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EVALUATING THE ALLELOPATHIC EFFECTS OF SORGHUM AQUEOUS EXTRACT TANK-MIXED WITH HERBICIDE FOR WEED MANAGEMENT IN SOYBEAN

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Abstract

Weeds are one of the major biotic constraints in crop production system. As an alternative approach, allelopathy can be used to develop eco-friendly weed control strategy for sustainable agriculture. The present study was planned, therefore, with the main objective to evaluate the effects of plant aqueous extract (PAE) of sorghum (*Sorghum bicolor* L.) 1% and 2% especially on *Avenafatua* L. and *Phalaris minor* Retz. The experiment was conducted for consecutive two years (2017 & 2018) at Farm research area of "The Islamia University of Bahawalpur", Pakistan. Plant aqueous extract @ 18 L ha^{-1} alone and in combination with reduced dose @ 75% and 50% of Pendimethalin, Metolachlor and Acetochlor and also recommended dose of all the mentioned herbicides were sprayed for weed control. A weedy check control treatment was also maintained with no application of plant aqueous extract and herbicide. Lower doses @ 75% and 50% of Pendimethalin in combination with plant aqueous extract gave statistically the same level of weed reduction and crop improvement as produced by label doses of Pendimethalin. Based upon this study, it is hereby concluded that the allelopathic plant aqueous extract of *Sorghum bicolor* L., in combination with 50% of the recommended dose of Pendimethalin, may act as potential and environment friendly herbicide to control weeds in soybean crop.

Key words: Soybean, Sorghum, Allelopathy, Environment, Weed management.

Introduction

Weeds are major threat to the agricultural production system and arable crops including soybean (Samad *et al*., 2008). In common, weeds are rivals to the domesticated crop plants for biotic and abiotic factors which result in stunted growth of the valuable crop plants by causing certain losses ranging almost 20%-30% (Rajcan & Swanton, 2001). Un-satisfactory weed control can affect the production of soybean especially at initial growth stages, where 20-70% decline in the crop yield is reported (Kurchania *et al.,* 2001). It is also reported that soybean yield is get curtailed by 37% due to weeds whereas insects, pests and diseases part this loss up-to 22% only (Oerke & Dehne, 2004). Moreover, it is observed that yield losses due to weeds depend upon type of weed, growth time and intensities of weed invasion (Kachroo *et al.,* 2003). Both the weeds *Avenafatua* L. (wild oat) and *Phalaris minor* Retz. (little seed canary grass) are harmful for potential production of agricultural crops as described by Jabran *et al.,* (2010). *Avenafatua* L. is reported for certain toxic chemicals which reduce the growth of crop plants (Shah & Khan, 2006; Waheed *et al*., 2009). Similarly, Malik *et al*., (1995) reported 50% yield decrease in wheat crop due to *Phalaris minor* Retz. which may be added-up to 80% in severe conditions.

In addition to the reduced yield of arable crops, synthetic chemicals e.g herbicides increase water and environmental pollution (Agrawal *et al*., 2010). The unchecked use of these chemicals are posing serious threat to the aquatic life and the environment. These chemicals are damaging the human health especially in infants, young children, agriculture farm workers and the pesticide applicators. So, the researchers are with no option but to develop environment and human health friendly ways to reduce the synthetic chemicals including herbicides.

The use of agrochemicals and synthetic herbicides can be minimized due to preamble of allelopathy in agriculture. Weed control through synthetic chemicals is a method being used at a vast level for weed suppression and enhancement of yield. This method is bringing results for the farmers where yield increment is observed through efficient weed control (Santos, 2009). However, the excessive application of herbicides is fetching various hazards i.e. soil and water pollution, disturbed healthiness of human and animals, crop injury and resistance in weeds against herbicides (Farooq *et al*., 2011) but most of the farmers are not familiar from the potential of toxicity of pesticides (Cherry *et al*., 2018). That's why it is recommended to use alternate approaches such as bio-products (plants, fungi and bacteria) aiming to minimize or replace the herbicides (Khan *et al.,* 2011; Khan *et al.,* 2016) for the development of safe, harmless, less expensive and environment friendly approaches, utilizing farm produced material, is essential for sustainable agriculture in climate-sensitive developing countries (Jouzi *et al*., 2017).

The dose of herbicides can be reduced up-to a reasonable extent, as its work synergistically when combined with plant water extracts (Cheema *et al*., 2005; Khan *et al*., 2016). It is reported in different studies that reduced rate of weedicides along with water extract of allelopathic crops is more effective to control the weeds in different crops such as soybean, cotton, canola, rice and wheat. It is observed by Jabran *et al.,* (2008) that Pendimethalin can reduce the weeds effectively in canola up-to 50% when applied in combination with sorghum and sunflower plant water extracts.

In present decades, the combination or mixture of herbicides and plant aqueous extracts are being well researched (Razzaq & Kappe, 2010). It is reported that sorghum and sunflower allelopathic weed control has resulted in enhanced the crop yield (Khan *et al*., 2015).

