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REDUCED HERBICIDE DOSES USED TOGETHER WITH ALLELOPATHIC SORGHUM AND SUNFLOWER WATER EXTRACTS FOR WEED CONTROL IN WHEAT

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Abstract: Water extracts from allelopathic crops possess the potential to control weeds effectively, especially when used in combination with reduced rates of herbicides. Label doses of different herbicides and their seventy percent reduced doses, were combined with 18 l/ha each of allelopathic sorghum and sunflower water extracts (WE). This combination was sprayed 30 days after sowing (DAS) for weed control in wheat (*Triticum aestivum*). Maximum reduction in total weed density and dry weight over the control, was recorded in a field sprayed with mesosulfuron + idosulfuron (Atlantis 3.6 WG) at 14.4 g active substance (a.s.)/ha. However, sorghum + sunflower WE each at 18 l/ha combined with doses which had been reduced by 70% of mesosulfuron + idosulfuron (Atlantis 12 EC at 36 g a.s./ha), or metribuzin + phenoxaprop (Bullet 38 SC at 57 g a.s./ha) or mesosulfuron + idosulfuron (Atlantis 3.6 WG at 4.32 g a.s./ha), reduced total weed dry weight by more than 90%, over the control. Sorghum and sunflower water extracts each at 18 l/ha combined with metribuzin + phenoxaprop (Bullet 38 SC at 57 g a.s./ha) produced a maximum number of productive tillers, spikelets per spike, number of grains per spike, biological yield and grain yield. Moreover, this treatment was the most economical along with having the maximum net benefits. The results suggested that weeds can be controlled in wheat, for a higher yield, when a 70% reduced herbicide dose is used in combination with allelopathic sorghum and sunflower water extracts.

Key words: wheat, weed control, allelopathy, yield, economic return

INTRODUCTION

Wheat (*Triticum estivum* L.) is the most important staple diet of a large population in Pakistan. For this reason, researchers and the farming community in Pakistan give wheat their utmost attention (Malik 2006; Jabran *et al.* 2011). Problems such as high weed infestation, delayed sowing, poor nutrition and drought are the major reasons which lower wheat yield and threatening food security in Pakistan (Hussain *et al.* 2010; Jabran *et al.* 2011). Weeds left unmanaged, cause massive yield losses in wheat and other field crops (Jabran *et al.* 2008, 2010 a, b; Razzaq *et al.* 2010; Akbar *et al.* 2011). In Pakistan, losses due to weeds in wheat crop are estimated to be 146 billion Pakistani rupees per year. Chemical weed control is a very effective method for suppressing weeds, and herbicides proffer a substantial boost in crop productivity through efficient weed control (Santos 2009). But 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 (Jabran *et al.* 2008; Farooq *et al*. 2011). Development of herbicidal resistance among weeds, and many others environmental and health issues due to continuous and non-judicious use of synthetic herbicides, compelled us to search for alternative weed control strategies (Jabran *et al*. 2010b; Farooq *et al.* 2011). 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 (Singh *et al*. 2003; Farooq *et al.* 2008; Hussain *et al*. 2007).

The phenomenon of allelopathy can be practically utilized for weed control in the form of crop rotations, intercropping, allelopathic mulches, and spray of allelopathic plant water extracts (Bhowmik and Inderjit 2003; Jabran *et al.* 2010a; Farooq *et al.* 2011). Sorghum (*Sorghum bicolor)* and sunflower (*Helianthus annus* L.) are well known allelopathic crops, which contain a number of allelochemicals which are toxic to weeds (Jabran *et al.* 2010a, b).

Application of sorghum and sunflower water extracts reduced weed biomass by 33–53% and increased wheat yield (7–14%), according to Cheema *et al*. (1997). Similar observations were made in other crops (Bhatti *et al.* 2000;

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Khaliq *et al*. 1999). Allelopathic water extracts and herbicides applied in combination work synergistically, helping to reduce the dose of herbicide (Cheema *et al.* 2005). Herbicide use could be reduced by combining the allelopathic water extracts with lower doses of herbicides (Jabran *et al.* 2010a; Razzaq *et al.* 2010). The objectives of the studies were to evaluate the effect of sorghum and sunflower water extracts used with reduced doses of some early post emergence herbicides, for weed control in wheat.

