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RELATIVE PERFORMANCE OF DIFFERENT METHODS OF WEED MANAGEMENT IN PEARL MILLET (*PENNISETUM GLAUCUM*)

AMARJEET NIBHORIA*, JITENDER KUMAR, BIKRAM SINGH, SATYAJEET, ASHOK KUMAR DEHINWAL AND MUKESH KUMAR

Chaudhary Charan Singh Haryana Agricultural University,
Regional Research Station, Bawal (Rewari), Haryana-123501, India
**(e-mail : amarnibhoria@gmail.com)*

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SUMMARY

The study was conducted during *Kharif* 2019 and *Kharif* 2020 at CCS HAU Regional Research Station, Bawal, India to assess the relative performance of different methods (manual, chemical and mechanical) of weed management in pearl millet. The crop was infested with Carpet weed (*Trianthema portulacustrum*), Nutsedge (*Cyperus rotundus*), Crow root grass (*Dactyloctenium aegyptium*) and *Digera arvensis* etc. Among all treatments, mechanical weed management integrated with supplementary manual weeding *viz*. mechanized interculture with tractor drawn cultivator at 15 and 25 DAS followed by one supplementary hand weeding at 30 DAS under crop geometry of 60 cm × 10 cm was found most productive and remunerative with grain yield of 23.17 q/ha, net returns (Rs. 18746/ha) and B:C (1.52). Yield and net returns achieved under this treatment were 3 and 177 per cent higher than manual interculture with kasola under 45 cm x 12 cm crop geometry, respectively. Mechanized interculture with tractor drawn cultivator or power weeder at 15 and 25 DAS followed by supplementary hand weeding at 30 DAS under crop geometry of 60cm × 10cm resulted into the highest weed control efficiency (WCE) of 91 percent, manual intercuture with kasola provided WCE of 85 percent over period of two years (2019 and 2020). While, Chemical weed management with atrazine @ 0.5 kg/ha as pre as well as post emergence gave WCE of 72 and 71 percent, respectively, while, Unchecked weeds caused yield loss of 43 percent over the study period.

Key words : Mechanized weed management, crop geometry, pearl millet, weed control efficiency

Pearl millet [(*Pennisetum glaucum* L.) R. Emend Stuntz], the major coarse grain crop of world, is the fourth most important grain crop after rice, wheat and sorghum; belongs to family Poaceae. It is a multipurpose crop cultivated for grain and stover. It shall continue to play a prominent role in the integrated agricultural and livestock economy (Yadav *et al*., 2013). Globally, pearl millet is grown on 31.0 million ha, mainly in Africa and Asia; and is staple food for 90 million poor people (ICRISAT, 2021). Among food crops (cereals and pulses), pearl millet is cheapest source of energy (361 k cal/100g), minerals viz. Phosphorus (296-360 mg/100g), Iron (8-11 mg/100g), Zinc (3.1-6.6 mg/100g), Calcium (40-42 mg/100 g), Magnesium (97-137 mg/100g) and Vitamins viz. Vitamin A, E, Riboflavin, Thiamine, Vitamin K and Niacin etc. Because of its rich nutritional composition, it is designated as nutri-cereals (Gazette of India, No. 133 dated 13th April, 2018).

Pearl millet grains are eaten cooked like rice or 'chapaties' are prepared out of flour like sorghum or maize. It is also used in making fermented breads, foods, thick porridges, steam cooked dishes, non-alcoholic beverages and snacks. Crop residue and green plants provide building materials for fencing, thatching and making basketry. It is also used as green fodder or dry *karvi* for cattle (Arya *et al*., 2014). It supplies energy at very reasonable cost to the large poor population (field workers), hence known as 'Poor mans' meat', 'Poor mans' food' and nutra-cereal also. It is mostly grown by resource poor farmers on low fertile, water deficit soils under hot, semi-arid and arid tropical regions of the world (Arya *et al*., 2013). In India, it was grown on an area of 7.52 million ha giving production of 10.28 million tones with average yield of 1368 kg/ha during 2019-20 (Anonymous, 2021). The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in the country.

