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RESPONSE OF WHEAT CROP (*TRITICUM AESTIVUM L.*) AND ITS WEEDS TO ALLELOPATHIC CROP WATER EXTRACTS IN COMBINATION WITH REDUCED HERBICIDE RATES

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A field trial to investigate the response of wheat *(Triticum aestivum L.)* crop and its weeds to various crop water extracts (sorghum, brassica and sunflower) in combination with reduced rates of herbicide (Bromoxynil + MCPA 20 + 20 EC) was carried out at Research Area, College of Agriculture, Dera Ghazi Khan. The treatment combinations were the mixture of all three crop water extracts each @ 15 and 18 L ha^{-1} combined with 1/2 and 1/3rd dose of Bromoxynil + MCPA. Individual herbicide (Bromoxynil + MCPA) treatments i.e. 1/2, 1/3, full dose and a weedy check were included for comparison. Experiment was laid out in randomized complete block design (RCBD) with 4 replications. An approved wheat cultivar, AS- 2002, was used as experimental material. The data recorded at 70 DAS (days after sowing) showed that water extracts @ 18 L ha^{-1} combined with Bromoxynil + MCPA 50 g a.i ha^{-1} inhibited total weeds density by 88%, total weeds fresh weight by 90% and total weeds dry biomass by 95% and increased grain yield by 35% over control. Highest marginal rate of return was observed in combination of crop water extracts each @18 La^{-1} tank mixed with 50 g a.i ha^{-1} Bromoxynil + MCPA with net benefit of Rs. 87117. It can be concluded that by the use of allelopathic crop water extracts herbicides use can be reduced up to 50%.
Keywords: herbicide dose, plant water extracts, wheat, allelopathy

INTRODUCTION

Allelopathy is generally associated with interactions between living plants and has been observed in agricultural lands from centuries. Allelopathy plays a significant role in plant-plant interaction. Growing environmental and public health concerns from the use of pesticides in agriculture has inspired the researchers to search new and environmentally safe technologies. The ability of some natural plant compounds to effectively inhibit weeds has opened new horizons for future research (Rice, 1994).

Allelopathy has been accepted as environment-friendly phenomenon, which may prove to be a useful means for weed management and thereby increase crop yields (Putnam *et al.,* 1983). It involves direct or indirect (harmful or beneficial) effects of one plant on another through the production of secondary chemical compounds that escape into the environment (Rice, 1984). Chemicals with allelopathic potential are present in virtually all plant parts or tissues, including leaves, stems, flowers, roots, seeds and buds. These allelochemicals offer great potential as natural pesticides and can be used for weed control directly or their chemistry could be used to develop new herbicides (Putnam *et al.,* 1990).

The use of water extracts from allelopathic plants may be comparatively cheaper. Despite the fact that allelopathic water extracts as such may be cost-effective, these control weeds only up to 40-50% which is also not feasible (Cheema and Khaliq, 2000). The farmers are generally hesitant to adopt this method and have a preference to purchase a ready-to-use formulation from the market. So there is a need to improve the efficiency of water extracts and to develop it in a handy form.

Allelopathic potential of sorghum *(Sorghum bicolor* L.) water extract has been demonstrated in many recent studies (Iqbal and Cheema, 2008). Besides sorghum, other plants such as sunflower *(Helianthus annuus L.)* and brassica *(Brassica compestris),* are reported to have allelopathic effects (Narwal, 1994; Iqbal and Cheema, 2007, 2009). Different allelochemicals sometimes show synergistic effects in mixture with other compounds (Duke and Lydon, 1993; Einhellig, 1996). In addition, allelopathic effects are concentration dependent. Amalgamation of natural products such as various allelopathic plant extracts and lower rates of commercial organic compounds or herbicides may be less expensive, helpful in conserving environment and promoting sustainable agricultural production systems. In the previous studies the water extracts of sorghum, sunflower and brassica were utilized in combinations with reduced rates of different herbicides up to 15 L ha^{-1}. In the present studies the water extracts doses were increased with further reduction in herbicides rates up to 67% to evaluate the suppressive capability of these plants against weeds of wheat.

