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Effect of nutrient management on growth, yield attributing characters, yield and economics of rainfed pearl millet [*Pennisetum glaucum* (L) R.Br.]

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Abstract
Pearl millet has high yield potential and is grown for food and feed purposes. To meet the need of balanced diet and Fe and Zn deficiency in human population, efficient use of nutrient management practices is indispensable. Therefore, nutrient management practices are the only option for increasing the pearl millet production and sustainability. The current study aimed to the find out the effect of different nutrient management practices on growth, grain yield and economics of rainfed pearl millet. In this, field experiment was conducted during *kharif* season of 2019 at Dryland Agriculture Research Farm, CCS Haryana Agricultural University, Hisar. The experiment consisted of thirteen nutrient management practices *viz*. T_1- control, T_2- 40:20 kg NP/ha, T_3- 50:25 kg NP/ha, T_4- 60:30 kg NP/ha, T_5- 40:20:10 kg NPK/ha, T_6- 50:25:12.5 kg NPK/ha, T_7- 60:30:15 kg NPK/ha, T_8- 40:20:10 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_9- 50:25:12.5 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{10}- 60:30:15 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{11}- 40:20:10 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS, T_{12}- 50:25:12.5 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS and T_{13}- 60:30:15 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS was laid out in randomized block design with three replications. Our investigation under field study revealed that combined application of fertilizers along with spray of Fe and Zn @ 0.5% at 30 DAS had significant and positive effects on growth parameters, grain yield and economics of rainfed pearl millet. Application of 60:30:15 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS gave highest grain yield (1911 kg ha^{-1}), stover yield (5006 kg ha^{-1}) and net returns (Rs. 23637 ha^{-1}) compared to other nutrient management practices.

Keywords: Economics, grain yield, growth parameters, nutrient management, pearl millet

Introduction
Pearl millet [*Pennisetum glaucum* (L.) R.Br.] is world's sixth and India's fourth most important food grain crop after rice, wheat and maize. Besides that, India is largest producer in the world occupying an area of 6.93 million ha, with the production of 8.61 million tons and average productivity of 1243 kg ha^{-1}(Anonymous 2021 a) [1]. In Haryana, pearl millet is grown over an area of 4.2 lakh ha with the production of 6.9 lakh tons and productivity of 1609 kg ha^{-1} (Anonymous 2021b) [2]. It is nutritionally better than many cereals and good source of protein having higher digestibility (12.1%), fat (5%), carbohydrate (69.4%) and minerals (2.3%). It is the most drought tolerant crop among cereals and millets. Grains of pearl millet are mainly used for human consumption in the form of diverse food and dry stover of pearl millet, a basis of ration for a large bovine population, that is regarded as the most critical component of providing stability in the risk prone crop-livestock farming system in water limited regions. Consumption of unbalanced foods affects billions of people worldwide and leads to poor health and socio-economic condition. Sustainable development goals laid by the United Nations urge the global communities to ensure food security along with nutritional security. Moreover, among all cereals, it is the cheapest source of energy, protein, iron and zinc. These qualities make pearl millet the major contributor to protein, iron, and zinc intake in the regions where it is grown.

Among the micronutrients, zinc (Zn) and iron (Fe), deficiencies are a growing public health and socio economic issue, particularly in the developing countries. About one third of the world's population is estimated to be at risk of Zn deficiency, especially in children who are present under 5 years of age. Similarly, in case of Fe, on an average over 60% of the world's population are deficient in Fe in which 2 billion people were affected by anaemia. Fertilization is one of the most important ways for improving qualitative and quantitative crop yield.

Foliar application of Zn and Fe adopted over the soil application because it eliminates the risk of Zn and Fe interacting with the other nutrients in soil (i.e. P) and also adsorption on soil itself and thus becoming immobilized and unusable. Due to the immobility of Zn and Fe in soil, their foliar application is necessary. Balanced fertilization is necessary to increase productivity of pearl millet. Regular and judicious use of primary nutrients not only helps in raising good crop yield but can help farmers to gain higher profit. Therefore, the study was conducted to find out the effect of nutrient management practices on growth, grain yield and economics of rainfed pearl millet.

