



Maximizing pearl millet (*Pennisetum glaucum*) productivity and profitability using site specific nutrient management strategy

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ABSTRACT

Field experiment was conducted during *kharif* 2014 and 2015 at farmers' field at Panwari village of Agra district (Uttar Pradesh) to study the effect of site specific nutrient management (SSNM) on productivity, profitability and uptake of nutrients by pearl millet [*Pennisetum glaucum* (L) R.Br.]. The experiment was laid out in randomized block design with 10 treatments and three replications. Results, pooled over two years, indicated that the SSNM led to significant increase in grain and stover yield of pearl millet as compared to the state recommended NPK fertilizers and farmers' practice. SSNM increased the grain yield of pearl millet by 30.6 and 42.2% over state recommended NPK fertilizers and farmer practice, respectively. The maximum net profits of ₹ 45209/ha with a B:C ratio of 2.71 was obtained from pearl millet under SSNM. The minimum net profits (₹ 29818/ha) and B:C ratio (2.53) were recorded under farmer practice. Omission of P, K, S and Zn nutrients caused grain yield reductions by 22.4%, 24.0%, 7.4% and 7.0% over SSNM, respectively. The uptake of N, P, K, S and Zn by pearl millet grain and stover in SSNM was higher than that of the farmer's practice. The protein content and protein yield also improved with various treatments over farmers' practice and the maximum values for both were recorded under SSNM. The fertility status of soil increased with various treatments and the maximum values of organic carbon (4.0 g/kg), available N (204.5 kg/ha), P (16 kg/ha), K (144 kg/ha), S (22.4 kg/ha) and Zn (0.61 mg/kg) were recorded with 120 kg N+60 kg P₂O₅ + 90 kg K₂O+ 20 kg S + 4 kg Zn/ha over other treatments. Omission of S and Zn caused a reduction in available S and Zn status over their initial values.

Key words: Economics, Nutrient uptake, Pearl millet, Productivity, Profitability, Quality, SSNM

Pearl millet [*Pennisetum glaucum* (L) R.Br.] is the fourth most important cereal and widely grown in India because of its tolerance to drought, high temperature and low soil fertility. Pearl millet grain is the staple diet and nutritious sources of vitamins, minerals and protein, while pearl millet stover is a valuable livestock feed. Pearl millet is a heavy nutrient feeder and leads to large withdrawal of plant nutrients from soil. This depletion will result in decline in yield of the crop. Major cause of this decline has been attributed to the imbalanced use of plant nutrients which has an adverse effect on the physico-chemical and biological properties of soils (Sharma *et al.* 2015). Development of appropriate nutrient management techniques is necessary to maintain the productivity of pearl millet because the burgeoning population pressure puts up a challenge and great threat to food security of India. Fertilizers played the pivotal role in boosting crop production. The loss of soil health due to unbalanced fertilizer use coupled with large mining of

nutrients under intensive cropping system posed a threat to the sustainability of our farming system. Due to intensive cultivation, the Indian soils have become deficient in most of the macro and micronutrients; these have considerably decreased the productivity. After the harvest of pearl millet, a negative balance of nutrients has been commonly observed. Presently, application of secondary (S) and micronutrient (Zn) has become as essential as N and P. The sulphur is now recognized as fourth element whose deficiency is wide spread in India. Sulphur deficiency is observed primarily due to high crop yield and, therefore, higher rates of S removal by crop and lesser use of S containing fertilizers. Zinc plays a key role as structural constituent or regulatory cofactors of wide range of different enzymes and protein in many important biochemical pathways. These are mainly concerned with carbohydrate metabolism, auxin (growth regulator) metabolism. Proper soil diagnosis and adoption of site specific nutrient and crop management ushers in production efficiency and profitability. Site specific nutrient management is a widely use term in all the parts of the world with references to addressing nutrient differences which exist within and between fields and making adjustments in nutrient application to match the location or soil difference (Johnston *et al.* 2009). The SSNM provided the field specific

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recommendations to a farmer in a cost effective and timely fashion. In view of the above-mentioned facts, present investigation was undertaken to achieve attainable yield and profits from pearl millet crop through site specific nutrient management practices.