MATERIALS AND METHODS

Sorghum *(Sorghum bicolor L.),* sunflower *(Helianthus annuus L.)* and brassica *(Brassica compestris)* were planted at their normal and respective growing seasons. These plants were harvested at full maturity and stored and dried under shade to avoid possible leaching by rain water. Each plant material was chopped with electric fodder cutter into 2-cm pieces. Chopped plant material was soaked in distilled water for 24 hours at room temperature (21°C) at a ratio of 1:10 (W/V) and was filtered through 10 and 60 mesh sieve according to the procedure devised by Cheema, *et al*. (2003c). These extracts were boiled at 100°C to concentrate up to 20 times for easy handling and application.

The field was irrigated about 10 days before planting wheat. It was ploughed at desirable field condition and followed by single planking. Finally 2-3 times ploughing and planking were done to a proper tilth for wheat. Seeds of wheat cv. AS 2002 were purchased from Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan. Sowing was done in the 2nd week of November, 2007 at seed rate of 110 kg ha^{-1} in 25 cm spaced rows with the help of single row hand dill. The plot size was 5m x 2.5m. Row to row distance of 25 cm was maintained. Recommended cultural practices were adopted for all the treatments uniformly. Commonly used broadleaf weed herbicide Bromoxynil + MCPA were obtained from the local market. The field experiment was laid out in a randomized complete block design (RCBD) with four replications. Nitrogen, Phosphorus and Potassium were applied @ 110, 55 and 60 kg ha^{-1}, respectively. Fertilizers used were urea, diammonium phosphate and sulphate of potash. The whole phosphorus and potassium and 1/3rd of nitrogen were applied at the time of sowing. The remaining 2/3rd nitrogen was applied with the first and second irrigation equally. The first irrigation was given 10 days after crop emergence, and subsequent irrigations were given at different critical crop stages especially at tillering, booting, anthesis and grain development stage. Six irrigations were done in the whole season. The crop was harvested manually at physiological maturity, when the green colour from the glumes and kernels disappeared completely. Threshing of each plot was done separately.

The treatments comprised of three crop water extracts (Sorghum, sunflower and brassica) each @ 15 and 18 L ha^{-1} combined with 1/3rd and ½ reduced rates of herbicide (Bromoxynil + MCPA each @ 33 and 50g a.i. ha^{-1}). The independent 1/3rd and ½ reduced rate and recommended rate (Bromoxynil + MCPA each @ 100g a.i. ha^{-1}) of these herbicides, and weedy check were also included for comparisons. To spray these water extracts and herbicides the volume of spray (300 L ha^{-l}) was calibrated using ordinary water. The concentrated plant water extracts along with other combinations were applied at 30 days after sowing (DAS) as post emergence in the respective plots according to treatments using a Knapsack Hand Sprayer fitted with T-Jet nozzle at a pressure of 207 k Pa. Data on weed density, dry weight of individual and total weeds were recorded. Wheat growth, yield and yield components were also recorded to quantify the weed control impact on wheat. Economic and marginal analyses were also done as suggested by Byerlee (1988) on the basis of variable costs and prevailing market prices of herbicide and wheat crop to evaluate the most economical treatment.

$$\text{Marginal rate of return (\%)} = \frac{\text{Change in profits}}{\text{Change in cost}} \times 100$$

Standard procedures were adopted for recording the data on various growth and yield parameters. Data collected were statistically analyzed by using the "MSTATC" statistical software package. Duncan's Multiple Range test (DMRT) at p 0.05 was applied to compare treatments means (Anonymous, 1986).