MATERIALS AND METHODS

This study was conducted at the Agronomic Research Area, University of Agriculture Faisalabad, Pakistan on sandy loam soils. The experiment was laid out in a completely randomized block design, with four replications, having a net plot size of 5 m x 1.80 m. A pre-soaking irrigation of 10 cm was applied before forming the seedbed. When the soil reached up to a workable moisture level, the seed bed was formed by cultivating the field twice with a tractor mounted cultivator; each time followed by planking. Wheat (variety Inqlab-91) was sown on a well prepared seedbed in 22.5 cm spaced rows using a single row hand drill, at a seed rate of 125 kg/ha. Fertilizer at 100 kg/ha N and 85 kg/ha P_2O_5 was added in the form of urea and di-ammonium phosphate, respectively. Half N and whole of P were applied at the time of sowing, while the remaining half N was applied 25 days after sowing (DAS) with the first irrigation. Crop water extracts were prepared using the method suggested by Cheema *et al*. (2002) and stored at room temperature. The spray volume (320 l/ha) was determined by calibration. Crop water extracts of sorghum and sunflower together were tank mixed with 70% reduced doses of the herbicides. The labeled doses of herbicides alone, and the combinations of reduced doses with allelopathic water extracts, were sprayed as an early post emergence spray at 30 DAS using a knapsack hand sprayer fitted with a T-jet nozzle. Isoproturon was used as the standard. A weedy check was also maintained as the control. The table 1. contains details about the herbicides and allelopathic water extracts in the treatments, and their application doses.

The data on total weed density and total weed dry weight were recorded at 70 DAS from two randomly selected quadrates measuring 0.25 m^2 and converted into m^{-2} from each experimental plot. Weeds were counted to determine total weed density and for recording total weed dry weight. Weeds were dried in an oven at 70°C for 48 hours. All the (spike bearing and non-spike bearing) tillers were counted from two randomly selected rows up to a length of 1 m, from two randomly selected points of each plot, to count fertile tillers. Conversion into m^{-2} was done by the simple unitary method. All spikelets from ten randomly selected spikes, were counted and averaged to record the number of spikelets per spike. Grains from ten randomly selected spikes were counted and then averaged to record the number of grains per spike. To record biological yield, two central rows from each manually harvested plot, were kept for drying up to three days in the field, tied into bundles, weighed by spring balance, and then converted into t/ha, while data for grain yield was taken from Razzaq *et al.* (2010).

Table 1. Detail of herbicides and allelopathic crop water extracts and their doses applied for weed control in wheat

Herbicides/allelopathic water extracts	Doses
Control (weedy check)	
Isoproturon (50 WP)	1,000 g a.s./ha
Bensulfuron + isoproturon (Cleaner 70 WP)	1,050 g a.s./ha
Metribuzin (Sencor 70 WP)	175 g a.s./ha
Metribuzin + phenoxaprop (Bullet 38 SC)	190 g a.s./ha
Mesosulfuron + idosulfuron (Atlantis 12 EC)	120 g a.s./ha
Mesosulfuron + idosulfuron (Atlantis 3.6 WG)	14.4 g a.s./ha
Sorghum + sunflower WE + Metribuzin (Sencor 70 WP)	18 l each/ha + 52.5 g a.s./ha
Sorghum + sunflower WE + Bensulfuron + isoproturon (Cleaner 70 WP)	18 l each + 315 g a.s./ha
Sorghum + sunflower WE + Metribuzin + phenoxaprop (Bullet 38 SC)	18 l each/ha + 57 g a.s./ha
Sorghum + sunflower WE + Mesosulfuron + idosulfuron (Atlantis 12 EC)	18 l each/ha + 36 g a.s./ha
Sorghum + sunflower WE + Mesosulfuron + idosulfuron (Atlantis 3.6 WG)	18 l each/ha + 4.32 g a.s./ha

a.s. – active substance

Obtained data were analyzed statistically by analysis of variance (ANOVA) and a least significant difference (LSD) test was employed to compare the treatment means (Steel *et al.* 1997). Economic analysis was performed to find out the most profitable treatment.

