Indian Journal of Agronomy **52** (1) : 16–20 (March 2007)

Balance-sheet of soil nitrogen in rice (*Oryza sativa*) - based cropping systems under integrated nutrient management

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Received : July 2006

ABSTRACT

A field experiment was conducted at Rice Research Station, Kayamkulam, Alappuzha in Kerala to assess the impact of integrated nutrient management (INM) on four rice (*Oryza sativa* L.)-based cropping systems, comprising rice during the rainy (*kharif*) and winter (*rabi*) seasons; and four different crops during the summer season, in terms of their productivity, effect on the organic carbon of soil and nitrogen balance. Inclusion of legumes in the cropping system and integrated nutrient management improved the organic carbon status of the soil. The crop sequences rice-rice-cowpea [*Vigna unguiculata* (L.) Walp.] and rice-rice-groundnut (*Arachis hypogaea* L.) showed a positive nitrogen balance in the soil, the maximum being after rice-rice-groundnut crop sequence. The crop sequences rice-rice-sesame (*Sesamum indicum* L.) and rice-rice-okra (*Abelmoschus esculentus* L.) reduced the available nitrogen status of the soil. Integration of nutrient sources made the predominant rice-rice-sesame cropping sequence more productive in the sandy-loam soil. Inclusion of groundnut and cowpea in rice-based crop sequences increased the yield of the succeeding crop of rice.

Key words : Integrated nutrient management, Cropping systems, Nitrogen balance

Rice (*Oryza sativa* L.) is a component of widely varying cropping systems. Rice-based cropping systems form an integral part of agriculture in Kerala. Several intensive rice-based cropping systems have been identified and are being practised by the farmers (KAU, Thrissur, 1989). While intensive agriculture, involving exhaustive high yielding varieties of rice and other crops, has led to heavy withdrawal of nutrients from the soil, imbalanced and indiscriminate use of chemical fertilizers has resulted in deterioration of soil helath (John *et al.,* 2001) in the marginal soils. The sandy-loam tract of Kerala (the Onattukara tract), in spite of being designated as a problem zone (KAU, Thrissur 1989), was once a major contributor to the state's rice production. However, this tract is facing the threat of stagnating rice yields (Padmaja *et al.,* 1993). This sort of a decline or stagnation in yields has been attributed to nutrient mining and reduced use of organics, which can be curbed only through an integrated approach involving inorganics and bio-organic resources (Gaur and Singh, 1982). Integration of organic soruces such as vermicompost (Ranwa and Singh, 1999), farmyard manure (Patra *et al.,* 1998) and bio-fertilizers like *Azospirillum* (Arumugam *et al.,* 1992) may also help in the restoration of soil health. Further, measures have to be sourght to identify suitable rice-based cropping systems, that can stimulate stability in production. Balance-sheet of major nutrients like nitrogen in the soil could be used for the judicious application of nutrients to crop sequences. Keeping these points in view, an experiment was conducted to assess the impact of various rice-based cropping systems managed under integrated nutrient management (INM) on the soil health, in terms of the organic carbon content and soil-nitrogen balance.

MATERIALS AND METHODS

The field experiment was conducted at Rice Research Station, Kayamkulam, Alappuzha in Kerala during the rainy (*kharif*), winter (*rabi*) and summer seasons of 2000-01 and 2001-02. The soil was sandy loam, acidic in reaction (pH 5.2), low in available nitrogen (172 kg/ha), medium in available phosphorus (17 kg/ha) and low in available potassium (62 kg/ha), with organic carbon content 0.4 per cent. The experiment was laid out in strip-plot design with four cropping systems in horizontal strips, viz. C_1, 'Red Triveni' rice (semi-dry)-'Dhanya' rice (transplanted)-'Tilak' sesame; C_2, rice–rice-'TG 3' groundnut; C_3, Rice-rice-'Kanakamoni' cowpea; C_4, rice–rice-'Arka Anamika' okra); and six levels of nutrient management in vertical strips. Nitrogen was used for designing the levels of substitution with various bio-organic sources. The six integrated nutrient-management (INM) treatments tested were: N_1, farmer's practice for all crops; N_2, KAU package of practices for all crops; N_3, ¾ recommended dose of nitrogen as chemical + ¼ as farmyard manure (FYM) for rice crops and KAU package of practices for summer crop; N_4, ¾ recommended dose of nitrogen as chemical + ¼ as farmyard manure (FYM) + *Azospirillum* for rice crops and KAU package of practices for summer crop; N_5, ¾ recommended dose of nitrogen as chemical + ⅛ as FYM + ⅛ as vermicompost + *Azospirillum* for rice and KAU package of practices for summer crop. The treatments were replicated four times. The details regarding the farmer's practice and the KAU package recommendations for the individual crops are given in Table 1.

