

Increasing the Efficiency of Sorghum Water Extract (Sorgaab) by Mixing with Lower Doses of Isoproturon to Control Weeds in Wheat

MUHAMMAD JAMIL, ZAHID ATA† AND ABDUL KHALIQ†

National Agricultural Research Center, Islamabad-Pakistan

†Department of Agronomy, University of Agriculture, Faisalabad- 38040, Pakistan

¹Corresponding author's e-mail: jamil_narc@yahoo.com

ABSTRACT

The proposed field study to enhance the efficiency of conc. sorgaab (*Sorghum bicolor* water extracts) by mixing it with lower doses of isoproturon to control weeds in wheat was carried out during two years. Concentrated sorgaab was combined with reduced rates of isoproturon i.e. 150, 300, 450, 600 and 1000 g a. i. ha⁻¹. Two sorgaab sprays each at 30 and 30 + 40 days after sowing (DAS) and a weedy check was also included. One foliar spray of conc. sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ appeared best treatment combinations with maximum reduction of total weed density (89-97%) and dry weight (91-99%) and this decrease was statistically equal to the standard dose of isoproturon @ 1000 g a. i. ha⁻¹. Sorgaab along with isoproturon reduced total weed density and biomass due to both allelopathic and herbicidal activities. Maximum increase in grain yield was obtained in plots treated with conc. sorgaab @ 12 L ha⁻¹ and isoproturon @ 600 g a. i. ha⁻¹ combination at 30 DAS. The yield influencing parameters as plant height, spike length, number of productive tillers m⁻², spikelets per spike and grains per spike were also significantly influenced by all the treatments and conc. sorgaab @ 12 L ha⁻¹ and isoproturon @ 600 g a. i. ha⁻¹ combination at 30 DAS performed better. Moreover T₁₁ i.e. one spray of conc. sorgaab @ 12 L ha⁻¹ with isoproturon @ 600 g a. i. ha⁻¹ appeared the best treatment among sorgaab and isoproturon combination with higher net benefits and MRR% during both years.

Key Words: Wheat; Weed control; Sorghum water extract; Isoproturon

INTRODUCTION

Sorgaab (Sorghum Water extract) used as foliar spray has been found to inhibit the dry weight of several weeds as *Avena fatua*, *Phalaris minor*, *Chenopodium album*, *Rumex dentatus*, *Anagallis arvensis*, *Cyperus rotundus*, *Convolvulus arvensis*, *Senibera didyma* and certain other weeds (Ahmad *et al.*, 1991; Cheema, 1999; Cheema *et al.*, 2000; 2002; 2003c). The suppression of weeds by sorgaab generally ranged between 28-48% (Cheema *et al.*, 2002), which is insufficient control. For minimizing the damage caused by weeds and to bring it to the economic threshold level, the weeds must be controlled up to 80% or more depending upon the nature of the weeds and the extent of infestation (Jalis & Shah, 1984). Isoproturon is widely used in Pakistan for weed control in wheat crop. Continuous use of one herbicide, might favour development of resistant biotypes or the herbicide may lose its effectiveness. Therefore, it is always required to develop new strategies for getting efficient weed control. One aspect is combination or mixing of different herbicides, another possibility is to combine herbicides with natural phytotoxins (Einhelling & Leather, 1988). This might provide environmentally safer and economically viable combinations. Some of the recent studies (Cheema *et al.*, 2003a, e) indicated that combination

of sorgaab @ 12 L ha⁻¹ with lower dose of herbicide as Atrazine @ 150 g a. i. ha⁻¹ was as effective as the full dose of the respective herbicide @ 300 g a. i. ha⁻¹ for controlling weeds. The present study was contemplated to explore possible reduction of isoproturon dose in combination with sorgaab, an allelopathic water extract for getting weed control up to 80-95% or similar to full dose of herbicides.

MATERIALS AND METHODS

The field trials to improve the efficiency of sorgaab (*Sorghum bicolor* water extracts) by combining with lower doses of isoproturon, was carried out at the Agronomic Research Area, University of Agriculture, Faisalabad for two years. The experiment was laid out in randomized complete block design (RCBD) with three replications in 7m x 2m plot size. Sorghum (*Sorghum bicolor* L.) was harvested at maturity, dried for a few days, chopped with electric fodder cutter into 2cm pieces and stored under shade. This chopped material was soaked in distilled water for 24 hours at room temperature (21°C) in a ratio of 1:10 (W/V) and were filtered with the help of sieve (10 & 60 mesh) according to procedure devised by Cheema *et al.* (1998). The extract was boiled at 100°C to concentrate up to 20 times for easy handling and application. The

concentrated sorghum water extract along with lower doses of organic compounds were used as a post emergence spray in the respective plots. In this trial twelve treatments were design to study their effects on weeds. Concentrated sorgaab each @ 6 and 12 L ha⁻¹ were combined with reduced rates of isoproturon i.e.150, 300, 450 and 600 g a.i.ha⁻¹. In other treatments two sorgaab sprays each at 30 and 30 + 40 days after sowing (DAS) and a weedy check were included. Standard dose of isoproturon @ 1000 g a. i. ha⁻¹ was also applied for comparison.