RESULTS AND DISCUSSION

The weed floras in the experimental area were swine cress (*Coronopus didymus* L.) and canary grass (*Phalaris minor* L.). Data indicated that all the treatments significantly reduced the weed population (Table 2). Label dose of mesosulfuron + idosulfuron (Atlantis 3.6 WG) at 14.4 g active substance a.s./ha reduced weed density by 96% over the control. Full doses of mesosulfuron + idosulfuron (Atlantis 12 EC) at 120 g a.s./ha, metribuzin (Sencor 70 WP) at 175 g a.s./ha, and sorghum and sunflower water extracts, each at 18 l/ha with a 70% reduced dose of bensulfuron + isoproturon (Cleaner 70 WP) at 315 g a.s./ha reduced the total weed density by 90.6, 90.2 and 88.24, respectively. Similarly, at 70 days after sowing (DAS), label dose of mesosulfuron + idosulfuron (Atlantis 3.6 WG) at 14.4 g a.s./ha, decreased total weed dry weight by 94%. Allelopathic crop water extracts of sorghum + sunflower each at 18 l/ha, combined with 70% reduced doses of mesosulfuron + idosulfuron (Atlantis 12 EC) at 36 g a.s./ha, metribuzin + phenaxaprop (Bullet 38 SC) at 57 g a.s./ha, and mesosulfuron + idosulfuron (Atlantis 3.6 WG) at 4.32 g a.s./ha, reduced total weed dry weight by 93, 92, and 90%, respectively, over the control and these were statistically at par with each other.

The results (Table 3) showed that all treatments significantly enhanced yield-related traits over the control. The treatment combination of sorghum + sunflower each at 18 l/ha, with a reduced dose of metribuzin + phenaxaprop 70% (Bullet 38 SC) at 57 g a.s./ha, produced a maximum

Table 2. Effect of allelopathic sorghum and sunflower water extracts combined with reduced doses of some early post emergence herbicides on total weed density and total weed dry weight at 70 DAS

Treatments	Rates	Total weed density [m^{-2}]	Total weed dry weight (g/m^2)
The control (weedy check)		102.0 a	19.04 a
Isoproturon (50 WP)	1,000 g a.s./ha	24.0 b (–76.27)	3.36 bc (92.35)
Bensulfuron + isoproturon (Cleaner70 WP)	1,050g a.s./ha	19.0 c (–81.37)	2.72 cd (85.71)
Metribuzin (Sencor 70 WP)	175g a.s./ha	10.0 d (–90.20)	2.72 cd (85.71)
Metribuzin + phenoxaprop (Bullet 38 SC)	190 g a.s./ha	13.0 d (–87.25)	2.72 cd (85.71)
Mesosulfuron + idosulfuron (Atlantis12 EC)	120 g a.s./ha	10.0 d (–90.6)	2.64 cd (86.13)
Mesosulfuron + idosulfuron (Atlantis3.6 WG)	14.4 g a.s./ha	4.0 e (–96.08)	1.24 f (93.49)
Sorghum + sunflower WE + Metribuzin (Sencor 70 WP)	18 l each/ha + 52.5 g a.s./ha	17.0 c (–83.33)	4.2 b (77.94)
Sorghum + sunflower WE + Bensulfuron + isoproturon (Cleaner 70 WP)	18 l each + 315 g a.s./ha	12.0 d (–88.24)	2.2 de (88.45)
Sorghum + sunflower WE + Metribuzin + phenoxaprop (Bullet 38 SC)	18 l each/ha + 57 g a.s./ha	13.0 d (–87.25)	1.6 ef (91.60)
Sorghum + sunflower WE + Mesosulfuron + idosulfuron (Atlantis 12 EC)	18 l each/ha + 36 g a.s./ha	13.0 d (–87.25)	1.36 ef (92.86)
Sorghum + sunflower WE + Mesosulfuron + idosulfuron (Atlantis 3.6 WG)	18 l each/ha + 4.32 g a.s./ha	13.0 d (–87.25)	1.84 ef (90.34)
LSD value at $p \leq 0.05$		10.12	0.89

DAS – days after sowing; WE – water extract; a.s. – active substances
Figures in the same column sharing the same letter do not differ statistically at $p \leq 0.05$ by LSD test

Table 3. Effect of allelopathic sorghum and sunflower water extracts combined with reduced doses of some early post emergence herbicides on yield related parameters of wheat