But the scientists are unfamiliar to use these mixtures for soybean. Reduced doses of herbicide (up to 70%),when used with sunflower, brassica and sorghum water extract (@ 18 L ha^{-1}) in wheat crop decreased considerably the total weed density and dry weight (Arif *et al*., 2015). Similarly, soil application of sorghum and sunflower plant aqueous extract (@ 10 mL kg^{-1}) and incorporation of sorghum and sunflower powder (@ 10 g kg^{-1}) by Kandhro *et al*., (2015) curtailed the germination, growth and development of target species. Moreover, it is observed by Khan *et al*., (2012) that aqueous extracts of different plants including brassica, sunflower and sorghum when applied in combination of atrazine with reduced doses, controlled the weeds meaningfully in maize.

It is observed that there is a huge gap in research for enhancement the yield of soybean especially in Pakistan. Therefore, it is need of hour to control the weeds in soybean by using environmental friendly techniques and to promote this valuable oil seed crop of the world in Pakistan. Keeping in view the importance of soybean and the environmental hazards of synthetic chemicals, reduced doses of herbicides are being tank mixed with plant aqueous extracts with the hypothesis that this combination will reduce the weeds significantly along with adding lesser to increasing environmental pollution.

Material and Methods

The experiment was conducted for consecutive two years (2017 & 2018) at Farm research area of Department of Agronomy, University College of Agriculture and Environment Sciences (UCA&ES), The Islamia University of Bahawalpur (IUB), Pakistan. Experiment was conducted in randomized complete block design (RCBD) with three replications. The soil, where the field experiment was carried out, got analyzed (each year) before sowing of the Soybean from Soil Fertility Lab of UCA&ES (IUB). The soil was observed as sandy loam naturally with properties and nutrient concentrations with pH (7.7), Total soluble salts (5.1 MEL^{-1}), Organic matter (0.96%), Nitrogen (0.51%), available P_2O_5 (12.7 ppm) and available K_2O (127 ppm). Field bed was prepared by cultivating the soil three times with tractor mounted cultivator each followed by planking. A registered soybean variety "NARC II" was planted in first week of February. The row to row distance was kept as 30 cm whereas plant to plant distance was kept 5 cm.

Crop husbandry: Nitrogen, phosphorus and potassium @ 25, 50, 50 kg ha^{-1} was applied in the form of urea, Di-ammonium phosphate (DAP) and Murate of potash (MOP) respectively. Phosphorus and Potash was applied at the sowing time whereas nitrogen in three splits. Initial fragment of nitrogen was applied at time of sowing whereas the second and third split was given at 25th day and 45th days after seeding the crop respectively. The crop was nourished with other agronomic practices as per recommendations.

Preparation of plant aqueous extract and implementation: The fresh, healthy leaves of sorghum were collected and washed with distilled water to remove the dust particles. Then, the leaves were dried at room temperature (25±2ºC) for 7 days and then dried in an oven, at 65ºC for 72 hours. The dried leaves were powdered and then mixed in distilled water in a ratio of 1:10 (w/v) for preparation of stock solution of 10% concentration following the method published by Shafique *et al*., (2005). The prepared stock solution was then used to formulate the aqueous extract treatments (1% and 2%) using parallel dilution technique.

Plant aqueous extracts of *S. bicolor* L. worth concentration 1% and 2%, @ of 18 L/ha was tank mixed with reduced doses (i.e.75% and 50%) of Pendimethalin, Metolachlor and Acetochlor and was applied as pre-emergence herbicides for two consecutive years (2017 and 2018). To compare the results, recommended dose of Pendimethalin (1.0 kg a.i ha^{-1}), Metolachlor (1.0 kg a.i ha^{-1}), Acetochlor (1.25 kg a.i ha^{-1}) and plant aqueous extracts (1% and 2%) were also used solely @ 18 l/ha. Along with this, a treatment with no-herbicide (either synthetic or bio) was also maintained for comparison. The study was kept under investigation for weed density, especially at 30 DAS, 60 DAS and 120 DAS (at the time of maturity). The study was conducted to develop the cost-effective and environment friendly means to reduce weeds in Soybean.

Crop parameters: Crop data was recorded for different parameters of growth and development e.g., plant height (cm), numbers of pods per plant, numbers of grain per pod, 1000 grain weight (gm), biological yield (kg/ha) and harvest index (%) which resulted in grain yield and % yield over weedy check.

Weed parameters

Weed density/ m^2: Data for density of individual narrow-leaf weeds (i.e. *Avenafatua* L. and *Phalaris minor* Retz.), others and total weed in a unit area was recorded at 30, 60 and 120 DAS for both of the years using a (1x1m) quadrate randomly placed in each experimental unit.

Weed fresh and dry weight: Above ground biomass of individual narrow leaf weeds (*Avenafatua* L. and *Phalaris minor* Retz.), others and total weed (which were considered for weed density) were collected at harvesting time and weighed for weed fresh weight in grams/m^2. The obtained weed biomass from each quadrate of each plot was dried in an oven at 70°C for 72 hours and weighed for weed dry weight. The recorded data was then converted from gram per m^2 to kg per hectare.

