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Productivity and Quality Enhancement of Pearl millet (*Pennisetum glaucum*) Through Integrated Use of Organic and Inorganic Sources of Nitrogen

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ABSTRACT: Chemical fertilizers are one of the costliest input for pearl millet cultivation and also its imbalanced usage results in deficiency of macro and micro nutrients, soil health and finally yield reduction. Considering this issue a field experiment was conducted to study the effect of different sources of nitrogen on the productivity of pearl millet (*Pennisetum glaucum*). The experiment was conducted at Agricultural College Farm, Bapatla *kharif* during 2019. Eight treatments of various inorganic and organic proportions were applied and replicated thrice in a randomized block design. The results revealed that the maximum growth, yield and quality of pearl millet was obtained with application of 75% STBN (Soil Test Based Nitrogen) + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}. Strategic planning in terms of a combined application of organic manures with inorganic fertilizers will not only improve soil health, but also benefits farmers by lowering their reliance and expenditure, exclusively on chemical fertilizers.

Keywords: *Azospirillum*, Soil test based nitrogen, Vermicompost, Yield.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) locally known as bajra is a dual purpose crop, its grain used for human consumption and the fodder for livestock feeding. It is an important crop component of agricultural and animal husbandry dominated rural economy of dryland areas (Bijarnia *et al*., 2020). Due to its C_4 nature and its ability to withstand high temperatures up to 42 degrees celsius during the reproductive stage, pearl millet outperforms all other cereals, making it a climate resilient crop (Kumar *et al*., 2018).

After rice, wheat, maize, and sorghum, pearl millet is India's fifth most important grain and a staple diet for millions of people living in drier areas. Pearl millet is a rich source of carbohydrate, energy, dietary fibres, fat, iron and zinc. It is also gluten free and retains its alkaline properties after cooking which is ideal for gluten allergic people. Globally India is the biggest producer of pearl millet both in terms of area (7.48 million hectares) and production (9.09 million tonnes) with an average productivity of 1231 kg ha^{-1} (www.indiastat.com, 2017-18). Pearl millet is mostly in Rajasthan (46 %), Maharashtra (19%), Gujarat (11 %), Uttar Pradesh (8 %) and Haryana (6%).

Deteriorating soil health, soaring market prices of farm inputs, variable rainfall and uneven use of plant nutrients have made the soils poor in organic matter and destructed physical properties leading to reduced growth and development of the crop (Thumar *et al*., 2016). Improper fertilizer management, particularly nitrogen management, is one of the major factors contributing to low productivity. Continuous application of only inorganic fertilizers have lead to steady decline in organic matter and native nitrogen status in the soil resulting in poor or stagnant yields. In the face of progressively prohibitive cost of fertilizer nitrogen, there is a need for low cost alternatives like organic manures.

The combined use of chemical and organic fertilizers has proven to be extremely advantageous for long-term crop productivity. Several studies have shown that combining chemical and organic fertilisers can help to alleviate deficiencies in several secondary and micronutrients in areas that have only received N, P, and K fertilisers for a few years and have not received any micronutrients or organic fertilizers. According to Dutta *et al.* (2003), using organic fertilizers in combination with chemical fertilizers had a greater favourable effect on microbial biomass and thus soil health than using organic fertilizers alone. Integrated nutrient management has been proving beneficial not only in sustaining productivity but also in improving soil microbial load, hence stabilising agricultural production. Organic manures, especially FYM and vermicompost will not only supply macronutrients but also meet the requirement of micronutrients, besides improving soil health (Singh *et al.*, 2020). This experiment was conducted to study the influence of organic and inorganic sources of nitrogen on productivity of pearl millet.

MATERIALS AND METHODS

A field experiment (*Kharif*-2019) was conducted at Agricultural College Farm, Bapatla. During the crop growth period, the weekly mean maximum and minimum temperature ranged from 29.8°C to 35.1°C and 23.5°C to 26.3°C respectively. The weekly mean relative humidity (8.30 hrs.) and (17.30 hrs.) ranged from 55 to 87 per cent and 48 to 85 per cent. A total rainfall of 608.2 mm was received during the crop growth period.

