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Effect of different water regimes and nitrogen application on growth, yield, water use and nitrogen uptake by pearl millet (*Pennisetum glaucum*)

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ABSTRACT

A study was conducted during rainy (*kharif*) season of 2004 and 2005 in a sandy loam soil of the semi-arid region of Delhi to study the effect of different doses of nitrogen (30, 60 and 120 kg/ha) under rainfed and irrigated condition on 'HHB 67' pearl millet [*Pennisetum glaucum* (L.) R.Br. emend. stuntz.]. Growth rate varied between different seasonal weather condition, but the relative growth rate and the partitioning of dry matter was similar. Yields were more influenced by water application than the nitrogen doses. Maximum yield (3.19 and 3.10 tonnes/ha in 2004 and 2005, respectively) was recorded with 120 kg N/ha application under irrigated condition, while optimum yield (2.30 and 2.40 tonnes/ha in 2004 and 2005, respectively) and water-use efficiency under rainfed condition was attained with 60 kg N/ha. Stem N concentration at panicle initiation and early boot stage was well correlated with yield, and might be used for predicting the grain yield. A dose of 60 and 120 kg N/ha are the optimum doses in attaining the maximum growth and yield of pearl millet under rainfed and irrigated conditions, respectively.

Key words: Biomass, Grain yield, Nitrogen uptake, Pearl millet, Water-use efficiency

Pearl millet [*Pennisetum glaucum* (L.) R.Br. emend. stuntz.], a major cereal crop in the arid and semi-arid regions of India, is getting more attention today due to increasing evidence of less seasonal rainfall, increase in temperature, frequent occurrence of extreme weather events coupled with scanty water resources, as the crop is hardy, require less water and has a short-growing period (Jakhar *et al*. 2006, Om Prakash *et al*. 2008). Though adapted to resource-poor situation, pearl millet also suffers badly due to low soil fertility and scarce water availability, thereby reducing the yield potential. However, the growth rate of this crop has been as high as wheat (*Triticum aestivum* L. emend. Fiori & Paol.) and much higher than other coarse cereals, like maize (*Zea mays* L.), and sorghum (*Sorghum bicolor* L. Moench) in the last few decades, mostly due to introduction of high-yielding disease-resistant varieties (Khairwal and Yadav 2005). It is obvious to generate site-specific information on performance of pearl millet under differential water and fertilizer regimes, which are meager in Indian conditions. The N-uptake and its utilization by the crop under rainfed and irrigated water regimes are also little known. Keeping these facts in view, field experiments were planned to study the response of rainfed and irrigated pearl millet to N application rates, which would help in deciding the optimum dose of N under different water application regimes in the semi-arid region of Delhi.

MATERIALS AND METHODS

A 2-year experiment was carried out on 'HHB 67' pearl millet [*Pennisetum glaucum* (L.) R.Br. emend. stuntz.] in a sandy loam soil (Typic Haplustept with *p*H 8.2, EC 0.26 dS m, organic carbon content 4.0 g/kg soil, and available N as 200 kg/ha in 0–30 cm depth) at Indian Agricultural Research Institute Farm, New Delhi during rainy (*kharif*) season 2004 and 2005. Treatments consisted of 2 water regimes (rainfed and irrigated) as main plot and 3 levels of nitrogen (30, 60 and 120 kg N/ha) as sub-plots in a split-plot design with 4 replications. The crop was planted on 16 July in 2004 and 21 July in 2005 and harvested on 3 and 10 October, respectively. The plot size was 4 m×7 m with row-to-row and plant-to-plant distances at 45 and 15 cm, respectively. For rainfed treatment, crop was only dependent on rain, while 3 irrigations at tillering, ear head emergence and grain-filling stages were given for irrigated crop. Biomass of the crop as

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well as its partitioning into stem, leaf and ear head were monitored on 20, 30, 40, 50 and 60 days after sowing and at harvest. Nitrogen concentration in plant parts was estimated following Kjeldahl method (Jackson 1973). Gravimetric moisture from 0–15, 15–30, 30–45, 45–60, 60–75 and 75–90 cm soil depths were recorded at sowing and harvest of crop to calculate the crop water use and use efficiency. Statistical analysis was performed with the help of Statistical Analysis System Software (SAS 1985).

