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The Effects of Soil Test Based Potassium Application and Manures on Yield and Quality of Sugarcane Grown on a Typical Calcareous Soil of Bangladesh

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Setup of the experiment in Bangladesh Sugarcane Research Institute (BSRI) at Ishurdi, Pabna farm. Photo by S.M. Bokhtiar.

Abstract

This field experimental study examines the potential to improve the yield and quality of sugarcane grown on a typical calcareous soil of Bangladesh through soil test-based (STB) application of potassium (K) combined with organic manure i.e. cowdung (CD) or poultry manure (PM). Five treatments were compared. In four treatments, K supply was varied with mineral fertilizer supply of N, P, S and Zn remaining the same across all treatments. Potassium was supplied as T_1 90 kg K ha^{-1}, T_2 127 kg K ha^{-1}, T_3 95 kg K ha^{-1} plus 10 mt ha^{-1} CD, and T_4 95 kg K ha^{-1} plus 5 mt ha^{-1} PM. In the fifth treatment no fertilizer was applied. The number of tillers and number of millable cane stalks did not differ significantly between the four K treatments, but the values were significantly greater than in treatment T_5 where no fertilizer was applied. Potassium application based on STB (T_2) increased cane yield by 25.4 percent in comparison to the present recommended K application (T_1) of 90 kg K ha^{-1}. However, applying only 75 percent K of STB along with CD (T_3) or with PM (T_4) increased cane yield by 16 percent and 17.7 percent respectively, when compared to the present recommended dose of K fertilizer (T_1). Maximum cane and sugar production in sugarcane monoculture requires an annual application of currently recommended doses of N, P, S and Zn fertilizer of 150 kg N, 50 kg P, 34 kg S, 3.5 kg Zn ha^{-1} with STB K fertilizer, i.e. 127 kg K to sustain high yields. Nevertheless, 75 percent of STB K fertilizer i.e. 95 kg K and 150 kg N, 50 kg P, 34 kg S, 3.5 kg Zn ha^{-1} supplied together with CD (10 mt ha^{-1}) or PM (5 mt ha^{-1}) is also suggested as a means to sustain both sugarcane yield and to maintain soil fertility. Further investigations are required to confirm these findings.

Keywords: Sugarcane, potassium, soil test base, organic manure, yield, calcareous soil.

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Introduction

The application of fertilizers plays a key role in increasing agricultural production by raising crop yields. STB fertilizer recommendations result in more efficient fertilizer use and maintenance of soil fertility. Among the various methods of fertilizer recommendations, the one based on yield targeting (Ramamoorthy *et al.,*1967) is unique as this recommendation not only indicates the STB fertilizer dose but also the level of yield that can be obtained if appropriate practices are followed in raising the crop. This targeted yield approach also takes into account balanced fertilization of the crop not only between the nutrients from the external sources but also from the soil available nutrients.

Sugarcane (*Saccharum officinarum* L.) is an important cash crop of Bangladesh covering 0.16 million ha and producing 7.8 mt cane in 2010-2011. Sugarcane is a high input demanding crop and capable of rapidly depleting soil nutrients, particularly potassium. Potassium, as an essential nutrient required for plant growth, plays a key role in many physiological processes, including photosynthesis, protein synthesis, water relations in plants, organic and inorganic nutrient mobility within the plant (Marschner, 1995; Thangavelue and Rao, 1997; and

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Subramanian, 1994). It has been found that 85 mt fresh weight of a sugarcane crop can remove 122, 24 and 142 kg N, P, K ha^{-1}, respectively from the soil (Bokhtiar *et al.,* 2001). If the depleted nutrients are not replaced, soil fertility and soil organic matter level decline creating a stressed soil environment that essentially requires optimal and balanced use of fertilizers (Ahmad, 2002). Under South African conditions, for instance, the aerial parts of an adequately fertilized 12 month old rainfed plant cane crop has been reported to contain 214 kg K ha^{-1} (Wood, 1990). Under irrigation, a cane crop of similar age and variety may remove as much as 790 kg K ha^{-1}. In the Histosols of Florida, an average of 343 kg K ha^{-1} was removed from the field at harvest of the sugarcane (Coale *et al.*, 1993). In Mauritius, more than 250 kg K ha^{-1} was recovered by sugarcane from soils high in available K, even when no K was applied (Cavalot *et al.,* 1990). In Australia the average kg K ha^{-1}, in the above-ground biomass of a crop of 84 tonnes cane ha^{-1}, was 198 kg K ha^{-1} (Chapman, 1996). It is thus clear that for the long-term and sustainable use of sugarcane lands, the removal of such large quantities of K needs to be balanced by an adequate re-application of K.