MATERIALS AND METHODS

Field experiment was conducted during *kharif* 2014 and 2015 at Panwari village of Agra district (Uttar Pradesh). The soil was sandy loam in texture, alkaline in reaction (pH 8.1), low in organic carbon (3.7 g/kg), low in available NPKS (160:10:115:16 kg/ha) and DTPA-Zn (0.54 mg/kg). The experiment was laid out in randomized block design with three replications. Soil test based fertilizer recommendation of N:P₂O₅:K₂O:S:Zn was 120:60:90:20:4 kg/ha and considered as optimum doses of fertilizers. The treatments were: T₁=N₁₂₀ P₆₀ K₉₀ S₂₀ Zn₄, T₂=N₁₂₀ P₃₀ K₉₀ S₂₀ Zn₄, T₃=N₁₂₀ P₀ K₉₀ S₂₀ Zn₄, T₄=N₁₂₀ P₆₀ K₄₅ S₂₀ Zn₄, T₅=N₁₂₀ P₆₀ K₀ S₂₀ Zn₄, T₆=N₁₂₀ P₆₀ K₉₀ S₀ Zn₄, T₇=N₁₂₀ P₆₀ K₉₀ S₂₀ Zn₀, T₈=N₁₂₀ P₆₀ K₉₀ S₀ Zn₀, T₉= state recommended dose of NPK (N₁₂₀ P₆₀ K₄₀) and T₁₀= farmers' practice (N 80 P 57.5). Urea, diammonium phosphate, muriate of potash, elemental sulphur and zinc oxide were used as sources of N, P, K, S and Zn, respectively. Pearl millet var. Pioneer 86M86 was sown in second week of July in both the years using 5 kg seed/ha. Appropriate management practices were adopted to raise the crop. The crop was harvested at maturity and grain and stover yields were recorded. The grain and stover samples were digested in di-acid mixture of HNO₃: HClO₄ (10:4) and zinc content in the digest was determined on atomic absorption spectrophotometer. Phosphorus, K and S were determined by vanadomolybdo phosphoric yellow colour method, flame photometer (Jackson 1973) and turbidimetric method (Chesnin and Yien 1951), respectively. Nitrogen content in grain and straw samples was estimated by modified Kjeldahl method. The uptake of nutrients was obtained as product of their concentration and yield. After harvest of the crop, soil samples were collected and analysed for available N (Subbiah and Asija 1956), P

(Olsen *et al.* 1954), K (1N NH₄OAc extractable), S (0.15% CaCl₂ extractable) and Zn (DTPA extractable) as described by Lindsay and Norvell (1978). The trend of results was similar during both the years, hence data were subjected to pooled analysis for results and discussion.

RESULTS AND DISCUSSION

Growth and yield attributes

Growth and yield components, viz. plant height, grain weight/ear, length of ear, width of ear and test weight of pearl millet varied significantly with various treatments (Table 1). The tallest (210 cm) plants were recorded under optimum dose of nutrients (N₁₂₀ P₆₀ K₉₀ S₂₀ Zn₄), while shortest (192 cm) plants in farmers practice (T₁₀). Plant height of pearl millet crop tended to decline with reduction in P and K levels (T₂ and T₄) and omission of nutrients (T₃, T₅, T₆, T₇ and T₈). Application of N₁₂₀ P₆₀ K₉₀ S₂₀ Zn₄ has resulted in greater length of ear (25.04 cm), width of ear (12.58 cm), more grain weight (33.15 g) and test weight (12.31 g) as compared to other treatments. The omission of P (T₃) significantly decreased the plant height and yield attributes as compared to balanced use of nutrients (T₁). With the decreased application of K up to 0 kg K₂O/ha, decreased the plant height, length and width of ear, grain weight of ear and test weight significantly (Singh 2018). Lower values of yield attributes were also recorded when S and Zn were omitted from the balanced use of nutrients (T₁). The balanced use of nutrients improved the partitioning of more photosynthesis towards yield attributes, ie grain/ear and test weight due to readily available from and amounts of nutrients from fertilizers. Similar results were reported by Singh *et al.* (2014) and Singh *et al.* (2015). The lowest values of these attributes were recorded under farmers practice.

