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Efficacy of different weed management practices on growth and yield of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

Surendra Kumar, Rakesh Choudhary and Anil Swami

Abstract
The field investigation was conducted at the Instructional Farm, College of Agriculture, Jodhpur during the *Kharif* season of 2019 on pearl millet. Twelve treatments were undertaken and replicated thrice. Amongst weed management treatments, weed-free recorded significantly higher growth attributes as compared to other treatments, but it was equally effective with the application of atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) followed by one hand weeding at 30 DAS showed significantly greater efficacy at all stages of crop growth and recorded higher growth, yield attributes and yield *viz.*, plant height (cm), dry matter accumulation (g plant^{-1}), plant population at all stages of crop growth, 1000-seed weight, productivity, grain and stover yield over rest of the treatments.

Keywords: Pearl millet, weed, crop growth, yield

Introduction
Pearl millet [*Pennisetum glaucum* (L.)] is a distinctive crop among the leading cereals, staple food of the world's poor and most food insecure communities in the arid and semi-arid tropical and sub-tropical areas across the country (Choudhary *et al.*, 2018). It is a drought tolerant cereal having the maximum potentiality of grain production in adverse conditions (Acharya *et al.*, 2017). India is the largest producer of pearl millet; it occupied an area of 6.93 million hectares with an annual production of 8.61 million tonnes and average productivity of 1243 kg ha^{-1} (DAC & FW, 2020). Rajasthan is a leading state in area 4.24 million hectares and production 3.75 million tones with productivity 886 kg ha^{-1} followed by Maharashtra and Gujarat. (GoR, 2020).

Pearl millet is a sensitive crop concerning biotic & abiotic stresses; weed is the leading factor among these, weeds are a major leading factor. In India, the presence of weeds in general reduces crop yields by 31.5% in winter, 22.7% in summer and 36.5% in *Kharif* season and some cases can cause complete devastation of the crop (Rao and Nagamani, 2010). The predominant methods of weed management are inter-culturing and hand weeding in pearl millet crop. These are found effective, but they have certain limitations like unavailability of labourers during peak periods under intensive farming and high labour cost, which in long run seek the help of herbicides as an effective tool for weed management and replacing conventional methods of weed management. Atrazine as pre-emergence is the most widely used herbicide for weed control in pearl millet. However, in the case of continuous rainfall after sowing, spraying of pre-emergence herbicide may not be feasible. Furthermore, the efficacy of pre-emergence herbicides is moisture dependent. Hence, there is a need to standardize the post-emergence herbicide in pearl millet crop for safe and efficient weed control. The use of chemicals along with manual weeding is the best option for effective weed management (Girase *et al*., 2017) as neither herbicides nor mechanical cultivation is adequate for consistent and acceptable weed control.

Materials and Methods
Field experiment was laid out in randomized block design (RBD) with sixteen treatments and replicated thrice. The treatments taken in the investigation were T_1- Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 20 DAS, T_2 - Tembotrione 42% SC @ 100 g *a.i.* ha^{-1}at 20 DAS, T_3- Tembotrione 42% SC @ 110 g *a.i.* ha^{-1}at 20 DAS, T_4 - Tembotrione 42% SC @ 120g *a.i.* ha^{-1} at 20 DAS, T_5- Tembotrione 42% SC @ 90 g *a.i.* ha^{-1}at 25 DAS, T_6 - Tembotrione 42% SC @ 100 g *a.i.* ha^{-1}at 25 DAS, T_7 - Tembotrione 42% SC @ 110 g *a.i.* ha^{-1}at 25 DAS, T_8 -

Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 25 DAS, T_9 - Atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS, T_{10} - Atrazine 50% WP @ 400 g *a.i.* ha^{-1} at 20 DAS *fb* one hand weeding at 35 DAS, T_{11} - Atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS, T_{12} - Weedy check, T_{13} - Weed-free. The effects of treatments on crop were recorded in terms of different indices of observation. Various growth and yield attributes observations were studied namely plant population initial and final stage, plant height (cm), number of effective plant^{-1} and dry matter accumulation (g plant^{-1}), test weight, Girth of ear head (mm), ear head length, harvest index (%) and productivity (kg day^{-1}). The correlation and regression coefficients were calculated between grain yield and yield components by using the method given by Snedecor and Cochran (1968).