RESULTS AND DISCUSSION

Weed density: Weed flora of the experimental site comprised mainly of *Convolvulus arvensis* (Retz), *Euphorbia helioscopia* (L) and *Melilotus alba*, while a very few plants of *Phalaris minor* and *Avena fatua* were also noticed. *Euphorbia helioscopia* density was significantly affected by all weed control treatments as compared to control (Table 1). Data revealed similar suppression in *E. helioscopia* density by water extracts combination each @ 18 L ha^{-1} with herbicides @ 33 and 50 g a.i ha^{-1} (T_4, T_5) and water extracts each @ 15 L ha^{-1} combined with herbicides @ 50 g a.i ha^{-1} (T_3) and were better than recommended dose of herbicides (Bromoxynil + MCPA @ 100 g a.i ha^{-1}). By increasing water extracts dose from 15 L ha^{-1} to 18 L ha^{-1} reduced weed density higher at lower doses of herbicides each @ 33 g a.i ha^{-1}. But at higher doses of herbicides @ 50

Table 1. Combined effect of crop water extracts (sorghum, sunflower and brassica) and reduced herbicide rates on weeds density

	Treatments	Rate	weed density (0.25 m^{-2})			
			Euphorbia helioscopia	***Melilotus alba***	***Convolvulus arvensis***	**Total**
1	Control (weedy check)		21 a	7.75 a	26.75 a	55.50 a
2	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 33g a.i. ha^{-1}	5 b (76.19)	2 bc (74.19)	4.25 bc (85.98)	10.75 b (81%)
3	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 50g a.i. ha^{-1}	3 cd (85.71)	2 bc (74.19)	2.0 c (92.52)	7.00 cd (87%)
4	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 33g a.i. ha^{-1}	3 cd (85.71)	2 bc (74.19)	3.0 bc (88.78)	8.00 bcd (86%)
5	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 50g a.i. ha^{-1}	2 d (90.47)	1.25 c (83.87)	2.0 c (92.52)	5.25 d (90%)
6	Bromoxynil + MCPA	33g a.i. ha^{-1}	4.5 bc (78.57)	3 b (64.29)	4 b (85.05)	11.50 b (79%)
7	Bromoxynil + MCPA	50g a.i. ha^{-1}	4 bc (80.95)	2.5 bc (67.74)	4 b (85.05)	10.25 bc (81%)
8	Bromoxynil + MCPA	100g a.i. ha^{-1}	4 bc (80.95)	1.5 c (80.64)	3.75 bc (85.98)	8.75 bcd (83%)

DAS: Days after sowing; Sorgaab: Sorghum water extract.
Figures in the same column sharing the same letter do not differ statistically at 5% probability.
Figures given in parenthesis show % decrease over control.

g a.i ha^{-1} there was no difference in suppression by increasing water extracts dose.

The density of *M. alba* was significantly affected by all the weed control treatments as compared to control (Table 1). All water extracts combinations each @ 15 and 18 L ha^{-1} tank mixed with herbicides @ 33 and 50 g a.i ha^{-1} caused similar inhibition and was on par with recommended dose of herbicides @ 100 g a.i ha^{-1} (T_8) and 50% reduction in herbicides i.e. 50 g a.i ha^{-1} alone. There was no difference in inhibition of *M. alba* by increasing water extracts dose.

Convulvulus arvensis density was significantly suppressed (64-85%) by all the weed control treatments as compared to control (Table 1). Maximum reduction in weed density was observed in sorgaab + brassica + sunflower each @ 15 L ha^{-1} mixed bromoxynil+ MCPA @ 50g a.i ha^{-1} (T_3; 93%), water extracts each @ 18 L ha^{-1} mixed with Bromoxynil + MCPA @ 50 g a.i ha^{-1}($T_{5;}$ 92%) and were statistically on par with full dose of herbicides @ 100 g a.i ha^{-1} ($T_{8;}$ 86%). Although reduced doses of Bromoxynil + MCPA alone ($T_{6,}$ T_7) showed significant weed density inhibition but less than water extracts combination tank mixed with reduced herbicides rate.