Statistical analysis: Fischer's analysis of variance technique was manipulated to analyze the data statistically. Least Significant Difference (LSD) test @ 5% probability level was used to compare the treatment means (Steel &Torrie, 1984).

Results

It is revealed from the results that grain yield of Soybean was significantly increased as compared to control during the year 2017 and 2018 respectively when plant aqueous extract and herbicide was applied (Table 1).

It was further observed that grain yield of Soybean tend to increase gradually with the increase in PAE concentration and herbicide dose. Non-significant effect on the grain yield of the crop was observed when PAE was used in combination with herbicide as compared to sole application of the herbicides.

During the year 2017, maximum grain yield (3.210 ton/ha) was recorded when Pendimethalin was used @ label dose as compared to the grain yield (0.746 ton/ha), obtained under control/ weedy check. During the year 2018, 2% of PAE tank mixed with 75% of Pendimethalin resulted maximum grain yield (3.337 ton/ha) with respect to (0.727 ton/ha) as produced by the weedy check/control. However, further reduced dose of Pendimethalin (50% of label dose) produced statistically similar results when tank mixed with 2% of PAE.

Percent yield of soybean over weedy check was increased significantly as compared to control, in 2017 as well as in 2018, when PAE and herbicides were used (Table 2). Even, reduced doses of herbicides and the PAE, whether used solely or in combination, increased the % yield of the crop as compared to control. Sole application of PAE produced similar results to the treatment where PAE was tank mixed with reduced doses of herbicides. Lowest increase over weedy check i.e. 33.564 % and 41.894% in 2017 and 2018 respectively, was observed in the treatments where PAE was used solely @ 1%. Percent yield was increased gradually when herbicides were used in alone or tank mixed with plant aqueous extracts.

In 2017, highest percent yield increase over weedy check control i.e., 330.12% was resulted when Pendimethalin was used @ label/ dose but statistically similar results were observed in the treatments where 75% and 50% of the label dose of Pendimethalin was tank mixed with 2% of PAE. In 2018, 2% of PAE tank mixed with 75% of the label dose of Pendimethalin resulted highest increase in % yield i.e., 358.77% over weedy check control which was statistically similar to the treatments where Pendimethalin was used @ label dose and 2% of PAE was tank mixed with 50% of the label dose of Pendimethalin.

Results revealed highest weed population was observed in weedy check control while applied herbicides and PAE reduced the weeds population significantly. In the experimental year 2017, after 30, 60 and 120 DAS, lowest population of *A. fatua* L. (1.00 plant m^{-2}) was found in the treatment where Pendimethalin was applied @ label dose and 75% of the label dose of Pendimethalin tank mixed with 2% of PAE. 50% of the label dose of Pendimethalin tank mixed with 2% of PAE showed statistically similar results. Lowest population of *P. minor* Retz. (1.33 plants m^{-2}) was resulted from the label dose of Pendimethalin which was statistically similar to the treatment where 75% and 50% of the label doses of Pendimethalin were tank mixed with 2% of PAE. At the same time, lowest population of weeds other than *A. fatua* L and *P Minor* Retz. (2.33 plant m^{-2} & 2.00 plantsm^{-2}) at 30 and 60 DAS respectively, was resulted from the mixture of 2% PAE and 50% of the label dose of Pendimethalin. While at 120 DAS minimum number of other weeds i.e. 2.000 plantsm^{-2} was observed in the treatments having reduced doses (75% and 50%) of the Pendimethalin tank mixed with 2% of PAE (Tables 3, 4 & 5).

Table 1. Grain yield of *G. max* L. as affected by *S. bicolor* L. water extracts tank mixed with reduced herbicide doses.

Treatments	PAE Conc.	2017	2018
Weedy check	0	0.7467 P	0.7277 P
PAE	1	0.9967 O	1.0325 O
	2	1.2100 N	1.2293 N
Pendimethalin @ Recommended Dose	0	3.2100 A	3.3241 A
Pendimethalin @ 75% of the Recommended Dose	0	2.2000 C	2.2290 C
	1	2.5633 B	2.5595 B
	2	3.1900 A	3.3376 A
Pendimethalin @ 50% of the Recommended Dose	0	2.1333 E	2.1200 E
	1	2.5767 B	2.5853 B
	2	3.1833 A	3.3132 A
Metolachlor @ Recommended Dose	0	1.8233 GH	1.8683 GH
Metolachlor @ 75% of the Recommended Dose	0	1.4133 L	1.4522 L
	1	1.6933 J	1.6856 J
	2	1.8633 G	1.8875 G
Metolachlor @ 50% of the Recommended Dose	0	1.2933 M	1.3004 M
	1	1.2967 M	1.3004 M
	2	1.6833 J	1.6653 J
Acetochlor @ Recommended Dose	0	2.1867 CD	2.2248 C
Acetochlor @ 75% of the Recommended Dose	0	1.7700 I	1.8078 I
	1	1.9567 F	1.9606 F
	2	2.1500 DE	2.2034 CD
Acetochlor @ 50% of the Recommended Dose	0	1.5133 K	1.5395 K
	1	1.8100 HI	1.8276 HI
	2	2.1533 DE	2.1676 DE

Table 2. % yield increase over weedy check of *G. max* L. as affected by *S. bicolor* L. water extracts tank mixed with reduced herbicide doses.

