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Combined application of sorghum and mulberry water extracts is effective and economical way for weed management in wheat

Shahbaz Khan[1], Sohail Irshad[2]*, Faisal Mehmood[1], Muhammad Nawaz[3]
[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.
[2]In-Service Agricultural Training Institute, Rahim Yar Khan, Pakistan.
[3]Department of Agronomy, College of Agriculture, BZU, Bahadur Campus Layyah, Pakistan.

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**Corresponding author email:*
sohail_99uaf@yahoo.com

Abstract

Wheat (*Triticum aestivum* L.) is of prime importance being staple food of the masses of Pakistan. Weed infestation in wheat not only reduce the yield but also affects the efficiency of other production factors. Allelopathy is sustainable and ecofriendly method for the management of weeds and diseases. A field trail was carried out to assess the allelopathic potential of mulberry and sorghum water extracts against invasive winter weeds like *Phalaris minor*. Retz, *Chenopodium album* L., *Avena fatua* L. and *Convolvulus arvensis* L. in wheat at Agronomic Research Farm, University of Agriculture, Faisalabad. Experiment was laid out in randomized complete block design (RCBD) with four replications. All the treatment application showed better weed management and enhanced final yield of the crop. Application of sorghum water extract (SWE) at the rate of 18 L ha^{-1} and mulberry water extract (MWE) at the rate of 18 L ha^{-1} indicated better weed management (51-55%) and improved grain yield (28%) as compared to control. SWE at the rate of 27 L ha^{-1} and MWE at the rate of 9 L ha^{-1} in combined application also showed better weed management and improved the grain yield while Atlatis (Standard herbicide) had 66-68% weed control and 32% increase in final yield but it was not found economical. Combined application of SWE at the rate of 18 L ha^{-1} and MWE at the rate of 18 L ha^{-1} was found best combination with maximum net return while hand weeding and herbicide application were extravagant because of high cost and low net return.

Keywords: Allelopathy, Wheat, Water Extracts, Weeds

Introduction

Wheat is of prime importance being the main source of food due to its nutritional value since long. Most of the nutritional requirements of human body are met through this crop. It has main role in national economy. The final yield of the crop is not enough to meet dietary requirements of ever increasing population. Multiple factors including weed infestation, late sowing, improper nutrition and water use efficiency are responsible for limiting the yield (Jabran et al., 2011). A number of constraints hinder wheat production like poor quality seed, poor storage conditions, high prices of fertilizers and inadequate measures of plant protection principally weed infestation. Noxious weeds of wheat like *Phalaris minor* and *Avena fatua* reduce the yield up to 30%. Reduction in the wheat yield up to 20-30% was observed in case of high infestation of field with *Avena fatua* L. (Hassan and Khan, 2007).

Most of the weeds have established resistance against herbicides (Heap, 2008) and use of these agrochemicals have many health concerns (Kudsk and Streibig, 2003) with the problems like their residual effects and degradation in soil. Application of Mesotrione (Selective herbicide) to soil affects the population of microbes (Crouzet et al., 2010). Allelopathy is a novel method for the management of weeds and diseases. It refers to positive or negative impact of one plant to other including both weed and crop species by the release of some allelochemicals from plant parts through leaching, residue decomposition, root exudates and other ways in agro ecosystem (Ferguson and Rathinasabapathi, 2003). It has stimulatory along with inhibitory effect on plants as well as on microorganism. Number of studies depicted the effectiveness of allelochemicals against crop pests while working on the effect of sorghum, sunflower and brassica water extracts along with reduced dose of glyphosate for the management of purple nutsedge in cotton, Iqbal et al. (2009) investigated a reduced density and biomass of purple nutsedge.

Allelochemicals can interrupt the normal functioning of plant and can affect the physiological functions like respiration, photosynthesis and cell elongation (Field et al., 2006). There is mounting problem of pesticide and herbicide resistance in modern agriculture. Owing to pesticide resistance number of health related problems are increasing, unselective use distressed the ecosystem with soil and environment concerns, in this scenario allelopathy can play its role to cope these problems (Zhu and Li, 2002; Roseveld and Bretveld, 2008; Dayan et al., 2009). It is common observation of reduced vegetation under mulberry tree and its leaf defoliation in autumn suppress the growth of neighboring weeds. Use of mulberry water extracts reduced germination, root and shoot length with reduced dry weight of raddish (Hong et al., 2003). Wheat yield is affected by different broad and narrow leaf weeds including broad leaf dock, sweet clover, swine cress, field bind weed, fumitory, wild medic, little seed canary grass and wild oat (Shamsi and Ahmed, 1984).

