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An Integrated Nutrient Management Approach to Improve Sugar Productivity

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ABSTRACT

Studies were conducted in Bangladesh to investigate the effects of using nutrient recycling of organic wastes and chemical fertilizers for developing integrated fertilizer management packages to improve sugar productivity and soil health. The incubation study revealed that organic wastes having low to moderate C/N ratios increased mineral N but that with high C/N ratio and lignin content favoured N immobilization, microbial biomass C and N formation in soil. In pot experiment, it was found that combined application of the organic wastes (press mud / cow dung / sugarcane trash / mustard oil cake) at 2 g C kg-1 soil along with chemical N increased mineral N, and microbial biomass C and N contents in soil. In field studies, it was confirmed that the integrated application by nutrients recycling from organic wastes of press mud at 10-20 and rice mill ash at 10 t ha^{-1} along with 25-50% reduced chemical fertilizers (N, P, K, S and Zn) gave higher yields in plant and ratoon sugarcane (72.34-102.42 t ha^{-1}) and higher economic return of Bangladesh Taka 15, 170.00 to 47, 340.00 (~ US $ 233 to 728) per hectare.

Keywords : Agricultural waste, recycling, INM, Sugar productivity

INTRODUCTION

Sugarcane is one of the most important industrial crop in Bangladesh. Sugarcane, being a long duration crop with high requirements of nutrients, removes considerable amount of nutrients from soil. Consequently, the nutrient supplying capacity of its soil declines progressively causing productivity decline. Moreover, Bangladesh agriculture is facing a challenge to prevent its soil resource base degradation, nutrient mining and depletion of fertility. Proper soil fertility management is of prime importance in an endeavor to increase sugar productivity. Sustainable crop production can never be achieved by using either chemical fertilizer alone or by applying only organic manure (Bair, 1990). Balanced use of organic and inorganic fertilizer is very essential for the stable soil fertility where nutrient turn over in the soil plant system is faster and larger. Sugarcane produces higher yield in the soils with sufficient level of organic matter and available nutrients (Islam *et al.*, 1995). Azmal *et al.* (1996a) confirmed that application of organic wastes in soil significantly increased soil microbial biomass and activity. Sugar productivity can not be sustained if the nutrients removed by crop harvests are not equally replenished by recycling back of the agricultural wastes to soil. It is being well accepted that soil organic matter is a key factor in maintaining long-term soil fertility, as it is the reservoir of metabolic energy, which derives soil biological processes involved in nutrient availability (Sumner, 1999). Kumar and Mishra (1992) reported that application with suitable combinations of organic and inorganic nutrients increased fertilizer use efficiency and sugar yield. Johnson (1994) also mentioned that integrated use with chemical fertilizers and organic wastes were suitable for nutrient recycling to soil. The main objective of integrated nutrient management is to improve and sustain soil fertility for providing a sound basis for crop production systems and to meet the changing needs (FAO, 2001). In this context, integrated nutrient management through combined use of chemical fertilizers and nutrient recycling of organic waste materials can be an effective approach to combat nutrient depletion and promote sustainable sugar productivity. In sugarcane growing areas, there is an ample scope for recycling back of some organic wastes (viz. press mud, rice mill ash, mustard oil cake, cow dung, sugarcane trash etc.) in soil and integrated application

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of that with reduced chemical fertilizers to improve sugar productivity. Unfortunately, the farmers have not yet been provided with the cost effective integrated nutrient management packages for sustainable sugarcane production. Considering the facts under discussion, several studies at laboratory, pot and field were conducted for investigating the effects on nutrient recycling of organic wastes and reduced chemical fertilizers in sugarcane with a view to develop economically suitable integrated nutrient management packages for sustaining sugar productivity.

MATERIALS AND METHODS

Five studies under different conditions at laboratory, pot and field were carried out and they are described below:

(i) Changes of microbial biomass carbon and nitrogen in upland sugarcane soil amended with different organic materials

An incubation study was carried out on soil amendment with press mud (PM), sugarcane trash (ST), mustard oil cake (MOC) and cow dung (CD) to investigate the periodic changes in mineral N, microbial biomass C and N in soil. A part of the moist soil samples was analyzed for mineral N after adjusting at 60% of maximum water holding capacity (MWHC). Another part of the samples were kept in polythene bags and incubated aerobically for 3 weeks at 25^{0}C to subside the effect of handling on soil respiration (Rovira and Greacen, 1957). Microbial biomass C in soil was measured by the chloroform fumigation-extraction method (Vance *et al.*, 1987). Biomass N was determined as suggested by Brookes *et al.* (1985 a, b). Bio-chemical characteristics of the OM are shown in Table 1. Moist soil samples at 60% of MWHC equivalent to 20g oven-dried soil were weighed in 200 ml conical flask and added with ground OM at 2g C kg-1 soil. Flasks were kept at 30^{0}C. Mineral N, microbial biomass C and N were measured at 0, 7, 14, 28, 42, 56, 70, and 84 days of incubation.

