Optimizing Nutrient Management for Pearl Millet: Insights from a Long-Term Field Experiment

Abstract

The study investigates the impact of integrated nutrient management strategies on the yield and nutrient uptake of pearl millet (*Pennisetum glaucum*), a vital crop in arid and semi-arid regions. Pearl millet is a significant source of dietary energy and essential nutrients for rural populations in India. However, its productivity remains low compared to other millet-producing countries. This research aims to enhance pearl millet yield through a combination of organic manures, biofertilizers, and chemical fertilizers, addressing the need for sustainable agricultural practices. The experiment was conducted at the Research Farm of Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya during the kharif seasons of 2022 and 2023. Twelve treatment combinations were tested, including 100% NPK along with farmyard manure (FYM) and seed treatments with biofertilizers. Results indicated that the treatment combining 100% NPK with FYM at 10 t/ha/year and biofertilizers significantly improved biological yield, nutrient uptake, and soil organic carbon content. Specifically, the highest biological yield recorded was 8026 kg/ha, with notable increases in total nitrogen, phosphorus, and potassium uptake. This study underscores the importance of integrated nutrient management in enhancing pearl millet productivity while maintaining soil health. By adopting these practices, farmers can improve crop yields and contribute to food security in regions reliant on pearl millet. The findings provide a framework for future research and practical applications in sustainable agriculture, emphasizing the need for balanced nutrient supply systems to optimize crop performance and soil fertility.

Key words: Azotobacter, FYM, Long-term, Physico-chemical properties

Introduction

Pearl millet (*Pennisetum glaucum*) is commonly known as Bajra, Bajri, Sajje, Kambu, Kamban, Sajjalu, *etc*. in various Indian local languages and is commonly used for food, feed, and forage. It is the most widely grown millet and it is one of the important millet crops in hot and dry areas of arid and semi-arid climatic conditions, particularly in Rajasthan. Pearl millet belongs to the family Gramineae or Poaceae. The inflorescence of pearl millet is known as spike. It is a highly cross-pollinated crop due to protogynous habit and C_4 plant, it has very high photosynthetic efficiency and dry matter production capacity. Pearl millet originated in tropical Western Africa about 4000 years ago. India is the largest producer of pearl millet, among all the states and UTs, Rajasthan (46%), Maharashtra (19%), Gujarat (11%), Uttar Pradesh (8%) and Haryana (6%)(Amarghade and2021) was among top pearl millet producing states.

In India, pearl millet is a primary source of dietary energy (360 kcal/kg) for rural populations and the fourth most important cereal after rice, wheat, and sorghum (Tomar *et al.* 2013) It is a rich source of protein, calcium, phosphorous, and iron. Pearl millet grain contains fairly high amounts of thiamine, riboflavin, and niacin. Pearl millet grain is also used for non-food purposes such as poultry feed, cattle feed, and alcohol extraction (Mohan and Singh 2022). The productivity of pearl millet is very low compared to important pearl millet-growing countries in the world. It is, therefore, necessary to increase the production and productivity of pearl millet by adopting scientific innovations (Thumar *et al.* 2016).

An integratednutrient supply system comprising biofertilizers, organic manures and FYM in conjunction with chemical fertilizers is necessary to meet the crop nutrient demand.In the research problem, various organic like FYM and seed treatment with PSB and Rhizobium and inorganic nutrient sources like nitrogen, phosphorus, potassium, sulphur, zinc and ferrous containing fertilizer were used.Long-term application of inorganic fertilizers depletes the physical, chemical, and biological qualities of soil and pollutes the environment when combined with organic additions (Singh *et al.* 2013). In addition to providing the soil with nutrients and organic matter, organic manures also influence the soil's structure, turnover of nutrients, biodiversity, and activity of the microbial population, among many other changes in the physical, chemical, and biological characteristics of the soil. The physico-chemical qualities of soils can be enhanced by the use of organic manures alone or in conjunction with chemical fertilizers(Parsad 2010).A judicious combination of chemical fertilizers, organic manures and bio-fertilizers should be formulated for crops and cropping system within the ecological, social and economic possibilities (Arya *et al.* 2022).

Since information pertaining to the above aspects is meagre, the present investigation was carried out to study the effect of integrated nutrient management (INM) on nutrient uptake, productivity and soil sustainability to enhance the fertility and productivity of the soil.