Yield

The grain and stover yields ranged with nutrient management options, but highest pooled average grain (4.0 t/ha) and stover (10.4 t/ha) yields were registered under

Table 1 Effect of nutrient management practices on growth and yield attributes of pearl millet (mean of 2 years)

Treatment	Plant height (cm)	Length of ear (cm)	Width of ear (cm)	Grain weight/ear (g)	Test weight (g)
N ₁₂₀ P ₆₀ K ₉₀ S ₂₀ Zn ₄	210.0	25.04	12.58	33.15	12.31
N ₁₂₀ P ₃₀ K ₉₀ S ₂₀ Zn ₄	207.0	24.59	12.37	30.44	12.22
N ₁₂₀ P ₀₀ K ₉₀ S ₂₀ Zn ₄	205.0	24.43	12.02	29.45	12.00
N ₁₂₀ P ₆₀ K ₄₅ S ₂₀ Zn ₄	209.0	24.70	12.44	30.62	12.26
N ₁₂₀ P ₆₀ K ₀₀ S ₂₀ Zn ₄	206.5	24.52	12.37	30.07	12.11
N ₁₂₀ P ₆₀ K ₉₀ S ₀ Zn ₄	208.0	23.79	12.02	29.50	12.20
N ₁₂₀ P ₆₀ K ₉₀ S ₂₀ Zn ₀	207.5	23.10	12.08	29.00	12.16
N ₁₂₀ P ₆₀ K ₉₀ S ₀ Zn ₀	202.0	22.87	11.90	28.08	12.00
N ₁₂₀ P ₆₀ K ₄₀ (SR)	197.5	21.13	11.50	26.66	11.78
Farmers practice (N ₈₀ P _{57.5})	192.0	20.93	11.21	24.07	11.59
SEM±	1.55	0.25	0.16	1.18	0.11
CD (P=0.05)	3.33	0.59	0.35	2.53	0.23

Table 2 Effect of nutrient management practices on the yield, quality and economics of pearl millet (mean of 2 years)

Treatment	Yield (t/ha)		Protein (%)		Protein yield (kg / ha)	% yield loss over T ₁	Net returns (₹/ ha)	B:C ratio
	Grain	Stover	Grain	Stover				
N ₁₂₀ P ₆₀ K ₉₀ S ₂₀ Zn ₄	4.00	10.4	10.2	2.7	407.7	-	45209	2.71
N ₁₂₀ P ₃₀ K ₉₀ S ₂₀ Zn ₄	3.48	8.81	10.1	2.6	351.2	13.0	36272	2.46
N ₁₂₀ P ₀₀ K ₉₀ S ₂₀ Zn ₄	3.10	8.05	10.0	2.5	310.0	22.4	31112	2.39
N ₁₂₀ P ₆₀ K ₄₅ S ₂₀ Zn ₄	3.32	8.40	10.1	2.6	332.4	16.8	32631	2.20
N ₁₂₀ P ₆₀ K ₀₀ S ₂₀ Zn ₄	3.04	7.91	10.0	2.5	304.0	24.0	28590	2.18
N ₁₂₀ P ₆₀ K ₉₀ S ₀ Zn ₄	3.70	9.81	9.9	2.4	366.3	7.4	41128	2.64
N ₁₂₀ P ₆₀ K ₉₀ S ₂₀ Zn ₀	3.72	9.88	10.0	2.5	371.8	7.0	41273	2.65
N ₁₂₀ P ₆₀ K ₉₀ S ₀ Zn ₀	3.46	9.04	9.8	2.4	339.1	13.4	37738	2.57
N ₁₂₀ P ₆₀ K ₄₀ (SR)	3.06	7.88	9.7	2.2	296.8	23.4	32765	2.54
Farmers practice (N ₈₀ P _{57.5})	2.81	7.00	9.6	2.2	269.8	29.7	29818	2.53
SEm±	0.06	0.14						
CD (P=0.05)	0.13	0.31						

complete treatment (T₁) supplying N, P, K, S and Zn in adequate and balanced amounts (Table 2). The higher yield may be ascribed to better yield attributes due to adequate and balanced supply of nutrients as per crop demand (Singh *et al.* 2015). Application of 60 kg P₂O₅/ha enabled the crop to produce 0.52 and 0.90 t/ha more grain than 30 kg P₂O₅/ha and without P, respectively. Similarly, application of 90 kg K₂O/ha gave 0.67 and 0.96 t/ha more grain yield over 45 kg K₂O/ha and no potassium, respectively. The magnitude of difference in yield was more with K application than that of P. The state recommended dose of NPK (N₁₂₀ + P₆₀ + K₄₀ kg/ha) produced higher yield than farmers practice but was inferior to balanced use of nutrients (T₁) highlighting the effects of inadequate nutrient supply (Gupta *et al.* 2009, Singh and Majumdar 2012). The lowest yields of grain (2.81 t/ha) and straw (7.00 t/ha) were recorded under farmers' practice, which may be attributed to inadequate and imbalance nutrition of pearl millet crop. Sharma and Singhal (2014) and Singh *et al.* (2012) also reported lowest yield under farmer practice. Application of S and Zn caused significant effect on grain and stover production of pearl millet. Optimum fertilization (T₁) was also compared against treatments omitting P, K, S and Zn to isolate the individual response of nutrients. The grain yield of pearl millet decreased by 22.4, 24.0, 7.4 and 7.0% with omission of P, K, S and Zn, respectively over complete treatment (T₁). The corresponding reductions in stover yields were 21.6, 23.7, 5.4 and 4.7%. The yield data revealed that P, K, S and Zn are the main limiting factors under the present experimental set up (Gupta *et al.* 2009, Singh 2018). Zinc application significantly increased the grain and stover yield of pearl millet which may be attributed to the beneficial role of zinc under condition of zinc deficiency. Similar observations due to zinc application in zinc deficient soil were also reported by (Singh and Singh 2017). Sulphur application also enhanced the grain and stover yield of pearl millet over farmer practice which may be due to its

