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Lower Doses of Pendimethalin Mixed with Allelopathic Crop Water Extracts for Weed Management in Canola (*Brassica napus*)

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ABSTRACT

Injudicious use of synthetic herbicides has resulted in environmental pollution, soil contamination, development of resistance among weed biotypes and threats to human health, which necessitate finding alternative weed management strategies to reduce the use of herbicides. This study was conducted to investigate the possibilities of reducing pendimethalin dosage by tank mixing with allelopathic crop water extracts for weed control in canola (*Brassica napus* L.). Allelopathic crop water extracts including sorghum (*Sorghum bicolor* L.), sunflower (*Helianthus annuus* L.), mustard (*Brassica campestris* L.) and rice (*Oryza sativa* L.) each at 15 L ha^{-1} were tank mixed with 0.4 and 0.6 kg active ingredient (a.i.) ha^{-1} pendimethalin and sprayed immediately after sowing. Control (weedy check) and standard dose of pendimethalin 1.2 kg (a.i.) ha^{-1} were used for comparison. Data regarding weed density, weed fresh weight, weed dry weight and yield components was recorded. Horse purslane (*Trianthema portulacastrum* L.), purple nutsedge (*Cyperus rotundus* L.), lambsquarters (*Chenopodium album* L.) and swine cress (*Cronopus didymus* L.) were the weeds present in the experimental field. Weed density, weed fresh weight and dry weight were lower than control in all the treatments; however the performance of various combinations of allelopathic crop water extracts and lower pendimathalin rates was better than the standard dose of herbicide particularly in case of purple nutsedge (*C. rotundus* L.). All the yield contributing parameters including number of branches per plant, number of pods per plant, numbers of seeds per pod and 1000-seed weight were higher, where combinations of allelopathic extracts were used with lower herbicide rates. In crux, pendimethalin dose for successful weed control in canola can be reduced up to 67% for environmental safety.

Key Words: Canola; Weed management; Allelopathy; Environment; Human health; Pendimethalin

INTRODUCTION

Herbicides offer substantial increase in crop yield through effective weed control (Kim, 1994; Santos, 2009). However overuse and misuse of synthetic herbicides has resulted in problems like environmental pollution, soil and water contamination (Judith *et al.*, 2001), development of resistance among weed biotypes (Heap, 2008) and threats to human health (Clarkson, 1995; Snelder *et al.*, 2008). So there is pressing need for the alternative weed management strategies, which can at least reduce the use of herbicides. Although use of herbicides can not be eliminated, their use can be reduced by exploiting allelopathy as an alternate weed management tool for crop production (Cheema & Khaliq, 2000; Jabran *et al.*, 2008). Herbicide dose can be effectively reduced in combination with allelopathic crop water extracts and the efficacy of these allelopathic extracts can be enhanced in combination with reduced rates of herbicides for managing weeds in field crops (Irshad & Cheema, 2005).

Use of allelopathic crop water extracts combined with lower herbicide rates offer an economically viable and environment friendly weed control option (Cheema *et al.*, 2004). Herbicide dose can be reduced by application of lower herbicide rates in combination with allelopathic products, which can work synergistically (Jabran *et al.*, 2008). Lower doses (half & one third of standards) of herbicides such as pendimethalin, s-metolachlor, fenoxaprop-*p*-ethyl, clodinafop proprargyl, atrazine, ethoxysulfuron, butachlor, when tank mixed with allelopathic crops (sorghum, sunflower, rice) water extracts offer successful weed control in cotton, maize, wheat and rice (Cheema *et al.*, 2002; Cheema *et al.*, 2003; Cheema *et al.*, 2005a; Cheema *et al.*, 2005b; Cheema *et al.*, 2005c). Ashiq and Cheema (2005) listed the hazardous weeds as *Trianthema portulacastrum*, *Cyperus rotundus*, *Cyndon dactylon*, *Chenopodium album*, *C. murale* and *Fumaria indica* in canola and reported 21-45% yield losses owing to these weeds.

The present study was therefore conducted to explore the possibility of reducing herbicide use in combination with allelopathic crop water extracts and to evaluate the

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combined effects of allelopathic crop water extracts as sorghum, sunflower, *brassica* and rice on weed growth in canola.

MATERIALS AND METHODS

Plant material: Canola hybrid "Hyola-401" seeds were purchased from ICI Pakistan (Pvt) Ltd., Pakistan.

Site and soil: The present study was executed at Agronomic Research Farm, University of Agriculture, Faisalabad, (31.5° N, 73.09° S) during winter 2005-2006 to evaluate the growth of canola and its weeds in response to allelopathic crop water extracts as sorghum, sunflower, rice and *brassica* tank mixed with low rates of pendimethalin. The soil of the experimental site was sandy clay loam.

