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ALLELOPATHIC PLANT WATER EXTRACTS TANK MIXED WITH REDUCED DOSES OF ATRAZINE EFFICIENTLY CONTROL *TRIANTHEMA PORTULACASTRUM* L. IN *ZEA MAYS* L.

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ABSTRACT

Environmental pollution, development of herbicidal resistance among weeds and health hazards due to non judicious use of herbicides has forced the researchers to make concerted efforts to develop alternate weed control strategies. In that scenario, use of allelopathic plant water extracts with reduced rates of herbicides to control weeds in arable crops has become an attractive option for the researchers. The present study was conducted to investigate the possible effects of allelopathic plant water extracts in combination with reduced doses of atrazine for weed control in maize. Atrazine was applied @ full dose (500 g a.i. ha^{-1}), ½ dose (250 g a.i. ha^{-1}), ⅓ dose (167 g a.i. ha^{-1}) and ¼ dose (125 g a.i. ha^{-1}) alone; reduced doses (½, ⅓ and ¼) of herbicide were applied in combination with 20 L ha^{-1} of allelopathic plant water extracts of sorghum, brassica, sunflower and mulberry; 20 L ha^{-1} of allelopathic plant water extracts of sorghum, brassica, sunflower and mulberry was applied alone; while weedy check was also maintained as control. The four levels of atrazine showed 65-81% suppression of weeds density and weeds dry weight over control (weedy check), while allelopathic plant water extracts showed 70-75% suppression of weeds density and dry weight when used in combination with half and 1/3rd dose of atrazine over control. Nonetheless, 49%, 36% and 31% more grain yield was obtained where full dose (alone) and half and ⅓ dose of atrazine in combination of allelopathic plant water extract were applied, respectively over control. In conclusion, allelopathic plant water extracts can be utilized with reduced doses of herbicide to keep environment healthy and efficient weed control in maize. Formulation of allelopathic water extracts into a handy product would facilitate their use for environment friendly weed management.

Key words: allelopathy, atrazine, herbicide reduction, maize, mulberry, weeds control.

INTRODUCTION

Being the third most important crop and the highest yielding cereal of world, maize has momentous importance for South Asian countries including Pakistan, where rapidly increasing population had already out stripped the available food supplies (Govt. of Pakistan, 2010; Hasan 2008). Average yield of maize in Pakistan is 3.8 t ha^{-1} which is far below than the potential yield; 12 t ha^{-1} (Govt. of Pakistan, 2010). Water paucity, costly farm inputs, poor quality seed, conventional sowing method, low level of farm mechanization and high weed infestation are the major yield limiting factors of maize. Among these, weed infestation is the main cause of low yields in Pakistan and probably reduces yields about 25-30%.

Weeds are the most abundant plant species which not only compete with crop plants for different resources but occasionally interfere with crop growth by releasing toxic substances in the rhizosphere (Rice, 1984; Riaz *et al.,* 2009; Riaz and Javaid, 2009; Farooq *et al.,* 2011a). Apart from direct effects, weeds may also serve as substitute host for insect pests. According to Baloch (1993), grain yield in Pakistan may be increased up to 37% if weeds are properly controlled. Herbicides are very effective in controlling weeds yet certain risks such as environmental pollution and human health are involved in herbicide use. Herbicides proffer sizeable increase in crop productivity through efficient weed control (Santos, 2009). But improper and non-judicious use of herbicide may lead to crop injury, health hazards, soil, and water pollution and in certain cases, target weeds are not controlled because of low doses used by farmers (Farooq *et al.,* 2011b). Environmental pollution, development of herbicidal resistance among weeds and health hazards due to non-judicious use of artificial herbicides has forced the researchers to make concerted efforts to develop alternative weed control options (Jabran *et al.,* 2010a, b). Allelopathy is considered to be one of the possible alternatives for achieving sustainable weed management (Singh *et al.,* 2003; Farooq *et al.,* 2008, 2011b). In that scenario, use of allelopathic plant water extracts with reduced rates of herbicides to control weeds in arable crops has become a well established fact (Jabran *et al.,* 2008). Plants express their allelopathic capability through production of allelochemicals and their exudation into the environment by either of the methods including volatilization, leaching and decomposition (Farooq *et al.,* 2008, 2011b). Photosynthesis inhibition, increase in free radicals, decrease in chlorophyll contents, enzymatic activity inhibition, cell membrane and cell structure disruption are some of the possible mechanisms through which allelochemicals affect the victim plant (Zeng *et al.,* 2001; Li *et al.,* 2001; Zhang *et al.,* 2010).