RESULTS AND DISCUSSION

Crop growth, yield and water-use efficiency

The amount of rain during the cropping season was more and uniformly distributed in 2004, thus facilitating an early and better crop establishment and more biomass. The increase

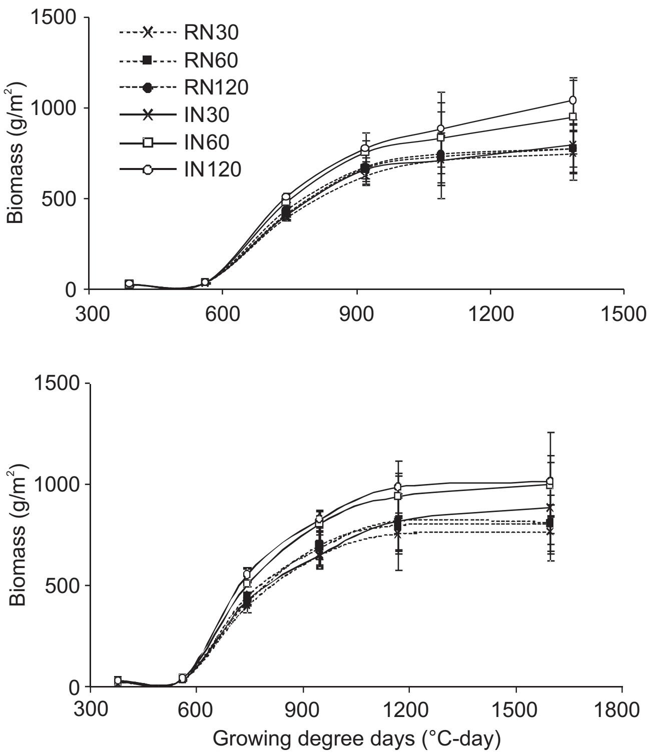

Fig 1. Biomass accumulation of pearl millet (each data point is average of 4 plants; error bars indicate ±1 SE)

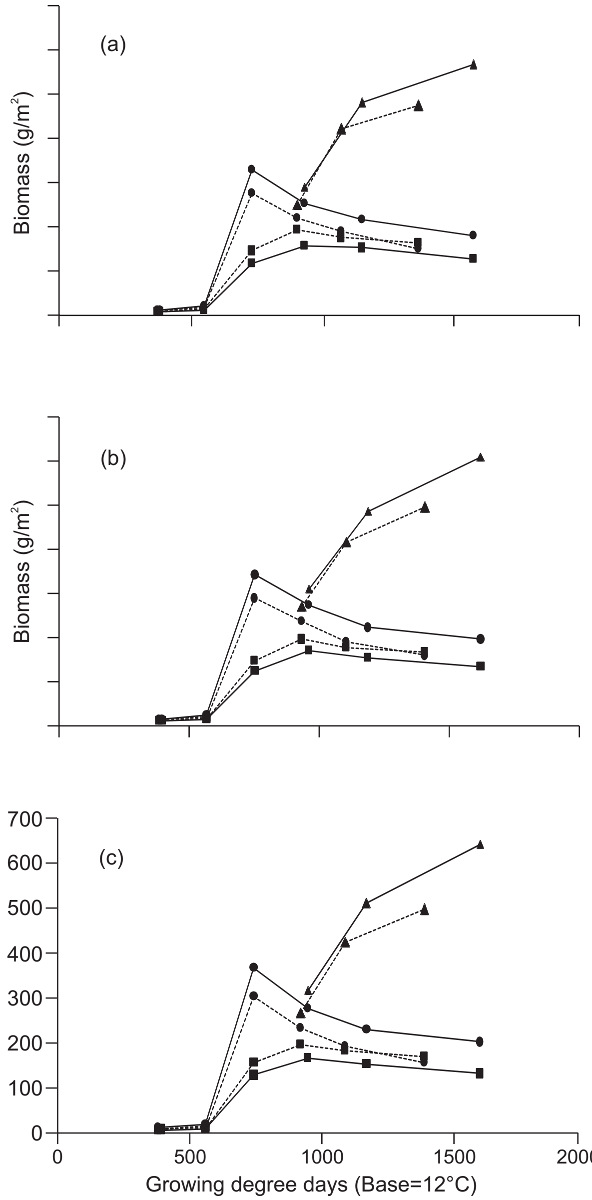

Fig 2. Biomass partitioning of pearl millet into leaf (■), stem (●) and ear head (▲) applied with of (a) 30 (b) 60 and (c) 120 kg N/ha (mean of 2 years; solid and dashed lines represent rainfed and irrigated water regimes, respectively)