Crop husbandry: Canola crop was planted using 5 kg ha^{-1} seed rate in 30 cm apart rows with hand drill on 6th of October 2005. The experiment was replicated four times and laid out in a randomized complete block design with a net plot size of 2.4 m x 5 m. Nitrogen and phosphorus were applied at 90 kg ha^{-1} and 60 kg ha^{-1}, respectively. Nitrogen was delivered in three equal splits at sowing, first irrigation and second irrigation, while all the phosphorus fertilizer was drilled at sowing.

Crop water extracts preparation and application: Crop water extracts were prepared through following procedure. Respective allelopathic crops were harvested at maturity, dried and then chopped into 2 cm pieces with the help of electric fodder cutter. This chopped material was soaked in the water 1:10 (w/v) ratio for 24 h. Water extracts were collected by passing through sieves. The filtrates were boiled at 100°C for reducing the volume by 20 times. The concentrated crop water extracts were stored at room temperature (Cheema *et al*., 2000a). Crop water extracts at 15 L ha^{-1} each were tank mixed with pendimethalin at 0.4 and 0.6 kg a.i. ha^{-1} and were sprayed immediately after sowing by knapsack hand sprayer fitted with flat fan nozzle. Volume of spray (320 L ha^{-1}) was determined by calibration. Recommended dose of pendimethalin 1.2 kg a.i. ha^{-1} was used as standard. A weedy check was also maintained for comparison.

Observations: Individual weed density was recorded at 20, 40 and 60 days after sowing (DAS), while fresh and dry weights were recorded at 40 and 60 DAS from quadrat of 0.25 m^2. Weeds were cleaned, air dried under shade for 24 h and then oven dried at 70°C until dried completely before recording their dry weights. Crop was harvested on March 21, 2006.

Harvested crop was kept under sunlight for one week to dry. Number of plants in 1.2 m^2 were counted from each experimental unit at the time of harvest and converted into number of plants per square meter. Plant height in cm was measured at maturity by taking the height of 15 plants randomly from each experimental unit. Plant height was measured from soil surface to tip of the plant by using a meter rod and then the average was calculated. The number of branches of 15 randomly selected plants from each experimental unit was recorded and then average was calculated. Number of pods from fifteen randomly selected plants was counted at the time of maturity and then average was calculated. Pod length of 25 randomly selected pods from each experimental unit was recorded using a measuring tape and then average was calculated. Twenty five pods were taken randomly from each experimental unit and the number of seeds was counted and then averaged to get number of seeds per pod. 1000 seeds were counted from each experimental unit and weighed using an electric balance.

Statistical analysis: Data were statistically analyzed using the software MSTAT-C. Analysis of variance was used to test the significance of variance sources, while LSD test (p=0.05) was used to compare the differences among treatment means.

RESULTS AND DISCUSSION

Horse purslane (*Trianthema portulacastrum* L.), purple nutsedge (*Cyperus rotundus* L.), lambsquarters (*Chenopodium album* L.) and swine cress (*Cronopus didymus* L.) were the weeds present in the canola field. All the treatments significantly reduced the horse purslane density at 20 and 40 days after sowing (DAS) (Table I). Pendimethalin alone at 1.2 kg a.i. ha^{-1} and sorghum and sunflower water extracts each at 15 L ha^{-1} with half the recommended dose (0.6 kg a.i. ha^{-1}) of pendimethalin showed 64.28 and 62.5% reduction in horse purslane density, respectively over control at 20 DAS. Most of the treatments gave 100% reduction in horse purslane density. No horse purslane in any field at 60 DAS was recorded probably due to low temperature. Cheema *et al.* (2003) reported the suppression of horse purslane density by combined application of allelopathic crop water extracts and reduced rates of pendimethalin.

All the treatments significantly decreased the density of purple nutsedge over control at 20, 40 and 60 DAS (Table I). Combined application of sorghum and rice water extracts each at 15 L ha^{-1} with pendimethalin (half dose) at 0.6 kg a.i. ha^{-1} was comparatively more effective than other treatments to suppress the density of purple nutsedge over control by 48.42, 53.99 and 71.41%, respectively at 20, 40 and 60 DAS. Pendimethalin alone is not effective against purple nutsedge so its full dose (1.2 kg a.i. ha^{-1}) inhibited the weeds only by 13.77, 8.2 and 33.2% at 20, 40 and 60 DAS, respectively while when used at reduced rates in mixture with crop water extracts, weed inhibition was enhanced. This was possibly due to the combined action of the allelopathic crop water extracts and herbicide (Cheema & Irshad, 2004; Jabran *et al.*, 2008). Sorghum allelopathy has important role in inhibition of purple nutsedge density as Cheema and Ahmad (1992) reported that sorghum residues incorporation into the soil inhibit purple nutsedge density by 55-94%.

