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Research Paper

Integrated nutrient management in pearlmillet (*Pennisetum glaucum*) in north-western Rajasthan

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 on loamy sand soil of Bikaner, Rajasthan, to study the integrated nutrient management in pearlmillet [*Pennisetum glaucum* (L.) R. Br.]. The experiment comprising of 8 treatments, viz. control, 50% recommended dose of fertilizer (30 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha), 50% recommended dose of fertilizer (RDF) + *Azotobactor* + phosphorus-solubilizing bacteria (PSB), 50% RDF + 5 t FYM + *Azotobactor,* 50% RDF + 5 t FYM + PSB, 50% RDF + 5 t FYM + *Azotobactor* + PSB, 100% RDF (60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha) and 100% RDF + *Azotobactor* + PSB in randomized block design with 3 replications. Application of 100% RDF + *Azotobactor* + PSB significantly increased plant height (182.2 cm), dry-matter accumulation (81.83 g/plant), total tillers (2.23), chlorophyll content (2.96 mg/g), effective tillers/plant (1.63), ear length (19.63), girth of ear (78.6 mm), grain weight/ear (6.19 g), 1,000-seed weight (7.73 g), grain (2.48 t/ha) and straw yields (4.34 t/ha), content of N (1.84 and 0.594%), P (0.293 and 0.141%) and K (0.735 and 2.28%) in grain and straw and total uptake of N (71.5 kg/ha), P (13.4 kg/ha) and K (117.0 kg/ha). Organic carbon, available N, P and K status of soil after harvest of pearlmillet increased significantly with 100% RDF + *Azotobactor* + PSB or 50% RDF + 5 t FYM + *Azotobactor* + PSB. Significantly maximum net returns (₹37,594/ha) with benefit: cost ratio (2.29) of pearlmillet was obtained under 100% RDF + *Azotobactor* + PSB.

Key words: *Azotobactor*, FYM, Pearlmillet, Phosphorus-solubilizing bacteria, Residual, Yield

Pearlmillet is one of the important cereal crops of arid and semi-arid regions of the country and is extensively cultivated as dual-purpose crop. In Rajasthan, pearlmillet cultivation is mainly confined to the arid (62% of total area) and semi-arid (12.6% of the total area) regions (Kumar and Gautam, 2004). Rajasthan stands first in the country and produced 4.49 million tonnes of grains from 4.10 million ha area, with average productivity of 1017 kg/ha (GoI, New Delhi, 2015). Integration of chemical fertilizers with organic manures has been found quite promising not only in sustaining the soil health and productivity but also in stabilizing the crop production in comparison to the use of each component separately. Most of the pearl millet-growing areas in the country are confined to the light-textured soils suffering from the problem of low soil-fertility status and poor moisture-retention capacity. In the present system of intensive agriculture, most of the farmers are using high-yielding hybrid or varieties of the crops that have led to heavy withdrawal of nutrients from the soil. During the past few years, fertilizer application remained much below as compared to removal. This gap between nutrient removal and supply cannot be bridged by fertilizers alone. It can only be achieved through integrated nutrient-supply approach (INSA). Indiscriminate use of fertilizers without recycling of organic wastes has not only aggravated multi nutrient deficiencies in soil-plant system but also deteriorated soil health and created environmental pollution. Moreover, chemical fertilizers are becoming costlier input in agriculture. Integration of chemical fertilizers with organic manures has been found quite promising not only in sustaining the soil health and productivity but also in stabilizing the crop production in comparison to the use of each component separately (Rathore *et al.* 2006). Therefore, it is the right time to evaluate the feasibility and efficiency of organic wastes along with biofertilizers not only for improving and building up of soil fertility but also to increase the fertilizer-use efficiency.

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MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at Agronomy farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan). The soil of the experimental site was loamy sand (83.4% sand, 10.3% silt and 6.3% clay), slightly above neutral in reaction (*p*H 8.2), low in organic carbon (0.11%), available nitrogen (117.1 kg/ha), available phosphorus (14.2 kg/ha) and medium in available potassium (172.4 kg/ha). The content of N, P and K in farmyard manure (FYM) was 0.52, 0.20 and 0.58% respectively. The FYM was applied 21 days before sowing of pearlmillet. About 125 g jaggery was boiled in 1 litre water and then cooled. One packet each of PSB and *Azotobactor* culture, i.e. *Azotobactor chroococcum* was added and mixed thoroughly in required quantity of jaggery solution. The required seed was mixed thoroughly with the paste of culture as per treatment and allowed to dry in shade. The total rainfall received during the rainy (*kharif*) seasons of 2014 and 2015 was 417.4 and 324.6 mm respectively.