Total weeds density was significantly inhibited by all weed control treatments as compared to control (Table 1). Highest reduction in weeds density was noted in sorgaab + brassica + sunflower each @ 18 L ha^{-1} mixed with bromoxynil+ MCPA @ 50 g a.i ha^{-1} ($T_{5;}$ 90%) which was statistically similar to water extracts each @ 15 L ha^{-1} mixed with Bromoxynil + MCPA @ 50 g a.i ha^{-1} (T_3) and full dose of herbicides @ 100 g a.i ha^{-1} ($T_{8:}$). However, reduced doses of herbicides alone ($T_{6,}$ T_7) caused significant weeds density reduction but less than water extracts combination tank mixed with reduced herbicides doses. It was interesting to note that reduced dose of the herbicides (Bromoxynil + MCPA) in combination with allelopathic crop water extracts reduced total weed density more than its label dose. These results support the hypothesis that allelopathic water extracts can be used to suppress weeds or in combination with lower herbicide rate, thereby their doses can considerably (50%) be decreased. Iqbal and Cheema, (2007) reported that herbicide dose can be reduced in combination with allelopathic crop water extracts up to 67% in cotton. These findings suggest that allelopathic water extracts of sorghum, brassica and sunflower can be combined (showed synergistic effect) with each other and their higher rates mixed with reduced dose by 67% than its label rate, can effectively inhibit the weed density. Lydon *et al*. (1997) reported the synergistic effect of mixture of allelochemicals, but Inderjit *et al.* (2002) found antagonistic effect with the binary mixture of two phenolic acids (either *p*-hydroxybenzoic and ferulic acids or *p*-hydroxybenzoic and *p*-coumaric acids or *p*-

coumaric and ferulic acids).

Weeds dry weight: The dry weight of *E. helioscopia* was significantly reduced by all weed control treatments as compared to control (Table 2). Water extracts each 18 L ha^{-1} combined with herbicides @ 50 g a.i. ha^{-1} (T_5) caused highest reduction (99%) in *E. helioscopia* dry weight as compared to control and was similar to water extracts each @ 18 and 15 L ha^{-1} tank mixed with herbicides @ 33 and 50 g a.i ha^{-1} (T_3 and T_4) and full dose of herbicides @ 100 g a.i. ha^{-1} (T_8). While the water extracts each @ 15 L ha^{-1} combined with herbicides @ 33 g a.i ha^{-1} (T_2) showed similar results to reduced doses of herbicides @33 and 50 g a.i ha^{-1} (T_6 and T_7) and also full dose of herbicides @ 100 g a.i ha^{-1} (T_8).

All the weed control treatments significantly inhibited dry weight of *M. Alba* as compared to control (Table 2). Maximum reduction in *M. alba* dry weight was observed in water extracts each 18 L ha^{-1} combined with herbicides @ 50 g a.i. ha^{-1} (T_5; 99%) as compared to control followed by water extracts each @15 L ha^{-1} tank mixed with herbicides 50 g a.i ha^{-1} (T_3). Other water extracts treatments each @ 15L ha^{-1} and 18 L ha^{-1} combined with herbicides @ 33 g a.i. ha^{-1} (T_2 and T_4) showed similar inhibitions to recommended dose of herbicides @ 100 g a.i. ha^{-1} (T_8). Higher dose of water extracts (18 L ha^{-1}) combined with higher reduced rates of herbicides (50 g a.i ha^{-1}) caused significant inhibition.

All the weed control treatments significantly suppressed C. *arvensis* dry weight as compared to control (Table 3). Sorgaab + brassica + sunflower each @ 18 L ha $^{-1}$ mixed with Bromoxynil + MCPA @ 50 g a.i ha^{-1} (T_5) decreased weed dry weight by 99% and was statistically similar to water extracts each @ 18 L ha^{-1} combined with herbicides @ 33 g a.i ha^{-1} (T_4) and full dose of herbicides @100 g a.i ha^{-1} (T_8). The water extracts each @ 15 L ha^{-1} combined with herbicides @ 33 g a.i ha^{-1} (T_2) significantly reduced dry weight by 95% over control similar to reduced dose of herbicides alone @ 33 and 50 g a.i ha^{-1} (T_6 and T_7). Higher doses of water extracts (18 L ha^{-1}) inhibited dry weight of C. arvensis significantly more than lower doses (15 L ha^{-1}).

