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Nitrogen-release pattern from organic sources of different C : N ratios and lignin content, and their contribution to irrigated rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted on a clayey vertisol (Typic Pellustert) for 3 years (2001-02 to 2003-04) during wet and dry seasons at Hyderabad to study the N-release pattern from three organic sources of different C:N ratios and lignin content, and their effect on rice (*Oryza sativa* L.) productivity. The three organic sources used were: paddy straw with C:N ratio 61.5 and lignin content 6.3%; greengram (*Phaseolus aureus*) with C:N ratio 19.5 and lignin content 8.7%; dhaincha (*Sesbania aculeata*) with C:N ratio 13.1 and lignin content 5.8%. These were used in different combinations along with inorganic fertilizers. The cumulative N released during the first month after planting was high in the plots receiving green-manure alone (106-319 mg N/kg soil) and during the second month it was high in the plots receiving green-manure + paddy straw (301-414 mg N/kg soil). Greengram with its medium C:N ratio as well as lignin content released N slowly and gradually for a longer period. Leaving a gap of 2 weeks after incorporation of green-manure like *dhaincha* resulted in higher release and loss of N in those 2 weeks, because of its succulence (low lignin) and very narrow C:N ratio. The grain yield was significantly higher in the treatments that received organics in place of inorganic fertilizers alone due to increase in the productive tillers (panicles) in the second and third year by 7-23%. The residual effect of organics added in the wet seson significantly increased grain yield in the second and third years in all the treatments that received organics compared with inorganic fertilizers alone. Thus, organics with moderate C:N ratio and lignin content released N slowly and gradually for longer periods and led to higher productivity in rice-rice system.

Key words: C : N ratio, Irrigated rice, Lignin, Nitrogen release, Organic sources, Productivity

Intensive cereal cropping after green revolution with inorganic fertilizers alone has depleted the inherent soil fertility, leading to deficiency of important plant nutrients. The widespread occurrence of soil fatigue in the intensively cultivated irrigated rice lands has led to the use of 40% more N to produce the same quantity of rice (*Oryza sativa* L.) as 10 years ago, accentuating the problem. Several long-term experiments all over India indicated a decrease in rice productivity due to continuous use of chemical fertilizes. Thus emphasis should be on reducing the use of chemical fertilizers. Integrated nutrient management (INM) has an important role here, owing to the practice of combining organics and inorganics. Organics constitute an important component of INM and they provide regulated and balanced supply of plant nutrients. Sharma (2002) reported increased yield and nutrient-use efficiency in rice with organics. Nitrogen, the key nutrient element for rice, is the major constituent of organic sources and its release from these organics depends mainly on their C:N ratio and lignin content. The C:N ratio is the most widely used index of residue quality and is the predictor of decomposition rate. Mineralization of N is generally rapid from plant residues with a low C:N ratio because N is in excess of the requirement for microbial growth; and is slow from the residues with high C:N ratio as the N is retained by the microbial biomass and released slowly. For lowering the C:N ratio, addition of fertilizer N or organics that are comparatively rich in N such as non-edible cakes, legumes and grasses can be practised. Lignin material degrades slowly in the soil, and the protection caused by lignin on other organic constituents causes a general reduction in the rate at which the organic materials are degraded. A high concentration of lignin and other structural carbohydrates together with a high C:N ratio will decrease the rate of decomposition. Keeping this in view, a field experiment was conducted to study the nitrogen-release pattern from organic sources of different C:N ratios and lignin content, and their effect on rice productivity.

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MATERIALS AND METHODS

A field experiment was conducted for 3 years (2001-2003) during wet (*kharif*) and dry (*rabi*) seasons on a clayey Vertisol (Typic Pellustert) of Directorate of Rice Research farm, Hyderabad to study the influence of organic sources of different C:N ratios and lignin content on N-release pattern and productivity of irrigated rice. The soil was clayey (28% sand, 23% silt and 49% clay); alkaline with pH 8.2, non-saline (EC 0.71 dS/m) and calcareous (free $CaCO_3$ 5.1%) in nature with CEC of 44 cmol(p^+)/kg soil. Organic C content was medium (0.61%), available N was low (225 kg/ha) and the available P (28.4 kg/ha) and K (442 kg/ha) were high. The three organic sources used were: paddy straw, greengram and *dhaincha* (*Sesbania aculeata*), having N content, moisture content, C:N ratio and lignin content respectively 0.88%, 10.0%, 61.5 and 6.3% for paddy straw, 2.05%, 80.0%, 19.5 and 8.7% for greengram; and 2.96%, 86.5%, 13.1 and 5.8% for *dhaincha*.