Allelopathic water extracts and herbicides applied in combination work synergistically that helps to reduce the dose of herbicide (Cheema *et al.,* 2005b; Razzaq *et al.,* 2012). For instance, reduced doses (half & one third of standards) of herbicides like pendimethalin, s-metolachlor, fenoxaprop-*p*-ethyl, clodinafop proprargyl, atrazine, ethoxysulfuron, butachlor, when tank mixed with allelopathic water extracts of crops (sorghum, sunflower, brassica, rice) proffer booming weed control in cotton, maize, brassica, wheat and rice (Cheema *et al.,* 2005, 2005a; Jabran *et al.,* 2008; Mahmood *et al.,* 2009; Razzaq *et al.,* 2010; Farooq *et al.,* 2011b). Likewise, Ahmad *et al.* (2000) reported that foliar spraying of sorghum water extract (sorgaab) reduced the total weed density by 34-57% and total weed biomasses by 13-54% and increased the yield of maize by 33-37%. Khaliq *et al.* (2002) concluded that one third and half dose of herbicide combined with sorgaab and sunfaab (sunflower water extracts) increase the maize grain yield up to 52% and 53%, respectively, while full dose of atrazine increase maize seed yield by 59% over control.

Although a lot of information about the allelopathic potential of sorghum, sunflower and brassica is available, but very little information regarding allelopathic potential of mulberry is present. Nonetheless, combined allelopathic potential of sorghum, sunflower, brassica and mulberry tank mixed with atrazine had never been reported. Therefore, the present study was designed to assess the possible effects of combined allelopathic potential of sorghum, sunflower, brassica and mulberry tank mixed with reduced doses of atrazine on horse purslane (*Trianthema portulacastrum* L.) [the most problematic weed of maize in the area] density, horse purslane dry weight, maize yield and yield components along with net benefits to the farmers.

MATERIALS AND METHODS

Experimental site description: The experimental plot was selected with abundance of weed horse purslane (*Trianthema portulacastrum* L.) at farmer's field at Lutfabad, Multan (71.43^o E, 30.2^o N and 122 meters a.s.l.), Pakistan, during summer 2007. The climate of the region is subtropical and semi-arid. The experimental area was quite uniform and soil analysis was done to assess the soil fertility status.

Experimental details: The experiment was laid out in randomized complete block design (RCBD) with a net plot size of 7 m x 2.8 m and replicated four times. Herbicide (Atrazine) @ full [standard] dose (500 g a.i. ha^{-1}), ½ dose (250 g a.i. ha^{-1}), ⅓ dose (167 g a.i. ha^{-1}) and ¼ dose (125 g a.i. ha^{-1}) was applied alone; reduced doses (½, ⅓ and ¼) of herbicide were applied in combination with 20 L ha^{-1} of allelopathic plant water extracts of sorghum, brassica, sunflower and mulberry; 20 L ha^{-1} of allelopathic plant water extracts of sorghum, brassica, sunflower and mulberry was applied alone; while weedy check was also maintained as control. All the atrazine levels along with its combinations with allelopathic plant water extracts were applied as post emergence 15 days after sowing (DAS) the crop. Maize hybrid (Pioneer-30Y87) was used as experimental material. Maize seed was collected from Pioneer Seeds Pvt. Ltd. Sahiwal with 95% germination and initial seed moisture contents of 9.24%.