Treatments	PAE Conc.	2017	2018
Weedy check	0	0.0000 N	0.0000 P
PAE	1	33.564 M	41.894 O
	2	62.123 L	68.948 N
Pendimethalin @ Recommended Dose	0	330.12 A	356.88 A
Pendimethalin @ 75% of the Recommended Dose	0	194.76 C	205.38 C
	1	243.37 B	206.36 C
	2	327.33 A	358.77 A
Pendimethalin @ 50% of the Recommended Dose	0	185.74 D	190.36 E
	1	240.54 B	253.34 B
	2	326.43 A	355.32 A
Metolachlor @ Recommended Dose	0	240.54 B	253.34 B
Metolachlor @ 75% of the Recommended Dose	0	89.355 J	99.560 L
	1	126.83 H	131.67 J
	2	149.56 F	159.34 GH
Metolachlor @ 50% of the Recommended Dose	0	73.237 K	78.719 M
	1	73.237 K	78.719 M
	2	125.48 H	128.87 J
Acetochlor @ Recommended Dose	0	192.91 CD	205.78 C
Acetochlor @ 75% of the Recommended Dose	0	137.14 G	148.44 I
	1	162.12 E	169.47 F
	2	188.00 CD	202.77 CD
Acetochlor @ 50% of the Recommended Dose	0	102.74 I	111.58 K
	1	144.49 FG	151.18 HI
	2	188.41 CD	197.88 DE

In the experimental year 2018 maximum reduction in the population of *A. fatua* L., *P minor* Retz and other weeds was also resulted in the treatments where Pendimethalin was solely applied or tank mixed with PAE. At 30, 60 and 120 DAS, recommended dose of Pendimethalin and its reduced dose @ 75% tank mixed with 2% of PAE resulted in lowest weed density of *A. fatua* L. (1.00 plants m^{-2}). This weed population was found to be statistically similar to the treatment where 50% of the Pendimethalin was used in combination with 2% of PAE. Recommended dose of Pendimethalin resulted in minimum number of *P. minor* Retz (1.33 plants m^{-2}) too which was statistically similar to the treatments where reduced doses i.e., 75% and 50% were tank mixed with 2% of PAE. At 30 and 60 DAS, 50% of the label doses of Pendimethalin combined with 2% of PAE resulted lowest density of other weeds than *A. fatua* L. and P Minor Retz (2.333 plants m^{-2} &2.000 plants $m^{-2,}$), while at 120 DAS minimum number of other weeds i.e 2.000 plants m^{-2} was observed in the treatment where label dose and reduced doses i.e. 75% and 50% of Pendimethalin was tank mixed with 2% of PAE (Tables 3, 4 & 5).

Results showed that weeds dry biomass was significantly reduced as compared to control during 2017 and 2018 when plant aqueous extract and herbicide was applied (Table 6). It is further observed that weeds dry biomass tend to decrease gradually with the increase in PAE concentration and herbicide dose. It was also observed that label doses of herbicides produced similar results to the treatments where reduced doses of these were tank mixed with PAE. In both of the experimental years, maximum dry biomass of *A. fatua* L., *P. minor* Retz.and other weeds was found in weedy check control.

In 2017 and 2018, lowest dry biomass of *A. fatua* L. (2.024 gm & 1.840 gm respectively) was resulted in the treatment where Pendimethalin was sprayed @ label dose and the results were statistically similar to the combination of 2% PAE with 75% and 50% of Pendimethalin. 50% of the label dose of Pendimethalin tank mixed with 2% of PAE resulted in lowest dry weight of P. minor Retz (2.549 gm & 2.321 gm) in 2017 and 2018 respectively. Lowest dry weight of weeds other than *A. fatua* L and P minor Retz for the years 2017 and 2018 respectively (7.409 gm & 6.692 gm) were observed in the treatments where label dose of Pendimethalin was used but during both of the experimental years, the results were statistically similar to the combination of reduced doses of Pendimethalin (75% and 50%) with 2% of PAE.

Discussion

From the study it was evident thatmost of the cereal crops and their grain weight provide the base for grain yield in *G. max* L. (Mostafavi, 2012). Regarding grain yield for the years 2017 and 2018, it was observed that highest grain yield was found where Pendimethalin was used @ label dose and were statistically resembled to those treatments where Pendimethalin was used in reduce doses tank mixed with 2% of *S. bicolor* L. plant aqueous extracts. The reason behind this may be the lowest weed density in the same treatments in both of the years which leaded to the minimum weed-crop competition for water and nutrients. The results that Pendimethalin, when homogenized with plant aqueous extract, significantly increased the yield resemble to those of Rehman *et al*., (2010) where the researchers applied the aqueous extracts of sorghum and sunflower, tank mixed with reduced doses of Pendimethalin which resulted in better crop yield.