Table I: Effect of various allelopathic crop water extracts in combination with reduced rates of pendimethalin on weed density in canola

Treatments	Rate	Horse purslane density (0.25 m^2)		Purple nutsedge density (0.25 m^2)			Lambsquarters density (0.25 m^2)		Swine cress density (0.25 m^2)	
	Extract/Herbicide	20 DAS[1]	40 DAS	20 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Control (weedy check)		14.0 a[2]	5.75 a	4.125 a	4.625 a	7.875 a	8.75 a	9.125 a	66.88 a	29.88 a
Pendimethalin (Standard	1.2 kg a.i.ha^{-1}	5.0 d	0 b	3.625 ab	4.25 ab	5.25 c	0.5 d	2.0 b	38.5 b	18.13 d
dose)		(64.28)[3]	(100)	(13.77)	(8.2)	(33.2)	(94.28)	(78.37)	(42.43)	(39.39)
Sorghum WE[4] +	15 L ha^{-1} +	5.25 d	0 b	2.5 bc	2.5 d	3.375 ef	1.0 d	2.5 b	36.5 b	21.13 c
sunflower WE +	15 L ha^{-1} +	(62.5)	(100)	(40.75)	(46.0)	(57.05)	(88.57)	(72.97)	(45.42)	(29.28)
pendimethalin	0.6 kg a.i.ha^{-1}									
Sorghum WE +	15 L ha^{-1} +	7.0 cd	0 b	3.0 abc	3.0 cd	3.75 e	3.0 c	2.25 b	39.88 b	27.13 b
sunflower WE +	15 L ha^{-1} +	(50.0)	(100)	(27.36)	(35.21)	(52.35)	(65.71)	(75.67)	(40.37)	(9.2)
pendimethalin	0.4 kg a.i.ha^{-1}									
Sorghum WE + brassica	15 L ha^{-1} +	7.75 c	0.5 b	3.0 abc	3.625 bc	4.5 d	1.25 d	2.375 b	29.88 c	10.13 e
WE + pendimethalin	15 L ha^{-1} +	(44.64)	(91.3)	(27.36)	(21.59)	(42.82)	(85.71)	(74.27)	(55.32)	(66.09)
	0.6 kg a.i.ha^{-1}									
Sorghum WE + brassica	15 L ha^{-1} +	8.875 bc	0 b	3.25 abc	2.375 d	3.25 f	3.25 c	2.5 b	38.38 b	17.0 d
WE + pendimethalin	15 L ha^{-1} +	(36.64)	(100)	(21.3)	(48.59)	(58.7)	(62.85)	(72.97)	(42.61)	(43.1)
	0.4 kg a.i.ha^{-1}									
Sorghum WE + rice	15 L ha^{-1} +	10.88 b	0.5 b	2.125 c	2.125 d	2.25 g	0.875 d	2.125 b	24.38 c	11.5 e
WE+ pendimethalin	15 L ha^{-1} +	(22.28)	(91.3)	(48.42)	(53.99)	(71.41)	(89.94)	(76.97)	(63.54)	(61.51)
	0.6 kg a.i.ha^{-1}									
Sorghum WE + rice WE	15 L ha^{-1} +	7.0 cd	0 b	3.5 ab	4.125 ab	6.125 b	5.75 b	2.25 b	41.63 b	18.5 d
+ pendimethalin	15 L ha^{-1} +	(50.0)	(100)	(15.25)	(10.8)	(22.1)	(34.28)	(75.67)	(37.75)	(38.08)
	0.4 kg a.i.ha^{-1}									
LSD value at $p \leq 0.05$		2.049	0.884	1.15	0.9207	0.4107	1.096	0.8473	6.118	1.921

[1]Days after sowing, [2]Any two means not sharing a letter in common differ significantly at $p \leq 0.05$, [3]The figures in the parentheses show percent decrease over control, [4]Water extract

Table II: Effect of various allelopathic crop water extracts in combination with reduced rates of pendimethalin on weed fresh weight (g) in canola

