Improving Sugarcane Productivity through Balanced Nutrition with Potassium, Sulphur, and Magnesium

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The prime concern of cane growers and the sugar industry is to achieve higher sugarcane productivity and high sugar recovery both of which support maximum economic return. In India, widely varying soil fertility domains is a major limitation to reaching this goal. The results of on-farm experiments conducted during 2003-04 and 2004-05 have clearly established that productivity can be significantly improved when balancing N and P use with K, S, and Mg.

India is a major sugarcane growing country, with production of about 281 million metric tons (M t) from a production area of approximately 4.2 M ha. Sugarcane occupies 51% of the total cultivated area of Uttar Pradesh, with a large number of supporting sugar factories. Despite large total production of sugarcane in the state, average productivity (58.2 t/ha) is lower than the national average of 66.9 t/ha (Indian Sugar, 2008). The productivity of the crop is low mainly due to its late planting after wheat harvest (April to May). A short growing period, coupled with inadequate and imbalanced fertiliser use, make the crop more susceptible to shoot borer infestation and other pest problems.

A recent farmer participatory survey conducted by the authors revealed that growers generally apply >200 kg N/ha and 45 to 60 kg P_2O_5/ha. However, use of K, secondary nutrients, and micronutrients is altogether missing. Farmers are experiencing declining responses to N and P due to omission of other essential nutrients in their fertiliser schedules. Adoption of balanced and judicious use of all needed nutrients can help improve cane productivity and enhance sugar recovery by rendering resistance against biotic and abiotic stresses, and better synthesis and storage of sugar (Yadav et.al., 1993). Farmers are reluctant to shift cane planting time to the spring season (February to March) and sacrifice staple wheat crops intended for human and animal use. Therefore, participatory on-farm experiments were planned to enhance the productivity of late planted sugarcane through fertiliser management including K, S, and Mg application along with N and P.

On-farm experiments were conducted at 10 locations in the Meerut district of western Uttar Pradesh during 2003-04 and 2004-05. The soils were sandy loam to loamy sand in texture, neutral to slightly alkaline in reaction (pH 6.4 to 8.1), low in EC (0.34 to 0.38 dS/m) and available N (76 to 103 mg/kg), and medium in available P (5.4 to 9.1 mg/kg) and K (64 to 99 mg/kg). Each experimental site served as one replication thus the six treatments were evaluated as 10 replications in both study years (**Table 1**). Nutrient application rates were determined based on soil testing and subsequent crop responses. In treatments 1 through 5, the sources of N, P, K, S, and Mg were: urea (46% N): diammonium phosphate (18% N and 46% P_2O_5); potassium chloride (60% K2O): elemental S; and magnesium sulphate (16% MgO and 13% S). The sixth treatment differed, as the K, Mg, and S rates were supplied through a potassium magnesium sulphate source having 22% K 22% S, and 11% Mg. One third of the N and the entire quantities of P, K, S, and Mg were applied at the time of planting. The remaining N was topdressed in two equal splits (i.e., 50 day after sowing (DAS) and 85 to 90 DAS). Basal application of Zn was uniformly done in all plots using 25 kg zinc sulphate ($ZnSO_4·7H_2O$). Other crop management was as per existing farm practice.

Sugarcane production in India can benefit greatly from more balanced nutrition. These plants show symptoms of K deficiency.

The crop was harvested manually at maturity and the yield and yield attributes were recorded. The cane samples from bulk produce were taken and quality parameters [brix (%), pol %, commercial cane sugar CCS (%)] were calculated as per formula given by Spencer and Mead (1963). Juice purity (%) was calculated using the following formula:

$$\text{Purity } \% = (\text{Pol } \% / \text{brix } \%) \times 100 \quad (1)$$

The responses to applied nutrients were computed using the following equation:

$$NR = \Delta Y\ Fn\text{-}1 \quad (2)$$

Where NR is the nutrient response to N, P, K, S, and Mg expressed as kg/kg, ΔY the incremental yield due to fertiliser N, P, K, S, and Mg input, Fn the amount of fertiliser N, P, K, S, and Mg applied. The ΔY, and Fn have been expressed as kg/ha. The economic analysis of different nutrient management options are in terms of total net return, per day economic gain and return due to individual nutrients.

Yield and Yield Attributes

Sugarcane productivity was influenced significantly by fertiliser management. The highest cane yield (111.7 to 112.8 t/ha) was achieved under T6. However, these yields were sta-

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; Mg = magnesium; Zn = zinc.

Table 1. On-farm yield and yield attributes of sugarcane as influenced by balanced fertilisation.