Soils of the experimental field were neutral in reaction, sandy in texture with low in organic carbon, available N and medium in available P, K. The field was ploughed twice with tractor-drawn cultivator and then harrowed by planking to provide a good tilth for crop growth. The experiment was laid out in a simple randomized block design with 8 treatments and each treatment was replicated thrice. The field was divided into 24 plots, each having a size of 5.4 m × 4.5 m. The treatments for field experiments were T_1: 100% STBN, T_2: 75% STBN + 25% FYM, T_3: 75% STBN + 25% vermicompost, T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}, T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}, T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}, T_7: 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1} and T_8: 100% STBN + *Azospirillum* @ 5 kg ha^{-1}. The N contents in the organic sources were farmyard manure (FYM) 0.5% and vermicompost 1.5%. Pearl millet (Rana hybrid) was sown in rows of 45 cm apart from each other manually during *kharif*. After germination, the crop was thinned and row to row and plant-to-plant distance was maintained at 45 cm and 15 cm each. The organic manures *viz.*, FYM and vermicompost were applied in field as per treatments before fifteen days of crop sowing and *Azospirillum* @ 5 kg ha^{-1} was applied as per treatments on the day of sowing. The respective doses of manures were applied as per treatments. Soil test based nitrogen @ 75 kg ha^{-1} was applied as per the treatments in two equal splits *i.e.*, half at basal and remaining half was top dressed at 40 days after sowing. As initial soil N status was low, additional 15 kg N (25%) apart from the recommended dose of nitrogen (60 kg) was added. Single superphosphate and MOP were applied to all the plots uniformly to supply 40 kg P_2O_5 ha^{-1} and 25 kg K_2O ha^{-1}. Fertilizer N was applied through urea. The data on SPAD, days to flowering, days to maturity, earheads m^{-2}, earhead length, test weight, grain yield, straw yield, protein content, nitrogen content and crude fibre content were recorded as per standard procedures. The crop was harvested at 90 DAS. Grain and stover yields were also recorded. Data were analyzed using ANOVA and the significance was tested by Fisher's (1950) least significance difference (p=0.05).

RESULTS AND DISCUSSION

Growth attributes. SPAD meter readings determine the availability of nitrogen during the crop period in leaf. The data presented in Table 1 revealed that SPAD values differed significantly with different nitrogen treatments imposed on pearl millet. It was found that readings increased initially from 30 DAS to 60 DAS and later on got gradually decreased till the end of harvest. Highest SPAD meter readings recorded with application of 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1} and it was on par with T_8 (100% STBN + *Azospirillum*@ 5 kg ha^{-1}) and T_4 (75% STBN + 25 % FYM + *Azospirillum* @ 5 kg ha^{-1}) at 30, 60 DAS and at maturity. Minimum value was recorded with 50% STBN though urea and 50% N through FYM along with *Azospirillum* @ 5 kg ha^{-1}. Singh *et al*. (2013) noticed significantly higher SPAD readings of pearl millet with application of 50% RDN through FYM + 50% RDN through urea and lower SPAD readings were recorded with control.

The observation on days to 50% flowering and days to maturity revealed that there was no significant difference with integrated use of organic and inorganic treatments.

Table 1: SPAD meter readings, Days to 50 % flowering and Days to maturity of pearl millet as influenced by organic and inorganic sources of nitrogen.

Treatments	SPAD meter readings			Days to 50 % flowering	Days to maturity
	30 DAS	60 DAS	At maturity		
T_1: 100% STBN	43.14	47.12	35.67	50	87
T_2: 75% STBN + 25% FYM	42.43	46.86	33.33	52	89
T_3: 75% STBN + 25% vermicompost	44.11	48.45	36.31	50	87
T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}	47.94	51.67	36.50	52	88
T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	55.07	57.11	42.26	49	85
T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}	39.12	44.67	31.00	56	91
T_7: 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	41.75	46.35	32.33	54	91
T_8: 100% STBN + Azospirillum @ 5 kg ha^{-1}	53.98	55.21	40.17	48	85
S.Em±	2.435	1.781	1.647	1.7	3.3
CD (P = 0.05)	7.37	5.39	4.98	NS	NS
CV (%)	9.4	6.3	8.0	5.8	6.5

Yield attribute. Data on number of earheads m^{-2}, earhead weight, earhead length and test weight were recorded at the time of harvest and were summarized in Table 2 and remarkable improvement was observed due to combined application of sources of nitrogen. Highest number of earheads m^{-2} (26.67), length of earhead (23.79 cm) and weight of earhead (49.00 g) was recorded in treatment which received 75% STBN through urea and 25% N through vermicompost along with *Azospirillum* @ 5 kg ha^{-1} (T_5) which was at a par with T_8 (100% STBN + *Azospirillum* @ 5 kg ha^{-1}). T_6 treatment recorded less number of earheads m^{-2} (18.67), length of ear head (18.42 cm) and weight of earhead (37.38 g). The increase in yield attributes was reported with application of 125% RDF + vermicompost @ 5 t ha^{-1} in a field experiment conducted by Senthilkumar *et al.* (2018).The results of the present experiment corroborated with the findings of Thumar *et al*. (2016) who found integrated nutrient management on summer pearl millet was beneficial in improving yield attributes and Samuruthi *et al*. (2020) who reported improvement in yield attributes due integration of nutrient sources.