Hong et al. (2004) reported decrease in weed density (65%) and dry weights (70%) when mulberry leaves were incorporated in soil at the rate of 2 t ha^{-1} in rice crop which ultimately increased the yield of the paddy by 23%. Some of the studies report the stimulatory effect of mulberry e.g. mulberry water extract of 50% concentration promoted the growth and development in broad bean and pea while in case of lentil, germination and growth showed positive impact by the single application of 25% concentration of mulberry water extract (Mughal, 2000).

Present study was conducted to assess the combined and alone application of mulberry and sorghum water extracts for the management of weeds in wheat and in particular to endorse an ecofriendly approach to reduce environmental and human health hazards by indiscriminate use of agrochemicals.

Material and Methods

A field trail was conceded to assess the allelopathic impact of sorghum and mulberry water extracts on weeds of wheat during the season 2014-2015 at Agronomic Research Area, University of Agriculture, Faisalabad, using randomized complete block design (RCBD) with four replications. Wheat cultivar AARI-2011 was sown by hand drill with R*R of 22 cm with gross plot size of 7 m × 2.2 m and 10 rows in each plot. Sowing was done in well pulverized soil (soil type: Lyallpur soil series (Aridsol-fine silty, mined, hyperthermic, ustalfic, Haplagrid) in USDA classification). Fertilizers were applied at the rate of 100-90-75 kg ha^{-1}. Irrigations were given according to the crop requirement. Treatments combination plan has been shown in table 1.

Preparation of extracts and herbicidal solution

Water extracts of sorghum and mulberry were prepared according to Cheema and Khaliq (2000a). Briefly, mulberry leaves were collected from the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. The leaves were washed three times under running tap water and were dried in an oven at 70°C for 48 h till a constant weight was attained. The dried leaves were soaked in tap water at 10% (w/v) at room temperature (25 _ 3°C) for 24 h. After that, the material was filtered to obtain a 10% extract. Then, the extract was boiled to concentrate it by 95%. This concentrated extract was named as 100% (stock solution). Mature sorghum crop was used for all these treatment preparations. It was placed in the shade for couple of days to avoid leaching by rain. After drying in the shade , it was chopped by ordinary fodder cutter ,thereafter, then this material was soaked in water in 1:10 ratio for 24 hours and concentrated to reduce its volume by 95% via boiling at100◦C (Cheema and khaliq, 2000a). The volume of the spray was 330 L ha $^{-1}$. Recommended doses of iodosulforun + mesosulforun at the rate of 14.4 g ha^{-1} a.i. (Atlantis 3.6 WG); product of Bayer crop sciences, was used.

Application of treatments
There was no application of treatment in weedy check plot. It was left untreated throughout the crop growth period. Hand weeding was done twice at 30 and 45 days after sowing the crop. Mixture of Iodosulfuran and Mesosulfuron (Atlantis 3.6WG) at the rate of 14.4 g a.i. ha^{-1} was sprayed after 30 days of sowing of crop. Similarly all other combinations of mulberry and sorghum water extracts were applied once in crop growth period after 30 days of sowing the wheat crop.

Weed Parameters
Weed density was calculated by counting all weeds present in 1 m^2. Fresh weight of all weeds was recorded by pulling out all of weeds plants and weighing them by ordinary scientific balance. After recording the fresh weight, weed samples were first sun dried, thereafter placed in an oven at 70ºC for 72 hours till then all of the moisture was removed. These samples were weighed by weighing balance to get dry weight.

Yield and yield components
Total number of tillers was calculated by counting the number of tiller from an area of 1 m^2. Regarding the data of number of spikelets/spike, five spikes were selected at random from each plot and number of spikelets was calculated and means of the calculated values was determined. For the estimation of final grain yield, an area of 1 m^2 of fully mature crop was harvested from each plot. After threshing, the weight of grains was taken.