Table 3. Weed density at 30 DAS as affected by *S. bicolor* L. water extracts tank mixed with reduced herbicide doses.

Treatments	PAE Conc.	*A. fatua* L.		*P. minor* Retz.		Others		Total	
		2017	2018	2017	2018	2017	2018	2017	2018
Weedy check	0	9.000 A	8.6667 A	10.333 A	10.000 A	8.0000 BCD	7.6667 AB	27.333 A	26.333 A
PAE	1	7.333 B	7.0000 B	7.000 B	6.667 B	9.6667 A	9.3333 A	24.000 B	23.000 B
	2	7.000 B	7.0000 B	6.667 BC	6.667 B	9.0000 AB	9.0000 A	22.667 BC	22.667 B
Pendimethalin @ Recommended Dose	0	1.0000 H	1.0000 I	1.333 K	1.333 J	3.0000 IJK	3.3333 EFG	5.333 L	5.333 J
Pendimethalin @ 75% of the Recommended Dose	0	2.6667 G	2.3333 GH	3.333 HI	3.000 GH	4.000 GHIJ	4.000 DEFG	10.000 JK	9.333 HI
	1	1.3333 H	2.3333 GH	2.000 JK	2.000 HIJ	5.3333 FGH	5.3333 CD	8.667 K	8.667 I
	2	1.0000 H	1.0000 I	1.667 JK	1.667 IJ	2.6667 JK	2.6667 FG	5.333 L	5.333 J
Pendimethalin @ 50% of the Recommended Dose	0	3.3333 FG	3.0000 FG	4.000 GH	3.667 FG	4.667 FGH	4.6667 DE	12.000 HIJ	11.333 FGH
	1	2.6667 G	2.6667 G	2.667 IJ	2.667 GHI	3.333 HIJK	3.3333 EFG	8.667 K	8.667 I
	2	1.3333 H	2.3333 GH	1.667 JK	1.667 IJ	2.3333 K	2.3333 G	5.333 L	5.333 J
Metolachlor @ Recommended Dose	0	5.3333 CD	5.0000 DE	5.000 EFG	5.000 DE	8.6667 ABC	8.3333 AB	19.000 EF	18.333 C
Metolachlor @ 75% of the Recommended Dose	0	6.3333 BC	6.3333 BC	5.667 CDE	5.667 BCD	9.3333 AB	9.3333 A	21.333 CDE	21.333 B
	1	5.6667 CD	5.3333 CD	5.333 DEF	5.000 DE	8.0000 BCD	7.6667 AB	19.000 EF	18.000 C
	2	5.000 DE	5.0000 DE	5.000 EFG	5.000 DE	8.3333 ABC	8.3333 B	18.333 F	18.333 C
Metolachlor @ 50% of the Recommended Dose	0	6.3333 BC	6.3333 BC	6.333 BCD	6.333 BC	9.3333 AB	9.3333 A	22.000 BCD	22.000 B
	1	6.3333 BC	6.3333 BC	6.333 BCD	6.333 BC	9.3333 AB	9.3333 A	22.000 BCD	22.000 B
	2	5.667 CD	4.6667 DE	5.667 CDE	5.333 CDE	9.0000 AB	8.6667 B	19.667 DEF	18.667 C
Acetochlor @ Recommended Dose	0	3.000 FG	2.6667 G	3.333 HI	3.000 GH	4.333 FGHI	4.3333 DEF	10.667 JK	10.000 GHI
Acetochlor @ 75% of the Recommended Dose	0	4.000 EF	4.0000 EF	4.333 FGH	4.333 EF	5.6667 EF	5.6667 CD	14.000 GH	14.000 DE
	1	3.0000 FG	3.0000 FG	3.667 HI	3.667 FG	4.6667 FGH	4.6667 DE	11.333 IJ	11.333 FGH
	2	2.6667 G	2.3333 GH	3.333 HI	3.000 GH	7.3333 CD	6.6667 BC	13.333 GHI	12.000 EFG
Acetochlor @ 50% of the Recommended Dose	0	4.000 EF	4.0000 EF	5.333 DEF	5.333 CDE	5.6667 EF	5.6667 CD	15.000 G	15.000 D
	1	3.3333 FG	3.0000 FG	3.667 HI	3.667 FG	6.6667 DE	6.6667 BC	13.333 GHI	13.333 DEF
	2	2.6667 G	2.6667 G	3.333 HI	3.333 FG	4.333 FGHI	4.3333 DEF	10.333 JK	10.333 GHI

Table 4. Weed density at 60 DAS as affected by *S. bicolor* L. water extracts tank mixed with reduced herbicide doses.