(ii) Contribution of organic matter and chemical nitrogen on soil microbial biomass and sugarcane yield

A pot experiment was conducted in soil amended with OM and chemical N to estimate the contribution of OM and chemical N on soil microbial biomass formation and dry yield in sugarcane. Each earthen pot of 37.5 cm x 35.0 cm in size was filled with 30 kg of soil. One-budded settling of sugarcane was transplanted in each pot. There were 20 treatment combinations comprising 4 sources of OM, viz. sugarcane trash (ST), press mud (PM), mustard oilcake (MOC) and cow dung (CD) with a control (OM$_0$) and 4 levels of chemical nitrogen at 0, 53, 107, 160 kg N ha-1. OM were ground and mixed with soil at 2g C kg-1 soil. Microbial biomass, C was measured by chloroform fumigation (Vance *et al.*, 1987) and N by method of Brookes *et al.* (1985a, b). Mineral N, microbial biomass C and N in soil were measured at tiller initiation and maximum tiller phases during 120 and 150 days after transplantation of sugarcane (Table 2).

(iii) Integrated nutrient management with organic and inorganic fertilizers on productivity of sugarcane in Bangladesh

A field study was conducted in Old Himalayan Piedmont Plain soils of Bangladesh to evaluate the effects of integrated use of different organic wastes and chemical fertilizers for developing an economically suitable package of fertilization to improve sugar productivity. It was laid out in randomized complete block design with three replications. Nine treatments were included as: T_1- Control, T_2- Recommended fertilizer doses of NPKSZn (RFD), T_3- RFD of NPSZn + 10 t ha^{-1} Rice mill ash, T_4- RFD of NPSZn + 75% K + 10 t ha^{-1} Rice mill ash, T_5- RFD +10 t ha^{-1} Rice mill ash, T_6- RFD + 20 t ha^{-1} Press mud, T_7- 75% RFD + 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash, T_8- 50% RFD + 20 t ha^{-1} Press mud and T_9- 50% RFD+20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash. Composition of OM for major nutrients is shown in Table 1. Results on sugarcane yield and economic return are presented in Table 3.

(iv) Contributions of rice mill ash and press mud with inorganic fertilizers on sugarcane production in Bangladesh

A field study was conducted in Old Himalayan Piedmont Plain soils of Bangladesh to find out an economically suitable combination of organic wastes and chemical fertilizer management package for sustainable sugarcane production. It was comprised of nine treatments. They were as: T_1- Usual farm practice (Control), T_2 – Recommended Fertilizer Doses of NPKSZn (RFD), T_3- 50% of RFD + 10 t ha^{-1} Rice mill ash + 10 t ha^{-1} Press mud, T_4- 75% of RFD + 10 t ha^{-1} Rice mill ash + 10 t ha^{-1} Press mud and T_5- 100% of RFD + 10 t ha^{-1} Rice mill ash + 10 t ha^{-1} Press mud. Composition of OM is shown in Table 1. Results on yield of sugarcane and economic return are presented in Table 4.

(v) Integrated nutrient management with organic and inorganic fertilizers on productivity of sugarcane ratoon in Bangladesh

A field study on sugarcane ratoon after harvest of the previous plant crop was conducted in Old Himalayan Piedmont Plain soils of Bangladesh to develop an economically suitable combination of organic wastes and chemical fertilizers for sustainable production. It was laid out in Randomized Complete Block Design with three replications. Nine treatments were accommodated as: T_1- Control (No fertilizer), T_2- Recommended Fertilizer Doses (RFD) of NPKSZn, T_3- RFD of NPSZn + 10 t ha^{-1} Rice mill ash, T_4- RFD of NPSZn + 75% K + 10 t ha^{-1} Rice mill ash, T_5- RFD +10 t ha^{-1} Rice mill ash, T_6- RFD + 20 t ha^{-1} Press mud, T_7- 75% RFD + 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash, T_8- 50% RFD + 20 t ha^{-1} Press mud and T_9

- 50% RFD + 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash. Results on yield of sugarcane and economic return are presented in Table 5.

Table 1: Bio-chemical properties of the organic waste materials (OM)

Organic waste materials	Org C (%)	Total N (%)	Total P (%)	Total K (%)	Total S (%)	C/N ratio	Lignin (%)
Sugarcane trash	40.40	0.51	0.52	0.86	-	79.2	17.01
Press mud	28.55	1.37	0.13	0.54	0.56	20.8	10.39
Mustard oil cake	44.46	5.54	1.85	1.20	-	8.0	5.25
Cow dung	25.05	1.28	0.60	1.70	-	19.6	9.76
Rice mill ash	-	-	0.12	1.02	0.09	-	-

RESULTS AND DISCUSSION

Changes of Microbial Biomass Carbon and Nitrogen in Upland Sugarcane Soil Amended with Different Organic Materials N mineralization-immobilization pattern in OM amended soil

