Nutrient Responses and Economics of Nutrient Use in Pearl Millet under Semi-Arid Conditions

By Vinay Singh and K. Majumdar

On-farm omission plot experiments with pearl millet in the semi-arid region of Uttar Pradesh showed a large variation in yield and nutrient responses among farmers' fields. Balanced nutrient application improved pearl millet yield, nutrient uptake, economic efficiency, crop productivity, partial factor productivity, net returns and B:C ratio.

Pearl millet (*Pennisetum glaucum* L) or *bajra* is an important crop of the rainfed region of India and is grown on about 8.9 M ha (FAI, 2010-11). The annual production is about 6.5 M t or 3% of the total food grain output in India. Most of the pearl millet is grown under dryland (non-irrigated) conditions and on poor to marginal soils with little or no fertiliser application. Thus, the national average productivity of pearl millet is only 731 kg/ha (FAI, 2010-11). From a quality point of view, pearl millet grain is rich in minerals (2.0 to 3.5%) and fat content (4.0 to 8.0%). It is a high protein grain (10.5 to 14.5%) with high levels of essential amino acids (Gautam, 2005). Pearl millet provides food and nutritional security to many poor farming communities in the country. The major pearl millet-growing states in India are Rajasthan (5.2 M ha), Maharashtra (1.03 M ha), Uttar Pradesh (0.85 M ha), Gujarat (0.67 M ha), Haryana (0.60 M ha), and Karnataka (0.31 M ha). Among these states, Uttar Pradesh has the highest productivity (1,638 kg/ha) of this crop followed closely by Haryana (1,593 kg/ha). Pearl millet-wheat is an important crop sequence in Agra region of Uttar Pradesh. Both these crops have been reported to deplete the soil fertility to a great extent. Pearl millet-wheat sequence removes 276 kg N, 42 kg P_2O_5, and 264 kg K_2O/ha, often exceeding the applied nutrients. Fertiliser management in this area is confined primarily to the application of N and P fertilisers. Very little or no K is being applied by farmers to pearl millet, and thus most of the K taken up by the crop comes from K reserves of the soil. Continuous cropping without K application has been reported to cause considerable yield losses in pearl millet and wheat (Dwivedi et al., 2011). Farmers are indeed experiencing declining responses to N and P due to omission of other essential nutrients in their fertiliser schedules. We hypothesised that the adoption of balanced and judicious use of all needed nutrients can help improve the productivity of pearl millet.

Fertiliser constitutes one of the costliest inputs in present day agriculture. Efficient management of plant nutrients through fertiliser best management practices can ensure that fertilisers are used economically while the crops are supplied with all essential plant nutrients at the appropriate time and in the required quantity. Proper understanding of soil nutrient supplying capacity is, therefore, essential for efficient management of fertilisers. The current study was initiated to: (a) estimate indigenous nutrient supplying capacity of the soils in Agra district of Uttar Pradesh through a plant-based approach, and (b) assess yield and economic losses in pearl millet associated with omission of N, P, K, and S from the fertilisation schedule.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; C = carbon; B:C = benefit:cost ratio.

Dr. Vinay Singh (left) inspects pearl millet nutrient omission plots at an on-farm field day held in Agra district, Uttar Pradesh.

On-farm experiments were conducted at four different locations, viz., Artoni, Panwari, Nanpur, and Sahara villages (four farmers' fields in each village) of Agra district of Uttar Pradesh, for 2010 and 2011. The area is characterised by a semi-arid, hot summer climate with mean maximum temperature of 45°C and mean minimum temperature of around 3°C in December-January. The average annual rainfall in the study area is 650 mm of which about 90% is received during *kharif* seasons from July to September and rest during the *rabi* season. The important characteristics of soils (0 to 15 cm) at the four locations are given in **Table 1**.

Treatments consisted of ample NPKS, N omission, P omission, K omission, and S omission plots in a randomised block design. The nutrient rates used in the ample NPKS treatment was 120 kg N, 70 kg P_2O_5, 100 kg K_2O, and 30 kg S/ha. In the ample NPKS treatment, all nutrients were applied in excess of actual requirement of pearl millet following the omission plot experiment protocol. Nutrients were subsequently omitted from the ample NPKS treatment for the omission treatments.