Weed management is one of most important hurdle to improve productivity of pearl millet

predominantly in rainy season under changing climate scenario. Weeds cause the lower grain and straw yields of pearl millet. The growth of pearl millet is slow during early stage and is a relatively poor competitor with weeds during the first few weeks after emergence. The major weeds of pearl millet are *Trianthema portulacastrum, Cyperus rotundus, Digera arvensis*, *Echinochloa colona, Phyllanthus niruri, Dactyloctenium aegyptium, Paspalum paspaloides, Celosia argentea* and *Alhagi camelorumdt.* They emerge and compete with crop for nutrients, moisture, light and space thereby may reduce yield to the extent of 16-94 % (Balyan *et al.* 1993), 41 % (Girase *et al.* 2017) and 35 % (Nibhoria *et al.* 2021).

Several methods of weed management have been in practice, among which hand weeding is the most ancient method and is still adopted for weed control in pearl millet. Later on manual hand tools were developed to derive some mechanical advantage in carrying out interculture operations (Sridhar, 2013). Chemical control (use of herbicides) is also prevalent to manage the weeds. All these methods have some advantages and limitations also. The traditional weeding operations are laborious, back breaking, tiresome, time consuming and expensive and may not be sometime undertaken at critical time due to non-availability of labours. Chemical method felicitates quick and relatively cheaper option, but sometimes, continuous rains and selectivity and residual effects confines chemical weed management. In the era of today's intensive agriculture, mechanical weed management offers easy, economical and timely operation; and also improves the soil aeration and water intake capacity (Pandey, 2018). A 75.5% reduction in time use was recorded with mechanized weeding compared with manual weeding (Abdourahamane *et al.* 2020). Mechanization of sowing and weeding should be an interesting option for the farmers because it enables timelier and more precise sowing and weeding, which can increase yield and reduce labour demand (Aune *et al.* 2019). Keeping all these facts in view, present study was planned to assess the relative performance of different weed management methods in pearl millet.

MATERIALS AND METHODS

General Procedures

Present study was conducted during *Kharif* seasons of 2019 and 2020 at Research farm, CCS Haryana Agricultural University, Regional Research Station, Bawal (India). The soil of the experimental field was light-textured loamy sand, slightly alkaline in reaction (pH 8.2), low in organic carbon (0.21 %) and available nitrogen (112 kg/ha); and medium in available phosphorus (12 kg/ha) and potassium (174 kg/ ha). The climate of the experimental site can be classified as tropical and semi-arid, accompanied by hot and dry winds in summer, severe cold in winter and humid - warm weather during the rainy season. Total, 470.8 and 248.6 mm rainfall was received during 2019 and 2020, respectively. The weather parameters during the crops seasons are presented in Fig. 1.

Experimental design

The experiment consisting of 11 treatments as described in Table 1 was laid out in a complete randomized block design with three replications. The pearl millet crop variety HHB 299 was sown on July 10 and 5 using seed @ 5.0 kg/ha; and harvested on September 25 and 23 during 2019 and 2020,