Treatments	Rates	Fertile tillers [m^{-2}]	Spikelets per spike	Grains per spike	Biological yield [t/ha]	Grain yield [t/ha]
The control (weedy check)		308.3 e	13.25 g	29.48 g	9.35 d	2.10 c
Isoproturon (50 WP)	1,000 g a.s./ha	351.3 bc	14.73 cde	32.94 cde	11.68 abc	2.40 b
Bensulfuron + isoproturon (Cleaner 70 WP)	1,050 g a.s./ha	333.5 d	14.30 ef	32.17ef	12.24 ab	2.42 b
Metribuzin (Sencor 70 WP)	175 g a.s./ha	359.5 abc	15.07 bcd	33.92 bcd	10.86 c	2.55 b
Metribuzin + phenoxaprop (Bullet 38 SC)	190 g a.s./ha	355.0 bc	14.90 cde	33.53 cde	11.24 bc	2.46 b
Mesosulfuron + idosulfuron (Atlantis 12 EC)	120 g a.s./ha	317.8 e	13.90 fg	31.09 f	11.26 bc	2.38 b
Mesosulfuron + idosulfuron (Atlantis 3.6 WG)	14.4 g a.s./ha	364.0 ab	15.75 ab	35.51 ab	10.74 c	2.62 ab
Sorghum + sunflower WE + Metribuzin (Sencor 70 WP)	18 l each/ha + 52.5 g a.s./ha	345.8 cd	14.50 def	32.62 def	11.61 abc	2.52 b
Sorghum + sunflower WE + Bensulfuron + isoproturon (Cleaner70 WP)	18 l each + 315 g a.s./ha	362.5 ab	15.70 ab	35.33 ab	11.49 abc	2.60 ab
Sorghum + sunflower WE + Metribuzin + phenoxaprop (Bullet 38 SC)	18 l each/ha + 57 g a.s./ha	370.5 a	15.88 a	36.32 a	12.5 a	2.82 a
Sorghum + sunflower WE + Mesosulfuron + idosulfuron (Atlantis 12 EC)	18 l each/ha + 36 g a.s./ha	360.0 abc	15.25 abc	34.34 bc	10.74 c	2.56 b
Sorghum + sunflower WE + Mesosulfuron + idosulfuron (Atlantis 3.6 WG)	18 l each/ha + 4.32 g a.s./ha	352.0 bc	14.88 cde	33.47 cde	10.86 c	2.53b
LSD value at $p \leq 0.05$		14.36	0.73	1.60	1.167	0.241

DAS – days after sowing; WE – water extract; a.s. – active substances
Figures in the same column sharing the same letter do not differ statistically at $p \leq 0.05$ by LSD test

Table 4. Economic analysis for the experiment

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	Remarks
Total grain yield	2,100	2,400	2,420	2,550	2,460	2,380	2,620	2,520	2,600	2,820	2,560	2,530	[kg/ha]
Adjusted grain yield	1,890	2,160	2,178	2,295	2,214	2,142	2,358	2,268	2,340	2,538	2,304	2,277	to bring at farm level [10%]
Income	44,887	51,300	51,727	54,506	52,582	50,872	56,002	53,865	55,575	60,277	54,720	54,079	Rs: 425 per 40 kg
Straw yield	7,250	9,280	9,830	8,310	8,770	8,880	8,120	9,100	8,890	9,680	8,180	8,330	[kg/ha]
Adjusted straw yield	6,525	8,352	8,847	7,479	7,893	7,992	7,308	8,190	8,001	8,712	7,362	7,497	to bring at farm level [10%]
Income	32,650	41,760	44,235	37,395	39,465	39,960	36,540	40,950	40,005	43,560	36,810	37,485	Rs: 60 per 40 kg
Gross income (grain+ straw)	77,537	93,060	95,962	91,901	92,047	90,832	92,542	94,800	95,580	103,837	91,530	91,564	[Rs/ha]
Cost of herbicide	0	875	1,687	450	694	1,458	1,625	112	421	241	364	406	according to their rates
Cost of extracts	0	0	0	0	0	0	0	240	240	240	240	240	Rs: 70 per 18 l
Sprayer rent	0	100	100	100	100	100	100	100	100	100	100	100	Rs: 60/ spray
Spray application	0	150	150	150	150	150	150	150	150	150	150	150	Rs: 120/ man/day/ ha
Cost that vary	0	1,125	1,937	637	944	1,708	1,538	602	911	731	854	896	[Rs/ha]
Net benefit	77,537	91,935	94,025	91,264	91,103	89,124	91,004	94,198	94,669	103,106	90,676	90,668	[Rs/ha]

