Physiological studies on pearl millet as affected by hybrids, plant density and fertility levels in semi arid environment

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ABSTRACT A field experiment was conducted at crop research farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar, during the *kharif* seasons of 2004 and 2005 to find out suitable spacing for pearl millet hybrids along with N & P levels so as to increase the productivity of pearl millet. The experiment was laid out in split plot design allocating two hybrids and three plant densities in main plots and four fertility levels in sub plots replicated thrice. HHB-67-2 showed significantly higher dry matter accumulation plant⁻¹ (9.65 %) at harvest, leaf area plant⁻¹ (9.34 %) at 55 DAS, leaf area index (8.87 %) and leaf area duration (9.65 %) at 41 to 55 DAS and crop growth rate (8.00) at 56 DAS to harvest over HHB-67 in first year. The fertility level 90 kg N + 45 kg P₂O₅ ha⁻¹ recorded significantly higher dry matter accumulation plant⁻¹, leaf area plant⁻¹, leaf area duration and crop growth rate over control and 30 kg N + 15 kg P₂O₅ in both the crop seasons. Hybrid HHB 67-2 recorded significantly higher biological yield over HHB-67 in both the seasons. However 60 kg N + 30kg P₂O₅ ha⁻¹ caused significant difference in biological yield over control and 30 kg N + 15 kg P₂O₅ ha⁻¹. HHB 67-2 recorded relatively higher value for consumptive water use and water use efficiency. The plant density of 45 x 12 cm produced significantly higher biological yield in both the seasons over 30 x 12 and 60 x 12 cm densities.

Key words: Pearl millet, biological yield, leaf area index, leaf area duration, crop growth rate, water use efficiency.

INTRODUCTION

Pearl millet (*Pennisetum glaucum*) is the fourth most important crop after rice, wheat and sorghum in India.

About 97 % of the acreage under pearl millet is rainfed, concentrated over arid and semi-arid regions of the country. The production of pearl millet is very low with existing cultivars. Some newly evolved hybrids are found to be more aggressive and responsive to fertilizers than the older ones. Intensive agriculture, being need of the hour, demands full exploitation of hybrids with available resources especially nutrients. Nutrients not only influence the physiological growth of the plant but also enhance below ground root proliferation. In this way replenishment of soil nutrients leads to more efficient water use. The quantity in terms of biological yield improved with application of fertilizers and maintenance of optimum plant density. Considering the immense importance of maintaining optimum plant density of newly evolved hybrids with proper fertilization under limited moisture conditions, an effort has been made to study the physiological parameters along with biological yield of pearl millet as affected by hybrids, plant density and fertility levels.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* seasons of 2004 and 2005 at the Crop Research Farm, Chaudhary Charan Singh, Haryana Agricultural University, Hisar. The soil of the experimental field was sandy loam (Typic ustochrepts) with organic carbon (0.46 %) and available nitrogen (191 kg ha⁻¹), available phosphorus (14 kg ha⁻¹) and high non available potassium (340 kg ha⁻¹). The experiment was laid out in split plot design, keeping combinations of two hybrids (HHB 67 and HHB 67-2) and three plant densities [30 x 12 cm (2747777 plants ha⁻¹), 45 x 12 cm (185185 plant ha⁻¹), 60 x 12 cm (138888 plant ha⁻¹) in main plots and four fertility levels (control, 30 kg N + 15 kg P₂O₅ ha⁻¹, 60 kg N + 30 kg P₂O₅ ha⁻¹, 90 kg N + 45 kg P₂O₅ ha⁻¹) in sub plots. The total number of treatment combinations (24) were replicated three times.

Whole P and half N as per treatments were drilled at the time of sowing. The remaining N was top dressed after thinning and gap filling (22 DAS). Pearl millet hybrids were sown on August 2, 2004 and July 20, 2005 as per plant density treatment using 5 kg seed per ha⁻¹. The recommended package of practices was followed in the crop for other agronomic operations. The total rainfall received during the crop season was 114.9 and 424.8 mm during *kharif* 2004 and 2005, respectively. The crop was harvested on October 7 and September 27 during 2004 and 2005, respectively.