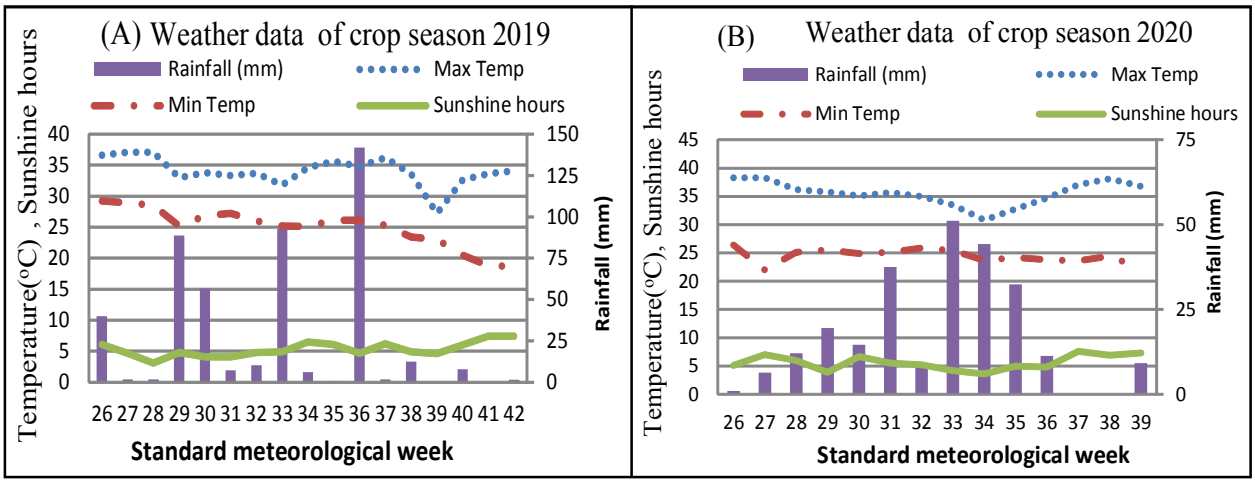

Fig. 1. A) Weather data of crop season 2019, B) Weather data of crop season 2020.

TABLE 1
Treatment details

T_1	Crop geometry of 45cm x 12cm, Atrazine 0.5 kg/ha (Pre-em)
T_2	Crop geometry of 45cm x 12cm, Atrazine 0.5 kg/ha (Post-em)
T_3	Crop geometry of 60cm x 10cm, interculture with tractor drawn cultivator at 15 and 25 DAS
T_4	Crop geometry of 60cm x 10cm, interculture with tractor drawn cultivator at 15 and 25 DAS followed by supplementary hand weeding (HW) at 30 DAS
T_5	Crop geometry of 60cm x 10cm, interculture with Power weeder (PW) at 15 and 25 DAS
T_6	Crop geometry of 60cm x 10cm, interculture with PW at 15 and 25 DAS followed by supplementary hand weeding (HW) at 30 DAS
T_7	Crop geometry of 60cm x 10cm, Atrazine 0.5 kg/ha (Pre-em), interculture with tractor drawn cultivator at 25 DAS
T_8	Crop geometry of 60cm x10cm, Atrazine 0.5 kg/ha (Pre-em), interculture with PW at 25 DAS
T_9	Crop geometry of 45cm x 12cm (weedy check)
T_{10}	Crop geometry of 45cm x 12cm (weed free)
T_{11}	Crop geometry of 45cm x 12cm, interculture with kasola at 20-25 and 30-35 DAS

* DAS denotes days after sowing.

respectively. The plot size was kept 7.0 m x 5.4 m. Excess plants were removed by thinning manually during 4th week after sowing. Crop geometry was bit modified from recommended 45 cm x 12 cm to 60 cm x 10 cm to felicitate mechanized interculture in the standing crop.

For mechanized interculture, power weeder (Make : BCS, HP : 6, RPM : 3600, Mass: 24 kg and Width : 48 cm) was run between two rows; and tines of tractor drawn cultivator were so fixed that that two tines run in one row to remove all weeds and not uproot the crop plants. All other practices were followed as per recommended package of practices by the State Agricultural University.