Wheat cv. Punjab-96 was planted in the first week of November by using single row hand drill in 25 cm apart rows. A basal dose of fertilizers in the form of Urea (46%N), Diammonium phosphate (18%N: 46%P₂O₅) and Sulphate of potash (50% K₂O) were used and applied @ 110-55-60 kg NPK ha⁻¹. The whole phosphorous and potassium and half of nitrogen, was applied at the time of sowing. The remaining half nitrogen was applied with second irrigation. The first irrigation was given 10 days after emergence of crop and subsequent irrigations were given according to the need of the crop. Volume of spray (320 L ha⁻¹) was determined by calibration. Spray was done with knapsack hand sprayer fitted with flat fan nozzle.

All other agronomic operations except those under study were kept normal and uniform for all the treatments. Standard procedures were adopted for recording the data on various growth and yield parameters. Data collected were statistically analysed by using the Fisher's Analysis of Variance technique and Duncan's New Multiple Range (DNMR) test at 0.05P was applied to compare the differences among treatments (Steel & Torrie, 1984).

RESULTS

Concentrated sorgaab combined with different doses of isoproturon exhibited significant effect on total weed density (Table I). Among sorgaab and isoproturon combinations, one foliar spray at 30 DAS of sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₁₁) appeared the best treatment combination with 89-97% suppression of total weed density recorded at 60 DAS during both years of study. Application of sorgaab @ 6 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₇) and sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 450 g a. i. ha⁻¹ (T₁₀) were the next better treatments reducing weed density by 87-88 and 86-90%, respectively during both years. These treatments were statistically equal to the full dose of isoproturon @ 1000 g a. i. ha⁻¹ (92-99%). The isoproturon and sorghum water extract worked complementarily and thus sorghum water extract along with lower isoproturon rates suppressed total weed density almost equal to the full dose of isoproturon and suggesting that the dose of isoproturon can be reduced by 40-55% in combination with sorgaab @ 6 or 12 L ha⁻¹.

Total weed dry weight was significantly reduced by all the treatments over control (Table I). One spray of sorgaab

@ 12 L ha⁻¹ along with isoproturon @ 600 g a. i. ha⁻¹ (T₁₁) reduced total weed dry weight by 91-99% at 60 DAS during both years of study and it was as effective as full dose of isoproturon @ 1000 g a. i. ha⁻¹ (94-100%). Sorgaab @ 12 L ha⁻¹ along with isoproturon @ 450 g a. i. ha⁻¹ (T₁₀) and sorgaab @ 6 L ha⁻¹ along with isoproturon @ 600 g a. i. ha⁻¹ (T₇) were the next better treatments reducing weed dry weight by 83-92 and 82-83%, respectively during both years. The allelochemicals in sorgaab exerted supplementary effects with the lower doses of isoproturon.

Plant height was significantly affected by different treatments during both the years (Table II). Maximum plant height (93-102 cm) was observed in case of one foliar spray of sorgaab @ 12 L ha⁻¹ with isoproturon @ 600 g a. i. ha⁻¹ and it was statistically on par with full dose of isoproturon @ 1000 g a. i. ha⁻¹. One foliar spray of sorgaab @ 6 L ha⁻¹ with isoproturon @ 600 g a. i. ha⁻¹ also produced taller plants (91-100 cm) after the preceding treatments. One or two sprays of sorgaab @ 12 L ha⁻¹ had only 82 to 95 cm plant height but when isoproturon @ 600 g a. i. ha⁻¹ was applied in combination with sorgaab @ 12 L ha⁻¹ the plant height increased up to 97.22 cm. The increase in wheat plant height was possibly due to better inhibition and suppression of weeds resulting in less competition with wheat for growth factors. Similarly, higher number of productive tillers (306-446 m⁻²) were found by the application of sorgaab @ 12 L ha⁻¹ combined with lower dose of isoproturon @ 600 g a. i. ha⁻¹ (T₁₁) during both years of study, among the sorgaab and isoproturon combination and it was statistically equal to the herbicidal treatment (full dose of isoproturon @ 1000 g a. i. ha⁻¹) producing 307-451 tillers m⁻². It was followed by one spray of sorgaab @ 6 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₇) having 291-438 tillers m⁻². Sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₁₁) produced 51.40-54.17 grains per spike during both years of study which were statistically on par with full dose of isoproturon @ 1000 g a. i. ha⁻¹ producing 51.83-54.30 grains per spike during both years. The treatment combinations as T₇, T₉ and T₁₀ also produced fairly good number of grains per spike. One foliar spray of sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₁₁) was as effective as full dose isoproturon. The increase in grain number may be attributed to suppression of weeds and reduction of competition. 1000-grain weight was affected by various treatments during 1st year of study and during 2nd year no treatment could reach the level of significance (Table III). Application of one foliar spray of sorgaab @ 6 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₇) produced heavier grains during 1st year and it was statistically on par with T₁₀, T₁₁ and T₄. One foliar spray of sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 300 g a. i. ha⁻¹ (T₉) resulted in lighter grain weight (36.17 g) during 1st year.