Result and Discussion

Crop Studies

Growth attributes

Growth is the irreversible process through which the biomass, weight and size of the stems of a plant increase. Progressive crop growth and varying attribute development were reported at 20, 40 DAS and at harvest time. Significant reduction in the crop-weed competition was observed under various weed management treatments that not only favoured crop plants through improving the availability of moisture, nutrients, light and space, but also all weed disturbance reduced, facilitated vigorous crop growth and development (Kalyani, 2011). Significant improvement in growth attributes *viz.*, plant population at the final stage, plant height and plant dry matter accumulation at 40 DAS and harvest stage were recorded under weed-free treatment which is followed by application of atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS and atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS (177.4 cm). These were statistically at par with each other. There is no significant effect of all weed management treatments on growth attributes *viz.*, plant population at the initial stage, plant height and plant dry matter accumulation at 20 DAS. These results conform with Das *et al.* (2013), Choudhary *et al.* (2016) and Samota (2019) in pearl millet. The correlation studies also showed a well-established significant positive correlation between plant population, plant height and dry matter accumulation.

Yield attributes and yield

Under particular agronomic management, the yield of any crop is the interactive result of environment and genotype. The crop yield (also known as 'agricultural output') refers primarily to the calculation of a crop yield per unit area of soil cultivation under a definite set of environments. A crop's growth pattern in its vegetative phase mainly determines the formation of sink number and size which ultimately serves as the basis for the development of yield attributes. Thus, a plant's yield attributing characters are closely associated with growth characters that have emerged during the vegetative process. Among treatments combined application of pre and post-emergence of herbicides *i.e.*, atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS followed by atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS with a lesser difference of about 3.08% had the maximum number of effective tiller plant^{-1} however these treatments were statistically at par with weed-free treatment. Test weight, the girth of ear head and length of ear head were recorded under application atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS, it was found at par with atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* tembotrione 42% SC @ 90 g *a.i.* ha^{-1}at 25 DAS and weed-free treatment. These findings are also in parallel with the earlier findings of Choudhary (2016) in pearl millet, Singh *et al.* (2017) and Akhtar *et al.* (2017) in maize.

The maximum grain, stover yield, biological yield and productivity of pearl millet were recorded under application atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS, it was found at par with atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS. Similar results were also reported by Guggari and mallappa (2017) in pearl millet and Triveni *et al*. (2017) in maize. It may have been due to improved yield attributing character growth in the weed-free and managed weeds atmosphere offered by most weed management treatments, thereby eventually increasing pearl millet yield. In weedy control, crop plants face increased competition with weeds throughout their lifetime, which can limit the development of tiller resulting in a minimum yield and yield attributes. Thus, the results showed that the rise in yield contributing characteristics increasing yield during critical growth time was due to reduced weed infestation and crop-weed competitiveness. As a result, these conditions made it possible for the crop to make full use of crop inputs, thereby increasing yield attributes with higher seed yields. Under the present investigation, the existence of a high positive and significant correlation between effective tillers and grain yield (kg ha^{-1}), ear head length (cm) and girth (mm) with respective values of r = 0.985 and 0.993, Similarly, grain yield was also observed positive and significantly correlated with test weight and respective value of r = 0.975.

Correlation

Correlation studies (Table 1) also showed a highly significant association between different components of growth and yield attributes of pearl millet *viz.*, effective tillers (0.995**) with dry matter accumulation, girth (mm) (1.000**) with length Ear head (cm), test weight (g) (1.000**) with dry matter accumulation (g), grain yield (1.000**) with dry matter accumulation, stover yield (0.989**) with dry matter accumulation, grain yield (0.995**) with effective tillers, grain yield (1.000**) with test weight and stover yield (0.989**) with grain yield. Thus, it is obvious from the results that herbicide application played a pivotal role in maintaining better growth and yield in pearl millet crop.

