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Effect of Organic and Inorganic Sources of Nitrogen on Yield, Microbial Load and Soil Nutrient Status of Pearl Millet

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Soil microbial population and soil nutrient status are important criteria for improving the yields. So this study is conducted with an objective to know the impact of organic and inorganic sources of nitrogen on yield, soil microbial load and nutrient status of the soil in pearl millet. A field experiment was conducted during *kharif,* 2019 at Agricultural College Farm, Bapatla on sandy soils with eight treatments consisting combined organic and inorganic nitrogen sources. The highest grain yield (2955 kg ha^{-1}), straw (5867 kg ha^{-1}) yield and soil nitrogen status (164.10 kg ha^{-1}) were recorded with 75% Soil Test Based Nitrogen (STBN) + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1} and was followed by statistically similar treatment 100% STBN + *Azospirillum* @ 5 kg ha^{-1}. Significantly higher microbial load (Bacteria, Fungi and Actinomycetes), P and K status in soil recorded with the treatments where 50% of STBN applied through FYM (50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}), whereas lowest was recorded with chemical fertilizer alone. The combined sources of nitrogen both organic and inorganic fertilizers would be able to improve soil fertility and soil microbial load and finally improve the yields.

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Keywords: Azospirillum; microbial load; Soil test based nitrogen; vermicompost; yield.

ABBREVATIONS

STBN : Soil test based nitrogen,
FYM : Farm yard manure,
cfu : colony forming units,
DAS : Days after sowing.

1. INTRODUCTION

Pearl millet (*Pennisetum glaucum* [L.] R.Br.) is the most important cereal crop native to Africa which belongs to the Gramineae (poaceae) family which is grown in arid and semi-arid regions with an annual rainfall between 150 and 700 mm, contributing 6% of total food grain production. It is the most important staple cereal in the diet of millions of people living in the drier areas [1]. In India pearl millet is the 5th most important multipurpose cereal after rice, wheat, maize and sorghum. In recent time this crop is gaining importance because of changing climate like less seasonal rainfall, terminal heat, frequent occurrence of extreme weather events and under these extremes pearl millet performs better than other cereal crops [2]. India is the leading producer of pearl millet both in terms of area it occupies an area of 6.93 million ha with an average production of 8.61 million tons and productivity of 1,243 kg ha^{-1} [3].

However, average yield of pearl millet is low when compared to its potential yield because it is mostly grown on marginal lands, variable rainfall and with poor management practices. So there is a need to focus on increasing the productivity of pearl millet with proper agronomic practices as climatic factors cannot be changed. Nutrient supply especially nitrogen is the most limiting factor next to the water for crop production. Though use of chemical fertilizers may increase the yields of pearl millet but its excessive application leads to deterioration of soil health due to reduced organic matter and in long run yields may reach plateau [4]. For obtaining optimum yields the fertility and health of soil is important and the absence of organic matter from soil results in unproductive soil. This can be achieved by applying adequate amounts, of organic material.

Combined use of chemical fertilizers along with organic manures has been seemed promising not only in maintaining high productivity but also ensuring stability to crop production, this has been found promising not only in sustaining the productivity but also preserving soil microbial load thereby stabilizing the crop production [5]. Nutrients available in organic manures are released slowly, remain in the soil for longer time and are available to plants, thereby maintaining soil fertility and enhance the soil microbial population. Considering the importance of soil biological fertility, the present investigation was carried out with an objective to know the influence of combined sources of nitrogen on yield, soil microbial load and soil nutrient status in pearl millet.

2. MATERIALS AND METHODS

A field experiment was conducted at Agricultural College Farm, Bapatla during *kharif* 2019 with eight treatments replicated thrice in randomized block design using pearl millet hybrid Rana with spacing 45 x 15 cm. Treatments were as follows, 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}. Sowing was done by manually and recommended agronomic and plant protection measures were followed. The grain yields were recorded on plot basis and then converted in to kg ha^{-1}.

Initial soil properties of the experimental location was analyzed (Table 1). The FYM (Farm Yard Manure), vermicompost and biofertilizer were used as organic source and urea as inorganic source and the organic manures were applied as per the treatments fifteen days before sowing. Chemical concentration of organic manures are given in Table 2. Soil test based nitrogen @ 75 kg ha^{-1} was applied as per the treatments in 2 equal splits *i.e.,* ½ at basal and remaining ½ was top dressed at 40 days after sowing. As initial soil N status was low, additional 15 kg N (25%) apart from recommended dose of nitrogen (60 kg) was added. Entire dose of 40 kg P_2O_5 ha^{-1} in the form of single super phosphate and 25 kg K_2O ha^{-1} in the form of muriate of potash were uniformly applied basally to all the plots. The biofertilizer *Azospirillum* mixed along with organic manure was soil applied @ 5 Kg ha^{-1} as per the treatments broadcasted in the field on the day of sowing.

