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Impact of combined application of sorghum and mulberry water extractson broad leaf weeds and yield attributes of wheat

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Abstract

Wheat has prime importance being a staple food of the region. Its production is hindered by a number of factors; the most important is weed infestation. Allelopathy is an organic and environment friendly approach to control the weed infestation in agronomic crops. A field experiment was conducted to evaluate the allelopathic potential of mulberry and sorghum water extracts at different concentrations against noxious broad leaf winter weeds like *Chenopodium album* L. and *Convolvulus arvensis* L. in wheat crop. Sorghum and mulberry water extracts in different concentrations were applied 30 days after sowing (DAS) of wheat. Weedy check plot was considered as control for comparison. All the treatments significantly reduced the weed infestation but maximum *C. arvensis* L. density was reduced by combine application of SWE and MWE @ 18 L ha^{-1} of each by 49% and 56% at 45 and 60 DAS respectively. Application of sorghum water extract (SWE) @ 36 L ha^{-1} reduced maximum *C. album* density by 48% and 52% at 45 and 60 DAS respectively as compared to control. Similarly combine application of SWE and MWE @ 18 L ha^{-1} of each showed fairly better results regarding number of grains per spike (45) and grain weight (35.79) as compared to control. Results showed that combined application of SWE and MWE @ 18 L ha^{-1} of each had maximum allelopathic potential with highest net benefits while herbicide and hand weeding were uneconomical due to higher cost and lower net benefits.

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Introduction

Wheat (*Triticum aestivum* L.) is among the main crops of Pakistan, accounts for 80% of cultivated area of around 9 million hectares during winter season. Wheat flour is major commodity that contributes about 72% of Pakistan's daily caloric intake with per capita consumption of around 124 kg/year which is one of the highest in the world (USDA, 2017). Among cereal crops, wheat has prime importance being staple food of Pakistani people (Aslam *et al.*, 2014; Blackshaw *et al.*, 2016). Weeds are serious threat to crop production and poses severe hindrance to attain maximum potential of crops. In spite of this fact weed management is unheeded factor pertinent to lack of knowledge and poor capitals of the farmers.

Hassan and Khan (2007) reported reduced wheat yield up to 20-30% due to higher population of weeds in the field like *Avena fatua* L. therefore, higher amount of seed rate is required to obtain optimum yield. Farmers are dealing these problematic weeds with different approaches like chemical and physical weed control methods. In fact chemical weed control method is easy, proved more effective in reducing weed biomass and less time consuming but at the same time, some weeds develop resistance against herbicides (Heap, 2008) and use of these chemicals has serious human health concerns (Kudsk and Streibig, 2003).

Furthermore, farmers with small land holdings cannot afford the cost of herbicides for weed management. Use of these chemicals results in many problems like degradation in soil, residual effects, herbicide resistance and blind use of these herbicides is very harmful for soil micro flora. Mesotrione, a selective herbicide used for maize crop when applied to the soil, affect the population of soil microbes (Crouzet *et al.*, 2010).

Unchecked growth of weeds in crops adversely affects yield and quality of the produce resulting in higher economic losses to the farmers. Some of the weed species are serious threat to environment and crop production as well; they compete for nutrients, light, space, sunlight and moisture with our main crops resulting in yield losses (Ozturk *et al.*, 2012). In Pakistan, weeds accounts for 30 percent grain yield losses in wheat amounting of Rs.1150 million annually (Marwat *et al.*, 2008). Additionally, the risk of weed resistance development and high cost-benefit ratio are other disadvantages of herbicides (Kordali *et al.*, 2009).

Therefore, in recent past, a new approach of allelopathyis found effective to suppress weeds in crop production. Allelopathy is ecofriendly, natural, inexpensive and organic approach which not only controls weeds but also increases crop yield. Practical implications of allelopathy for weed management can be in the form of intercropping, crop rotation, allelopathic mulches and by spraying allelopathic plant water extracts (Bhowmik and Inderjit, 2003; Farooq *et al.*, 2008; Jabran *et al.*, 2010a).

