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Research Communication

Planting density and nitrogen management effects on productivity, quality and water-use efficiency of rainfed pearlmillet (*Pennisetum glaucum*) under conservation agriculture

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ABSTRACT

A field experiment was conducted during the rainy season 2015 at New Delhi, to study the effect of planting density and nitrogen-management practices on conservation agriculture-based rainfed pearlmillet [*Pennisetum glaucum* (L.) R. Br. Emend stuntz]. The experiment comprised 3 main-plot treatments, viz. normal distance sowing (D_1), high density sowing followed by (*fb*) alternate row harvesting for fodder at 35 days after sowing (DAS), (D_2) and high density sowing *fb* alternate row harvesting for fodder at 45 DAS (D_3) and 5 subplot treatments, viz. control, 60 kg N/ha as basal, 30 kg N/ha as basal + 30 kg N/ha as side dressing, 75 kg N/ha as basal and 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing. Maximum production efficiency (56.2 kg/ha-day), system yield (4.49 t/ha), net returns (33.9 × 10^3 ₹/ha) and monetary efficiency (₹424/ha-day) was recorded under D_2. The highest protein yield (285 kg/ha), consumptive use (423.5 mm), water-use efficiency (6.4 kg/ha-mm) and rate of moisture use (5.3 mm/day) were realized from treatment D_1. Among N-management treatments, 75 kg N/ha as basal resulted in the highest system yield (4.69 t/ha), production efficiency (58.6 kg/ha-day), net returns (36.6 × 10^3₹/ha) and monetary efficiency (₹457/ha-day). Protein content in grain (11.4%) and protein yield (298 kg/ha), consumptive use of water (429 mm) and water-use efficiency (7.1 kg/ha-mm) were found highest in 37.5 kg N/ha as basal + 37.5 kg N/ha as side-dressing.

Key words : Conservation agriculture, Nitrogen management, Pearlmillet, Planting density, Water-use efficiency

Pearlmillet is a crucial component to the food security of the rural population in dry areas. In addition, its stover is an important source of fodder, accounting for 40–50% of dry matter intake year round, and the only source of feed during the dry months in majority of arid and semi-arid agro-climatic conditions (Rana and Bana, 2012). Being a crop of marginal environments and arid tropics, it suffers from many abiotic stresses, moisture stress being the most important. Further, profit fetched from the crop is also low due to lesser productivity under soil-moisture scarcity and comparatively higher cost of cultivation. Application of organic mulch effectively reduces evaporative moisture losses with the added advantage of reduced weed growth and improved soil health (Bana *et al.,* 2016). Conservation agriculture (CA) interventions (zero-tillage + mulching) offer a viable alternative for production of this crop as CA practices helps to retain more profile moisture and essential nutrients and reduce cost of cultivation (Choudhary *et al.,* 2016). But, the major obstacles in adoption of CA in dryland ecosystems are less biomass availability for mulching and competing uses of crop residues for livestock component of farming systems of this ecosystem. High density planting followed by alternate row harvesting for fodder at different growth stages may provide a partial solution to the problem of fodder shortage occurring under CA systems. Further, research findings on N-management protocols for pearlmillet are not available under CA. Keeping these in view, the present investigation was carried out to study the effect of planting density and nitrogen management on productivity, quality and water-use efficiency in conservation agriculture-based pearlmillet.

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A field experiment was conducted at the Indian Agricultural Research Institute, New Delhi, during the rainy (*kharif*) season of 2015. The field had an even topography and good drainage system. Soil of the experimental site was sandy loam, poor in organic carbon content (0.44%) as well as available N (146 kg/ha) and medium in available P (15.8 kg/ha) and available K (184 kg/ha), soil was slightly alkaline in reaction with *p*H 7.5. The total rainfall received during crop-growing period was 685 mm. The experiment was conducted in fixed layout of split-plot design, replicated thrice. The field experiment comprised of 3 main plot treatments of planting density, viz. normal distance sowing (45 cm × 10 cm), high density sowing (22.5 cm × 10 cm) followed by (*fb*) alternate row harvesting for fodder at 35 days after sowing (DAS) and high density sowing (22.5 cm × 10 cm) *fb* alternate row harvesting for fodder at 45 DAS and 5 subplot treatments of nitrogen management, viz. control (N_1), 60 kg N/ha as basal [100% recommended dose of nitrogen (RDN); N_2], 30 kg N/ha as basal + 30 kg N/ha as side-dressing (N_3), 75 kg N/ha as basal (125% RDN; N_4), and 37.5 kg N/ha as basal + 37.5 kg N/ha as side-dressing (N_5). Pearlmillet variety 'Pusa Composite 443' was sown by happy seeder following the seed rate of 4 kg seed/ha in normal distance plot and 8 kg seed/ha in high density plots. For basal application urea was drilled in bands 5 cm below the surface during pearlmillet sowing and later, side-dressing of urea was done at 30 DAS as per treatments. The grain-equivalent yield of green fodder and grain-equivalent yield of stover are added in to grain yield to work out system yield. The system yield was divided by duration of crop to work out the production efficiency. Acid and neutral detergent fibre in forage samples were estimated by method described by Van Soest (1963). Consumptive use was calculated as:

