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Influence of Organic Nutrients and Bioinoculants on Growth and Productivity of Pearl Millet (*Pennisetum glaucum* L.) under Semi-arid Conditions of Rajasthan

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ABSTRACT

Background: Pearl millet is also called as the "Powerhouse of Nutrition" as it consists of most of the important nutrients in good quantity and quality which are required for maintaining healthy life. Indiscriminate use of high analysis chemical fertilizers results in the environment pollution which is detrimental to the sustainability; there is an urgent need for adoption of farming practice which ensures sustainability, good soil, human and environmental health.

Methods: A field experiment was taken for three consecutive years during *kharif* season of 2018 to 2020 at Agronomy Research Farm, Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan to study the impact of various sources of organic nutrients and bioinoculants on growth and productivity of pearl millet. The treatments were comprised of chemical fertilizers, organic manures and microbial biofertilizer consortia (consisting of Azotobactor, Azospirillum and phosphate solubilizing bacteria) commercially branded as Biomix, which were tested in randomized block design with three replications.

Result: All the treatments including farmyard manure (FYM) and vermicompost with and without Biomix had significant effect on soil properties, growth andyield parameters and yield of pearl millet. The pooled data clearly showed that recommended dose of fertilizer (RDF) recorded significantly higher grain (3494 kg/ha) and stover (8612 kg/ha) yields of pearl millet and found at par with treatments T_6: 100% RDN through FYM + Biomix; T_7: 75% RDN through FYM + Biomix; T_8: 100% RDN through vermicompost + Biomixand T_9: 75% RDN through vermicompost + Biomixover rest of the treatments. With respect to economics T_6 (100% RDN through FYM + Biomix) recorded highest net returns of Rs. 75602 and B:C ratio (4.14) followed by treatment T_7 (75% RDN through FYM + Biomix). Continuous application of organic manures with biofertilizers had also significant improvement on soil OC (0.39%), phosphorus (54 kg/ha), potash (310 kg/ha), Zn (0.92 ppm) and Fe (6.92 ppm) over initial soil status.

Key words: Chemical fertilizer, Integrated nutrient management, Microbial inoculants, Organic manure, Pearl millet, Yield.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) is the most widely grown staple food of majority of poor and small land holders in Asia and Africa in arid and semi-arid regions. It is also consumed as feed and fodder for livestock. It accounts for almost half of global millet production. Itis the world's sixth and India's fourth important cereal food crop after rice, wheat and maize. Pearl millet is not only a quick growing short duration crop, but also a high drought tolerant and well adapted to different soil types. Pearl millet in India is being cultivated on an area of 7.47 million ha with a production of 9.80 million tones and the average productivity of 1312 kg/ha (Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, 2018-19). The major pearl millet growing states in India are Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana contributing 90% of total national production.In Rajasthan, pearl millet occupies 4.15 million ha area with the production of 4.15 million tones and average productivity of 1001 kg ha^{-1} (Rajasthan Agricultural Statistics at a Glance, 2018-19).

Pearl millet is also called as the "Powerhouse of Nutrition" as it consists of most of the important nutrients in good quantity and quality which are required for maintaining healthy life. It has high concentration of macronutrients and micronutrients such as iron, zinc, calcium, magnesium, copper, manganese, phosphorous and rich in folic acid and riboflavin. It contains a fairly good amount of unsaturated fatty acids (75%). Nutritional value of pearl millet is better in comparison to wheat, rice, maize and sorghum. It is a good source of energy, carbohydrate, fat (5-7%), ash, dietary fiber (1.2 g/100 g), α-amylase activity, quality protein (9-13%), vitamin A and B, minerals (2.3 mg/100 g), antioxidants such as ferulic acid and coumaric acids with better fat digestibility

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(Poshan, 2019). Pearl millet has special health benefiting properties for people suffering from life style diseases like diabetes, obesity *etc*. as it has high proportions of slowly digestible starch (SDS) and resistant starch (RS) that contribute to low glycemic index (GI). Pearl millet is gluten free and retains its alkaline properties even after being cooked which is ideal for people suffering from gluten allergy and acidity. Due to the excellent nutritional properties and resilience to climate change, pearl millet along with other millets is renamed as nutri-cereals (Gazette of India, No. 133 dated 13 April, 2018) for production, consumption, trade and was included in public distribution system.