There is dire need to explore allelopathic potential of plant species including weeds, crops and trees for their practical implications in weed control programs. Blackshaw *et al.* (2006) reported that in the recent scenario, farmers are showing keen interest in weed control programs that are more effective in reducing the biomass of weeds and at the same time these are environmentally safe with lower production costs. A number of plants like oat, sorghum and sunflower have many allelochemicals that are hormones at low concentration while high amount of these substances act as herbicides. Keeping in view the losses of weeds, resistance of weeds to herbicides and practical implications of allelochemicals in weed management, present study was conducted to evaluate the potential of sorghum and mulberry water extracts for weed management in wheat and to provide safe and cheap method for controlling weeds for poor wheat grower.

Materials and methods

A field study was carried out to evaluate different preparations of sorghum and mulberry extracts for their phytotoxic effects on weeds in wheat crop during the season 2014-2015 at Agronomic Research Area, University of Agriculture, Faisalabad, using randomized complete block design with four replications. The wheat (Cultivar AARI-2011) was sown by hand drill in 22 cm apart row to row distance with gross plot measuring 7 m × 2.2 m with 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 according to the general recommendations of wheat (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

The allelopathic water extracts of sorghum and mulberry were prepared according to Cheema and Khaliq (2000). Recommended doses of iodosulforun + mesosulforun @ 14.4 g ha^{-1} a.i. (Atlantis3.6 WG); products of Bayer crop sciences, were 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 of crop. Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @ 14.4 g a.i. ha^{-1} were applied after 30 days of sowing. Similarly all other combinations of sorghum and mulberry water extracts were applied once in crop growth period after 30 days of sowing the wheat crop.

Weed parameters

Weed density of *Chenopodium album* (lambsquarters) and *Convolvulus arvensis* was calculated by counting all plants of particular specie present in 1 m^2 separately. Fresh weight of individual weed was recorded by pulling out all of plants of particular specie and weighing them by ordinary scientific balance.

After recording the fresh weight, weed samples were first sun dried, thereafter placed in an oven at 70°C for 72 hours till then all of the moisture was removed. These samples were weighed by ordinary balance to get dry weight.

Yield components

In case of number of grains per spike, five spikes were taken from each plot and grains were counted and mean value was determined. 1000-grain weight was calculated by counting the 1000 wheat grains and weighing through ordinary balance. The harvest index was calculated as the ratio of grain yield to the biological yield using the following formula.

$$Harvest\ index = \frac{Grain\ Yield}{Biological\ Yield} X\ 100$$

Statistical analysis

Data collected regarding weed and yield parameters were analyzed statistically using Statistix 8.1 version; a computer package for statistical analysis, and difference among treatments' means were compared by employing least significant difference (LSD) test at 5% probability level (Steel *et al.*, 1997).

Results and discussion

Density, fresh and dry weights of Chenopodium album L.

In the present study, effects of sorghum and mulberry water extracts were checked against density of *C. album*. All of the treatments significantly inhibited C. *album* L. population (Table 3). Amongst the water extracts, application of sorghum water extract (SWE) @ 36 L ha $^{-1}$ reduced the *C. album* density by 48% and 52% at 45 and 60 DAS respectively was followed by the SWE @ 27 L ha $^{-1}$ reduced the *C. album* density by 45% and 47% at 45 and 60 DAS respectively. Mulberry water extract treatments were less effective than sorghum extracts. Combined spray of sorghum and mulberry water extracts gave less reduction in weed density as compared to sorghum water treatments (Table 3). These results indicate that sorghum preparations significantly decrease the weed density because of allelopathic effect of sorghum. These findings relate with the previous work of cheema and khaliq (2000) as they concluded that 39% reduction in *C. album* density was observed. In another study conducted by Cheema *et al.* (2001) 31% reduction *of C. album* density was observed. These results were also supported by the previous work of Cheema *et al.* (2002) who reported about 27-31% reduction in *C. album* population.

Regarding fresh weight of *C. album*, among the sorghum mulberry water extracts, combine application of SWE @ 18 L ha^{-1} and MWE @ 18 L ha^{-1} was best to decrease the fresh weight of lambsquarters by 56% followed by SWE @ 36 L ha^{-1} decreased the fresh weight by 52% as compared to weedy check (Table 3). Present results reveal that sorghum and mulberry have weed suppressing ability. The findings are supported by the work reported by Purvis *et al.* (1985) who stated that sorghum (*Sorghum bicolor* L.) suppressed the fresh weight due to its harmful allelopathic activity.

Table 1. Treatment combinations.