This might be due to integrated application of nitrogen (inorganic fertilizer, vermicompost, *Azospirillum*) in which inorganic fertilizer make more availability of nitrogen which provides to a higher availability to the plant, while vemicompost improves the soil properties, hydraulic conductivity of soil and also NPK availability, which have promoted growth and provided greater site for photosynthesis and have resulted in higher manufacture of food and its subsequent partitioning towards sink and resulting in increasing yield attributes of pearl millet (Kumar *et al*., 2014). Use of bio-fertilizer (*Azospirillum*) led to higher availability of nitrogen as well as promoted the root growth, that promoted yield attributing characters. The findings of present investigation were supported by Kumar *et al*. (2019); Divya *et al*. (2017).

Test weight was not significantly influenced by nitrogen sources the range of test weight was between 12.23 g to 10.14 g. As the test weight was mostly governed by genetic makeup of the crop, the environmental and managerial factor had lesser effect on test weight. These results were in similarity with observations made by Bana *et al*. (2012).

Yield. The grain and straw yield of *kharif* pearl millet (Table 3) were significantly influenced by integration of fertilizers, manures and biofertilizers that resulted in a remarkable effect over application of chemical fertilizer alone. Significantly higher grain yield (2955 kg ha^{-1}) and stover yield (5867 kg ha^{-1}) was observed with application of 75% STBN through urea and 25% through vermicompost along with *Azospirillum* @ 5 kg ha^{-1} (T_5) however, plots applied with 100% STBN through urea and *Azospirillum* @ 5 kg ha^{-1} was found to be on par with it. The lowest grain yield and straw yield was registered with 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1} during the year of study. The results were in accordance with Singh *et al.* (2020) who reported the maximum yield with INM treatment where 25% N was replaced with vermicompost. Increase in grain and straw yield of pearl millet with application of N through integrated sources had also been reported by Chaudhari *et al*. (2016) and Singh *et al*. (2013).

Table 2: Number of earheads m^{-2} and earhead weight (g) of pearl millet as influenced by organic and inorganic sources of nitrogen.

Treatments	No. of earheads m^{-2}	Earhead weight	Earheads length	Test weight
T_1: 100% STBN	21.00	41.25	21.10	11.35
T_2: 75% STBN + 25% FYM	20.67	40.59	20.43	10.55
T_3: 75% STBN + 25% vermicompost	22.00	42.86	21.53	11.83
T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}	23.00	43.01	21.71	11.91
T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	26.67	49.00	23.79	12.23
T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}	18.67	37.38	18.42	10.14
T_7:50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	20.33	40.50	20.20	10.43
T_8: 100% STBN + *Azospirillum* @ 5 kg ha^{-1}	24.67	47.18	23.57	12.17
S.Em±	1.09	1.81	0.886	0.594
CD (P = 0.05)	3.304	5.481	2.66	NS
CV (%)	8.6	7.4	7.2	9.1

The efficacy of organic fertilizers improved with its integration with organic manures (Vermicompost, FYM). The increased vegetative growth and balanced C:N ratio might have increased the carbohydrates synthesis which promoted yield. Due to increased yield attributes like earheads m^{-2}, earhead weight, earhead length and test weight coupled with the higher crop dry matter observed with these treatments due to increased availability of nitrogen to plant through inorganic nitrogen fertilizer at initial crop stages and then in later stages by organic manures like vermicompost and FYM that corresponded to the crop requirement throughout the growing season by slow mineralization. A positive effect of organic manures on yield of pearl millet have also been reported by Jain *et al.* (2018).

