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Research Paper

Effect of integrated weed management on growth and yields of rainy-season sorghum (*Sorghum bicolor*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2011 and 2012 at Indore, Madhya Pradesh, to identify the suitable and effective integrated weed-management practices for sorghum [*Sorghum bicolor* (L.) Moench]. The experiment was laid out in a randomized block design replicated thrice with 10 treatments of weed-management practices on sorghum hybrid 'CSH 16'. Mean data of 2 years indicated that all the weed-management practices significantly reduced the density and dry weight of weeds and helped in a significant enhancement in yield attributes and yield of sorghum. Among different weed-management practices applied, pre-emergence applications of pendimethalin @ 0.50 kg a.i./ha + 1 hand-weeding at 30 days after sowing was an effective practice in controlling the weeds 63.9% weed-control efficiency (WCE) and remunerative in terms of net returns (₹35,049/ha), followed by the application of atrazine @ 0.25 kg a.i./ha + 2 hand-weeding at 30 and 45 DAS (60.29% weed-control efficiency and net returns (₹33,548/ha). It was also observed that both the weed-management practices recorded the lower weed density and dry weight of weeds as compared to all other methods of weed control.

Key words : Genotypes, Net returns, Pre-emergence, Sorghum, Weed-control efficiency

Sorghum is one of the major staple food crops of million of the people in semi-arid tropics. It is mostly grown as rainfed crop in *kharif* season in India. It is preferred for its adaptability under aberrant environments especially on marginal lands. In Madhya Pradesh, it was an area of 0.39 million ha and production 0.61 million tonnes with a productivity of 1583 kg /ha. With the increase in human and animal populations and a fragile balance between food supplies and demand for it, production of sorghum must be increased to meet the current and future food and fodder needs. Weeds are major hindrance in increasing productivity of any crop. Yield loss in grain sorghum due to weeds ranges from 15 to 97%, depending on the nature and intensity of weeds, duration of weed infestation and environmental conditions.

Being a rainy season crop, sorghum faces heavy infestation of mixed population weeds, such as sedges (*Cyperus rotundus),* grasses (*Echinochloa* spp.*)* and broad-leaf weeds (*Digera arvensis, Amaranthus viridis, Commelina benghalensis* etc.). Manual weeding and hoeing is a difficult task in monsoon, as these operations coincide with continuous rains, particularly in heavy soil. Expensive wages of labours and their unavailability during the critical period of weed competition make situation worse to worst. Atrazine as pre-emergence and 2,4-D as post-emergence are standard habits for controlling weeds in sorghum but weeds dominate in early slow growth of sorghum, when 2,4-D is used and broad-leaf weeds create severe problem in latter stage in case of atrazine is applied. Pre-emergence application of herbicides has been found to provide excellent and adequate control of weeds in the early stage of crop growth through reduction of crop-weed competition resulting in an increase in production. Therefore, interaction of weed-management practices offers great potential under such a situation to get effective control of composite weed flora and proper knowledge of various weed-management practices. Keeping this in view, an investigation was carried out to study the effect of integrated weed-management practices on rainy (*kharif*) season sorghum.

