicolor* L.), sunflower (*Helianthus annuus* L.) and mulberry (*Morus alba* L.) were combined (each at 18 l/ha) with Atlantis 3.6 WG (mesosulfuron + idosulfuron) @ 14.4 (recommended), 7.20 and 4.80g a.s/ha alongwith weedy check. Dried and chopped parts of sorghum and sunflower mature plants and dry leaves of mulberry were soaked in water, boiled and filtered and then these extracts were mixed as per treatments and applied at 50 days after sowing. The results revealed that application of extracts of sunflower+sorghum+mulberry mixed with Atlantis 3.6 WG @ 7.20 g a.s/ha exhibited higher weed reduction in total weed density (86%) and total weed dry weight (88%). The same treatment also produced maximum grain yield (2.90 t/ha), which was 36 percent higher than control (2.13 t/ha) and 3.94 percent higher than recommended dose of herbicide (2.79 t/ha). The data further showed superiority of this treatment for higher net return of Rs. 71322 per hectare and 4221 percent marginal rate of return.

KEYWORDS: *Triticum aestivum*; weeds; *Sorghum bicolor*; *Helianthus annuus*; *Morus alba*; herbicides; plant extracts; allelopathic effects; cost benefit analysis; Pakistan.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important staple food of a large population in Pakistan. For this reason, researchers and the farming community in Pakistan greatly focus on wheat crop (21, 30). Problems such as high weed infestation, delayed sowing, poor nutrition and drought are the reasons which lower wheat yield and are threatening food security in

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Pakistan (19, 21). Weeds left unmanaged, cause massive yield losses in wheat and other field crops (1, 22, 23). Weeds not only compete with crop plants for nutrients, water, space and light but also give refuge to pests and diseases. These interfere the crop growth by releasing allelopathic substances into rhizosphere of crop plants (37). These also create difficulty in harvest operations and increase the processing costs and significantly reduce (21-45%) crop yields (6). Traditional methods for controlling weeds are time consuming, weather dependent and labour intensive. Herbicides offer promising increase in crop yield through effective weed control. Chemical weed control is very effective method for suppressing weeds and herbicides proffer a substantial boost in crop productivity through efficient weed control (38). However, excessive and non-judicious use of herbicide may lead to crop injury, human and animal health concerns, soil and water pollution and herbicide resistance in weeds (15, 22).

Development of herbicidal resistance among weeds, and many other environmental and health issues due to continuous and non-judicious use of synthetic herbicides, necessitated to search for alternative weed control strategies (15, 23). One of the possible strategies for reducing or minimizing the use of herbicides may be the use of natural products and allelopathy manipulation for crop improvement and environmental protection (16, 19, 39).

Allelopathy holds great prospects for meeting some of these demands. Some workers (2, 12) proposed the use of allelopathic crop water extracts mixed with lower herbicide rates as an economically viable and environment friendly weed control technique. Herbicides and allelopathic products can work complementary and herbicidal dose might be reduced when applied in combination with allelopathic products and also effectiveness of allelopathic products i.e. sorghum water extract could be enhanced by using with lower rates of herbicides (11). Herbicide use could be reduced by combining the allelopathic water extracts with lower doses of herbicides (23, 34).

Sorghum (*Sorghum bicolor*) is well recognised for its allelopathic effects on other crops (33). Mature sorghum plants possess nine water soluble allelochemicals which are phytotoxic to the growth of certain weeds such as *Phalaris minor* Retz., *Chenopodium album* L., *Rumex dentatus* L. and *Convolvulus arvensis* L. (14). Sunflower plant has allelochemicals viz. chlorogenic acid, isochlorogenic acid, α -naphthol, scopolin and annuionones (3, 28, 29). The allelopathic potential of mulberry plant has also been well documented (17, 31). Under prevailing cropping system of the region wheat and rice are sown as major crops. Effect of allelopathic plant water extracts

mixed with Atlantis herbicide has not yet been evaluated against weeds under rice wheat cropping system.

The present study was conducted under field conditions to evaluate the efficacy of allelopathic aqueous extracts of sorghum+sunflower+mulberry plants by combining with Atlantis 3.6 WG herbicide at reduced rates for weed control in wheat under semi arid conditions of Sheikhpura.

