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Tank Mixing of Allelopathic Crop Water Extracts with Pendimethalin Helps in the Management of Weeds in Canola (*Brassica napus*) Field

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ABSTRACT

A field experiment was conducted to investigate the allelopathic effects of sorghum, sunflower, brassica and rice combined with low rates of pendimethalin for weed management in canola (*Brassica napus* L.) field. Crop water extracts at 15 L ha^{-1} each in combination with pendimethalin at 400 and 600 g active ingredient (a.i.) ha^{-1} were sprayed immediately after sowing. Full dose of pendimethalin 1200 g a.i ha^{-1} was used as standard. A weedy check was also maintained for comparison. Sorghum and rice water extracts each at 15 L ha^{-1} combined with 600 g a.i. ha^{-1} showed maximum (67.58 & 66.21%) reduction in total weed density at 40 and 60 days after sowing (DAS), respectively. All the treatments offered more than 80% reduction in total weed dry weight over control at 40 DAS, while 44.93 to 63.99% reduction in total weed dry weight over control at 60 DAS was recorded in all the treatments. The plots treated with sorghum and sunflower water extracts each at 15 L ha^{-1} combined with 600 g a.i. ha^{-1} pendimethalin recorded maximum seed yield (2.604 Mg ha^{-1}), which was 39.99% greater as compared to control. Herbicide dose may be reduced by 50-67% in combination with allelopathic water extracts for effective weed control and higher yields in canola field.

Key Words: Canola; Weed management; Allelopathy; Herbicide reduction; Pendimethalin

INTRODUCTION

In Pakistan, canola is grown on area of 131 thousand ha producing 162 thousand tonnes of canola seeds and 58 thousand tonnes of canola oil. The average yield of canola in Pakistan is 202.8 kg ha^{-1} (Government of Pakistan, 2006), which is very low compared with its potential yield. Heavy weed infestation is an important reason for low yields in canola. Weeds not only compete with crop plants for nutrients, water space and light but also give refuge to pests and diseases; interfere with crop growth by releasing allelopathic substances into the rhizosphere of the crop plants (Rice, 1984), interfere with harvest operations, and increase the processing costs and significantly reduce (21-45%) the crop yields (Ashiq & Ata, 2005). Herbicides offer promising increase in crop yield through effective weed control. However non-judicious use of herbicides has resulted in environmental and health problems. It has also been found that in some cases herbicide use can cause some weed species to dominate fields, because the weeds develop resistance to herbicides (Heap, 2007). Environmental, health and resistance development issues, therefore, have warranted the development of economical and environment friendly technologies for weed control.

Use of herbicides can be reduced by exploiting allelopathy as an alternate weed management tool. Cheema *et al.* (2003a) proposed the use of allelopathic crop water extracts combined with lower herbicide rates as an economically viable and environment friendly weed control technique. Herbicides and allelopathic products can work complementary and the herbicidal dose might be reduced when applied in combination with allelopathic products and effectiveness of the allelopathic products i.e., sorghum water extract could be enhanced by using with lower rates of herbicides (Cheema *et al.,* 2005).

Present study was therefore, conducted to explore the possibilities of reducing herbicide use in combination with allelopathic crop water extracts and to evaluate the combined effects sorghum, sunflower, brassica and rice water extracts on weed growth in canola field. Another objective of the study was to exploit the efficacy of allelopathic crop water extracts by mixing them with a common pre-emergence herbicide pendimethalin.

MATERIALS AND METHODS

An experiment was conducted at Agronomic Research Farm, University of Agriculture Faisalabad, (31.5° N, 73.09° S) during winter 2005-2006 to investigate the allelopathic effects of sorghum, sunflower, rice and brassica

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water extract with low rates of pendimethalin for weed control in canola field. Seeds of canola hybrid "Hyola 401" were obtained from ICI Pakistan (Pvt.) Limited and were planted in 30 cm apart rows with hand drill on 6th of October 2005. Experiment was laid out in a randomized complete block design with four replications. The net plot size was 2.4 m x 5 m. Seed rate of 5 kg ha^{-1} was used for sowing. Nitrogen was applied at 90 kg ha^{-1} while phosphorus was applied at 60 kg ha^{-1}. All the phosphorus fertilizer was drilled at sowing, while nitrogen was applied in three equal splits at sowing, first irrigation and second irrigation.