The experimental design was a split plot with two main treatments, where the organics were incorporated 1 day (M_1) and 2 weeks (M_2) before transplanting of rice seedlings respectively. Six subtreatments were: S_1, inorganic fertilizers alone; S_2, paddy straw (5 t/ha); S_3, greengram (10 t/ha); S_4, *dhaincha* (10 t/ha); S_5, greengram (5 t/ha) + paddy straw (2.5 t/ha), and S_6, *dhaincha* (5 t/ha) + paddy straw (2.5 (t/ha). Each plot was of 8 m × 6 m (48 m^2) size and was replicated thrice. Nitrogen content was estimated in these organic sources on dry-weight basis. Based on the moisture content and N content in these organic sources, they were added to supply 40 kg N/ha to the treatments S_2-S_6. After accounting for N added through these organics, i.e. 40 kg/ha, the remaining dose (80 kg/ha) of the recommended N (120 kg/ha) was added through chemical fertilizer (urea) in three equal splits (at basal, tillering and panicle-initiation stages) to these treatments (S_2-S_6). For the treatment S_1, only inorganic N @ 120 kg N/ha was added through urea in three equal splits. Phosphorus, potassium and zinc were given @ 60, 40 and 10 kg/ha basal through single superphosphate, muriate of potash and zinc sulphate respectively.

During the wet season (*kharif*), organic sources *dhaincha* (*Sesbania aculeata*) and greengram (*Phaseolus aureus*) were grown in separate plots up to 60 days and were incorporated in different combinations along with paddy straw and inorganic fertilizers. During the dry season (*rabi*), the residual effect of organics applied in the wet season was studied in terms of rice productivity, by giving chemical fertilizers only. Irrigation and plant protection measures were taken as per the recommended schedule of practices. Rice 'Krishnahamsa' (120-125 days duration) of 30 days-old seedlings was transplanted at a spacing of 20 × 10 cm in both the seasons.

In wetland rice soils, 2 M KCl-extractable NH_4-N in the soils was found to be the best N-availability index, and this method was used by many authors for estimating N availability during the crop-growth period (Nayyar *et al.* 2006). Wet soil samples were collected at weekly intervals after transplanting up to 60 days after transplanting (DAT) and were analysed for NH_4-N using KCl extract, during the wet seasons. Here 20 g fresh wet soil was weighed into a 250 ml conical flask and 100 ml of 2 M KCl was added. The contents were shaken on a mechanical shaker for 30 min. and filtered. The NH_4-N in the filtrate was estimated after steam distillation with NaOH by absorbing the NH_4-N into boric acid and titrated against standard HCl. A separate set of soil was weighted and kept in oven at 105°C for moisture estimation, and N content in the soil was estimated on dry-weight basis. Cumulative N release was calculated at the end of first and second months. Yield components and the grain and straw yields were recorded at harvest for all the 3 years in both wet and dry seasons and the data were statistically analysed. In addition, the effect of time of incorporation of organics on N-release pattern and grain yield during wet season was also studied.

RESULTS AND DISCUSSION

Nitrogen-release pattern

The data on cumulative N release during 2 months of crop growth period for 3 years are given in Table 1. In all the 3 years the cumulative N released during the first month after planting was high in the plots in which green-manure alone (106-319 mg N/kg soil) was incorporated, with maximum values in *dhaincha*-treated plots irrespective of the time of incorporation. Thus green-manure with very low C:N behaving similarly to mineral fertilizer was unable to immoblize N, as was also reported by Bhandari *et al.* (2002). During the second month, N release was more in the plots that received green-manure + paddy straw (327-414 mg N/kg soil) and the values were almost equal in both greengram + paddy straw (S_5) and *dhaincha* + straw (S_6) treatments when both were incorporated a day before transplanting (M_1). But when these were incorporated 2 weeks before transplanting (M_2), the cumulative N-release values were higher in greengram + paddy straw (S_5) treatment compared with *dhaincha* + paddy straw (S_6) treatment. This indicated that having a gap of 2 weeks after incorporation of green-manure like *dhaincha* resulted in higher release of N during those 2 weeks period because of its succulence (low lignin) and very narrow C:N ratio and that lost N could not be accounted for and thereby led to lower values. Palaniappan (1994) reported that 80% of the total N present in *dhaincha* was released