Table 1. Soil characteristics of the experimental fields (mean of four farmer fields at each site).

Soil characteristics	Artoni	Panwari	Nanpur	Sahara
pH (1:2.5 soil:water suspension)	7.70	7.60	8.00	8.10
EC, dS/m	0.21	0.30	0.27	0.33
Organic C, g/kg	3.90	3.70	3.80	3.90
Available N, kg/ha	178	161	161	164
Available P, kg/ha	12.1	10.7	12.7	11.3
Available K, kg/ha	132	124	130	129
Available S, kg/ha	16.8	12.2	15.7	14.7

Hybrid pearl millet (var. Mahyco 2210) was sown in July and harvested in last week of September in both experimental years. Urea, diammonium phosphate, muriate of potash, and elemental S were used as sources for N, P, K and S, respectively. Phosphorus was applied as single superphosphate in the N omission treatment. The plot size at different locations was approximately 500 m^2 except for N omission treatment (approximately 100 m^2). Each farmer field was treated as a replication for statistical analysis of the results. At harvest, yield data of the crop (grain and straw) were recorded. Nutrient contents in grain and straw and available nutrients in soils were determined using standard methods. Uptake of nutrients was calculated by multiplying nutrient content in grain and straw with their respective yields.

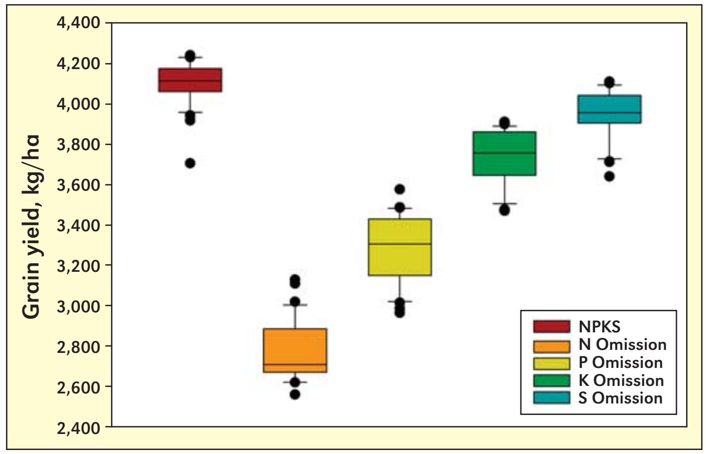

Figure 1. Grain yield of pearl millet in various treatments at farmers' fields. The error bars represent 10th to 90th percentile of the data.

Results

Average yields in ample NPKS, N omission, P omission, K omission and S omission plots were 4,103, 2,770, 3,286, 3,743, and 3,948 kg/ha, respectively (**Figure 1**). Yield responses across sites and years varied considerably with an average of 1,333, 816, 359, and 155 kg/ha for N, P, K, and S, respectively. Significantly lower pearl millet grain and straw yields were recorded in N omission treatment plots at all the experimental sites as compared to any other treatments (**Table 2**). In the P omitted treatment, pearl millet grain yield exhibited a significant decrease of 860, 773, 835, and 805 kg/ha at Artoni, Panwari, Nanpur, and Sahara, respectively, over the NPKS (T_1) treatment. The corresponding mean reductions in grain yield due to K omission treatment were 8.2, 8.3, 8.5, and 10.2% of the ample nutrient treatment. The reduction in grain yield due to S omission at different sites ranged from 3.0 to 5.1%. The mean grain yields of pearl millet reduced by 32.5, 19.9, 8.8, and 3.8% due to N, P, K, and S omissions across locations, respectively. Application of NPK fertiliser with S (T_1) resulted in highest pearl millet grain yield at all the experimental sites indicating a synergistic relationship of NPK with S. Similar results were earlier reported by Dwivedi et al. (2011).