In the upland sugarcane soil at 60% MWHC and under 30oC of incubation, mineral N in soils amended with OM of low to moderate C/N ratios increased gradually and then decreased. But, the soil amended with OM of wide C/N ratio showed immobilization (Fig.1). Similar results were reported by (Azmal *et al.*, 1996a; Kaur *et al.*, 1999) in their experiments. Fig. 1 shows that N released from the soil amended with MOC having the lowest C/N ratio produced the highest amount of mineral N ranging from 106.27 to 170.01 mg kg-1 soil throughout the incubation period of 84 days. Soils amended with PM and CD having moderate C/N ratios produced the second (46.82 to 101.61 mg kg-1 soil) and third (51.22 to 96.94 mg kg-1 soil) highest quantity of mineral N, respectively throughout the incubation period. Mineral N released from the control ranged from 32.38 to 69.85 mg kg-1 soil, where ST amended soil significantly produced the lowest amount of mineral N ranging from 10.22 to 32.69 mg N kg-1 soil. Addition of OM with lower C/N ratio showed a higher rate of N mineralization but OM with higher C/N ratio encouraged N immobilization in soil (Fig.2). Fig.3 shows that N mineralization-immobilization patterns of the added OM were highly depended on their C/N ratios and N released from added OM was negatively correlated with the respective C/N ratios of OM at 1% level of significance (r = -0.896**). The negative relationship between N mineralization and C/N ratios of the added OM were also supported by Azmal *et al.* (1996 a) Fig. 4 shows significant negative correlation (r = -0.909**) between the amounts of

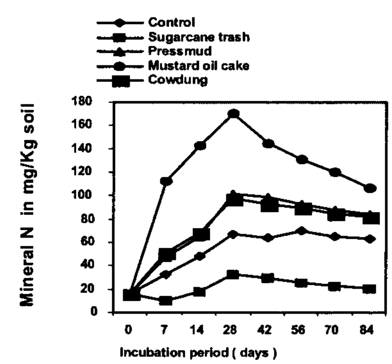

Fig. 1. N mineralization in upland soil amended with OM

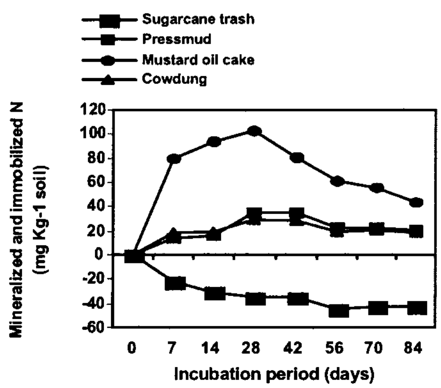

Fig. 2. N mineralization and immobilization patterns in OM amended upland soil

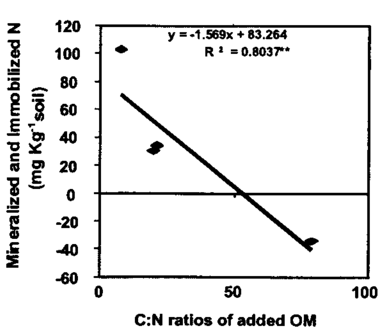

Fig. 3. Relationship between the amount mineralized-immobilized N and C/N ratios of OM

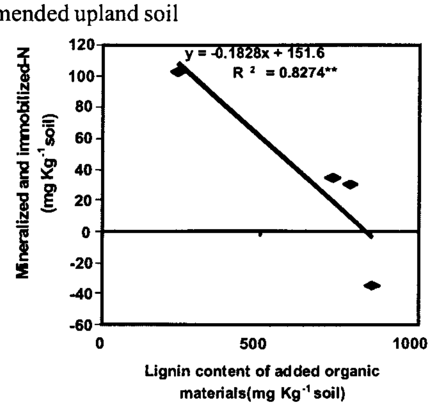

Fig. 4. Relationship between the amount of mineralized N and lignin content of the added OM after 28 days of incubation

mineralized N and lignin content of the added OM after 28 days of incubation. A similar negative relationship between the N mineralization and lignin content was reported by many scientists in their studies (Azmal *et al.*, 1996 a, Kaur *et al.*, 1999).

Changes in microbial biomass C in OM amended soil

The amount of microbial biomass C in OM amended soils was significantly higher than that in control throughout the incubation period. OM amended soils produced biomass C in the range of 103.63 – 246.33 mg kg-1soil where it was only 78.80 – 123.41 mg kg-1 soil in control (Fig.5). In this study, the amount of biomass C in all the OM amended soils increased rapidly within 7 days and decreased thereafter and reached a constant level after 28-42 days of incubation, except in control where it reached a constant level only after 14 days of incubation. These results are similar with the findings obtained by Friedel *et al.*, (2000). Significantly higher amount of biomass C (246.33 mg kg-1 soil) was observed in ST treated soil followed by MOC (229.39 mg kg-1 soil), PM (220.27 mg kg-1 soil) and CD (189.05 mg kg-1 soil) treated soils after 7 days of incubation (Fig.6). Azmal *et al.* (1996 a) found similar effects in their studies. At the end of incubation, the significantly higher amount of biomass C was also observed in ST amended soil (163.45 mg kg-1 soil) followed by PM (149.20 mg Kg-1 soil), CD (128.25 mg kg-1 soil) and MOC (103.63 mg kg-1 soil) amended soils. Many scientists by their their experiments reported similar findings where they found that addition of OM with higher C/N ratio produced higher microbial biomass C in soil (Hema *et al.*, 1999; Shukry *et al.*, 1999).