Grain yield of wheat was also significantly improved by different treatments as compared to control (weedy check) during both the years of experimentation (Table III).

Table I. Total weed density (m⁻²) and total weed dry weight (g m⁻²) at 60 DAS as affected by sorgaab with lower doses of Isoproturon

Treatments	Total weed density (m ⁻²)					Total weed dry weight (g m ⁻²)				
	1 st year		2 nd year		Mean	1 st year		2 nd year		Mean
T ₁ Control (weedy check)	304.00a ¹	(-) ²	118.67a ¹	(-) ²	211.33	161.70a ¹	(-) ²	70.52a ¹	(-) ²	116.11
T ₂ Conc. sorgaab @ 12 L ha ⁻¹ (30 DAS)	272.67a	(10.31)	106.67a	(10.11)	189.67	113.81b	(29.62)	44.35b	(37.11)	79.08
T ₃ Conc. sorgaab @ 12 L ha ⁻¹ (30 + 40DAS)	214.00b	(29.61)	78.67b	(33.71)	146.33	89.63c	(44.57)	31.08cd	(55.93)	60.36
T ₄ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	145.33c	(52.19)	53.33c	(55.06)	99.33	96.43c	(40.36)	38.04bc	(46.06)	67.23
T ₅ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	122.00c	(59.87)	48.00c	(59.55)	85.00	75.70d	(53.18)	31.51cd	(55.31)	53.61
T ₆ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	65.33d	(78.51)	24.00d	(79.78)	44.67	47.95e	(70.35)	18.17e	(74.24)	33.06
T ₇ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	40.00de	(86.84)	14.67de	(87.64)	27.33	29.77f	(81.59)	11.94ef	(83.07)	20.86
T ₈ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	120.00c	(60.53)	45.33c	(61.80)	82.67	72.14d	(55.39)	27.53b	(60.96)	49.83
T ₉ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	66.67d	(78.07)	25.33d	(78.65)	46.00	39.30ef	(75.70)	15.91e	(77.44)	27.60
T ₁₀ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	44.00de	(85.53)	12.00de	(89.89)	28.00	27.14fg	(83.22)	5.64fg	(92.01)	16.39
T ₁₁ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	33.33de	(89.04)	4.00e	(96.63)	18.67	15.26gh	(90.56)	0.90g	(98.72)	8.08
T ₁₂ Isoproturon @ 1000 g a. i. ha ⁻¹ (standard)	25.33e	(91.67)	1.33e	(98.88)	13.33	9.63h	(94.05)	0.00g	(100.0)	4.82
LSD	33.24		14.09			13.27		3.051		

1. Means not sharing a letter in common differ significantly at 0.05 p
2. Figures in parenthesis show percent decrease over control

Table II. Yield component and yield of wheat as affected by sorgaab with lower doses of Isoproturon

Treatments	Plant height (cm)		Spike length (cm)		Number of productive tillers m ⁻²		Number of spikelets per spike	
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year
T ₁ Control (weedy check)	87.27e ¹	79.04f ¹	10.92f ¹	9.24d ¹	279.67e	220.33f ¹	18.10e	15.27b ¹
T ₂ Conc. sorgaab @ 12 L ha ⁻¹ (30 DAS)	93.75d	81.63ef	11.50ef	9.33d	295.00ef	233.33e	18.90d	15.35b
T ₃ Conc. sorgaab @ 12 L ha ⁻¹ (30 + 40DAS)	94.62d	86.33cd	11.47ef	10.48abc	305.33ef	245.33e	19.50c	16.83ab
T ₄ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	95.49cd	83.13cde	11.55def	9.27d	334.00de	237.67e	19.67bc	16.05ab
T ₅ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	96.28bcd	83.81cde	12.27bcde	9.44cd	362.00cd	275.33d	20.27ab	17.30ab
T ₆ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	98.85abc	87.03bc	12.22bcde	9.87cd	397.00bc	278.33cd	20.63a	17.36ab
T ₇ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	99.63ab	90.68ab	12.52abc	10.51abc	438.33ab	291.00b	20.77a	17.80a
T ₈ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	94.88d	82.60def	11.76cde	9.52cd	337.00de	243.67e	19.73bc	17.32ab
T ₉ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	96.10bcd	83.65cde	12.32bcd	9.69cd	372.00cd	275.67d	20.43a	17.37ab
T ₁₀ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	97.23bcd	84.63cde	12.65ab	10.08bcd	399.00bc	288.33bc	20.87a	17.92a
T ₁₁ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	101.72a	92.72a	13.20a	11.18a	445.67a	305.67a	20.90a	18.20a
T ₁₂ Isoproturon @ 1000 g a. i. ha ⁻¹ (standard)	101.88a	90.62ab	13.22a	10.97ab	451.00a	307.00a	20.93a	18.03a
LSD	3.320	3.508	0.730	0.958	39.99	12.02	0.589	1.972