No	Description
T_1	Weedy check (weeds were not removed throughout growth period)
T_2	Hand weeding (30 and 45 DAS; days after sowing)
T_3	Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @ 14.4 g a.i. ha^{-1} (30 DAS)
T_4	Sorghum water extract (SWE) @ 18 L ha^{-1} (30 DAS)
T_5	Sorghum water extract (SWE) @ 27 L ha^{-1} (30 DAS)
T_6	Sorghum water extract (SWE) @ 36 L ha^{-1} (30 DAS)
T_7	Mulberry water extract (MWE) @ 18 L ha^{-1} (30 DAS)
T_8	Mulberry water extract (MWE) @ 27 L ha^{-1} (30 DAS)
T_9	Mulberry water extract (MWE) @ 36 L ha^{-1} (30 DAS)
T_{10}	SWE @ 27 L ha^{-1} + MWE @ 09 L ha^{-1} (30 DAS)
T_{11}	SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1} (30 DAS)
T_{12}	SWE @ 09 L ha^{-1} + MWE @ 27 L ha^{-1} (30 DAS)

In case of dry weight of *C. album*, all of the treatments significantly suppressed the dry weight. Amongst plant water extracts, combine application of sorghum and mulberry extracts @ 18 L ha^{-1} of each reduced the maximum dry weight up to 57% as compare to control (Table 3). Sorghum water extract @ 36 L ha^{-1} suppressed the *C. album* dry weight by 51% and 53% at 45 and 60 DAS respectively followed by application of SWE @ 27 L ha^{-1} which reduced the dry weight by 42% and 43% at 45 and 60 DAS respectively. Mulberry water extracts were less effective than sorghum extracts.

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

Treatments	Number of grains per spike	1000 grain weight	Harvest index
Weedy check	32 g	30.50 g	29.87 f
Hand weeding	45 a	35.79 a	35.57 a
Iodosulfuran + Mesosulfuron	42 b	35.30 b	35.42 a
SWE @ 18 L ha^{-1}	35 f	32.12 f	30.93 de
SWE @ 27 L ha^{-1}	36 ef	32.56 e	30.39 ef
SWE @ 36 L ha^{-1}	39 cd	33.54 d	30.97 de
MWE @ 18 L ha^{-1}	35 f	31.35 g	31.54 cd
MWE @ 27 L ha^{-1}	38 de	31.60 f	31.37 cde
MWE @ 36 L ha^{-1}	39 cd	33.39 e	31.62 cd
SWE @ 27 L ha^{-1} + MWE @ 09 L ha^{-1}	42 b	34.56 bc	33.21 b
SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1}	42 b	34.48 b	34.98 a
SWE @ 09 L ha^{-1} + MWE @ 27 L ha^{-1}	40 bc	33.8 cd	32.36 bc
LSD at 5% probability level	2.7550	0.5646	1.0170

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

These results indicate that sorghum preparations significantly decrease the weed biomass because of allelopathic effect of sorghum. These findings relate with the previous work of Cheema *et al.,* 2002 who reported 29-40 % decrease in weeds dry weight of *Chenopodium album.*

Density, fresh and dry weights of Convolvulus arvensis L. *(m^{-2})*

Application of all treatments significantly reduced the density, fresh and dry weight of *Convolvulus arvensis* L. as compared weedy check which is considered as control (Table 4).

Convolvulus arvensis L. density was significantly reduced by application of Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @14.4 g a.i. ha^{-1} by 74-75% as compared to control and it was followed by application of SWE @ 36 L ha^{-1} and combine application of SWE and MWE @ 18 L ha^{-1} of each by 48-49% and 55-56% at 45 and 60 DAS respectively.

Table 3. Effect of sorghum and mulberry water extracts on density of *Chenopodium album* L. (m^{-2}).