The data regarding weed dry weight were collected after oven drying the weeds whose fresh weight had been taken before. All the weed control treatments significantly suppressed total weeds dry weight as compared to control (Table 4.9). Maximum total dry weight of weeds inhibition was observed in sorgaab + brassica + sunflower each @ 18 L ha^{-1} mixed with Bromoxynil + MCPA @ 50 g a.i ha^{-1} (T_5; 99%) and was followed by water extracts each @ 15 L ha^{-1} sprayed as a tank mixed with herbicides @ 50 g a.i ha^{-1} (T_3) and full dose of herbicides @100 g a.i ha^{-1} (T_8). The water extracts each @ 15 L ha^{-1} combined with herbicides @ 33 g a.i ha^{-1} (T_2) was statistically similar to reduced doses of herbicides alone @ 33 and 50 g a.i ha^{-1} (T_6 and T_7). Higher doses of water extracts (18 L ha^{-1}) inhibited dry weight of significantly more than lower doses (15 L ha^{-1}). The inhibition in dry weight of weeds by the application of water extracts with reduced doses of herbicides has also been reported by Iqbal and Cheema (2007).

Wheat growth and yield

Plant height: Wheat plant height recorded at maturity was significantly enhanced by all the weed control treatments as compared to control (Table 3). The tallest plants were recorded in water extracts (sorgaab + brassica + sunflower) each @ 18L ha^{-1} tank mixed with herbicides (Bromoxynil + MCPA) @ 50g a.i. ha^{-1} (T_5) and were statistically similar to water extracts each @15 L ha^{-1} combined with herbicides @ 50 g a.i. ha^{-1} (T_3). The water extracts each @18 L ha^{-1} combined with herbicides @ 33 g a.i ha^{-1} (T_4) showed similar results to recommended dose of herbicides @100g a.i ha^{-1} (T_8). Although the reduced doses of herbicide alone @ 33 and 50 g a.i ha^{-1} (T_6 and T_7) produced smaller plants as compared to water extracts combinations with these reduced herbicides rates but significantly higher than control. Results are in line with the findings of Kamal and Bano (2008) who reported that wheat plants height was increased by application of sunflower water extracts.

Number of productive tillers: The number of productive tillers was significantly enhanced by all the weed control treatments as compared to control (Table 3). The maximum number of productive tillers (251) was obtained in water extract (sorgaab + brassica + sunflower) each @18L ha^{-1} combined with herbicide (Bromoxynil + MCPA) @ 50 g a.i. ha^{-1} (T_5). The water extracts each @15L ha^{-1} combined with herbicide @ 50g a.i. ha^{-1} (T_3) followed by water extracts each @ 18 L ha^{-1} combined with herbicides @ 33 g a.i ha^{-1} and recommended dose of herbicides @ 100 g a.i ha^{-1}. The reduced doses of herbicides alone @33 and 50 g a.i ha^{-1} (T_6 and T_7) enhanced less productive tillers as compared to water extracts combinations with herbicides reduced rats but increased as compared to control. This showed the role of water extracts with reduced doses of herbicide in increasing productive tillers. These results are also in lines with findings of Sharif *et al* (2005) who reported that no of fertile

Table 1. Combined effect of crop water extracts (sorghum, sunflower and brassica) and reduced herbicide rates on weeds density