Crop Husbandry: Pre-soaking irrigation of 10 cm was applied to create conditions apposite to craft seedbed. When soil reached to feasible moisture level, the seedbed was prepared by cultivating the field twice with tractor mounted cultivator each followed by planking. Maize hybrid (Pioneer 30Y87) was sown on 10th August, 2007 and sowing was done manually by maintaining row to row distance of 70 cm and plant to plant distance of 15 cm by using hand dibbler. All the treatment combinations were sprayed with the help of knapsack sprayer after 15 days of sowing (DAS). Spray volume was determined by calibration. Allelopathic plant water extracts were prepared following the procedures developed by Cheema *et al.* (2002). Fertilizers were applied @ 250, 100 and 100 kg N, P_2O_5 and K_2O ha^{-1}, respectively by using urea, di-ammonium phosphate (DAP) and sulphate of potash (SOP) as source. Nitrogen (1/3rd) along with full dose of potassium and phosphorus were applied at the time of sowing by side dressing. Remaining 2/3rd nitrogen was applied at second irrigation and at tasseling stage of crop in equal splits. First irrigation was applied one week after sowing and subsequent irrigations were adjusted according to the need of the crop. Mature crop was harvested on 5th December, 2007.

Observations recorded: Horse purslane was the major weed in the experimental area. Horse purslane density and dry weight was recorded three times at 30, 45, 60 days after sowing (DAS) from randomly selected two quadrates each of (0.25 m^{-2}) from each experimental plot. Total number of weeds were counted in both quadrates and averaged to record weed density. After that weeds were harvested and then dried in an oven at 78^{o}C for 48 hours to record the dry weight. Height of ten randomly selected plants from each plot were measured from base to top of the plant with measuring tape and averaged to record plant height. Ten cobs were randomly selected;

their length was measured with the help of foot scale and then averaged to record cob length. Grains from ten randomly selected cobs were counted and then averaged to record number of grains per cob. Likewise, number of grains per row was counted from ten randomly selected cobs and then averaged to calculate number of grains per row. Three random samples of 1000 grains from each seed lot were counted, weighed on an electronic weighing balance and averaged to record 1000-grain weight. Ten randomly selected cobs were sun dried, threshed and grain pith ratio was calculated according to this formula:

Grain/pith ratio (%) = Grain weight/Pith weight ×100

All plants from each plot were harvested, tied into bundles, sun dried for 4 days and weighed with the help of spring balance to record biological yield. Then biological yield was converted into tons ha^{-1}. After that, all cobs from all plants were separated, threshed with the help of mechanical sheller and grain yield was recorded on plot basis, converted into tons ha^{-1} by unitary method and then adjusted at 10% moisture contents. Harvest index was calculated by using the following formula:

Harvest index (%) = Grain yield/Biological yield × 100

Statistical Analysis: The collected data were statistically analyzed by using Fisher's analysis of variance technique and LSD test at 5% probability was used to compare the differences among treatments' means (Steel *et al.,* 1997).

Economic analysis: A cost–benefit analysis was carried out to determine the economic feasibility of atrazine application alone at recommended and reduced levels along with its reduced levels in combination with allelopathic plant water extracts of sorghum, sunflower, brassica and mulberry to control weeds. The amount of atrazine used in the study was 500, 250, 167 and 125 g ha^{-1} a.i., at its recommended, half, one third and one fourth rate, respectively. The cost of atrazine per 500 g a.i. and 20 L plant water extracts was PKR 1000 and 200 (1 PKR = 0.016 US$), respectively. The production costs included field preparation, seed, sowing, fertilizing, crop protection measures and harvesting. The production income was estimated using the prevailing average market price in Pakistan, PKR 25 kg^{-1}.