Treatments	Weed density @45 DAS	Weed density @60 DAS	Fresh weight @45 DAS	Fresh weight @60 DAS	Dry weight @45 DAS	Dry weight @60 DAS
Weedy check	7.25 a	5.25 a	9.70 a	16.09 a	1.16 a	1.93 a
Hand weeding	0.00 i	0.00 f	0.00 h	0.00 g	0.0 h	0.00 g
Iodosulfuran + Mesosulfuron	2.75 h	1.25 e	3.31 g	5.25 f	0.39 g	0.62 f
SWE @ 18 L ha^{-1}	4.50 ef	2.75 cd	5.69 cde	9.25 cd	0.68 cde	1.11 cd
SWE @ 27 L ha^{-1}	4.00 fg	2.75 cd	5.50 def	9.36 cd	0.65 def	1.12 cd
SWE @ 36 L ha^{-1}	3.75 g	2.500 d	4.72 ef	7.47 de	0.56 ef	0.89 de
MWE @ 18 L ha^{-1}	6.50 b	4.00 b	7.39 b	12.31 b	0.88 b	1.43 b
MWE @ 27 L ha^{-1}	6.25 bc	3.75 b	6.83 bc	10.81 bc	0.81 bc	1.30 bc
MWE @ 36 L ha^{-1}	6.00 bcd	3.50 bc	6.14 bcd	10.18 c	0.73 bcd	1.22 bc
SWE @ 27 L ha^{-1} + MWE @09 L ha^{-1}	4.75 e	3.25 bcd	6.31 bcd	10.29 c	0.75 bcd	1.23 bc
SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1}	5.75 cd	3.50 bc	4.23 fg	6.85 ef	0.50 fg	0.82 ef
SWE @ 09 L ha^{-1} + MWE @ 27 L ha^{-1}	5.50 d	4.00 b	5.92 cde	9.48 c	0.71 cde	1.13 cd
LSD at 5% probability level	0.7373	0.9286	1.2837	1.9633	0.1552	0.2418

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; NS = Non significant (statistically).

Mulberry water extract treatments were less effective to decrease the density of *Convolvulus arvensis* L. as compared to sorghum water extract treatments. It may be due to presence of natural chemicals in plant water extracts that plays inhibitory role instead of killing weeds completely. Our results are supported by the work reported by Putnam and Defrank (1979) who said that crop plants release allelochemicals which could be utilized for managing weeds. The findings are supported by the work reported by Purvis *et al.* (1985) who stated that sorghum (*Sorghum bicolor* L.) suppressed the fresh weight due to its harmful allelopathic activity.

Convolvulus arvensis L. fresh weight was significantly lower in Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @14.4 g a.i. ha^{-1} by 57-60% as compared to control and it was followed by SWE 36 L ha^{-1} up to 43-44% (Table 4). Among the combine application of sorghum and mulberry water extracts @ 18 L ha^{-1} also suppress the fresh weight by 40-41% which is statistically at pat with Iodosulfuran + Mesosulfuron. Mulberry water extract treatments were less effective to suppress the fresh weight of *Convolvulus arvensis* L. as compared to sorghum water extract treatments. Similar trend was observed regarding dry weight of *Convolvulus arvensis* L. in response to application of SWE and MWE (Table 4). It may be due to presence of natural chemicals in plant water extracts that plays inhibitory role instead of killing weeds completely. Our results are supported by the work reported by Putnam and Defrank (1979) who said that crop plants release allelochemicals which could be utilized for managing weeds. The findings are supported by the work reported by Purvis *et al.* (1985) who stated that sorghum (*Sorghum bicolor* L.) suppressed the fresh and dry weight due to its harmful allelopathic activity.

Number of grains per spike

Application of sorghum and mulberry water extracts significantly affected the number of grains per spike as compared to control (Table 2). Hand weeding improved the maximum number of grains per spike followed by application of Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @14.4 g a.i. ha^{-1}.

Among the sorghum and mulberry water extracts, combine application of SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1} and SWE @ 27 L ha^{-1} + MWE @ 09 L ha^{-1} showed fairly better results to increase in number of grains per spike that is statistically at par with SWE @ 09 L ha^{-1} + MWE @ 27 L ha^{-1}. Minimum number of grains per spike was recorded by the application of SWE @ 18 L ha^{-1} and MWE @ 18 L ha^{-1}. Higher grain number in certain treatments may be due to weed suppressing ability resulting in less competition by weeds and ultimately the more reproductive growth. These findings are supported by the work of Cheema, (1988) who said that *Sorghum bicolor* L. contains several allelochemicals which could be effectively used for managing some of important weeds.

Table 4. Effect of sorghum and mulberry water extracts on density of *Convolvulus arvensis*L. (g m^{-2}).