Looking to the nutritional value of the pearl millet, day by day it is becoming popular among the farming community. Fertilizer management is one of the important cost-effective factors known to augment the crop production. But, inadequate or excess supply of any plant nutrient limits the crop production. Due to increasing demands for food supply by the ever-growing population, production systems using chemical fertilizers were adopted. Excessive and injudicious use of chemical inputs in agriculture caused land degradation, decline in factor productivity and health hazards, which attracted the attention towards integrated nutrient management for sustainable crop production. Indiscriminate use of high analysis chemical fertilizers results in the deficiency of secondary and micronutrient in soil. Bio-fertilizers offer great potential for not only improving soil fertility but also provide for efficient use of various resources for increasing crop production on sustainable basis. They helps in maintaining long term soil fertility and sustainability by fixing atmospheric N_2, mobilizing fixed macro and micro nutrients or convert insoluble P in the soil into forms available to plants, there by increases their efficiency and availability. Wahane *et al*. (2020). With the present scenario with environment pollution which is detrimental to the sustainability, there is an urgent need for adoption of farming practice which ensures soil health, human health, animal health and environmental health. INM involves the use of organic manures and bio-fertilizer with a view to reduce the quantity of inorganic fertilizers use in agriculture Reddy *et al*. (2013). Inclusion of organic nutrients enhances soil organic matter which has great importance in maintaining soil fertility. It is a store house of essential plant nutrients, affects soil physical, chemical and biological properties; provides energy material for the soil organisms and plays a vital role for sustainable crop productivity. Organic manures, particularly farmyard manure (FYM) and vermicompost not only supply macronutrients but also meet the requirement of micronutrients besides improving soil health. At this critical juncture, there is an urgent need to optimize nutrient demand to sustain crop production without affecting soil health and protecting the environment. Keeping in view of the above situation, the present investigation was carried out to explore the possibility of organic cultivation of pearl millet crop under rainfed situation in semi-arid conditions of Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted under All India Coordinated Research Project on Pearl millet for three consecutive years during *kharif* season of 2018 to 2020 at Agronomy Research Farm, Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan to study theimpact of various sources of organic nutrients and bioinoculants on growth and productivity of pearl milletunder semi-arid condition of Rajasthan". The experimental site was located at 26°512′ N latitude and 75°472′ E longitude and at an altitude of 390 m above mean sea level. The mean maximum temperature was 34.7°C, 31.62°C, 33.42°C and minimum temperature was 22.4°C, 22.5°C, 23.1°C and total rainfall was 582.0 mm, 718.2 mm and 489.4 mm during the crop period in the year 2018, 2019 and 2020, respectively. The soil of the experimental site was well-drained loamy sand and coarse in texture. It was low in organic carbon (0.298%) and available nitrogen (115.65kg/ha), medium in available phosphorus (35.0 kg/ha) and available potash (216.20 kg/ha) with pH 7.4 and EC 0.14 dS m^{-1}. DTPA extractable Zn and Fe was 0.55 and 4.32 ppm. There were tentreatments of organic manures with and without biofertilizers consortia (named as Biomix, comprised of Azotobactor, Azospirillum and phosphate solubilizing bacteria)which were tested in randomized block design with three replications. The treatments consisted of T_1: Recommended dose of fertilizer (RDF)(60 + 30 + 0 NPK kg/ha); T_2: 100% recommended dose of nitrogen (RDN) through FYM; T_3: 75% RDN through FYM;T_4: 100% RDN through vermicompost; T_5: 75% RDN through vermicompost; T_6:100% RDN through FYM + Biomix; T_7: 75% RDN through FYM + Biomix; T_8:100% RDN through vermicompost + Biomix; T_9: 75% RDN through vermicompost + Biomix. The experiment was taken as rain fed on the fixed site continuously for all the three years. A plot size of 4.0 m × 3.6 m was kept by leaving 0.5 m bund space between to plots. The certified seeds of pearl millethybridRHB 173 were used for sowing. The seeds were sown manually 2-3 cm deep after treating them with Biomix@ 4 ml/kg seed in previously opened furrows as per the treatments with a recommended seed rate of 4.0 kg ha^{-1}. In organic plots, whole RDF was applied through FYM and vermicompost after calculating the concentration of nutrients present in them. For applying 100% and 75% RDN per hectare through FYM, 12 tons and 9 tons of well decomposed FYM respectively, having 0.5, 0.25, 0.15% NPK was applied in the plots before sowing and mixed well. Likewise, 4 tons and 3 tons of vermicompost having 1.5, 0.8, 0.75% NPK was applied for 100 and 75% RDN respectively, in the plots before sowing. In all the years crop was sown in first week of July and harvested in last week of September. For working out the economics, prevailing market prices for grain @ Rs. 16.0/kg and stover@ Rs. 2.0/kg and other inputs were considered. The data were statistically analyzed and the pooled results are presented.