Economic analysis
Economic analysis was carried to determine which treatment was much cost effective. Economic analysis was done through method prescribed by Byerlee et al. (1986).

Statistical analysis
Data were analyzed statistically by using Statistix 8.1 version (a computer software package for statistical analysis) and the difference between treatments' means was compared by employing LSD test at 5% level of probability (Steel et al., 1997).

Results

Weed Parameters
Total weed density/m^{-2}
Significant impact was observed on growth parameters of weed when applied with allelopathic water extracts. A number of weed growth parameters like fresh and dry biomass of weeds and weed density provides the information of weed infestation in the field. In the present study, weed density was calculated after 45 and 60 after sowing of the crop. Different broad and narrow leaf weeds like *Phalaris minor, Avena fatua, chenopodium album* and *convolvulus arvensis* infestation in the field was observed. Most of treatments applied showed reduced weed population (Table 3) but combined application of SWE at the rate of 18 L ha^{-1} and MWE at the rate of 18 L ha^{-1} reduced extreme weed density by 55% at 45 days after sowing (DAS) and 60% at 60 DAS while combined application of SWE at the rate of 27 L ha^{-1} and MWE at the rate of 09 L ha^{-1} depressed weed density by 41% at 45 DAS and 54% at 60 DAS. Total fresh and dry weed biomass was also affect significantly by the phytotoxic effect of allelochemicals of extracts when compared to control. Fresh biomass of weeds was also reduced by the application of mixture of Iodosulfuran + Mesosulfuron (Atlantis 3.6 WG) at the rate of 14.4 g a.i. ha^{-1} up to 65-75% in comparison to other treatments this trend was followed by combined application of water extracts of both sorghum and mulberry at the rate of 18 L ha^{-1} each by 51-56% while alone application of both the extracts found less effective in reducing the fresh biomass of weeds. In case of dry weights of the weeds similar observations were recorded and it was reduced up to 66-68% in case of application of (Atlantis 3.6WG) at the rate of 14.4 g a.i. ha^{-1}) this trend was followed by combined application of both the water extracts at the rate of 18 L ha^{-1} of each with the reduction in dry weight up to 51-55%. It was observed that the combine application of both water extracts reduced the dry weight of weeds as compared to sole application but alone application of MWE was found less effective as compared to SWE in reducing dry weight of weeds.

Yield parameters
Total tillers, number of spikelets/spike and grain yield were expressively affected by the application of definite treatments in comparison with control. In case of hand weeding, number of tillers and spikelets/spike were more and this trend was at par where herbicide

application was done. In case of crop water extracts, combined application of both the extracts at the rate of 18 L ha^{-1} of both produced maximum number of tillers which were statistically similar to application of herbicide (Table 2). Least number of tillers and spikelets/spike were observed in case of weedy check which was found statistically similar to alone application of MWE at the rate of 18 L ha^{-1}. Same was the case with the grain yield; maximum grain yield was recorded in hand weeding which was similar to herbicide application while minimum grain yield was observed in case of weedy check (Table 2).

Economic analysis

Effectiveness of the production scheme can be assessed for its economic fitness for the farmers. Present study was evaluated by conducting economic analysis along with marginal rate of return to determine best treatments applied. Results of the analysis depicted increase in income of Pakistani rupees 2570 to 25803 ha^{-1} in different combination of treatments as compared to control treatment. Maximum net benefits (Pak Rs. 25803) (236.72$) were obtained with combined application of both crop water extracts at the rate of 18 L ha^{-1} each while it was followed by application of herbicide (Pak Rs. 25463) (233.60$) and hand weeding with Pakistani rupees of 24850.5. Minimum net return (Pak Rs. 2570) (23.57$) was obtained in case of sole application of MWE at the rate of 18 L ha^{-1}.

