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Research Paper

Integrated nutrient management in rice (*Oryza sativa*)–sugarcane (*Saccharum officinarum*) (plant)–sugarcane (ratoon) cropping sequence

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ABSTRACT

Field investigation was carried out at Navsari Agricultural University, Navsari to study the integrated nutrient management in rice (*Oryza sativa* L.)–sugarcane (*Saccharum officinarum* L.) (P)–sugarcane (R) cropping sequence during the years 2000 to 2006. For securing higher yield and remuneration in rice - sugarcane (plant)–sugarcane (ratoon) cropping sequence, application of 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer to the rice–sugarcane (plant)–sugarcane (ratoon) cropping sequence not only gave net return and B:C ratio close to that obtained with application of 100% recommended dose of fertilizer as per soil test value or as per general state recommendation but also improved the soil health in terms of positive nutrient balance.

Key words : Cane yield, INM, Organics, Rice grain yield, Rice–sugarcane sequence, Soil properties

Rice is one of the staple food crops of approximately half of the world population. The rice grain is termed as the global grain. It is the most important food crop of India and second most important crop of the world. Similarly, sugarcane is grown extensively in tropical and subtropical regions of the world including India as cash crop. It plays a pivotal role in both agricultural and industrial economy of the country. In India, sugarcane is grown under different agro-climatic conditions and occupies about 4.94 million ha area with an average productivity of 68.6 t/ha. In Gujarat, it is grown only in the southern region and occupies 0.188 million ha with a productivity of 75.7 t/ha (Anonymous, 2012).

Due to adequate rainfall as well as perennial irrigation facilities rice-rice and rice-sugarcane are dominant cropping systems in south Gujarat region. Such system need high doses of fertilizers and frequent irrigation. Indiscriminate prolonged use of chemical fertilizers causes soil and plant health problems resulting in poor yields. The ill effects of fertilizers and over irrigation are accepted by the scientific community world over. Continuous use of heavy doses of fertilizers and plant protection chemicals potentially impair the soil microbial activity, leading to poor soil health (Singh *et al.*, 2007).

It is recognized fact that neither chemical fertilizers nor organic manures alone can be used for sustainable crop production. At present, when sustainability of the crop and soil productivity is the burning issue, the integrated use of organics and inorganics needs to be emphasized to use nutrient and energy more efficiently than conventionally managed system (Mader *et al*., 2002; Blaise and Prasad, 2005). In this context, judicious integration of organic and inorganic sources of nutrient can play an important role looking to sustainable crop production. Keeping this in view, the present investigation was proposed to find out the proper integrated nutrient management in rice - sugarcane (plant) - sugarcane (ratoon) cropping sequence.

MATERIALS AND METHODS

Field investigation was carried out to study the integrated nutrient management in rice–sugarcane (plant)–sugarcane (ratoon) cropping sequence in *Vertic Ustochrepts* of south Gujarat during 2000–2006 at Navsari Agricultural University, Navsari. Sugarcane (plant) and sugarcane (ratoon) are abbreviated as sugarcane (P) and sugarcane (R). The soil of experimental at field was heavy black containing 0.46 % organic carbon, 243 kg/ha available N, 17.2 kg/ha available P and 303.4 kg/ha available K. The twelve treatments *viz.*, 100% N through FYM, 75% N through FYM + 25% N through castor cake/ *Azolla*, 50% N through FYM + 50% N through castor