	Treatments	Rate	weed density (0.25 m^{-2})			
			Euphorbia helioscopia	*Melilotus alba*	*Convolvulus arvensis*	Total
1	Control (weedy check)		21 a	7.75 a	26.75 a	55.50 a
2	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 33g a.i. ha^{-1}	5 b (76.19)	2 bc (74.19)	4.25 bc (85.98)	10.75 b (81%)
3	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 50g a.i. ha^{-1}	3 cd (85.71)	2 bc (74.19)	2.0 c (92.52)	7.00 cd (87%)
4	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 33g a.i. ha^{-1}	3 cd (85.71)	2 bc (74.19)	3.0 bc (88.78)	8.00 bcd (86%)
5	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 50g a.i. ha^{-1}	2 d (90.47)	1.25 c (83.87)	2.0 c (92.52)	5.25 d (90%)
6	Bromoxynil + MCPA	33g a.i. ha^{-1}	4.5 bc (78.57)	3 b (64.29)	4 b (85.05)	11.50 b (79%)
7	Bromoxynil + MCPA	50g a.i. ha^{-1}	4 bc (80.95)	2.5 bc (67.74)	4 b (85.05)	10.25 bc (81%)
8	Bromoxynil + MCPA	100g a.i. ha^{-1}	4 bc (80.95)	1.5 c (80.64)	3.75 bc (85.98)	8.75 bcd (83%)

DAS: Days after sowing; Sorgaab: Sorghum water extract.
Figures in the same column sharing the same letter do not differ statistically at 5% probability.
Figures given in parenthesis show % decrease over control**.**

Table 2. Combined effect of crop water extracts (sorghum, sunflower and brassica) and reduced herbicide rates on total weeds dry weight

	Treatments	Rate	Weed dry weight (g 0.25 m^{-2})			
			Euphorbia helioscopia	*Melilotus alba*	*Convolvulus arvensis*	Total
1	Control (weedy check)		6.7975 a	2.3575 a	7.7075 a	16.86 a
2	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 33g a.i. ha^{-1}	0.23 bc (96.61)	0.112 c (95.22)	0.345 b (95.52)	0.96 bc (96)
3	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 50g a.i. ha^{-1}	0.156 bcd (97.70)	0.061 d (97.41)	0.176 c (92.72)	0.34 bcd (98)
4	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 33g a.i. ha^{-1}	0.15 cd (97.79)	0.127 c (94.59)	0.12 cd (98.44)	0.40 (cd)
5	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 50g a.i. ha^{-1}	0.1 d (98.52)	0.022 e (99.04)	0.0672 d (99.13)	0.01 de (99)
6	Bromoxynil + MCPA	33g a.i. ha^{-1}	0.253 b (96.27)	0.705 b (70.09)	0.384 b (95.02)	1.34 b (97)
7	Bromoxynil + MCPA	50g a.i. ha^{-1}	0.202 bc (97.03)	0.135 c (94.27)	0.303 b (96.07)	0.65 (96)
8	Bromoxynil + MCPA	100g a.i. ha^{-1}	0.192 bcd (97.17)	0.105 c (95.55)	0.132 cd (98.02)	0.34 bcd (98)

DAS: Days after sowing; Sorgaab: Sorghum water extract.
Figures in the same column sharing the same letter do not differ statistically at 5% probability.
Figures given in parenthesis show % decrease over control**.**

Table 3. Combined effect of crop water extracts (sorghum, sunflower and brassica) and reduced herbicide rates on growth and yield of wheat