Table 1: Treatment Combinations

	Description
T_1	Weedy check (Weed was not removed throughout growth period)
T_2	Hand weeding (30 and 45 DAS; days after sowing)
T_3	Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) at the rate of 14.4 g a.i. ha^{-1} (30 DAS)
T_4	Sorghum water extract18 L ha^{-1} (30 DAS)
T_5	Sorghum water extract 27 L ha^{-1} (30 DAS)
T_6	Sorghum water extract 36 L ha^{-1} (30 DAS)
T_7	Mulberry water extract 18 L ha^{-1} (30 DAS)
T_8	Mulberry water extract 27 L ha^{-1} (30 DAS)
T_9	Mulberry water extract 36 L ha^{-1} (30 DAS)
T_{10}	Sorghum water extract 27 L ha^{-1} + Mulberry water extract 09 L ha^{-1} (30 DAS)
T_{11}	Sorghum water extract 18 L ha^{-1} + Mulberry water extract 18 L ha^{-1} (30 DAS)
T_{12}	Sorghum water extract 09 L ha^{-1} + Mulberry water extract 27 L ha^{-1} (30 DAS)

Table 2: Effect of sorghum and mulberry water extracts on yield parameters of wheat

Treatments	**Number of tillers m^{-2}**	**Number of spikelets per spike**	**Grain yield (t ha^{-1})**
Weedy check	331 g	11 e	3.88 f
Hand weeding	382 a	18 a	5.31 a
Iodosulfuran + Mesosulfuron	374 ab	17 ab	5.17 ab
SWE at the rate of 18 L ha^{-1}	347 ef	13 de	4.08 de
SWE at the rate of 27 L ha^{-1}	350 de	13 de	4.10 de
SWE at the rate of 36 L ha^{-1}	357 cd	14 cd	4.44 d
MWE at the rate of 18 L ha^{-1}	337 fg	13 de	4.02 e
MWE at the rate of 27 L ha^{-1}	343 ef	13 de	4.08 de
MWE at the rate of 36 L ha^{-1}	352 de	14 cd	4.27 d
SWE at the rate of 27 L ha^{-1} + MWE at the rate of 09 L ha^{-1}	358 cd	16 bc	4.70 c
SWE at the rate of 18 L ha^{-1} + MWE at the rate of 18 L ha^{-1}	368 bc	16 abc	5.00 b
SWE at the rate of 09 L ha^{-1} + MWE at the rate of 27 L ha^{-1}	361 cd	15 bc	4.50 c
LSD at 5% probability level	11.695	2.2781	0.2166

Different lettering shows the statistically significant difference among the performance of treatments (*P* < 0.05) DAS = Days after sowing; SWE = Sorghum water extract; MWE = Mulberry water extract; LSD = Least significant difference.

Table 3: Effect of sorghum and mulberry water extracts on total weed density (m^{-2})

Treatments	**Weed density at 45 DAS (m^{-2})**	**Weed density at 60 DAS (m^{-2})**	**Fresh weight at 45 DAS (g m^{-2})**	**Fresh weight at 60 DAS (g m^{-2})**	**Dry weight at 45 DAS (g m^{-2})**	**Dry weight at 60 DAS (g m^{-2})**
Weedy check	35.25 a	38.25 a	47.25 a	56.07 a	5.97 a	7.09 a
Hand weeding	0.00 i	0.00 i	0.00 h	0.00 h	0.00 i	0.00 h
Iodosulfuran + Mesosulfuron	8.25 h	7.250 h	15.00 g	14.00 g	1.89 h	2.37 g
SWE at the rate of 18 L ha^{-1}	27.00 bc	23.75 bc	40.25 bc	48.18 bc	5.09 bc	6.09 bc
SWE at the rate of 27 L ha^{-1}	25.25 d	24.25 bc	39.00 bc	45.01 bcd	4.93 cd	5.94 bc
SWE at the rate of 36 L ha^{-1}	23.75 e	21.75 de	33.50 d	38.23 d	4.23 e	5.09 d
MWE at the rate of 18 L ha^{-1}	28.25 b	25.50 b	44.00 ab	50.37 ab	5.48 b	6.62 ab
MWE at the rate of 27 L ha^{-1}	26.75 c	23.50 cd	42.00 b	49.65 ab	5.34 b	6.53 ab
MWE at the rate of 36 L ha^{-1}	26.50 cd	23.00 cd	35.75 cd	40.87 cd	4.52 de	5.42 cd
SWE at the rate of 27 L ha^{-1} + MWE at the rate of 09 L ha^{-1}	20.75 f	17.50 f	24.50 ef	31.42 ef	3.09 f	3.92 ef
SWE at the rate of 18 L ha^{-1} + MWE at the rate of 18 L ha^{-1}	15.75 g	15.00 g	20.75 f	26.90 f	2.63 g	3.44 f
SWE at the rate of 09 L ha^{-1} + MWE at the rate of 27 L ha^{-1}	22.00 f	20.75 e	27.50 e	32.97 e	3.42 f	4.17 e
LSD at 5% probability level	1.3849	1.8073	5.0765	6.9199	0.4145	0.7176

