Long-Term Effects of Integrated Nutrient Management on Planted and Successive Ratoon Sugarcane Crops

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Improving soil organic matter and soil fertility are important factors in sustaining sugarcane production. This long-term experiment evaluated the effect of organic amendment, green manuring, and fertiliser combinations on yield and soil fertility status within a multi-ratooning cane cropping system. Over the 7-year period, high yields were sustained, and soil organic carbon, total N, available P, and exchangeable K were increased with long-term, annual applications of press mud and/or farmyard manure (FYM) plus fertilisers compared to fertiliser application alone.

The possibility of increasing the area under sugarcane in Bangladesh (presently 150,000 ha) remains meager due to a continued, heavy demand for cereals destined for staple food production. Thus, the primary option available to meet the requirement for sugar and jaggery is through an increase in the productivity per unit area, and ratoon cane fields represent such an opportunity. In sugarcane production, ratoon cropping is an established practice contributing significantly to overall profitability. Ratoon crops are 25 to 30% cheaper to grow than planted cane fields (Sundara, 1987), since no cost is involved for fresh seed material and land preparation, and there is a savings in irrigation and crop maintenance through reduced crop duration.

In many sugarcane growing countries of the world, raising several successive ratoons is common, with the number of ratoons ranging from 1 to 20 (Hunsigi, 1989). Despite this, multi-ratooning is seldom practiced in Bangladesh due to significant yield declines over time. One of the major causes for this cane yield reduction is the decline in soil nutrient status (Plucknett et al. 1970; Soopramanien and Hunsigi 1995). In Bangladesh, most of the cultivated land contains less than 2% organic matter and the soils of high and medium-high lands have organic matter contents less than 1% (FRG, 2005). It is understood that declining productivity of Bangladesh soils is the result of depletion of organic matter due to increasing cropping intensity, higher rates of decomposition of organic matter under the prevailing hot and humid climate, and limited or no use of organic matter or green manures. The country is in great need of nutrient replenishment strategies that integrate the addition of organic matter with fertiliser for higher yields in both planted and ratoon crops.

The Bangladesh Sugarcane Research Institute (BSRI) farm at Ishurdi, Pabna (24° 8' N latitude and 92°5' E longitude), located on the High Ganges River floodplain, was selected for the study conducted between 2001-02 and 2007-08. Composite soil samples (0 to 15 cm) were collected randomly from each replicated plot before fertiliser application. The soil was a calcareous silt loam (Typic Eutrochrepts) with a pH near 8.0, low organic matter (1.14%), and very low in total N, available P, and S...0.06%, 8.0 mg/kg, and 6.0 mg/kg, respectively. Exchangeable K (0.19 cmol/kg) and soil cation exchange capacity (14.0 cmol/kg) of the experimental soil were also low.

Treatments tested various nutrient management options including: T_0 = Control (no fertiliser); T_1 = NPKS and Zn based on soil test results and an optimum yield target of 100 ± 10 t/ha; $T_2 = T_1$ + farmyard manure (FYM); T_3 = 25% less fertiliser than T_1 + FYM; $T_4 = T_1$ + press mud; T_5 = 25% less fertiliser than T_1 + press mud; $T_6 = T_1$ + green manure (*Crotalaria juncea*); T_7 = Current recommended rates; and T_8 = 25% more fertiliser than T_7 **(Table 1)**. Treatments were replicated four times and experimental plots were set up in a randomised complete block design. Urea, triple superphosphate (TSP), potassium chloride

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; Ca = calcium; Mg = magnesium; Mn = manganese; Cu = copper; Fe = iron; Zn = zinc.

Table 1. A description of treatments used in the study.