Materials and Methods

Field experiment was conducted at Dryland Agriculture Research Farm, CCS Haryana Agricultural University, Hisar during 2019 (20°-10' N, 75°46' E and 215.2 m above mean sea level). The experiment was laid out in randomized block design having 13 treatments with three replications. The treatments comprised of T_1- control, T_2- 40:20 kg NP/ha, T_3- 50:25 kg NP/ha, T_4- 60:30 kg NP/ha, T_5- 40:20:10 kg NPK/ha, T_6- 50:25:12.5 kg NPK/ha, T_7- 60:30:15 kg NPK/ha, T_8- 40:20:10 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_9- 50:25:12.5 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{10}- 60:30:15 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{11}- 40:20:10 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS, T_{12}- 50:25:12.5 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS and T_{13}- 60:30:15 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS. The sandy loam soil of the experimental field was low in organic carbon (0.33%), low in available nitrogen (135 kg ha^{-1}), medium in available phosphorus (14.20 kg ha^{-1}) and available potassium (240 kg ha^{-1}). Fertilizers were applied in the form of urea, DAP and MOP. Foliar application of Fe and Zn was done through iron sulphate and zinc sulphate. Recommended dose of NPK for pearl millet was 40:20:0 as per rainfed conditions of Hisar. Full quantity of phosphorus and potash fertilizers was given at the time of sowing. Half amount of nitrogen was applied as basal dose and rest was given at 25 DAS when some amount of rainfall received after sowing. Row to row spacing was 45 cm and the plot size was 6.0 m x 4.5 m. Certified seed of hybrid (HHB 272) was sown by *kera* method at about 2-3 cm depth using 5 kg seed ha^{-1}. The economics of the treatments was worked out considering the prevailing cost of inputs and outputs. All the results were then analysed statically for drawing conclusion using Analysis of Variance (ANOVA) procedure.

Result and Discussion

Weather parameters

The data on rainfall was recorded by the rain guage located at the experimental site and other climatological data was collected at meteorological station of CCS Haryana Agricultural University, Hisar (Table 1). The total rainfall received during the crop growth period was 98.7, 104.2, 68.2, 17.3 mm in June, July, August and September, respectively. The maximum and minimum temperature ranged from 35.5-43.7 and 23.7-26.0ºC, respectively. The relative humidity varied from 55 to 93% in the morning to 17 to 73% in the morning. The average wind speed ranged from 3.8 to 8.8 km/hr. The bright sun shine hours ranged between 4.1 on a cloudy day to 9.9 on a clear day. Evaporation from open pan evaporimeter ranged between 3.7 to 9.6 mm/day.

Growth parameters

The different nutrient management treatments significantly affected growth parameters *viz*., plant height, dry matter accumulation and leaf area index of pearl millet. In our observations with regard to plant height, leaf area index and dry matter accumulation were recorded at harvest. However, the tallest plants were produced with T13 (60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS). Plant height increased with application of 60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS (T13) at harvest. (Table 2). The reason for increase in plant height might be due to better nutritional environment in root zone for growth and development with the application of 60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS. Similar results were observed by Mostafa *et al.* (2013) [10], Mukhtar *et al.* (2011) [11], Naveen *et al*. (2021) [13] and Yadav *et al*. (2021) [19].

The rate of increase in dry matter accumulation was showed slight increase from 60 DAS at harvest (Table 2). At harvest, significantly higher dry matter accumulation $plant^{-1}$ was observed in treatment T13 (60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS). The production of dry matter is the outcome of growth, photosynthetic activity of the plants and their capacity to utilize available nutrients and is dependent on the balance between photosynthesis and respiration. Therefore, any nutrient management practice affecting the rate of photosynthesis is likely to affect dry matter accumulation. The results are in conformity with the findings of Yadav *et al*. (2021) [19], Narolia and Poonia (2011) [12], Naveen *et al*. (2021) [13] and Chouhan *et al*. (2015) [5].

Leaf area index (LAI) attained their maximum values at maturity stage. (Table 2). LAI was recorded highest in T13 (60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS) at harvest. This might be due to the extent and size of canopy which is a major factor of interception of solar radiations, determining net photosynthesis and photosynthetic activity of plant. It is generally accepted that leaf area represents a measure of photosynthetic efficiency of plants. The increase in fertilizer levels under different nutrient management treatments resulted in an increase in leaf area per plant and finally LAI. These findings are in close conformity with those of Neha *et al.* (2017), Chouhan *et al*. (2015) [5], Naveen *et al*. (2021) [13] and Yadav *et al.* (2020) [20].