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cake/*Azolla*, 25% N through FYM + 75% N through castor cake/*Azolla*, 100% N through castor cake/*Azolla*, 25% N through organics of which 50% N through each from FYM and castor cake/*Azolla* + 75% N through inorganic fertilizer, 50% N through organics of which 50% N through each from FYM and castor cake/*Azolla* + 50% N through inorganic fertilizer, 75% N through organics of which 50% N through each from FYM and castor cake/*Azolla* + 25% N through inorganic fertilizer, 25% N through FYM + 25% N through poultry manure + 50% N through castor cake/*Azolla*, 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer, 100% NPK as per soil test through inorganic fertilizers and 100% general state RDF through inorganic fertilizers were tested in randomized block design with three replications. Rice 'Jaya' was sown at 20cm × 15cm spacing with 30 kg/ha seed rate. Sugarcane 'CoN 91132' was planted in rows at 90 cm apart with seed rate of 35,000 three eyes budded setts/ha. The manuring was done as per the treatments. The treatment receiving inorganic fertilizers *i.e.*, N, P and K were applied through urea, single super phosphate and muriate of potash respectively, in both crops. *Azolla* was applied to paddy crop and castor cake was used in sugarcane crop. Recommended dose of fertilizer for rice is 120-13-0 kg/ha and sugarcane plant crop is 250-55-105 and 300-27.3-105 kg NPK/ha for ratoon crop.

The crop was managed as per recommended package of practices. During first cycle of rice–sugarcane (P) – sugarcane (R), the rice crop was sown during the third week of June 2000 and harvested in the first week of November 2000; sugarcane (P) was planted during the last week of November 2000 and harvested at second week of January 2002 while, sugarcane (R) ratooning was done in the third week of January 2002 and harvested in the third week of January 2003. During second cycle of rice–sugarcane (P)–sugarcane (R), the rice crop was sown during the first week of June 2003 and harvested in the third week of October 2003; sugarcane (P) was planted during the first week of January 2004 and harvested in the last week of January 2005 while, sugarcane (R) ratooning was done in the second week of February 2005 and harvested in the first week of February 2006. The average rainfall received during six years of experimental period was 1628 mm in 52 rainy days. The mean minimum and maximum temperatures were 21.4 and 37.1°C, respectively.

Growth parameters, yield attributes, yield and nutrient uptake obtained from rice and sugarcane (plant and ratoon) crop for consecutive two years were statistically analyzed using the *f* test. The net realization was calculated by deducting the total cost of cultivation from the gross realization for each treatment. The benefit cost ratio (BCR) was then calculated.

RESULTS AND DISCUSSION

Rice

Significantly higher plant height (120 cm) and effective tillers/m^2 (286) were recorded with 100% RDF (T_{12}), which also resulted in increased grain (5.74 t/ha) and straw yield (7.74 t/ha). However, it was at par with application of 25% N through organics of which 50% N was through each from FYM and *Azolla* + 75% N through inorganic fertilizer 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer and 100% NPK as per soil test through inorganic fertilizers for grain yield. Thus, proper integration of organic and inorganic fertilizers recorded yield and yield attributes, which are comparable to inorganic fertilizers alone. It could be ascribed to the slow release of nutrients from organics ensuring continuous supply of nutrients, without much losses of nitrogen as in the case of nitrogenous fertilizer (Pathak *et al*., 2009). Moreover, organics, besides supplying macro also supply micro nutrients and have also solubilizing effect on native soil nutrients due to the action of organic acids produced during decomposition (Pandey *et al*., 2007 and Tripathi *et al.*, 2009). Similarly, (Chaudhary *et al*. 2011) also reported the beneficial effect of integration of organic and inorganic fertilizer over inorganic fertilizer alone.

Plant and ratoon sugarcane

Sugarcane yield of plant as well as ratoon crop were influenced significantly during experimental period due to different nutrient management practices in the rice–sugarcane (P)–sugarcane (R) cropping system (Table 1). Cane length, number of millable cane and cane yield were significantly higher (222 cm, 112 and 101.3 t/ha, respectively) in the treatment fertilized with 100% NPK as per soil test through inorganic fertilizers which was on par with the treatments fertilized with 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer, 25% N through FYM + 25% N through poultry manure + 50% N through castor cake, 75% N through FYM + 25% N through castor cake, 50% N through FYM + 50% N through castor cake and 100% RDF in plant crop. The increase in growth and yield attributes in the treatment having application of 100% NPK as per soil test through inorganic fertilizers resulted in significantly higher cane yield (101.3 t/ha), which was found at par with application of 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer and 100% RDF in plant crop.