Changes in microbial biomass N in OM amended soil

Addition of OM in soils significantly increased the microbial biomass N in soils over control. Biomass N formations accounted from 19.33 – 43.60 mg kg-1 soil in OM amended soils and 14.21 – 22.04 mg kg^{-1} soil in control (Fig.6). The amount of microbial biomass N in all OM amended soils significantly increased within 7 days and decreased immediately and then reached a constant level after 28 - 42 days of incubation. Azmal *et al.* (1996 a) reported similar results. Significantly higher amount of biomass N (43.60-mg kg^{-1} soil) was produced in ST amended soil compared to other OM amended soils. MOC produced the second highest quantity of biomass N (41.38-mg kg^{-1} soil) followed by PM (39.76-mg kg^{-1} soil) and CD (37.05-mg kg^{-1} soil) amended soils (Fig. 6). Nira and Nishimune (2000) reported the similar pattern of microbial biomass N increment with OM amended soils. Higher microbial biomass N formation through addition of straw of higher C/N ratio in soil was observed by Vliet *et al.*(2000).

Contribution of Organic Matter and Chemical Nitrogen on Soil Microbial Biomass and Sugarcane Yield

Results in Table 2 indicate that addition of MOC, PM and CD with low to moderate C/N ratio of 8.0-20.8 significantly increased mineral N in soil over control at tiller initiation stage. ST having high C/N ratio of 79.2 increased N immobilization in soil. Similar immobilization of N was observed in soils with the addition of wheat straw and ST having wide C/N ratio by Vliet *et al.* (2000). Maximum mineral N was observed with MOC followed by PM and CD. Hema *et al.* (1999) also reported that addition of OM with low C/N ratio increased inorganic N in soil. Table 2 shows that addition of increasing amount of chemical N to soil significantly increased mineral N and microbial biomass C and N in all the treatments over control. Tiwari and Nema (1999) reported that integrated use of chemical N and OM increased available N in soil. It was found that in all the OM amended soils; microbial biomass C and N contents were higher at tiller initiation phase than at maximum tiller phase of sugarcane. Table 2 further shows that addition

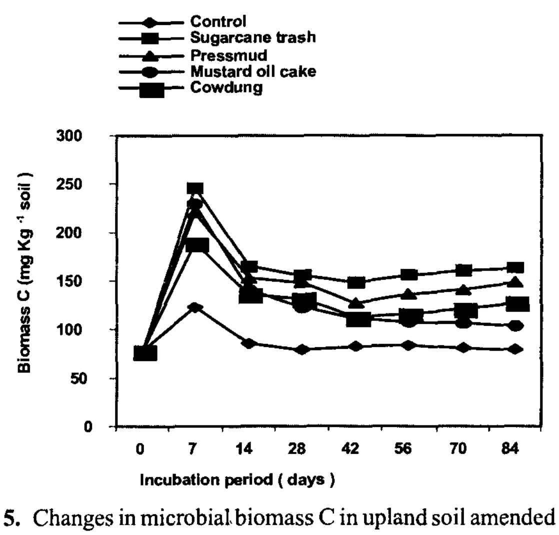

Fig. 5. Changes in microbial biomass C in upland soil amended with OM

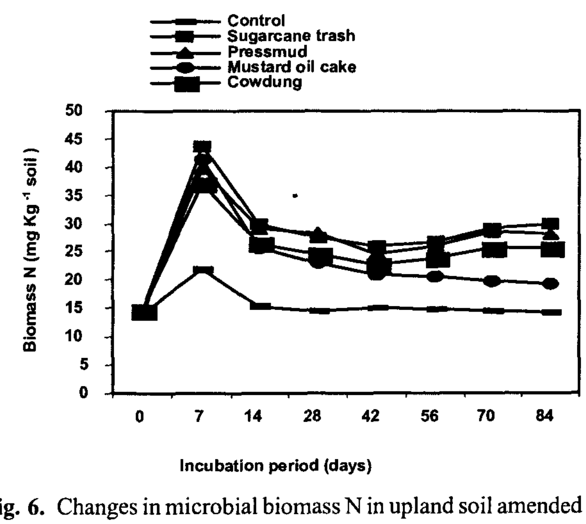

Fig. 6. Changes in microbial biomass N in upland soil amended with OM

of ST of high C/N ratio and higher level of chemical N significantly increased microbial biomass C and N in soil followed by PM, CD and MOC at both the phases of sugarcane growth which was similar to the observations made by Fliessback *et al.* (2000).

Table 2: Effect of OM and chemical N on mineral N and microbial biomass C and N in soils at different phases of sugarcane growth