Yield attributes and yield

A significant increase in total number of tiller $plant^{-1}$, effective tiller $plant^{-1}$ earhead length, earhead girth and test weight of pearl millet was observed with the application of 60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS (T13) over control under different nutrient management treatments (Table 2). This may be due to better nutrition as a result of different nutrient management treatments which aided in higher root growth, development and enhanced the uptake and translocation of nutrients. Neelum *et al*. (2009) also reported the improved yield attributes of pearl millet due to different nutrient management treatments. Nutrient supply of essential nutrients by application of fertilizes might have resulted in higher photosynthates and its subsequent partition towards sink, which might have resulted in higher length and girth of earhead. These findings were in accordance with Divya *et al.* (2017) [7] were observed that due to different nutrient management treatments produced significantly higher number of earheads $plant^{-1}$ test weight, grain and fodder yield

of pearl millet. The probable reason for increased test weight was mainly due to balanced supply of nutrients throughout the grain filling and development period which might have resulted in bold grains and consequently higher test weight. Apoorva *et al.* (2010) [3] and Thumar *et al.* (2016) [18] also reported the improved yield attributes of pearl millet with different nutrient management treatments.

Yield of a crop is the function of interaction between genetic potential of the crop cultivar and the environment. In present study, large variations ranging from 1036 to 1911 kg ha^{-1} were noticed in the grain yield among all the treatments (Table 5). Maximum grain yield in pearl millet was recorded with the application of 60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% $FeSO_4$ at 30 DAS (T_{13}) which has found significantly superior over control and other treatments. The increase in yield due to N, P and K application could be ascribed to better plant growth and dry matter production due to higher photosynthetic area. This is further supported by the fact that soil of experimental field was low in NPK. Thus, an increase in nitrogen, phosphorus and potassium supply might have increased all growth parameters, yield attributing characters which ultimately contributed to increase in grain and stover yield. Treatment T_{13} (60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% $FeSO_4$ at 30 DAS) have maximum stover yield, biological yield and harvest index which was significantly superior over control. This could be due to better nutrient uptake, which accelerated the photosynthetic rate, which leads to higher plant growth and biomass production that reflected on grain and stover yield due to higher photosynthetic area. These results are in accordance with Debnath *et al.* (2015) [6], Sakarvadia *et al.* (2012) [16] and Reddy *et al.* (2016) [15]. This is further supported by the fact that soil of experimental field was low in N and medium in P and K. Thus, an increase in nutrient supply might have increased all growth parameters, yield attributing characters which ultimately contributed to increase in grain and stover yield. This might also attributed to more P fixing capacity of experimental plots. Effect of phosphorus may also be due to that available phosphorus of soil was in medium range and application of phosphorus improved the nutrient availability status, resulting into greater uptake which might have increased the photosynthesis and then translocated to different plant parts and hence increased the growth parameters which contributed to yield. These results are in close conformity with the findings of Yadav *et al.* (2021) [19], Katiyar *et al.* (2017) [8], Malakar *et al.* (2022) [9], Naveen *et al.* (2021) [13] and Samruthi *et al.* (2020) [17].

Economics

Among various nutrient management treatments, application of 60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS (T_{13}) produced higher net returns of Rs. 23637 ha^{-1} and BC ratio of 1.96 over other nutrient management practices. The highest net returns and BC ratio was associated with its higher grain and stover yield per unit of added cost. Narolia and Poonia (2011) [12] also found that the economics of fertilizer treatments resulted in significantly net returns over control. These results are in agreement with the results of Ashewar *et al.* (2018) [4] and Samruthi *et al.* (2020) [17].

Table 1: Climatic data during crop season (June to Sept.) of the region during the study period

Parameters	Months			
	June	July	August	September
Rainfall(mm)	98.7	104.2	68.2	17.3
Max. Temp (ºC)	35.5 – 43.7	32.5 -38.6	33.3 – 35.6	33.4 – 36.2
Min. Temp (ºC)	24.6 – 26.0	23.7 – 26.2	25.1 – 27.0	24.3 – 27.4
Bright sunshine hours	5.5 – 7.4	6.2 – 9.9	4.7 – 7.2	4.1- 6.8
Wind speed (km/hr)	7.6 – 8.8	3.8 – 6.5	4.5 – 8.2	6.2 – 7.2
Evaporation (mm/day)	5.6 – 9.6	3.8 – 6.5	3.7 – 4.7	4.6 – 5.1
Relative humidity (%)				
Morning	55 – 77	74 - 93	86 - 89	83 - 89
Evening	17 – 44	56 - 73	56 - 70	49 – 59