It was interesting to note that soil application of *Azospirillum* to the plot along with inorganic fertilizers (T_8) produced beneficial effect on yield in comparison to N alone (T_1). It appeared from the results that biofertilizers also play useful role for these crops. Use of biofertilizers (*Azospirillum*) also significantly influenced the grain yield as *Azospirillum* bacteria fixes atmospheric nitrogen and produces growth hormones like IAA, GA and cytokinin. Golada *et al.* (2012) also observed that *Azospirillum* application significantly increased yield of pearl millet over the untreated control. Improvement in grain yield of peal millet due to application of biofertilizers was reported by Khambalkar *et al.* (2012) in 14 year long term fertility experiment. Thus balanced use of chemical fertilizers in combination with organic manures and biofertilizers is necessary for sustaining the fertility and increasing cop productivity. Corroborative results have also been reported by Rathore *et al*. (2004); Chaudhari *et al*. (2016); Kumar *et al*. (2009); Jadhav *et al*. (2011); Shrivastava *et al*. (2017).

Table 3: Grain yield (kg ha^{-1}), stover yield (kg ha^{-1}) and harvest index (%) of pearl millet as influenced by organic and inorganic sources of nitrogen.

Treatments	Yield (kg ha^{-1})	
	Grain yield	Stover yield
T_1: 100% STBN	2403	4491
T_2: 75% STBN + 25% FYM	2399	4476
T_3: 75% STBN + 25% vermicompost	2419	4804
T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}	2527	4998
T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	2955	5867
T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}	2182	4241
T_7: 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	2277	4322
T_8: 100% STBN + *Azospirillum* @ 5 kg ha^{-1}	2691	5590
S.Em ±	115.0	239.6
CD (P = 0.05)	348	726
CV (%)	8.1	8.7

Grain quality. Nitrogen content in grain differed significantly (Table 4) due to application of different organic sources of nitrogen. Accordingly, the variation in protein content in pearlmillet grain was found to be significant. Nitrogen in grain was responsible for higher protein content in grain as nitrogen is the structural component of amino acid which constitutes the basis of protein and thus had a connection with nitrogen content in grain (Bana *et al*., 2012). Maximum protein and nitrogen content in pearl millet grain was recorded with application of 75% STBN + 25% vermicompost +*Azospirillum* @ 5 kg ha^{-1}and it was on par with 100% STBN + *Azospirillum* @ 5 kg ha^{-1}treatment. And these treatments have been significantly superior over rest of the treatments. Lowest protein content (9.58 %) was achieved with application of 50% STBN through urea and 50% N through FYM along with *Azospirillum* @ 5 kg ha^{-1}. Kumar *et al.* (2014) reported the improved quality of pearl millet grain with application of integrated nutrient sources.

Due to application of vermicompost with high N % along with inorganic fertilizers the nitrogen content of grain was high and also due to increased nitrogen uptake by increased mineralization native soil nitrogen. This is due the fact that higher protein content in pearl millet grain with *Azospirillum* application might be due to more atmospheric N fixation and increased concentration of nutrients in soil solution. Quality improvement through these organic sources might be due to better microbial activity and the microbes secrete many growth promoting substances that accelerates the physiological processes like synthesis of carbohydrates and proteins. Another reason for increased nitrogen content in seed is increased activity of nitrogenise reductase activity (Singh *et al.*, 2013).

These present observations were in close conformity with the findings made by Bar and Gautam (1991).

The lowest crude fiber content was reported in treatment T_5 (75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}) and T_6 (50% STBN 50% FYM + *Azospirillum* @ 5 kg ha^{-1}) indicating improvement in seed quality by these treatments. The results were in line with the findings of Singh *et al*. (2018).

Table 4: Protein content (%), nitrogen content (%) and crude fiber content (%) in grain of pearl millet crop as influenced by organic and inorganic sources of nitrogen.

Treatments	Protein content (%)	Nitrogen content (%)	Crude fiber content (%)
T_1: 100% STBN	10.14	1.62	3.17
T_2: 75% STBN + 25% FYM	10.02	1.60	2.17
T_3: 75% STBN + 25% vermicompost	10.25	1.64	2.22
T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}	10.27	1.66	2.05
T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	11.34	1.82	1.57
T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}	9.58	1.53	1.70
T_7: 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	9.89	1.58	1.97
T_8: 100% STBN + *Azospirillum* @ 5 kg ha^{-1}	11.01	1.76	2.80
S.Em ±	0.315	0.057	0.153
CD (P = 0.05)	0.94	1.62	0.45
CV (%)	5.2	1.60	12.1

CONCLUSION

From the present investigation it can be concluded that different organic sources in combination with inorganic sources had a remarkable effect of yield of pearl millet. Application of 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1} recorded highest growth, yield and quality of pearl millet. Strategic planning in terms of combined application of organic manures with inorganic fertilizers would not only improves soil health, but also benefit farmers by lowering their reliance and expenditure on chemical fertilizers.

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Conflict of Interest. None.

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