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INTEGRATED CONTROL OF JUNGLE RICE IN HYBRID MAIZE THROUGH SORGHUM ALLELOPATHY

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Abstract

Sorghum allelopathy has long been utilized as a bio-control technique for unwanted flora in economic crops and circumvent undue dependency on chemical weed control. An experiment was conducted during kharif season of 2017 to examine the integration of sorghum water extract (SWE), sorghum mulch (SM) and half dose of post emergence herbicide mesotrione + atrazine (MA_{50}) for controlling jungle rice in hybrid maize (HC-8080). The treatments included; T_0: Check, T_1: Full dose (1250 ml ha^{-1}) of mesotrione + atrazine (MA_{100}), T_2: Half dose (625 ml ha^{-1}) of mesotrione + atrazine (MA_{50}), T_3: SWE @ 15 L ha^{-1} + 625 ml ha^{-1} (1/2 dose) of mesotrione + atrazine (MA_{50}), T_4: SM @ 8 t ha^{-1} + 625 ml ha^{-1} (1/2 dose) of mesotrione + atrazine (MA_{50}), T_5: SM @ 8 t ha^{-1} + SWE @ 15 L ha^{-1} and T_6: SM @ 8 t ha^{-1} + SWE @ 15 L ha^{-1} + 625 ml ha^{-1} (1/2 dose) of mesotrione + atrazine (MA_{50}). The results of the study unveiled that combination of SWE + SM + MA_{50} reduced the fresh weed biomass by 84.82% and dry weed biomass by 87.37% and increased all the agronomic parameters eventually registering maximum kernel yield (4.80 t ha^{-1}). Overall, the response of this treatment was similar as that of standard herbicide dose. Therefore it was concluded that standard dose of mesotrione + atrazine herbicide can be reduced to half with the integration of sorghum water extract and sorghum mulch which will ensure efficient and eco-friendly control of jungle rice.

Key words: Sorghum aqueous extracts, Sorghum mulch, Half dose of herbicide, *Echinochloa. colona* control, Hybrid maize.

Introduction

Maize (*Zea mays* L.) is a prominent cereal crop which completes its growth in short period of time and provides ample nutrition to human beings and livestock (Afzal *et al*., 2014). One of the biggest threats to maize production is high infestation of weeds which can reduce its potential yield by 24-47% (Cheema *et al*., 2002).

Among other weed species, *Echinochloa colona* (L.) Link, also known as jungle rice, is a very serious summer grassweed which interferes with the normal life cycle of several crops, including maize (Rao *et al*., 2007). It may act as a host for several insects, pests and diseases and is among the dominant weed species in many crops, particularly rice (Ramachandra *et al*., 2012). It thrives best under varying photoperiodic conditions due to its short dormancy period, profound seed germination and fast growing nature which makes it a more cumbersome weed in a variety of environmental conditions (Chauhan & Johnson, 2010). Chemical weed control via herbicides may be an efficient weed control measure for controlling weeds (Nazarko *et al*., 2003), however, frequent use of herbicides may deteriorate the environmental conditions altogether (Judith *et al*., 2001) and may also cause herbicide resistance in certain weed species (Heap, 2008). *E. colona* has been reported to have developed resistance against many selective and non-selective herbicides (Zand *et al*., 2010). Since the evidencial confirmation of allelopathy as a natural tool for suppressing weeds, much attention has been paid on plant allelopathy research (Khanh *et al*., 2018). Throughout the globe, researchers are attempting to devise appropriate alternative weed control strategies which are efficient, eco-friendly and inexpensive as well, in order to avoid heavy reliance on herbicides (Jabran *et al*., 2008).

For this purpose, allelopathy can be a possible alternative technique which can ensure sustainable weed management (Hussain *et al*., 2007). Sorghum (*Sorghum bicolor* (L.) Moench) is an alleopathic plant which can inhibit the growth of neighboring plants (Cheema *et al*., 2004) due to the presence of cyanogenic glucosides and other potential allelochemicals in it (Cheema *et al*., 2007).