T_1 – the control (weedy check); T2 – Isoproturon (50 WP) at 1,000 g a.s./ha; T3 – Bensulfuron + isoproturon (Cleaner 70 WP) at 1,050 g a.s./ha; T4 – Metribuzin (Sencor 70 WP) at 175 g a.s./ha; T5 – Metribuzin + phenoxaprop (Bullet 38 SC) at 190 g a.s./ha; T6 – Mesosulfuron + idosulfuron (Atlantis 12% EC) at 120 g a.s./ha; T7 – Mesosulfuron + idosulfuron (Atlantis 3.6 WG) at14.40 g a.s./ha; T8 – Metribuzin (Sencor 70 WP) at 52.50 g a.s./ha + sorgaab + sunfaab WE each at 18 l/ha; T9 – Bensulfuron + isoproturon (Cleaner 70 WP) at 315 g a.s./ha + sorgaab + sunfaab WE each 18 l/ha; T10 – Metribuzin + phenoxaprop (Bullet 38 SC) at 57g a.s./ha + sorgaab + sunfaab WE each at 18 l/ha; T11 – Mesosulfuron + idosulfuron (Atlantis 12% EC) at 36 g a.s./ha + sorgaab + sunfaab WE each at 18 l/ha; T12 – Mesosulfuron + idosulfuron (Atlantis 3.6 WG) at 4.32 g a.s./ha + sorgaab and sunflower water extract each at 18 l/ha

(2.82 t/ha) yield with a 34.29% increase over the control, and it was significantly more than its label dose of 190 g a.s./ha. The increase in grain yield was due to greater fertile tillers, spikelets per spike, and grains per spike in this treatment. The grain yield in other treatments either with their label dose or allelopathic water extracts (sorghum + sunflower), each at 18 l/ha, mixed with a reduced dose of each herbicide by 70%, respectively, was almost equal.

Economic analysis (Table 4) showed that, the combination of sorghum + sunflower each at 18 l/ha with a reduced dose by 70% of metribuzin + phenaxaprop (Bullet 38 SC) at 57 g a.s./ha, was the most economical treatment with the highest net benefits. Minimum net benefits were recorded for the control treatment *i.e.* the weedy check.

Many researchers have stressed the need for decreasing the use of herbicides in crop production. Water extracts of the 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 (Jabran *et al.* 2008), wheat (Razzaq *et al.* 2010), cotton, rice, and soybean (Khaliq *et al.* 1999). Farooq *et al.* (2011) reviewed the practical implications of the various strategies which can be used for allelopathic weed control in crops. They considered allelopathic crop water extracts mixed with reduced doses of herbicides as an effective means of weed management. Some researchers have also reported that allelpathic extracts suppress the weeds in wheat, and aid in improving the growth and yield of wheat (Razzaq *et al.* 2010; Jabran *et al.* 2011). Our results for this experiment indicate that allelopathic extracts have specific compatibility for certain herbicides, such as metribuzin + phenoxaprop (Bullet 38 SC) at 57 g a.s./ha. Moreover, these findings suggest that herbicide doses can be decreased considerably (70%) when the dose is used in combination with allelopathic crop water extracts (Jabran *et al.* 2010; Farooq *et al.* 2011). Similarly, Jabran *et al.* (2008) reported that dose of pendimethalin used for effective weed control of canola, can be reduced by more than 50% if the herbicide is used mixed together with sorghum and sunflower water extracts (15 l/ha). A combination of pendimethalin 600 g a.s./ha and sorghum + sunflower water extracts (15 l/ha) registered a grain yield of canola which was almost 40% higher than the control, and 3% more than when a double dose of pendimethalin (1,200 g a.s./ha) is used. Combining lower doses of herbicides with allelopathic water extracts is highly economical compared with the use of herbicides by themselves (Table 4; Jabran *et al.* 2008).

In conclusion, the use of allelopathic crop water extracts (sorghum and sunflower) used with reduced rates of herbicides is highly economical – by up to 70%. These results provide a reasonable base for suggesting that combined use of allelopathic crop water extracts together with lower herbicide rates will raise net benefits on one hand, and increase environmental safety by reducing reliance on synthetic herbicides on other hand.

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