Table 1 Seasonal water use and water-use efficiency of pearl millet as influenced by differential water regime and N application

Treatment	Grain yield (tonnes/ha)		Crop water use (mm)		Water-use efficiency (kg/ha/mm)	
	2004	2005	2004	2005	2004	2005
Rainfed + N@ 30 kg/ha	1.80	2.00	287	288	6.27	6.94
Rainfed + N@ 60 kg/ha	2.30	2.40	295	300	7.80	8.00
Rainfed + N@ 120 kg/ha	2.40	2.50	334	320	7.18	7.81
Irrigated + N@ 30 kg/ha	2.10	2.30	322	311	6.51	7.39
Irrigated + N@ 60 kg/ha	2.90	2.93	365	358	7.94	8.10
Irrigated + N@ 120 kg/ha	3.19	3.10	350	367	8.81	8.17
CD (*P=0.05*)	0.17	NS				

in biomass followed similar trend in both the years (Fig 1) and recorded maximum (at harvest) value as 1 037 and 1 010 g/m^2 under irrigated condition with 120 kg/ha N application. For rainfed crop, the final biomass was at par between 60 and 120 kg N/ha in both the years. Owing to differential rainfall distribution between the years, the growth rate of pearl millet continued to increase up to 947°C-day in 2005, as against 744°C-day in 2004, though the relative growth rate was similar in both the years (data not presented). The plant density was not significant between the years, thus, the increased biomass in 2005 was effectively translated in getting more yield of pear millet. The effect was more evident in rainfed treatments with 6% increase in yield during 2005 as against only 3% under irrigated condition (Table 1). Though the biomass of rainfed crop with 30 or 60 kg N/ha increased similarly as irrigated crop with 30 kg N/ha in 2004, the irrigated crop produced higher biomass with low N than rainfed with higher doses of N in 2005. A possible explanation of this could be that no rain with increased evaporative demand prevailed during grain filling in 2005 where the rainfed crop suffered more water stress.

Pattern of differentiation of dry matter into stem, leaf and ear head was also similar in both the years (Fig 2). Stem dry matter continued to increase till 560 GDD, while leaf up to 740 GDD, and then both started falling. Growth of ear head started at 560 growing degree days (GDD) and continued till maturity. In irrigated plots, maximum dry matter in ear head was recorded with 120 kg N/ha, while in rainfed plots, peak growth appeared only up to 60 kg N/ha application and further application of N actually reduced the dry matter translocation to ear head. Dry matter partitioning among stem, leaf and ear head was found at 3: 2: 5, which was generally observed among high-yielding varieties grown in semi-arid climate of India (Maiti and Bidinger 1981).

Though maximum grain yield was obtained with 120 kg N/ha application in irrigated treatment (3.19 tonnes/ha in 2004 and 3.10 tonnes/ha in 2005), effect of nitrogen on grain yield was less pronounced than the water. Seasonal water use was more in irrigated than the rainfed crop due to more water availability to plants, which also increased with increase in N application (Table 2). Maximum water-use efficiency (WUE) was obtained with 120 kg N/ha under irrigated condition, while for rainfed crop, maximum WUE was achieved with 60 kg N/ha. Positive linear relation could be established between yield and water-use efficiency.