Data collection and statistical analysis

The data on plant population were recorded at 21 DAS by counting plants/plot and converting into plants/ha. Weed count were recorded at 45 DAS with the help of quadrant of 0.5m x 0.5m at three spots and converted into no. of weeds/m^2. To record weed dry weight, counted weeds were uprooted, sundried for few days, then oven dried at 65 ^{0}C to obtain constant weight and was converted into g/m^2. To record grain and stover yield, crop of two m^2 from center of each plot was harvested separately and threshed manually and recorded as q/ha after multiplying by common factor. A sample was taken from each plot, 1000-grains were counted manually and weighed and recorded as 1000-grain weight. Before harvesting, tillers of randomly selected five plants in each plot were counted and divided by five to calculate tillers/plant at harvest. The economics was calculated based on prevailing market prices of inputs and outputs. The data were statistically analyzed using 'OPSTAT' (Sheoran *et al.,* 1998) software of CCS Haryana Agricultural University, Hisar, India. Significance of treatments was judged with the help of 'F'test at 5 % level of significance.

RESULTS AND DISCUSSION

Mean of two years (2019 and 2020) data pertaining to plant population, yield attributes and yield of pearl millet is given in Table 2. The plant population of pearl millet varied significantly (1.60–1.82 lakh/ha) among different treatments over two years. It was higher in treatments with crop geometry of 45cm x 12 cm in comparison to 60 cm x 10 cm. Effective tillers/plant were found significantly higher in different weed management treatments as compared with weedy check. However, maximum effective tillers were recorded under T_4 followed by T_6. No significant variation was observed in spike length among all treatments. Test weight (1000- grains weight) also increased significantly under all treatments as compared with weedy check. Similarly grain and stover yield of pearl millet varied significantly among different weed control treatments. The grain yield of pear millet varied from 13.34 q/ha (under weedy check) to 23.17 q/ha (after weed free 23.31 q/ha) under T_4 {crop geometry of 60 cm x 10 cm, interculture with Tractor drawn cultivator at 15 and 25 DAS followed by one supplementary hand weeding (HW) at 30 DAS} and T_6 (same as T_4 but interculture with power weeder), it was 74% higher than weedy check (crop geometry of 45 cm x 12 cm). That was probably due to early weed control as well as loosening of soil and also more space available to plants, which resulted into higher values of yield attributes *viz.* tillers/plant, spike length and 1000- grain weight. Consequently, improvement in yield attributes was reflected into higher grain and stover yield. Similarly, Duraisamy

TABLE 2
Effect of different treatments on plant population, yield and its attributes (mean of 2019 and 2020)

	Treatment	Pl. Popln. (Lakh/ha)	Yield attributes			Grain yield (q/ha)	Stover yield (q/ha)
			Effective tillers (No./pl.)	Spike length (cm)	1,000-grain weight (g)		
T_1	45 cm x 12 cm, Atrazine 0.5 kg/ha (PE)	1.81	1.85	21.58	6.85	20.40	29.56
T_2	45 cm x 12 cm, Atrazine 0.5 kg/ha (PoE)	1.82	1.89	22.00	7.05	20.43	29.49
T_3	60 cm x 10 cm, cultivator at 15 and 25 DAS	1.61	2.05	23.46	7.54	21.32	31.66
T_4	60 cm x 10 cm, cultivator at 15 and 25 DAS and HW at 30 DAS	1.61	2.10	24.39	7.75	23.17	33.46
T_5	60 cm x 10 cm, Power Weeder (PW) at 15 and 25 DAS	1.60	2.07	23.10	7.49	21.51	31.34
T_6	60 cm x 10 cm, PW at 15 and 25 DAS and HW at 30 DAS	1.61	2.08	24.31	7.77	23.17	33.66
T_7	60 cm x 10 cm, Atrazine (PE), cultivator at 25 DAS	1.60	1.94	22.33	6.95	20.56	29.95
T_8	60 cm x 10 cm, Atrazine (PE), PW at 25 DAS	1.61	1.96	21.90	6.90	20.71	29.56
T_9	45 cm x 12 cm (Weedy check)	1.80	1.44	18.10	5.57	13.34	21.53
T_{10}	45 cm x 12 cm (Weed free)	1.81	1.95	25.18	7.92	23.31	33.80
T_{11}	45 cm x 12 cm, kasola at 20-25 and 30-35 DAS	1.81	1.95	23.72	7.44	22.46	32.50
CD (P=0.05)		0.14	0.28	NS	0.70	2.83	3.12