As per the ratoon crop, application of 25% N through FYM + 25% N through poultry manure + 50% N through

Table 1. Effect of different treatments on growth parameters, yield attributes and yield of rice and sugarcane (Pooled data of two cycle)

Treatment	Rice				Sugarcane					
					Plant crop			Ratoon crop		
	Plant height (cm)	Effective tillers/m^2	Grain yield (t/ha)	Straw yield (t/ha)	Cane length (cm)	No. of millable canes ($\times10^3$/ha)	Cane yield (t/ha)	Cane length (cm)	No. of millable canes ($\times10^3$/ha)	Cane yield (t/ha)
100% N through FYM	110	273	4.80	6.07	195	92	83.0	145	60	42.4
75% N through FYM + 25% N through castor cake or *Azolla*	100	264	4.43	5.47	208	101	91.5	148	63	44.5
50% N through FYM + 50% N through castor cake or *Azolla*	97	257	4.08	4.87	207	102	91.6	152	66	47.0
25% N through FYM + 75% N through castor cake or *Azolla*	92	251	3.69	4.69	197	96	86.8	160	71	49.4
100% N through castor cake or *Azolla*	90	248	3.37	4.37	196	92	83.6	159	71	48.8
25% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 75% N through inorganic fertilizer	117	280	5.33	6.71	200	98	88.2	148	63	44.0
50% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 50% N through inorganic fertilizer	113	275	4.94	6.29	204	100	89.5	150	64	44.6
75% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 25% N through inorganic fertilizer	106	269	4.51	5.92	204	99	89.4	156	68	47.9
25% N through FYM + 25% N through poultry manure + 50% N through castor cake or *Azolla*	95	256	4.02	5.06	210	107	93.9	165	75	51.2
25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer	115	279	5.29	6.47	215	110	97.4	154	67	46.1
100% NPK as per soil test through inorganic fertilizers	119	282	5.50	7.69	222	112	101.3	155	67	46.3
100% RDF through inorganic fertilizers	120	286	5.74	7.74	214	107	95.0	150	66	45.7
SEm±	3.5	2.8	0.22	0.21	5.6	3.8	4.0	2.0	2.3	1.2
CD (P=0.05)	10	8	0.69	0.60	15	11	11.4	6	7	3.4

Note: *Azolla* for rice and castor cake for sugarcane

castor cake gave significantly longer canes (165 cm) and number of millable cane (75), which resulted in significantly higher ratoon yield (51.2 t/ha), which was at par with the application of 75% N through organics of which 50% N was through each from FYM and castor cake + 25% N through inorganic fertilizer (47.9 t/ha), 25% N through FYM + 75% N through castor cake (49.4 t/ha) and 100% N through castor cake (48.8 t/ha). The lowest plant and ratoon cane yield were obtained from the treatment with application of 100% N through FYM. The positive response to combined application of organics and inorganics may be attributed to the better nutrient availability and its favourable effect on soil physical and biological properties resulting in increased yield attributes and finally the yield. These results are in close agreement with the observation with Chaudhary *et al.* (2011).

Nutrient uptake

The pooled data on NPK contents in grain and straw of rice as well as in sugarcane plant and ratoon crop showed non significant differences due to various nutrient management treatments. Among the integrated use of fertilizers, significantly higher total N (89.5 kg/ha), P (14.1 kg/ha) and K (111.9 kg/ha) uptake was recorded with the application of 100% RDF through inorganic fertilizers. Regarding total uptake of N and K, 100% RDF through inorganic fertilizers was found at par with the application 100% NPK as per soil test through inorganic fertilizers and 25% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 75% N through inorganic fertilizer while total uptake of P, application 100% RDF through inorganic fertilizers remained at par with the application 100% NPK as per soil test through inorganic fertilizers.