Grain nitrogen content and uptake efficiency

Higher dose of fertilizer N increased N content in grains under irrigated condition in all three stages of crop, but in rainfed situation, applied N did not always increases ear head N content, probably due to limited availability of water (Table 2). Limited water availability in rainfed crop adversely affected the translocation of dry matter to ear head when the N application was increased beyond 30 kg N/ha, while maximum ear head biomass of irrigated crop was recorded with 120 kg N/ha dose. Thus the water-nitrogen interaction in augmenting the physiological growth and maturity of the crop is well documented. In the present study, 60 kg N/ha seems to be optimum for attaining good growth and yield of rainfed crop; and best results can only be achieved through more application of water, which is likely to help in more effective translocation of the dry biomass to ear heads which

Table 2 Ear head nitrogen concentration at different growth stages of pearl millet

Treatment	Ear head nitrogen concentration (g/kg)					
	2004			2005		
	921	1 090	1 387	947	1 171	1 600
	GDD					
Rainfed	13.33	13.30	13.50	13.76	14.50	14.10
Irrigated	15.20	14.13	14.50	13.80	14.87	14.73
CD (*P*=0.05)	0.22	0.29	0.29	0.57	0.07	0.11
Nitrogen (*N*)						
N@ 30 kg/ha	12.70	13.50	13.10	13.55	14.15	13.55
N@ 60 kg/ha	15.25	14.25	14.35	12.88	15.15	14.70
N@ 120 kg/ha	14.85	13.40	14.55	14.90	14.75	15.00
CD (*P*=0.05)	0.27	0.35	0.35	NS	0.09	0.14
Interaction (*water×nitrogen*)						
Rainfed×N @ 30 kg/ha	11.20	12.00	12.20	13.10	14.00	13.00
Rainfed×N @ 60 kg/ha	14.70	14.20	14.00	13.10	15.10	14.50
Rainfed×N @ 120 kg/ha	14.10	13.70	14.30	15.10	14.40	14.80
Irrigated×N @ 30 kg/ha	14.20	15.00	14.00	14.00	14.30	14.10
Irrigated×N @ 60 kg/ha	15.80	14.30	14.70	12.70	15.20	14.91
Irrigated×N @ 120 kg/ha	15.60	13.10	14.80	14.70	15.10	15.20
CD (*P*=0.05)	0.38	0.50	0.50	0.99	0.12	0.19

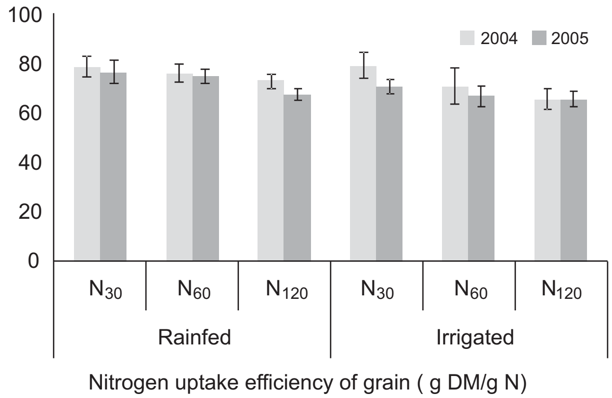

Fig 3. Nitrogen uptake efficiency of pearl millet grains under various N application rates (error bars indicates ± 1 SE; DM = dry matter)

ultimately translates in improved grain yield.

Maximum N uptake efficiency for grain yield was obtained in irrigated crop with 30 kg N/ha application as 79 and 77 g dry matter/g N in 2004 and 2005, respectively (Fig 3), progressively decreasing with higher doses of N.

The study indicates that water and not N becomes limiting factor for rainfed crop yield beyond 60 kg N/ha. More N application coincides well with more use of water, when water is non-limiting, increasing the yield and thereby improving the WUE of the crop. For rainfed crop, the efficiency was optimum with N application @ 60 kg/ha. Results indicate that while soil moisture becomes less, like in a dry season, less N should be applied, as water becomes the limiting factor. Experiments in the same field earlier reported an average 1.9 tonnes/ha yield of pearl millet with no fertilizer N application; therefore, the yield increase with initial N application was quite substantial, even of rainfed crop, as the soil was low to medium in available N concentration (Kennedy *et al.* 2002).

Thus it may be concluded that in soils with low available N content, the response of pearl millet to initial N application is always better, though the subsequent yield benefit with incremental dose of N depend on the soil water availability. In our study, optimum dose of N was identified as 120 kg N/ha for irrigated and 60 kg N/ha for rainfed crop, as these corresponded to the optimum yield, water use and N uptake by the crop. Varietal differences in water and N-response also need to be evaluated under limited and adequate water applications for giving the final recommendation.

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