NITROGEN AND POTASSIUM SUPPLIED TO FLOODED RICE BY RECYCLING RICE STRAW

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ABSTRACT

The chemical analysis of a large number of samples of rice straw collected from different locations in Sri Lanka reveal that N content may range from 0.66 — 0.84 percent and K content from 1.30 — 2.03 percent. Field experiments conducted with flooded rice show that rice straw can be recycled by direct incorporation, mulching before and after transplanting, and as compost. The grain yields of rice obtained by addition of recommended doses of N and K as chemical fertilizer were similar to those obtained by adding rice straw with reduced chemical N fertilizer and zero potassium fertilizer, suggesting that the nitrogenous and potash fertilizers for a rice crop can be reduced by recycling rice straw.

KEY WORDS : Flooded rice, Nitrogen, Nutrients, Potassium, Recycling, Rice straw.

INTRODUCTION

Although cereal residues, particularly rice straw, are rich in nitrogen and potassium and contain all other plant nutrients (Amarasiri and Perera, 1975; De Datta, 1981) insufficient attention has been paid in the tropics towards finding suitable methods of returning straw to the land and to the evaluation of chemical fertilizer savings which can be effected thereby. The amounts of N and K present in the rice straw produced annually in Sri Lanka have been estimated to be nearly equal to a third of the N and more than double the K in chemical fertilizer consumed by rice (Amarasiri and Wickramasinghe, 1984). Yet most of the rice straw is burnt at the threshing floor and the ash allowed to remain there, in spite of the fact that rice farmers are among the least affluent in the farming community having very little cash resources to purchase the recommended dosages of fertilizer. Among the reasons why farmers do not return the straw to the land are, lack of awareness of the nutrient content of straw, cost and drudgery involved in transporting the bulky material from the threshing floor back to the field, hindrance to land preparation by the undecomposed straw, possible adverse effects of incorporation on plant growth under some edaphological conditions and use in thatching roofs, as animal feed and in the paper industry.

The objectives of this study are the determination of N and K contents in rice straw collected from different parts of Sri Lanka, evaluation of different methods of straw recycling in flooded rice culture and examining whether chemical fertilizer application can be reduced by the addition of straw.

MATERIALS AND METHODS

Chemical analysis of soil and rice straw

The pH of soil was determined in a 1 : 1 soil-to-water extract. Exchangeable soil K was determined by flame photometry after extracting soil with 1N NH_4OAc buffered at pH 7.0.

Rice straw was digested in a mixture of nitric, sulphuric and perchloric acids and K determined as above. Nitrogen was determined by micro-Kjeldahl procedure and carbon by dichromate-sulphuric acid oxidation.

Preliminary field experiment

A preliminary non-replicated field experiment was conducted in farmers' fields during maha 80/81 to determine the effect of rice straw incorporation on growth and yield of rice. The soils were ultisols with pH values ranging from 5.2 to 5.6. Rice straw chopped to pieces of 15 cm length was added to the experimental plots just before first ploughing at rates shown in Table 2. The plots were 4 m $\times$ 4 m with independent inlets and outlets for irrigation and drainage. Fertilizer was added at the rate of 90 kg N (urea), 55 kg P_2O_5 (triple superphosphate) and 45 kg K_2O (muriate of potash) per ha. Nitrogen was split applied with 8% at basal, 50% at maximum tillering and 42% at primordia initiation. Phosphorus and potassium were added as a basal application. Rice variety Bg 94—1 was transplanted when seedlings were 18 days old.

Long term field experiment

The experiment was conducted in a farmer's field at Ulpothagama, Hasalaka. The soil was a loamy sand (alfisol) with pH 5.7, organic matter 1.6%, total N 0.14%, Olsen P 3.5 ppm and exchangeable K 0.06 me/100 g. The treatments (Table 3) numbering eight were replicated four times in a randomized block design. The plot size was 4m × 4m. Each plot had independent inlets and outlets for irrigation and drainage. The experiment was initiated in yala 82 and planted to rice variety Bg 94—1. At harvest the straw collected from each plot, except in treatments 1 and 8 was added back to the same plot in the manner outlined below :

Addition as straw ash: Air dried straw was packed tight manually and set on fire. Burning was controlled as far as possible to arrest combustion at the black ash stage. Prolonged burning at high temperatures yields white ash with very low organic matter and nitrogen. The ash was applied just before transplanting.