Table 1. Cumulative N release as influenced by different organic sources (mg NH_4-N/kg) soil

Treatment	Incorporation 1 day before transplanting			Incorporation 2 weeks before transplanting		
	I month	II month	Total	I month	II month	Total
			Wet season (kharif) 2001			
S_1	80.0	140.1	220.1	69.8	135.0	204.8
S_2	58.9	203.4	262.3	78.1	271.0	349.1
S_3	157.7	308.2	465.9	145.3	286.0	431.3
S_4	319.1	249.0	569.1	210.1	200.0	410.1
S_5	75.9	404.9	480.8	197.4	338.0	515.4
S_6	83.3	414.4	497.7	203.9	301.1	505.0
			Wet season (kharif) 2002			
S_1	61.8	94.6	156.4	70.2	99.5	169.7
S_2	43.4	186.3	229.7	77.1	245.1	322.2
S_3	119.0	294.5	413.5	114.0	224.1	338.1
S_4	200.5	248.3	448.8	183.2	212.3	395.5
S_5	77.3	326.7	404.0	184.4	381.7	566.1
S_6	93.0	331.6	424.6	192.0	331.2	523.2
			Wet season (kharif) 2003			
S_1	70.9	117.5	188.5	73.4	124.0	197.4
S_2	68.9	206.3	275.2	80.1	281.0	361.1
S_3	133.7	276.5	410.2	105.5	245.1	350.6
S_4	225.5	249.3	474.8	142.5	206.3	348.8
S_5	80.3	341.9	422.2	148.4	359.5	507.9
S_6	100.1	352.5	452.6	155.9	330.5	486.4

in 10 days. In greengram, due to its moderate lignin content and medium C:N ratio, the release of N was slow and gradual for a longer period. Becker *et al.* (1990) reported release of NH_4-N more slowly due to wide C:N ratio and lignin content in *Sesbania rostrata* than in *Aeschynomene afraspera*. Aulakh *et al.* (2001) also observed longer periods of high mineral N levels in green-manured plots compared with urea N or urea N+wheat residue.

The N release from plots treated with only paddy straw (S_2) was slow and less (43-69 mg N/kg soil) than that of the control (S_1) with only inorganic fertilizers (62-80 mg N/kg soil) when incorporated a day before transplanting (M_1) during the first month, whereas when incorporated 2 weeks before transplanting (M_2), the release was slightly higher in paddy straw (S_2) treatment. By the end of second month, N released from paddy straw-treated plots was higher (186-281 mg N/kg soil) than that from inorganic fertilizers (95-140 mg N/kg soil), perhaps due to the slow mineralization of paddy straw with very wide C:N ratio. Nitrogen in plant residue with a high C:N ratio is retained by the microbial biomass and only slowly released. Mineralization of straw N was accelerated by incoporated green-manure in addition to urea N, which was clearly observed from the treatments S_5 and S_6 where straw+green-manure + urea N were added compared with paddy straw + urea N treatment (S_2). Aulakh *et al.* (2001) also reported similar results with wheat residue in rice crop.

A comparision of the data of these 3 years shows lesser accumulation and carry-over of N from organics in the second and third years. The reason may be that the residual crop in dry season must have utilized the accumulated from the organics. In tropical areas with high temperatures, organic matter is quickly lost, and hence every year fresh applications are necessary.

Yield components

In the first wet season none of the yield parameters were influenced by the treatments (Table 2). There was no significant influence of treatments on grain weight in all the six crops. As the main treatments did not influence the yield parameters significantly, only the influence of subtreatments is discussed here. The yield parameters such as panicles/m^2 (277-310 and 271-290) and grains/panicle (108-112 and 109-116) during other wet seasons were significantly higher where organic sources were added compared with the inorganics alone (with 224 and 218 panicles/m^2 and 102 and 104 grains/panicle). This increase could be attributed to the gradual and increased N availability due to organic sources. The residual effect of these organics was observed only in panicle number in all the three dry seasons (Table 2).