Table 1. Soil physical, chemical and biological properties of the experimental plot

Soil properties	Value
Sand (%)	85.6
Silt (%)	5.7
Clay (%)	8.7
Texture	Sandy
pH (1:2.5 - Soil: water suspension)	6.80
EC (dS m^{-1} at 25^{o}C)	0.1
Organic Carbon (%)	0.3
Available N (kg ha^{-1})	172
Available P_2O_5 (kg ha^{-1})	29.2
Available K_2O (kg ha^{-1})	235
Bacterial population (cfu g^{-1} soil)	17 $\times 10^6$
Fungal population (cfu g^{-1} soil)	6 $\times 10^3$
Actinomycetes population (cfu g^{-1} soil)	19 $\times 10^4$

Table 2. N, P_2O_5 and K_2O contents (%) of organic manures on dry weight basis

Organic manures	N	P_2O_5	K_2O
FYM	0.5	0.2	0.5
Vermicompost	1.5	1.6	1.1

Soil samples (0-15cm) were collected after harvest of the crop from each treatment for analysis. Organic carbon was determined by using wet digestion method [6], available N by alkaline permanganate [7], available P by [8] method, available K by Flame photometer method [9]. Viable counts of microbial populations under different combination of nitrogen management treatments were determined using serial dilution plating method [10]. Various dilutions were spread on appropriate medium plates and incubated for 5 days. Number of colonies (colony forming units; cfu) developed on different dilution media plates was recorded and population of each bacterium per gram soil was enumerated. The observations recorded were subjected to statistical analysis in accordance with the 'Analysis of variance' technique as suggested by [11] for randomized block design.

3. RESULTS AND DISCUSSION

3.1 Yield

Combined application of organic and inorganic sources of nitrogen to pearl millet significantly enhanced the grain and stover yield (Table 3). Highest grain and stover yields were recorded with application of 75% STBN through urea and 25% N through vermicompost along with *Azospirillum* @ 5 kg ha^{-1}. However, plot applied with 100% STBN through urea and *Azospirillum* @ 5 kg ha^{-1} was found to be on par with it. Lowest yields were reportd with 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1} because of less availability of nitrogen as FYM releases nitrogen slowly. Significant increase in grain and stover yield of pearl millet due to might be due to improvement in yield attributes. The results have indicated that 25% of inorganic nitrogen requirement of pearl millet can be easily substituted with organic manures which increased availability of nitrogen to plant through inorganic nitrogen source initially and then by organic manures like vermicompost and FYM during the later stages of crop which corresponds to the need of crop throughout the growing season by slow mineralization of nutrients, mainly nitrogen from organic source may be the most probable reason of higher grain yield [2 and 12]. Use of biofertilizers (*Azospirillum*) also significantly influenced the yield as *Azospirillum* bacteria fixes atmospheric nitrogen and produces growth hormones like IAA, GA and cytokinin which led to higher availability of nitrogen, and promoted plant growth and yield characteristics thereby improved grain yield. Similar results were reported [13] where highest yields were recorded with integration of organic and chemical fertilizers. Integration of Biofetilizers, organic manures and mineral fertilizers supplies all essential plant nutrients in a balanced forms and also maintains soil quality [14], necessary for sustaining the higher productivity of crop.

3.2 Soil Microbial Population

Soil microbial population increased from initial stage to 60 DAS thereafter decreasing trend was observed from 60 DAS to harvest. Overall analysis of the result indicated that bacterial load at any time were more than that of actinomycetes which in turn was more than fungi. The soil microbial population (Table 4) at different growth stages *viz*., 30, 60 DAS and at maturity was significantly influenced by combined nitrogen sources and it was observed that total bacterial, fungal and actinomycetes population increased with *Azospirillum* inoculated and organic manured plots compared to uninoculated and inorganic plots.

3.3 Bacteria (× 10^6 cfu g^{-1} Soil)

At 30 DAS highest bacterial population was observed with treatment which received 50% inorganic nitrogen, 50% organic nitrogen and biofertilizer which was on par with 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}) and significantly superior to other treatments. However lowest population was observed with complete inorganic treatment (100% STBN). At 60 DAS and at maturity significantly highest bacterial population was recorded same as 30 DAS. This data was closely confirmative with the results reported by Thakare and Wake [15] who reported that the bacterial population increased in organically amended plot (FYM and Vermicompost). [16] and [17] has reported maximum bacterial populations with combined organic manures and inorganic fertilizers application compared to inorganic fertilizers alone in case of rice and sorghum. Relatively higher rate of multiplication of bacteria was associated with organic manures, which might be due to the ready source of carbon organic manures that acts as substrate for stimulation of bacterial growth.