1. Means not sharing a letter in common differ significantly at 0.05 p
2. Figures in parenthesis show percent increase over control

One foliar spray of sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (T₁₁) significantly enhanced grain yield by 79-153% over control during both years of study and it was statistically on par with full dose of isoproturon. It was followed by one foliar spray of sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 450 g a. i. ha⁻¹ (T₁₀) increasing wheat yield by 65-89% during both years. Sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ was as effective as full dose of isoproturon and in this

way about 40% herbicide use can be reduced by mixing with sorgaab @ 12 L ha⁻¹. The increase in wheat grain yield under different treatments may be attributed to suppression of weed density and growth, which favoured increase in number of tillers m⁻², number of spikelets per spike and number of grains per spike.

All the treatments gave higher net income as compared to control while full dose of isoproturon @ 1000 g a. i. ha⁻¹ was the best treatment combination with

Table III. Yield component and yield of wheat as affected by sorgaab with lower doses of Isoproturon

Treatments	Number of grains per spike		1000-grain weight (g)		Grain yield (t ha ⁻¹)		1 st year (+)	2 nd year (+)
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year		
T ₁ Control (weedy check)	48.67d	44.65c ¹	38.59abc ¹	40.66 ²	2.60g ¹	(+) ³	2.46f	(+) ³
T ₂ Conc. sorgaab @ 12 L ha ⁻¹ (30 DAS)	50.52c	44.65c	36.56ef	40.79	3.09fg	(15.99)	2.91ef	(17.81)
T ₃ Conc. sorgaab @ 12 L ha ⁻¹ (30 + 40DAS)	51.17bc	45.80c	37.54cde	40.68	3.53ef	(32.23)	3.60bcd	(45.75)
T ₄ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	51.20bc	44.72c	38.59abc	41.46	3.89de	(45.98)	3.14de	(27.31)
T ₅ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	51.90bc	47.07bc	36.46ef	40.51	4.49bcd	(68.48)	3.45cd	(39.81)
T ₆ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	52.03b	47.70bc	37.31de	40.29	4.79bc	(79.73)	3.50cd	(41.70)
T ₇ Conc. sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	52.37b	50.20ab	39.17a	41.00	4.88bc	(82.85)	3.88bc	(57.20)
T ₈ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	51.63bc	45.37c	38.50abc	40.64	4.28cd	(60.35)	3.21de	(30.13)
T ₉ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	52.00b	49.35ab	36.17f	40.38	4.54bcd	(70.10)	3.66bcd	(48.36)
T ₁₀ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	52.25b	50.53ab	38.74ab	40.02	5.03b	(88.60)	4.07ab	(64.68)
T ₁₁ Conc. sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	54.17a	51.40a	38.96ab	40.52	6.75a	(152.97)	4.43a	(79.18)
T ₁₂ Isoproturon @ 1000 g a. i. ha ⁻¹ (standard)	54.30a	51.83a	38.00bcd	40.15	7.25a	(171.84)	4.56a	(84.52)
LSD	1.294	3.139	1.01	-	0.671		0.482	

1. Means not sharing a letter in common differ significantly at 0.05 p

2. Non-significant

3. Figures in parenthesis show percent increase over control

Table IV. Economic Analysis 1st year

	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂	Remarks
Total grain yield	2.60	3.09	3.53	3.89	4.49	4.79	4.88	4.28	4.54	5.03	6.75	7.25	t ha ⁻¹
10% less	0.26	0.31	0.35	0.39	0.45	0.48	0.49	0.43	0.45	0.50	0.67	0.73	t ha ⁻¹
Adjusted yield	2.34	2.78	3.17	3.50	4.04	4.31	4.39	3.85	4.08	4.53	6.07	6.53	t ha ⁻¹ (10% reduction)
Gross income (Rs. ha ⁻¹)	17572.5	20880.0	23805.0	26280.0	30330.0	32355.0	32917.5	28867.5	30622.5	33952.5	45540.0	48937.5	wheat grain price @ Rs.750/100kg
Cost of Sorg WE	-	40.00	80.00	20.00	20.00	20.00	20.00	40.00	40.00	40.00	40.00	-	Rs. 20/40 kg sorghum, 1/4 man day for preparing sorgaab
Cost of herbicide	-	-	-	112.50	225.00	337.50	450.00	112.50	225.00	337.50	450.00	750.00	Rs.840/1000 g a. i.
Spray application cost	-	100.00	200.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	Rs.100/man (one man /day/ha)
Spray rent	-	50.00	100.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	Rs.50/spray
Cost that vary	-	190.00	380.00	282.50	395.00	507.50	620.00	302.50	415.00	527.50	640.00	900.00	Rs. ha ⁻¹
Net benefit	17572.5	20690.0	23425.0	25997.5	29935.0	31847.5	32297.5	28565.0	30207.5	33425.0	44900.0	48037.5	Rs. ha ⁻¹