Treatments	Rate	Horse purslane fresh weight (g/0.25 m^2)	Purple nutsedge fresh weight (g/0.25 m^2)		Lambsquarters fresh weight (g/0.25 m^2)		Swine cress fresh weight (g/0.25 m^2)	
	Extract/Herbicide	40 DAS[1]	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Control (weedy check)		24.25 a[2]	2.9 a	4.738 a	2.188 a	3.375 a	5.24 a	6.828 a
Pendimethalin	1.2 kg a.i.ha^{-1}	0 b	2.737 a	3.895 b	0.25 e	2.125 b	3.563 c	4.89 b
(Standard dose)		(100)[3]	(5.6)	(17.79)	(88.57)	(37.03)	(32.0)	(28.38)
Sorghum WE[4] +	15 L ha^{-1} +	0 b	1.275 c	2.63 c	0.4375 de	1.112 cd	3.75 c	3.89 c
sunflower WE +	15 L ha^{-1} +	(100)	(56.03)	(44.49)	(80.0)	(67.05)	(28.43)	(43.03)
pendimethalin	0.6 kg a.i.ha^{-1}							
Sorghum WE +	15 L ha^{-1} +	0 b	1.75 b	2.622 c	0.75 cd	1.095 cd	2.75 d	5.145 b
sunflower WE +	15 L ha^{-1} +	(100)	(39.65)	(44.66)	(65.72)	(67.55)	(47.52)	(24.65)
pendimethalin	0.4 kg a.i.ha^{-1}							
Sorghum WE + brassica	15 L ha^{-1} +	1.125 b	1.93 b	1.975 d	0.62 cde	1.237 c	3.0 d	2.895 e
WE + pendimethalin	15 L ha^{-1} +	(95.36)	(33.45)	(58.31)	(71.66)	(63.35)	(42.75)	(57.6)
	0.6 kg a.i.ha^{-1}							
Sorghum WE + brassica	15 L ha^{-1} +	0 b	1.275 c	1.48 e	1.5 b	1.087 cd	4.5 b	3.625 c
WE + pendimethalin	15 L ha^{-1} +	(100)	(56.03)	(68.76)	(31.44)	(67.79)	(14.12)	(46.91)
	0.4 kg a.i.ha^{-1}							
Sorghum WE + rice	15 L ha^{-1} +	1.063 b	1.305 c	1.755 de	0.375 de	0.955 d	2.793 d	3.14 de
WE+ pendimethalin	15 L ha^{-1} +	(95.62)	(55.0)	(62.96)	(82.86)	(71.7)	(46.7)	(54.01)
	0.6 kg a.i.ha^{-1}							
Sorghum WE + rice	15 L ha^{-1} +	0 b	1.73 b	2.943 c	1.0 c	1.205 c	3.938 c	3.497 cd
WE + pendimethalin	15 L ha^{-1} +	(100)	(40.34)	(37.88)	(54.29)	(64.29)	(24.85)	(48.78)
	0.4 kg a.i.ha^{-1}							
LSD value at $p \leq 0.05$		1.855	0.2867	0.4810	0.4133	0.2416	0.40	0.4337

[1]Days after sowing, [2]Any two means not sharing a letter in common differ significantly at $p \leq 0.05$, [3]The figures in the parentheses show percent decrease over control, [4]Water extract

All the treatments significantly inhibited the lambsquarters density over control (Table I). Maximum inhibition (94.28%) in lambsquarters density was recorded in plots treated with standard dose of pendimethalin 1.2 kg a.i. ha^{-1} followed by the plots treated with sorghum and rice water extracts each at 15 L ha^{-1} with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin at 40 DAS, although both the treatments were statistically similar. More than 70% reduction in lambsquarters density over control was recorded in all the treatments at 60 DAS and they were statistically similar with each other. Inhibition in lambsquarters density in case of allelopathic crop water extracts combined with reduced herbicide doses is almost equal to recommended rate of herbicide. This effect is possibly due to enhanced efficacy of herbicide when mixed with allelopathic crop water extracts as Cheema *et al.* (2005a) reported that sorghum water extract combined with reduced rate of pendimethalin (0.5 & 0.667 kg a.i. ha^{-1}) gave weed control in cotton equal to their label doses. The swine cress density was significantly decreased in all the treatments over control (Table I). Maximum inhibition (63.54 & 66.09%) in swine cress density over control was recorded in fields treated with sorghum and rice water extracts each at 15 L ha^{-1} with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin and sorghum and *brassica* water extracts each at 15 L ha^{-1} with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin at 40 and 60 DAS, respectively. Cheema *et al.* (2003) reported weed density reduction by combined application of allelopathic crop water extracts and lower rates of herbicides.

