International Journal of Chemical Studies 2017; 5(4): 849-853

International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(4): 849-853

Received: 25-05-2017
Accepted: 26-06-2017

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Effect of planting density and nitrogen management on micronutrient content, soil fertility and microbial properties in conservation agriculture based rainfed pearlmillet

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Abstract
A field experiment was carried out during 2015 at IARI, New Delhi to study the effect of planting density and nitrogen management practices on growth, micronutrient content and soil fertility under conservation agriculture based pearlmillet (*Pennisetum glaucum* L. R. Br. emend Stuntz). The experiment comprised of three main-plot treatments viz. normal distance sowing, high density sowing *fb* alternate row harvesting for fodder at 35 DAS and high density sowing *fb* alternate row harvesting for fodder at 45 DAS and five sub-plot 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. High density planting resulted in significant improvement in growth parameters (plant height, dry matter accumulation and leaf area index) at initial stage. But at later stages, these parameters along with no. of tillers were significantly higher in normal distance sowing. Higher growth was obtained with basal application of 75 and 60 kg N/ha over split application and control. Whereas, all the above growth parameters and total no. of tillers during later stages (60 DAS and at harvest), were improved significantly by 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing and remained equivalent to basal application of 75 kg N/ha. Similarly, micronutrient uptake was also higher under normal distance sowing. In pearlmillet, micronutrients content and total uptake, available N, P and K and soil microbial biomass carbon and enzymatic activities were increased significantly with the application of 75 kg N/ha either as basal or in splits.

Keywords: Conservation agriculture, Micronutrients, Nitrogen, Pearlmillet, Planting density and Soil fertility

Introduction

Rainfed agriculture is fundamental to agricultural production and underpins food, nutrition and fodder security in almost every part of the globe. It covers around 82% of the world's crop land area, hosts nearly 40% of humanity and produces more than 60% of cereal grains and fodder (Bana, 2014) [1]. In India also, around 80 million hectare (58%) of the 141 million hectare net sown area is rainfed. In fact, the rainfed drylands are characterized by severe drought, poor soil fertility high temperatures, soil salinity and alkalinity and also are vulnerable to climate change effects (Gautam and Bana, 2014) [8]. Pearlmillet is well adapted to such challenging environmental conditions and often found in truly marginal areas where other cereal crops, such as maize or wheat, can't survive (Bana *et al*., 2012) [2].

Pearlmillet is a staple provider of food, nutrition and income for millions of resource-poor people living on harsh agricultural lands. Its crop residues as well as grains are vital feedstocks for cattle, goats and chickens. But, severe drought substantially reduces yields of pearlmillet. Application of organic materials including mulches is considered poor heat conductor to effectively moderate soil temperature, maintain soil moisture and improve soil fertility (Bana *et al.*, 2016) [3]. Therefore, conservation agriculture (CA) practices (like residue retention) are the viable approach to retain and maintain soil moisture and essential plant nutrients under semi-arid dryland situations, besides reducing cost of cultivation. To overcome production constrains of rainfed pearlmillet, CA can be a sustainable alternate (Choudhary *et al.*, 2016a) [5]. Since information pertaining to nitrogen management and alternate options for competitive uses of crop residue in CA based rainfed pearlmillet is meagre.

So the present investigation was carried out to study the effect of planting and nitrogen management on growth parameters, micronutrient content, soil fertility and microbial properties in conservation agriculture based rainfed pearlmillet.