Grain yield of rice

The grain-yield data as influenced by different organic sources for the three wet seasons (Table 3) show that in the wet season of first year greengram either alone (4.44 t/ha) or in combination with straw (4.44 t/ha) significantly increased the grain yield by 7-13% compared with other

Table 2. Yield components of rice as influenced by different organic sources

Treatment	2001				2002				2003			
	Tillers/ m^2	Panicles/ m^2	Grains/ panicle	1,000-grain weight (g)	Tillers/ m^2	Panicles/ m^2	Grains/ panicle	1,000-grain weight (g)	Tillers/ m^2	Panicles/ m^2	Grains/ panicle	1,000-grain weight (g)
Wet season												
S_1	310	264	89	20.95	238	224	102	20.18	251	218	104	21.20
S_2	323	264	86	21.82	323	310	98	20.22	297	271	109	21.12
S_3	304	257	95	22.07	323	304	112	20.60	310	290	115	21.30
S_4	310	284	85	21.80	343	297	108	20.52	317	277	109	21.66
S_5	290	257	91	22.37	317	304	109	21.70	317	290	116	21.47
S_6	297	271	86	21.73	297	277	112	20.47	317	290	114	21.40
Mean	306	266	89	21.96	307	286	107	20.61	301	273	111	21.36
CD (P=0.05)	NS	NS	NS	NS	59	73	6	NS	53	46	9	NS
Dry season												
S_1	264	218	116	22.21	264	224	115	20.52	251	224	100	21.51
S_2	317	304	114	22.22	284	257	117	20.75	290	251	100	21.90
S_3	304	277	108	22.17	304	277	108	20.61	290	277	95	21.68
S_4	277	251	118	22.42	277	251	116	20.32	277	257	100	21.35
S_5	317	290	106	22.95	290	271	111	21.02	290	271	102	21.53
S_6	310	277	105	22.85	304	271	111	20.75	277	251	106	21.67
Mean	298	270	111	2.47	287	259	113	20.66	279	255	100	21.61
CD (P=0.05)	NS	53	NS	NS	NS	46	NS	NS	NS	41	NS	NS

treatments (3.93-4.16 t/ha). In the other two years the grain yield was significantly higher in all the treatments that received organic sources (5.00-6.05 and 5.30-6.04 t/ha) over inorganics alone (4.23 and 4.33 t/ha), with maximum being greengram + paddy straw (6.04 and 6.05 t/ha) treatment. The organics provide a balanced supply of all the essential nutrients, which synchronize with crop needs and uptake and thus result in significantly higher grain yields over inorganic fertilizers. The increased grain yield with organics in the present experiment could be attributed to the increased number of panicles in the treatments where organic sources were added. Prasad (1985) also observed higher rice yields due to combined application of green-manure and fertilizer N than fertilizer N alone. In the paddy straw alone treatment, the yield was superior to inorganic fertilizers alone from the second year onwards, recording 17-23% higher grain yield over inorganic fertilizers.

For the time of incorporation, wherever straw was added a time gap of 2 weeks between incorporation of organics and transplanting resulted in significant yield increase for 2 years, and no difference on account of time of incorporation was observed in the third year perhaps to the carryover effect of straw from the previous years. For green-manures alone, there was no difference in the yield regarding time of incorporation. But the higher yields in greengram alone compared with *dhaincha* alone could be attributed to the loss of N due to faster decomposition and release on account of very narrow C:N ratio and low lignin from *dhaicnha*, which also resulted in production of panicles less than under greengram treatment.

Regarding grain yield during dry seasons, the residual effect was not observed in the first year (Table 4). In the second and third years, the residual effect of wet season added organics significantly increased the grain yield (by 13-24 and 13-30% in second and third years respectively) in all treatments that received organics over inorganic fertilizers alone (S_1). The maximum effect was observed in green-manure + straw treatments (S_5 and S_6), perhaps due to slow mineralization and release of nutrients from these sources owing to straw addition. In general, the grain yield in the second and third dry seasons was lower than that in wet seasons, perhaps due to delayed planting along with other factors, which resulted in reduced panicle number also. Gaur and Mathur (1990) reported residual effect of crop residues to subsequent crops, and Ladha *et al.* (2000) reported the residual effects of green-manures on rice-grain yield in rice-rice systems. In general, the treatments with maximum N release and for longer periods during wet seasons resulted in maximum residual effect in terms of increased grain yield during dry seasons.