Direct incorporation of straw: The straw was kept in a bundle in the experimental plot immediately after harvest and allowed to remain there until the commencement of the next season by which time it is partially decomposed due to the exposure to sun and rain over a period of more than a month. This straw was spread on the surface after first plough. A week to ten days later it was incorporated and usual land preparation practices were followed.

Incorporation of chopped straw: Rice straw was placed on a block of wood and manually cut with a knife to pieces of about 15 cm length. This was added to the field just before first plough.

Addition as a mulch after transplanting: Straw was placed in between rows of transplanted rice one week after planting.

Addition as a mulch before transplanting: Straw was spread uniformly on the field just before transplanting. Rice seedlings were then transplanted in the usual manner.

Composting straw in the field: Straw was placed in a heap in the plot so as to occupy the minimum land area. The top of the heap was shaped as a basin to collect maximum incident rain into the body of the heap, Rice was cultivated in the usual manner around the heap. The deoomposed straw was spread to other parts of the field prior to commencement of the next season.

Except for treatments 3 and 7, the straw from the previous season was kept in a covered enclosure until it was required for recycling.

Chemical fertilizer addition

Nitrogen: Treatments 1, 2 and 8 received 120 kg N/ha as urea per season up to yala 1983 and 90 kg N/ha per season thereafter. For other treatments the amount of N added was reduced by the quantity of N present in the straw being recycled. The straw harvested from each plot was weighed and analysed for N to arrive at the quantity of N to be added. The manner of N addition for treatments 1, 2 and 8 was as described in the preliminary field experiment, For other treatments urea was added in three equal splits at planting, maximum tillering and primordia initiation.

Phosphorus: Fifty five kg P_2O_5/ha as triple superphosphate was added at the beginning of each season for all treatments.

Potassium: Treatment 1 received 45 kg K_2O/ha as muriate of potash as a basal application. None of the other treatments received potash throughout the eight season experiment. The K content of the straw being recycled exceeded 45 kg K_2O/ha at all times.

RESULTS AND DISCUSSION

Chemical analysis of rice straw

The results of analysis of 361 samples of rice straw collected from different regions in Sri Lanka for its N content, and of 670 samples for its K content are reported in Table 1. The mean values for the regions ranged from 0.66—0.84% for N and from 1.30—2.03% for K. The potassium content of rice straw is more variable than that of N. Taking the above range of values, a 4 t/ha crop of rice with a 1 : 1 grain to straw ratio will contain about 26—33 kg N and about 52—80 kg K in the straw. These quantities represent about 30% of the nitrogen and more than 100% of the potassium presently recommended as chemical fertilizer for rice cultivation.

The potassium contained in rice straw is readily leached on contact with water (Amarasiri and Wickramasinghe, 1977). When straw is burnt it loses almost all its nitrogen, sulphur and carbon but retains about 80% of the potassium in the ash (Amarasiri and Wickramasinghe, 1977). These considerations point out the importance of protecting straw from rain and discouraging its being burnt in order to conserve plant nutrients as well as organic matter.

Preliminary field experiment

The grain yields obtained from incorporation of up to 6 t/ha chopped straw at four locations are shown in Table 2. High grain yields were obtained at all sites. Although only about 7 kg N/ha was added as urea at planting, retardation of early growth arising from soil N immobilization or from some other factor associated with straw incorporation was not observed. However, a light green colour was evident in plants in treatments which received 6 t/ha straw but this discolouration quickly disappeared after the first N top dressing. Remnants of the added straw in the soil were not visible at harvest. The results from this preliminary experiment serve to demonstrate that these flooded soils have the chemical and biological capability to breakdown chopped straw without any adverse effects on plant growth.

Long term field experiment

The data obtained from eight seasons of experimentation (Table 3) show clearly that under the experimental conditions straw could be added to rice fields by chopping, incorporation after partial breakdown, *in situ* composting, mulching before planting and mulching after planting, without affecting grain yields differentially. A slight temporary yellowing of plants was observed during some seasons in treatments which received chopped straw. Weed growth was significantly less when a straw mulch was applied, particularly where straw was added in between rows of planted rice. The organic matter content of soil did not increase (Table 4) in spite of adding nearly 5 t/ha rice straw per season for eight seasons showing that this soil was able to decompose the straw at that rate of addition.