	- - - Fertiliser, kg/ha - - -					Organic amendments, t/ha		Green
Treatment	N[2]	P	K	S	Zn	PM	FYM	manure
T_0 = Control (no fertiliser)	0	0	0	0	0	0	0	0
T_1 = Soil test-based NPKS and Zn[1]	178	53	54	26	2.6	0	0	0
$T_2 = T_1$ + FYM	178	53	54	26	2.6	0	15	0
T_3: = 75% T_1 + FYM	138	40	40	20	2.0	0	15	0
$T_4 = T_1$ + PM	178	53	54	26	2.6	15	0	0
T_5 = 75% T_1 + PM	138	40	40	20	2.0	15	0	0
$T_6 = T_1$ + GM	178	53	54	26	2.6	0	0	GM
T_7 = Current recommendation	130	35	60	20	3	0	0	0
T_8 = 125% Current recommendation	163	45	75	25	4	0	0	0

[1]Based on target yield of 100 t/ha ± 10 t/ha.
[2]N rates indicated were applied in the planted crop. Successive ratoon crops received 50% more N than the planted crop.

Table 2. Composition of press mud, FYM, and green manure (oven-dry basis).

Amendment	Moisture, %	pH	OC	Total N	P	K	S	Ca	Mg	Cu	Fe	Mn	Zn
			%							mg/kg			
Press mud	55.95	5.8	19.5	2.01	0.13	0.54	0.56	6.64	0.46	128	6,300	308	883
FYM	45.83	7.1	14.0	1.21	0.08	0.41	0.22	2.98	0.94	84	6,490	200	546
G. manure	76.03	-	45.9	1.79	0.18	1.44	0.17	-	-	-	-	-	-

Table 3. Effects of integrated nutrient management practices on yield (t/ha) of the planted and successive ratoon cane crops at Ishurdi, Pabna, Bangladesh.

Treatments	Planted cane	First ratoon	Second ratoon	Third ratoon	Fourth ratoon	Fifth ratoon	Sixth ratoon
T_0	50.82 e	35.26 d	26.35c	22.26 d	13.07 e	14.34 c	8.49 e
T_1	91.24 cd	78.94 c	61.25b	64.41 abc	59.58 bc	61.66 ab	37.53 d
T_2	108.40 a	96.82 a	73.54a	71.51 a	62.97 abc	63.78 ab	47.58 b
T_3	105.40 ab	89.96 ab	72.50ab	70.46 ab	64.74 ab	68.88 ab	39.62 cd
T_4	100.50 abc	89.65 ab	72.18ab	65.89 abc	69.63 a	70.37 ab	52.41 a
T_5	100.70 abc	84.97 bc	67.97ab	60.95 abc	69.32 a	72.58 a	43.93 bc
T_6	97.17 bcd	80.46 bc	63.90ab	58.17 c	49.53 d	63.43 ab	37.70 d
T_7	88.60 d	80.81 bc	61.93ab	60.38 bc	56.98 cd	58.87 b	36.79 d
T_8	96.80 bcd	84.24 bc	65.73ab	63.68 abc	55.31 cd	69.57ab	38.69 d
LSD at 0.05	9.91	10.52	11.69	10.84	7.73	12.00	4.55

Means followed by different letters within a column are significantly different ($p < 0.05$).

(KCl), gypsum, and zinc sulphate were used as the sources of N, P, K, S, and Zn, respectively.

Sugarcane plants (variety Isd 20) with 3 to 4 leaves were transplanted on December 10, 2001. The plot size was 8 m × 6 m in which six rows of cane were planted within an inter-row spacing of 1 m and 0.45 m interplant spacing. The green manure crop was seeded at 250 g/plot (without fertiliser) during the summer season (mid April) in-between cane rows and then ploughed down in-situ 45 days after sowing. Other farming practices such as supplementary irrigation, weeding, earthing-up, tying, and pest control were done as and when required.

For planted sugarcane, the full amount of press mud, FYM, TSP, gypsum, zinc sulphate, and one-third of the KCl were applied in trenches and thoroughly mixed with soil prior to seedling transplantation and irrigation. The N fertiliser was applied in three equal splits; at establishment of seedlings [i.e. 20 days after planting (DAP)], at tillering completion stage (90 DAP), and at grand growth phase (180 DAP). The remaining two-thirds of KCl was applied as top dressing at 90 DAP and 180 DAP as was N fertiliser. The nutrient composition of press mud collected from the North Bengal Sugar Mills, Bangladesh, well rotten FYM, and green manure is shown in **Table 2**.