$$\text{Consumptive use (mm)} = \Sigma(bj\text{-}ej) + \text{effective rainfall}$$

where, bj = total profile moisture content at the beginning of the j^{th} interval; ej = total profile moisture at the end of the j^{th} interval

Water-use efficiency was worked out by dividing grain yield with seasonal crop consumptive use of water. Rate of moisture use was worked out by dividing consumptive use of water by crop duration.

Significantly higher system yield (4.49 t/ha) was observed with high density sowing *fb* alternate row harvesting for fodder at 35 DAS compared to other planting density. This treatment registered 0.1 and 0.53 t/ha improvement in system yield over high density sowing *fb* alternate row harvesting for fodder at 45 DAS and normal distance sowing respectively. The same treatment also recorded the maximum production efficiency (56.2 kg/ha-day). The next best treatment was high density sowing *fb* alternate row harvesting for fodder at 45 DAS (54.8 kg/ha-day), followed by normal distance sowing (49.4 kg/ha-day). System yield and production efficiency enhanced significantly with high density sowing *fb* alternate row harvesting for fodder at 35 and 45 DAS owing to higher grain-equivalent yield of green forage obtained by alternate row harvesting at different growth stages.

Nitrogen-management practices also significantly influenced system yield. The maximum system yield (4.69 t/ha) was noted with 75 kg N/ha as basal (125% RDN); it was found at par with 37.5 kg N/ha as basal + 37.5 kg N/ha as side-dressing (4.68 t/ha). Almost all the nitrogen management treatments significantly affected production efficiency as compared to the control. The maximum production efficiency was recorded with 75 kg N/ha either as basal or under split application (58.5 kg/ha-day). In residue-based zero-till farming systems, slower soil N mineralization and greater immobilization, especially during initial periods of adoption of CA, hinders the crop production. So, application of slightly higher than recommended dose of N (i.e. 60 kg/N) under CA-based system compensates the lesser N availability due to immobilization of N and thus enhance system yield and production efficiency. Availability of nitrogen through mineralization of N at reproductive stage might be responsible for the similar performance of basal application than split application of N.

Grain protein content was non-significantly affected by planting density but marked decline in protein yield was noticed with high density. Pearlmillet planted under normal distance registered significantly higher protein yield (285 kg/ha). This is because of lower grain yield in high density sowing treatments as compared to normal distance sowing. Appreciable increase in protein per cent in pearlmillet grain was observed with an increase in subsequent level of nitrogen. Application of 37.5 kg N/ha as basal + 37.5 kg N/ha as side-dressing resulted in the highest grain protein content (11.4%) as well as protein yield (298 kg/ha). Nitrogen is an important constituent of protein, which always shows a marked promoting influence on protein synthesis by way of promoting synthesis of amino acids, which are constituent building blocks of protein (Bana and Gautum, 2009; Jhadav *et al.,* 2011; Bana *et al.*, 2012). The different treatments of planting density were failed to produce any significant variation on neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude protein (CP) content in green fodder of pearlmillet. Data on NDF and ADF content reveal that increasing level of nitrogen fertilizer shows remarkable decline in NDF and ADF content. The highest NDF and ADF value (70.8 and 42.5% respectively) were noticed in the control. In

Table 1. Effect of planting density and nitrogen management on system yield, production efficiency and quality parameters water-use efficiency and economics of pearlmillet