MATERIALS AND METHODS

This study was conducted at Adaptive Research Farm, Sheikhpura, Pakistan during winter 2010-2011. Wheat crop (cv. Fareed-2006) at seed rate of 125 kg per hectare was sown in 22.5 cm apart rows with hand drill on November 26, 2010. Experiment was laid out in a RCBD with four replications. The net plot size was 7 m x 4.5 m. A basal dose of NPK fertilizer in the form of urea (46%N), diammonium phosphate (18%N: 46% P₂O₅) and sulphate of potash (50% K₂O) was applied @ 128-114-62 kg per hectare. Whole P, K and half N were drilled at sowing, while remaining half N was applied with second irrigation. The first irrigation was given 18 days after emergence of crop and subsequent irrigations were applied according to the need of crop.

Plant water extracts were prepared following the procedures reported by Cheema and Khaliq (8). Full dose of aqueous extracts of sorghum+sunflower+mulberry (18 l/ha each) were tank mixed with herbicide Atlantis 3.6 W.G. @ 14.40 g (recommended), 7.20 and 4.8 g a.s./ha. These were applied at 50 days after sowing (DAS). Herbicide Atlantis 3.6 WG was also solely sprayed once as per recommended rate (14.40 g a.s./ha) at 50 DAS by knapsack hand sprayer fitted with flat fan nozzle. A weedy check was also maintained as control treatment for comparison. Volume of spray (320 l/ha) was determined by calibration. Weed density and dry weights were recorded at 10 days after spray from quadrat of 0.25 m². Weeds were cleaned, air dried under shade for 24 hours and then oven dried at 70°C for 72 hours before recording their dry weight. Crop was harvested on 16th April, 2011, threshed with mini thresher and grains obtained were weighed and converted into grain yield per hectare. Data on plant height, spike length, number of productive tillers, number of spikelets per spike, number of grains per spike and 1000-grain weight were also recorded from each plot using standard sampling procedures.

Economic and marginal analyses were performed according to procedure recommended by CIMMYT (4). Data were statistically analyzed using

MSTAT-C (5). Fischer's analysis of variance technique was used to test the significance of variance sources, while LSD test ($P \leq 0.05$) was used to compare the differences among treatment means (40).

RESULTS AND DISCUSSION

Weed flora

Weed flora of experimental field mainly consisted of canary grass (*Phalaris minor* Retz.), wild oat (*Avena fatua* L.), common lambsquarter (*Chenopodium album* L.), black clover (*Medicago polymorpha* L.) while few plants of blue pimpernel (*Anagalis arvensis* L.), fumitory (*Fumaria indica* L.), field bindweed (*Convolvulus arvensis* L.) and sweet clover (*Melilotus parviflora* L.) were also recorded.

Total weed density/m²

The data (Table 1) revealed that all treatments significantly suppressed total weed density as compared with control. Minimum weed density (10.33/m²) was noted in the application of sorghum+sunflower+mulberry water extracts with half dose of Atlantis 3.6 WG (7.20 g a.s./ha) which decreased the total weed density by 86 percent as compared with control. It was followed by full dose of Atlantis (14.00/m² with 81% reduction). Application of sorghum+sunflower+mulberry water extracts with one third dose of Atlantis suppressed total weed density by 67 percent. These results are in conformity with the previous findings (32, 35).

Total weed dry weight (g/m²)

Almost similar trend was observed among all treatments for controlling total weed dry weight in wheat crop as was noted in case of total weed density (Table 1). All treatments significantly decreased the weed dry weight more than 75 percent as compared to control. Minimum weed dry weight (1.607g) with maximum reduction (88%) was noted in application of plant water extracts with half dose of herbicide over control (Table 1). Razzaq *et al.* (34) have also reported that combination of sorghum+sunflower water extracts (18 l/ha each) with reduced dose of metribuzin+fenoxaprop significantly reduced dry weed biomass by 92 percent. Similar findings have also been reported by Mushtaq *et al.* (32) where sorghum+sunflower water extracts mixed with one fourth (75% less) of label doses of herbicides inhibited dry matter production of wild oat upto 89 percent and canary grass upto 92 percent. Sorghum+sunflower water extracts mixed with reduced doses of iodo+mesosulfuron gave weed control in wheat crop equal to recommended dose of herbicide.