	Treatments	Rate	Plant Height	No. of Productive tillers (m^2)	No. of Grains per spike	1000-grain weight (g)	Grain Yield (t ha^{-1})
1	Control (weedy check)		47.38 f	138.5 h	31.5 f	37 f	4.55 g
2	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 33g a.i. ha^{-1}	58.2 d	193.5 e	37 de	44.90 d	4.90 e
3	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @15L ha^{-1} + 50g a.i. ha^{-1}	70.82 a	241.5 b	41.25 ab	51.29 b	5.90 b
4	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 33g a.i. ha^{-1}	65.4 b	216.5 d	36.25 cd	47.57 c	5.09 d
5	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	each @18L ha^{-1} + 50g a.i. ha^{-1}	72.06 a	251.5 a	46 a	53.5 a	6.15 a
6	Bromoxynil + MCPA	33g a.i. ha^{-1}	51.63 e	168 g	35 e	41.24 e	4.90 g
7	Bromoxynil + MCPA	50g a.i. ha^{-1}	59.86 c	179.5 f	36.25 e	43.00 d	4.95 f
8	Bromoxynil + MCPA	100g a.i. ha^{-1}	63.70 b	222.25 c	41.25 bc	50.08 b	5.10 c

DAS: Days after sowing; Sorgaab: Sorghum water extract.
Figures in the same column sharing the same letter do not differ statistically at 5% probability.
Figures given in parenthesis show % decrease over control**.**

Table 4. Economic analysis

	T1	T2	T3	T4	T5	T6	T7	T8	Remarks
Total grain yield	3640	3920	4720	4072	4920	3920	3960	4080	Kg ha^{-1}
Adjusted grain yield	3276	3528	4248	3565	4428	3528	3564	3672	To bring at farm level (10%)
Income	49140	52920	65120	55475	66420	52920	53460	55080	Rs: 600 per 40 kg
Straw yield	7824	9640	10640	10384	10864	8272	8960	10000	Kg ha^{-1}
Adjusted straw yield	7056	8676	9576	9345	9777	7444	8064	9000	To bring at farm level (10%)
Income	14112	17352	19152	18690	19554	14888	16128	18000	Rs: 80 per 40 kg
Gross income (grain+ straw)	63252	70272	76696	74165	85974	67808	69588	73080	Rs. ha^{-1}
Cost of herbicide	0	502	753	502	753	502	753	1506	Rs.1200/L
Cost of extracts	0	150	150	180	180	0	0	0	Rs: 10 L^{-1}
Sprayer rent	0	80	80	80	80	80	80	80	Rs.80/ spray
Spray application	0	180	180	180	180	180	180	180	Rs.180/man/day/ha^{-1}
Cost that vary	0	912	1163	942	1143	762	1013	1766	Rs.ha^{-1}
Net benefit	63252	71184	77859	75107	87117	68570	70601	74846	Rs.ha^{-1}

T_1: Control (weedy check); T_2: Sorgaab + brassica + sunflower each @15L ha^{-1} + Bromoxynil + MCPA each @ 33g a.i. ha^{-1}; T_3: Sorgaab + brassica + sunflower each @15L ha^{-1} + Bromoxynil + MCPA each @ 50g a.i. ha^{-1}; T_4: Sorgaab + brassica + sunflower each @18L ha^{-1} + Bromoxynil + MCPA each @ 33g a.i. ha^{-1}; T_5: Sorgaab + brassica + sunflower each @18L ha^{-1} + Bromoxynil + MCPA each @ 50g a.i. ha^{-1}; T_6: Bromoxynil + MCPA each @ 33g a.i. ha^{-1} (1/3 rd of full dose); T_7: Bromoxynil + MCPA each @ 50g a.i ha^{-1} (1/2 of full dose); T_8: Bromoxynil + MCPA each @ 100g a.i. ha^{-1} (full dose).

Table 5. Dominance and marginal analysis of wheat as influenced by different weed control treatments