Supply of potassium by straw

Although the soil had a low exchangeable K content of 0.06 me/100g, a response to addition of potassium was not found in spite of its removal by about 50 t/ha grain and nearly 40 t/ha straw produced. This soil may be able to release K to meet the requirements of the crop although the soil K content itself is low. Addition of 360 kg K_2O/ha in the form of muriate of potash or an even higher quantity of K from straw over the eight seasons failed to increase the exchangeable K content of soil (Table 5). This lack of K build up may be due to plant uptake, percolation losses and retention by soil in a form not extracted by ammonium acetate. While the results obtained in this experiment cannot be used to prove that straw supplied K to the rice crop, data from several other researchers are available to show that addition of straw increases the K content of soil (Nagarajah, 1987; Ponnamperuma, 1984). The ready release of K in rice straw on contact with water indicates that rice straw can supply potassium to a crop during the season of addition. Supporting evidence is provided from a field experiment in rice conducted with rates of incorporated chopped straw up to 10 t/ha, where the K content of the straw from the harvested crop rose steadily from 0.79% in the control to 2.58% in the treatment receiving the maximum amount of straw (W. Wickramasinghe, 1984, unpublished).

Supply of N to the ricc plant

Although the addition of chemical N fertilizer to treatments receiving straw was reduced by the quantity of N present in the added straw, which amounted to about 30 kg N/ha per season, the grain yields obtained remained at about the same level as with full addition of chemical N (Table 3). Similar results have been reported in recycling *in situ* composted rice straw (Amarasiri and Wickramasinghe, 1984). In a nitrogen response experiment on this soil, rice responded significantly to applied N up to 80 kg N/ha although there was a yield increase even up to 120 kg N/ha (Table 6). This result and the observation that about 60 kg N/ha added as urea combined with straw yielded about the same as 90 kg N/ha as urea alone during the last five seasons (Table 3), suggest that straw may have directly or indirectly supplied N to the rice plants. This is also supported by the observation that straw decomposed rapidly in the field in the present study. On the other hand, straw recycling treatments with reduced N may have attained the yields of the no straw treatment due to other benefits from straw. The lack of response to chemical fertilizer K rules out extra K added with rice straw as a significant factor. The attainment of high yield levels throughout the eight seasons suggests that no serious nutritional and other limitations were present that could have been corrected by straw.

Nagarajah (1987) studied the chemical kinetics of NH_4^+—N in soil after addition of rice straw in greenhouse and in field conditions in the Philippines and showed clearly that straw immobilizes ammonium N. He questioned therefore the utility of straw as a source of N in rice soils especially during the season of application. There are several basic differences in the experiments conducted by Nagarajah (1987) and those reported here. He used straw levels as high as 9—18 t/ha and conducted the experiments for one season, whereas in this eight-season study the amount of straw recycled averaged about 5 t/ha. Furthermore, in the experiments reported here, straw was recycled by five methods. Fresh straw was recycled only in one method where it was added after first plough giving a time interval of 2 to 3 weeks before rice seedlings were planted. Nagarajah (1987) added chopped fresh straw in all his experiments and planted rice seedlings soon after incorporation. Williams *et al* (1968) studied the effect of incorporating rice straw on grain yield and N recovery by rice plants under field conditions in California and showed that when rice straw was added at the rate of about 6 t/ha, it increased grain yields and N recovery provided that the N content of the added straw exceeded 0.54%. At lower percentages of N both grain yield and N recovery were reduced. The authors concluded that under the former conditions, rice straw supplied nitrogen to the rice crop in an amount approximately equal to the N content of the added straw, in agreement with our suggestions in this study.

Although the present study shows that chemical fertilizer N application can be reduced by the amount of N found in the straw without affecting rice yields, such an equivalence may only be fortuitious. The net supply of N to rice can depend on the actions and interactions of a number of factors. Some of these are, amount of straw added, its N content and C/N ratio, immobilization of soil N, nitrogen fixation in floodwater and the rhizosphere, and effect of straw on the cation exchange capacity of soil and hence on NH_4^+ retention. Although the entire straw was recycled without adverse effect on plant growth in this soil, such may not be the case for another soil differing in physical, chemical and biological properties. Based on the results of several field experiments conducted in South Korea, Oh (1984) suggested that 5—6 t/ha straw may be returned per season unless the fields are poorly drained in which case the amount added should be reduced to 2—3 t/ha. Research is needed to develop technologies to recycle straw in different soil environments so as to reduce use of both N and K chemical fertilizer. While addition of straw with its high C/N ratio will immobilize soil N, this should not be considered as an adversity. In fact, a certain degree of immobilization can be advantageous in that it will reduce N losses from the rhizosphere and also perhaps regulate N supply to plants to match their needs.