Maximum fresh weight for horse purslane was recorded in the weedy check at 40 DAS (Table II). Most of the treatments caused 100% reduction in horse purslane fresh weight over control at 40 DAS. Cheema *et al.* (2000b) reported reduction in weed fresh weight by application of sorghum water extract for weed management in wheat. Most of the treatments significantly reduced the purple nutsedge fresh weight over control (Table II) at 40 and 60 DAS. Maximum inhibition (56.03%) in purple nutsedge fresh weight was recorded in both the plots treated with sorghum and sunflower water extracts each at 15 L ha^{-1} with (half dose) pendimethalin at 0.6 kg a.i. ha^{-1} and sorghum and *brassica* water extracts each at 15 L ha^{-1} with (half dose) pendimethalin at 0.6 kg a.i. ha^{-1} at 40 DAS. Sorghum and *brassica* water extracts applied each at 15 L ha^{-1} with pendimethalin at 0.4 kg a.i. ha^{-1} gave maximum inhibition (68.76%) in purple nutsedge fresh weight over control at 60 DAS and was followed by the plots, where sorghum and rice water extracts were applied each at 15 L ha^{-1} with pendimethalin at 0.6 kg a.i. ha^{-1}.

Maximum inhibition (88.57%) in lambsquarters fresh weight (Table II) was noted in plots treated with standard dose (1.2 kg a.i. ha^{-1}) of pendimethalin and was followed by plots treated with sorghum and rice water extracts each at 15 L ha^{-1} combined with (half dose) pendimethalin 0.6 kg a.i. ha^{-1}, which suppressed lambsquarters fresh weight by 82.86% over control at 40 DAS. Maximum suppression in lambsquarters fresh weight (71.7%) over control was recorded in case of sorghum and rice water extracts each at 15 L ha^{-1} combined with (half dose) pendimethalin (0.6 kg a.i. ha^{-1}) at 60 DAS. Swine cress fresh weight (Table II) was reduce by 47.52% in plots treated with sorghum and sunflower water extracts each at 15 L ha^{-1} combined with pendimethalin (0.4 kg a.i. ha^{-1}) and was followed by sorghum and rice water extracts each at 15 L ha^{-1} combined with half dose pendimethalin (0.6 kg a.i. ha^{-1}) and sorghum and *brassica* water extracts each at 15 L ha^{-1} combined with half dose pendimethalin at (0.6 kg a.i. ha^{-1}) at 40 DAS. However all the three treatments were statistically similar. Combined application of sorghum and *brassica* water extracts each at 15 L ha^{-1} combined with pendimethalin (0.6 kg a.i. ha^{-1}) gave maximum reduction (57.6%) in swine cress fresh weight at 60 DAS.

Most of the weed control treatments killed the horse purslane (Table III) completely at 40 DAS. However there was no horse purslane at 60 DAS probably due to unfavorable low temperature. Cheema *et al.* (2002) stated that 76% reduction in horse purslane dry weight over control in cotton crop was obtained when treated with sorghum water extract at 12 L ha^{-1} plus (half dose) 0.5 kg a.i. ha^{-1} of pendimethalin.

Pendimethalin is not effective against purple nutsedge, however when lower rates of pendimethalin were combined with different allelopathic crop water extracts; efficiency of the herbicide to suppress purple nutsedge dry weight over control treatment was enhanced. Sorghum and rice water extracts each at 15 L ha^{-1} combined with (half dose) pendimethalin 0.6 kg a.i. ha^{-1} gave maximum reduction in purple nutsedge dry weight by 58.47 and 51.05% at 40 and 60 DAS, respectively. Cheema *et al.* (2003) reported 60.47% reduction in purple nutsedge dry weight over control when treated with sorghum water extract at 10 L ha^{-1} combined with 0.667 kg a.i. ha^{-1} of pendimethalin for weed control in cotton.

Standard dose of pendimethalin (1.2 kg a.i. ha^{-1}), sorghum and sunflower water extracts each at 15 L ha^{-1} combined with half rate (0.6 kg a.i. ha^{-1}) of pendimethalin and sorghum and rice water extracts each at 15 L ha^{-1} combined with half rate (0.6 kg a.i. ha^{-1}) of pendimethalin offered more than 90% reduction in lambsquarters dry weight over control (Table III) and all the three treatments were statistically similar at 40 DAS. Maximum inhibition (83.07%) in lambsquarters dry weight at 60 DAS was recorded in plots treated with full dose of pendimethalin 1.2 kg a.i. ha^{-1} and was followed by 73.0% inhibition in lambsquarters dry weight that was noted in plots treated with sorghum and rice water extracts each at 15 L ha^{-1} combined with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin. Cheema *et al.* (2001) reported reduction in lambsquarters dry weight by application of sorghum water extract for weed management in spring mungbean.