Treatment	Cane yield, t/ha	Plant height, cm	Inter node/cane	Millable cane/m[2]	Cane weight, kg	Girth of cane, cm
2003-04						
T_1 N_{200}	61.4	155	10	13	0.84	6.1
T_2 N_{200} P_{100}	79.9	172	12	17	0.90	7.1
T_3 N_{200} P_{100} K_{150}	92.2	174	12	20	0.96	7.4
T_4 N_{200} P_{100} $K_{150}S_{60}$	101.0	183	15	21	1.00	8.1
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	110.6	190	16	24	1.06	8.5
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}†	111.7	188	16	23	1.08	8.6
2004-05						
T_1 N_{200}	61.1	153	11	12	0.82	6.9
T_2 N_{200} P_{100}	72.7	168	12	15	0.91	7.5
T_3 N_{200} P_{100} K_{150}	85.1	178	15	18	0.96	7.9
T_4 N_{200} P_{100} $K_{150}S_{60}$	96.9	188	16	21	0.99	8.3
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	111.4	194	17	24	1.05	8.7
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}†	112.8	195	18	24	1.08	8.7
CD at 5%						
2003-04	6.2	5.2	1	1.1	0.02	0.4
2004-05	3.9	3.8	1.3	1.6	0.03	0.3

†Includes a single potassium-magnesium-sulphate source.

ing high yield targets. The corresponding yield reduction due to P, K, S, and Mg omissions varied from 18.4 to 11.6 t/ha, 12.3 to 24 t/ha, 8.8 to 11.8 t/ha, and 9.6 to 14.5 t/ha, respectively. The increase in cane yield due to balanced fertilisation is attributed to a larger number of millable canes (24 to 25/m²), higher cane weight (1.05 to 1.06 kg/cane), wider cane girth (8.5 to 8.7 cm), and larger plant height (190 to 194 cm) (**Table 1**). These results confirm the findings of long-term experiments conducted with different crop sequences at various locations in India, wherein application of N alone depleted the native P, K, S, and micronutrient reserve of soil, thus causing significant yield loss (Swarup and Wanjari, 2000).

tistically at par with T5, which had the same nutrient input from individual K, S, and Mg fertiliser sources (**Table 1**). Yield obtained under T5 was 80 to 83% higher than plots receiving 200 kg N/ha alone (T1). Omission of P, K, S, and Mg from the fertiliser schedule resulted in a marked yield loss, indicating the significance of replenishment of these nutrients for achiev-

Table 2. Agronomic efficiency (AE) of N, P, K, S, and Mg application in sugarcane as influenced by balanced fertilisation.

	AE, kg sugarcane/kg nutrient[1]				
Treatment	N	P	K	S	Mg
2003-04					
T_1 N_{200}	307	–	–	–	–
T_2 N_{200} P_{100}	400	1,816	–	–	–
T_3 N_{200} P_{100} K_{150}	461	2,095	750	–	–
T_4 N_{200} P_{100} $K_{150}S_{60}$	505	2,295	821	1,683	–
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	553	2,514	899	1,848	3,687
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}†	559	2,538	908	1,862	3,723
2004-05					
T_1 N_{200}	306	–	–	–	–
T_2 N_{200} P_{100}	364	1,652	–	–	–
T_3 N_{200} P_{100} K_{150}	426	1,934	692	–	–
T_4 N_{200} P_{100} $K_{150}S_{60}$	485	2,202	788	1,615	–
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	557	2,532	906	1,857	3,713
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}†	564	2,564	917	1,860	3,760

[2]Computed based on actual content basis.
†includes a single potassium-magnesium-sulphate source.

Agronomic Efficiency

Agronomic efficiency (kg sugarcane/kg nutrient) was greater in plots with balanced supply of K, S, and Mg along with N and P (**Table 2**). The concomitant increase in N use

Table 3. Quality parameters of sugarcane as influenced by balanced fertilisation.

Treatment	Brix, %	Pol, %	Purity, %	CCS, %	CCS, t/ha
2003-04					
T_1 N_{200}	18.6	15.4	82.8	8.34	5.12
T_2 N_{200} P_{100}	19.8	16.6	83.8	8.79	7.02
T_3 N_{200} P_{100} K_{150}	20.9	18.1	86.6	9.68	8.92
T_4 N_{200} P_{100} $K_{150}S_{60}$	21.2	18.7	88.2	10.05	10.15
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	21.4	19.0	88.8	10.37	11.20
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}†	21.4	19.4	90.7	10.46	11.68
2004-05					
T_1 N_{200}	19.1	15.3	80.2	7.98	4.88
T_2 N_{200} P_{100}	20.6	16.8	81.6	8.44	6.14
T_3 N_{200} P_{100} K_{150}	21.3	17.8	83.8	9.02	7.68
T_4 N_{200} P_{100} $K_{150}S_{60}$	21.6	18.4	85.3	9.42	9.13
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	21.5	18.5	85.9	9.84	10.69
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}†	21.7	18.8	86.6	10.07	11.36
CD at 5%					
2003-04	0.3	0.5	3.1	0.30	0.94
2004-05	0.6	0.4	2.0	0.36	1.01

†includes a single potassium-magnesium-sulphate source

Table 4. Net profit and per day economic productivity of sugarcane as influenced by balanced nutrient management options.