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MATERIALS AND METHODS

The experiment was carried out during the rainy (*kharif*) seasons of 2011 and 2012 under All-India Coordinated Sorghum Improvement Project (AICSIP) at College of Agriculture, Indore, (Malwa Plateau in western parts of Madhya Pradesh at 22.43° N and 75.66° E, with an altitude of 555.5 m above the mean sea-level) Madhya Pradesh. The soil of the experimental field was clay in texture, neutral in reaction (*p*H 7.0) and was low in available N (180 kg/ha), organic carbon (0.30%) and available P_2O_5 (9.64 kg/ha), but high in available K_2O (538 kg/ha). The recommended dose of fertilizer (80, 18 and 33 kg N, P and K/ha) was applied in sorghum. The experiment was laid out in randomized block design having 3 replications. There were 10 treatments T_1, atrazine @ 0.50 kg a.i./ha pre-emergence (PE) + 1 hand-weeding 30 days after sowing (DAS); T_2, atrazine @ 0.25 kg a.i./ha as PE + 2 hand-weedings at 30 and 45 DAS; T_3, pendimethalin @ 0.50 kg a.i./ha as PE + 1 hand-weeding at 30 DAS; T_4, pendimethalin @ 0.50 kg a.i./ha (PE) + 2,4-D @ 0.50 kg a.i./ha as post-emergence at 20–25 DAS; T_5, atrazine @ 0.25 kg a.i. + pendimethalin @ 0.25 kg a.i /ha as PE as tank mixed; T_6, atrazine @ 0.25 kg a.i. + pendimethalin @ 0.50 kg a.i./ha as PE as tank mixed; T_7, atrazine @ 0.25 + pendimethalin @ 0.50 a.i./ha as PE + 2,4-D @ 0.50 kg a.i./ha as post-emergence; T_8, atrazine @ 0.25 kg a.i./ha (PE) + 2, 4-D @ 0.50 kg a.i./ha as post-emergence; T_9, atrazine @ 0.25 kg a.i./ha as PE + pendimethalin @ 0.50 kg a.i./ha at 30 DAS; and T_{10}, weedy check, on weed-management practices were tested on sorghum hybrid 'CSH 16'. Total rainfall received during the crop-growing period was 1,432.8 and 938.2 with 37 and 31 rainy days, respectively, in both the years. The weekly rainfall distribution was not satisfactory because of continuous rains from beginning of July to mid-September reduced the crop yields during 2012. Sorghum seed was treated with Thiomethoxam @ 3 g/kg seed. Seed rate of sorghum was used 8 kg/ha. Hand-sowing was done on 21 June 2011 and 28 June 2012, with the help of argada with row-to-row distance of 45 cm. Depth of sowing 3–4 cm was kept. Under plant-protection measures, Phorate 10 G @ 20 kg/ha was applied before sowing in the experimental plots. Application of Carbofuran 3 G @ 10 kg/ha was done at 35 DAS for the control of stem borer.

The total number of species-wise weeds was counted in a quadrate of 1 m at 3 random places in each plot and mean was worked out for recording weed population/m^2. The weeds from each quadrate were then uprooted and bulked. The dry weight of this bulk was recorded after kept in an oven at 54°C for drying. The average dry weight per quadrate (1 m) was worked out and expressed in g/m^2. Weed-control efficiency was calculated and expressed as:

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

where, WCE, weed-control efficiency; DWC, dry weight of weeds in control plots; DWT, dry weight of weeds in treated plots

Plant population of crop was counted at the time of harvesting, in each net plot and mean was worked out and converted in 000/ha. The plant height was measured on the main shoot from the ground surface to the tip at harvest. The observation of leaf-area index was taken at harvesting. It expresses the total leaf area in relation with the total ground area in which the crop is grown, as calculated by the following equation:

$$LAI = \frac{\text{Total leaf area of the crop}}{\text{Total ground area under the crop}}$$

Dry matter/plant studies were made on a sample of 3 plants per plot removed from each of the plot at harvesting and was kept in an oven at 54°C for 24 hours. The dry weight of the sample was recorded and averaged for recording dry matter/plant. Gross monetary returns were calculated by adding the prevailing market rates of grain and stover obtained in different treatments. Net monetary returns were obtained by subtracting cost of cultivation from gross returns. Benefit: cost ratio was calculated by dividing gross returns with cost of cultivation. The crop was harvested on 11 and 20 October, respectively, in 2011 and 2012.

RESULTS AND DISCUSSION

Important weed species observed in the experimental field were: *Echinochloa colonum, Cyprus rotundus, Digera arvensis, Euphorbia geniculata, Amaranthus viridis, Commelina benghalensis* and other weeds. During both the years, *Echinochloa colonum* and *Cyperus rotundus* were predominant weeds.