Practical considerations in recycling riee straw

While the available information suggests that straw can be recycled by a number of methods and that N and K fertilizer can be saved, numerous practical problems of recycling remain. Although addition of chopped rice straw will quicken the decomposition, chopping manually is labour consuming and chopping mechanically would be expensive. Placing a straw mulch in between rows of transplanted rice can be done on experimental plots but the practice would be very cumbersome on a field scale. On the other hand, mulching before transplanting is less difficult and the extra labour involved may be compensated by reduced weed growth. *In situ* composting in a part of the field is a more feasible technique and has been practised by farmers in Indonesia, Philippines and Sri Lanka. The loss of about 1—2% of the land area is accepted by farmers, specially in view of the increased grain yields that are obtained in the vicinity of the compost heap. A major disadvantage of this method is the inability of the farmer to control the extent of composting as the heap can almost flatten completely in some seasons due to rapid decomposition leaving little material behind for effective spread. A further disadvantage is the loss of potassium in straw by leaching. The chemical analysis of the resulting compost collected from farmers' fields is shown in Table 7, where it is seen in comparison with data supplied in Table 1, that much of the K has been lost. The N content on the other hand is higher than that in the original straw, probably due to the reduction in mass and the resulting increase in concentration. A significant factor in this method is that the C/N ratio of the compost is brought down very appreciably from the original value which may have been as high as 75, without the addition of chemical N or a low C/N material. *In situ* composting has its advantage in ill drained areas where direct incorporation of 5 t/ha straw may be harmful to crop growth. Another practical method of recycling is to place straw in small heaps of 25—30 kg each at different parts in the field immediately after threshing, to allow partial decomposition from sun and rain until land preparation time and to incorporate it after first plough. At this time the straw is fragile and does not hinder land preparation. No single method can be recommended for all conditions. The farmer has to select the method most suited to his particular farming situation.

In the long term experiment reported here, N was applied in equal proportions basally and as top dressings when straw was added. Yet currently only 8% of the chemical fertilizer N is recommended as a basal application in the majority of rice growing areas. Although no yield advantage has been obtained by adding a higher dose of N basally in some straw recycling field experiments (Amarasiri and Wickramasinghe, 1984) such a practice may be generally preferable in order to minimise N deficiencies to rice plants that may arise from N immobilization under certain soil conditions.

While the organic matter content of soil had not increased after eight seasons in this experiment, there is evidence of such increases from other experiments in the tropics (Ponnamperuma 1984). A lack of increase of organic matter at the end of a season is not indicative of a lack of benefit to the rice crop since much of the straw and its secondary decomposition products remain in the field during the early part of crop growth.

Recycling of rice straw in flooded rice culture may have its disadvantages. Incorporation of straw may lead to excessive reduction in poorly drained soils with adverse effects on plant growth. A build up of harmful insects, diseases and weeds may arise from carry-over effects from one season to another. Rice seeds of the previous season may get introduced with the straw and pose a problem to quality seed production when different varieties are cultivated from one season to another.

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Table 1. Nitrogen and potassium content of rice straw collected from different locations

Location	*No. of samples*	*Nitrogen* (%)*	*No. of samples*	*Potassium* (%)*
Ampara	14	0.84 ± 0.06	14	1.30 ± 0.17
Badulla	20	0.84 ± 0.04	20	1.93 ± 0.18
Galle	10	0.78 ± 0.07	10	1.69 ± 0.23
Gampaha	16	0.81 ± 0.08	16	1.55 ± 0.16
Hambantota	28	0.79 ± 0.03	28	1.53 ± 0.06
Kalutara	12	0.66 ± 0.10	12	1.48 ± 0.20
Kandy	38	0.75 ± 0.02	195	1.74 ± 0.05
Kegalle	53	0.71 ± 0.02	175	2.03 ± 0.08
Matara	11	0.72 ± 0.09	11	1.70 ± 0.23
Minipe	143	0.76 ± 0.03	173	1.78 ± 0.07
Polonnaruwa	16	0.73 ± 0.10	16	1.75 ± 0.21