Cheema & Ahmad (1992) reported 55-94% reduction in the population density of *Cyperus rotundus* due to soil incorporated sorghum residues. Khaliq *et al*., (2002) combined pendimethalin and S-metachlor with sorghum concentrated extracts and reported 75% and 78% reduction in dry weed biomass, respectively. Similarly, Cheema *et al*. (2005) revealed that mixing of sorghum aqueous extracts @ 12 L ha^{-1} with 75% and 50% doses of two pre-emergence herbicides reduced the dry weight of weeds by 76 to 77%.

The present study was planned to examine the combined efficacy of sorghum mulch, sorghum water extracts and half dose of mesotrione + atrazine herbicide for the control of junglr rice (*E. colona*).

Materials and Methods

The experiment was undertaken at the student's farm of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyberpakhtun Khwa, Pakistan during summer season of 2017 in order to examine the combined efficacy of sorghum aqueous extracts and sorghum mulch with half dose of a post-emergence herbicide; mesotrione + atrazine against jungle rice (*Echinochloa colona* (L.) Link) in maize hybrid HC-8080. Field was ploughed twice with a cultivator and disc harrow followed by rotavator in order to prepare proper seedbed for sowing. The experiment was laid out in a randomized complete block design (RCBD) comprising four replications. The net plot size was 12 m^2. The crop was planted on four ridges 60cm apart in each plot, while plants were kept at 25cm distance from each other. 25 kg ha^{-1} seed was sown with a manually operated seed drill. Recommended doses of N, P and K (120: 90: 60 kg ha^{-1}) were applied through urea, single super phosphate (SSP) and sulfate of potash (SoP). Nitrogen was distributed in two splits and applied once during sowing while the rest with first irrigation, whereas phosphorus and potash sources were applied completely during sowing.

Sorghum was planted prior to Maize. It was harvested at maturity, sundried, chaffed with a fodder cutter and then the material was doused in distilled water under room temperature for 48 hours in the ratio 1:10 (w/v), as described by (Cheema & Khaliq, 2000).

The mulch material obtained was surface spread in the allocated plots according to the treatments.

The treatments included; T_0: Check, T_1: Full dose (1250 ml ha^{-1}) of mesotrione + atrazine (MA_{100}), T_2: Half dose (625 ml ha^{-1}) of mesotrione + atrazine (MA_{50}), T_3: SWE @ 15 L ha^{-1} + 625 ml ha^{-1} (1/2 dose) of mesotrione + atrazine (MA_{50}), T_4: SM @ 8 t ha^{-1} + 625 ml ha^{-1} (1/2 dose) of mesotrione + atrazine (MA_{50}), T_5: SM @ 8 t ha^{-1} + SWE @ 15 L ha^{-1} and T_6: SM @ 8 t ha^{-1} + SWE @ 15 L ha^{-1} + 625 ml ha^{-1} (1/2 dose) of mesotrione + atrazine (MA_{50}).

Weed density was calculated by counting the number of jungle rice plants in a square meter area. The plants were uprooted and their fresh weight was obtained using an electronic balance. These plants were then oven dried at 70ºC for 48 hours and their dry weight was recorded.

Ten maize plants were chosen randomly from each plot for measuring plant height (cm) with a meter rod, obtaining number of cobs ($plant^{-1}$), number of rows (cob^{-1}), number of grains (cob^{-1}), length of cob (cm) and cob height (cm). For 1000-grains weight, 1000 kernels were counted in each plot and weighed. Grain yield and biological yield was recorded in $1m^2$ area and then the result was converted to kg ha^{-1} (grain or biological yield m^{-2} x10000). Harvest index was worked out as;

$$\frac{Grain\ yield}{Biological\ yield}\ X\ 100$$

The data were statistically analyzed through Analysis of Variance Technique (Steel *et al.*, 1997), while the means were compared via LSD test using Statistix 8.1 software.

Results

Fresh and dry weed weight (g): It is vivid from the data (Table 1) that fresh and dry weight of *E. colona* got significantly reduced due to the application of SWE, SM and MA_{50}.