A significant reduction occurred in dry weight of swine cress weed under different treatments (Table III). Maximum reduction (65.95 & 65.75%) in swine cress dry weight was noted in plots, where sorghum and rice water extracts each at 15 L ha^{-1} were sprayed in combination with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin and sorghum and *brassica* water extracts each at 15 L ha^{-1} combined with 1/3rd dose (0.4 kg a.i. ha^{-1}) of pendimethalin at 40 DAS. A standard dose of pendimethalin at 1.2 kg a.i. ha^{-1} was less effective as compared to the treatments, where allelopathic crop water extracts were combined with reduced doses of

Table III: Effect of various allelopathic crop water extracts in combination with reduced rates of pendimethalin on weed dry weight (g) in canola

Treatments	Rate	Horse purslane dry weight (g/0.25 m^2)	Purple nutsedge dry weight (g/0.25 m^2)		Lambsquarters dry weight (g/0.25 m^2)		Swine cress dry weight (g/0.25 m^2)	
	Extract/Herbicide	40 DAS[1]	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Control (weedy check)		4.342 a[2]	0.7225 a	0.8275 a	0.71 a	1.315 a	1.263 a	2.115 a
Pendimethalin (Standard dose)	1.2 kg a.i.ha^{-1}	0 b (100)[3]	0.6252 b (13.47)	0.775 b (6.34)	0.0325 e (95.42)	0.2225 f (83.07)	0.6 c (52.49)	1.327 c (37.25)
Sorghum WE[4] + sunflower WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.6 kg a.i.ha^{-1}	0 b (100)	0.3625 de (49.83)	0.4625 f (44.11)	0.0575 e (91.9)	0.4075 d (69.01)	0.675 b (46.55)	0.985 d (53.43)
Sorghum WE + sunflower WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.4 kg a.i.ha^{-1}	0 b (100)	0.4475 c (38.06)	0.5475 c (33.84)	0.17 d (76.05)	0.3625 e (72.43)	0.4925 de (61.01)	1.435 b (32.15)
Sorghum WE + brassica WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.6 kg a.i.ha^{-1}	0.2525 b (94.18)	0.335 ef (53.63)	0.5175 d (37.46)	0.145 d (79.57)	0.405 d (69.2)	0.5575 cd (55.9)	0.625 g (70.45)
Sorghum WE + brassica WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.4 kg a.i.ha^{-1}	0 b (100)	0.375 de (48.1)	0.475 ef (42.59)	0.2825 b (60.21)	0.4325 c (67.11)	0.4325 e (65.75)	0.8425 e (60.17)
Sorghum WE + rice WE+ pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.6 kg a.i.ha^{-1}	0.2325 b (94.65)	0.3 f (58.47)	0.405 g (51.05)	0.0425 e (94.01)	0.355 e (73.0)	0.43 e (65.95)	0.7725 f (63.47)
Sorghum WE + rice WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.4 kg a.i.ha^{-1}	0 b (100)	0.3825 d (47.1)	0.4875 e (41.09)	0.23 c (67.61)	0.4625 b (64.83)	0.585 c (53.68)	0.8525 e (59.69)
LSD value at $p \leq 0.05$		1.521	0.04650	0.01471	0.04650	0.01471	0.06576	0.04650

[1]Days after sowing, [2]Any two means not sharing a letter in common differ significantly at $p \leq 0.05$, [3]The figures in the parentheses show percent decrease over control, [4]Water extract

Table IV: Effect of various allelopathic crop water extracts in combination with reduced rates of pendimethalin on yield parameters of canola

Treatments	Rate	Number of plants m^{-2}	Plant height (cm)	Number of branches per plant	Number of pods per plant	Pod length (cm)	Number of seeds per pod	1000-seed weight (g)
	Extract/herbicide							
Control (weedy check)		20.75[ns]	150.2 c[1]	16.98 d	464.4 e	8.65 c	18.88 e	2.85 d
Pendimethalin (standard dose)	1.2 kg a.i.ha^{-1}	18.5	171.6 b	20.8 ab	609.9 b	9.075 ab	23.08 b	3.225 bc
Sorghum WE[2] + sunflower WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.6 kg a.i.ha^{-1}	18.0	178.6 ab	21.3 ab	640.6 a	9.175 a	26.27 a	3.325 b
Sorghum WE + sunflower WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.4 kg a.i.ha^{-1}	17.75	182.3 a	20.05 bc	572.45 c	8.9 abc	20.67 c	3.6 a
Sorghum WE + brassica WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.6 kg a.i.ha^{-1}	20.25	175.4 ab	19.05 c	581.7 c	8.97 abc	23.45 b	3.15 c
Sorghum WE + brassica WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.4 kg a.i.ha^{-1}	17.75	176.3 ab	18.94 c	560.85 c	8.9 abc	19.8 d	3.275 bc
Sorghum WE + rice WE+ pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.6 kg a.i.ha^{-1}	20.5	178.2 ab	22.3 a	509.55 d	8.8 bc	19.58 de	2.9 d
Sorghum WE + rice WE + pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 0.4 kg a.i.ha^{-1}	19.25	170.8 b	21.3 ab	574.4 d	8.95 abc	22.8 b	2.95 d
LSD value at $p \leq 0.05$			9.831	1.578	24.71	0.3417	0.8637	0.1677