multiple roles in metabolism as an essential constituent of amino acids (Singh *et al.* 2014, Chauhan *et al.* 2017).

Quality

The protein content in grain and stover of pearl millet ranged from 9.6 to 10.2 and 2.2 to 2.7%, respectively (Table 2). The complete treatment (T₁) had significantly higher protein content in grain and stover. The increase in protein content with this treatment might be due to improved nutritional environment in the rhizosphere as well as in plant system leading to enhanced translocation of N and P to reproductive parts (Singh *et al.* 2015). The phosphorus and potassium omissions had markedly lower protein content than the optimum treatment (T₁). The lower values of protein content in grain and stover were recorded in farmers' practice. Omission of S and zinc alone or in combination reduced the protein content in grain and stover of pearl millet. Similar results were reported by Singh *et al.* (2014) and Singh and Majumdar (2012). The results clearly indicate that the highest yield of protein (407.7 kg/ha) was obtained with balanced use of fertilizers (T₁). This may be attributed to higher grain production of pearl millet as reported by Singh *et al.* (2015). The extent of response was lower in farmer's practice due to lower yield of grain.

Uptake of nutrients

The uptake of nutrients in grain and stover of pearl millet was significantly influenced by the various treatments over farmers' practice (Table 3). The uptake of nutrients; N, P, K, S and Zn by pearl millet grain ranged from 46.0 to 72.2 kg/ha, 4.8 to 8.0 kg/ha, 16.0 to 26.0 kg/ha, 4.5 to 9.2 kg/ha and 65.0 to 113.2 g/ha, respectively. The corresponding values of uptake of nutrients by stover were from 26.5 to 47.7 kg/ha, 5.9 to 12.4 kg/ha, 168.0 to 259.3 kg/ha, 5.6 to 12.4 kg/ha and 217.0 to 383.0 g/ha. The results showed that the complete treatment (T₁) maintained higher uptake values of all the five nutrients (N, P, K, S and Zn) most

Table 3 Effect of nutrient management practices on uptake of N, P, K, S (kg/ha) and Zn (g/ha) in pearl millet (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium		Sulphur		Zinc	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T ₁	72.2	47.7	8.0	12.4	26.0	259.3	9.2	12.4	113.2	383.0
T ₂	60.4	39.3	6.3	8.8	22.6	220.3	8.0	10.6	97.7	318.0
T ₃	53.9	35.4	4.9	6.4	19.8	200.8	6.8	8.8	92.0	292.0
T ₄	59.6	37.8	6.6	10.1	20.3	205.8	7.5	10.1	93.3	340.0
T ₅	52.8	34.8	6.1	8.7	17.6	189.7	6.7	7.9	85.8	292.0
T ₆	63.1	41.2	7.0	10.5	23.3	243.3	7.0	8.8	104.2	362.0
T ₇	64.5	42.4	7.4	10.5	23.0	245.1	7.4	11.9	85.9	308.0
T ₈	58.1	37.1	6.8	9.9	20.7	223.3	5.5	8.1	79.7	282.0
T ₉	54.1	29.9	5.5	7.9	18.4	186.4	5.2	7.1	70.9	245.0
T ₁₀	46.6	26.5	4.8	5.9	16.0	168.0	4.5	5.6	65.0	217.0
SEm±	1.33	0.79	0.27	0.76	0.67	4.69	0.41	0.84	2.43	2.89
CD (P=0.05)	2.80	1.66	0.56	1.60	1.42	9.86	0.85	1.77	5.10	6.08