The dry matter accumulation in plants was recorded after drying them first in the sun and then in oven at 60 ± 5 °C to constant weight. The leaf area per plant was measured by LI 3000 area meter, LICOR Ltd., Nebraska, U.S.A. The leaf area index (LAI) was calculated by dividing leaf area by ground area.

Leaf area duration was calculated from leaf area index by using formula:

$$LAD = \frac{LAI_2 + LAI_1 (t_2 - t_1)}{2}$$

Where,

LAI₂ = Leaf area index at t₂

LAI₁ = Leaf area index at t₁

Crop growth rate was worked out by using formula

$$CGR = \frac{W_2 - W_1}{(t_2 - t_1)}$$

Where, W₁ and W₂ = Dry weight of plants (g) from a given land area at time t₁ and t₂, respectively.

t₂ - t₁ = Time interval of observations (days)

Net area from each of the plots was harvested and sun dried separately. Total weight of these plants (stover + ear) from each net plot was recorded and computed as biological yield ha⁻¹. Harvest index (HI) was computed by dividing economic yield by biological yield and multiplied by 100. Attraction index was computed by dividing grain yield by stover yield and multiplied by 100 to express in per cent.

The consumptive use of water by pearl millet was worked out for different treatments by summing up the soil moisture depleted from the profile for different periods. The periodical effective rain fall was also added to compute consumptive water use of corresponding period. Consumptive water use was calculated by the formula given by Michael et al. (1977). Water-use efficiency (WUE) of the crop in different treatments was determined by dividing grain yield (kg/ha) by consumptive use of water (mm) and expressed in kg ha⁻¹ mm⁻¹.

RESULTS AND DISCUSSION

Growth

Growth in terms of dry matter accumulation, leaf area index, leaf area plant⁻¹, leaf area duration and crop growth rate varied under various treatments (Table 1). HHB-67-2 showed significantly higher dry matter accumulation plant⁻¹ (9.65 %) at harvest, leaf area plant⁻¹ (9.34 %) at 55 DAS, leaf area index (8.87 %) and leaf area duration (9.65 %) at 41 to 55 DAS and crop growth rate (8.00) at 56 DAS to harvest over HHB-67 in first year. Differences in growth of different hybrids might be attributed to the differences in their genetic constitutions. Further, comparatively better growth of hybrid HHB-67-2 than HHB-67 might be due to its downy mildew resistant character. These results corroborate earlier findings reported by Parihar *et al.*, (2005).

Plant density of 60 x 12 cm resulted in an increase of 17.88, 11.66 and 15.25 per cent in dry matter accumulation plant⁻¹, leaf area plant⁻¹ (55 DAS) and crop growth rate (55 DAS) at harvest, respectively over the density of 30 x 12 cm in first year. However, significantly higher leaf area index and leaf area duration was recorded when pearl millet was planted at 30 x 12 cm over 60 x 12 cm. Thus, improvement in the performance of individual plant (dry matter accumulation, leaf area and crop growth rate) was brought about by decrease in plant density. Wider row spacing might be attributed to proper utilization of resources like moisture and nutrients which might have under utilized due to mutual plant competition developed by more plants in closer spacing. Overall improvement in the growth of individual pearl millet plants due to wider spacing have also been reported by Kumar et al. (2004).

Increasing levels of fertility significantly improved dry matter accumulation plant⁻¹ and leaf area plant⁻¹. The highest fertility level of 90 kg N + 45 kg P₂O₅ ha⁻¹ recorded significantly higher dry matter accumulation plant⁻¹, leaf area plant⁻¹, leaf area duration and crop growth rate over control and 30 kg N + 15 kg P₂O₅ in both the crop seasons.