The gross returns worked out by considering current cost of nutrients and minimum support price (MSP) of pearl millet increased from Rs 26,716 to 40,066, Rs 27,726 to 39,618, Rs 26,023 to 39,631, and Rs 26,630 to 40,172 at Artoni, Panwari, Nanpur, and Sahara, respectively, in plots receiving NPKS (T_1) over N omission (-N) treatment. A comparison of net returns and benefit cost ratio (B:C) for different treatments in pearl millet revealed the economic benefit of applying NPKS fertilisers. There was a maximum mean net profit of Rs 25,561/ha in pearl millet with NPKS application. A minimum net profit of Rs 13,767 per ha was recorded under N omission treatment (**Table 2**). Among the sites, the maximum net

Table 2. Yield and economics of pearl millet grown in farmers' fields (mean of two years, 2010 and 2011).

Treatments	Grain yield, kg/ha	Straw yield, kg/ha	Yield difference, kg/ha	Gross return, Rs/ha	Net return, Rs/ha	B:C Ratio
Artoni, Site 1 (n=4*)						
T_1 (NPKS)	4,122	8,130		40,066	25,454	1.75
T_2 (–N)	2,770	5,320	1,352 (32.8)	26,716	13,718	1.06
T_3 (–P)	3,262	6,153	860 (20.9)	31,453	18,298	1.39
T_4 (–K)	3,784	7,273	338 (8.2)	33,617	22,727	1.64
T_5 (–S)	3,913	7,658	209 (5.1)	37,998	24,386	1.80
C.D. (p=0.05)	100.0	188.0	-	-	-	-
Panwari, Site 2 (n=4)						
T_1 (NPKS)	4,078	8,031		39,618	24,981	1.71
T_2 (–N)	2,866	5,494	1,212 (29.7)	27,726	14,717	1.13
T_3 (–P)	3,305	6,196	773 (18.9)	32,077	18,836	1.45
T_4 (–K)	3,741	7,063	337 (8.3)	36,135	22,245	1.61
T_5 (–S)	3,957	7,757	121 (3.0)	38,404	24,792	1.84
C.D. (p=0.05)	95.0	182.0	-	-	-	-
Nanpur, Site 3 (n=4)						
T_1 (NPKS)	4,077	8,066		39,631	25,020	1.71
T_2 (–N)	2,688	5,189	1,390 (34.1)	26,023	13,013	1.00
T_3 (–P)	3,242	6,248	835 (20.5)	31,307	18,154	1.38
T_4 (–K)	3,730	7,154	348 (8.5)	36,056	22,167	1.60
T_5 (–S)	3,954	7,678	122 (3.0)	38,315	24,703	1.83
C.D. (p=0.05)	91.5	185.6	-	-	-	-
Sahara, Site 4 (n=4)						
T_1 (NPKS)	4,140	8,094		40,172	25,561	1.75
T_2 (–N)	2,756	5,276	1,384 (33.4)	26,630	13,620	1.05
T_3 (–P)	3,335	6,418	805 (19.4)	32,228	19,074	1.45
T_4 (–K)	3,719	7,032	421 (10.2)	35,865	21,976	1.58
T_5 (–S)	3,966	7,858	174 (4.2)	38,458	24,846	1.84
C.D. (p=0.05)	97.0	190.0	-	-	-	-

*n = number of farmer fields in each site. Values in parentheses are percent decline in yield relative to the NPKS treatment.

Table 3. Total uptake of nutrients (kg/ha) by pearl millet (mean of two years, 2010-11).