The farmyard manure used for the study analysed to contain 0.35 per cent N, 0.60 per cent, P_2O_5 and 0.24 per cent K_2O; vermicompost contained 1.60 per cent N, 0.76 per cent P_2O_5 and 2.71 per cent K_2O, and poultry manure contained 1.25 per cent N, 1.42 per cent P_2O_5 and 0.83 K_2O.

The soil was analysed for organic carbon and nitrogen after the first and second years of study. The nitrogen balance-sheet of the soil was worked out by adopting the method suggested by Palaniappan (1985). Subtraction of the total quantity of nutrients removed by the crops in a sequence from that added by fertilizers and soil gave the computed balance of soil nitrogen. The actual balance of nitrogen is indicated by the available nitrogen status of the soil. The balance-sheet of nitrogen was arrived at by subtracting the computed balance from the actual balance. A positive balance indicates soil storage and a negative balance indicates depletion.

RESULTS AND DISCUSSION

Organic carbon content of soil

The organic carbon status of the soil (Table 2) increased after all the crop sequences tested, the maximum being after cowpea in the rice-rice-cowpea sequence and the minimum after sesame in the rice-rice-sesame sequence. Singha *et al.* (1993) also reported increase in the organic carbon content of the soil in the rice-based cropping systems involving cowpea. Such an increase in the organic carbon content is attributed to the accumulation of root residues and shedding of leaves by the leguminous crops (Thakur and Sharma, 1988). Another possible reason for the build up of organic carbon following cowpea is the application of farmyard manure @ 20 tonnes/ha as per the recommendations of KAU package of practices (Table 1) for the crop. Nambiar (1994) also reported increase in the organic carbon content due to the application of farmyard manure.

Table 2. Effect of cropping systems and nutrient management on productivity of first crop rice and on organic carbon content of soil

Treatment	Productivity of first crop of rice (kg/ha)		Organic C content (%) of soil after experiment	
	I Year	II Year	I Year	II Year
Cropping systems				
C_1 : Rice-rice-sesame	2,736	2,250	0.427	0.426
C_2 : Rice-rice-groundnut	2,671	2,832	0.443	0.444
C_3 : Rice-rice-cowpea	2,687	2,806	0.465	0.466
C_4 : Rice-rice-*okra*	2,708	2,736	0.443	0.441
CD (P=0.05)	NS	238	0.007	0.006
Nutrient management				
N_1	1,674	1,678	0.413	0.412
N_2	2,439	2,198	0.450	0.450
N_3	2,474	2,506	0.451	0.450
N_4	2,872	2,834	0.449	0.450
N_5	3,144	3,154	0.451	0.451
N_6	3,608	3,564	0.452	0.452
CD (P=0.05)	130	121	0.009	0.009

The effect of nutrient-management levels on the cropping systems indicated a positive change in the organic cabron content of the soil though the treatments N_2 to N_6 which received optimal doses of nutrients along with organics or bio-fertilisers. The treatment N_1 (farmer's practice) recorded a slight decrease in the organic carbon content over the initial soil status, because this practice involved the application of nutrients and organic manure at suboptimal doses. Nambiar (1994) concluded that intensive cultivation decreases the organic carbon content of the soil, especially at suboptimal doses of NPK and farmyard manure. Thus INM was instrumental in building up

Table 1. KAU pacakge of practices recommendations and farmer's practice for the component crops

Crop	KAU package of practrices recommendations	Farmers' practice
Rice (first crop)	FYM 5 t/ha ; NPK 70: 35:35 kg/ha	FYM 3 t/ha; NPK 36 : 11 : 22 kg/ha
Rice (second crop)	FYM 5 t/ha ; NPK 60: 30:30 kg/ha	FYM 3 t/ha; NPK 30 : 10 : 32 kg/ha
Sesame	FYM 5 t/ha ; NPK 30: 15:30 kg/ha	FYM Nil; NPK Nil
Groundnut	FYM 2 t/ha ; Lime 1 t/ha; NPK 10: 75:75 kg/ha	FYM Nil; NPK Nil
Cowpea	FYM 20 t/ha ; NPK 20: 30:10 kg/ha	FYM Nil; NPK Nil
Okra	FYM 12 t/ha ; NPK 25: 8:25 kg/ha	FYM 6 t/ha; poultry manure 1 t/ha

the organic carbon content of the soil.