T₁ = Control (weedy check), T₂ = Conc. sorgaab @ 12 L ha⁻¹ (40 DAS), T₃ = Conc. sorgaab @ 12 L ha⁻¹ (30+40 DAS), T₄ & T₈ = Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹ + isoproturon @ 150 g a. i. ha⁻¹ (30 DAS) T₅, T₉ = Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹ isoproturon @ 300 g a. i. ha⁻¹ (30 DAS) T₆, T₁₀ = Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹ + isoproturon @ 450 g a. i. ha⁻¹ (30 DAS) T₇, T₁₁ = Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹ + isoproturon @ 600 g a. i. ha⁻¹ (30 DAS) T₁₂ = Isoproturon @ 1000 g a. i. ha⁻¹ (30 DAS)

maximum net benefits (Rs. 29880-48038) during both years of experimentation (Tables IV & V) and followed by one foliar spray of sorgaab @ 12 L ha⁻¹ combined with isoproturon @ 600 g a. i. ha⁻¹ (Rs. 29263-44900). The other next better treatment was one spray of sorgaab @ 12 L ha⁻¹ with lower dose of isoproturon @ 450 g a. i. ha⁻¹ (T₁₀) with net benefits (Rs. 26945-33425). The dominance and marginal analysis (Tables VI & VII) reveal that during 1st year treatments T₃ and T₇ and during 2nd year treatments T₅, T₆ and T₇ were dominated while the rest of the treatments showed returns on each additional expenditure. These

results show that use of full dose of isoproturon was economical treatment however the treatment combination as sorgaab @ 12 L ha⁻¹ plus isoproturon @ 600 g a. i. ha⁻¹ was better in terms of higher MRR% and environmental safety with 40% reduction in the herbicide usage.

DISCUSSION

Sorgaab (Sorghum water extract) combined with lower doses of isoproturon significantly suppressed total as

Table V. Economic Analysis 2nd year

	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂	Remarks
Total yield	grain 2.46	2.91	3.60	3.14	3.45	3.50	3.88	3.21	3.66	4.07	4.43	4.56	t ha ⁻¹
10% less	0.25	0.29	0.36	0.31	0.35	0.35	0.39	0.32	0.37	0.41	0.44	0.46	t ha ⁻¹
Adjusted yield	2.21	2.62	3.24	2.83	3.11	3.15	3.49	2.89	3.29	3.66	3.99	4.10	t ha ⁻¹ (10% reduction)
Gross income (Rs. ha ⁻¹)	16605.0	19642.5	24300.0	21195.0	23287.5	23625.0	26190.0	21667.5	24705.0	27472.5	29902.5	30780.0	wheat grain price @ Rs.750/100kg
Cost of WE		40.00	80.00	20.00	20.00	20.00	20.00	40.00	40.00	40.00	40.00		Rs. 20/40 kg sorghum, 1/4 man day for preparing sorgaab
Cost of herbicide				112.50	225.00	337.50	450.00	112.50	225.00	337.50	450.00	750.00	Rs.840/1000 g a. i.
Spray application cost		100.00	200.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	Rs.100/man (one man /day/ha)
Spray rent		50.00	100.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	Rs.50/spray
Cost that vary		190.00	380.00	282.50	395.00	507.50	620.00	302.50	415.00	527.50	640.00	900.00	Rs. ha ⁻¹
Net benefit	16605.0	19452.5	23920.0	20912.5	22892.5	23117.5	25570.0	21365.0	24290.0	26945.0	29262.5	29880.0	Rs. ha ⁻¹

T₁ = Control (weedy check), T₂ = Conc. sorgaab @ 12 L ha⁻¹ (40 DAS), T₃ = Conc. sorgaab @ 12 L ha⁻¹ (30+40 DAS), T₄ & T₅= Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹+ isoproturon @ 150 g a. i. ha⁻¹ (30 DAS) T₅, T₉ = Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹ isoproturon @ 300 g a. i. ha⁻¹ (30 DAS) T₆, T₁₀= Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹+ isoproturon @ 450 g a. i. ha⁻¹ (30 DAS) T₇, T₁₁= Conc. sorgaab @ 6 L ha⁻¹ and 12 L ha⁻¹+ isoproturon @ 600 g a. i. ha⁻¹ (30 DAS) T₁₂= Isoproturon @ 1000 g a. i. ha⁻¹ (30 DAS)