and Tajuddin (1999) also stated that deep mechanized interculture provides mulch and results into loosening of soil to greater depth leading to more soil aeration and helps to retain moisture for longer periods. Stover yield of pearl millet also followed similar trends.The yield achieved under chemical (atrazine @ 0.5 kg/ha applied as pre or post emergence)and manual weed management treatments (interculture with kasola at 20-25 and 30-35 DAS) were also significantly similar yield to mechanized weed control treatments.

Economics

Among economic parameters cost of cultivation, gross returns, net returns and B:C were worked out (Table 3). The cost of cultivation was computed based on prevailing market rates of inputs and labour charges. It varied from Rs. 29663 under weedy check to R. 46875/ ha in weed free. Difference in cost was due to higher cost of labour deployed for weeding in weed free treatment. Among other treatments, chemical weed management with atrazine @ 0.5 kg/ha applied either PE or PoE was cheapest with Rs. 30619/ha in both treatments. Maximum gross returns were achieved in weed free (Rs. 55663/ha) followed by T_6 (Rs. 55346/ha) and T_4 (Rs.55294/ha). However, the economic viability of any treatment is judged on basis of net returns and B: C. In the present

TABLE 3
Effect of different treatments on economics of pearl millet (mean of 2019 and 2020)

	Treatment	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B : C
T_1	45 cm x 12 cm, Atrazine 0.5 kg/ha (PE)	30619	48702	16235	1.50
T_2	45 cm x 12 cm, Atrazine 0.5 kg/ha (PoE)	30619	48777	16310	1.50
T_3	60 cm x 10 cm, cultivator at 15 and 25 DAS	31958	51081	17083	1.50
T_4	60 cm x 10 cm, cultivator at 15 and 25 DAS and HW at 30 DAS	34508	55294	18746	1.52
T_5	60 cm x 10 cm, Power weeder (PW) at 15 and 25 DAS	33998	51419	15126	1.42
T_6	60 cm x 10 cm, PW at 15 and 25 DAS and HW at 30 DAS	36548	55346	16504	1.43
T_7	60 cm x 10 cm, Atrazine (PE), cultivator at 25 DAS	31690	49195	15529	1.46
T_8	60 cm x 10 cm, Atrazine (PE), PW at 25 DAS	32710	49449	14636	1.42
T_9	45 cm x 12 cm (Weedy check)	29663	32346	898	1.03
T_{10}	45 cm x 12 cm (Weed free)	46875	55663	5091	1.11
T_{11}	45 cm x 12 cm, kasola at 20-25 and 30-35 DAS	43509	53581	6757	1.15
CD (P=0.05)		-	-	-	-

Note: Price of pearl millet grain and straw in 2019 and 2020 @ Rs. 2000 and 190; and 2150 and 250/q, respectively.

TABLE 4
Weed density, dry weight of weeds and weed control efficiency as influenced by different intercultural operations in pearl millet at 45 DAS (mean of 2019 and 2020)