It was concluded that organics with moderate C:N ratio and lignin content (greengram) release N slowly and gradually over a period of time compared with those with very narrow (*dhaincha*) and very wide (straw) C:N ratios

Table 3. Grain yield (t/ha) of rice as influenced by different organic sources during wet season

Treatment	2001			2002			2003		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1	3.92	3.97	3.94	4.26	4.30	4.28	4.30	4.35	4.33
S_2	3.72	4.17	3.93	4.68	5.32	5.00	5.20	5.44	5.32
S_3	4.37	4.52	4.44	5.85	5.81	5.83	5.82	6.05	5.93
S_4	4.10	4.02	4.06	5.48	5.40	5.44	5.27	5.36	5.31
S_5	4.28	4.60	4.44	5.70	6.40	6.05	5.86	6.22	6.04
S_6	4.02	4.31	4.16	5.52	6.27	5.89	5.49	5.92	5.70
Mean	4.07	4.26		5.22	5.58		4.99	5.20	
CD (P=0.05)									
M		NS			NS			NS	
S		0.27			0.25			0.43	
M in S		0.25			0.37				
S in M		0.25			0.36			NS	

M_1, Incorporation 1 day before transplanting; M_2, incorporation 2 weeks before transplanting

Table 4. Residual effect of organic sources on grain yield (t/ha) of rice in dry season

Treatment	2001-02			2002-03			2003-04		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1	5.72	5.98	5.85	4.48	4.53	4.51	3.87	4.03	3.95
S_2	5.79	6.01	5.90	4.97	5.67	5.32	4.55	4.22	4.48
S_3	6.09	5.36	5.73	5.43	5.08	5.26	4.63	4.77	4.70
S_4	5.79	5.73	5.76	5.07	5.13	5.10	4367	4.63	4.65
S_5	5.85	5.69	5.77	5.65	5.51	5.58	5.23	5.00	5.12
S_6	5.77	5.55	5.66	5.30	5.42	5.36	5.17	4.77	4.97
Mean	5.84	5.72		5.15	5.22		4.37	4.25	
CD (P=0.05)									
M		NS		NS			NS		
S		NS		0.46			0.50		
M×S		NS		NS			NS		

M_1, Incorporation 1 day before transplanting; M_2, incorporation 2 weeks before transplanting

and low lignin content. These have resulted in maximum productivity by showing a residual effect also in the dry season. Addition of paddy straw along with green-manures regulates the N release from the latter and makes it available for a longer period. Similarly, mixing of green-manures with paddy straw results in hastening of mineraliation process, thus preventing immobilization. Hence proper mixing of organics of wide and narrow C:N ratios with low and high lignin content regulates the release of nutrients from these sources and make them available for longer periods, thereby resulting in higher productivity of intensive rice-rice system.

REFERENCES

Aulakh, M.S., Khera, T.S., Doran, J.W. and Bronson, K.F. 2001. Managing crop residue with green manure, urea and tillage in a rice-wheat rotation. *Journal of Soil Science Soceity of America* **65**: 820-827.

Becker, M., Ladha, J.K. and Ottow, J.C.G. 1990. Growth and N_2 fixation of two stem-nodulating legumes and their effects as green manure on low land rice. *Soil Biolgy and Biochemistry* **22**: 1109-1119.

Bhandari, A.L., Ladha, J.K., Pathak, H., Padre, A.T., Dawe, D. and Gupta, R.K. 2002. Yield and soil nutrient changes in a long-term rice-wheat rotation in India. *Journal of Soil Science Society of America* **66**: 162-170.

Gaur, A.C. and Mathur, R.S. 1990. Organic manures. In *Soil Fertiltiy and Fertiliser Use*, Vol. IV. IFFCO, New Delhi. pp. 149-159.

Ladha, J.K., Dawe D., Ventura, T.S., Singh, U., Ventura, W. and Watanabe, I. 2000. Long-term effects of urea and green manure on rice yields and nitrogen balance. *Journal of Soil Science Society of America* **64:** 1993-2001.

Nayyar, Atul, Singh, Bijay and Singh, Yadvinder. 2006. Nitrogen-supplying capacity of soils for rice and wheat and nitrogen availability indices in soils of northwest India. *Commnications in Soil Science and Plant Analysis* **37**: 961-976.

Palaniappan, SP. 1994. Green manuring: nutrient potentials and management. In: *Fertilisers, Organic Manures, Recyclable Wastes and Bio-fertilisers*, pp. 52-71. H.L.S. Tandon (Ed.).

Prasad, T.V.P.R. 1985. Management of pulses in rice-based cropping systems. M.Sc. (Agric) thesis, TNAU, Coimbatore.

Sharma, S.N. 2002. Nitrogen management in relation to wheat (*Triticum aestivum*) residue management in rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **72**: 449-452.