However, maximum reduction in fresh weight (84.82%) and dry weight (87.37%) was noticed with the integrated application of SWE @ 15 L ha^{-1}, SM @ 8 t ha^{-1} and MA_{50}. This treatment proved more efficient method of controlling weed growth as compared to the standard dose of herbicide which caused a reduction of 81.83% and 87.55% in the fresh and dry weight of weed, respectively. Combination of SWE with half dose of herbicide and that of SM with the same dose of herbicide performed better causing reduction in fresh weight by 75.50% and 71.10% and dry weight by 72.44% and 67.38%, respectively over half dose of herbicide alone which reduced fresh weight by 62.29% and dry weight by 61.04%. Likewise, the SWE + SM lowered the fresh and dry weight by 63.72% and 65.71% showing a suppressing effect similar to that of MA_{50}. SWE, SM and MA_{50} matched the full dose of herbicide in restricting the weed growth which confirms the presence of allelochemicals in them and suggests that the standard dose of this herbicide may be reduced to half if integrated with SWE and SM.

All the included treatments for controlling weeds contributed positively towards various agronomic traits in maize due to varying efficacy in controlling the weed, however the most significant contribution resulted through the treatment SWE + SM + MA_{50} (Table 2).

Plant height (cm): Maximum and statistically similar plant height (189.5cm and 188.05cm, respectively) was achieved with MA_{100} and integration of SWE, SM and MA_{50}. Similarly SWE + MA_{50} and combination of mulch and extract produced 186.07cm and 183.75cm tall plants, respectively which were also found statistically non-significant with each other. Whereas, integration of sorghum mulch and 50% dose of the herbicide produced the next taller plants of 180.82cm, while the least height (165.03cm) was observed in the plants of weedy check plots.

Table 1. Efficacy of various weed controlling methods in reducing fresh and dry weight of jungle rice.

Treatments	*E. colona* density (m^{-2})	Fresh weight (g) before spray	Fresh weight (g) after spray	Dry weight (g) before spray	Dry weight (g) after spray
Weedy check	11.50 ab	44.11^{NS}	----	33.01 a	----
MA_{100}	12.75 ab	44.02	7.77 bc (-81.83)	22.22 b	2.62 c (-87.55)
MA_{50}	11.25 ab	43.61	16.58 a (-62.29)	22.52 b	8.83 a (-61.04)
SWE @ 15 L ha^{-1} + MA_{50}	14.00 a	39.41	9.59 bc (-75.50)	20.05 b	5.51 b (-72.44)
SM @ 8 t ha^{-1} + MA_{50}	10.00 b	32.19	9.12 bc (-71.10)	18.45 b	5.94 b (-67.38)
SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1}	10.50 ab	33.99	11.89 b (-63.72)	17.14 b	6.03 b (-65.71)
SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1} + MA_{50}	11.50 ab	46.09	6.63 c (-84.82)	23.08 b	2.78 c (-87.37)
$LSD_{0.05}$	**3.58**	**----**	**3.59**	**9.76**	**2.03**

Similar letter(s) against the mean values in a column represent non-significant differences at 5% level of probability

NS = Non-significant

MA_{50} = Half dose of Mesotrione + Atrazine

MA_{100} = Full dose of Mesotrione + Atrazine

Note: The values in parenthesis represent percent reduction

Number of cobs (plant^{-1}): All the studied treatments significantly increased the number of cobs (plant^{-1}) as compared to control where average number of cobs (plant^{-1}) was 1.00. SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1} + MA_{50} and SWE @ 15 L ha^{-1} + MA_{50} produced maximum number of cobs on average i.e. 1.75 each. SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1} gave the next higher cobs amounting 1.50 on average basis. This was followed by statistically similar values for number of cobs (1.25 each for MA_{100}, MA_{50} and SM @ 8 t ha^{-1} + MA_{50} treatments. Afzal *et al*., (2014) also reported enhancement in number of cobs (plant^{-1}) with sorghum extracts used in different combinations than the control and other treatments included in the study.