Weed population and dry weight

Weed-management practices significantly reduced the weed population and their dry weight as compared to weedy check. In case of weed species count and their dry weight, the lowest values were recorded for *Euphorbia geniculata* and *Commelina benghalensis* with the application of atrazine @ 0.25 kg a.i./ha as PE + 2 hand-weedings at 30 DAS and 45 DAS. The application of atrazine @ 0.5 kg a.i./ha as PE + 1 hand-weeding at 30 DAS was found effective to control the *Amaranthus viridis* weed. However, application of pendimethalin @ 0.50 kg a.i./ha as PE

Table 1. Effect of weed-management practices on species-wise population of weeds/m^2 at harvesting (mean data of 2 years)

Treatment	Species-wise population of weeds/m^2 at harvesting							
	Echinochloa colonum	*Cyperus rotundus*	*Digera arvensis*	*Euphorbia geniculata*	*Amaranthus viridis*	*Commelina benghalensis*	Other weeds	Total
Atrazine @ 0.5 kg a.i./ha as pre-emergence + 1 HW at 30 DAS	6.87	5.88	4.09	3.33	2.95	3.39	4.24	30.75
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2 HW at 30 and 45 DAS	3.01	2.85	3.60	2.61	3.82	1.83	11.78	29.50
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence +1 HW at 30 DAS	2.49	2.67	2.88	4.80	3.26	3.26	8.14	27.50
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence at 20–25 DAS	4.09	2.98	5.06	6.50	4.78	5.35	8.91	37.67
Atrazine @ 0.25 kg a.i./ha + pendimethalin@ 0.25 kg a.i./ha as pre-emergence	4.34	3.05	5.20	6.15	3.74	2.65	12.96	38.08
Atrazine @ 0.25 kg a.i./ha + pendimethalin@ 0.50 kg a.i./ha as pre- emergence	4.02	3.15	7.20	7.45	6.13	3.13	8.76	39.83
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	2.78	2.95	5.61	4.78	4.30	2.07	9.59	32.08
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	5.16	4.40	6.19	6.75	7.71	5.82	13.21	49.25
Atrazine @ 0.25 kg a.i./ha as pre-emergence + pendimethalin @ 0.50 kg a.i./ha at 30 DAS	3.69	3.75	5.31	4.98	5.62	5.77	12.55	41.67
Weedy check	7.61	6.54	9.76	12.35	9.59	8.55	19.93	74.33
SEm±	0.47	0.39	0.59	0.81	0.48	0.49	0.86	0.95
CD (P=0.05)	1.39	1.16	1.75	2.42	1.43	1.47	2.55	2.83

HW, Hand-weeding; DAS, days after sowing

Table 2. Effect of weed-management practices on species-wise dry weight of weeds (g/m^2) at harvesting (mean data of 2 years)

Treatment	Species-wise dry weight of weeds (g/m^{-2}) at harvesting							
	Echinochloa colonum	*Cyperus rotundus*	*Digera arvensis*	*Euphorbia geniculata*	*Amaranthus viridis*	*Commelina benghalensis*	Other weeds	Total
Atrazine @ 0.5 kg a.i. /ha as pre-emergence + 1 HW at 30 DAS	4.08	3.61	3.70	5.10	4.67	4.69	11.47	37.32
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2 HW at 30 and 45 DAS	3.29	3.26	3.87	3.30	5.70	3.71	12.44	35.57
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence +1 HW at 30 DAS	2.88	2.90	3.53	5.01	4.72	3.74	11.96	34.75
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence+ 2,4-D @ 0.50 kg a.i./ha as post-emergence at 20–25 DAS	3.45	5.18	4.34	4.89	6.72	5.21	13.33	43.12
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.25 kg a.i./ha as pre-emergence	3.85	5.06	4.51	3.85	5.93	8.77	12.02	43.98
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre-emergence	4.27	4.14	4.03	3.61	7.35	8.39	16.12	47.90
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	3.64	4.32	4.08	4.76	4.64	5.06	11.80	38.29
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post- emergence	3.73	4.87	6.11	5.37	6.69	6.96	19.36	53.10
Atrazine @ 0.25 kg a.i./ha as pre-emergence + pendimethalin @ 0.50 kg a.i./ha at 30 DAS	3.81	5.09	6.62	5.07	5.22	5.43	16.15	47.38
Weedy check	7.84	10.65	7.48	9.06	7.51	11.16	29.35	83.05
SEm±	0.57	0.81	0.58	0.83	1.00	0.75	1.24	1.19
CD (P=0.05)	1.69	2.42	1.73	2.45	2.96	2.22	3.69	3.52