Total uptake of N and K by sugarcane plant crop did not differ significantly due to various treatments. On the other hand, total P uptake was found significantly higher (26.3 kg/ha) with 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer (T_{10}), which

Table 2. Effect of different treatments on uptake of NPK (kg/ha) by rice, sugarcane (P*) and sugarcane (R) crops (Pooled over two years)

Treatment	Rice									Sugarcane					
	N			P			K			Plant crop			Ratoon crop		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	N	P	K	N	P	K
100% N through FYM	40.2	30.7	70.9	6.2	4.9	11.1	12.7	71.4	84.1	99.7	20.3	108.4	56.9	16.0	86.0
75% N through FYM + 25% N through castor cake or *Azolla*	38.1	30.7	68.8	5.8	4.2	10.0	11.1	65.3	76.4	100.2	24.3	123.0	48.9	15.6	74.4
50% N through FYM + 50% N through castor cake or *Azolla*	34.0	26.0	60.0	5.1	3.7	8.8	10.3	59.0	69.3	107.2	23.9	122.4	50.9	14.7	72.7
25% N through FYM + 75% N through castor cake or *Azolla*	29.2	24.1	53.4	5.2	3.5	8.7	9.5	52.1	61.6	98.0	24.0	116.0	58.8	16.4	84.3
100% N through castor cake or *Azolla*	26.7	22.4	49.0	4.6	3.1	7.7	8.4	47.6	56.0	92.2	19.0	103.7	60.4	18.2	92.9
25% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 75% N through inorganic fertilizer	48.8	33.9	82.7	7.1	5.0	12.1	13.5	87.2	100.7	99.6	23.6	109.4	50.8	15.3	78.3
50% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 50% N through inorganic fertilizer	41.8	30.5	72.2	6.8	4.5	11.3	12.5	79.7	92.2	106.6	22.3	120.2	57.7	17.3	82.8
75% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 25% N through inorganic fertilizer	36.1	30.7	66.8	6.2	4.1	10.3	11.6	68.4	80.1	109.1	25.9	120.7	53.6	15.8	75.1
25% N through FYM + 25% N through poultry manure + 50% N through castor cake or *Azolla*	30.7	25.1	55.8	5.6	3.2	8.8	10.9	64.3	75.2	110.0	25.4	118.9	56.9	17.4	82.4
25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer	43.8	33.6	77.4	6.9	4.7	11.6	13.5	82.4	95.8	110.4	26.3	120.5	60.5	17.6	85.4
100% NPK as per soil test through inorganic fertilizers	45.7	38.9	84.6	7.9	5.8	13.7	14.2	95.6	109.8	111.3	25.2	119.8	56.0	17.1	80.6
100% RDF through inorganic fertilizers	49.4	40.1	89.5	8.2	5.9	14.1	14.7	97.2	111.9	116.2	24.3	121.2	54.7	16.2	78.9
SEm ±	3.4	1.8	3.1	0.5	0.3	0.6	0.4	4.7	4.9	7.3	1.4	8.8	2.6	0.7	3.8
CD (P=0.05)	10.7	5.0	8.7	1.4	0.8	1.7	1.2	13.4	13.9	NS	4.1	NS	7.5	2.1	10.7

was at par with all other treatments except application of 100% N through FYM (T_1).

In sugarcane ratoon crop, significantly higher N uptake (60.5 kg/ha) was recorded with 25% N through FYM + 25% N through Poultry manure + 50% N through inorganic fertilizer (T_{10}), which was at par with all other treatments except application 75% N through FYM + 25% N through castor cake or *Azolla;* 50% N through FYM + 50% N through castor cake or *Azolla* and 25% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 75% N through inorganic fertilizer. With respect to total uptake of P and K, application of 100% N through castor cake recorded higher value of 18.1 kg P/ha and 92.9 kg K/ha, respectively. Increased nutrient uptake with combined application of organic manures might be due to consistent supply of nutrients and reduced rate of loss of released nutrients during the process of decomposition of organic manures and also due to improved root growth and its functional activity which helped in greater extraction of nutrient.