Materials and methods

An experiment was conducted in rainfed condition at Indian Agricultural Research Institute, New Delhi (28˚ 4'N, 77˚ 12'E and at 228.6 m above mean sea level) in 2015. The test soil was sandy loam, slightly alkaline (7.5) and poor in organic carbon content (0.44%). It was also poor in available N (146 kg/ha) and medium in available P (15.8 kg/ha) and K (184 kg/ha). The total rainfall received during crop growing period was 685 mm. The experiment was carried out in the fixed plot of split-plot design, replicated thrice. There were three main plot treatments of planting density *viz.* normal distance sowing (D_1), high density sowing *fb* alternate row harvesting for fodder at 35 DAS (D_2) and, high density sowing *fb* alternate row harvesting for fodder at 45 DAS(D_3) and five sub-plot treatments of nitrogen management viz. control (N_1), 60 kg N/ha as basal (100% 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 using happy seeder on 15th July 2015 following a seed rate of 4 kg seed/ha in normal distance plot and 8 kg seed/ha in high density plots. A closer spacing of 22.5 x 10 cm was adopted for high density planting while it was 45 x 10 cm under normal distance. Urea, DAP and muriate of potash were drilled in bands 5 cm below the surface during pearlmillet sowing. Side-dressing of urea was done at 30 DAS as per treatments. Application of glyphosate @ 1.5 kg ha^{-1} was done in all plots and peripheral bunds to kill existing weeds about a week prior to sowing of the crops. Two hand weeding were done at 25 DAS and 40 DAS. Tank mix solution of chloropyriphos (0.05%) was applied before sowing of the crop in order to control termite infestation. Growth parameters, yield attributes and other biometrics observations were undertaken as per requirements for validation of findings. The area of leaves of 5 plants was measured with the help of leaf area meter (Modal: LI-COR 310) and leaf area index was calculated. SPAD value was recorded from middle of the top-most leaf of selected plants. Soil and plant analysis were made following standard procedures. The uptake of micronutrients was calculated by multiplying their respective concentration with grain and stover yield. Microbial biomass carbon was estimated using the standard procedure of Vance *et al*. (1987) [15] method. The activity of alkaline phosphatase in soil was analysed by Tabatabai and Bremner (1969) method and dehydrogenase activity of soil samples was estimated by Casida *et al*. (1964) [4] method. The economics was worked out on prevailing market prices. In order to compare the treatments analysis of variance technique was carried out following split plot design (Gomez and Gomez, 1984) [9]. The significance of treatment effect was determined using F- test at 5% level of significance. The mean difference between the treatments was compared using the least significant difference (LSD).

Result and discussion

Plant growth parameters

Planting of pearlmillet under high density resulted in significant improvement in dry matter accumulation per m^2 and LAI at initial growth stage (30 DAS) and plant height of pearlmillet at all growth stages. Despite low dry matter per plant, dry matter accumulation per m^2 at 30 DAS was higher at high density plots due to more no. of plants per unit area. Increase in leaf area at high planting density was due to increased plant population even though lower leaf length and leaf width per plant. Plant height increases with increasing seed rates due to competition for light. Further, auxin is sensitive to light, shading prevents its destruction and thus, higher accumulation of auxin in shady plants triggers its growth to height (Mahdi *et al*., 2012) [11]. Earlier Mahdi *et al*. (2011) [10] and Saba *et al*. (2015) [13] agreed with the same results. Contrary to above, at later growth stages, significantly higher values of dry matter, LAI and total number of tillers was recorded under normal distance as compared to high density sowing treatments. Here, it may be pointed out that this type of response may be regarded mainly due to lower competition under low plant population level for space, moisture, nutrients, light and other environmental resources. At initial growth stage, significantly higher value of SPAD reading (45.9) was recorded at normal planting density probably due to lesser competition for N which leads to more greenness of leaves with higher chlophyphyll contents.

The maximum plant height (69.6 cm), dry matter (563.9 g/m^2), LAI (2.60) and SPAD value (47.6) at 30 DAS were recorded with basal application of 75 kg N/ha (125% RDN) closely followed by 60 kg N/ha as basal (100% RDN). Basal application of 75 and 60 kg N/ha resulted in lesser immobilization and greater mineralization of N at initial growth stages in conservation agriculture practices so N is fairly available for plants growth and development. Nitrogen is a principle constituent of proteins, enzymes, hormones, vitamins, chlorophyll and nucleotides and it cause cell elongation and accelerate the meristematic activity of plant that led to progressive increase in internodes length and photosynthetic area. So, increase in N dose resulted in increased plant height, number of functional leaves per plant, stem diameter and finally dry matter accumulation. Whereas, at 60 DAS and at harvest the maximum plant height (253.3 cm), plant dry matter (2155 g/m^2), number of tillers per m^2 (34), LAI (5.12) and SPAD value (57.0) were observed with 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing treatment which was found at par with 75 kg N/ha as basal (125% RDN). Basal application perform almost similar to split application during initial period of conservation agriculture adoption probably due to N immobilization during early plant growth period because of higher crop residue loads and thereafter, mineralization of the N from crop residues at later growth stages, ensuring supply of N to the crop up to the maturity stage.

Micronutrients uptake

Micronutrients (Fe, Mn, Cu and Zn) concentration in grain and stover of pearlmillet was statistically similar in all planting densities except Cu concentration in stover, which was significantly higher in normal distnance sowing. Significantly maximum total micronutrient uptake was found with normal distance sowing. Uptake is the function of nutrient concentration and dry matter yield and the yield is more deciding factor. Thus, more nutrient uptake was noticed under normal distance sowing which had the higher grain as well as stover yield.