Materials and methods

The present investigation is a part of an ongoing long-term field experiment ofintegrated nutrient management on pearl millet. The experiment was initiated in 2002 on permanent plots with latitude of 260 13'N and longitude 760 10'E with an altitude 197 meters. The climate of the experimental site is semi-arid and subtropical with extreme weather conditions having hot and dry summer and cold winter, where maximum temperature goes up to 45 ^{0}C during summer and minimum as low as 2.80 ^{0}C. The mean annual rainfall of the area is 700-800 mm. The soil of the experimental field is alluvial, sandy clay loam in texture and classified as Typic Ustochreptsat great group level comes under Inceptisols.The experiment was laid out with randomized block design having three replications comprising of 12 treatments, *viz* T_1-Absolute Control, T_2-100% N, T_3-100% NP, T_4-100% NPK, T_5-100% NPK + 25 kg $ZnSO_4$/ha/yr, T_6-100% NPK + 50 Kg $FeSO_4$/ha/yr, T_7-100% NPK + $FeSO_4$ + $ZnSO_4$, T_8-100% NPK + 1% ($FeSO_4$ + $ZnSO_4$ Spray), T_9-50% NPK + FYM @ 10t/ha/yr, T_{10}-75% NPK + FYM @ 10t/ha/yr, T_{11}-100% NPK+ FYM @ 10t/ha/yr and T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment)}, respectively.

The recommended dose of fertilizer for pearl millet was 80 N + 40 P_2 O_5 + 20 K_2O kg/ha. Half of the nitrogen was applied in the form of urea as a basal dose and the remaining was top-dressed after 1st irrigation at 30 DAS. Full dose of phosphorus and potash applied as basal through single supper phosphate and muriate of potash. The treatments were applied as per treatment details and FYM was applied 1 month before sowing. The azotobacter was applied as seed treatment at the rate of 10g/ kg seed. The JBV-3, cultivar was sown 5 kg/ha seed rate during July month and harvested in the second week of October.The pH, EC and OCcontent in soil before sowing were 7.72, 0.23 dSm^{-1}, and 0.39 % respectively.

Results and Discussion

The data furnished (Table1.0) that the test weight and harvest index were found non-significantin both years. The data showed that the pooled mean found significantly higherbiological yield(Table1.0) (8026 kg/ha) were recorded with treatment T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment), closely followed by T_{11}-100% NPK+ FYM @ 10t/ha/yr and T_{10}-75% NPK + FYM @ 10t/ha/yr (7380 and 6702 kg/ha). The minimum biological yield was recorded with the control treatment (2987 kg/ha).The application of the organic and inorganic nutrient sources including 100% NPK + FYM + PSB+ Azotobacter (Seed treatment) provided balanced nutrients to the pearlmillet which resulted into significant enhancement in biological yield.Similar result also reported byAbraham *et al.,* (2007),Devi *et al.,* (2011), Ram and Dhaliwal (2012), Kumar *et al.,* (2014) and Susmitha *et al.* 2022.

The data obtained that total nitrogen uptake (Table 2.0) significantly higher the pooled mean were recorded with T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment) (89.84 kg/ha), closely followed by T_{11}-100% NPK+ FYM @ 10t/ha/yr and T_{10}-75% NPK + FYM @ 10t/ha/yr (78.39 and 67.41 kg/ha). The minimum total nitrogen uptake was recorded with the control treatment (20.87 kg/ha).This might due to the addition of FYM enhanced significantly total nitrogen uptake by the crop. More uptake of N under the treatment with FYM resulted in mineralized N from FYM could meet the need of nutrients of crop. The outcome is turned with findings by Dahiya *et al.* (1987) and Singh *et al.* (1994).The data obtained that pooled mean of total phosphorus uptake (Table 2.0) maximum recorded with T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment) (17.90 kg/ha), closely followed by T_{11}-100% NPK+ FYM @ 10t/ha/yr and T_{10}-75% NPK + FYM @ 10t/ha/yr (15.97 and 13.25 kg/ha). The minimum total phosphorus uptake was recorded with control treatment (4.05 kg/ha).This might be due to the higher availability of P from applied FYM resulting in the decomposing of the organic materials which produced from the solubilizing action of organic acid. The data obtained that pooled mean of total potassium uptake (Table 2.0) maximum recorded with T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment) (111.50 kg/ha), closely followed by T_{11}-100% NPK+ FYM @ 10t/ha/yr and T_{10}-75% NPK + FYM @ 10t/ha/yr (100.07 and 87.40 kg/ha). The minimum total potassium uptake was recorded with control treatment (30.27 kg/ha). These results also confirmed by Ramdas *et al.,* (2016), Choudhary *et al.,* (2017), Yadav*etal.,*(2018) and Sunag *et al.,* (2021).

The data furnished (Table 3.0) that the pH and electrical conductivity were found to be non-significantin both years. The data presented that the pooled mean found significantly higher (Table 3.0) organic carbonrecorded with T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment) (0.408 %), it was at par with T_{11}-100% NPK+ FYM @ 10t/ha/yr (0.405 %). The minimum organic carbon recorded with control treatment with (0.373 %).The organic carbon content of the soil due to the application of Farm Yard Manure might be due to the deposition of organic matter in the soil in the crop residues and the direct addition of OM through FYM along with inorganic fertilizer. Similar concluded by Kumar *et al.* 2012,Rao *et al.,* (2021), Bairwa *et al.,* (2021) and Kalaliya *et al.,* (2022).