Treatments	PAE Conc.	*A. fatua* L.		*P. minor* Retz.		Others		Total	
		2017	2018	2017	2018	2017	2018	2017	2018
Weedy check	0	9.0000 A	8.6667 A	10.333 A	10.000 A	7.6667 ABC	7.3333 BCD	27.000 A	26.000 A
PAE	1	7.3333 B	7.0000 B	7.000 B	6.667 B	9.0000 A	8.6667 AB	23.333 B	22.333 B
	2	7.0000 B	7.0000 B	6.667 BC	6.667 B	8.6667 AB	8.6667 AB	22.333 B	22.333 B
Pendimethalin @ Recommended Dose	0	1.0000 H	1.0000 I	1.333 J	1.333 J	2.3333 IJ	2.3333 KL	4.667 I	4.667 I
Pendimethalin @ 75% of the Recommended Dose	0	2.6667 G	2.3333 GH	3.667 GH	3.000 GH	3.6667 GHI	3.6667 IJK	9.667 GH	9.000 GH
	1	1.3333 H	1.3333 HI	2.000 IJ	2.000 HIJ	4.6667 EFG	4.6667 FGHI	8.000 H	8.000 H
	2	1.0000 H	1.0000 I	1.667 IJ	1.667 IJ	2.3333 IJ	2.3333 KL	5.000 I	5.000 I
Pendimethalin @ 50% of the Recommended Dose	0	3.0000 FG	3.0000 FG	3.667 GH	3.667 FG	4.0000 FGH	4.0000 HIJ	10.667 FG	10.667 FG
	1	2.6667 G	2.6667 G	2.667 HI	2.667 GHI	2.6667 HIJ	2.6667 JKL	8.000 H	8.000 H
	2	1.3333 H	1.3333 HI	1.667 IJ	1.667 IJ	2.0000 J	2.0000 L	5.000 I	5.000 I
Metolachlor @ Recommended Dose	0	5.3333 CD	5.0000 DE	5.000 EF	5.000 DE	8.0000 AB	7.6667 ABC	18.333 D	17.667 C
Metolachlor @ 75% of the Recommended Dose	0	6.3333 BC	6.3333 BC	5.667 CDE	5.667 BCD	9.0000 A	9.0000 A	21.000 BC	21.000 B
	1	5.6667 CD	5.3333 CD	5.333 DEF	5.000 DE	7.6667 ABC	7.0000 CDE	18.333 D	17.333 C
	2	5.0000 DE	5.0000 DE	5.000 EF	5.000 DE	7.3333 BC	7.6667 ABC	17.667 D	17.667 C
Metolachlor @ 50% of the Recommended Dose	0	6.3333 BC	6.3333 BC	6.333 BCD	6.333 BC	9.0000 A	9.0000 A	21.667 B	21.667 B
	1	6.3333 BC	6.3333 BC	6.333 BCD	6.333 BC	9.0000 A	9.0000 A	21.667 B	21.667 B
	2	5.0000 DE	4.6667 DE	5.667 CDE	5.333 CDE	8.0000 AB	8.0000 ABC	18.667 CD	18.000 C
Acetochlor @ Recommended Dose	0	3.0000 FG	2.6667 G	3.667 GH	3.000 GH	4.0000 FGH	3.6667 IJK	10.333 FGH	9.333 GH
Acetochlor @ 75% of the Recommended Dose	0	4.0000 EF	4.0000 EF	4.333 FG	4.333 EF	5.3333 DEF	5.3333 FGH	13.667 E	13.667 DE
	1	3.0000 FG	3.0000 FG	3.667 GH	3.667 FG	4.0000 FGH	4.000 HIJ	10.667 FG	10.667 FG
	2	2.6667 G	2.3333 GH	3.667 GH	3.000 GH	6.3333 CD	6.0000 DEF	12.333 EF	11.333 EFG
Acetochlor @ 50% of the Recommended Dose	0	4.0000 EF	4.0000 EF	5.333 DEF	5.333 CDE	5.3333 DEF	5.3333 FGH	14.667 E	14.667 D
	1	3.0000 FG	3.0000 FG	3.667 GH	3.667 FG	5.6667 DE	5.6667 EFG	12.333 EF	12.333 DEF
	2	2.6667 G	2.6667 G	3.667 GH	3.333 FG	4.3333 EFG	4.3333 GHI	10.333 FGH	10.333 FGH

Table 5. Weed density at 120 DAS as affected by *S. bicolor* L. water extracts tank mixed with reduced herbicide doses.