Application of 90 kg N + 45 kg P₂O₅, 60 kg N + 30 kg P₂O₅ and 30 kg N + 15 kg P₂O₅ ha⁻¹ resulted in about 37.48, 35.26 and 19.21 per cent increase in dry matter accumulation over control, respectively. Adequate supply of fertilizers resulted in better root development, high photosynthetic rate, better utilization of carbohydrates in the synthesis of more protoplasm and higher accumulation of dry matter and overall improvement in the growth of pearl millet has been reported earlier by Sharma and Gupta (2001). Days taken to 50 % flowering

Table 1. Effect of various treatments on dry matter accumulation, leaf area, leaf area index, leaf area duration, crop growth rate, 50 % flowering, biological yield, harvest index and attraction index.

Treatments	Dry matter accumulation (g/plant)		Leaf area/plant (cm ²)		Leaf area index		Leaf area duration (days)		Crop growth rate (g/plant/days)		Days taken to 50 % flowering		Biological yield (q/ha)		Harvest index (%)		Attraction index (%)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
HYBRIDS																		
HHB-67	64.04	61.75	846.50	800.50	1.679	1.588	26.32	25.19	0.533	0.438	38.86	38.42	103.60	100.30	24.36	22.98	32.11	29.86
HHB-67-2	70.22	65.58	925.50	880.80	1.828	1.737	28.86	27.73	0.681	0.354	38.92	39.08	116.70	109.10	24.36	23.04	32.11	29.95
SEm ±	1.41	1.20	18.53	17.52	0.037	0.035	0.59	0.56	0.012	0.008	0.83	0.82	2.43	2.20	0.54	0.49	0.68	0.63
CD at 5 %	4.45	3.79	58.43	55.24	0.118	0.112	1.87	1.77	0.039	0.026	NS	NS	7.68	6.93	NS	NS	NS	NS
SPACING (cm)																		
30 X 12	61.50	58.13	828.30	784.00	2.301	2.178	36.45	35.04	0.455	0.281	38.04	37.63	105.10	99.75	23.82	22.41	31.14	28.89
45 X 12	67.40	63.75	904.70	856.00	1.675	1.585	26.05	24.96	0.616	0.417	38.50	38.50	123.60	117.70	24.80	23.44	32.86	30.63
60 X 12	72.50	69.13	925.00	882.00	1.285	1.225	20.27	19.38	0.750	0.490	40.13	40.13	101.40	96.75	24.46	23.19	32.32	30.20
SEm ±	1.73	1.48	22.69	21.45	0.046	0.043	0.73	0.70	0.015	0.010	1.04	1.01	2.98	2.69	0.66	0.60	0.83	0.77
CD at 5 %	5.45	4.68	71.55	67.64	0.145	0.137	2.29	2.20	0.048	0.032	NS	NS	9.40	8.49	NS	NS	NS	NS
Fertility Levels																		
Control	54.58	52.00	717.60	671.60	1.420	1.328	22.26	21.11	0.317	0.278	37.56	37.00	85.69	81.00	23.87	22.21	31.22	28.55
30 kg N +15 kg P ₂ O ₅ ha ⁻¹	65.07	63.17	869.30	815.30	1.721	1.612	27.18	26.13	0.457	0.403	38.33	38.17	109.30	102.80	24.48	22.98	32.29	29.84
60 kg N +30 kg P ₂ O ₅ ha ⁻¹	73.83	68.50	968.80	928.30	1.917	1.837	30.14	28.86	0.800	0.431	39.33	39.67	121.10	115.30	24.56	23.24	32.54	30.29
90 kg N +45 kg P ₂ O ₅ ha ⁻¹	75.04	71.00	988.30	947.30	1.956	1.873	30.78	29.73	0.854	0.472	40.33	40.17	124.60	119.80	24.52	23.63	32.36	30.95
SEm ±	1.23	1.06	16.27	15.47	0.033	0.031	0.51	0.47	0.013	0.009	0.72	0.70	1.85	1.95	0.40	0.42	0.59	0.55
CD at 5 %	3.54	3.35	46.69	44.41	0.094	0.089	1.48	1.36	0.036	0.025	2.04	2.02	5.30	5.59	NS	NS	NS	1.57

Table 2. Effect of various treatments on consumptive use of water and water use efficiency.