HW, Hand-weeding; DAS, days after sowing

+ 1 hand-weeding at 30 DAS minimized the incidence of weeds, *Digera* viz. *Echinochloa colonum, Cyprus rotundus* and *Digera arvensis*

Application of pre-emergence atrazine @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 DAS statistically at par with PE application of pendimethalin @ 0.50 kg a.i./ha + 1 hand-weeding at 30 DAS and both these practices significantly reduced the total weed population and dry weight of weeds as compared to all other practices except atrazine @ 0.50 kg a.i./ha as PE + 1 hand weeding at 30 DAS (Tables 1, 2). This may be because of effective control of weeds by different weed management practices. These results corroborate the findings of Rao *et al*. (2007) and Changseluk (2003).

Weed-control efficiency

Weed-control efficiency of different weed-management practices varied from 33.75 to 63.01%, maximum (63.01%) being with PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 DAS, followed by pendimethalin @ 0.50 kg a.i./ha as PE + 1 hand weeding at 30 DAS (60.29%). Similar results were also reported by Kaushik and Shaktawat (2005) and Rao *et al*. (2007).

Growth and yield attributing parameters

On the basis of pooled data of 2011 and 2012, it was indicated that different weed control measures significantly increased the growth and yield attributes over weedy check (unweeded control). Atrazine PE @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 DAS being at par with PE pendimethalin @ 0.50 kg a.i./ ha + 1 hand-weeding at 30 DAS recorded the maximum plant height, dry-matter/plant, leaf area-index and 1,000-grain weight. But the longest ear with more number of grains and their weight/ear was realized by PE application of pendimethalin @ 0.50 kg a.i./ha + 1 hand-weeding at 30 DAS; however, at par with PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 (Table 3). This may be because of lesser weeds were observed in these treatments, which may have resulted in increased nutrient, water, space and light supply to sorghum crop due to absence of crop-weed competition. Pandey *et al.* (2001), Singh *et al*. (2007) and Satheeshkumar *et al*. (2011) reported similar findings.

Grain and stover yields

On the basis of pooled data, significantly higher grain yield was recorded with the PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings of 30 and 45 DAS over all other weed-management practices; however, the differences in yield of grain was not conspicuous when PE application of pendimethalin @ 0.50 kg/ha + 1 hand-weed-

Table 3. Effect of weed-management practices on growth and yield-attributing characters of sorghum (mean data of 2011 and 2012)

Treatment	WCE (%)	Plant population (000 /ha)	Plant height (cm)	Dry matter/ plant (g)	Leaf area index	Length of earhead (cm)	Grain weight/ earhead (g)	Grains/ earhead	1,000-grain weight (g)
Atrazine @ 0.5 kg a.i./ha as pre-emergence + 1 HW at 30 DAS	58.6	112	209.7	118.4	3.4	32.5	50.8	2423	32.4
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2 HW at 30 and 45 DAS	63.0	111	222.5	137.5	3.8	32.9	52.7	2932	34.6
Pendimethalin @ 0.50kg a.i./ha as pre-emergence +1 HW at 30 DAS	60.3	108	217.6	131.1	3.8	33.3	53.3	3036	34.0
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence+ 2,4-D @ 0.50 kg a.i./ha as post- emergence at 20–25 DAS	49.4	100	202.3	125.8	3.6	31.3	41.3	2349	33.0
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.25 kg a.i./ha as pre-emergence	48.8	99	215.3	128.3	3.8	31.4	44.0	2505	32.2
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre-emergence	46.4	99	213.3	121.5	3.4	31.6	48.5	2462	32.4
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	56.8	100	220.2	129.8	3.8	32.5	51.7	2273	32.8
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	33.8	104	216.9	128.0	3.7	31.6	45.7	2349	32.2
Atrazine @ 0.25 kg a.i./ha as pre-emergence + pendimethalin @ 0.50 kg a.i./ha at 30 DAS	43.9	100	206.9	102.3	3.4	31.3	49.67	2423	33.9
Weedy check	0.0	106	188.4	95.4	3.4	27.7	37.0	2040	30.8
SEm±	1.3	4.01	5.09	3.0	0.2	0.7	2.5	329	0.7
CD (P=0.05)	3.8	NS	15.11	8.9	0.6	2.1	7.6	965	2.2