Number of rows (cob^{-1}): Statistically similar higher values (17.00, 16.75 and 15.50, respectively) for number of rows (cob^{-1}) were recorded against full dose of herbicide, integrated application of SWE, SM and MA_{50} and half dose of herbicide alone. On the other hand SWE + MA_{50}, SM + MA_{50} and SWE +SM followed the same results by producing 14.75, 14.50 and 14.00 rows (cob^{-1}), respectively. Weedy check produced 11.75 grain rows which were the least among the treatments.

Number of grains (cob^{-1}): Maximum number of kernels (cob^{-1}) amounting 401.00 and 391.25 were also produced by herbicide full dose and SWE + SM + MA_{50}. Sorghum water extract + MA_{50} and Sorghum water extract + sorghum mulch were next in line setting 380.25 and 376.50 grains (cob^{-1}). These were followed by MA_{50} alone and sorghum mulch + MA_{50} treatments which respectively produced 371.75 and 367.50 grains (cob^{-1}). Least value (267.00) in this regard was found in weedy check treatment.

Cob length (cm): Significantly long cobs of 19.92cm, 19.27cm and 19.17cm, respectively were recorded with MA_{100}, SWE + SM + MA_{50} and SWE + MA_{50}. Half dose of herbicide produced next longer cobs of 18.62cm. This was followed by 17.82cm and 17.37cm long cobs produced by SWE + SM and SWE + MA_{50}, respectively. In contrast, shortest cobs (11.45cm) were recorded in weedy check (control).

Data for cob height, 1000-kernel weight, kernel yield, biological yield and harvest index are presented in Table 3. The data elucidated significant differences among the mean values of the parameters due to applied treatments.

Cob height (cm): Maximum cob height of 92.15cm and 90.42cm was obtained in SWE +SM +MA_{50}. SWE + MA_{50} treatment gave next higher cobs of 85.97cm. This was followed by sorghum water extract + sorghum mulch, MA_{50} alone and sorghum mulch + MA_{50} giving 82.62cm, 79.70cm and 76.82cm cob height, respectively. Whereas, the lowest cob height (62.02cm) was noted in weedy check.

1000-grains weight (g): Heaviest thousand kernels were respectively produced by SWE + SM + MA_{50} and MA_{100} which weighed 237.43g and 234.18g. Rest of the treatments did not significantly alter the weight of thousand grains, nevertheless all these treatments had heavier grains than the weedy check control whose grains weighed 168.68g.

Grain yield (t ha^{-1}): Grain yield, following the same trend, was recorded maximum in the integrated treatment of SWE + SM +MA_{50} and MA_{100} treatment which turned out to be 4.80 t ha^{-1} and 4.75 t ha^{-1} in the order given. Sorghum water extract + MA_{50} produced 4.51 t ha^{-1}, while SWA + SM produced 4.36 t ha^{-1} kernel yield and stood next in line. Significantly similar yield of 4.32 and 4.28 t ha^{-1} was obtained in sorghum mulch + MA_{50} and MA_{50} alone treatments in the respective manner. Lowest grain yield (2.88 t ha^{-1}) was produced by weedy check treatment.

Biological yield (t ha^{-1}): Biological yield was found maximum (13.43 t ha^{-1}) in the plots treated with sorghum mulch accompanied by half dose of herbicide. This was statistically at par with SWE + SM, MA_{50}, SWE + MA_{50}, and SWE + SM + MA_{50}, which respectively produced 12.89, 12.31, 12.28 and 12.20 t ha^{-1} biological yield. Similarly, 11.96 t ha^{-1} biological yield was produced by MA_{100} which was lesser than all other treatments except control (9.87 t ha^{-1}).