Treatments	Pearl millet N	P	K	S
Artoni, Site 1 (n=4*)				
T_1 (NPKS)	115	18.2	210	19.0
T_2 (-N)	67.7	11.1	163	10.3
T_3 (-P)	85.7	11.6	160	11.7
T_4 (-K)	101	14.9	170	14.6
T_5 (-S)	103	16.5	199	13.8
C.D. (p=0.05)	2.40	0.59	6.25	2.22
Panwari, Site 2 (n=4)				
T_1 (NPKS)	114	17.9	208	19.2
T_2 (-N)	69.8	11.3	140	10.4
T_3 (-P)	83.3	11.1	161	12.0
T_4 (-K)	99.8	14.7	167	14.8
T_5 (-S)	103	16.4	202	14.5
C.D. (p=0.05)	2.31	0.64	6.22	2.17
Nanpur, Site 3 (n=4)				
T_1 (NPKS)	114	18.0	208	18.7
T_2 (-N)	65.6	10.9	133	10.1
T_3 (-P)	85.8	11.5	161	11.9
T_4 (-K)	99.6	14.5	167	14.7
T_5 (-S)	103	17.0	200	14.3
C.D. (p=0.05)	2.61	0.67	6.40	2.09
Sahara, Site 4 (n=4)				
T_1 (NPKS)	115	17.9	209	19.3
T_2 (-N)	70.1	10.8	135	10.2
T_3 (-P)	87.8	11.4	166	12.1
T_4 (-K)	98.9	14.3	166	15.2
T_5 (-S)	101	16.4	204	14.8
C.D. (p=0.05)	2.25	0.55	6.14	2.11

*n = number of farmer fields in each site.

profit was obtained at site IV under ample NPKS treatment. The minimum net profit and B:C ratios were recorded under N omission treatment at site III.

Nutrient uptake followed trends similar to those observed for grain and stover yields (**Table 3**). The total uptake of nutrients was significantly influenced by the balanced application of nutrients. The maximum total uptake of N (114 to 115 kg/ha), P (17.9 to 18.2 kg/ha), K (208 to 210 kg/ha), and S (18.7 to 19.3 kg/ha) was recorded with the T_1 (NPKS) treatment, respectively. It was due to the fact that added nutrients increased the N, P, K, and S content in grain and straw of the crops due to no limitation of nutrients, which resulted in more uptake and higher yields. The highest average yield of 4.1 t/ha was obtained at a removal of 18 kg N, 2.1 kg P, 6.3 kg K, and 2 kg S per t of pearl millet grain yield. By comparison, the total uptake of nutrients under nutrient omission treatments decreased considerably, which suggests that limitation of one nutrient in the soil affects the uptake of other nutrients, again highlighting the importance of balanced fertilisation to crops. In general, the lowest total uptakes of N, P, K, and S were recorded under treatments omitting N, P, K, and S, respectively.

Summary

Results from our on-farm experiments clearly showed that N is the most limiting nutrient in the study area, followed by P, K, and S. The responses of nutrients varied widely across farmers' fields and years, which emphasised the need for site-specific nutrient management based on indigenous nutrient supply, yield target, and realistic estimation of achievable nutrient use efficiencies. Inadequate or no application of any limiting nutrient would reduce pearl millet yield and adversely affect the uptake and utilisation of other amply provided nutrients, further reducing yields. Balanced application of nutrients could double pearl millet yields from the current value with consequent increase in farmer profits. BC-SA

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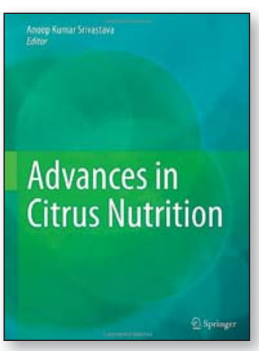

Despite many breakthroughs in the diagnosis and management of nutrient constraints, citrus nutritionists are still baffled by the complex processes associated with precise field diagnosis of different nutrient constraints. Currently available diagnostic tools are more applicable to next season's crop, instead of addressing the constraints in the current standing crop. However, there have been some distinctive developments in the recent past that appear to be quite promising in addressing these constraints. These developments include the application of geospatial tools including non-destructive proximal sensing, metalloenzymes through increasing involvement of genomics and metabolomics (e.g. expressed tag analysis), exploiting the dynamic relationship between soil enzymes and fertility variations etc. This book is a maiden effort to consolidate the information related to different aspects of citrus nutrition in a holistic manner. The book has 30 chapters written by 72 eminent researchers from 19 different countries and has been published by Springer-Verlag, Netherlands.

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