WCE, Weed-control efficiency; HW, hand-weeding; DAS, days after sowing

Table 4. Sorghum yields and monetary returns as influenced by weed-management practices (mean data of two years)

Treatment	Yield (t/ha)		Monetary returns (× 10³ ₹/ha)		Benefit: cost ratio
	Grain	Stover	Gross	Net	
Atrazine @ 0.5 kg a.i./ha as pre-emergence + 1 HW at 30 DAS	4.11	8.84	45.8	29.8	2.86
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2 HW at 30 and 45 DAS	4.67	9.52	51.6	33.5	2.87
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence +1 HW at 30 DAS	4.58	9.94	51.2	35.0	3.21
Pendimethalin @ 0.50 kg a.i./ha as pre-emergence+ 2,4-D @ 0.50 kg a.i./ha as post-emergence at 20–25 DAS	3.56	7.70	39.7	25.8	2.89
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.25 kg a.i./ha as pre-emergence	3.72	8.15	41.6	27.6	3.02
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre- emergence	3.45	8.10	39.2	24.8	2.75
Atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	4.00	8.63	44.6	30.3	3.14
Atrazine @ 0.25 kg a.i./ha as pre-emergence + 2,4-D @ 0.50 kg a.i./ha as post-emergence	3.85	8.81	43.5	29.6	3.13
Atrazine @ 0.25 kg a.i./ha as pre-emergence + pendimethalin @ 0.50 kg a.i./ha at 30 DAS	3.55	7.54	39.5	25.5	2.87
Weedy check	2.87	6.55	32.4	18.9	2.44
SEm±	0.19	0.38	2.0	2.0	0.13
CD (P=0.05)	0.56	1.12	5.9	5.9	0.38

Rate, Grain 9000/t and stover 1000/t; HW, Hand-weeding; DAS, days after sowing

ing at 30 DAS. But in case of stover yield, significantly higher stover yield was obtained by the application of pendimethalin @ 0.50 kg ha as pre-emergence + 1 hand-weeding at 30 DAS as compared to all other weed- management practices except pre-emergence application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 DAS and atrazine @ 0.50 kg a.i./ha as (PE) + 1 hand-weeding at 30 DAS (Table 2). This may be due to cumulative effect of reduced weed competition and higher value of yield attributes. This is in conformity with the findings of Kausik and Shaktawat (2005) and Satheeshkumar *et al.* (2011).

Economics

Gross returns, net returns and benefit: cost ratio were influenced significantly by various weed-management practices. The PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 DAS, being at par with application of pendimethalin @ 0.50 kg a.i./ha as pre-emergence + 1 hand-weeding at 30 DAS and atrazine @ 0.50 kg a.i./ha as PE + 1 hand-weeding at 30 DAS, gave significantly higher gross returns than the other weed-management practices. In respect of net returns, maximum net returns were recorded with PE application of pendimethalin @ 0.50 kg a.i/ha + 1 hand-weeding at 30 DAS, followed by PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings of 30 and 45 DAS. In case of benefit: cost ratio, the highest benefit: cost ratio was received by application of pendimethalin @ 0.50 kg/ha as PE + 1 hand-weeding at 30 DAS, followed by PE application of atrazine @ 0.25 kg a.i./ha + pendimethalin @ 0.50 kg a.i./ha + post-emergence application of 2, 4-D @ 0.50 kg a.i./ha (3.14). The while PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings of 30 and 45 DAS recorded benefit: cost ratio 2.87. Similar findings were also reported by Dhar *et al*. (2006), Sunitha *et al.* (2010) and Shah *et al.* (2011).

It was concluded that pre-emergence (PE) application of pendimethalin @ 0.50 kg a.i./ha + 1 hand-weeding at 30 DAS and PE application of atrazine @ 0.25 kg a.i./ha + 2 hand-weedings at 30 and 45 DAS proved remunerative and effective in controlling the weeds in sorghum.

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