Treatment	Cost of nutrients, Rs*/ha	Gross return, Rs/ha	Net return due to nutrient options, Rs/ha				Per day net economic productivity[‡], Rs/ha/day
			Over N	Over NP	Over NPK	Over NPKS	
2003-04							
T_1 N_{200}	2,100	67,540	–	–	–	–	185
T_2 N_{200} P_{100}	3,750	87,890	20,350	–	–	–	241
T_3 N_{200} P_{100} K_{150}	4,875	101,420	33,880	13,530	–	–	278
T_4 N_{200} P_{100} $K_{150}S_{60}$	6,465	111,100	43,560	23,210	9,680	–	305
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	7,897	121,660	54,120	33,770	20,240	10,560	333
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}[†]	10,425	122,870	55,330	34,980	21,540	11,860	337
2004-05							
T_1 N_{200}	2,100	67,210	–	–	–	–	184
T_2 N_{200} P_{100}	3,750	79,970	12,760	–	–	–	219
T_3 N_{200} P_{100} K_{150}	4,875	93,610	26,400	13,640	–	–	257
T_4 N_{200} P_{100} $K_{150}S_{60}$	6,465	105,710	38,500	25,740	12,100	–	290
T_5 N_{200} P_{100} $K_{150}S_{60}$ Mg_{30}	7,897	122,540	55,330	42,570	28,930	16,830	336
T_6 N_{200} P_{100} K_{150} S_{60} Mg_{30}[†]	10,425	124,080	56,870	44,110	30,470	18,370	340
CD at 5%							
2003-04	–	3,780	–	–	–	–	14
2004-05	–	3,510	–	–	–	–	9

[†]Includes a single potassium-magnesium-sulphate source.
[‡]Economic growth rate per day.

efficiency due to P, K, S, and Mg application was in the range of 364 to 557 kg cane/kg nutrient. The increase in efficiency of the individual nutrient was 1,652 to 2,532 kg cane/kg with P_2O_5, 692 to 906 kg cane/kg with K_2O, 1,615 to 1,857 kg cane/kg S, and 3,687 to 3,713 kg cane/kg Mg. Similar evidence was gathered by Ghosh et al. (1990) who reported that S application helped increase cane productivity by way of increased nitrate reductase activity and ultimately higher N use efficiency. Increased nutrient use efficiency with balanced fertilisation indicates that the existing N-driven agriculture cannot sustain high yield goals (Tiwari, 2002).

Effect on Quality

Juice quality viz. brix (%), pol (%), purity (%), and CCS (%) were significantly influenced by fertiliser treatment. The best cane quality parameters were recorded with either T5 or T6 (**Table 3**). The significance of S and Mg application along with adequate NPK was noted for Pol (%) and CCS (%). This improvement in juice quality may be due to an increase in activity of sucrose synthesizing enzymes which also helped increase CCS yield. An improvement in juice quality with the application of P and K has also been reported by Kumar et al. (2002).

Economics

Application of P, K, S, and Mg increased the cost of inputs by Rs.8,325/ha over application of 200 kg N alone but it returned an extra net profit of Rs.55,330 to 56,870/ha. The net economic gain due to individual nutrient application ranged from Rs.12,760 to 20,350/ha for P_2O_5, Rs.13,640 to 13,530/ha for K_2O, Rs.9,680 to 12,100/ha for S, and Rs.10,560 to 16,830/ha for Mg (**Table 4**). Economic productivity per day reached Rs 337 to 340/ha/day, or 1.8 times that obtained under N application alone (Rs.185/ha/day). Daily economic productivity improved the most with the inclusion of P_2O_5 (Rs.46/ha/day) followed by K_2O (Rs.38/ha/day), Mg (Rs.37/ha/day), and S (Rs.30/ha/day). Application of K, S, and Mg through the sole source product had a small edge over T5. Thus K-S-Mg supply can be effectively maintained through the potassium-magnesium-sulphur source in case of the lack of availability of straight fertiliser, such as potassium chloride, elemental S, and magnesium sulphate.

Conclusion

The results of this study establish the significance of balanced fertilization with K, S, Mg for higher yield, higher sugar recovery, and higher farmer profit with sugarcane in north India. Year-to-year weather variability and location-specific soil fertility variability greatly influence yield and nutrient use efficiency, but this can be minimised through fertiliser best management practices. BC-INDIA

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