Table VI. Dominance and marginal analysis 1st year

Treatments	Total cost that vary (Rs.ha ⁻¹) ^a	Net benefits (Rs. ha ⁻¹)	MRR ^b
T ₁ Control (weedy check)	0.00	17572.50	-
T ₂ Concentrated sorgaab @ 12 L ha ⁻¹ (30DAS)	190.00	20690.00	1640.79
T ₄ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	282.50	25997.50	5737.84
T ₈ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	302.50	28565.00	12837.50
T ₃ Concentrated sorgaab @ 12 L ha ⁻¹ (30 + 40 DAS, Standard)	380.00	23425.00	D
T ₅ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	395.00	29935.00	1481.08
T ₉ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	415.00	30207.50	1362.50
T ₆ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	507.50	31847.50	1772.97
T ₁₀ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	527.50	33425.00	7887.50
T ₇ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	620.00	32297.50	D
T ₁₁ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	640.00	44900.00	10200.00
T ₁₂ Isoproturon @ 1000 g a. i. ha ⁻¹ (standard)	900.00	48037.50	1206.73

^a Cost that vary: The sum of all the costs (both costs and opportunity costs) that vary for a particular treatment ^b MRR: Marginal rate of return, D = Dominated treatment, the treatment which have higher costs but lower net benefits

Table VII. Dominance and marginal analysis 2nd year

Treatments	Total cost that vary (Rs.ha ⁻¹) ^a	Net benefits (Rs. ha ⁻¹)	MRR ^b
T ₁ Control (weedy check)	0.00	16605.00	-
T ₂ Concentrated sorgaab @ 12 L ha ⁻¹ (30DAS)	190.00	19452.50	1498.68
T ₄ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	282.50	20912.50	1578.38
T ₈ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 150 g a. i. ha ⁻¹ (30 DAS)	302.50	21365.00	2262.50
T ₃ Concentrated sorgaab @ 12 L ha ⁻¹ (30 + 40 DAS, Standard)	380.00	23920.00	3296.77
T ₅ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	395.00	22892.50	D
T ₉ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 300 g a. i. ha ⁻¹ (30 DAS)	415.00	24290.00	1057.14
T ₆ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	507.50	23117.50	D
T ₁₀ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 450 g a. i. ha ⁻¹ (30 DAS)	527.50	26945.00	2360.00
T ₇ Concentrated sorgaab @ 6 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	620.00	25570.00	D
T ₁₁ Concentrated sorgaab @ 12 L ha ⁻¹ + Isoproturon @ 600 g a. i. ha ⁻¹ (30 DAS)	640.00	29262.50	2060.00
T ₁₂ Isoproturon @ 1000 g a. i. ha ⁻¹ (standard)	900.00	29880.00	237.50

^a Cost that vary: The sum of all the costs (both costs and opportunity costs) that vary for a particular treatment ^b MRR: Marginal rate of return, D = Dominated treatment, the treatment which have higher costs but lower net benefits

Fig. 1. Relationship between grain yield (t ha⁻¹) and total weed density m⁻² during 1st year (a) and 2nd year (b)

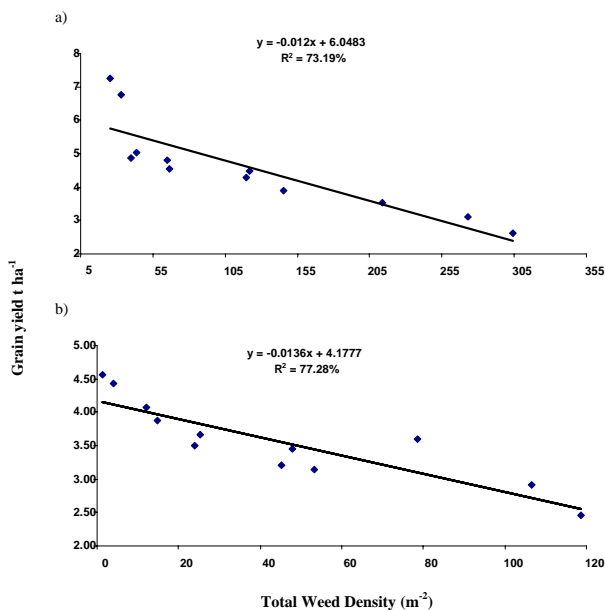
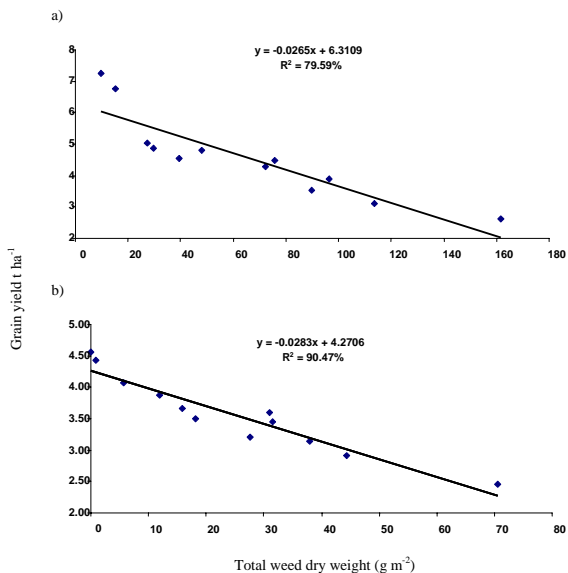