3.4 Fungi (× 10^3 cfu g^{-1} Soil)

Highest fungal population at 30 DAS was observed with application of 50% STBN through urea and 50% through FYM along with *Azospirillum* 5 kg ha^{-1} which was followed by T_7 (50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}) and T_5 (75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}) are on par with each other. These three treatments have been superior to other treatments and lowest number of fungi was recorded with T_1 (100% STBN). Similar results were also observed at 60 DAS and at maturity. [18] reported application of 50% RDF through fertilizers + 50% N through FYM significantly recorded the highest fungal population. Similarly [19] revealed that application of vermicompost @ 2.5 t ha^{-1} + 100% RDF + seed inoculation with biofertilizers (*Azotobacter* + PSB) significantly increased fungal population. The results illustrated that the favourable effect of increased fungal population were related to application of organic manures. Yadahalli [20] have also reported the similar results.

Table 3. Grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) 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

Table 4. Microbial population at different growth stages of pearl millet as influenced by organic and inorganic sources of nitrogen

Treatments	Bacteria (× 10^6 cfu g^{-1} soil)			Fungi (× 10^3 cfu g^{-1} soil)			Actinomycetes (×10^4 cfu g^{-1} soil)		
	30 DAS	60 DAS	At maturity	30 DAS	60 DAS	At maturity	30 DAS	60 DAS	At maturity
T_1: 100% STBN	25.67	26.00	21.33	11.33	13.00	12.33	17.17	20.57	19.32
T_2: 75% STBN + 25% FYM	31.33	34.00	32.00	13.67	15.67	15.00	20.47	25.97	24.35
T_3: 75% STBN + 25% vermicompost	29.00	32.00	29.33	13.00	14.67	14.67	19.32	23.45	26.53
T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}	32.33	36.33	34.67	14.33	16.33	15.33	23.01	29.78	28.29
T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	31.67	34.33	32.67	13.33	15.00	14.33	21.07	27.62	27.01
T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}	39.00	45.67	41.33	17.67	20.33	19.33	28.13	36.14	33.86
T_7: 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	37.00	42.00	37.00	15.00	17.67	16.67	25.73	34.84	30.27
T_8: 100% STBN + *Azospirillum* @ 5 kg ha^{-1}	27.33	28.33	24.72	12.00	14.33	13.33	18.92	21.23	20.28
S.Em ±	2.121	2.551	2.147	1.012	1.094	1.223	1.518	1.971	2.243
CD (P = 0.05)	6.40	7.74	6.50	3.06	3.32	3.70	4.59	5.99	6.78
CV (%)	11.3	12.4	11.4	12.4	11.8	13.7	11.8	12.1	14.3

3.5 Actinomycetes (× 10^4 cfu g^{-1} Soil)

The maximum number of colony forming units with respect to actinomycetes at 30, 60 DAS and at maturity were recorded in treatment which received 50% STBN through urea and 50% N through FYM along with *Azospirillum* @ 5 kg ha^{-1} and it has been followed by 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}. Compared to the treatment which received only inorganic source, the other treatments which received either organic source or biofertilizers along with inorganic sources recorded highest actinomycetes population at all the growth stages. Lowest actinomycetes population at all stages were recorded in 100% STBN.

Beneficial effect of organic manures on actinomycetes population was noticed by Mali et al. [18]. The microbial population increased with combined application of organic and inorganic nitrogen source compared to inorganic nitrogen alone. Among the organic manures the FYM performed better in improving the soil microbial load.

3.6 Soil Organic Carbon (%)

Results of post experimentation analysis at the end of cropping season showed that there was no significant improvement in soil organic carbon status due to integrated nitrogen management treatments. Compared to initial soil status, organic carbon is improved in organic treated plots. The highest build-up of organic carbon in the soil was reported in 50% STBN through urea and 50% N through FYM along with *Azospirillum* @ 5 kg ha^{-1} than the treatments supplied only with inorganics. This is in agreement with the results of [21] who reported that the organic carbon of the soil improved with the application of organic manures with graded dose of fertilizers. The increase in organic carbon content in the manurial treatments may be due to increased activity of microorganisms and also due to better root growth, resulting in the higher production of biomass, stubbles and residues and the consequent decomposition of these might have resulted in the enhanced organic carbon content of soil [22].