Micronutrients contents in pearlmillet grain and stover enhanced with increasing nitrogen levels. The maximum concentration was recorded under application of 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing being at par with 75 kg N/ha as basal (125% RDN). The improvement in micronutrient content by N fertilization ascribed to the role of N in many physiological processes such as changes in rhizosphere and apoplast pH or in the synthesis of organic acids which, in turn, may act as micronutrient chelators as well as in the uptake, translocation and remobilization of micronutrients (Marschner, 2012) [12]. Similarly total micronutrients uptake was remained more with 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing being at par with 75 kg N/ha as basal (125% RDN). Since, uptake of the nutrient is the function of nutrient content and biomass production, the significant boost in content of micro nutrients together with increased grain and stover yield under N fertilization enhanced the total uptake of these nutrients. The finding also corroborates with the results of Choudhary *et al*., 2016a [5].

Soil microbial activities

Planting density treatments to pearlmillet was fail to bring any significant variation in microbial biomass carbon (MBC) and different soil enzymatic activities viz. dehydrogenase activity (DHA), alkaline phosphatase activity (ALP) and fluorescein diacetate activity (FDA). Soil microbial activity in terms of DHA, FDA, ALP and MBC was more with nitrogen application than control. Data further exhibit that 37.5 kg N/ha as basal + 37.5 kg N/ha as side dressing treatment brought about maximum MBC, activities of dehydrogenase, alkaline phosphatase and fluorescein diacetate activity. Soil enzymes are largely governed by microbial activities and influenced by agronomic practices. The higher microbial and enzymatic activities under nitrogen fertilization were attributed to adequate supply of N for microbial activities. Choudhary *et al*., 2014 [7] also observed the similar results on soil microbial activity after pearlmillet crop under conservation agricultural systems.

Soil fertility

Different planting density treatments could not bring any significant effect on SOC and available NPK content in soil. Nitrogen management was also had non-significant on SOC content. But the soil fertility status in respect of available NPK contents in present investigation showed discernible improvement due to N application. 75 kg/ha N led to higher available NPK than 60 kg N/ha and control**.** Enhancement of N content with higher dose of N endorsed due to direct contribution toward the available N pool. Mineralization of previous crop residue through soil micro-organisms in the presence of ample N led to improved available nutrient status in the soil (Choudhary *et al.*, 2016) [6].

On the basis of the one year study, it is concluded that high density planting followed by alternate row harvesting at 35 DAS and 45 DAS enhance dry matter production of pearlmillet. So, these practices may be a viable alternative to residue shortage in rainfed regions, which is major obstacle in adoption of conservation agriculture. Further, application of 25% additional dose of N than recommended dose to pearlmillet especially during initial period of CA adoption enhance growth parameters, micronutrients uptake, soil microbial activities and soil fertility. To confirm the finding a long-term experimentation is required for pearlmillet under conservation agriculture.

Table 1: Effect of planting density and N management on growth parameters of pearlmillet under conservation agriculture

Treatment	Plant height (cm)			Tillers/m²		Leaf area index		SPAD value	
	30 DAS	60 DAS	At harvest	At flowering	At harvest	30 DAS	60 DAS	30 DAS	60 DAS
Planting density									
D_1	55.3	231	240	31	32	2.20	4.87	45.9	53.4
D_2	65.5	244	252	27	29	2.41	4.73	43.7	52.9
D_3	64.9	246	254	26	28	2.40	4.73	41.6	52.0
SEm±	2.10	2.5	2.3	0.6	0.5	0.04	0.01	0.78	1.1
CD (*P=0.05*)	8.23	9.7	9.2	2.5	2.0	0.17	0.05	3.06	NS
Nitrogen management									
N_1	52.9	222	227	20	23	1.91	4.32	38.5	46.5
N_2	65.0	237	245	27	28	2.59	4.68	46.3	51.8
N_3	60.7	240	247	28	29	2.29	4.77	42.7	52.3
N_4	69.6	251	260	32	33	2.60	5.00	47.6	56.3
N_5	61.4	253	263	34	34	2.51	5.12	43.6	57.0
SEm±	2.05	3.7	4.2	1.5	1.1	0.06	0.06	1.00	1.22
CD (*P=0.05*)	5.98	10.9	12.4	4.4	3.1	0.17	0.18	2.93	3.55