RESULTS AND DISCUSSION

Growth and yield attributing characters

All the growth and yield attributing characters, *viz.*, plant height, total number and effective number of tillers per plant, ear head length and girth were significantly influenced byintegrated nutrient management. Results revealed that significantly taller plants (202 cm) were found under treatment T6: 100% RDN through FYM +Biomix which was being at par with T1, T7, T8 and T9. Likewise, total number of tillers was significantly higher (5.56) under treatment T8 and it remained atpar with rest of the treatments except T3 and T5. Treatment T1 (RDF) recordedsignificantly higher number of effective tillers per plant (3.0) which remained atpar with T_6, T_7, T_8 and T_9 (Table 1).

Earhead length andgirth of pearl millet were also significantly influenced by INM. Among the different treatments tried, application of 100% RDN through FYM and Vermicompost along with seed treatment with Biomix (T_6 and T_8) recorded highest length of earhead (28.27cm and 30.9 cm) and girth of earhead (30.4 mm and 30.9 mm), respectively over rest of the treatments. Test weight (9.9 g, 9.6 g) and protein content (8.0 %) were also recorded highest under T_6 and T_8 treatments (Table 1). Organic manures along with biofertilizers had significant favourable effects on soil physical, chemical and biological properties which directly or indirectly influence the plant growth and yield attributing characters by increasing the water holding capacity of soil, increasing organic carbon, enhancing microbial activity in the soil which is resulted into more availability of nutrients by solubilizing or mobilizing the fixed pool of nutrients in the soil. Results were also in close conformity with those found by Singh *et al.* (2013), Bagla *et al*. (2008) and Choudhary and Gautam (2007).

Grain and stover yield

Crop yield is the complex function of physiological processes and biochemical activities which modify anatomy and morphology of the growing plants. Judicious use of available nutrients is a basic requirement throughout the crop growth period for smooth running of all physiological processes. The results revealed that organic manure along with biomix

Table 1: Effect of integrated nutrient management on growth, yield attributing characters and quality of pearl millet (pooled data of 3 years).

Treatments	Total tillers plant^{-1}	Effect tillers plant^{-1}	Plant heigh t(cm)	Ear head lengt (cm)	Ear head girth (mm)	Test weight (g)	Prote in (%)
RDF	5.44	3.00	192	28.06	29.4	9.6	7.3
RDN through FYM	4.89	2.44	178	28.13	28.3	9.4	8.0
75% RDN through FYM	4.08	2.35	173	25.46	27.3	8.6	7.5
RDN through Vermicompost	5.33	2.89	180	27.53	29.8	9.1	7.9
75% RDN through Vermicompost	4.72	2.44	180	26.53	28.1	8.4	7.3
T_2 + Biomix (*Azo* + PSB+Myco)	5.45	2.78	202	28.27	30.4	9.9	7.7
T_3 + Biomix (*Azo* + PSB +Myco)	5.22	2.63	192	26.09	29.4	9.0	7.6
T_4 + Biomix (*Azo* + PSB + Myco)	5.56	2.82	200	30.25	30.9	9.6	8.0
T_5 + Biomix (*Azo* + PSB + Myco)	4.89	2.61	183	27.42	28.3	9.2	7.8
SEm±	0.23	0.14	6.75	0.87	0.97	0.27	0.18
CD at 5%	0.70	0.42	20.0	2.61	NS	0.80	0.55
CV%	7.96	9.04	6.17	5.48	5.74	5.04	4.17

Table 2: Effect of integrated nutrient management on grain and stover yield of pearl millet.