Regression

Simple linear regression coefficients (b) of different characters on yield were computed (Table 2). The regression coefficients of all the characters are found to be highly significant with positive effects (values). The positive values of the regression coefficient suggested that the rate of increases of grain yield due to one unit increase in the independent variable (plant characters). The regression coefficient value of test weight (874.51) signifies that the yield of pearl millet may be increased by increasing one unit of test weight. Similarly, the yield of the pearl millet may also be enhanced by increasing the other plant characters. The highest regression coefficient was found in test weight (874.51) followed by effective tillers (827.96), ear head length (87.45), a girth of ear head (80.16) and so on. The

marginal regression coefficient was found in the plant population (0.034). The coefficients of determination (R^2) values of all the pearl millet characters under study were found in the range from (0.689) to (0.981). The highest value of R^2 (0.993) was recorded in dry matter accumulation and stover yield, it suggests that (93.3) per cent of the variation in grain yield could be explained by the dry matter accumulation and stover yield when other variables are kept constant. Hence, the traits dry matter accumulation and stover yield is the most important component of grain yield in pearl millet followed by effective tillers (R^2=0.969), test weight (R^2=0.952), plant height (R^2=0.917) and so on. The R^2 values of plant population (0.689), ear head length (0.818) and girth (mm) (0.883) were comparatively lower than the other plant characters. Thus, these variables had comparatively less influence on grain yield compared with other remaining variables.

Table 1: Initial and final plant population of pearl millet as influenced by various weed management treatments

Treatments	Initial plant population ('000)	final plant population ('000)
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 20 DAS	145.0	142.5
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 20 DAS	144.5	142.0
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 20 DAS	144.1	141.6
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 20 DAS	144.3	141.8
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	145.2	143.0
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 25 DAS	145.2	139.7
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 25 DAS	144.9	142.6
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 25 DAS	145.4	143.3
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	144.0	141.6
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} at 20 DAS *fb* one hand weeding at 35 DAS	146.0	139.7
Atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS	143.3	142.2
Weedy check	146.3	111.2
Weed free	148.5	144.3
SEm±	4.8	5.7
C.D. (*P*=0.05)	NS	16.5

Table 2: Plant height of pearl millet as influenced by various weed management treatments

Treatments	Plant height (cm)		
	20 DAS	40 DAS	At harvest
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 20 DAS	26.2	71.6	172.7
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 20 DAS	27.1	72.1	175.0
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 20 DAS	27.4	72.7	175.3
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 20 DAS	26.9	72.4	174.9
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	27.3	70.3	170.2
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 25 DAS	27.2	70.7	171.7
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 25 DAS	27.5	70.6	170.1
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 25 DAS	27.0	70.3	171.7
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	29.4	73.4	177.4
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} at 20 DAS *fb* one hand weeding at 35 DAS	26.2	73.6	171.3
Atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS	29.7	74.9	179.6
Weedy check	25.7	58.3	139.3
Weed free	31.4	77.9	183.0
SEm±	1.1	2.8	7.1
C.D. (*P*=0.05)	NS	8.1	20.6

Table 3: Dry matter accumulation of pearl millet as influenced by various weed management treatments

Treatments	Dry matter accumulation (g m^{-2})		
	20 DAS	40 DAS	At harvest
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 20 DAS	16.6	70.1	567.6
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 20 DAS	17.0	71.2	579.0
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 20 DAS	17.1	73.8	586.0
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 20 DAS	16.9	73.9	584.3
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	17.1	64.3	540.7
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 25 DAS	17.0	68.4	548.1
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 25 DAS	17.1	69.6	566.7
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 25 DAS	17.0	69.7	555.1
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	18.1	76.1	653.1
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} at 20 DAS *fb* one hand weeding at 35 DAS	16.8	76.2	612.2
Atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS	18.4	77.7	672.1
Weedy check	16.4	62.6	356.7
Weed free	19.4	81.0	724.4
SEm±	0.7	2.7	18.7
C.D. (*P*=0.05)	NS	7.9	54.8

Table 4: Effective tillers, test weight, girth and ear head length of pearl millet as influenced by various weed management treatments

Treatments	Effective tillers	Test weight (g)	Girth of ear head (mm)	Ear head length (cm)
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 20 DAS	2.06	7.86	24.93	22.62
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 20 DAS	2.11	7.91	25.57	23.21
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 20 DAS	2.19	7.99	26.58	24.13
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 20 DAS	2.15	7.95	26.10	23.69
Tembotrione 4% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	1.94	7.54	23.51	21.34
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 25 DAS	1.97	7.69	23.84	21.63
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 25 DAS	2.01	7.78	24.36	22.11
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 25 DAS	1.99	7.72	24.12	21.89
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	2.67	8.18	32.32	29.33
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} at 20 DAS *fb* one hand weeding at 35 DAS	2.32	8.10	28.12	25.52
Atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS	2.59	8.29	31.43	28.53
Weedy check	1.12	6.96	18.00	17.82
Weed free	2.82	8.62	33.32	31.06
SEm±	0.11	0.18	1.15	1.14
C.D. (*P*=0.05)	0.32	0.54	3.35	3.34