Table 1.0 Effect of integrated nutrient management on yield attributes and yield of pearl millet

Treatments	Test weight (g)			Harvest index (%)			Biological yield (kg/ha)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	7.46	7.45	7.46	30.69	29.78	30.24	2917	3056	2987
T_2	7.52	7.50	7.51	31.22	30.71	30.96	3574	3623	3599
T_3	7.54	7.53	7.54	31.27	30.58	30.92	4431	4575	4503
T_4	7.58	7.62	7.60	28.65	28.45	28.55	5324	5486	5405
T_5	7.62	7.61	7.62	28.11	28.54	28.32	5534	5496	5515
T_6	7.60	7.60	7.60	28.58	28.27	28.43	5353	5466	5409
T_7	7.63	7.62	7.63	28.78	28.76	28.77	5596	5637	5617
T_8	7.61	7.60	7.61	28.42	28.40	28.41	5189	5478	5334
T_9	7.65	7.66	7.66	27.78	27.53	27.65	6049	6093	6071
T_{10}	7.69	7.72	7.71	28.26	27.57	27.91	6549	6856	6702
T_{11}	7.50	7.52	7.51	29.14	29.64	29.39	7362	7398	7380
T_{12}	7.50	7.50	7.50	29.45	29.27	29.36	7988	8064	8026
S. Em. (±)	0.319	0.343	0.234	1.275	1.192	0.873	213.86	245.46	162.78
CD (0.05%)	NS	NS	NS	NS	NS	NS	627.24	719.93	463.95

Table 2.0 Effect of integrated nutrient managementon total uptake by pearl millet

Treatments	Total nitrogen uptake (kg/ha)			Total phosphorus uptake (kg/ha)			Total potassium uptake (kg/ha)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	20.47	21.26	20.87	3.34	4.77	4.05	30.52	30.02	30.27
T_2	30.92	31.34	31.13	4.74	6.40	5.57	39.15	39.74	39.45
T_3	38.83	39.97	39.40	7.60	9.98	8.79	48.96	50.71	49.84
T_4	47.99	48.86	48.43	8.74	12.13	10.44	66.06	67.56	66.81
T_5	49.62	49.61	49.62	8.87	12.24	10.56	69.22	68.45	68.84
T_6	49.74	50.21	49.98	9.00	12.30	10.65	66.50	68.24	67.37
T_7	52.14	53.67	52.91	9.57	13.14	11.36	70.34	70.87	70.61
T_8	49.58	49.95	49.77	8.99	12.35	10.67	68.47	76.47	72.47
T_9	57.31	57.86	57.58	9.24	12.94	11.09	74.69	78.06	76.37
T_{10}	66.13	68.69	67.41	11.12	15.38	13.25	85.02	89.77	87.40
T_{11}	78.05	78.73	78.39	13.41	18.52	15.97	99.92	100.21	100.07
T_{12}	89.53	90.14	89.84	15.13	20.66	17.90	110.68	112.31	111.50
S. Em. (±)	1.52	1.73	1.15	0.23	0.42	0.24	1.60	1.78	1.20
CD (0.05%)	4.46	5.09	3.29	0.69	1.23	0.68	4.69	5.21	3.41

Table 3.0 Effect of integrated nutrient management on pH, Electrical conductivity and Organic carbon in soil after harvest of pearl millet

Treatments	Soil pH			Electrical conductivity (dSm^{-1})			Organic carbon (%)		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
T_1	7.70	7.70	7.70	0.119	0.117	0.118	0.372	0.373	0.373
T_2	7.60	7.60	7.60	0.119	0.118	0.119	0.375	0.378	0.376
T_3	7.60	7.60	7.60	0.121	0.120	0.121	0.378	0.376	0.377
T_4	7.60	7.60	7.60	0.123	0.123	0.123	0.389	0.390	0.390
T_5	7.60	7.60	7.60	0.125	0.125	0.125	0.390	0.391	0.390
T_6	7.60	7.60	7.60	0.125	0.126	0.126	0.389	0.390	0.390
T_7	7.60	7.60	7.60	0.126	0.126	0.126	0.391	0.392	0.392
T_8	7.60	7.60	7.60	0.123	0.123	0.123	0.388	0.389	0.389
T_9	7.60	7.50	7.55	0.126	0.125	0.126	0.392	0.394	0.393
T_{10}	7.50	7.50	7.50	0.125	0.125	0.125	0.395	0.397	0.396
T_{11}	7.50	7.50	7.50	0.124	0.124	0.124	0.405	0.404	0.405
T_{12}	7.50	7.50	7.50	0.124	0.123	0.124	0.407	0.409	0.408
S. Em. (±)	0.212	0.204	0.147	0.003	0.003	0.002	0.005	0.005	0.003
CD (0.05%)	NS	NS	NS	NS	NS	NS	0.014	0.014	0.009

Conclusion

On the basis of these findings, it was concluded that treatment T_{12}-100% NPK +FYM @ 10 t/ha/yr + {PSB+ Azotobacter (Seed treatment) found best among remaining treatment. This research showed the highest yield was obtained and a significantly impact on soil properties as prospective to soil fertility.

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