Crop water extracts were prepared following the procedures reported by Cheema *et al.* (2000). Crop water extracts at 15 L ha^{-1} each were tank mixed with pendimethalin at 400 and 600 g 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 (1200 g a.i. ha^{-1}) was used as standard. A weedy check was also maintained for comparison. Weed density and dry weight were recorded at 40 and 60 days after sowing (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 for 72 h before recording their dry weight. Crop was harvested on 21st March 2006. Harvested crop was kept under sunlight for one week to dry. Biological yield of each plot was recorded through spring balance and then converted to Mg ha^{-1}. The crop was threshed manually and the seeds obtained were weighed and then converted into seed yield (Mg ha^{-1}). The harvest index (HI) was calculated as the ratio of seed yield to biological yield and was expressed in %. Economic and marginal analyses were performed according to procedure laid out by (CIMMYT, 1988). 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 in the treatment means.

RESULTS AND DISCUSSION

Weed flora of the experimental field consisted of purple nutsedge (*Cyperus rotundus* L.), horse purslane (*Trianthema portulacastrum* L.), lambsquarters (*Chenopodium album* L.) and swine cress (*Cronopus didymus* L.). Data (Table I) revealed that all the treatments significantly suppressed total weed density over control. Combined spray of sorghum and rice water extracts each at 15 L ha^{-1} with pendimethalin at 600 g a.i. ha^{-1} gave 67.58% inhibition in total weed density over control and it was followed by sorghum and brassica water extracts each at 15 L ha^{-1} combined with half the recommended rate of pendimethalin, with 59.01% reduction in total weed density was recorded at 40 DAS (days after sowing). Application of sorghum and rice water extracts each at 15 L ha^{-1} with 600 g a.i. ha^{-1} pendimethalin and the combined spray of sorghum and brassica water extracts each at 15 L ha^{-1} with 600 g a.i. ha^{-1} pendimethalin suppressed total weed density by 66.21 AND 63.83% respectively as compared with control at 60 DAS. All the treatments significantly decreased more than 80% reduction in total weed dry weight at 40 DAS as compared to control (Table I). Minimum weed dry weight at 60 DAS was recorded in plots applied with sorghum and brassica water extracts each at 15 L ha^{-1} combined with pendimethalin at 600 g a.i. ha^{-1} and sorghum and rice water extracts each at 15 L ha^{-1} combined with pendimethalin at 600 g a.i. ha^{-1} and both the treatments were statistically similar. Full dose of pendimethalin at 1200 g a.i. ha^{-1} was comparatively less effective at 60 DAS showing 45.39% reduction in total weed dry weight over control.

Reduction in total weed dry weight at 60 DAS was lesser as compared to that recorded at 40 DAS that might be due to loss in efficacy of herbicide and water extracts over time. These results indicated that the half dose of herbicide tank mixed with allelopathic crop water extracts offer better weed control than the full dose of herbicide. This might be attributed to strong allelopathic influence of different crop water extracts and increase in herbicide efficacy when combined with allelopathic crop water extracts. Similar results have been reported by Cheema and Irshad (2004) on sorghum allelopathy for barnyard grass management in rice. It is inferred from above mentioned results that pendimethalin dose can be reduced upto 50-67% when combined with allelopathic water extracts for weed control in canola field. Similarly, Cheema *et al.* (2002) suggested that pendimethalin dose can be reduced (more than 50%) when combined with concentrated sorghum water extract. Reducing herbicide dose in combination with allelopathic products for controlling weeds in field crops has been previously suggested by Cheema *et al.* (2003b, 2005).

Minimum seed yield was recorded in weedy check that was due to competition for resources i.e., nutrients, light, space and water among the weeds and the crop plants (Table II). All the treatments increased seed yield over control. Maximum seed yield 2.604 Mg ha^{-1} was recorded in plots where sorghum and sunflower water extracts each at 15 L ha^{-1} combined with 600 g a.i. ha^{-1} pendimethalin were applied and this was 39.99% more over control and 2.94% more as compared with full dose (1200 g a.i. ha^{-1}) of pendimethalin. Sorghum and brassica water extracts each at 15 L ha^{-1} with 600 g a.i. ha^{-1} pendimethalin produced grains equal to the full dose (1200 g a.i. ha^{-1}) of pendimethalin. Khaliq *et al.* (2002) reported increase in mungbean grain yield over control with application of sorghum water extract tank mixed with reduced dose of pendimethalin. Similar results were reported by Cheema *et al.* (2003b).