Treatments	Yield (kg/ha)							
	Grain			Pooled	Stover			Pooled
	2018	2019	2020		2018	2019	2020	
RDF	1722	4543	4218	3494	4733	11136	9966	8612
RDN through FYM	1333	3477	3621	2810	3909	8992	8442	7114
75% RDN through FYM	1107	3210	2942	2420	3786	8169	6916	6290
RDN throughVermicompost	1422	4280	3786	3163	4527	11049	8719	8098
75% RDN through Vermicompost	1308	3827	3128	2754	3621	7140	6540	5767
T_2 + Biomix (*Azo* + PSB + Myco)	1488	4362	4074	3308	4115	11461	9543	8373
T_3 + Biomix (*Azo* + PSB + Myco)	1425	4168	3786	3126	4321	11255	7896	7824
T_4 + Biomix (*Azo* + PSB + Myco)	1529	4341	4198	3356	4527	10432	9136	8032
T_5 + Biomix (*Azo* + PSB + Myco)	1435	4300	3827	3187	3827	9297	8765	7296
SEm±	83.07	217.49	213.17	170.87	226.60	730.71	515.69	490.13
CD at 5%	249	652	639	513	679	2191	1546	1472
CV%	10.14	9.26	9.90	9.76	9.45	12.81	10.59	10.87

treatments had significant influence on grain and stover yields of pearl millet. Application of 75% and 100% RDN through FYM and vermicompost along with seed treatment with biomix recorded atpar yield with RDF (3494 kg/ha grain, 8612 kg/ha stover) (Table 2). The economically higher grain (3308 kg/ha) and stover (8373 kg ha^{-1}) yield was recorded under treatment T6: 100% RDN through FYM + Biomix which recorded highest net returns (75602 Rs/ha) and B:C ratio (4.14) over rest of the treatments and it remained at par with T_1 and T_7 (Table 3). It might be attributed to the favourable effect of organic manures which play a key role in root development, energy translocation and metabolic processes of plant through which increased translocation of photosynthates towards the sink development might have occurred. The beneficial effect of combined use of organic manures (FYM or vermicompost) and Biomixon seed and straw yields could be attributed to the fact that proper decomposition and mineralization of organic manures due to increased microbial activity resulted into increased supply of available P and N with other essential plant nutrients directly to the plant and also solubility effects on fixed form of (Patel *et al.* (2014). These findings are in close agreement with those reported by Meena *et al.* (2011), Golada *et al.* (2011), Kanzaria *et al*. (2010) and Rajput (2008).

Soil properties

EC and pH

Results with respect to EC and pH of the soil after harvest showed that the plant nutrient applied throughorganic manures with and without Biomix did not show any significant effect on EC and pH of the soil in different treatments. Though, numerically higher values compared to RDF was observed in organically treated plots.

Organic carbon

Organic carbon content varied between 0.29 to 0.39%. Organic carbon content showed significant increase with most of the treatments over RDF (60:30:0 NPK kg/ha) (T_1), T_3 and T_5. Significantly highest organic carbon content (0.39%) was obtained with application of RDN through FYM + Biomix (T_6) followed by 0.38% with T_4, T_8 and 0.36% with T_9 and T_2. Organic carbon content was influenced significantly due to application of organic manures. The relative increase in organic carbon content of the soil due

Table 3: Effect of integrated nutrient management on yield and economics of pearl millet (Pooled basis).

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Net returns (Rs/ha)	B:C
RDF	3494	8612	71099	4.39
RDN through FYM	2810	7114	60656	3.53
75% RDN through FYM	2420	6290	51060	3.27
RDN through vermicompost	3163	8098	61652	2.81
75% RDN through vermicompost	2754	5767	48148	2.60
T_2 + Biomix (*Azo* + PSB+ Myco)	3308	8373	75602	4.14
T_3 + Biomix (*Azo* + PSB + Myco)	3126	7824	71266	4.16
T_4 + Biomix (*Azo* + PSB + Myco)	3356	8032	65198	2.91
T_5 + Biomix (*Azo* + PSB + Myco)	3187	7296	62874	3.09
SEm±	170.87	490.13	-	-
CD at 5%	513.47	1471.82	-	-
CV%	9.76	10.87	-	-