Treatment combinations		Mineral N		Biomass C		Biomass N	
		(TIP)	(MTP)	(TIP)	(MTP)	(TIP)	(MTP)
	N_0	6.3 k	2.6 l	63.6 i	45.6 m	13.2 i	9.3 k
	N_{53}	7.5 j	3.3 k	77.5 hi	59.1 l	15.8 i	12.1 j
OM_0	N_{107}	9.2 ghi	3.9 j	78.3 hi	68.3 k	16.1 i	13.9 i
	N_{160}	12.5 d	4.7 i	81.2 h	76.4 j	16.5 i	15.5 h
	N_0	3.3 m	6.0 e	172.2 a	124.8 c	34.2 b	27.1 b
	N_{53}	4.4 l	7.0 c	180.9 a	134.1 b	36.1 ab	28.0 b
ST	N_{107}	5.5 k	7.5 b	183.7 a	142.0 a	36.7 ab	29.6 a
	N_{160}	6.1 k	8.2 a	185.1 a	144.8 a	37.6 a	30.1 a
	N_0	8.4 i	4.5 i	129.6 be	99.0 fgh	27.5 c-g	22.7 def
	N_{53}	10.2 f	5.4 g	132.4 bcd	105.7 def	29.0 cde	23.5 cd
PM	N_{107}	11.2 e	5.6 f	136.3 bc	111.8 d	29.5 cd	25.0 c
	N_{160}	14.3 bc	5.9 e	139.6 b	112.9 d	30.1 c	24.9 c
	N_0	9.5 fgh	5.4 fg	104.2 g	84.7 i	23.8 h	20.1 g
MOC	N_{53}	14.9 b	6.4 d	111.1 fg	92.4 h	25.2 fgh	21.7 ef
	N_{107}	16.9 a	7.1 c	113.3 efg	96.6 gh	25.8 e-h	22.6 def
	N_{160}	17.2 a	7.4 b	114.2 efg	100.3 efg	26.0 d-h	23.2 de
	N_0	7.5 j	3.9 j	103.8 g	95.3 gh	24.6 gh	21.1 fg
CD	N_{53}	8.6 hi	4.6 i	110.5 fg	102.1 efg	26.4 d-h	22.4 def
	N_{107}	9.9 fg	5.1 h	116.6 d-g	106.8 de	28.7 c-f	23.4 cde
	N_{160}	13.6 c	5.4 g	123.2 c-f	107.3 de	29.1 cde	23.7 cd
CV (%)		5.4	2.4	7.3	3.9	7.1	4.2

Values mg kg^{-1} soil, TIP=Tiller initiation phase, MTP=Maximum tiller phase, OMo= No OM. Means followed by common letter (s) are not significantly different at 5% level by DMRT

Integrated nutrient management with organic and inorganic fertilizers on productivity of sugarcane in Bangladesh

From the results shown in Table 3, it is evident that the treatment T_7 having integrated application with 75 % recommended inorganic NPKSZn fertilizers + press mud at 20 t ha^{-1} + rice mill ash at 10 t ha^{-1} produced significantly higher cane yield (102.42 t ha^{-1}) over T_8, T_2 and T_1. Results revealed that the effect of T_7 on cane yield was found superior over all other treatments, but it was statistically identical to T_9, T_6, T_5, T_4, and T_3. It further revealed that the treatment T_5 produced the second highest cane yield (101.92 t /ha) among the rest of the treatments. Similarly, Tiwari and Nema (1999) reported that application of PM with chemical N had favourable effect on tillering and other yield contributing factors in sugarcane. The findings are supported with the results found by many investigators (Anon.1986, Sarker *et al.* 1983, Parthasarathy, 1972). Singh (1993) further confirmed our findings who reported that use of press mud was effective as manure on sugarcane. Integrated use of press mud with inorganic fertilizers demonstrated significantly higher yield of sugarcane. The results are also in close conformity with the findings of Singh and Singh (2002) who reported that integrated use of chemical fertilizer and organic wastes resulted higher sugarcane yield. It further demonstrated that the integrated use with 50 % recommended chemical N, P, K, S and Zn fertilizers + press mud at 20 t ha^{-1} + rice mill ash at 10 t ha^{-1} gave the highest net benefit of Bangladesh Taka 47, 340.00 (~ US $ 728.3) per hectare with Benefit/Cost ratio of 6.52 (Table 3). Islam *et al* (1998) found similar observation of higher economic return from combined application of organic and inorganic fertilizers in sugarcane.

Contributions of Rice Mill Ash and Press Mud with Inorganic Fertilizers on Sugarcane Production in Old Himalayan Piedmont Plain Soils of Bangladesh

Evaluating the results reported in Table 4, it is found that the treatment T_4 having 75% of recommended chemical fertilizers (NPKSZn) along with Rice mill ash and Press mud at 10 t ha^{-1} produced significantly higher cane yield (72.34 t ha^{-1}) over all other treatments except T_5, which was statistically similar. While the treatment T_1 (usual farm practice) produced significantly lower cane yield (52.81 t ha^{-1}) among all other treatments in the study. Furthermore, the treatment T_5 produced the second highest cane yield (70.00 t ha^{-1}) among the rest of the treatments. Similar result was obtained by Bokhtiar *et al.* (2001) in their experiment where they applied

Table 3: Integrated effect of organic and inorganic fertilizer management packages on the yield and economic benefit of sugarcane cultivation

Treatments	Cane yield (t ha^{-1})	Added benefit for added nutrient management (Taka ha^{-1})	Added cost for added nutrient management (Taka ha^{-1})	Net benefit for added nutrient management (Taka ha^{-1})	Benefit/Cost Ratio for added nutrient management
T_1: Control (No fertilizer)	44.92 d	-	-	-	-
T_2: Recommended Fertilizer Doses (RFD) of NPKSZn	78.58 c	33, 660.00	7, 140.00	26, 520.00	4.71
T_3: RFD of NPSZn + 10 t ha^{-1} Rice mill ash	98.67 a	53, 750.00	7, 940.00	45, 810.00	6.77
T_4: RFD of NPSZn + 75%K + 10 t ha^{-1} Rice mill ash	99.83 a	54, 910.00	9, 590.00	45, 320.00	5.73
T_5: RFD +10 t ha^{-1} Rice mill ash	101.92 a	57, 000.00	10, 140.00	46, 860.00	5.62
T_6: RFD + 20 t ha^{-1} Press mud	97.17 ab	52, 250.00	9, 140.00	43, 110.00	5.72
T_7: 75%RFD + 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash	102.42 a	57, 500.00	10, 355.00	47, 145.00	5.55
T_8: 50%RFD + 20 t ha^{-1} Press mud	88.00 bc	43, 080.00	5, 570.00	37, 510.00	7.73
T_9: 50%RFD+ 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash.	100.83 a	55, 910.00	8, 570.00	47, 340.00	6.52