Treatments	PAE Conc.	*A. fatua* L.		*P. minor* Retz.		Others		Total	
		2017	2018	2017	2018	2017	2018	2017	2018
Weedy check	0	9.0000 A	8.667 A	10.333 A	10.000 A	7.3333 AB	7.000 A	26.667 A	25.667 A
PAE	1	7.3333 B	7.000 B	7.000 B	6.667 B	8.6667 A	8.000 A	23.000 B	21.667 B
	2	7.0000 B	7.000 B	6.667 BC	6.667 B	7.6667 AB	7.667 A	21.333 BC	21.333 B
Pendimethalin @ Recommended Dose	0	1.0000 H	1.000 I	1.333 J	1.333 J	2.000 F	2.000 E	4.333 K	4.333 J
Pendimethalin @ 75% of the Recommended Dose	0	2.6667 G	2.333 GH	3.333 GH	3.000 GH	3.3333 DEF	3.333 CDE	9.333 HIJ	8.667 GHI
	1	1.3333 H	1.333 HI	2.000 IJ	2.000 HIJ	4.3333 CD	4.333 BC	7.667 J	7.667 I
	2	1.0000 H	1.000 I	1.667 IJ	1.667 IJ	2.0000 F	2.000 E	4.6667 K	4.667 J
Pendimethalin @ 50% of the Recommended Dose	0	3.0000 FG	3.000 FG	3.667 GH	3.667 FG	4.0000 CDE	4.000 BCD	10.667 H	10.667 FG
	1	2.6667 G	2.667 G	2.667 HI	2.667 GHI	2.6667 EF	2.667 DE	8.000 IJ	8.000 HI
	2	1.3333 H	1.333 HI	1.667 IJ	1.667 IJ	2.0000 F	2.000 E	5.000 K	5.000 J
Metolachlor @ Recommended Dose	0	5.3333 CD	5.000 DE	5.000 EF	5.000 DE	7.3333 AB	7.000 A	17.667 E	17.000 C
Metolachlor @ 75% of the Recommended Dose	0	6.3333 BC	6.333 BC	5.667 CDE	5.667 BCD	8..3333 AB	8.333 A	20.333 CD	20.333 B
	1	5.6667 CD	5.333 CD	5.333 DEF	5.000 DE	7.3333 AB	7.000 A	18.333 DE	17.333 C
	2	5.0000 DE	5.000 DE	5.000 EF	5.000 DE	7.0000 B	7.000 A	17.000 E	19.000 DE
Metolachlor @ 50% of the Recommended Dose	0	6.3333 BC	6.333 BC	6.333 BCD	6.333 BC	8..3333 AB	8.333 A	21.000 BC	21.000 B
	1	6.3333 BC	6.333 BC	6.333 BCD	6.333 BC	8..3333 AB	8.333 A	21.000 BC	21.000 B
	2	5.0000 DE	4.667 DE	5.667 CDE	5.333 CDE	7.0000 B	7.000 A	17.667 E	17.000 C
Acetochlor @ Recommended Dose	0	3.0000 FG	2.667 G	3.333 GH	3.000 GH	4.0000 CDE	3.667 BCD	10.333 HI	9.333 FGHI
Acetochlor @ 75% of the Recommended Dose	0	4.0000 EF	4.000 EF	4.333 FG	4.333 EF	5.0000 C	5.000 B	13.333 FG	13.333 DE
	1	3.0000 FG	3.000 FG	3.667 GH	3.667 FG	5.0000 C	4.000 BCD	10.667 H	10.667 FG
	2	2.6667 G	2.333 GH	3.333 GH	3.000 GH	4.6667 CD	5.000 B	10.667 H	10.333 FGH
Acetochlor @ 50% of the Recommended Dose	0	4.0000 EF	4.000 EF	5.333 DEF	5.333 CDE	5.0000 C	5.000 B	14.333 F	14.333 D
	1	3.0000 FG	3.000 FG	3.667 GH	3.667 FG	5.0000 C	5.000 B	11.667 GH	11.667 EF
	2	2.6667 G	2.667 G	3.333 GH	3.333 FG	4.000 CDE	4.000 BCD	10.000 HIJ	10.000 FGHI

Table 6. Weed Dry Biomes as affected by *S. bicolor* L. water extracts tank mixed with reduced herbicide doses.