3.7 Nitrogen (kg ha^{-1})

Data on available soil nitrogen after harvesting of pearl millet crop revealed that there is significant variations in post harvest soil N status (Table 5) among treatments supplied with different organic and inorganic sources of nitrogen. Among different treatments, the treatments which received 100% soil test based nitrogen through urea along with *Azospirillum* @ 5 kg ha^{-1} recorded highest soil nitrogen and remained statistically on par with 75% STBN + 25% N vermicompost + *Azospirillum* @ 5 kg ha^{-1} and 100% STBN through urea. The lowest soil nitrogen status was recorded with treatments which received 50% nitrogen through FYM or vermicompost. Das and Dkhar [21] has observed that post harvest nutrient status of soil was significantly influenced by organic fertilizers where maximum post harvest N, was observed with integrated treatment. Significantly the build-up of available N in the soil under this combination of chemical fertilizer and organic manures might be due N added through organic matter *i.e*., vermicompost remained for longer period in the soil as residual nutrient and also fixed biologically atmospheric nitrogen by *Azospirillum*. The findings of present investigation are in agreement with those of [23], [24] and [2].

3.8 Phosphorous (kg ha^{-1})

The data presented in Table 5 revealed that the post harvest phosphorous status in soil was significantly influenced by the treatments.

The highest post-harvest available soil phosphorous was recorded with 50% STBN through urea and 50% N through vermicompost along with *Azospirillum* @ 5 kg ha^{-1} followed by application of 50% STBN through urea and 50% N through FYM along with *Azospirillum* @ 5 kg ha^{-1} and 75% STBN through urea and 25% N through vermicompost along with *Azospirillum* @ 5 kg ha^{-1} which maintained parity among them and were significantly higher than other treatments. The lowest post harvest soil available phosphorous was recorded with complete inorganic treatment. Kumar et al. [25] noticed that maximum available available P_2O_5 level in soil recorded with application of 50% N through chemical fertilizers + 50% N through FYM. Similar results were also observed by the [26]. The highest availability of phosphorous might be due to CO_2 and organic acid released during decomposition of organic matter in vermicompost and FYM increased the availability of P from native as well as applied sources by dissolving the acid soluble P. These results gain support from [27], [28] and [29].

Table 5. Soil nutrient status after harvest of pearl millet as influenced by organic and inorganic sources of nitrogen

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1: 100% STBN	0.47	154.87	21.93	283.231
T_2: 75% STBN + 25% FYM	0.53	143.80	23.86	306.47
T_3: 75% STBN + 25% vermicompost	0.50	145.27	24.77	309.2
T_4: 75% STBN + 25% FYM + *Azospirillum* @ 5 kg ha^{-1}	0.55	146.67	25.93	313.57
T_5: 75% STBN + 25% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	0.54	160.10	26.57	339.6
T_6: 50% STBN + 50% FYM + *Azospirillum* @ 5 kg ha^{-1}	0.58	137.00	29.97	343.83
T_7: 50% STBN + 50% vermicompost + *Azospirillum* @ 5 kg ha^{-1}	0.54	141.97	33.35	352.17
T_8: 100% STBN + *Azospirillum* @ 5 kg ha^{-1}	0.48	164.10	22.02	292.037
S.Em ±	0.035	5.432	2.271	11.423
CD (P = 0.05)	NS	16.46	6.87	34.6
CV (%)	9.9	6.4	14.8	6.7

3.9 Potassium (kg ha^{-1})

It is evident from the data that available potassium in soil after harvest of crop is significantly influenced by integrated nitrogen management practices to pearl millet crop during the year of study. The soil potassium followed a same trend as in case of phosphorous. The highest post harvest potassium in soil was reported with application of 50% STBN through urea and 50% N through vermicompost along with *Azospirillum* @ 5 kg ha^{-1} which might be due to reduction in potassium fixation and mobilization of native and non exchangeable forms of potassium by the organic acids released during decomposition of organic matter added through vermicompost and FYM. Addition of organic manures increases the microbial population and their activity and thus increasing the availability soil nutrients status [15].

4. CONCLUSION

From the present study, it can be concluded that addition of organic manures, chemical fertilizers and biofertilizers in combination, helped in increasing soil microbial population and soil nutrient status which has been improved pearl millet productivity. Although chemical fertilizers provides a good amount of nutrients at initial stages of plant growth but its continuous use cause environmental hazards. Therefore integration of organic and inorganic sources should be adopted so that chemical fertilizers are reduced to some extent and also soil production potential is maintained for longer period.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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