Studies on integrated weed management in sorghum

(*Keywords:* Herbicide, herbicide combination, weed control, sorghum)

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Abstract. Field trials were conducted for two seasons with the objective of testing the comparative efficacy of herbicides applied singly or in combination, and the integration of chemical and manual methods of controlling weeds in grain sorghum. All the treatments reduced the density and dry weights of dominant weeds, and increased the grain yields compared to weedy control plots. Treatments having metolachlor at 1·0–1·25 kg ha^{-1}, a combination of atrazine + metolachlor, sequential application of metolachlor and bentazon, atrazine at 0·75 and metolachlor at 1·0 kg ha^{-1} as pre-emergence followed by one manual weeding around 30 days after sowing were superior to the rest. The grain yield from the above herbicide-treated plots did not differ significantly from the yields of plots which were repeatedly hand-weeded. However, atrazine alone at all rates or in combination with other herbicides significantly reduced the sorghum height and stover yields.

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an important food crop grown during the rainy and post-rainy seasons in the semi-arid regions. Being a warm-season crop, sorghum is grown under conditions favourable for the growth of weeds, especially during the rainy season when weed infestation and competition is greatest. Sorghum seedlings do not compete well against weeds; yield reductions due to competition are reported to range from 20% to 100% in India, and from 8% to 41% in other countries, depending on the weed flora, time of infestation, management practices, soil type and rainfall pattern (Wiese *et al.*, 1964; Burnside and Wicks, 1969; Phillips, 1970; Shetty, 1978).

During the early stages, weeds are generally more competitive than sorghum. Water and nutrient requirements of many sorghum weeds are greater than those of the crop, and reductions in crop yield are greater when moisture and nutrients are limiting (Shetty, 1978; Sankaran and Mani, 1972). These workers showed that weeds remove moisture and nutrients at a faster rate than sorghum in the early stages of growth, which is the critical period for weed competition.

The traditional tall local cultivars compete with the weeds better than the short-statured improved cultivars. Therefore, more intensive weed control measures are needed for the high-yielding dwarf cultivars (Shetty and Krantz, 1977).

Hand-weeding is a common practice in the tropics, but the cost and availability of labour, and frequent rains which render the soils difficult to work, often delay weeding. Alternative methods include the use of herbicides. Atrazine, simazine and propazine have shown good performance in controlling the weeds of sorghum under semi-arid conditions (Upadhyay and Khan, 1978; Subba Reddy *et al.*, 1976). However the pre-emergence application of herbicides usually will not control total weed flora, and it also allows the emergence of weeds at a later time, depending on the rainfall. Thus, an approach using both pre- and post-emergence herbicides and integration of manual methods may be necessary to control weeds. The present study was therefore undertaken to compare the efficacy of herbicides and the integration of chemical and manual methods for the control of weeds in sorghum.

2. Materials and methods

Trials were carried out during the rainy seasons of 1987 and 1988 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. The soil was a medium-deep Alfisol (Udic Rhodostalf), sandy clay loam in texture with a pH of 8·4, low in available nitrogen, phosphorus and with medium content of organic carbon and potassium. Rainfall during the cropping season (June–October) was 463 and 886 mm in 1987 and 1988 respectively.

The herbicide applications and post-emergence weed control practices evaluated in these experiments are described in Table 1. Treatments were replicated thrice in a randomized complete-block design. Each plot was 9·0 × 7·0 m in size. Plots received 60 kg N/ha and 36 kg P_2O_5/ha, of which 18 kg N and 36 kg P_2O_5 was applied at planting. Sorghum (cv. hybrid CSH-9) was seeded on 22 June 1987 and 16 June 1988 with a tractor-drawn seed drill in rows 60 cm apart. After emergence, plants were thinned to 10 cm spacing between plants within the rows. An area of 3·0 × 7·0 m from the centre of each plot was hand-harvested on 6 October 1987 and 7 October 1988.

Sorghum height was recorded at 30 and 60 days after sowing (d.a.s.). The lengths of the panicle, grain and stover yields were also recorded. Weeds collected at 60 d.a.s. and at harvest from a randomly placed quadrant of 1·0 m^2 were counted, washed and then oven-dried to compute weed density and dry matter. A knap-sack sprayer was used to apply herbicide. The weed-free control was maintained by repeated hand-weedings every 10 days until harvest. Since the responses to herbicide were similar in the two years, data were pooled and analysed.