Table 1. Effect of allelopathic plant water extracts in combination with reduced rate of Atlantis 3.6 WG on total weed density and weed dry weight in wheat.

Treatments	Rate (Water extracts+herbicide)	Total weed density/m ²	Total weed dry weight (g/ m ²)
Weedy check (Control) (T ₁)	-	72.33 a	13.58 a
Recommend rate of Atlantis 3.6 WG (T ₂)	14.40 g a.s. /ha	14.00 c (-81)	2.183 b (-84)
Sorghum WE + Sunflower WE + Mulberry WE + Atlantis 3.6 WG (T ₃)	18 l/ha each + 7.20 g a.s./ ha	10.33 c (-86)	1.607 b (-88)
Sorghum WE + Sunflower WE + Mulberry WE + Atlantis 3.6 WG (T ₄)	18 l/ha each + 4.80 g a.s./ ha	24.00 b (-67)	3.453 b (-75)
LSD p≤0.05		9.395	2.787

Means not having common letter differ significantly at $P \leq 0.05$. Values given in parenthesis show percent decrease over control; WE=Water extract

The present results indicated that half dose of herbicide tank mixed with allelopathic crop water extracts offered better weed control than full dose of herbicide. This might be attributed to strong allelopathic influence of different plant water extracts and increase in herbicide efficacy when mixed with allelopathic crop water extracts. Similar results have also been reported by Cheema and Irshad (7) on sorghum allelopathy for barnyard grass management in rice. Similarly, Cheema *et al.* (10) suggested that Pendimethalin dose can be reduced (more than 50%) when mixed with concentrated sorghum water extract. Reducing herbicide dose in combination with allelopathic products for controlling weeds in field crops has also been previously suggested by Cheema *et al.* (9, 11).

Plant height (cm)

Significantly the lowest plant height was recorded in weedy check which might be due to competition for resources i.e. nutrients, light, space and water among the weeds and crop plants (Table 2). All treatments significantly increased plant height over control. Significantly more plant height (92 cm) was recorded in plots treated with full dose of Atlantis 3.6 WG (14.40 g a.s./ha) followed by combination of sorghum+sunflower+mulberry water extracts mixed with half dose of Atlantis 3.6 WG (90.33 cm). The combination of water extracts with one third dose of Atlantis 3.6 WG gave plant height of 86.67 cm. However, all these treatments were statistically at par with one another. These results are in accordance with the previous work (24).

Spike length (cm)

The data showed significantly the highest spike length (11.13 cm) in plots where sorghum + sunflower + mulberry water extracts were mixed with half dose of Atlantis 3.6 WG followed by full dose of Atlantis herbicide (10.97 cm).

Table 2. Effect of allelopathic plant water extracts in combination with reduced rate of Atlantis 3.6 WG on yield and yield components of wheat.

Treatments	Plant height (cm)	Spike length (cm)	No. of productive tillers/m ²	No. of spikelets/spike	No. of grains/spike	1000 grain weight (g)	Grain yield (t/ha)
Weedy check (Control) (T ₁)	78.67 b	8.750 b	230.3 c	14.67 c	38.17 b	40.00 c	2.13c
Recommended rate of Atlantis 3.6 WG (14.40 g a.s./ ha) (T ₂)	92.00 a	10.97 a	320.7 a	17.67 a	44.27 a	43.67 ab	2.79ab (31)
Sorghum WE+Sunflower WE+ Mulberry WE (18 l/ha each) + Atlantis 3.6 WG (7.20 g a.s./ha)(T ₃)	90.33 a	11.13 a	323.3 a	17.00 ab	42.36 a	45.67 a	2.90a (36)
Sorghum WE + Sunflower WE + Mulberry WE (18 l/ha each) + Atlantis 3.6 WG (4.80 g a.s./ ha) (T ₄)	86.67 a	9.400 b	280.0 b	15.33 bc	41.83 a	42.33 bc	2.54b (19)
LSD p≤0.05	5.369	0.833	12.840	1.970	2.522	3.034	0.359

Means not having common letter differ significantly at $P \leq 0.05$. Values given in parenthesis show percent increase over control; WE=water extract

However, both these treatments were statistically at par with each other. The combination of sorghum+sunflower+mulberry water extracts mixed with 4.8 g Atlantis ($1/3^{\text{rd}}$ of label rate) gave spike length of 9.40 cm. Jamil *et al.* (24) also indicated that spike length increased by combining sorghum water extract (12 l/ha) with Isoproturon (600 g a.s./ha).