Treatments	Consumptive use of water (mm)		Water use efficiency (kg ha-mm ⁻¹)	
	2004	2005	2004	2005
HYBRIDS				
HHB-67	203.6	237.7	12.40	9.74
HHB-67-2	205.4	240.5	13.85	10.49
SPACING (cm)				
30 X 12	208.1	242.7	11.99	9.21
45 X 12	204.3	238.6	15.00	11.63
60 X 12	201.0	235.4	12.40	9.55
FERTILITY LEVELS				
Control	198.1	232.9	10.30	7.72
30 kg N +15 kg P ₂ O ₅ ha ⁻¹	203.5	238.0	13.13	9.94
60 kg N +30 kg P ₂ O ₅ ha ⁻¹	207.2	241.6	14.37	11.10
90 kg N +45 kg P ₂ O ₅ ha ⁻¹	209.3	243.8	14.56	11.62

Fig. 1. Soil moisture studies from sowing to harvesting of the crop (2004 and 2005).

was not influenced significantly by hybrids and spacing in both the seasons. The crop applied with 90 kg N + 45 kg P_2O_5 ha⁻¹ took maximum number of days to reach at 50 % flowering was significantly higher than control but at par with lower doses of fertility in both the crop seasons. Least days to 50 % flowering were taken with control and was significantly lesser than all fertilizer treatments in both the seasons.

Biological Yield

Hybrid HHB67-2 recorded significantly higher biological yield over HHB-67 in both the seasons. Plant density 45 x 12 cm produced significantly higher biological yield in both the seasons over spacing 30 x 12 and 60 x 12 cm. The fertility level up to 60 kg N + 30 kg P_2O_5 ha⁻¹ resulted in significant difference in biological yield over control and 30 kg N + 15 kg P_2O_5 ha⁻¹ but beyond this level there was no significant response in biological yield. The results corroborate the findings of Kumar (2001). The hybrids, plant density and fertility levels failed to cause significant influence on harvest index of pearl millet. Similarly, hybrids and plant density failed to cause any significant influence in attraction index. Further, fertility levels in first year did not produce any significant difference in attraction index but in second year fertility level 90 kg N + 45 kg P_2O_5 ha⁻¹ significantly increased attraction index over control and remained at par with 30 kg N + 15 kg P_2O_5 ha⁻¹ and 60 kg N + 30 kg P_2O_5 ha⁻¹. Similar findings have been reported by Kumar et al. (2004).

Water use studies

Pearl millet hybrid HHB 67-2 recorded relatively higher value for consumptive use of water (205.4mm in 2004 and 240.5 mm in 2005) than HHB67 (203.6mm in 2004 and 237.7 mm in 2005). Water use efficiency was markedly higher with HHB67-2 than HHB67. Such variations in consumptive water use and water use efficiency might be viewed on the basis of differences in their growth in terms of leaf area and dry matter accumulation plant⁻¹. The differences in the value of consumptive water use and water use efficiency of pearl millet hybrids were also reported by Kumar et al. (2003).

Plant density 30 x 12 cm gave higher consumptive water use (Table 2) compared with 45 x 12 cm and 60 x 12 cm densities owing to larger crop canopy. However, 45 x 12 cm spacing resulted in higher water use efficiency. This can be explained on the basis of yield data (Table 1) which support the view that there was proper utilization of nutrient as well as moisture under optimum plant population. These results are in close conformity with

those of Kaushik and Gautam (1991).

The nitrogen and phosphorus had favorable effect on consumptive water use and water use efficiency. The increasing levels of fertility increase the consumptive water use and water use efficiency. This might be due to increased in plant growth (Table 1). Besides this phosphorus might have increased the root volume thereby increasing consumptive water use and water use efficiency. Soil moisture increases with increasing soil depth during both the seasons. The moisture was higher at sowing and depleting slowly till harvest (Fig. 1). Similar findings also reported by Malik and Sharma (1984).

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