The experiment comprising 8 treatments, viz. T_1, control; T_2, 50% recommended dose of fertilizer (RDF) (30 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha); T_3, 50% RDF + *Azotobactor* + phosphate-solubilizing becteria (PSB); T_4, 50% RDF + 5 t FYM + *Azotobactor*; T_5, 50% RDF + 5 t FYM + PSB; T_6, 50% RDF + 5 t FYM + *Azotobactor* + PSB; T_7, 100% RDF (60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha) and T_8, 100% RDF + *Azotobactor* + PSB, in randomized block design with 3 replications. Pearlmillet hybrid 'RHB 177' was sown on 14 and 10 July of 2014 and 2015 respectively, using seed rate @ 4.0 kg/ha with row spacing of 30 cm and harvested on 29 and 23 September of 2014 and 2015. The field observations on plant height, dry-matter accumulation, total tillers, chlorophyll content, effective tillers/plant, length of ear, girth of ear, grain weight/ear, 1,000-seed weight, grain and stover yields were recorded. Five randomly selected plants from each plot were uprooted and later cleaned and observations like plant height, dry-matter and chlorophyll content at peak growth stage (60 DAS) were recorded and averaged. The yield attributes were recorded at harvesting to assess the contribution to yield. The experimental data analysed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F test and conclusion were drawn at 5% probability level. Economics of treatments was also worked out.

RESULTS AND DISSCUSION

Growth attributes

The highest plant height, dry-matter accumulation at 60 days after sowing (DAS), total tillers and chlorophyll content of leaves at harvesting (Table 1) of pearlmillet were obtained with application of 100% RDF + *Azotobactor* + PSB over the control and the other treatments, but it remained at par with 100% RDF and 50% RDF + 5 t FYM + *Azotobactor* + PSB. Further, application of 50% RDF + 5 t FYM + PSB significantly increased the plant height, dry-matter accumulation, total tillers and chlorophyll content of leaves at 60 DAS over the control, 50% RDF and 50% RDF + *Azotobactor* + PSB but remained at par with 50% RDF + 5 t FYM + *Azotobactor*. Hence a suitable combination of fertilizers, manures and biofertilizer maintained a long-term soil fertility and sustained high level of productivity. Being a cereal crop, pearlmillet required nutrients throughout the growing season and therefore, better growth and development under these treatments might be owing to the increased availability of nutrients to plant initially through inorganic fertilizers and then by organic manure like FYM and biofertilizer matching to the need of crop throughout the growing season. This increase in growth parameters might be ascribed to supply of super-optimal fertility dose and to additional advantages provided by biofertilizers with seed inoculation of *Azotobacter* and PSB having ability to produce plant growth-producing substances and antifungal substances in addition to the contribution of atmospheric nitrogen made available to plant (Kumar, 2015). The positive effect of nitrogen and phosphorus supplied through combinations of N and P fertilizers with adequate dose of manures on growth could be ascribed to its effectiveness in providing a balanced nutritional environment favourably both in rhizosphere and plant system. The results obtained in the present investigation are in close conformity with the findings of Chaudhary *et al.* (2013).

Yield attributes and yield

Application of 100% RDF + *Azotobactor* + PSB significantly improved yield attributes like number of effective tillers/plant, length of ear, girth of ear, grain weight/ear and 1,000-seed weight of pearlmillet (Table 1) over all other treatments, but it remained at par with 100% RDF and 50% RDF + 5 t FYM + *Azotobactor* + PSB. This could mainly be associated with the increased growth of the crop in terms of plant height, chlorophyll content and dry-matter accumulation at growth stage recorded under these treatments owing to greater availability of most of the macro- and micro-nutrients in appropriate amounts and balanced proportion that lead to higher uptake of the nutrients. The increased growth provided greater site for photosynthesis and diversion of photosynthates towards sink (ear and grain). The beneficial effect on yield attributes might also be owing to the increased supply of all

the essential nutrients by FYM and enhanced availability of nitrogen and phosphorus by *Azotobactor* and PSB might have resulted in higher manufacture of food and its subsequent partitioning towards sink. The findings of present investigation are supported by Parihar *et al.* (2010) in pearlmillet. The significantly higher grain yield was obtained by the application of 100% RDF + *Azotobactor* + PSB (Table 1). The higher values of yield attributes like effective tillers/plant, length of ear, girth of ear, grain weight/ear and 1,000-seed weight coupled with the higher crop dry matter observed with this treatment might be the most probable reason of higher grain and stover yields. The increase in stover yield with application of 100% RDF + *Azotobactor* + PSB could be partly attributed to its direct influence on dry-matter production of each vegetative part and indirectly through increased morphological parameters of growth (plant height and number of total tillers). Our results are in close agreement with the findings of Khambalkar *et al.* (2012) and Singh *et al.* (2013) in pearlmillet.