*Calculations made on the following price for different inputs and outputs of the experiment (In Bangladeshi Taka per kg): Urea-6.50, Triple super phosphate-14.00, Muriate of potash-11.00, Gypsum-4.00, Zinc sulphate-40.00, Press mud-0.10, Rice mill ash-0.30 and Sugarcane-1.00
**Figures in column with same letter (s) do not differ significantly at 5% level as per LSD test

press mud at 20 t ha-1 in combination with 200 kg N ha-1. The reasonably higher proportionate of apparent nutrient balance in soil was also found by T_4. Many scientists supported similar result of higher apparent nutrient balance in soil and improvement in soil fertility for the integrated use of organic waste materials and chemical fertilizers (Mathur, 1997; Singh and Singh, 2002). It further confirmed that the integrated use with 75% recommended chemical fertilizers + press mud 10 t ha-1 + rice mill ash 10 t ha-1 gave the higher net economic benefit of Bangladesh Taka 15, 170.47 (~233 US $) per hectare for the additional inputs in sugarcane production (Table 4). Islam *et al.* (1998) found similar observation of higher economic return from the combined application of organic wastes and chemical fertilizers in sugarcane. This result is consistent with the findings of Singh *et al.* (1995). Yadhuvanshi and Yadav (1992) similarly confirmed the beneficial effect of press mud application in sugarcane production.

Integrated Nutrient Management with Organic and Inorganic Fertilizers on Productivity of Sugarcane Ratoon in Bangladesh

The integrated use of recommended chemical fertilizer and that with organic materials had significant positive effect on yield and economic benefit in ratoon crop of sugarcane (Table 5). From the results shown in Table 5, it was evident that the treatment T_7 having integrated application with 75% recommended chemical fertilizers (N, P, K, S and Zn) + press mud at 20 t ha-1+ rice mill ash at 10 t ha-1 produced significantly higher cane yield (75.07 t ha-1) over T_8, T_2 and T_1 in ratoon sugarcane. But it was statistically identical to the effects in T_9, T_6, T_5, T_4 and T_3. The findings were supported with the results found by many investigators (Anon. 1986, Sarker *et al.* 1983, Parthasarathy, 1972). Singh (1993) further confirmed our findings that use of press mud was effective as manure on

Table 4: Integrated effect of organic and inorganic fertilizer management packages on the yield and economic benefit of sugarcane production

Treatments	Cane yield (t ha^{-1})	Added benefit for added nutrients (Taka ha^{-1})	Added cost for added nutrients (Taka ha^{-1})	Net benefit for added nutrients (Taka ha^{-1})	Benefit/Cost Ratio for added nutrient
T_1:Usual farm practice (Control)	52.81 d	-	-	-	-
T_2:Recommended Fertilizer Doses (RFD) of NPKSZn	59.43 c	6, 620.00	1812.70	4, 807.30	3.65
T_3: 50% of RFD + 10 t ha^{-1}Rice mill ash + 10 t ha^{-1} Press mud	62.78 bc	9, 970.00	3, 906.35	6, 063.65	1.65
T_4: 75% of RFD + 10 t ha^{-1}Rice mill ash + 10 t ha^{-1} Press mud	72.34 a	19, 530.00	4, 359.53	15, 170.47	4.48
T_5: 100% of RFD + 10 t ha^{-1}Rice mill ash + 10 t ha^{-1} Press mud	70.00 a	17, 190.00	4, 812.70	12, 377.30	3.57

*Calculations made on the following price for different inputs and outputs of the experiment (In Bangladeshi Taka /kg): Urea-6.50, Triple super phosphate-14.00, Muriate of potash-11.00, Gypsum-4.00, Zinc sulphate-40.00, Press mud-0.10, Rice mill ash-0.30 and Sugarcane-1.00
**Figures in column with same letter (s) do not differ significantly at 5% level as per LSD test

Table 5: Integrated effect of organic and inorganic fertilizer management packages on the yield and economic benefit of ratoon cane production