The ratoon cane experiment was initiated in 2002-03 and continued up to the sixth ratoon crop in 2007-08. Ratoon cane received 50% more N than the planted crop, but all other fertilisers and amendments were kept at the same levels mentioned above. Ratoon crops require more N because 3 to 6 weeks after sugarcane ratoons start growing from old stubble roots, these old root system cease to function and new root systems are formed. Since these new root systems are surrounded by old, decomposing tissue with high C:N ratio, the potential for microbial immobilisation of available soil N is high in the root zone and higher rates of N application are required to overcome this microbial tie up of nutrients.

Table 4. Changes in soil pH, organic carbon and available nutrients as influenced by integrated nutrient management practices after 7 years at Ishurdi, Pabna, Bangladesh.

Treatments	Soil pH	Organic C, %	Total N, %	Available P, mg/kg	Exchangeable K, $cmol_+/kg$
T_0	7.83a	0.74c	0.05c	9.00d	0.16c
T_1	7.79ab	0.74c	0.07b	16.67c	0.17bc
T_2	7.73bcd	0.84bc	0.07b	20.67c	0.20a
T_3	7.74bcd	0.86bc	0.07b	19.67c	0.18ab
T_4	7.79ab	1.02a	0.08ab	47.33a	0.17bc
T_5	7.73cd	1.04a	0.09a	40.00b	0.17bc
T_6	7.79ab	0.86bc	0.08ab	21.33c	0.17bc
T_7	7.71d	0.96ab	0.07b	17.00c	0.17bc
T_8	7.78abc	0.80c	0.07b	11.00d	0.17bc
LSD at 0.05	0.05	0.13	0.02	4.35	0.02

Means followed by different letters within a column are significantly different ($p < 0.05$).

Results

Use of organic amendments and fertilization significantly increased the yield of planted cane and successive ratoon crops **(Table 3)**. The maximum cane yields were obtained from soil test-based fertilisation plus FYM (T_2) in the planted, first, second, and third ratoon crops. The maximum yields for the fourth to sixth crop were achieved with either of the fertiliser/press mud combinations (T_4 or T_5). But regardless of the rankings, sustained agronomic performance of treatments providing an organic amendment along with soil test-based fertilisation highlights the significance of this practice in multi-ratooned crops. Tiwari et al. (1998) also found increased cane and sugar yield with continuous application of press mud and N fertiliser, as did researchers at TNAU where sugarcane intercropped with green gram and press mud application at 25 t/ha generated similar results (TNAU, 2000). Press mud at 12.5 t/ha + 75% of the recommended NPK rate increased cane yield by 20% over 100% NPK alone (Suguna Devakumari, 2005). In addition to their direct nutrient value, organic amendments (and green manures), when incorporated into the soil, increase biological activity, nutrient availability, soil organic carbon, and physiochemical properties of soil through their biodegradation. Organic amendments are likely to improve the porosity in soil, improve water holding capacity, reduce soil compaction, improve root penetration, and encourage vigorous growth and development of planted and ratoon crops.

Table 5a. Economic analysis of sugarcane as affected by different fertilisers management practices for planted cane.

Treatments	Planted cane yield, t/ha	Gross return, BDT/ha	Variable cost[1], BDT/ha	Gross margin, BDT/ha	Marginal benefit to cost ratio (MBCR) over the control
T_0	50.8	89,951	0	89,951	-
T_1	91.2	161,495	15,187	146,308	3.7
T_2	108.4	191,868	24,187	167,681	3.2
T_3	105.4	186,558	20,550	166,008	3.7
T_4	100.5	177,885	18,187	159,698	3.8
T_5	100.7	178,239	14,550	163,689	5.1
T_6	97.2	171,991	15,187	156,804	4.4
T_7	88.6	156,822	12,124	144,698	4.5
T_8	96.8	171,336	15,390	155,946	4.3

[1]Variable cost includes the cost of fertilisers and amendments only. BDT = Taka, a unit of Bangladeshi currency. 1 USD = approximately 69 BDT.
Costs of inputs: urea (12 BDT/kg), triple superphosphate (22 BDT/kg), potassium chloride (25 BDT/kg), gypsum (8 BDT/kg), zinc sulphate (120 BDT/kg), press mud (0.20 BDT/kg), and FYM (0.60 BDT/kg).
Price of output: Sugarcane (1,770 BDT/t).