The weed flora in the experimental area consisted of *Digera arvensis* Forsk., *Celosia argentea* L., *Eclipta alba* L. Hassk, *Phyllanthus niruri* L., *Phyllanthus maderaspatensis* L., *Amaranthus viridis* L., *Digitaria sanguinalis* L. Scep., *Dinebra retroflexa* (Vahl) Panz., *Echinocloa crusgalli* Beau V. and *Brachiaria eruciformis* Stapf.

Table 1 Effect of different treatments on the density and dry weight of weeds

Treatments	Rate (kg a.i./ha)	Time of application	Weed count/m^2		Dry weight of weeds (g/m^2)	
			60 d.a.s.	At harvest	60 d.a.s.	At harvest
Atrazine	0·5	Pre	79 (8·9)	50 (7·1)	151 (12.3)	132 (11.5)
Atrazine	0·75	Pre	45 (6·8)	39 (6·3)	88 (9·3)	88 (9·4)
Atrazine	1·00	Pre	35 (6·0)	29 (5·3)	67 (8·2)	69 (8·3)
Metolachlor	0·75	Pre	73 (8·6)	40 (6·4)	114 (10·7)	118 (10·9)
Metolachlor	1·00	Pre	46 (6·8)	34 (5·9)	77 (8·8)	80 (8·9)
Metolachlor	1·25	Pre	30 (5·5)	26 (5·2)	52 (7·2)	59 (7·7)
Atrazinre + Metolachlor	0·4 + 0·6	Pre	24 (5·0)	23 (4·8)	49 (7·0)	75 (8·7)
Bentazon	1·00	Post	82 (9·1)	78 (8·9)	258 (16·1)	158 (12·6)
Bentazon	1·50	Post	73 (8·6)	60 (7·8)	217 (14·7)	120 (11·0)
Bentazon	2·00	Post	55 (7·4)	53 (7·3)	189 (13·8)	105 (10·3)
Atrazine – Bentazon	0·75 + 1·0	Pre-post	48 (6·9)	36 (6·0)	51 (7·2)	83 (9·1)
Metolachlor – Bentazon	1·0 + 1·0	Pre-post	68 (8·3)	30 (5·5)	42 (6·5)	53 (7·3)
Atrazine + Metolachlor – Bentazon	0·4 + 0·6 – 1·0	Pre-post	23 (4·8)	20 (4·5)	35 (6·0)	61 (7·9)
Atrazine + manual weeding	0·75	30 DAS	40 (6·4)	22 (4·8)	16 (4·0)	43 (6·6)
Metolachlor + manual weeding	1·0	30 DAS	26 (5·2)	19 (4·5)	17 (4·2)	21 (4·6)
Weed-free	—	—	0 (0·7)	0 (0·7)	0 (0·7)	0 (0·7)
Weedy check	—	—	138 (11·8)	100 (10·0)	229 (17·0)	273 (16·5)
S.E.			3 (0·3)	4 (0·3)	9 (0·3)	5 (0·3)
LSD (0·05)			0·9	0·9	0·9	0·9

Data in parentheses are transformed values $\sqrt{(X + 0{\cdot}5)}$.
Pre = Pre-emergence; post = post-emergence; d.a.s. = days after sowing.

3. Results and discussion

3.1. *Effects on Weeds*

All the herbicide treatments significantly reduced the weed density compared to the weedy control (Table 1). Metolachlor alone at 1·25 kg, metolachlor at 1·0 kg followed by one manual weeding at 30 days after sowing (d.a.s.), a combination of atrazine + metolachlor (0·75 + 1·0 kg) and atrazine + metolachlor applied before emergence followed by bentazon after emergence were significantly superior to all other treatments by recording the lowest weed counts both at 60 d.a.s. and at harvest. Besides the above treatments, atrazine alone at 1·0 kg or at 0·75 kg followed by a hand-weeding were equally effective in reducing the weed population at harvest but were significantly different from the above treatments at 60 d.a.s. None of the treatments was as effective as the weed-free control maintained by repeated hand-weedings.