Soil nutrient status

After completion of two rice - sugarcane (P)–sugarcane (R) crop sequences, the soil samples were collected for various determinations. All the treatments having organics and integration of organics with inorganics showed the built up of organic carbon and available nitrogen as compared to initial organic carbon and available nitrogen status of soil (Table 3). However, treatments having only inorganic application of fertilizer reduced the soil organic carbon. With respect to available P status in soil, all the treatments found improvement than initial status of available P in soil except plots fertilized with 100% NPK as per soil test through inorganic fertilizers and application of 100% RDF through inorganic fertilizers. The positive soil N and P balance observed in plot receiving organic manures or organics plus inorganics at the end of rice–sugarcane (P)–sugarcane (R) cycle may be attributed to the richness of these sources in terms of organic matter and enhance microbial activity. Available K status in soil was improved in the application 75% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 25% N through inorganic fertilizer; 25% N through FYM + 25% N through poultry manure + 50% N through castor cake or *Azolla;* 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer and 25% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 75% N through inorganic fertilizer as compared to

Table 3. Effect of different treatments on fertility status of soil after completion of rice – sugarcane (P) – sugarcane (R) crop sequences with economics.

Treatment	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Total income (×10³/ha)	Total cost (×10³/ha)	Net return (×10³/ha)	Benefit : cost ratio
100% N through FYM	0.54	253	20.1	292.4	206.3	111.0	95.3	0.86
75% N through FYM + 25% N through castor cake or *Azolla*	0.53	251	20.4	291.6	217.8	115.6	102.2	0.88
50% N through FYM + 50% N through castor cake or *Azolla*	0.52	250	20.3	298.3	218.6	120.2	98.4	0.82
25% N through FYM + 75% N through castor cake or *Azolla*	0.52	249	20.9	296.6	212.8	124.8	87.9	0.70
100% N through castor cake or *Azolla*	0.53	247	19.8	290.8	205.3	129.3	76.0	0.59
25% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 75% N through inorganicfertilizer	0.52	245	18.1	306.7	219.5	86.2	133.3	1.55
50% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 50% N through inorganic fertilizer	0.52	247	18.2	296.6	219.2	97.6	121.7	1.25
75% N through organics of which 50% N through each from FYM and castor cake or *Azolla* + 25% N through inorganic fertilizer	0.53	248	19.2	315.1	220.6	108.2	112.3	1.04
25% N through FYM + 25% N through poultry manure + 50% N through castor cake or *Azolla*	0.55	250	17.9	319.3	227.2	112.1	115.1	1.03
25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer	0.52	247	20.3	310.1	234.3	84.8	149.5	1.76
100% NPK as per soil test through inorganic fertilizers	0.44	242	16.8	261.3	238.5	81.6	156.9	1.92
100% RDF through inorganic fertilizers	0.43	240	17.8	266.4	234.7	82.3	152.4	1.85
Initial	0.46	243	17.2	303.4				

Prevailing prices of inputs

FYM	0.30/kg	AS	6.72/kg
Castor cake	4.80/kg	SSP	3.30/kg
Poultry manure	0.40/kg	MOP	4.40/kg
Azolla green	2.00/kg	Urea	5.00/kg

Prevailing prices of produce

Rice grain	5.93/ kg
Rice straw	1.20/ kg
Sugarcane	1360/ ton

the initial status. However, higher depletion of available K was recorded in the treatments fertilized with 100% NPK as per soil test through inorganic fertilizers and application of 100% RDF through inorganic fertilizers. Positive balance of major nutrient in soil at the end of rice–sugarcane (P)–sugarcane (R) cycle might be due to soil fertility enriching effect of various organics.

Economics

As far as economics of rice–sugarcane (P)–sugarcane (R) crop sequence is concerned (Table 3), the maximum net income (₹156920/ha) and B:C ratio (1.92) was secured when the crops were fertilized with 100% NPK as per soil test value through inorganic fertilizes, and was closely followed by 100% RDF through inorganic fertilizers 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer.

Application of 25% N through FYM + 25% N through poultry manure + 50% N through inorganic fertilizer to the rice–sugarcane (P)–sugarcane (R) cropping sequence not only gave net return and B:C ratio very close to that obtained with 100% recommended dose of fertilizer as per soil test value or as per general state recommendation but also improved the soil health in terms of positive nutrient balance.

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