Nutrient content and uptake

Application of 100% RDF + *Azotobactor* + PSB significantly increased nutrient content and uptake of N, P and K in grain and stover of pearlmillet crop (Table 2). Combined application of inorganic fertilizers, manures and biofertilizer significantly increased the content of nitrogen, phosphorus and potassium in grain and stover. It can chiefly be associated with the better growth of the crop owing to favourable nutritional environment mainly for supply of most of the macro nutrients in balanced and available form throughout the growing period of the crop and in adequate amounts. Since the uptake of nutrients in grain and stover is a function of their content and yield,

Table 1. Effect of integrated nutrient management on growth, yield attributes and yield of pearlmillet (data pooled over 2 years)

Treatment	Plant height (cm)	Dry-matter accumulation (g/plant)	Chlorophyll content (mg/g)	Total tillers/ plant	Effective tillers/ plant	Ear-length (cm)	Girth of ear (mm)	Grain weight /ear (g)	1,000-seed weight(g)	Yield (t/ha)	
										Grain	Stover
T_1	95.1	41.34	2.23	1.33	1.09	12.78	62.1	4.13	6.11	1.22	2.37
T_2	115.6	50.21	2.51	1.55	1.22	14.72	67.7	5.07	6.64	1.59	2.94
T_3	117.1	51.66	2.56	1.61	1.25	15.20	68.8	5.13	6.71	1.70	3.19
T_4	142.9	59.20	2.73	1.85	1.40	17.36	72.6	5.62	7.17	2.01	3.66
T_5	147.3	61.10	2.75	1.91	1.44	17.48	73.1	5.66	7.20	2.03	3.70
T_6	175.2	79.65	2.91	2.15	1.58	19.07	77.3	6.08	7.65	2.35	4.15
T_7	178.2	81.16	2.94	2.19	1.60	19.31	77.9	6.11	7.67	2.40	4.21
T_8	182.2	81.83	2.96	2.23	1.63	19.63	78.6	6.19	7.73	2.48	4.34
SEm±	2.48	0.84	0.03	0.04	0.02	0.29	0.80	0.09	0.10	0.06	0.10
CD (P=0.05)	7.17	2.44	0.08	0.12	0.07	0.85	2.33	0.25	0.28	0.18	0.28

T_1, control; T_2, 50% recommended dose of fertilizer (RDF) (30 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha); T_3, 50% RDF + *Azotobactor* + phosphate-solubilizing becteria (PSB); T_4, 50% RDF + 5 t FYM + *Azotobactor*; T_5, 50% RDF + 5 t FYM + PSB; T_6, 50% RDF + 5 t FYM + *Azotobactor* + PSB; T_7, 100% RDF (60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha) and T_8, 100% RDF + *Azotobactor* + PSB

Table 2. Effect of integrated nutrient management on nutrient content and uptake of pearlmillet (data pooled over 2 years)

Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Total uptake (kg/ha)		
	Grain	Stover	Grain	Stover	Grain	Stover	Nitrogen	Phosphorus	Potassium
T_1	1.44	0.464	0.229	0.111	0.575	1.56	28.6	5.4	44.1
T_2	1.55	0.500	0.246	0.119	0.615	1.75	39.2	7.4	61.1
T_3	1.57	0.505	0.248	0.120	0.625	1.76	42.6	8.0	66.8
T_4	1.71	0.562	0.268	0.130	0.697	2.02	55.6	10.2	88.8
T_5	1.68	0.557	0.271	0.132	0.686	2.00	54.2	10.4	86.8
T_6	1.82	0.585	0.287	0.139	0.723	2.23	67.0	12.5	109.6
T_7	1.83	0.589	0.290	0.140	0.729	2.27	68.7	12.8	113.0
T_8	1.84	0.594	0.293	0.141	0.735	2.28	71.5	13.4	117.0
SEm±	0.02	0.003	0.003	0.001	0.005	0.04	1.2	0.2	2.6
CD (P=0.05)	0.05	0.010	0.009	0.003	0.014	0.11	3.5	0.6	7.6

T_1, control; T_2, 50% recommended dose of fertilizer (RDF) (30 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha); T_3, 50% RDF + *Azotobactor* + phosphate-solubilizing becteria (PSB); T_4, 50% RDF + 5 t FYM + *Azotobactor*; T_5, 50% RDF + 5 t FYM + PSB; T_6, 50% RDF + 5 t FYM + *Azotobactor* + PSB; T_7, 100% RDF (60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha) and T_8, 100% RDF + *Azotobactor* + PSB