Our results also indicate that the application of FYM and/or press mud was more effective than green manure or fertiliser in maintaining ratoon crop yields over time. However, due to additive effects of combining nutrient sources on ratoon crop yields, maximum crop cycle yields were recorded for treatments with a combination of press mud and/or FYM. Our results concur with Gilbert et al. (2008).

Among the different fertiliser management practices, a combined application of press mud and/or FYM and fertiliser generated slight improvements in soil organic carbon, total N, available P, and exchangeable K over the control treatment **(Table 4)**.

Details economic data for the different nutrient management practices provide the basis for marginal benefit: cost ratios (MBCR) presented for planted **(Table 5a)** and ratoon sugarcane **(Table 5b)**. MBCR values varied with yield as well as the associated cost as per treatment description. Importantly, the incorporation of organic manure and fertiliser in these long-term, planted/ratoon cropping systems was profitable. Based on the seven years of experimentation, the following recommendations were drawn.

- A 25% reduction in the current fertilizer recommendation (i.e., 138-40-40-20-2 kg N-P-K-S-Zn/ha) plus either a similar quality FYM or press mud at 15 t/ha may be recommended for higher yields, incomes, and soil fertility maintenance in planted crops.
- Successive ratoon crops perform better under the same recommendation outlined above; however, these crops should be compensated with 50% more N than is applied in planted crops due to the high potential for microbial immobilisation of available soil N. BC-SA

Table 5b. Marginal benefit to cost ratio over the control as affected by different nutrient management practices for successive ratoon crops.

Treatments	Marginal benefit cost ratio (MBCR) over the control[1]					
	First ratoon	Second ratoon	Third ratoon	Fourth ratoon	Fifth ratoon	Sixth ratoon
T_0	-	-	-	-	-	-
T_1	3.4	2.5	3.1	3.7	3.8	1.9
T_2	3.1	2.2	2.3	2.3	2.3	1.6
T_3	3.3	2.7	2.8	3.1	3.3	1.5
T_4	3.7	3.0	2.8	3.9	4.0	2.8
T_5	4.4	3.5	3.2	5.1	5.3	2.8
T_6	3.6	2.8	2.6	2.7	4.0	2.0
T_7	4.8	3.6	3.9	4.6	4.7	2.6
T_8	4.0	3.0	3.2	3.3	4.6	2.0

[1]To calculate MBCR for ratoon crops, 50% more N cost was considered in the variable costs. All other fertilizers and amendments were kept at the same levels.

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References

Fertiliser Recommendation Guide (FRG). 2005. Bangladesh Agricultural Research Council. Soils Publication No. 45. p. 48.

Gilbert, A. Robert., D.R. Morris, C.R. Rainbolt, J.M. Mccray, R.E. Perdomo, B. Eiland, G. Powell, and G. Montes. 2008. Agron J. 100, 845–854. doi:10.2134/agronj2007.0247

Hunsigi, G. 1989. Outlook on Agriculture, 18: 175-184.

Plucknett, D.L., J.P. Evenson, and W.G. Sanford. 1970. Adv Agron. 22, 285-330.

Soopramanien, G.C. and G. Hunsigi. 1995. Co-operative Sugar. 22: 831-849.

Suguna Devakumari, S. 2005. Ph.D thesis. Tamil Nadu Agric. Univ., Coimbatore.

Sundara B., 1987. Proc. Internl. Symposium on Sugarcane Varietal Improvement: Present status and future thrusts. Sugarcane Breeding Institute, Coimbatore, Tamil Nadu, India, Sept. 1987, pp. 37.

Tamil Nadu Agricultural University (TNAU). 2000. Sugarcane Research Station, Tamil Nadu Agric Univ. www.tnau.ac.in/ Cuddalore.

Tiwari, R.J., K.S. Bangar, G.K. Nema, and R.K. Sharma. 1998. J. Indian Soc. Soil Sci. 46: 243-245.