[1]Any two means not sharing a letter in common differ significantly at $p \leq 0.05$, [2]Water extract, NS=Non-significant

pendimethalin at 40 and 60 DAS. Highest reduction in swine cress dry weight (70.45%) was recorded in plots applied with sorghum and *brassica* water extracts each at 15 L ha^{-1} combined with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin at 60 DAS. These results indicated that use of allelopathic extracts in combination with lower herbicide dose may be more effective against this weed.

Different treatments did not significantly affect the number of plant m^{-2} (Table IV) of canola at harvest. It revealed that no treatment had phytotoxic effects on canola plants. The height of the plant is a combined effect of both genetic and environmental factors to which plant is subjected during its growth and development. Weed control treatments significantly influenced canola plant height (Table IV) at harvest. Minimum plant height was recorded in the weedy check that was due to competition between weeds and the canola plants. Maximum plant height (182.3 cm) was noted in plots treated with sorghum and sunflower water extracts each at 15 L ha^{-1} combined with one third rate (0.4 kg a.i. ha^{-1}) of pendimethalin. This can be attributed to certain growth regulatory influence of allelopathic water extracts, because weed control was almost equal to other treatments (Cheema *et al.*, 2002).

Maximum number of branches per plant (Table IV) was recorded in case of sorghum and rice water extracts each at 15 L ha^{-1} combined with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin. Minimum number of branches per plant was recorded in weedy check. Maximum number of pods per plant (Table IV) was noted in plots treated with sorghum and sunflower water extracts each at 15 L ha^{-1} combined with half the recommended dose of pendimethalin (0.6 kg a.i. ha^{-1}) and was followed by the standard dose (1.2 kg a.i. ha^{-1}) of pendimethalin. The minimum number of pods per plant was recorded in case of weedy check. Application of sorghum and sunflower water extracts each at 15 L ha^{-1} combined with (half dose) pendimethalin (0.6 kg a.i. ha^{-1}) produced maximum number of seeds per pod and was followed by application of sorghum and *brassica* water extracts each at 15 L ha^{-1} combined with ½ dose (0.6 kg a.i. ha^{-1}) of pendimethalin. Longest pods were noted in the experimental unit, which was treated with sorghum and sunflower water extracts each at 15 L ha^{-1} combined with half rate (0.6 kg a.i. ha^{-1}) of pendimethalin (Table IV), however the minimum pod length (8.65 cm) was recorded in the control treatment.

Seed weight expresses the extent of translocation of photosynthates towards the economically desirable plant parts. It is an important determinant of grain yield per hectare. Data regarding 1000 seed weight (Table IV) revealed that most of the treatments significantly enhanced 1000 seed weight as compared to control. Combined application of sorghum and sunflower water extracts each at 15 L ha^{-1} with one third dose of pendimethalin (0.4 kg a.i. ha^{-1}) produced heaviest grains, which was followed by sorghum and sunflower water extracts each at 15 L ha^{-1} combined with half dose (0.6 kg a.i. ha^{-1}) of pendimethalin. Minimum seed weight was recorded in the weedy check. Khaliq *et al.* (2002) reported the increase in 1000-seed weight over control by application of sorghum water extract with reduced rates of pendimethalin for weed control in mungbean.

CONCLUSION

It can be inferred that reduced herbicide dose (50-67%) combined with allelopathic crops water extracts can be employed for successful weed management in canola crop. Reduction in herbicide usage will ultimately lead to environmental safety.