Number of productive tillers/m²

All treatments significantly enhanced the number of productive tillers as compared with control (Table 2). Maximum number of productive tillers (323.3/m²) was recorded in plots treated with sorghum+sunflower+mulberry water extracts mixed with 7.20g Atlantis followed by plots treated with full dose of Atlantis (320.7/m²). However, both these treatments were statistically at par with each other. Water extracts mixed with 4.8 g Atlantis produced 280 productive tillers. These results are in conformity with those reported by Razzaq *et al.* (35).

Number of spikelets per spike

The data indicated that all treatments increased number of spikelets per spike over control (Table 2). Significantly higher number of spikelets per spike (17.67) was recorded in plots treated with full dose of Atlantis 3.6 WG (14.40g a.s./ha) which was statistically at par with sorghum+sunflower+mulberry water extracts mixed with 7.20 g Atlantis (17.0). Lowest number of spikelets per spike was recorded in weedy check that was due to competition among the weeds and crop plants for resources like nutrients, light, space and water. These results are supported by the findings of Jamil *et al.* (24) and Razzaq *et al.* (35).

Number of grains per spike

All treatments significantly increased number of grains per spike over control. The highest number of grains per spike (44.27) was recorded in plots where full dose of Atlantis was applied followed by plant water extracts mixed with herbicide @ 7.20 g (42.36/spike). The lowest number of grains per spike was recorded in weedy check (38.17) that was due to competition among weeds and crop plants for resources i.e., nutrients, light, space and water. The data further indicated that all treatments were statistically at par except control. These findings are in accordance with those reported by Jamil *et al.* (24), Khaliq *et al.* (25) and Razzaq *et al.* (35).

1000-grain weight (g)

All treatments also significantly increased 1000-grain weight of wheat over control (Table 2). The highest 1000-grain weight (45.67 g) was recorded in plots where sorghum+sunflower+mulberry water extracts mixed with 7.20 g Atlantis were applied followed by plots treated with full dose of Atlantis (43.67 g). However, both these treatments were statistically equal to each other.

The combination of sorghum+sunflower+mulberry water extracts with 4.8 g Atlantis produced 42.33 g 1000-grain weight. These findings are in conformity with those of Jamil *et al.* (24) and Khaliq *et al.* (25). The lowest 1000-grain weight (40 g) was recorded in weedy check that might be due to competition among weeds and crop plants for resources i.e., nutrients, light, space and water.

Grain yield (t/ha)

All treatments also increased the wheat grain yield significantly over control (Table 2). The highest grain yield (2.90 t/ha) was recorded in plots treated with sorghum+sunflower+mulberry water extracts mixed with 7.20 g herbicide which gave 36 percent more grain yield than control. Full dose of herbicide produced 31 percent more than control. Similar results were also reported by earlier workers (11, 24, 25, 34, 35). The lowest grain yield (2.13 t/ ha) of wheat was recorded in weedy check that might be due to hard competition for resources i.e. nutrients, light, space and water among weeds and crop plants. Khaliq *et al.* (26) have also reported an increase in mungbean grain yield over control with application of sorghum water extract mixed with reduced dose of Pendimethalin.

Economic analyses

Maximum net benefits (Rs. 71322/ha) with higher marginal rate of return (4221%) were obtained from sorghum+sunflower+mulberry water extracts mixed with 7.2 g Atlantis followed by full dose of herbicide (Rs. 68277/ha) and plant water extracts mixed with 4.8 g Atlantis (Rs. 62457/ha) with marginal rate of return of 1033 percent (Table 3 and 4). The net benefit in case of full dose of Atlantis 3.6 WG (Rs. 68277/ ha) was dominated due to high cost involved. Cheema *et al.* (10) supported these findings and stated that net benefit of Rs. 44445.9 with marginal rate of return of 426.7 percent was achieved by application of sorghum water extract (12 l/ha) mixed with 500 g a.s./ha of Pendimethalin for weed control in cotton. These results are also supported by Razzaq *et al.* (34) who reported that combination of sorghum + sunflower (18 l/ha each) with 70 percent reduced dose of metribuzin + phenaxaprop (Bullet 38 SC @ 57 g a.s./ha) was the most economical treatment for the highest net benefits.