RESULTS AND DISCUSSION

Analyzed data (Table 2) show that herbicide alone and in combination with allelopathic plant water extracts had significant effect on density of horse purslane (*Trianthema portulacastrum* L.) at 30 and 60 days after sowing (DAS), while non-significant effects was noted at 45 DAS. At 30 DAS, maximum reduction in horse purslane density was recorded where full dose of atrazine (500 g a.i. ha^{-1}) was applied but it was statistically at par with all other treatments except control (weedy check) that resulted in maximum horse purslane density (Table 2). While at 60 DAS, the maximum reduction in horse purslane density was found where full dose of atrazine (500 g a.i. ha^{-1}) was applied but statistically it was at par with half dose of atrazine alone and reduced doses of atrazine ½, ⅓, and ¼ in combination with allelopathic plant water extracts (Table 2). Likewise, herbicide alone and in combination with allelopathic plant water extracts had significant effect on dry weight of horse purslane. At 30 DAS, half dose of atrazine alone (250 g a.i. ha^{-1}) caused maximum reduction in dry weight of horse purslane but it was at par with full dose of atrazine (500 g a.i. ha^{-1}) alone; and ½, ⅓, and ¼ dose of atrazine in combination with allelopathic plant water extracts, while minimum horse purslane dry weight reduction was recorded in control (weedy check). At 45 DAS, full dose of atrazine alone, and ½ and ⅓ dose of atrazine in combination with allelopathic plant water extracts caused maximum reduction in horse purslane dry weight, while minimum reduction was recorded in control (weedy check) (Table 2). At 60 DAS, all levels of atrazine alone, and reduced doses of atrazine in combination with allelopathic plant water extracts caused a reduction in horse purslane dry weight, while minimum reduction was recorded in control (weedy check) (Table 2). Full dose of atrazine caused 73%, 77% and 94% reduction in horse purslane dry weight at 30, 45 and 60 DAS, respectively while half dose of atrazine in combination of 20 L ha^{-1} of allelopathic plant water extracts of sorghum, brassica, sunflower and mulberry caused 73%, 73% and 90% reduction in horse purslane dry weight at 30, 45 and 60 DAS, respectively compared with weedy check (control) (Table 2). Reduced doses of herbicides mixed allelopathic water extracts presented a higher reduction in weeds density and dry weight compared with the alone reduced doses of herbicides (Table 2).

The aforementioned reduction in horse purslane density and dry weight with reduced doses (½ and ⅓ of recommended dose) of herbicide tank mixed with allelopathic water extracts might be due to the fact that herbicide had synergistic effect to control weeds, when tank mixed with allelopathic crop water extracts of sorghum, brassica, sunflower and mulberry. Sorghum has been intensively reported to posses strong allelopathic potential and obstruct the growth processes of other plant species (Hejl and Koster, 2004; Jabran *et al.,* 2008). Nonetheless, allelopathic potential of the mulberry has also been reported previously by Mughal (2000) and Hong *et al.* (2003) on pulses and radish, respectively. The results of the study confirm the earlier work of Cheema *et al.* (2003), who reported that herbicide dose can be reduced up to 67% with sorgaab (sorghum water extract) and sunfaab (sunflower water extract). Recently, based on their findings, Mahmood *et al.* (2009) and Jabran *et al.* (2010a) suggested that dose of phenoxoprop *p-ethyl* and pendimethalin can be reduced up to 67% in combination with sorghum and sunflower water extracts for effective weed control in wheat and canola, respectively. The non-significant affect of weed control treatments on horse purslane density at 45 DAS might be due surplus soil moisture contents which allowed more weeds to grow in all the treatments; however, the difference in horse purslane dry weight for the different weed control treatments at 45 DAS (Table 2) clearly indicates that the newly germinated weeds didn't attain sufficient dry weight after germination.

Taller plants (Table 3) were produced where full dose of atrazine (500 g a.i. ha^{-1}) alone and ⅓ dose of atrazine in combination with allelopathic plant water extract was applied, whereas plants with minimum height were produced in control (weedy check). Cob of larger size (Table 3) were produced where full dose of atrazine (500 g a.i. ha^{-1}) alone and its half dose with allelopathic plant water extracts was applied while smaller cobs were produced in control (weedy check). Maximum number of grains per cob (Table 3) was recorded where full and half dose of atrazine alone; and half dose of atrazine combined with allelopathic plant water extracts were applied, whereas weedy check (control) resulted in minimum number of grains per cob (Table 3). More number of grains per row (Table 3) were produced where full and half dose of atrazine alone; and ½ and ⅓ dose of atrazine in combination with allelopathic plant water extracts was applied, whereas lesser number of grains per row were recorded in control (weedy check). Heavier grains (1000-grain weight) along with higher grain-pith ratio were produced where full dose of atrazine (500 g a.i. ha^{-1}) was applied, while control (weedy check) produced grains with lesser weight along with lower grain-pith ratio (Table 3 & 4).