Treatment	System yield (t/ha)	Production efficiency (kg/ha-day)	Grain quality: Protein content (%)	Grain quality: Protein yield (kg/ha)	Green fodder quality: NDF[a] (%)	Green fodder quality: ADF[b] (%)	Green fodder quality: CP[c] (%)	Consumptive use of water (mm)	Water-use efficiency (kg/ha-mm)	Rate of moisture use (mm/day)	Net returns (× 10^3 ₹/ha)	Monetary efficiency (₹/ha-day)
Planting density												
D_1	3.96	49.5	11.1	285	67.9	41.4	7.7	429.7	7.5	5.4	28.5	356
D_2	4.49	56.2	11.0	258	67.4	41.2	7.5	423.5	6.4	5.3	33.9	424
D_3	4.39	54.8	10.6	226	67.2	41.1	7.3	420.0	5.3	5.2	32.3	404
SEm±	0.04	0.5	0.12	6.17	0.36	0.16	0.13	1.40	0.10	0.02	0.56	6.9
CD(P=0.05)	0.17	2.13	NS	24.3	NS	NS	NS	5.48	0.38	0.07	2.20	27.1
Nitrogen management												
N_1	3.41	42.7	10.3	187	70.8	42.5	6.1	417.0	5.9	5.2	21.3	266
N_2	4.30	53.7	10.7	251	67.8	41.3	8.2	423.8	6.1	5.3	31.8	397
N_3	4.32	53.9	10.8	261	67.3	41.5	7.4	424.2	6.2	5.3	31.7	397
N_4	4.69	58.6	11.3	285	65.8	40.3	8.3	428.0	6.6	5.4	36.6	457
N_5	4.68	58.6	11.4	298	65.9	40.4	7.5	428.9	7.1	5.4	36.3	454
SEm±	0.07	0.86	0.13	4.50	0.51	0.33	0.17	1.25	0.14	0.02	0.87	10.9
CD (P=0.05)	0.20	2.51	0.38	13.1	1.49	0.96	0.49	3.64	0.41	0.05	2.55	31.9

D_1, normal distance; D_2, high density sowing followed by (*fb*) alternate row harvesting for fodder at 35 days after sowing (DAS); and D_3, high density sowing *fb* alternate row harvesting for fodder at 45 DAS; N_1, Control; N_2, 60 kg N/ha as basal; N_3, 30 kg N/ha as basal + 30 kg N/ha as side dressing; N_4, 75 kg N/ha as basal; and N_5, 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing

[a]Neutral detergent fibre, [b]acid detergent fibre and [c]crude protein

contrary to NDF and ADF value, crude protein content in pearlmillet fodder increased with N levels. The maximum crude protein content (8.3%) in green fodder was recorded in 75 kg N/ha as basal treatment (125% RDN), being at par with 60 kg N/ha as basal (100% RDN).

Normal distance sowing resulted in significantly higher consumptive use of water and water-use efficiency in pearlmillet. Consumptive use (CU) of water increases in exact proportion to the dry weight production. Up to alternate row harvesting stage, CU was more at high density plots attributed to enhanced vegetative growth/unit area. After that, it was higher in normal distance sowing plot due to more dry weight and leaf area/plant. Despite more CU, increased water-use efficiency (WUE) of pearlmillet under normal distance sowing could be ascribed to higher pearlmillet grain yield under this treatment, which is numerator in WUE calculation formula. The utmost CU coupled with rate of moisture use was observed with application of 37.5 kg N/ha as basal + 37.5 kg N/ha as side-dressing to pearlmillet, being at par with 75 kg N/ha as basal (125% RDN). It may be ascribed due to enhanced vegetative growth and an extensive proliferation and deeper root-system that enabled the plant to utilize more moisture from deeper horizons of soil profile. The findings are in close proximity that of Tetarwal and Rana (2006) and Kumar *et al*. (2015). Water-use efficiency was also increased with increasing N levels. It might be owing to the fact that increase in yield was of higher magnitude than the corresponding increase in CU of water, eventually resulted in considerable increase in WUE owing to N levels. The maximum WUE was obtained with 120 kg N/ha under irrigated condition, while for rainfed crop, maximum WUE was achieved with 60 kg N/ha (Singh *et al.,* 2010).

High density sowing *fb* alternate row harvesting for fodder at 35 DAS was found more profitable because of higher net returns and monetary efficiency. Higher profit under this treatment might be owing to more returns from green forage yield as compared to cost involved under this treatment. With increasing doses of N up to the highest level, the net return was increased over the control. Application of 75 kg N/ha as basal (125% RDN) fetched significantly higher net returns and monetary efficiency over all other nitrogen-management treatments and 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing was at par to it. The increased profitability under this treatments may be ascribed to the comparatively lower cost involved under this treatment.

The effect of CA on soil health may not be visible during initial years of experimentation and only long-term experimentation could provide better insight and more clarity to the present findings. In a short period study, it can be concluded that high density sowing *fb* alternate row harvesting for fodder at 35 DAS is a suitable practice to achieve more forage yield and profits. Hence, it can be a potential panacea to the problem of forage shortage under CA. For getting higher yield with more return under conservation agriculture especially during initial period of CA adoption, pearlmillet should be fertilized with 75 kg/ha either as basal or in split application (37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing).

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