Fig. 2. Relationship between grain yield (t ha⁻¹) and total weed dry weight (g m⁻²) during 1st year (a) and 2nd year (b)



well as individual weed populations and their growth. Treatment combination as sorgaab @ 12 L ha⁻¹ plus isoproturon @ 600 g a. i. ha⁻¹ proved to most suitable treatment combination which reduced weed density by 89-97% and weed dry weight by 91-99% recorded at 60 DAS during both years of study and it was almost on par with full dose of isoproturon @ 1000 g a. i. ha⁻¹. One spray of

sorgaab @ 6 or 12 L ha⁻¹ along with lower doses of isoproturon @ 600, 400 and 300 g a. i. ha⁻¹ were next best treatments combinations. The higher rate of sorgaab @ 12 L ha⁻¹ with lower rates of isoproturon was more effective and reduced more weed density and biomass as compared to its application @ 6 L ha⁻¹ along with lower rates of isoproturon. These findings suggest the possibilities of combining allelopathic water extracts with lower doses of

Fig. 3. Relationship between grain yield (t ha⁻¹) and plant height (cm) of wheat during 1st year (a) and 2nd year (b)

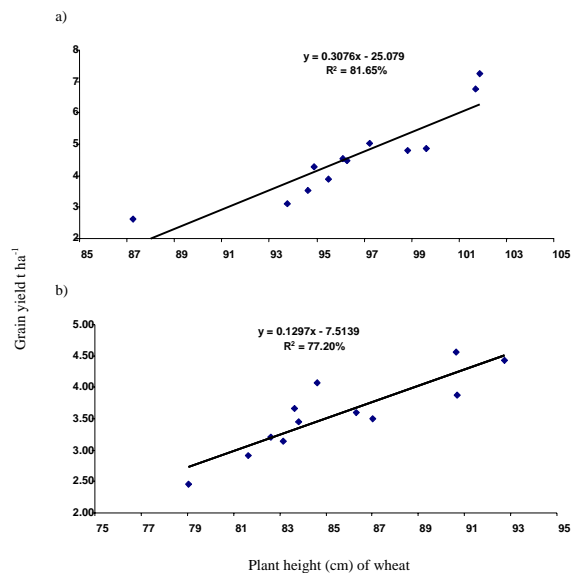


Fig. 4. Relationship between grain yield (t ha⁻¹) and number of productive tillers m⁻² of wheat during 1st year (a) and 2nd year (b)

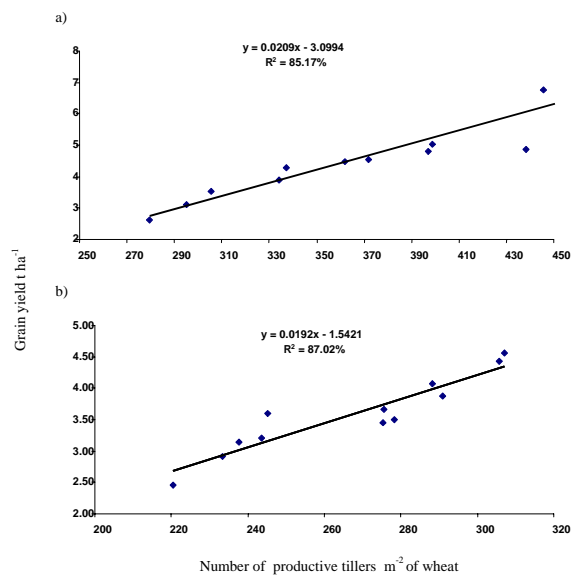
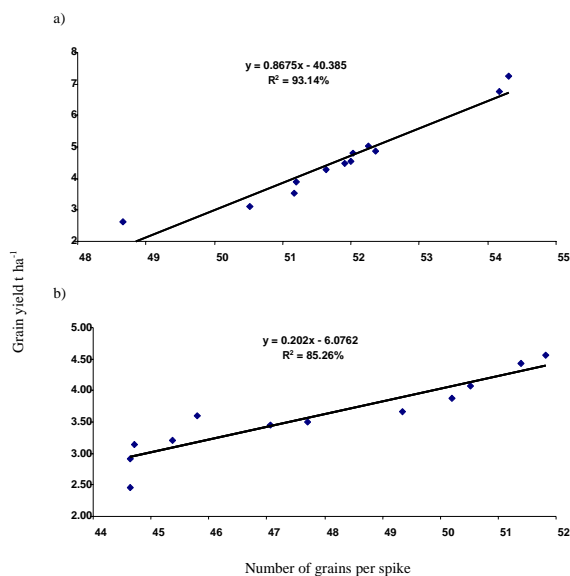