	TREATMENTS	RATES	Total Cost that vary (Rs.)	Net profits (Rs.)	Change in cost (Rs.)	Change in net profits (Rs.)	Marginal rate of return (%)
1	Control (weedy check)	0	0	63252	---	---	---
6	Bromoxynil + MCPA	33 g a.i.ha^{-1}	762	68570	762	5318	698
2	Sorgaab + brassica + sunflower+Bromoxynil + MCPA	15 L each ha^{-1} + 33 g a.i .ha^{-1}	912	71184	150	2614	1742
4	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	18 L each ha^{-1} + 33 g a.i. ha^{-1}	942	75107	180	3923	2179
7	Bromoxynil + MCPA	50 g a.i. ha^{-1}	1013	70601	---	---	D
5	Sorgaab + brassica + sunflower + Bromoxynil + MCPA	18 L each ha^{-1} + 50 g a.i. ha^{-1}	1143	87117	201	12010	5975
3	Sorgaab+brassica+sunflower each + Bromoxynil + MCPA each	15 L each ha^{-1} + 50 g a.i .ha^{-1}	1163	77859	---	---	D
8	Bromoxynil + MCPA	100 g a.i. ha^{-1}	1766	74846	---	---	D

D= Dominated

tillers were increased by application of sorghum water extracts and Bromoxynil + MCPA.

Number of grains per spike: The number of grains per spike directly contributes to the final yield. The number of grains per spike was significantly increased by all weed control treatments as compared to control (Table 3). The maximum number of grains (46) were recorded in water extracts (sorgaab + brassica + sunflower) each @ 18L ha^{-1} tank mixed with herbicides (Bromoxynil + MCPA) @ 50g a.i. ha^{-1} (T_5) and was similar to water extracts each @15L ha^{-1} combined with herbicides @ 50g a.i. ha^{-1}(T_3) followed by full dose of herbicides @100 g a.i ha^{-1} (T_8). The water extracts each @ 15 and 18 L ha^{-1} combine with herbicides @ 33 g a.i ha^{-1} (T_2 and T_4) gave similar results. While the reduced doses of herbicides alone @ 33 and 50 g a.i ha^{-1} enhanced no of grains over control but less than water extracts with other reduced herbicide doses. Cheema *et al.* (2003b) also reported that grain number per spike was significantly increased with the application of sorghum, sunflower and eucalyptus water extracts.

1000 grain weight: The most important parameter which contributes much more to the final yield is 1000 grain weight. The heavier grains of a crop depict its efficacy to store more and more photosynthates in the seed. Data (Table 3) showed that maximum 1000 grain weight (52.5 g) was obtained from allelopathic crop water extracts of Sorgaab + brassica + sunflower each @18 L ha^{-1} combined with Bromoxynil + MCPA @ 50g a.i. ha^{-1} (T_5) and it was followed by allelopathic crop water extracts of Sorgaab + brassica + sunflower each @15 L ha^{-1} mixed with Bromoxynil + MCPA @ 50 and 33 g a.i. ha^{-1} (T_3) and recommended dose of herbicides i.e., Bromoxynil + MCPA @ 100 g a.i ha^{-1} (T_8). This clearly shows the advantage of allelopathic crop water extracts combined with lower doses of herbicides. The results of present study support the findings of Kamal and Bano (2008) who reported the increase in grains weight with the application of sunflower water extract.

Grain yield: Results (Table 3) show that all treatments significantly enhanced grain yield over control. The treatment combination of Sorgaab + brassica + sunflower each @18L ha^{-1} + Bromoxynil + MCPA @ 50 g a.i. ha^{-1} (T_5) produced maximum grain yield (6.15 t ha^{-1}) over control (4.55). The increase in grain yield was due to greater productive tillers and grains per spike. Probably the allelopathic extracts promoted growth. The grain yield in other water extracts combinations (sorgaab + brassica + sunflower) each 15 L ha^{-1} mixed with reduced dose of each herbicides (Bromoxynil + MCPA) @ 50 g a.i ha^{-1}(T_3), water extracts each 18 L ha^{-1} mixed with reduced dose of each herbicides @ 33 g a.i ha^{-1} (T_4) and recommended dose of herbicides (T_8) produced 5.90, 5.09 and 5.10 t ha^{-1} respectively. Moreover, these findings suggest that herbicides dose can considerably be decreased (50%) by using in combination with allelopathy. The increase in grain yield with reduced herbicide rate combined with allelopathy was also reported by Cheema *et al.* (2003a).

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