Balance-sheet of available N

The crop sequence of rice-rice-sesame and rice-rice-okra showed a loss in the soil nitrogen after 2 years of study (Table 5). On the contrary, the rice-rice-groundnut and the rice-rice-cowpea crop sequences were found to improve the soil-nitrogen status. The gain in the available nitrogen was 72.19 kg/ha and 48.32 kg/ha during the first year and 86.65 kg/ha and 22.70 kg/ha after the second year for the rice-rice-groundnut and rice-rice-cowpea sequences respectively. Legumes make less demand on the soil resources and at the same time they have the capacity to fix atmospheric nitrogen in their root nodules. The results support the findings of Singh *et al.* (1996).

Rice-rice-sesame is the most predominant cropping sytem followed by the farmer's practice in the sandy-loam tract. However, this sequence was observed to have a negative impact on the soil-nitrogen status. The substitution of chemical nitrogen applied to rice with vermicompost and the application of *Azospirillum* resulted in a positive balance for available nitrogen, as evidenced in the treatments N_5 and N_6 in the crop sequence rice-rice-sesame. Further, the negative trend in the balance-sheet of soil nitrogen decreased from the first year (–29.70 kg/ha) to the second year (–9.38 kg/ha). This shows clearly that the rice-rice-sesame cropping system can be modified into a sustainable one through the proper integration of organic, biological and inorganic nutrient sources. Application of vermicompost improves the activity of nitrogen-fixers like *Azospirillum* (Kale, 1992). This may be the reason for the decrease in negativity in the soil-nitrogen balance in the treatment that integrated vermicompost and *Azospirillum.*

The actual balance of soil nitrogen was higher than the computed balance in the crop sequences rice-rice-groundnut and rice-rice-cowpea, and opposite in the other two sequences. Thus irrespective of whether the balance-sheet was positive or negative, there existed some amount of unaccountable nitrogen. Crop rotations with legumes and integration of nutrient sources improve the multiplication of microbes, which could convert the organically bound nitrogen to inorganic forms (Das *et al.*, 2004). Further, high mobility of nitrogen and its rapid loss through leaching, volatilization and denitrification can also be responsible for the unaccountability of nitrogen in the balance-sheet.

The yield of rice succeeding cowpea and groundnut increased (Tables 2, 3), whereas of that which followed sesame decreased. Kumar *et al.* (1993) reported similar results, pointing out the superiority of cowpea and groundnut in increasing the yield of the succeeding crop of rice. They also observed a reduction in the yield of rice grown after sesame. Goplakrishna *et al.* (1971) attributed such a reduction after sesame to the complex nature of its nutrition.

Nitrogen uptake

Integrated nutrient management showed positive influence on the uptake of N in the four cropping sequences

Table 3. Effect of treatments on yield of component crops

Cropping system	Yield (kg/ha)													
	N_1		N_2		N_3		N_4		N_5		N_6		Mean	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
Rice -	1,696	1,192	2,463	1,933	2,517	2,119	2,932	2,408	3,202	2,763	3,609	3,083	2,736	2,250
rice -	1,800	1,915	2,773	3,027	2,961	3,100	3,223	3,293	3,424	3,517	3,543	3,842	2,954	3,116
sesame	246	236	348	322	359	371	433	421	463	440	467	437		
Rice -	1,737	1,967	2,446	2,481	2,477	2,720	2,757	2,870	3,041	3,247	3,571	3,705	2,671	2,832
rice -	1,703	2,109	2,561	2,927	2,646	3,026	3,173	3,607	3,675	3,717	3,759	3,887	3,920	3,222
groundnut	918	902	1,093	1,077	1,062	1,109	1,053	1,192	1,385	1,455	1,392	1,468		
Rice -	1,545	1,746	2,435	2,155	2,451	2,677	2,897	3,088	3,226	3,416	3,569	3,752	2,687	2,806
rice -	1,488	1,854	2,283	2,646	2,348	2,762	3,115	3,514	3,547	3,640	3,606	3,720	2,731	3,023
cowpea	314	315	507	510	5,444	553	588	592	607	612	598	604		
Rice -	1,719	1,807	2,414	2,222	2,451	2,509	2,903	2,972	3,108	3,191	3,658	3,714	2,708	2,736
rice -	1,670	1,898	2,634	2,872	2,761	2,933	3,203	3,456	3,656	3,656	3,732	3,798	2,942	3,094
okra	5,644	5,613	6,681	6,652	6,745	6,943	7,190	6,848	7,242	6,897	7,422	6,898		
CD (P=0.05)		First crop rice		:		I year			II year		190.7			
		Second crop rice		:		I year	186.9		II year		204.1			
		Sesame		:		I year	50.0		II year		32.5			
		Groundnut		:		I year	163.3		II year		223.4			
		Cowpea		:		I year	61.7		II year		59.4			
		Okra		:		I year	865.5		II year					