One of the main constraints for optimum sugarcane yield is its high nutritional requirements along with increased cost of fertilizers (Gholve *et al.,* 2001). Similarly, spiraling prices, coupled with a lack of availability of fertilizers on the market (Khandagave, 2003) and depletion of available nutrients and organic matter in the soil due to continuous cane cropping with inorganic fertilizers (Kumar & Verma, 2002; Ibrahim *et al.,* 2008; Sarwar *et al.,* 2008), necessitates the integrated use of organic and mineral fertilizer inputs. Cowdung (CD) and poultry manure (PM) can serve as good sources of organic manure. Therefore, an attempt was made to study the effect of the application of K supplied on a soil test basis in the form of mineral fertilizer, with or without organic manure, for the cultivation of sugarcane on a calcareous soil typical of many such soils across Bangladesh.

Materials and methods

An experiment was conducted at the Bangladesh Sugarcane Research Institute (BSRI) on the calcareous farm soil at Ishurdi, Pabna during the 2009-2010 season and on a soil typical of calcareous soils of Bangladesh. The soil samples (0-15 cm depth) were collected from experimental plots, air-dried, and passed through a 2 mm sieve. The pH of the calcareous soil was 7.64 and its organic carbon (OC) 0.78%. Total N was 0.07% and P, K, S and Zn contents were 12.0, 70.0, 17.0 and 0.86 mg kg^{-1} soil, respectively. The experiment comprised five treatment combinations.

- T_1: 150N-50P-90K-34S-3.5Zn kg ha^{-1} (current recommended dose).
- T_2: 150N-50P-127K-34S-3.5Zn kg ha^{-1} (K applied on a soil test basis (STB)).
- T_3: 150N-50P-95K-34S-3.5Zn kg ha^{-1} plus 10 mt ha^{-1} CD (K as 75% STB).
- T_4: 150N-50P-95K-34S-3.5Zn kg ha^{-1} plus 5 mt ha^{-1} PM (K as 75% STB).
- T_5: no fertilizer.

The treatments T_2, T_3 and T_4 were designed to supply STB K together with current recommended doses of N, P, S and Zn; animal manure (CD or PM) was also added to T_3 and T_4 respectively. Treatments were replicated three times in a randomized complete block design. Thirty-five day two-budded settlings raised in a soil bed were transplanted on January 13, 2010. Each plot had an area of 5 m × 6 m in which five rows of cane were planted at an inter-row spacing of 1 m. The sugarcane variety Isd 37 was used as the test crop. Urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, and zinc sulfate were used as the sources of N, P, K, S, and Zn, respectively. The nutrient status of the organic manures used in the experiment, CD and PM (on oven dry

Dr. Gopal Chandra Paul, Head of Soils and Nutrition Division at the Bangladesh Sugarcane Research Institute with farmers at one of the project's experimental plots. Photo by B. Tirugnanasotkhi.

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basis) is shown in Table 1. The full amount of TSP, gypsum, zinc sulfate and all the CD, PM - together with one third of MOP - were applied in trenches and thoroughly mixed with the soil prior to settlings transplantation. Irrigation was applied just after planting of the settlings. N fertilizers were given in three equal splits: the first after establishment of the settlings, i.e. 20 days after planting (DAP); the second at tiller completion stage (90 DAP); and the third at grand growth phase (180 DAP). The remaining amounts of MOP were applied as top dressing at 90 DAP and 180 DAP like the N fertilizer. Cultural practices such as inter-row plowing, weeding, irrigation, earthing up, and tying were performed when required. The pesticide Curaterr 5G was applied at 40 kg ha^{-1} to control shoot borer during the early growth stage.