Although, plant height is a genetically controlled trait but it is also significantly affected by prevailing environmental conditions. Increased plant height by application of atrazine at recommended dose (500 g a.i. ha^{-1}) along with reduced doses (½ and ⅓ of recommended dose) of atrazine tank mixed with allelopathic water extracts of sorghum, brassica, sunflower and mulberry might be the direct result of reduced competition among weeds and maize plants as indicted by reduced density and dry weight of horse purslane at 30, 45 and 60 DAS (Table 2 & 3), so maize plants get proper nutrition for their proper growth that results in more plant height. Mahmood *et al.* (2009) also presented similar findings in wheat. Likewise, condensed competition among horse purslane and maize plants with full dose of atrazine (500 g a.i. ha^{-1}) alone and half dose of atrazine tank mixed with water extracts of sorghum, brassica, sunflower and mulberry applied provided an edge to maize plants to extract more water and nutrients from the soil resulting in vigorous growth which produced larger sized cobs with more grains (Table 3). Similarly, individual grain weight can be increased, decreased or un-affected due to input applied and environmental stresses (Whinguiri and Kemp, 1980). Maximum grain weight might be due to effective weed control of weeds in plots treated with full dose of herbicide alone and reduced doses with allelopathic plant water extracts. So, maize plants got maximum nutrition and water from available resources of soil. More plant height, higher number of grains per plant and enhanced 1000-grain weight at reduced doses of herbicides tank mixed with allelopathic plant water extracts of different plants like sorghum, brassica, sunflower and mulberry in different crops like wheat, mungbean, canola and maize is earlier reported (Khaliq *et al.,* 2002; Jabran *et al.,* 2008; Mahmood *et al.,* 2009; Razzaq *et al.,* 2010, 2012).

Full dose of atrazine applied alone and half dose of atrazine with allelopathic plant water extracts resulted 49% and 36% higher grain yield than control (weedy check), respectively (Table 4). Application of reduced doses of herbicides mixed allelopathic water extracts attained a higher grain yield compared with the alone reduced doses of herbicides (Table 4). Maximum biological and stalk yield (Table 4) was recorded where full dose of atrazine (500 g a.i. ha^{-1}) alone and ½ dose of atrazine (250 g a.i. ha^{-1}) in combination with allelopathic plant extracts was used while minimum biological and stalk yield was produced in control (weedy check). Likewise atrazine alone at all levels and reduced doses combined with allelopathic plant water extracts exhibited higher harvest index compared with control and allelopathic plant water extracts of sorghum, brassica, sunflower and mulberry alone (Table 4). Nonetheless, full dose of atrazine applied alone and half dose of atrazine with allelopathic plant water extracts resulted 87% and 66% higher net income than control (weedy check), respectively (Table 5).

Higher grain yield with full dose of atrazine (500 g a.i. ha^{-1}) alone and ½ dose of atrazine tank mixed with allelopathic plant water extracts of sorghum, brassica and sunflower was the direct result of improved yield components i.e. cob length, number of grains per cob and 1000-grain weight (Table 3 & 4). Minimized competition due to better weed control, maize plants uptake more water and nutrients that resulted in vigorous growth at early stages and also improved the yield components such as cob length, number of grains per cob, 1000-grain weight thus, resulting in higher stalk, grain and biological yield. Higher net income and BCR (Table 5) due to atrazine application alone at full dose and ½ dose with allelopathic plant water extracts was the direct result of higher grain yield (Table 4) obtained by effective weeds control (Table 2; Akbar *et al.,* 2011). There are many earlier reports available that signify the role of reduced doses of commercial herbicides in combination with allelopathic plant water extracts to enhance grain and biological yield, harvest index, net income and BCR in variety of agronomic crops including maize (Cheema *et al.,* 2002, 2005, 2005b: Khaliq *et al.,* 2002; Jabran *et al.,* 2008, 2010a; Mehmood *et al.,* 2009; Razzaq *et al.,* 2012). Some positive influences of allelopathic water extracts on crop growth has also been reported which might had resulted in higher grain yield in addition to the one resulted from better weed control (Jabran *et al.,* 2011).