Harvest Index: Standard dose of herbicide, SWE + SM + MA_{50} and SWE + MA_{50} gave the maximum and statistically similar harvest index of 39.79%, 39.36% and 36.78%, respectively. Next to these was the harvest index of MA_{50} treatment amounting 34.82%. This was followed by statistically at par values of 34.27% and 32.18% for harvest index recorded against SWE + SM and SM + MA_{50}, in the order followed. Weedy check had the lowest harvest index of 29.41%.

Integrated treatments suppressed the weed growth and thereby kept the resources, like nutrients etc, for crop use. This enabled more nutrients to transfer from source to the sink which ultimately increased the harvest index (%).

Table 2. Effect of various treatments (through reducing weed growth) on plant height (cm), cobs (plant^{-1}), rows (cob^{-1}), grains (cob^{-1}) and cob length (cm) in hybrid maize.

Treatments	Plant height (cm)	Number of cobs (plant^{-1})	Number of rows (cob^{-1})	Number of grains (cob^{-1})	Cob length (cm)
Weedy check	165.03 d	1.00 b	11.75 c	267.00 d	11.45 d
MA_{100}	189.5 a	1.25 ab	17.00 a	401.00 a	19.92 a
MA_{50}	180.5 c	1.25 ab	15.50 ab	371.75 c	18.62 abc
SWE @ 15 L ha^{-1} + MA_{50}	186.07 abc	1.75 a	14.75 b	380.25 bc	19.17 ab
SM @ 8 t ha^{-1} + MA_{50}	180.82 bc	1.25 ab	14.50 b	367.50 c	17.37 c
SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1}	183.75 abc	1.50 ab	14.00 b	376.50 bc	17.82 bc
SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1} + MA_{50}	188.05 ab	1.75 a	16.75 a	391.25 ab	19.87 a
$LSD_{0.05}$	**7.52**	**0.73**	**1.86**	**15.07**	**1.43**

Similar letter(s) against the mean values in a column represent non-significant differences at 5% level of probability

MA_{50} = Half dose of Mesotrione + Atrazine

MA_{100} = Full dose of Mesotrione + Atrazine

Table 3.Effect of various treatments (through reducing weed growth) cob height (cm), 1000-grains weight (g), grain yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) in hybrid maize.

Treatments	Cob height (cm)	1000-grains weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Weedy check	62.02 e	168.68 c	2.88 d	9.87 c	29.41 d
MA_{100}	90.42 a	234.18 a	4.75 a	11.96 b	39.79 a
MA_{50}	79.70 cd	215.93 b	4.28 c	12.31 ab	34.82 bc
SWE @ 15 L ha^{-1} + MA_{50}	85.97 b	221.95 b	4.51 b	12.28 ab	36.78 ab
SM @ 8 t ha^{-1} + MA_{50}	76.82 d	216.73 b	4.32 c	13.43 a	32.18 cd
SWE @ 15 L ha^{-1} + Mulch @ 8 t ha^{-1}	82.62 bc	218.43 b	4.36 bc	12.89 ab	34.27 cd
SWE @ 15 L ha^{-1} + SM @ 8 t ha^{-1} + MA_{50}	92.15 a	237.43 a	4.80 a	12.20 ab	39.36 a
$LSD_{0.05}$	**4.17**	**11.25**	**0.16**	**1.46**	**4.05**

Similar letter(s) against the mean values in a column represent significance at 5% level of probability

MA_{50} = Half dose of Mesotrione + Atrazine

MA_{100} = Full dose of Mesotrione + Atrazine

Discussion

The direct or indirect use of allelochemicals to manage weeds can be an alternative strategy to herbicides (Dayan *et al*., 2000; Duke *et al*., 2002). Most commonly existing allelochemicals as secondary metabolites in vegetative parts of crop plants include tannins, steroids, terpenoids, phenolics, quinines, coumarins, alkaloids and flavonoids (Won *et al*., 2013). One of the major area of weed research in Pakistan is the use of allelochemicals in combination with reduced doses of herbicides.