The number of tiller and millable cane stalks were counted at two different growth stages; peak tillering stage (150 DAP) and maturing stages (270 DAP). Soil pH was measured in a 1:2.5 soil water suspension by glass electrode pH meter. Total N was determined by micro Kjeldhal procedure and organic carbon by the Walkley and Black method. Available soil P was extracted with 0.5M sodium bicarbonate ($NaHCO_3$) and the amount was determined by spectrophotometry. Exchangeable K [1N ammonium acetate (NH_4OAc) extractable] was determined by flame photometry and available S by a turbidimetric method (Black, 1965) for soil and plant leaf. Leaf samples (3^{rd}-4^{th}) from the top of main cane stalks were collected from the sampled cane and separated into leaf blade and leaf sheath. Midribs were removed from leaf blade and samples were dried at 65°C and milled for nutrient analyses. The experimental plots were harvested on January 26, 2011. Data were statistically analyzed using analysis of variance (ANOVA) and the treatment differences were adjudged by least significant difference (LSD) test.

Results and discussion

Effects of K on sugarcane yields and growth parameters

In treatments T_1-T_4, the effect of potassium fertilizer was significantly higher in tiller number, number of millable cane stalks, and yield, in comparison to the no fertilizer plots in T_5. On the other hand, stalk height, stalk thickness and pol cane percent did not differ significantly from the no fertilizer treatment (Table 2). The highest cane yield of 126.3 mt ha^{-1} was recorded in treatment (T_2) where K (127 kg K ha^{-1}) fertilizer was applied on soil test basis (STB). This was followed by 75% STB K (95 kg K ha^{-1}) + PM (5 mt ha^{-1}) with 118.5 mt ha^{-1} and 75% STB K (95 kg K ha^{-1}) + CD (10 mt ha^{-1}) with 116.8 mt ha^{-1}. There was no significant difference between these two treatments. A significantly lower cane yield of 100.7 mt ha^{-1} was obtained in T1 where the current recommended dose of K (90 kg K ha^{-1}) fertilizer was applied. Results showed that K fertilizer application based on STB increased cane yield by 25.4 percent over current recommended doses of K fertilizer. This result agrees with Bokhtiar *et al.* (1995) who found in two locations of Tista Meander Flood Soils of Bangladesh that cane yield increased up to 37.7 percent at 166 kg K ha^{-1} but, beyond that dose, yield gradually decreased. Based on a field experiment of 11 locations in Sao Paulo State of Brazil, Korndorfer (1990) also found that raising application of K to 150 kg K ha^{-1} progressively increased cane yield. Table 2 shows that combined application of CD or PM with K fertilizers based on STB significantly enhanced the yield over the current recommended dose of K fertilizer. Application of CD or PM along with 75% STB K fertilizer increased yield by 16 percent and 17.7 percent respectively over present recommended dose of K fertilizer. Maximum stalk height and thickness were unaffected by different potassium treatments. Pol cane percent was similarly unaffected by potassium treatments. Possible beneficial long term effects of addition of organic manure together with mineral K fertilizer are worth studying from both the viewpoint of recycling K as well as the positive influence of additions of organic matter to improve soil structure.

Table 1. The nutrient status of the organic manures used in the experiment (on oven dry basis).

Characteristics	Manure	
	PM	CD
pH	7.88	8.60
Organic C (%)	20.53	15.76
Total N (%)	0.59	0.54
P (%)	0.13	0.16
K (%)	0.12	0.14
S (%)	0.21	0.12
Zn (%)	0.014	0.013

Table 2. Effect of potassium fertilizer on the yield and yield parameters of a sugarcane crop.

Potassium (kg ha^{-1}) and manure treatments	Yield	No. of tillers	No. millable cane stalks	Stalk height	Stalk thickness	Pol Cane
	mt ha^{-1}	--------×10^3 ha^{-1}--------		*m*	*cm*	*%*
T_1: 90[(1)]	100.7 b	92.84 a	82.72 a	3.663	2.127	10.35
T_2: 127[(1)]	126.3 a	93.22 a	84.92 a	3.740	2.277	9.947
T_3: 95[(1)] + 10 mt ha^{-1} CD	116.8 ab	92.51a	86.21 a	3.827	2.100	10.41
T_4: 95[(1)] + 5 mt ha^{-1} PM	118.5 ab	93.28 a	86.90 a	3.460	2.080	10.22
T_5: no fertilizer	60.1 c	73.48 b	70.51 b	3.713	2.270	10.71
LSD (.05)	18.9	13.02	11.75	NS	NS	NS

[(1)]Received also the recommended dose of 150, 50, 34 and 3.5 kg ha^{-1} of N, P, S and Zn, respectively.