REFERENCES

Ashiq, M. and Z.A. Cheema, 2005. *Effective Use of Herbicides*, p: 7. Weed Science Allelopathy Lab. Department of Agronomy University of Agriculture Faisalabad, Pakistan

Cheema, Z.A. and A. Irshad, 2004. Effect of sorghum extract on management of barnyardgrass in rice crop. *Allelopathy J*., 14: 1–8

Cheema, Z.A. and A. Khaliq, 2000 Use of sorghum allelopathic properties to control weeds in irrigated wheat in a semi arid region of Punjab. *Agric. Ecos. Environ.,* 79: 105–112

Cheema, Z.A. and S. Ahmad, 1992. Allelopathy: a potential tool for weed management. *National Seminar on Role of Plant Health and Care in Agricultural Production.* December 28-29, 1988 University of Agriculture Faisalabad, Pakistan

Cheema, Z.A., A. Khaliq and M. Tariq, 2002. Evaluation of concentrated sorgaab alone and in combination with reduced rates of three pre-emergence herbicides for weed control in cotton (*Gossypium hirsutum* L.). *Int. J. Agric. Biol.,* 4: 549–552

Cheema, Z.A., A. Khaliq and N. Iqbal, 2005a. Use of allelopathy in field crops in Pakistan. Establishing the Scientific Base. *Proc. 4th World Congress on Allelopathy*, pp: 550–553. August, 21-26, 2005. Wagga Wagga, Australia

Cheema, Z.A., A. Khaliq and R. Hussain, 2003. Reducing herbicide rate in combination with allelopathic sorgaab for weed control in cotton. *Int. J. Agric. Biol.,* 5: 4–6

Cheema, Z.A., A. Khaliq and S. Saeed, 2004. Weed control in maize *(Zea mays* L.) through sorghum allelopathy. *J. Sustain. Agric.*, 24: 73–86

Cheema, Z.A., A. Khaliq and S. Akhtar, 2001. Use of sorgaab (sorghum water extract) as a natural weed inhibitor in spring mungbean. *Int. J. Agric. Biol.,* 3: 515–518

Cheema, Z.A., A.H. Khichi and A. Khaliq, 2005c. Feasibility of reducing herbicide dose in combination with sorgaab for weed control in transplanted fine rice (*Oryza sativa* L). *Int. J. Agric. Biol.,* 7: 892–894

Cheema, Z.A., B. Ali and A. Khaliq, 2005b. Detemining suitable combination of sorgaab and pendimethalin for weed control in cotton (*Gossypium hirsutum*). *Int. J. Agric. Biol.,* 7: 889–891

Cheema, Z.A., H.M.I. Sadiq and A. Khaliq, 2000b. Efficacy of sorgaab (sorghum water extract) as a natural weed inhibitor in wheat. *Int. J. Agric. Biol.,* 2: 144–146

Cheema, Z.A., M. Asim and A. Khaliq, 2000a. Sorghum allelopahty for weed control in cotton (*Gossypium arboreum*). *Int. J. Agric. Biol.,* 2: 37–41

Clarkson, T.W., 1995. Environmental contaminants in the food chain. *American J. Cli. Nutr.,* 61: 682–686

Heap, I., 2008. *The International Survey of Herbicide Resistant Weeds.* Online Internet. December 02, 2008. Available online: http://www.weedscience.com/

Irshad, A. and Z.A. Cheema, 2005. Comparative efficacy of sorghum allelopathic potential for controlling barnyardgrass in rice. *Proceedings of Fourth World Congress on Allelopathy.* August, 21-26, 2005. Wagga Wagga, Australia

Jabran, K., Z.A. Cheema, M. Farooq, S.M.A. Basra, M. Hussain and H. Rehman, 2008. Tank mixing of allelopathic crop water extracts with pendimethalin helps in the management of weeds in Canola (*Brassica napus*) field. *Int. J. Agric. Biol.,* 10: 293–296

Judith, C.S., A.T. Lemley, S.I. Hogan, R.A. Weismiller and A.G. Hornsby, 2001. *Health Effects of Drinking Water Contaminants.* Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Available online: http://edis.ifas.ufl.edu/SS299

Khaliq, A., Z. Aslam and Z.A. Cheema, 2002. Efficacy of different weed management strategies in mungbean (*Vigna radiata* L.). *Int. J. Agric. Biol.,* 4: 237–239

Kim, K.U., 1994. Integrated management of paddy weeds in Korea with an emphasis on allelopathy. *In*: Bay-Peterson, J. (ed.), *Integrated Management of Paddy and Aquatic Weeds in Asia*, pp: 144–159. Taiwan

Santos, B.M., 2009. Drip-applied metam potassium and herbicides as methyl bromide alternatives for *Cyperus* control in tomato. *Crop Prot.,* 28: 68–71

Snelder, D.J., M.D. Masipiqueña, G.R. De Snoo, 2008, Risk assessment of pesticide usage by smallholder farmers in the Cagayan Valley (Philippines). *Crop Prot.,* 27: 747–762

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