In conclusion, full dose of atrazine alone and ½ dose of atrazine in combination with allelopathic plant water extracts of sorghum, sunflower, brassica and mulberry caused maximum reduction in weed density and dry biomass, and also enhanced the grain yield and net income over control. Therefore, doses of herbicides can effectively be lowered to control weeds if applied in combination with allelopathic plant water extracts which would result in less harmful impacts to the environment.

Table 1: Pre-sowing physico-chemical soil analysis

Determination	Unit	Value
Physical Analysis		
Sand	%	27
Silt	%	53
Clay	%	20
Textural class	Silty clay loam	
Chemical Analysis		
pH		7.9
Saturation percentage	%	35.0
EC	$dS\ m^{-1}$	2.95
Organic matter	%	0.81
Total nitrogen	%	0.05
Available phosphorus	ppm	10.2
Available potassium	ppm	195

Table 2: Effect of allelopathic plant water extracts in combination with reduced doses of herbicide on density and dry weight of horse purslane in maize

Treatments	Horse purslane density (0.25 m^2)			Horse purslane dry weight (g/0.25 m^2)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1 = Control (weedy check)	26.38 a	6.02	7.32 a	33.93 a	39.62 a	106.85 a
T_2 = Atrazine @ 500 g a.i. ha^{-1}	7.56 b	7.73	5.30 b	9.21 de (73)	9.19 g (77)	6.91 c (94)
T_3 = Atrazine @250 g a.i. ha^{-1}	8.47 b	7.72	6.67 ab	9.08 e (73)	16.58 de (58)	16.80 c (84)
T_4 = Atrazine @167 g a.i. ha^{-1}	9.42 b	6.7	6.51 ab	15.03 bc (56)	20.72 d (48)	22.88 c (78)
T_5 = Atrazine @125 g a.i. ha^{-1}	11.53 ab	7.51	7.10 a	14.79 bcd (56)	26.55 c (33)	26.41 c (75)
T_6 = Sorghum+Brasicca+Sunflower +Mulbery water extracts @20 L ha^{-1}	9.95 b	6.00	7.19 a	17.29 b (49)	32.18 b (19)	80.25 b (24)
T_7 = Atrazine @250 g a.i. ha^{-1} + Sorghum+ Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	7.79 b	7.17	5.79 ab	9.28 de (73)	10.88 g (73)	10.36 c (90)
T_8 = Atrazine @167 g a.i. ha^{-1} + Sorghum + Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	8.10 b	6.08	6.56 ab	10.71 cde (68)	11.83 fg (70)	11.15 c (89)
T_9 = Atrazine @125 g a.i. ha^{-1} + Sorghum+ Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	10.13 ab	1.10	6.66 ab	12.31 bcde (64)	15.77 ef (60)	15.21 c (85)
LSD value at 5%	16.31	NS	1.78	5.69	4.68	20.11

Means not sharing the same letters differ significantly at 5% probability level
Figures in parenthesis represent the %age decrease in dry weight over control

Table 3: Effect of allelopathic plant water extracts in combination with reduced dose of herbicide on yield components of maize

Treatments	Plant Height (cm)	Cob length (cm)	No. of grains per cob	No. of grains per row	1000-grain weight (g)
T_1 = Control (weedy check)	187.7 f	14.80 f	434.69 c	26.53 f	244.30 g
T_2 = Atrazine @ 500 g a.i. ha^{-1}	211.26 a	17.76 a	499.93 a	35.12 a	307.85 a
T_3 = Atrazine @250 g a.i. ha^{-1}	201.25 cd	16.68 cd	484.95 ab	33.58 ab	272.31 cd
T_4 = Atrazine @167 g a.i. ha^{-1}	201.15 cd	16.58 cd	482.65 b	32.77 bc	267.00 de
T_5 = Atrazine @125 g a.i. ha^{-1}	200.53 cd	16.38 de	475.75 b	29.03 de	260.81 ef
T_6 = Sorghum+Brasicca+Sunflower +Mulbery water extracts @20 L ha^{-1}	195.54 e	15.92 e	475.26 b	28.91 e	256.54 f
T_7 = Atrazine @250 g a.i. ha^{-1} + Sorghum+ Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	204.88 bc	17.74 ab	487.80 ab	33.94 ab	291.47 b
T_8 = Atrazine @167 g a.i. ha $^{-1}$ + Sorghum + Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	207.86 ab	17.12 bc	482.14 b	33.76 ab	276.31 c
T_9 = Atrazine @125 g a.i. ha^{-1} + Sorghum+ Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	197.88 de	16.96 cd	481.25 b	31.16 cd	271.6 cd
LSD value at 5%	4.92	0.61	15.39	2.2	6.34