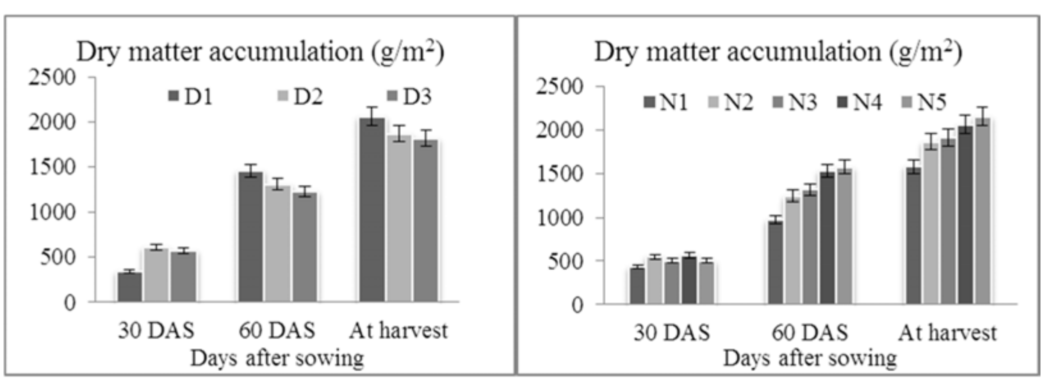

Fig 1: Dry matter accumulation as influenced by planting density and N management practices under conservation agriculture

Table 2: Effect of planting density and N management on micronutrients content by grain and stover of pearlmillet under conservation agriculture

Treatment	Micronutrients content (mg/kg)							
	Fe		Mn		Zn		Cu	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Planting density								
D_1	120.9	226.2	45.8	75.8	25.5	17.5	15.1	26.2
D_2	120.3	224.5	46.0	75.7	25.6	17.6	14.9	26.1
D_3	122.6	224.3	45.3	75.3	25.4	17.5	14.9	25.8
SEm±	0.85	0.66	0.30	0.22	0.14	0.16	1.02	0.13
CD (*P=0.05*)	NS	NS	NS	NS	NS	NS	NS	0.52
Nitrogen management								
N_1	113.7	210.0	43.3	72.9	23.5	15.5	13.2	25.5
N_2	118.0	224.7	45.2	75.2	25.3	17.3	14.6	26.0
N_3	119.6	225.2	45.8	75.6	25.5	17.5	14.9	26.1
N_4	126.2	230.3	47.2	77.2	26.5	18.7	15.9	26.2
N_5	129.0	234.7	47.2	77.3	26.7	18.7	16.1	26.3
SEm±	0.81	1.62	0.45	0.47	0.34	0.33	0.91	0.30
CD (*P=0.05*)	2.36	4.72	1.31	1.36	0.99	0.97	NS	NS

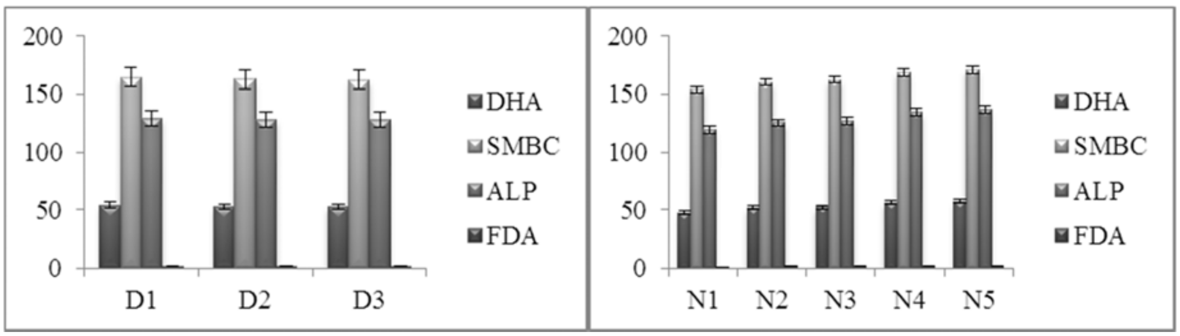

Fig 3: Influence of different planting density and N management practices on soil microbial properties under conservation agriculture

Table 3: Soil fertility parameters as influenced by different planting density and N management strategies under conservation agriculture

Treatment	SOC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Planting density				
D_1	0.446	143	13.9	183
D_2	0.447	142	15.3	182
D_3	0.448	140	14.5	181
SEm±	0.003	1.59	0.28	1.30
CD (*P=0.05*)	NS	NS	NS	NS
Nitrogen management				
N_1	0.440	128	13.3	176
N_2	0.445	139	14.5	180
N_3	0.448	142	14.7	183
N_4	0.452	148	14.9	186
N_5	0.451	150	15.3	185
SEm±	0.004	1.50	0.31	2.04
CD (*P=0.05*)	NS	4.38	0.89	5.94

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