Treatment		Weed density (No./m^2)	Dry weight of weeds (g/m^2)	Weed control efficiency (%)
T_1	45 cm x 12 cm, Atrazine 0.5 kg/ha (PE)	7.80 (59.84)	6.84 (45.74)	72
T_2	45 cm x 12 cm, Atrazine 0.5 kg/ha (PoE)	7.72 (57.10)	6.74 (44.44)	71
T_3	60 cm x 10 cm, cultivator at 15 and 25 DAS	7.15 (50.17)	6.37 (39.60)	72
T_4	60 cm x 10 cm, cultivator at 15 and 25 DAS and HW at 30 DAS	3.79 (13.36)	2.54 (5.46)	91
T_5	60 cm x 10 cm, Power weeder (PW) at 15 and 25 DAS	5.68 (31.26)	4.97 (23.70)	76
T_6	60 cm x 10 cm, PW at 15 and 25 DAS and HW at 30 DAS	3.70 (12.68)	2.71 (6.33)	91
T_7	60 cm x 10 cm, Atrazine (PE), cultivator at 25 DAS	7.11 (49.54)	5.88 (33.56)	78
T_8	60 cm x 10 cm, Atrazine (PE), PW at 25 DAS	7.07 (49.05)	5.50 (29.21)	80
T_9	45 cm x 12 cm (Weedy check)	22.88 (522.50)	20.21 (407.43)	
T_{10}	45 cm x 12 cm (Weed free)	1.00 (0.00)	1.00 (0.00)	100
T_{11}	45 cm x 12 cm, kasola at 20-25 and 30-35 DAS	4.45 (18.80)	3.99 (14.96)	85
CD (P=0.05)		2.9	3.1	-

Note : Figures in parenthesis indicate original values which were subjected to square root transformation before analysis.

study, mechanized weed management with tractor drawn cultivator in combination with supplemental hand weeding at 30 DAS (T_4) with crop geometry of 60 x 10 cm was found most economical with highest net returns and B:C (Rs. 18746/ha and 1.52) in comparison to chemical weed control with atrazine @ 0.5 kg /ha applied as pre or post- emergence under crop geometry of 45 x 12 cm fetching net returns (Rs. 16235 and 16310/ha; and 1.50 under both treatments), respectively. Manual interculture with kasola (T_{11}) under crop geometry of 45 x 12 cm recorded grain yield of 22.46 q/ha, but due to higher cost of labour employed for interculture, it fetched net returns and B:Cof Rs. 6757/ ha and 1.15, respectively. This was mainly because of high cost of labour employed in weeding operations in comparison to mechanized interculture (Nibhoria *et al.,* 2021). The mechanized interculture is not only cost effective but also time saving (Desta, 2000).

Weed studies

The field under study was infested with Carpet weed (*Trianthema portulacustrum*), Nutsedge (*Cyperus rotundus*), Crow root grass (*Dactyloctenium aegyptium*) and *Digera arvensis etc*. Weed density as well as dry weight of weeds reduced significantly under all treatments as compared to weedy check (Table 4). Mechanized interculture with tractor drawn cultivator as well as power weeder at 15 and 25 DAS followed by one supplementary hand weeding at 30 DAS (T_4 and T_6) under crop geometry of 60 cm x 10 cm recorded lowest weed density and dry weight of weeds; and highest weed control efficiency *i.e.* 91 per cent each followed by manual interculture with kasola at 20-25 and 30-35 DAS under crop geometry of 45 cm x 12 cm (85%). Under mechanized weeding tines of tractor or power weeder pulverize the soil and cut the weed roots to a depth of up to 10 cm or more while in case of manual interculture with kasola depth of weeding was maximum upto 5-6 cm. Weeding to more depth holds the emergence of 2nd flush of weeds and reduce the weed density and dry weight. Weeds and weed seeds are buried to a greater depth in mechanized weeding compared with manual weeding (Abdourahamane *et al.,* 2020). Chemical weed management with atrazine @ 0.5 kg/ha as pre or post emergence recorded 72 and 71 percent weed control efficiency, respectively.

CONCLUSION

On the basis of present study it can be concluded that owing to highest weed control efficiency, mechanical interculture with tractor drawn cultivator at 15 and 25 DAS followed by supplementary hand weeding (HW) at 30 DAS under crop geometry of 60 cm x 10 cm produced statistically similar grain yield over two years (23.17 q/ha) to chemical weed management with atrazine @ 0.5 kg pre or post emergence and manual weed management *viz.* interculture with kasola at 20-25 and 30-35 DASas well. It was found most economical treatment with highest net returns (Rs. 18746) and B:C (1.52).

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