Treatments	Weed density @45 DAS	Weed density @60 DAS	Fresh weight @45 DAS	Fresh weight @60 DAS	Dry weight @45 DAS	Dry weight @60 DAS
Weedy check	14.50 a	20.75 a	9.10 a	11.66 a	1.46 a	1.84 a
Hand weeding	0.00 h	0.00 h	0.00 g	0.00 g	0.00 g	0.00 g
Iodosulfuran + Mesosulfuron	3.75 g	5.25 g	3.57 f	4.80 f	0.57 f	0.76 f
SWE @ 18 L ha^{-1}	10.25 bc	14.50 bc	6.38 cd	8.27 cd	1.03 bcde	1.31 cd
SWE @ 27 L ha^{-1}	9.00 cde	12.75 cde	5.52 de	7.16 de	0.89 cde	1.13 de
SWE @ 36 L ha^{-1}	7.50 ef	10.50 ef	5.01 e	6.48 e	0.80 ef	1.03 e
MWE @ 18 L ha^{-1}	11.00 b	15.75 b	7.63 b	9.91 b	1.22 ab	1.57 b
MWE @ 27 L ha^{-1}	10.50 bc	14.75 bc	6.98 bc	8.89 bc	1.14 bc	1.41 bc
MWE @ 36 L ha^{-1}	9.50 bcd	13.50 bcd	6.77 bc	8.77 bc	0.98 de	1.39 bc
SWE @ 27 L ha^{-1} + MWE @09 L ha^{-1}	8.50 de	11.75 def	6.69 bc	8.62 bcd	1.07 bcd	1.36 bcd
SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1}	6.50 f	9.50 f	5.34 de	6.94 e	0.85 de	1.13 e
SWE @ 09 L ha^{-1} + MWE @ 27 L ha^{-1}	7.75 ef	11.25 def	6.70 bc	8.70 bc	1.07 bcd	1.38 bc
LSD at 5% probability level	1.6105	2.2634	1.0521	1.5013	0.2612	0.2360

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; NS = Non significant (statistically).

1000 grain weight

All treatments except mulberry water extract @ 18 L ha^{-1} significantly influenced grain weight as compared to control. Maximum grain weight was produced by hand weeding and it was statistically at par with Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @ 14.4 g a.i. ha^{-1}. Among combined sorghum and mulberry water extracts treatments SWE @ 18 L ha^{-1} significantly produced highest grain weight as compared to other treatments. Minimum grain weight was observed with weedy check. Sorghum water extract @ 18 L ha ha^{-1}, SWE 27 L ha ha^{-1} and MWE 18 L ha ha^{-1} were statistically same.

Increase in grain weight of wheat may be due to the weed suppressing ability of sorghum and mulberry water extracts that result in less competition among crop and weed plants and ultimately the more grain weight.

These results also resembles with the findings of Haq *et al.* (2010) who said that mulberry water extract effectively control the weeds population and increased the grain weight.

Harvest index

Different treatments used in the study significantly influenced harvest index as compared to control and except sorghum water extract @ 27 L ha ha^{-1}. Highest harvest index was observed in hand weeding and it was statistically equal with Iodosulfuran + Mesosulfuron (Atlantis 3.6WG) @ 14.4 g a.i. ha^{-1} and SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1}. Among sorghum and mulberry water extracts treatments, combine application of SWE @ 18 L ha^{-1} + MWE @ 18 L ha^{-1} significantly improve the harvest index as compared to other treatments and it was followed by SWE @ 27 L ha^{-1} + MWE @ 09 L ha^{-1} and SWE @ 09 L ha^{-1} + MWE @ 27 L ha^{-1}. Combined application of sorghum and mulberry water extracts was more effective in increasing the harvest index as compared to separate application of sorghum or mulberry water extract. Minimum harvest index was recorded control treatment (weedy check) which was statistically at par with SWE @ 27 L ha^{-1}. These findings relate with the previous work of Cheema *et al.,* (2002) who reported that harvest index was increased with sorghum preparations application.

Conclusion

Sorghum and mulberry water extracts showed prominent results but herbicides showed best results in controlling weeds in wheat. These water extracts had either stimulatory or inhibitory effects depending on the stage of wheat growth and quantity of sorghum. From the study it could be concluded that use of these extracts is less costly, ecofriendly and organic method of weed management in the fields of wheat infested with weeds.So, the allelopathic potential of sorghum and mulberry and their effects on weed flora should be further explored and should be included in weed management programs.

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