Table 4 Effect of various treatments on status of available nutrients in post harvest soil (mean of 2 years)

Treatment	Org. carbon (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available S (kg/ha)	Available Zn (mg/kg)
T ₁	4.0	204.5	16.0	144.0	22.4	0.61
T ₂	3.8	200.0	13.0	143.0	22.0	0.61
T ₃	3.6	194.5	9.5	141.0	21.0	0.60
T ₄	3.7	201.0	15.0	130.0	22.0	0.61
T ₅	3.5	197.0	14.0	112.0	21.5	0.60
T ₆	3.5	195.0	13.0	140.0	15.0	0.61
T ₇	3.4	196.0	12.0	141.0	20.0	0.59
T ₈	3.3	198.5	13.0	142.0	19.0	0.55
T ₉	3.2	180.0	11.0	135.0	15.0	0.55
T ₁₀	3.2	176.0	9.5	110.0	14.0	0.52
SEm±	0.009	1.89	0.23	1.91	0.45	0.006
CD (P=0.05)	0.02	3.97	0.49	4.01	0.95	0.014

probably due to the higher yields recorded in this treatment (Sharma and Singhal 2014, Singh *et al.* 2013). These results again emphasize the importance of balanced fertilization in providing adequate nutrition to the plants. The farmer's practice (T₁₀) recorded the lowest uptake values, which is again the reflection of the lowest yield recorded in this treatment. Similar results were reported by Gupta *et al.* (2009) and Singh and Singh (2017).

Net profit

The maximum net profit of ₹ 45209/ha in pearl millet was obtained with soil test based SSNM (T₁) fertilizer practice (Table 2). It may be due to higher grain yield of pearl millet with this fertilizer practice. Therefore, the balanced use of nutrients could be the most accepted treatment to obtain maximum benefit from the pearl millet. The minimum net profit of ₹ 29818/ha in pearl millet was obtained with farmer's practice. Singh *et al.* (2015) also reported higher net returns and benefit: cost ratio with higher dose of fertilizers. Cost of cultivation differed marginally on an account of

nutrient omissions but resulted in large decrease in net profit. Potassium omission reduced the net returns markedly and phosphorus proved to be the second most limiting nutrient in pearl millet production. The effect of S and Zn omission on net profit was only marginal.

Soil fertility

Organic carbon content varied from 3.2 to 4.0 g/kg and maximum value (4.0 g/kg) was recorded with N₁₂₀P₆₀K₉₀S₂₀Zn₄ (T₁) treatment. This increase in organic carbon content might be due to improvement in root and shoot growth and thus higher production of biomass, which in turn, increased the organic carbon content in soil (Singh *et al.* 2012). Available N, P, K, S, and Zn status of post harvest soil was significantly higher than farmer practice under almost all the treatments. Improvement in N, P and K status was noted due to optimum and adequate amounts of NPK (120:60:90). Available N ranged from 176.0 to 204.5 kg/ha and that the highest value of available N was found associate with optimum doses of nutrients (T₁). A

reduction in available P was observed in P omission and farmers' fertilizer practice which may be due to removal of P by the crop in the absence of P supplementation through the external source. A marked build up of available P status of soil was observed under $N_{120}P_{60}K_{90}S_{20}Zn_4$ (T_1). In the plots with K omission the available K decreased by 22 kg/ha over T_1 . The maximum decline was observed in case of farmer's fertilizer practice followed by $N_{120}P_{60}K_0S_{20}Zn_4$ (T_5). This reduction in available K may be due to omission of K. The increase in available S and Zn with optimum dose (T_1) treatments were 7.4 kg/ha and 0.60 mg/kg over farmer's practice, respectively. Improvements in the status of available S and Zn in soil after harvest of the crop were due to addition of these nutrients through their application (Singh and Singh 2017, Singh *et al.* 2014). Available S and Zn status of the soil reduced in the soil from their initial status in S and Zn free-treatments.

Conclusion

Based on results of on farm trials, it may be concluded that site-specific nutrient management (SSNM) increased the grain yield and net profits from the pearl millet as compared to the state recommendation of fertilizer. Variability introduced due to treatments was reflected in the uptake of nutrients by the crop. Higher yields of pearl millet with SSNM approach over state recommendation and farmer's practice clearly indicates that the site and crop specific balanced fertilization in addition to maintaining food security and soil fertility will also help to fetch higher economic benefits. The omission of nutrients resulted in marked reduction in yield and productivity of pearl millet.

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