Fig. 5. Relationship between grain yield ($t\ ha^{-1}$) and number of grains per spike during 1st year (a) and 2nd year (b)



herbicides, which is according to Einhelling and Leather (1988) who postulated this hypothesis. The combination of isotoproturon with sorgaab could enhance its phytotoxic effects (Cheema *et al.*, 2004) and allelopathic inhibitory effects of sorgaum allelochemicals along with herbicidal activities of isotoproturon reduced maximum weed in the field. So, the efficiency of sorgaab to reduce total dry weight of weeds can be increased by mixing it with lower doses of isotoproturon and use of herbicides can be lowered up to 40%. Combined effect of conc. sorgaab with the isotoproturon tested in the present study was according to the objectives, i.e., the efficiency of sorgaab was improved on one side and on the other hand herbicide dose was lowered by 40%.

Maximum increase in grain yield was obtained in plots where full dose of isotoproturon @ $1000\ g\ a.\ i.\ ha^{-1}$ was used and it was statistically on par to the yield in case of one spray of sorgaab @ $12\ L\ ha^{-1}$ with isotoproturon @ $600\ g\ a.\ i.\ ha^{-1}$ (T_{11}) Grain yield was positively correlated with plant height, productive tillers m^{-2} , and number of grains per spike while negatively associated with weed density and biomass. In another similar field study, Cheema *et al.* (2004) suggested that the dose of isotoproturon can be reduced

considerably (50%) by combining with sorgaab @ $12\ L\ ha^{-1}$. Conc. sorgaab @ $12\ L\ ha^{-1}$ + isotoproturon @ $500\ g\ a.\ i.\ ha^{-1}$ produced almost equal wheat grain yield to the full dose of isotoproturon @ $1000\ g\ a.\ i.\ ha^{-1}$ which clearly revealed that isotoproturon dose can be reduced by 50% in combination with sorgaab @ $12\ L\ ha^{-1}$.

Economic analyses showed that among the sorgaab and isotoproturon combinations T_{11} i.e. one spray of conc. sorgaab @ $12\ L\ ha^{-1}$ with isotoproturon @ $600\ g\ a.\ i.\ ha^{-1}$ appeared the best treatment among sorgaab and isotoproturon combination with higher net benefits and MRR% during both years. The treatment combination T_{10} i.e. sorgaab @ $12\ L\ ha^{-1}$ with isotoproturon @ $450\ g\ a.\ i.\ ha^{-1}$ at 30 DAS was also fairly good in terms of net benefits and MRR% however standard dose of herbicide gave the highest net benefits during both years but had relatively low MRR as compared to T_{11} .

These findings suggest that there is considerable scope to reduce herbicide usage in combination with allelopathic sorghum water extract under field conditions.

REFERENCES

- Ahmad, S., Z.A. Cheema and A. Mahmood, 1991. Response of some rabi weeds and wheat to allelopathic effects of irrigated sorghum in a sorghum wheat cropping system. *Pakistan J. Weed Sci. Res.*, 4: 45–9
- Cheema, Z.A., I. Jaffer and A. Khaliq, 2004. Reducing isotoproturon dose in combination with sorgaab for weed control in wheat. (In press).
- Cheema, Z.A., A. Khaliq and R. Farooq, 2003. Efficacy of concentrated sorgaab alone and in combination with herbicides and a surfactant in wheat. *J. Anim. Pl. Sci.*, 13: 10–3
- Cheema, Z.A., M.S. Farid and A. Khaliq, 2003a. Efficacy of concentrated sorgaab with low rates of atrazine for weed control in maize. *J. Anim. Pl. Sci.*, 13: 48–51
- Cheema, Z.A., A. Khaliq and M. Tariq, 2002. Evaluation of concentrated sorgaab alone and in combination with reduced rates of 3 pre-emergence herbicides for weed control in cotton (*Gossypium hirsutum* L.). *Int. J. Agric. Biol.*, 4: 549–52
- Cheema, Z.A., H.M.I. Sadiq and A. Khaliq, 2000. Efficacy of sorgaab (sorghum water extract) as a natural weed inhibitor in wheat. *Int. J. Agric. Biol.*, 2: 144–6
- Cheema, Z.A., 1998. Sorghum allelopathy-A new weed control technology for enhancing wheat productivity. *J. Anim. Pl. Sci.*, 8: 19–21
- Cheema, Z.A., 1999. *A New Technology to Control Weeds*. Daily Dawn. Lahore
- Einhelling, F.A. and G.R. Leather, 1988. Potentials for exploiting allelopathy to enhance crop production. *J. Chem. Ecol.*, 14: 1829–44
- Steel, R.G.D. and J.H. Torrie, 1984. *Principles and Procedure of Statistics, A Biometrical Approach*. 2nd Ed. p. 107–9. McGraw Hill Book Co. Inc. Tokyo

(Received 05 January 2005; Accepted 20 June 2005)