Treatments	Cane yield ($t\ ha^{-1}$)	Added benefit for added nutrient management ($Taka\ ha^{-1}$)	Added cost for added nutrient management ($Taka\ ha^{-1}$)	Net benefit for added nutrient management ($Taka\ ha^{-1}$)	Benefit/Cost Ratio for added nutrient management
T_1: Control (No fertilizer)	40.42 d	-	-	-	-
T_2: Recommended Fertilizer Doses (RFD) of NPKSZn	62.62 c	22, 200.00	7, 140.00	15, 060.00	3.11
T_3: RFD of NPSZn + 10 t ha^{-1} Rice mill ash	72.08 ab	31, 660.00	7, 940.00	23, 720.00	3.99
T_4: RFD of NPSZn + 75%K + 10 t ha^{-1} Rice mill ash	73.28 ab	32, 860.00	9, 590.00	23, 270.00	3.43
T_5: RFD +10 t ha^{-1} Rice mill ash	74.72 ab	34, 300.00	10, 140.00	24, 160.00	3.38
T_6: RFD + 20 t ha^{-1} Press mud	72.81 ab	32, 390.00	9, 140.00	23, 250.00	3.54
T_7: 75%RFD + 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash	75.07 a	34, 650.00	10, 355.00	24, 295.00	3.35
T_8: 50%RFD + 20 t ha^{-1} Press mud	70.18 b	29, 760.00	5, 570.00	24, 190.00	5.34
T_9: 50%RFD+ 20 t ha^{-1} Press mud + 10 t ha^{-1} Rice mill ash.	73.67 ab	33, 250.00	8, 570.00	24, 680.00	3.88

sugarcane productivity. He added that integrated use with press mud and inorganic fertilizers demonstrated significantly higher yield of sugarcane. The results were also in close conformity with the findings of Singh and Singh (2002) who reported that integrated use with chemical fertilizer and organic waste materials resulted higher sugarcane yield. Again, it revealed that the reasonably higher apparent nutrient balance in soil was found for the integrated use of 50-75% recommended chemical fertilizers + press mud at 20 t ha^{-1} + rice mill ash at 10 t ha^{-1}. Many scientists demonstrated similar results of higher apparent nutrient balance in soil and improvement in soil fertility after ratoon sugarcane production for integrated use with organic wastes and chemical fertilizers (Singh and Singh, 2002). Furthermore, the integrated use of 50% recommended chemical fertilizers + press mud at 20 t ha-1 + rice mill ash at 10 t ha^{-1} demonstrated the highest net economic benefit of Bangladesh Taka 24, 680.00 (~379.69 US $) per hectare for the added nutrients with Benefit/Cost ratio of 3.88 (Table 5). Islam *et al.* (1998) found similar observation of higher economic return from the combined application of organic waste materials and chemical fertilizers in sugarcane productivity.

CONCLUSION

An optimistic conclusion on improving sugar productivity can be drawn based on the discussions under results of the studies. In selecting proper organic waste materials for nutrient recycling in soil and to develop the effective integrated nutrient management packages of that with reduced chemical fertilizer for sugarcane, all the findings generated in laboratory, pot and field studies should reasonably be considered. From the incubation study, it was found that organic wastes of low to moderate C/N ratios increased mineral N but that with high C/N ratio favoured N immobilization in soil. Microbial biomass C and N in soil were increased rapidly within 7 days and decreased immediately and then reached a constant level after 28-42 days of incubation for all kinds of organic wastes. Microbial biomass C and N formation in soil was higher for organic wastes of higher C/N ratios and lignin content. In pot experiment, it was found that combined application of the organic waste (press mud / cow dung / sugarcane trash / mustard oil cake) at 2 g C kg^{-1} soil with chemical N increased mineral N, and microbial biomass C and N contents in soil. From the results under field studies, it was confirmed that the integrated application of 25-50% reduced recommended chemical fertilizers along with nutrients by recycling from organic wastes of press mud at 10-20 t and rice mill ash at 10 t ha^{-1} produced higher yields in plant and ratoon sugarcane. It further gave higher net economic return. Thus, considering all the facts under study, it can be suggested to practice and popularize the integrated nutrient management packages with nutrient recycling from available organic wastes and reduced chemical fertilizers for improving sugar productivity, generating higher income and sustaining soil health.

REFERENCES

Anonymous (1986). Influence of different kinds of organic manures with NPK fertilizers for improvement of soils. *Ann. Report, SRTI*, pp: 14-42.

Azmal, A. K. M., Marumoto, T., Shindo, H. and Nishiyama, M. (1996a). Mineralization and microbial biomass formation in upland soil amended with some tropical plant residues at different temperatures. *Soil Sci. Plant Nutr.*, **42 (3):** 463-473.

Bair, W. (1990). Characterization of the environment for sustainable agriculture in the semi-arid tropics. In: Sustainable Agriculture

Issues, Perspective and Prospects in Semi-arid Tropics. R. P. Singh, Hyderabad, India, **1:** 90-128.

Bokhtiar, S. M., Paul G. C., Rashid, M.A. and M. Rahman, ABM. (2001). Effect of press mud and inorganic nitrogen on soil fertility and yield of sugarcane grown in High Ganges River Floodplain soils of Bangladesh. *Indian Sugar* LI **(4):** 235-241.

Brookes, P. C., Kragit J. F., Powlson D. S. and Jenkinson D. S. (1985a). Chloroform fumigation and the release of soil nitrogen. The effects of fumigation time and temperature. *Soil Biol. Biochem.*, **17 (6):** 831-835.

Brookes P. C., Landsman, A., Pruden, G. and Jenkinson, D. S. (1985b). Chloroform fumigation and the release of soil nitrogen. A rapid direct extraction method to measure microbial biomass nitrogen in soil. *Soil Biol. Biochem.*, **17 (6):** 837-840.