Figures with same letter do not differ significantly at 5% level as per DNMR test.

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Effects of K on leaf nutrient concentrations

Nutrient concentrations of N, P, K, S and Zn in leaves appear little affected by K fertilizer management (Table 3).

Effects of K treatments on soil properties

Levels of available soil nutrients at the beginning and end of the experiment are provided in Table 4. For the most part they show, as would be expected, little evidence of change over a period of only one cropping season. Lack of statistical data also means that only suspected trends can be reported. K availability appears to have increased by about 13 percent in the dung treated and current K recommendation treated plots. Interestingly, the K availability value was the same as the original soil status for the STB treatment. S and Zn appear to have increased in all treatments, but especially in the poultry manure treatment (59%) and (224%) respectively.

Table 3. Effect of K fertilizer on the nutrient contents in leaf tissues (Means of three replicates).

Potassium (kg ha^{-1}) and manure treatments	Total N	P	K	S	Zn
	--------------------%.--------------------				*ppm*
T_1: 90[(1)]	2.11	0.20	1.23	0.17	26.6
T_2: 127[(1)]	2.00	0.19	1.28	0.18	26.0
T_3: 95[(1)] + 10 mt ha^{-1} CD	1.85	0.20	1.23	0.17	24.5
T_4: 95[(1)] + 5 mt ha^{-1} PM	2.02	0.19	1.29	0.17	25.8
T_5: no fertilizer	1.96	0.19	1.22	0.16	22.0

[(1)]Received also the recommended dose of 150, 50, 34 and 3.5 kg ha^{-1} of N, P, S and Zn, respectively.

Table 4. Effect of K fertilizer on pH, organic carbon (OC) and available nutrient contents in the 0-15 cm soil layer (Means of three replicates).

Potassium (kg ha^{-1}) and manure treatments	pH	OC	Total N	P	K	S	Zn
	Initial soil nutrient status						
		-----------%-----------		-------------*mg kg^{-1}*-------------			
	7.64	0.78	0.070	12.0	70.0	17.0	0.86
	Post harvest soil nutrient status						
T_1: 90[(1)]	7.48	0.67	0.086	11.0	88.0	22.0	0.93
T_2: 127[(1)]	7.40	0.78	0.085	13.0	70.0	22.5	0.95
T_3: 95[(1)] + 10 mt ha^{-1} CD	7.57	0.74	0.096	11.0	88.0	22.5	1.07
T_4: 95[(1)] + 5 mt ha^{-1} PM	7.56	0.71	0.081	12.0	88.0	27.0	1.93
T_5: no fertilizer	7.57	0.64	0.071	10.0	70.0	20.5	0.80

[(1)]Received also the recommended dose of 150, 50, 34 and 3.5 kg ha^{-1} of N, P, S and Zn, respectively.

Conclusions

Potassium application of 127 kg K ha^{-1} made according to soil test basis (STB) significantly increased yield of sugarcane monoculture on a calcareous soil, by 25 percent over the current recommended dose of potassium for the region. The addition of animal manures (CD at 10 mt ha^{-1} or PM at 5 mt ha^{-1}) to the recommended fertilizer application in the region increased the cane yields by 16-18 percent. We suggest that adding manures is not only important in increasing yield but also in maintaining soil fertility. Further long-term investigations are required to evaluate the benefits of these organic manure treatments on soil fertility in relation to higher inputs of K.

Acknowledgement

The project is grateful to the International Potash Institute, Horgen, Switzerland, for it's support.

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The paper "The Effects of Soil Test Based Potassium Application and Manures on Yield and Quality of Sugarcane Grown on a Typical Calcareous Soil of Bangladesh" appears also at:

Regional Activities/East India, Bangladesh and Sri Lanka