Table 3. Economic analysis of application of plant water extracts combined with herbicide.

Parameters	T ₁	T ₂	T ₃	T ₄
Grain yield of wheat (t/ ha)	2.13	2.79	2.90	2.54
10% less yield	0.21	0.28	0.29	0.25
Adjusted grain yield (t/ ha)	1.92	2.51	2.61	2.28
Grain value (Rs. 23750/t)	45529	59636	61988	54221
Wheat straw yield (t/ ha)	2.13	2.79	2.90	2.54
10% less yield	0.21	0.28	0.29	0.25
Adj. straw yield (10% less (t/ ha)	1.92	2.51	2.61	2.28
Wheat straw value (Rs. ha (4000/t)	7668	10044	10440	9132
Gross benefits (Rs./ha)	53197	69680	72428	63353
Cost of herbicides (Atlantis 3.6 WG (Rs.600/160 g)	-	1253	626	416
Labour charges of spray (Rs.100/man/day)	-	100	100	100
Spray rent (Rs.50/ ha)	-	50	50	50
Cost of sorghum, sunflower & mulberry water extracts preparation (Sorghum, sunflower & mulberry (Rs.160,85,85/18 l/ha respectively)	-	0	330	330
Cost that varies (Rs./ha)	-	1403	1106	896
Net benefits (Rs./ha)	53197	68277	71322	62457

T₁: Weedy check (Control); T₂: Recommended rate of Atlantis 3.6 WG (14.4 a.s/ha); T₃: Sorghum WE + Sunflower WE + Mulberry WE + Atlantis 3.6 WG @ 7.2 a.s/ha T₄: Sorghum WE + Sunflower WE + Mulberry WE + Atlantis 3.6 WG @ 4.8 a.s/ha, WE= Water extract.
Cost that varies = It is the sum of costs (both costs and opportunity costs) that varies for a particular treatment

Table 4. Dominance and marginal analysis.

Treatments	Total cost that varies (Rs)	Net benefits (Rs)	Marginal costs (Rs)	Marginal net benefits (Rs)	Marginal rate of return (%)
Weedy check (Control) (T ₁)	-	53197			
Sorghum WE + Sunflower WE + Mulberry WE + Atlantis 3.6 WG (4.80 g a.s./ha) (T ₄)	896	62457	896	9260	1033
Sorghum WE + Sunflower WE + Mulberry WE + Atlantis 3.6 WG (7.20 g a.s./ha) (T ₃)	1106	71322	210	8865	4221
Recommended rate of Atlantis 3.6 WG (14.40 g a.s./ha) (T ₂)	1403	68277	-	-	D

Marginal costs = Increase in variable cost which can be obtained by changing from one production alternative to another. Marginal benefits = Increase in net benefit which occurs in changing from one production alternative to another

D = Dominated treatment (Treatment which has higher costs but lower net benefits)

Many researchers have stressed the need for decreasing the use of herbicides in crop production. Water extracts of allelopathic plants can serve as the means of using allelopathy for practical weed management. Use of allelopathic crop water extracts and reduced rates of herbicides, have been effective for weed management in field crops, such as canola (22), wheat (34), cotton, rice, and soybean (27). Some researchers have also reported that allelopathic extracts suppress the weeds in wheat, and aid in improving the growth and yield of wheat (21, 34). The present results indicate that allelopathic extracts have specific compatibility for certain herbicides, such as Atlantis 3.6 WG. Moreover, these findings suggest that herbicide doses can be decreased considerably (50 %) when used in combination with allelopathic crop water extracts (15, 23, 32). Similarly, Rehman *et al.* (36) reported that application of sorghum+sunflower+rice water extracts mixed with half of label rates of butachlor herbicides (pre-emergence) improved rice grain yield by 61 percent.

CONCLUSION

Use of sorghum+sunflower+mulberry allelopathic water extract combined with half dose of Atlantis 3.6 WG performed better than full dose of herbicide (Atlantis 3.6 WG). It was noted that herbicide dose may be reduced by 50 percent in combination with allelopathic plant water extracts and environmental safety may be increased by reducing reliance on synthetic herbicides. However, it would be meaningful to further investigate the role of different combinations of plant water extracts.

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