Treatments	PAE Conc.	*A. fatua* L.		*P. minor* Retz.		Others		Total	
		2017	2018	2017	2018	2017	2018	2017	2018
Weedy check	0	18.216 A	15.947 A	20.505 A	18.071 A	66.684 A	58.598 A	105.40 A	92.616 A
PAE	1	13.083 B	11.353 BC	12.243 BC	10.619 BC	47.892 B	43.689 B	73.22 B	65.661 BC
	2	11.368 BCD	10.335 BCD	10.614 CDE	9.667 C	41.615 BCD	37.588 BC	63.60 BCD	57.589 BCD
Pendimethalin @ Recommended Dose	0	2.024 J	1.840 K	2.646 K	2.410 L	7.409 J	6.692 K	12.08 K	10.942 L
Pendimethalin @ 75% of the Recommended Dose	0	4.331 GHIJ	3.445 HIJK	5.838 HI	4.350 HIJ	15.853 GHIJ	12.529 HIJK	25.49 HIJ	20.324 JKL
	1	2.699 IJ	2.453 JK	3.969 IJK	3.614 JKL	9.879 IJ	8.923 JK	16.55 IJK	14.991 KL
	2	2.040 J	1.855 K	3.333 JK	3.036 KL	7.468 J	6.745 K	12.84 JK	11.635 L
Pendimethalin @ 50% of the Recommended Dose	0	4.872 GHI	4.429 GHIJ	5.307 HIJ	5.317 HIJ	17.835 GHI	16.109 GHIJ	28.54 HI	25.855 HIJK
	1	3.264 HIJ	2.967 IJK	3.200 K	2.914 KL	11.949 HIJ	10.792 IJK	18.41 IJK	16.674 KL
	2	2.053 J	1.867 K	2.549 K	2.321 L	7.517 J	6.789 K	12.12 K	10.977 L
Metolachlor @ Recommended Dose	0	10.795 BCD	9.200 CDE	9.922 DE	9.036 CDE	39.516 BCD	33.461 CD	60.23 CDE	51.697 DEF
Metolachlor @ 75% of the Recommended Dose	0	12.819 BC	11.653 B	11.244 BCD	10.240 BC	46.925 BD	42.384 B	70.99 BC	64.278 BC
	1	11.469 BCD	9.813 BCD	10.583 CDE	9.036 CDE	41.986 BCD	35.692 BC	64.04 BCD	54.541 CDE
	2	10.120 DE	9.200 CDE	9.922 DE	9.036 CDE	37.046 DE	33.461 CD	57.09 DEF	51.697 DEF
Metolachlor @ 50% of the Recommended Dose	0	13.047 B	11.861 B	12.803 B	11.660 B	47.760 B	43.138 B	73.61 B	66.659 B
	1	13.047 B	11.861 B	12.803 B	11.660 B	47.670 B	43.138 B	73.61 B	66.659 B
	2	10.400 CDE	8.824 DE	11.556 BCD	9.905 BC	38.071 CDE	32.095 CDE	60.03 CDE	50.824 DEF
Acetochlor @ Recommended Dose	0	8.070 EF	6.521 FG	8.824 EF	7.232 EFG	29.542 EF	23.718 EFG	46.44 FG	37.472 GH
Acetochlor @ 75% of the Recommended Dose	0	8.096 EF	7.360 EF	8.599 EFG	7.831 DEF	29.637 EF	26.769 DEF	46.33 FG	41.960 FG
	1	6.072 FG	5.520 FGH	7.276 FGH	6.626 FGH	22.228 FG	20.077 FGH	35.58 GH	32.223 GHI
	2	5.397 GH	4.293 GHIJ	6.614 GH	5.421 GHIJ	19.758 GH	15.615 GHIJ	31.77 H	25.330 IJK
Acetochlor @ 50% of the Recommended Dose	0	8.096 EF	7.360 EF	10.583 CDE	9.638 CD	29.637 EF	26.769 DEF	48.32 EFG	43.767 EFG
	1	6.138 FG	5.580 FGH	7.348 FGH	6.692 FGH	22.469 FG	20.295 FGH	35.96 GH	32.567 GHI
	2	5.397 GH	4.907 GHI	6.614 GH	6.024 FGHI	19.758 GH	17.846 GHI	31.77 H	28.776 HIJ

The premium indicators of the efficacy of any herbicide (synthetic or natural) is the ability to control the weed density along with reducing weed fresh and dry biomass at different time intervals. Weed density at 30 and 60 days after sowing, is very important to inspect as it is the critical time of weed-crop competition (Khaliq & Matloob, 2011) where weeds compete with crop plants for water, nutrients and sunlight. Weed fresh and dry weight is the display of overall growth rate and nutrient uptake by weed plants. From most of the results gathered at 30 DAS, 60 DAS and 120 DAS (at the time of harvesting), for the years 2017 and 2018, it is clear that Pendimethalin at its label dose is the best herbicide against narrow leaf and other weeds in crop soybean (*G. max* L.) to minimize the number of weed plants along with reducing their dry weight. But at the same time, its reduced dosage i.e., 75% and 50% produced statistically same results when tank mixed with 2% of plant aqueous extracts of *S. bicolor* L. These results are similar to those of Jabran *et al*., (2010) who mixed alleopathic crop water extracts from *Sorghum bicolor* L., *Helianthus annuus* L., *Brassica campestris* L. and *Oryza sativa* L. with lower doses of Pendimethalin in the crop "*Brassica napus* L." and found significantly inhibited horse purslane (*Trianthema portulacastrum* L.), purple nuts edge (*Cyperus rotundus* L.), lambs quarters (*Chenopodium album* L.) and swine cress (*Cronopus didymus* L.) The results are also coherent to those of Cheema *et al.*, (2005) where the scientist combined the plant aqueous extract from *S. bicolor* L. with 50% of the label/ endorsed doses of Pendimethalin, via mixing in sprayer tank, used as pre-emergent herbicide and found significant weed control in cotton which was statistically equal to their label doses. These findings are coherent with those of Rehman *et al.*, (2010) who tank mixed allelopathic crop water extracts of sorghum, sunflower and rice with reduced rates (1/2&1/3 of recommended rate) of three pre-emergence herbicides and revealed that combined application of allelopathic water extracts with 1/2 of the label/ endorsed dose of pre-emergence herbicides reduced the weed density and dry weight at significant level.

Conclusion

Keeping the environmental hazards of herbicides in view, it is concluded and recommended that plant aqueous extract worth concentration 2% of *S. bicolor* L. should be tank mixed @ 18 l/ha with half of the label/ endorsed dosage of Pendimethaline to obtain maximum yield of *G. max* L. and to save the environment.

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