Table 5: Grain yield, stover yield, biological yield, harvest index and productivity of pearl millet as influenced by various weed management treatments

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index (%)	Productivity (kg day^{-1})
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 20 DAS	1809	3867	5676	32	21.8
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 20 DAS	1855	3935	5790	32	22.4
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 20 DAS	1892	3967	5860	32	22.8
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 20 DAS	1873	3970	5843	32	22.6
Tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	1692	3715	5407	31	20.4
Tembotrione 42% SC @ 100 g *a.i.* ha^{-1} at 25 DAS	1724	3757	5481	31	20.8
Tembotrione 42% SC @ 110 g *a.i.* ha^{-1} at 25 DAS	1751	3915	5667	31	21.1
Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} at 25 DAS	1726	3824	5551	31	20.8
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} (PE) *fb* tembotrione 42% SC @ 90 g *a.i.* ha^{-1} at 25 DAS	2120	4411	6531	32	25.5
Atrazine 50% WP @ 400 g *a.i.* ha^{-1} at 20 DAS *fb* one hand weeding at 35 DAS	1940	4182	6122	32	23.4
Atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS	2194	4527	6721	33	26.4
Weedy check	865	2702	3567	24	10.4
Weed free	2383	4861	7244	33	28.7
SEm±	99.0	161.3	187.8	1.7	1.2
C.D. (*P*=0.05)	288.8	470.7	548.2	NS	3.5

Table 6: Correlation matrix of selected attributes (growth and yield) of pearl millet

Variables	PP	PH	DMA	ET	EHL	GT	TW	GY	SY
PP	1								
PH	0.198**	1							
DMA	0.099**	0.830**	1						
ET	0.077**	0.824**	0.995**	1					
EHL	0.077**	0.824**	0.995**	1.000**	1				
GT	0.077**	0.824**	0.995**	1.000**	1.000**	1			
TW	0.099**	0.830**	1.000**	0.995**	0.995**	0.995**	1		
GY	0.099**	0.830**	1.000**	0.995**	0.995**	0.995**	1.000**	1	
SY	0.110**	0.791**	0.989**	0.984**	0.984**	0.984**	0.989**	0.989**	1

**significant at 1% level of significance

PP= Plant population; PH= Plant height (cm); DMA= Dry matter accumulation (g); ET= Effective tiller; EHL= Ear head Length (cm); GT= Girth (mm); TW= Test weight (g); GY= Grain yield (kg/ha); SY= Stover yield (kg/ha)

Table 7: Regression coefficients (b values) and intercept (a) of different component traits on grain yield of pearl millet along with their coefficient of determination (R^2)

Characters	A	B	R^2
Plant Population	-2935.749	0.034	0.689**
Plant height (cm)	-3759.798	32.571	0.917**
Dry matter accumulation (g)	-555.58	4.114	0.993**
Effective tillers	53.201	827.967	0.969**
Length of ear head	-272.063	87.451	0.818**
Girth of ear head	-277.414	80.163	0.883**
Test weight (g)	-5068.565	874.514	0.952**
Stover yield (kg/ha)	-921.513	0.693	0.981**

Summary and Conclusion

In the experiment thirteenth treatments were taken. Among these treatment significant taller plant and plant dry matter at all crop growth stages (74.9 cm & 179.6 cm) and (77.7 g m^{-2} & 672.1 g m^{-2}) were recorded with the application of atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS. The maximum value of yield attributes *viz.* effective tillers (2.67 $plant^{-1}$), test weight (8.29 g), girth (31.43 mm), ear head length (28.53 cm), grain yield (2194 kg ha^{-1}), stover yield (4527 kg ha^{-1}) and biological yield (6721 kg ha^{-1})were observed with the treatment atrazine 50% WP @ 500 g *a.i.* ha^{-1} (PE) *fb* one hand weeding at 30 DAS.

The maximum positive and significant correlation was observed between effective tillers and grain yield (kg ha^{-1}), ear head length (cm) and girth (mm) with respective values of r = 0.985 and 0.993, Similarly, grain yield was also observed positive and significantly correlated with test weight and respective value of r = 0.975.

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