Table 3. Effect of integrated nutrient management on economics and soil fertility (data pooled over 2 years)

Treatment	Economics (×10³₹/ha)			Soil fertility			
	Cost of cultivation	Net returns	Benefit: cost ratio	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	13.2	14.5	1.09	0.112	117.7	14.96	170.1
T_2	15.2	20.5	1.38	0.113	121.5	15.72	173.7
T_3	15.3	22.9	1.53	0.114	122.2	15.86	175.4
T_4	18.7	26.2	1.49	0.115	125.8	16.42	179.3
T_5	18.7	26.6	1.52	0.116	126.1	16.68	179.8
T_6	18.8	33.3	1.89	0.116	129.9	17.15	183.3
T_7	17.1	36.0	2.20	0.117	130.8	17.17	184.3
T_8	17.3	37.5	2.29	0.119	131.9	17.25	184.9
SEm±	–	0.98	0.08	0.001	0.8	0.09	0.63
CD (P=0.05)	–	2.85	0.24	0.002	2.4	0.27	1.82

T_1, control; T_2, 50% recommended dose of fertilizer (RDF) (30 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha); T_3, 50% RDF + *Azotobactor* + phosphate-solubilizing becteria (PSB); T_4, 50% RDF + 5 t FYM + *Azotobactor*; T_5, 50% RDF + 5 t FYM + PSB; T_6, 50% RDF + 5 t FYM + *Azotobactor* + PSB; T_7, 100% RDF (60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha) and T_8, 100% RDF + *Azotobactor* + PSB

the increase in grain and stover yields coupled with increased nutrient content also resulted in higher total uptake of nitrogen, phosphorus and potassium with the application of 100% RDF + *Azotobactor* + PSB. Use of FYM has been also known to help in reducing the soil *p*H to some extent by producing carbonic acids while their decomposition that may also be the reason of greater availability and mobility of nutrients mainly of micronutrients. This could have also helped in additional uptake of the nutrients by plants. Similar results were reported by Manan *et al.* (2013). The content and uptake of any nutrient in the plant is directly related to its availability in the root zone and growth of the plant. Use of *Azotobactor* and PSB in combination with recommended dose of fertilizers increased the nitrogen, phosphorus and potassium content in grain and stover significantly that might be attributed to their availability in soil in appropriate amount and in the available form due to these microbial inoculants. *Azotobactor* improved the nitrogen content in grain and stover owing to greater availability of it through biological nitrogen fixation. It also promotes secretion of growth promoting substances. This also resulted in better utilization of other nutrients like phosphorus and potassium by plants. These results confirm the findings of Ansari *et al*. (2011).

Economics

Application of 100% RDF + *Azotobactor* + PSB significantly increased the net returns (₹37,594/ha) of pearl millet with benefit: cost (B:C) ratio (2.29) as evident in Table 3. It is obvious because grain and stover yields of pearlmillet increased with combined application of fertilizer, FYM and biofertilizer in soil and hence net returns and benefit: cost ratio. The increase in net returns and benefit: cost ratio owing to chemical fertilizer, FYM and biofertilizer was also observed by Kumar *et al.* (2014).

Soil fertility

Significant improvement in organic carbon, available N, P and K status of soil was observed owing to incorporation of 100% RDF + *Azotobactor* + PSB in pearlmillet after harvesting (Table 3). This may be ascribed to the beneficial role of fertilizers in mineralization of native as well as nutrients through fertilizer in addition of its own nutrient content which enhanced the available nutrient pool of the soil after harvesting. The favourable conditions for microbial as well as chemical activities because of addition of FYM and integrated with other nutrients augmented the mineralization of nutrients and ultimately increased the available nutrients status of soil. It could be further understood in the light of differential solubility of fertilizers and manures. It is quite established fact that only a part of FYM is mineralized in one season and the rest has carryover effect. The residual status of nutrient is a function of nutrients supplied and their loss or removal by crop. This can be chiefly ascribed to the fact that a part of nitrogen and phosphorus requirement of the crop was met through the nitrogen fixation and phosphorus solubilization by the microbial inoculants. This resulted in less removal of these nutrients from the soil by the crop that could be the result of higher availability of these nutrients in soil after harvest. These results are in agreement with those obtained by Khambalkar *et al.* (2012).

Hence it may be concluded that growing of pearlmillet with 100% RDF + *Azotobactor* + PSB or 50% RDF + 5 t FYM + *Azotobactor* + PSB holds great promise for increased productivity of pearlmillet in north western Rajasthan.

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