Table 2: Effect of different nutrient management treatments on growth and yield attributing characters of pearl millet

Treatments	Plant height (cm) at harvest	Dry matter accumulation (g $plant^{-1}$) at harvest	Leaf area index at harvest	Total no. of tillers $plant^{-1}$	Effective tillers $plant^{-1}$	Earhead length (cm)	Earhead girth (mm)	Test weight (g)
T_1	134.40	55.01	0.761	2.03	1.56	15.66	19.00	6.00
T_2	138.66	60.08	0.793	2.56	2.13	18.33	22.66	7.26
T_3	140.86	61.12	0.831	2.86	2.47	18.96	24.70	7.46
T_4	143.96	63.89	0.851	3.33	2.87	20.76	26.10	7.96
T_5	139.56	60.19	0.835	2.73	2.26	18.26	23.23	7.26
T_6	140.70	63.16	0.842	3.23	2.76	18.98	25.20	7.66
T_7	143.60	64.91	0.852	3.57	3.30	20.96	27.13	8.03
T_8	139.36	61.12	0.836	2.99	2.67	18.46	24.40	7.33
T_9	142.76	63.99	0.842	3.45	3.20	19.93	26.80	7.70
T_{10}	145.23	65.55	0.856	3.78	3.65	21.60	28.03	8.10
T_{11}	139.96	62.02	0.849	3.23	2.96	19.00	25.50	7.43
T_{12}	143.33	64.32	0.853	3.63	3.33	20.33	27.73	7.70
T_{13}	146.53	66.05	0.859	4.10	3.75	21.73	29.13	8.19
CD at 5%	3.64	3.39	0.010	0.49	0.55	2.19	2.46	0.49

T_1- control, T_2- 40:20 kg NP/ha, T_3- 50:25 kg NP/ha, T_4- 60:30 kg NP/ha, T_5- 40:20:10 kg NPK/ha, T_6- 50:25:12.5 kg NPK/ha, T_7- 60:30:15 kg NPK/ha, T_8- 40:20:10 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_9- 50:25:12.5 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{10}- 60:30:15 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{11}- 40:20:10 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS, T_{12}- 50:25:12.5 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS and T_{13}- 60:30:15 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS

Table 3: Effect of different nutrient management treatments on grain yield and economics of pearl millet

Treatments	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)	BC ratio	Net Returns (Rs ha^{-1})
T_1	1036	4033	5069	20.4	1.34	7305
T_2	1386	4381	5767	24.0	1.58	13457
T_3	1500	4511	6012	24.9	1.68	15853
T_4	1612	4716	6317	25.3	1.77	18242
T_5	1411	4461	5927	24.7	1.58	13706
T_6	1591	4596	6187	25.7	1.71	17078
T_7	1719	4801	6512	26.2	1.80	19572
T_8	1540	4543	6084	25.3	1.69	16305
T_9	1681	4699	6385	26.4	1.78	18938
T_{10}	1819	4905	6706	26.9	1.88	21632
T_{11}	1640	4651	6306	26.2	1.78	18483
T_{12}	1776	4799	6575	27.0	1.87	21001
T_{13}	1911	5006	6912	27.6	1.96	23637
CD at 5%	176	209	411	0.6		

T_1- control, T_2- 40:20 kg NP/ha, T_3- 50:25 kg NP/ha, T_4- 60:30 kg NP/ha, T_5- 40:20:10 kg NPK/ha, T_6- 50:25:12.5 kg NPK/ha, T_7- 60:30:15 kg NPK/ha, T_8- 40:20:10 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_9- 50:25:12.5 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{10}- 60:30:15 kg NPK/ha + $ZnSO_4$ @ 0.5% at 30 DAS, T_{11}- 40:20:10 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS, T_{12}- 50:25:12.5 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS and T_{13}- 60:30:15 kg NPK/ha + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ at 30 DAS

Conclusion

Based on experimental findings it can be concluded that application of 60:30:15 kg NPK/ha + 0.5% ZnSO4 + 0.5% FeSO4 at 30 DAS is beneficial in terms of crop productivity of rainfed pearl millet.

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