In our study, the integrated application of SWE @ 15 L ha^{-1} SM @ 8 t ha^{-1} and ½ dose of Mesotrione + Atrazine herbicide showed maximum reduction in the fresh and dry weight of jungle rice giving statistically at par results with label dose of herbicide. It was probably due to synergistic effect of extract and mulch when combined with the herbicide. Cheema *et al*., (2005) used sorghum aqueous extract @ 12 L ha^{-1} in combination with 1/3 and 1/2 dose of ethoxysulfuron and reported up to 77% reduction in dry weight of weeds in rice crop. Elahi *et al*., (2011) reported that sunflower and rice extracts along with1/3 dose of phenoxaprop-p-ethyl caused equal reduction in narrow leaf weed population and its dry matter as did the label dose. Iqbal *et al*., (2014) depicted 86.89% reduction in the fresh weight of horse pursulane when they applied sorghum and sunflower water extracts (20 L ha^{-1} each) with 1/3 dose of paraquat. Alsaadawi *et al*., (2017) indicated 62-78% reduction in the weed dry biomass over control when they applied sorghum mulch @ 10 t ha^{-1}. Their results are in a strong agreement with our present findings.

Combination of sorghum allelopathic materials (SWE and SM) with the test herbicide also proved best for enhancing yield as well as yield attributes of maize which is indicative of the presence of certain allelochemicals in sorghum water extracts as well as sorghum residues which rendered inhibitory effect on jungle rice, thereby increasing the studied parameters in maize. These results suggest that integrated weed control strategy using sorghum allelopathy may be a possible alternative to reduce herbicide dose by at least half. Latifi & Jamshidi (2011) utilized sorghum water extracts with half dose of foramsulfuron and reported statistically similar results for plant height (225.33cm), ear length (18.00cm), seeds per ear (420.65) and 1000-kernel weight (225.36g) as that of full dose of foramsulfuron which showed 231.67cm, 20.01cm, 428.65 and 232.99g for these parameters respectively. Similarly, Jabran *et al*., (2008) indicated that pendimethalin at its full dose was not as efficient in controlling purple nutsedge as was its mixture with crop water extracts. Alsaadawi *et al*., (2017) reported increase in 100-grain weight of faba bean over the control due to surface spreading of sorghum mulch at 5 and 10 t ha^{-1}. Cheema *et al.,* (1997) observed an inhibition of up to 40% in the dry weight of weeds with single spray of sorghum aqueous leachates which in turn produced 14% more grain yield in wheat. Jabran *et al*., (2008) executed integrated weed management and unveiled that integration of sorghum and sunflower water extracts with half dose of pendimethalin increased the biological yield, grain yield and harvest index and proved better than any other treatment included in the study. Likewise, Jabran *et al.,* (2010) recorded maximum 1000-grain weight in canola when they combined sorghum and sunflower water extracts with half dose of pendimathaline. Our results are corroborated by the results indicated by these researchers.

Suppression of weeds and amelioration of crop growth parameters suggests that sorghum exhibited strong allelochemicals which negatively interfered with the life cycle of jungle rice and turned the results in favor of maize crop. According to Arif *et al.,* (2015) several allelochemicals are found in sorghum plant which include sorgoleone, benzoic acid, gallic acid, syringic acid, protocateuic acid, p-hydroxybenzoic acid, vanillic acid, ferulic acid, p-coumaric acid, caffeic acids, m-coumaric acid, p-hydroxybenzaldehyde and dhurrin which play pivotal role in subjugating weed population.

Conclusion

Sorghum water extracts and sorghum herbage both showed encouraging results for controlling jungle rice in this experiment. When combined with half dose of mesotrione + atrazine herbicide, their results were better than sole application of herbicide half dose. Sorghum water extracts, nevertheless, were more effective than sorghum mulch. However combination of all three viz. sorghum water extract, sorghum mulch and half dose of mesotrione + atrazine proved to be more lucrative treatment which improved all the yield parameters including the kernel yield, thereby efficiently controlling weed growth as well. Therefore, it is concluded from the results of this research that integration of sorghum allelopathy may be a possible alternative which could reduce herbicide dependency at least by half and give as much profitable results as would give the standard dose of herbicide.

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