Means not sharing the same letters differ significantly at 5% probability level

Table 4: Effect of allelopathic plant water extracts in combination with reduced dose of herbicide on yield of maize

Treatments	Grain/ pith ratio	Stalk yield (t ha^{-1})	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1 = Control (weedy check)	1.27 f	20.12 f	3.73 f	24.17 f	15.43 c
T_2 = Atrazine @ 500 g a.i. ha^{-1}	2.11 a	26.81 a	5.54 a (49)	29.61 a	18.70 a
T_3 = Atrazine @250 g a.i. ha^{-1}	1.57 cd	24.58 bcde	4.79 bc (28)	27.33 cd	17.52 ab
T_4 = Atrazine @167 g a.i. ha^{-1}	1.48 de	23.44 de	4.74 bcd (27)	27.05 d	17.52 ab
T_5 = Atrazine @125 g a.i. ha^{-1}	1.39 ef	23.94 cde	4.44 de (19)	25.92 e	17.13 ab
T_6 = Sorghum+Brasicca+Sunflower +Mulbery water extracts @20 L ha^{-1}	1.36 ef	23.12 e	4.13 e (11)	25.24 e	16.36 bc
T_7 = Atrazine @250 g a.i. ha^{-1} + Sorghum+ Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	1.89 b	25.83 ab	5.08 b (36)	28.98 ab	17.53 ab
T_8 = Atrazine @167 g a.i. ha $^{-1}$ + Sorghum + Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	1.68 c	25.50 abc	4.87 b (31)	28.17 bc	17.91 ab
T_9 = Atrazine @125 g a.i. ha^{-1} + Sorghum+ Brasicca + Sunflower + Mulbery water extracts @20 L ha^{-1}	1.61 cd	24.88 bcd	4.53 cd (21)	26.07 e	17.38 ab
LSD value at 5%	0.13	1.71	0.32	0.88	1.60

Means not sharing the same letters differ significantly at 5% probability level
Figures in parenthesis represent the percent increase in yield over control (weedy check)

Table 5: Economic Analysis

Treatments	Grain yield kg ha^{-1}	Gross income Rs. ha^{-1}	Cost of herbicide Rs. ha^{-1}	Cost of extracts Rs. ha^{-1}	Sprayer rent Rs. ha^{-1}	Spray application Rs. ha^{-1}	Cost that vary Rs. ha^{-1}	Net profit Rs. ha^{-1}
T_1	3730	46158	0	0	0	0	0	46158
T_2	5540	68557	745	0	60	120	925	67632
T_3	4790	59276	372	0	60	120	552	58724
T_4	4740	58107	245	0	60	120	425	57682
T_5	4440	54946	186	0	60	120	366	54580
T_6	4130	51108	0	120	60	120	300	50808
T_7	4880	67100	372	120	60	120	672	66428
T_8	4870	66362	245	120	60	120	545	65817
T_9	4530	56058	186	120	60	120	486	55572

T_1: Control (weedy check); T_2: Atrazine @ 500 g a.i ha^{-1}; T_3: Atrazine @250 g a.i ha^{-1}; T_4: Atrazine @167 g a.i ha^{-1}
T_5: Atrazine @125 g a.i ha^{-1}; T_6: Sorghum, Brasicca, Sunflower and Mulberry water extracts @20 L ha^{-1}
T_7: Atrazine @250 g + Sorghum, Brasicca, Sunflower and Mulberry water extracts @ 20 L ha^{-1}
T_8: Atrazine @167g + Sorghum, Brasicca, Sunflower and Mulberry water extracts @ 20 L ha^{-1}
T_9: Atrazine @125 g + Sorghum, Brasicca, Sunflower and Mulberry water extracts @ 20 L ha^{-1}

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