Yield expressed: Rice, grian yield; sesame, seed yield.; groundnut, pod yield; cowpea, grain yield; okra, fruit yield

Table 4. Effect of treatments on nitrogen uptake by component crops

Cropping system	Nitrogen uptake (kg/ha)													
	N_1		N_2		N_3		N_4		N_5		N_6		Mean	
	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
Rice-	50.6	35.9	54.2	42.8	54.7	46.7	64.1	52.5	67.1	60.0	73.7	65.6	60.7	50.8
rice-	67.4	72.7	95.4	104.5	102.2	107.0	106.2	108.5	106.9	110.9	103.3	114.0	96.9	103.3
sesame	11.3	10.1	13.7	13.2	14.1	14.5	16.2	16.3	17.2	16.8	18.0	17.3	15.1	14.7
Total	129.3	118.8	163.3	160.5	171.0	168.2	186.5	177.3	191.2	187.7	195.0	196.9	172.7	168.8
Rice-	55.6	61.6	54.1	54.8	54.0	58.8	64.3	60.3	65.2	68.4	74.5	74.5	61.3	63.1
rice-	64.2	80.6	87.3	105.1	91.7	106.6	104.2	121.3	114.9	121.0	109.8	118.5	95.4	109.2
groundnut	66.3	62.1	74.3	75.3	76.7	77.6	76.1	83.4	100.2	101.8	100.5	102.0	82.3	83.9
Total	186.1	203.3	215.7	235.2	222.4	243.0	244.6	265.0	280.3	291.2	284.8	295.0	239.0	256.2
Rice-	49.5	55.0	52.3	47.4	52.9	58.1	65.0	66.3	67.8	72.2	71.3	75.2	59.8	62.2
rice-	56.4	73.2	77.9	97.8	80.2	90.3	102.6	123.3	110.9	119.4	106.5	114.8	89.4	104.4
cowpea	22.1	21.4	34.6	32.5	35.0	35.7	36.9	38.1	39.1	39.5	39.1	39.1	34.3	34.3
Total	128.0	149.6	164.8	177.7	169.1	192.1	204.5	227.7	217.8	231.1	216.9	229.1	183.5	200.9
Rice-	55.6	58.8	50.9	50.4	52.8	55.1	64.4	63.5	64.6	67.5	73.1	74.4	60.6	61.6
rice-	62.6	71.0	90.6	102.0	95.4	102.1	105.2	112.4	114.3	116.1	109.3	113.8	96.3	103.0
okra	17.3	16.7	20.5	19.8	21.2	20.2	22.6	20.7	23.0	20.9	24.2	21.4	21.5	20.0
Total	135.5	146.5	162.0	172.2	169.4	177.4	192.2	196.6	201.9	204.5	206.6	209.6	178.4	184.6
CD (P=0.05)	First crop rice		:		I year			II year		4.74				
	Second crop rice		:		I year		6.53	II year		7.68				
	Third season crops		:		I year		4.49	II year		8.03				

Table 5. Balance-sheet of available nitrogen (kg/ha) in soil as influenced by cropping sequence and nutrient management