Greatest increase in biological yield (Table II) over control was recorded in case of sorghum and rice water extracts each at 15 L ha^{-1} combined with pendimethalin at 400 g a.i. ha^{-1}. Minimum biological yield (9.077 Mg ha^{-1}) was recorded in the weedy check. The increase in biological yield in different treatments over control was due to

Table I. Effect of various allelopathic crop water extracts in combination with reduced rates of pendimethalin on total weed density and weed dry weight in canola

Treatments	Rate	Total Weed Density (0.25 m^2)		Total Weed Dry Weight (g/0.25 m^2)	
	Extract/Herbicide	40 DAS[1]	60 DAS	40 DAS	60 DAS
Control (weedy check)		86.0 A[2]	46.88 A	7.037 A	4.258 A
Pendimethalin	1200g a.i.ha^{-1}	43.25 C	25.38 C	1.285 B	2.325 B
		(49.7)[3]	(46)	(81.73)	(45.39)
Sorghum WE[4] + Sunflower WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 600g a.i.ha^{-1}	40.0 CD (53.49)	27.0 C (42.55)	1.095 B (84.43)	1.855 C (56.43)
Sorghum WE + Sunflower WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 400g a.i.ha^{-1}	45.88 BC (46.65)	33.13 B (29.51)	1.11 B (84.23)	2.345 B (44.93)
Sorghum WE + Brassica WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 600g a.i.ha^{-1}	35.25 D (59.01)	17.0 E (63.83)	1.29 B (81.67)	1.548 E (63.66)
Sorghum WE + Brassica WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 400g a.i.ha^{-1}	44.0 C (48.84)	22.75 D (51.59)	1.09 B (84.51)	1.75 D (58.9)
Sorghum WE + Rice WE+ Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 600g a.i.ha^{-1}	27.88 E (67.58)	15.88 E (66.21)	1.005 B (85.71)	1.533 E (63.99)
Sorghum WE + Rice WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 400g a.i.ha^{-1}	51.5 B (40.12)	26.88 C (42.81)	1.197 B (82.99)	1.803 CD (57.65)

[1]Days after sowing [2]Any two means not sharing a letter in common differ significantly at P<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 biological yield (Mg ha^{-1}), seed yield (Mg ha^{-1}) and harvest index (%) of canola

Treatments	Rate	Biological Yield (Mg ha^{-1})	Seed Yield (Mg ha^{-1})	Harvest Index (%)
	Extract/Herbicide			
Control (weedy check)		9.077 D[1]	1.86 F	20.61 E
Pendimethalin	1200g a.i.ha^{-1}	10.56 BC	2.529 B (35.99)[2]	23.95 AB
Sorghum WE[3] + Sunflower WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 600g a.i.ha^{-1}	10.79 AB	2.604 A (39.99)	24.14 AB
Sorghum WE + Sunflower WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 400g a.i.ha^{-1}	10.71 B	2.455 C (32.0)	23.54 BC
Sorghum WE + Brassica WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 600g a.i.ha^{-1}	9.97 C	2.529 B (35.99)	25.14 A
Sorghum WE + Brassica WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 400g a.i.ha^{-1}	11.09 AB	2.381 D (28.0)	21.5 DE
Sorghum WE + Rice WE+ Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 600g a.i.ha^{-1}	10.04 C	2.232 E (19.99)	22.26 CD
Sorghum WE + Rice WE + Pendimethalin	15 L ha^{-1} + 15 L ha^{-1} + 400g a.i.ha^{-1}	11.38 A	2.455 C (32.0)	21.6 DE

[1]Means not sharing a letter in common differ significantly at P<0.05. [2]The figures in the parentheses show percent increase over control. [3]Water extract

Table III. Economic analysis of allelopathic crop water extracts in combination with reduced rates of pendimethalin used for weed control in canola field

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Remarks
Total seed yield	1.86	2.529	2.604	2.455	2.529	2.381	2.232	2.455	Mg ha^{-1}
Adjusted yield	1.674	2.276	2.343	2.209	2.276	2.142	2.008	2.209	Mg ha^{-1}
Gross income	50222.7	68302.8	70311.6	66293.7	68302.8	64287.0	60267.0	66293.7	Rs: 1200 per 40 kg
Cost of herbicide	0	1272.73	636.4	424.2	636.4	424.2	636.4	424.2	Rs: 350 per L
Cost of extracts	0		120	120	120	120	120	120	Rs: 60 per 15 L
Spray rent	0	60	60	60	60	60	60	60	
Spray application	0	120	120	120	120	120	120	120	
Cost that vary	0	1452.73	936.4	724.2	936.4	724.2	936.4	724.2	
Net benefit	50222.7	66850.07	69375.2	65569.5	67366.4	63562.8	59330.6	65569.5	Rs ha^{-1}