Different lettering shows the statistically significant difference among the performance of treatments (*P* < 0.05) DAS = Days after sowing; SWE = Sorghum water extract; MWE = Mulberry water extract; LSD = Least significant difference

Discussion

Weed density is the key parameter that gives index of weed infestation in the field. In present study, weed density was recorded after 45 DAS and 60 DAS. Infestation of different braod and narrow leaf weeds like *convolvulus arvensis*, *Avena fatua*, *chenopodium album* and *Phalaris minor* was observed during the study in the field. Combined application of SWE and MWE at the rate of 18 L ha^{-1} of both showed maximum weed control as compared to other treatments as depicted in Table 3. There was substantial variation in weed control between 45 and 60 DAS; this might be due to natural variation of weed seed bank in soil. Findings of our study depicted that sole or combine application of both crop water extracts had more or less effect on weed density in field. These results are in line with the findings of Cheema and Khaliq (2000) who reported less population of weeds when applied with sorghum water extract. Our findings are quite similar to the findings of Cheema et al. 2000 who reported weed control up to 16-55% by spraying sorghum water extract. Hong et al. (2004) reported 65% reduction in weed density in paddy field when applied with mulberry water extract. Parameters like fresh and dry weight are also of prime importance as it regulates the uptake of different nutrients from soil profile by altering it into micro and macro molecules. Allelopathic extracts when applied to the crop, affected the fresh as well as dry weight (Table 3).

Alone application of MWE was less effective in suppressing weed fresh weight as compared to SWE. It might be possible due to the presence of allelochemicals present in water extracts that possessed inhibitory effect rather than killing weeds. Our results are in line with the findings of Putnam and Defrank (1979) who reported that crop plants release some of the chemicals that have inhibitory effect which could be used for the management of weeds. Our findings also confirm the study of Purvis et al. (1985) who stated inhibitory effect of sorghum that suppressed the dry biomass of weeds due to these allelochemicals.

Improvement in the yield parameters of wheat was observed due to less wheat density by the application of water extracts. Present study revealed that presence of allelochemicals in water extracts have promoting effect on wheat while negative impact on weed growth and development. Application of water extracts significantly affected yield parameters like number of spikelets/spike, total tillers and grain yield. Maximum number of tillers, spikelets/spike, total tillers and grain yield were observed in case of hand weeding which was statistically at par with herbicide application. In case of water extracts, combined application of water extracts of SWE and MWE at the rate of 18 L ha^{-1} produced maximum number of tillers and other yield parameters (Table 2). Improvement in spikelets/spike may be due to better weed management. Our results are supported the findings of Einhelling and Rasmussen (1989) who reported inhibitory effect of sorghum on weeds resulted in improvement in the yield of wheat. Likewise, findings of Hejl and Koster (2004) and Jabran et al. (2008) also supports our findings who reported inhibitory effects of sorghum and mulberry on weeds and their growth. Increase in grain yield might be due to suppressing ability of water extracts to weeds which ultimately caused in less competition of nutrients between crop and weeds resulted in more number of tillers, more spikelets/spike, increase in spike length, more number of grains/spike and grain weight. These results are in accordance with Haq et al. (2010) who reported better weed management in wheat by the application of MWE resulted in increase in grain yield.

Conclusion

It is concluded from present study that combined application of SWE at the rate of 18 L/ ha and MWE at the rate of 18 L/ha at 45 and 60 days after sowing of wheat helped to achieve maximum weed control. It also produced highest grain yield by improvement in yield contributing parameters with maximum net benefit returns. Sorghum and mulberry water extracts can be used effectively to control weed in wheat crop. It is recommended to use both these water extracts as tool for better weed management approach in wheat as these are safe and ecofriendly.

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