Cropping system	Nutrient management	Addition of N (kg/ha)		Removal of N (kg/ha)		Computed balance of N (kg/ha)		Actual balance of N (kg/ha)		Net loss or gain in N (kg/ha)	
		I year	II Year	I year	II Year	I year	II Year	I year	II Year	I year	II Year
C_1: Rice-	N_1	258.1	171.6	129.3	118.7	128.8	52.9	85.8	89.9	–43.1	+37.1
rice-	N_2	384.8	416.9	163.3	160.5	221.5	256.4	204.4	259.1	–17.1	+2.6
sesame	N_3	384.8	405.6	171.0	168.2	213.8	237.5	193.1	220.9	–20.7	–16.6
	N_4	384.8	389.6	186.5	177.3	198.3	212.3	177.1	192.1	–21.2	–20.2
	N_5	384.8	384.9	191.2	187.7	193.6	197.2	172.4	179.2	–21.2	+18.0
	N_6	384.8	347.4	195.0	196.9	189.8	150.5	134.9	109.3	–54.9	+41.2
Mean		363.7	352.7	172.7	168.2	191.0	184.5	161.3	175.1	–29.7	–9.4
C_2: Rice	N_1	258.1	208.0	186.1	203.3	72.0	4.7	122.2	173.1	+50.2	+168.4
rice-	N_2	354.3	398.6	215.7	235.2	138.6	163.4	216.6	237.0	+78.0	+73.4
groundnut	N_3	354.3	375.8	222.4	242.9	131.9	132.8	193.8	201.8	+61.8	+68.9
	N_4	354.3	353.3	244.6	264.9	109.7	88.4	171.3	162.1	+61.6	+73.7
	N_5	354.3	327.3	280.3	291.2	74.1	36.1	145.3	118.1	+71.3	+81.9
	N_6	354.3	361.7	284.8	295.0	69.5	66.7	179.7	120.1	+110.2	+53.3
Mean		339.5	337.5	239.0	255.4	99.3	82.0	171.5	168.7	+72.2	+86.7
C_3: Rice-	N_1	258.1	229.6	128.0	149.6	130.1	80.1	143.8	105.5	+13.7	+25.5
rice-	N_2	427.3	583.4	164.8	177.7	262.5	405.7	328.4	416.9	+65.9	+11.1
coewpea	N_3	427.3	566.4	169.0	192.1	258.2	374.3	311.4	391.4	+53.2	+17.1
	N_4	427.3	532.0	204.5	227.7	222.8	304.3	277.0	331.5	+54.2	+27.2
	N_5	427.3	523.7	217.8	231.1	209.6	292.6	268.7	324.6	+59.2	+31.9
	N_6	427.3	509.4	216.9	229.1	210.5	280.2	254.4	303.6	+43.9	+23.3
Mean		338.3	490.7	183.5	201.2	215.6	289.5	263.9	312.2	+48.3	+22.7
C_4: Rice-	N_1	290.9	254.7	135.5	146.5	155.4	108.2	136.1	108.7	–19.4	+0.5
rice-	N_2	429.3	527.4	162.0	172.2	267.4	355.2	270.4	334.7	+3.0	–20.5
okra	N_3	429.3	505.2	169.4	177.4	259.9	327.8	248.2	303.4	–11.7	–24.4
	N_4	429.3	483.6	192.2	196.6	237.1	287.0	226.6	250.9	–10.5	–36.1
	N_5	429.3	479.5	201.9	204.5	227.4	275.0	222.5	238.2	–4.9	–36.8
	N_6	429.3	448.0	206.6	209.6	222.7	238.4	191.0	182.2	–31.8	–56.2
Mean		406.3	449.7	177.9	184.4	228.3	265.3	215.8	236.4	–12.6	–28.9

(Table 4). The maximum uptake was recorded with combined application of chemical, organic and bio-fertilizer (¾ recommended dose of N as chemical + $^1/_8$ as FYM + $^1/_8$ as vermicompost + *Azospirillum*). The rice-rice-groundnut sequence recorded significantly high N uptake during the first year (239 kg/ha) and second year (256.2 kg/ha). Among the four summer crops, groundnut recorded the maximum uptake of N and sesame recorded the minimum. Higher availability of nutrients under INM might have improved the physiological and metabolic functions inside the crops, and led to higher biomass production. This may be the reason for the higher uptake of nutrients under better integration of nutrient sources. This finding is in close agreement with that of Singh *et al.* (1999). Thus the study on the effect of INM on rice-based cropping systems revealed that inclusion of legumes in crop sequences and INM is helpful in maintaining or even improving the status of organic carbon in the soil, the mainstay of soil quality. Application of nutrients at suboptimal doses decreased the organic carbon status of the soil. The crop sequences rice-rice-groundnut and rice-rice-cowpea made the soil richer in available nitrogen and contributed towards better yield of the succeeding crop of rice. Rice-rice-sesame, which is the predominant crop sequence of the sandy-loam tract of Kerala, could be made more productive without affecting the soil fertility by adopting integrated nutrient management.

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