T_1 = Control (weedy check); T_2 = pendimethalin (Stomp, 330EC) at 1200 g a.i ha^{-1}; T_3= sorghum and sunflower WE each at 15 L ha^{-1} + pendimethalin at 600 g a.i. ha^{-1}; T_4 = sorghum and sunflower WE each at 15 L ha^{-1} + pendimethalin at 400 g a.i. ha^{-1}; T_5 = sorghum and brassica WE each at 15 L ha^{-1} + pendimethalin at 600 g a.i. ha^{-1}; T_6 = sorghum and brassica WE each 15 L ha^{-1} + pendimethalin at 400 g a.i. ha^{-1}; T_7 = sorghum and rice WE each at 15 L ha^{-1} + pendimethalin at 600 g a.i. ha^{-1}; T_8 = sorghum and rice WE each at 15 L ha^{-1} + pendimethalin at 400 g a.i ha^{-1}

effective weed control. Erman *et al*. (2003) also reported that effective weed control increases biological yield. Different treatments significantly improved harvest index over control (Table II). Minimum harvest index 20.61% was recorded in weedy check. Maximum harvest index 25.14% was recorded in plots treated with sorghum and brassica water extracts each at 15 L ha^{-1} combined with 600 g a.i. ha^{-1} pendimethalin and was followed by sorghum and sunflower

Table IV. Marginal analysis of allelopathic crop water extracts in combination with reduced rates of pendimethalin used for weed control in canola field

Treatments	Cost that vary	Net benefits Rs.	Change in cost	Change in net benefit	Marginal rate of return %
T_1 = Control	0	50222.7	-	-	-
T4 = Sorghum + sunflower WE each at 15 L ha^{-1} + pendimethalin (Stomp, 330EC) 400 g a.i. ha^{-1} (pre-emergence)	724.2	65569.5	724.2	15346.8	2059.5
T8 = Sorghum + rice W.E.each at 15 L ha^{-1} + pendimethalin 400 g a.i ha^{-1} (pre-emergence)	724.2	65569.5	724.2	15346.8	2059.5
T6 = Sorghum + brassica WE each 15 L ha^{-1} + pendimethalin 400 g a.i. ha^{-1} (pre-emergence)	724.2	63562.8	-	-	D
T3 = Sorghum + sunflower WE each at 15 L ha^{-1} + pendimethalin 600 g a.i. ha^{-1} (pre-emergence)	936.4	69375.2	212.2	3805.7	1793.45
T5 = Sorghum + brassica WE each at 15 L ha^{-1} + pendimethalin 600 g a.i. ha^{-1} (pre-emergence)	936.4	67366.4	-	-	D
T7 = Sorghum + rice WE each at 15 L ha^{-1} + pendimethalin 600 g a.i. ha^{-1} (pre-emergence)	936.4	59330.6	-	-	D
T2 = Pendimethalin at 1200 g a.i ha^{-1} (pre-emergence)	1452.73	66850.07	-	-	D

D=dominated due to less benefits than preceding treatments; variable cost is the cost of purchase of inputs, labor and machinery ha^{-1} that vary among the treatments; net benefit is gross income less variable cost; marginal rate of return % (MRR) is change in net benefit divided by variation in cost (%).

water extracts each at 15 L ha^{-1} combined with pendimethalin at 600 and 1200 g a.i. ha^{-1} of pendimethalin. The results are supported by findings of Khaliq *et al.* (2002) who reported increase in harvest index by incorporating sorghum allelopathy as weed control technique. The usefulness of a weed control method is evaluated on the basis of its economics. Economic and marginal analyses of the experiment are given in Table III and IV, respectively.

Maximum net benefits (Rs. 69375.2 ha^{-1}) were obtained from sorghum and sunflower water extracts each at 15 L ha^{-1} combined with half the recommended dose of pendimethalin (600 g a.i. ha^{-1}). Sorghum and sunflower water extracts each at 15 L ha^{-1} combined with $1/3^{rd}$ the recommended dose of pendimethalin (400 g a.i. ha^{-1}), sorghum and rice water extracts each at 15 L ha^{-1} combined with $1/3^{rd}$ the recommended dose of pendimethalin, sorghum and sunflower water extracts each at 15 L ha^{-1} combined with half the recommended dose of pendimethalin were the economical treatments with 2059.5%, 2059.5% and 1793.45% marginal rates of returns, respectively. The results are supported by the findings of Cheema *et al*. (2002) who stated Rs. 44445.9 net benefit and 426.7% marginal rate of return by application of sorghum water extract at 12 L ha^{-1} combined with 500 g a.i. ha^{-1} of pendimethalin for weed control in cotton.

The findings of this study suggest that sorghum + sunflower combinations were better than sorghum + brassica or rice. Moreover, it is also noted that herbicide dose may be reduced by 50-67% in combination with allelopathic crop water extracts. Furthermore, it may be meaningful to continue studied with different combinations of water extracts.

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