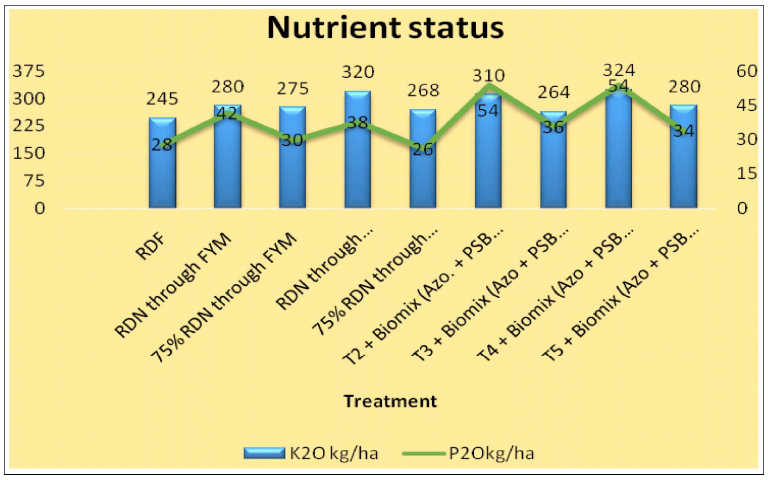

Fig 1: Post harvest available P and K status of the soil.

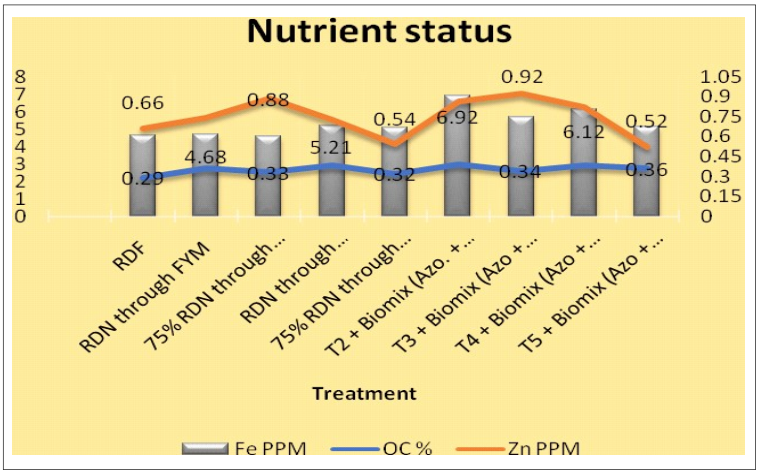

Fig 2: Post harvest organic carbon content (%) and available Zn (ppm) and Fe (ppm) status of the soil.

to vermicompost and FYM application, which may be attributed largely by addition of organic matter and higher microbial activity (Fig 2) Similar results were also reported by Tolanur and Badanur (2003).

Available P and available K

Available P and K also influenced by the application of organic manures with Biomix over RDF through inorganic fertilizer. Significantly highest available P (54 kg/ha) and available K (310kg/ha) was recorded with application of RDN through FYM + Biomix (T_6) followed by RDN through vermicompost + Biomix (T_8) which is also recorded 54kg/ha available P and 324kg/ha available Kover T_1 (Fig 1). This might be due to decomposition of organic matter present in manures, released organic acids helped in dissolving the fixed P and K, which increased the available soil phosphorus and potassium resulting in higher post-harvest nutrient status of soil. Further, biomixapplication increased the microbial activity in the soil and helped in solubilizing and mobilizing the fixed nutrients and made it available to plants. Tolanur and Badanur (2003) and Mostafa Mohamed Selim (2020) have also highlighted the importance of manures in enhancing the nutrient status of soil.

DTPA extracted Zn and Fe

Results with respect to available Zn and Fe revealed that significantly higher values of Zn (0.86 ppm, 0.92 ppm and 0.82 ppm) and Fe (6.92, 5.72 and 6.12) were recorded under treatment T_6, T_7 and T_8 respectively, over rest of the treatments. Continuous application of organic manures particularly FYM and Vermicompost not only supply macronutrients but also meet the requirement of micronutrients besides improving soil health (Vora *et al.*, 2010).

CONCLUSION

Based on the results of present investigation, it can beconcluded that long term application of 100% RDN through FYM with microbial inoculant Biomix@ 4 ml/kg as seed treatment can replace a portion of the inorganic fertilizers and produce economically higher grain (3308 kg/ha) and stover (8373 kg/ha) yield with highest net returns (75602 Rs/ha) and B: C ratio (4.14). The treatmentis also found to be effective in improvingpost-harvest available nutrient status of the soil as well as soil health. Hence, the study concludes that *kharif* pearl millet can be grown in semi-arid conditions of Rajasthan by adoption of integrated nutrient management to obtain higher productivity and economic return and to improve the soil quality.

Conflict of interest

All authors declare that they have no conflict of interest.

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