The dry weight of weeds at 60 d.a.s. and at harvest was most reduced in plots treated with metolachlor at 1·0 kg followed by one manual weeding. Atrazine at 0.·75 kg followed by one manual weeding was the next-best treatment (Table 1). All the herbicide treatments significantly reduced the weed dry weight compared to the weedy control. Increasing the application of atrazine, metolachlor, bentazon and their combinations inhibited the emergence of weeds in the later stages of crop growth.

3.2. *Effects on crop*

Plant height of sorghum at 30 and 60 d.a.s. was significantly reduced by all rates of atrazine alone or in combination with other herbicides (Table 2). The effect on plant height was more pronounced at higher rates where the plants were significantly shorter than those in the weedy control. The application of bentazon also tended to reduce height but the effect was not consistent between seasons.

Panicle length was reduced significantly in the weedy control and also by bentazon at all the rates (Table 2). None of the other herbicide treatments reduced the length of the panicle below that in the weed-free control.

Highest grain and stover yields were recorded in the weed-free plots (Table 2). Among the herbicide treatments, metolachlor at 1·0–1·25 kg, atrazine + metolachlor combination, metolachlor at 1·0 kg applied before emergence followed by bentazon at 1·0 kg after emergence, atrazine at 0·75 kg or metolachlor at 1·0 kg as pre-emergence followed by one manual weeding around 30 d.a.s. recorded grain and stover yields comparable to weed-free control and were significantly superior to all other treatments.

All the herbicide treatments except atrazine at 1·0 kg were found to be superior to the weedy control in improving grain and stover yields. The superiority of metolachlor alone, or its combination with other herbicides, and the pre-emergent application of atrazine or metolachlor followed by one manual weeding may be attributed to better growth and yield components of sorghum compared to other treatments. The above treatments were effective in controlling the weeds at critical stages of crop-weed competition.

3.3 *Other effects*

The unweeded control recorded minimum grain and stover yields. The decrease in grain and stover yield when compared to the weed-free control was 53% and 44% respectively. Atrazine and metolachlor applied before emergence showed good weed control activity by reducing the weed population and dry matter when applied alone or in combination as compared to post-emergence application of bentazon. Increased concentrations of all the herbicides

Table 2. Effect of different treatments on plant height, ear-length, grain and stover yields of sorghum

Treatments	Rate (kg a.i./ha)	Plant height (cm)		Panicle length (cm)	Grain yield (kg/ha)	Stover yield (kg/ha)
		30 d.a.s.	60 d.a.s.			
Atrazine	0·5	79	139	26	4350	9841
Atrazine	0·75	74	134	26	4304	9990
Atrazine	1·00	66	132	26	2872	7741
Metolachlor	0·75	85	144	26	4299	10684
Metolachlor	1·00	85	143	26	4909	11958
Metolachlor	1·25	82	143	27	4722	11573
Atrazine + Metolachlor	0·4 + 0·6	79	141	26	4733	10981
Bentazon	1·00	83	140	25	3407	8083
Bentazon	1·50	81	140	23	3558	9166
Bentazon	2·00	83	143	25	3509	8472
Atrazine – Bentazon	0·75 + 1·0	75	135	26	4440	10133
Metolachlor – Bentazon	1·0 + 1·0	83	145	27	4745	11995
Atrazine + Metolachlor – Bentazon	0·4 + 0·6 – 1·0	81	143	25	4458	10930
Atrazine + manual weeding	0·75	76	136	26	5083	11459
Metolachlor + manual weeding	1·0	84	145	26	4968	11852
Weed-free	—	85	147	27	5107	12713
Weedy check	—	80	140	23	2401	7134
SE		1·1	1·5	0·5	159	393
LSD (0·05)		3·3	4·5	1·5	475	1175

resulted in lower weed density and dry matter. Toxic effects of atrazine on height and vigour were observed at all the levels. At lower levels it was slightly phytotoxic to sorghum initially and the crop recovered into normal plants at later stages. However, higher levels were phytotoxic, resulting in crop mortality and poor stand, in turn resulting in lower grain and stover yields. Singh and Rao (1974) observed that the toxicity of atrazine depended upon the concentration used. The application of atrazine at 0·5 kg had no adverse effect on plant stand. Shelke (1968) and Sankaran and Mani (1974) reported that dry matter per plant was inversely related to concentrations of atrazine, and recommended less than 0·5 kg ha^{-1} of atrazine followed by one late-season manual weeding to secure best weed control; this recorded the highest net returns.