FAO. Food and Agricultural Organization (2001). Report of the 3rd research Co-ordinator Meeting of the FAO/IAEA Co-ordinated Research Project on Management of Nutrients and Water in Rainfed Arid and Semi-arid Areas for Increasing Crop Production. 24-28 September, Vienna.

Fliessbach, A., Mader, P. and Niggli, U. (2000). Mineralization and microbial assimilation of 14C-labeled straw in soils of organic and conventional agricultural systems. *Soil Biol. Biochem.*, **32:** 1131-1139.

Friedel, J. K., Herrmann, A. and Kleber, M. (2000). Ion exchange resin-soil mixture as a tool in net nitrogen mineralization studies. *Soil Biol. Biochem.*, **32:** 1529-1536.

Hema, S., Singh, S. K., Singh, A. N., Raghubanshi, A.S. and Singh H. (1999). Impact of plant residue quality on the size of the microbial biomass pool and net N-mineralization. *Tropical-Ecol.*, 40: 313-318.

Islam, M. J., Mazid, M. A. and Hossain, A. H. M. D. (1995). Updating Fertilizer Recommendation for sugarcane based cropping pattern. The paper was presented in the workshop on *" Updating Fertilizer Recommendation Guide*" held on 5-7 June, 1995 at BARC, Dhaka.

Islam, M. J., Majid, M. A., Paul, G. C., Bokhtiar, S. M. and Hossain, A. (1998). Integrated effect of organic and inorganic fertilizers on sugarcane production. *Proceedings of the National Workshop on Integrated Nutrient Management for Crop Production and Soil Fertility*, held on 24-25 March 1998, pp: 159-166.

Johnston, A. E. (1994). The efficient use of plant nutrients in Agriculture. Special Publication. International Fertilizer Association. Paris.

Kaur B., Gupta S. R., Malik V. and Agarwal A. K. (1999). Litter quality effects on carbon mineralization, nitrogen release and microbial biomass in forest soil. *J. Plant Biol.*, **26:** 83-91.

Kumar, R. S. and Mishra, D. (1992). Manural value of press mud cake (Ganna-Khai). *Indian Far. Dig.*, **25:** 33-34.

Mathur, G. M. (1997). Effect of long term application of fertilizers and manures on soil properties and yield under cotton-wheat rotation in North-West Rajashtan. *J. Indian Soc. Soil Sci.* **45:** 421-428.

Nira, R. and Nishimune, A. (2000). Nitrogen release and formation of microbial biomass from N15 labeled crop residues in soils under field condition. *Jpn. J. Soil Sci. Plant Nutr.,* **71:** 321-329.

Parthasarathy, S. V. (1972). *Sugarcane in India*. The K. C. P. Ltd., Madras, pp: 332-348.

Paul, G. C., M. J. Islam, and Bokhtiar, S.M. (1999). Efficacy of cake-o-meal-an organic manure on sugarcane yield. *Bangladesh J. Sugarcane*, **21:** 37-40.

Rovira A. D. and Greacen, E. L. (1957). The effect of aggregate disruption on the activity of microorganism in the soil. *Aust. J. Agric. Res.*, **8:** 659-673.

Sarker, M. A. A., Saha, S. C., Rahman, S. B. M. F. and Hoque, M. J. (1983). Effect of press mud on the yield and quality of sugarcane. *Bangladesh J. Sugarcane*, **5:** 20-22.

Singh, K. D. N. (1993). Utilization of press mud cake in sugarcane and reclamation of salt affected calcarious soils of Bihar. *Indian Sugar,* XLIII **(6):** 369-374.

Singh, P. P., Saini, S. K. and Kumar, K. (1995). Response of sugar to organic source and nitroen. *Indian J. Sug. Tech.*, **10:** 24-27.

Singh, T. and Singh, P. N. (2002). Effect of integrated nutrient management on soil fertility status and productivity of sugarcane grown under sugarcane based cropping sequence. *Indian J. Sugarcane Technol.* **17 (1 & 2):** 53-55.

Shukry W. M., El-Fallal A. A. and El-Bassiouny H M. S. (1999). Effect of spent wheat straw on growth, growth hormones, metabolism and rhizosphere of *Cucumis sativus*. *Egypt. J. Physiol. Sc.* 23: 39-69.

Sumner, A. (1999). Handbook of Soil Science. CRC Press, Washington, D. C.

Tiwari, R. J., and Nema, G. K. (1999). Response of sugarcane (*Saccharum officinarum*) to direct and residual effect of pressmud and nitrogen. *Indian J. Agric. Sci.*, **69 (9):** 644-646.

Vance, E. D., Brookes, P. C. and Jenkinson, D. S. (1987). An extraction method for measuring soil microbial biomass C. *Soil Biol. Biochem.*, **19:** 703-707.

Vliet, P. C. J. V., Gupta, V. V. S. R. and Abbott, L. K. (2000). Soil biota and crop residue decomposition during summer and autumn in South Australia. *Appl. Soil Ecol.*, **14:** 111-124.

Yaduvanshi, N. P. S. and Yadav, D. V. (1993). Integrated management of sulphitation press mud with fertilizer nitrogenfor better yield of cane and sugar, nitrogen economy and improving soil properties in sugarcane ratoon. *Indian J. Sugar Tech.*, **8:** 36-40.

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