Atrazine application stunted growth, making plants more vulnerable to shootfly and stemborer attack resulting in a drastic reduction in sorghum population. Metolachlor was found to be quite safe, and plants were normal and robust without any herbicide injury. Vigour in the early stages of plant growth provides some protection from shootfly and stemborer incidence. Mate *et al.* (1988) also found that taller genotypes, having higher growth rates and vigour, showed greater shootfly tolerance. However, to avoid injury to sorghum from acetanilide herbicides such as metolachlor, seed treatment with safener called Oxabetrinil (1,3-dioxolan-2-ylmethoxyimino (phenyl) acetonitrile), commercially known as Concep-II, is necessary. Concep-II is a herbicide antidote which, when used as a seed treatment, protects grain sorghum from the phytotoxic effects of metolachlor (Anonymous, 1988).

4. Conclusions

Effective control of weeds in sorghum is provided by a pre-emergence application of metolachlor at 1·0–1·25 kg, or a combination of 0·4 atrazine + 0·6 kg metolachlor. Metolachlor at 1·0 kg or atrazine at 0·75 kg before emergence followed by one manual weeding at 30 d.a.s. can also be used. These treatments did not injure sorghum plants while producing yields comparable to weed-free control obtained by repeated hand weedings.

References

ANONYMOUS, 1988. *Crop Protection Chemicals Reference* (New York: John Wiley & Sons), 4th ed.

BURNSIDE, O. C. and WICKS, G. A., 1969. Influence of weed competition on sorghum growth. *Weed Science*, **17**, 332–334.

MATE, S. M., PHADANWIS, B. A. and MEHETRE, S. S., 1988. Studies on growth and physiological factors in relation to the shootfly attack in sorghum. *Indian Journal of Agricultural Research*, **22**, 81–84.

PHILLIPS, W. M., 1970. Weed control methods, losses and costs due to weeds and benefits of weed control in grain sorghum. In *FAO International Conference on Weed Control, Urbana, Illinois*: Weed Science Society of America, pp. 101–108.

SANKARAN, S. and MANI, V. S., 1972. Effect of weed growth on nutrient uptake and see yield of sorghum (cv. CSH-1). *Indian Journal of Weed Science*, **4**, 23–28.

SANKARAN, S. and MANI, V. S., 1974. Comparative efficiency of physical, chemical and combination methods of weed control in grain sorghum. *Madras Agricultural Journal*, **61**, 344–352.

SHELKE, V. B., 1968. Studies on the toxicity and persistence of soil applied simazine and atrazine and their effects on growth and yield of *kharif* sorghum (*Sorghum vulgare*, Pers.) and weed-flora. M.Sc. thesis, Nagpur University, Nagpur.

SHETTY, S. V. R., 1978. Weed control in sorghum in the tropics. Paper presented at the 10th Anniversary meeting of the Weed Science Society of Philippines, Manila, 3–5 May, p. 21.

SHETTY, S. V. R. and KRANTZ, B. A., 1977. Weed research needs of small farmers. In *Proceedings of Indian Society of Weed Science Conference, Hyderabad, India*, 17–19 January, pp. 47–49.

SINGH, D. J. C. and RAO, K. N., 1974. Residual effects of herbicides in black soils. *Pesticides*, **8**, 57–58.

SUBBA REDDY, G., VENKATESHWARLU, J. and DRYDEN, R. D., 1976. Weed Management in rainfed sorghum. *Indian Journal of Weed Science*, **8**, 95–100.

UPADHYAY, U. C. and KHAN, P. A., 1978. Weed management in sorghum CSH-4. *Sorghum Newsletter*, **21**, 39–40.

WIESE, A. F., COLLIER, J. W., CLARK, L. E. and HAVELA, V. D., 1964. Effect of weeds and cultural practices on sorghum yields. *Weeds*, **12**, 209–211.