*Confidence limit of 5% probability

Table 2. Effect of rice straw incorporation on grain yield of rice in farmers' fields (maha 1980/81)

*Rice straw**	*Grain yield (t/ha)*			
t/ha	*Rambukkana*	*Dedigama*	*Kulugammana*	*Bandarapola*
0	6.2	7.6	6.8	7.0
1.5	5.4	7.7	7.4	7.0
3.0	6.4	7.5	6.8	7.0
4.5	5.6	7.9	7.1	7.1
6.0	5.8	7.9	6.8	7.0

*All treatments received chemical fertilizer at the rate of 90 kg N, 55 kg P_2O_5 and 45 kg K_2O per hectare

Table 3. Effect of methods of recycling rice straw on grain yield of rice at Ulpothagama

Treatment*	*Grain yield (t/ha)*							
	yala 82	*maha 82/83*	*yala 83*	*maha 83/84*	*yala 84*	*maha 84/85*	*yala 85*	*maha 85/86*
1 NPK	7.2	5.9	6.6	5.3	5.6	5.7	6.4	5.8
2 Straw ash	6.9	5.6	6.6	5.4	6.2	5.6	6.3	5.5
3 Straw incorporated	7.3	5.7	6.5	6.1	5.8	5.4	6.1	6.1
4 Chopped straw incorporated	7.3	5.9	6.4	6.1	5.7	5.7	6.4	5.5
5 Mulch before transplanting	7.2	5.6	6.7	5.9	5.5	5.9	6.5	5.4
6 Mulch after transplanting	7.3	6.0	6.9	6.2	6.0	5.3	6.2	5.4
7 Straw compost	7.2	5.7	6.6	5.8	5.8	5.2	6.2	5.4
8 NP	7.1	5.5	6.6	5.0	5.5	5.2	6.1	5.4
LSD 0.05	NS	NS	NS	0.6	NS	NS	NS	NS
CV (%)	4.4	5.3	5.2	6.9	6.1	9.6	6.2	5.8
Variety	Bg94-1	Bg400-1	Bg94-1	Bg94-1	Bg94-1	Bg400-1	Bg94-1	Bg379-2

*Treatments 1, 2 and 8 received 120 kg N/ha per season up to yala 83 and 90 kg N/ha per season thereafter; in treatments 3 to 7 the amount of chemical fertilizer N added was reduced by the quantity of N present in the straw.

Table 4. Effect of methods of recyling rice straw on organic matter content of soil

Treatment*	*Organic matter (%)***							
	yala 82	*maha 82/83*	*yala 83*	*maha 83/84*	*yala 84*	*maha 84/85*	*yala 85*	*maha 85/86*
1	1.60	1.33	1.25	1.49	1.19	1.22	1.69	1.79
2	1.45	1.43	1.51	1.30	1.04	1.41	1.65	1.62
3	1.51	1.49	1.45	1.47	1.51	1.62	1.78	1.96
4	1.54	1.20	1.54	1.36	1.27	1.45	1.62	1.73
5	1.48	1.46	1.45	1.52	1.34	1.47	1.76	1.73
6	1.51	1.46	1.57	1.62	1.16	1.45	1.69	1.73
7	1.48	1.46	1.35	1.62	1.93	1.34	1.75	1.70
8	1.51	1.52	1.39	1.51	1.30	1.38	1.65	1.68
CV (%)	10.5	9.6	9.8	11.1	7.3	8.8	10.2	9.1

*Details as in Table 3

**Differences between treatments not significant (0.05) in all seasons

Table 5. Effect of methods of recycling rice straw on exchangeable K content of soil

Treatment*	Exchangeable K (me/100g soil)**							
	yala 82	*maha* 82/83	*yala* 83	*maha* 83/84	*yala* 84	*maha* 84/85	*yala* 85	*maha* 85/86
1	0.06	0.05	0.05	0.07	0.07	0.05	0.06	0.06
2	0.05	0.05	0.05	0.06	0.08	0.05	0.06	0.06
3	0.05	0.05	0.04	0.06	0.08	0.06	0.06	0.06
4	0.06	0.05	0.04	0.07	0.06	0.08	0.06	0.07
5	0.05	0.05	0.04	0.07	0.07	0.06	0.06	0.06
6	0.05	0.05	0.04	0.06	0.06	0.05	0.05	0.05
7	0.06	0.05	0.04	0.07	0.07	0.06	0.04	0.05
8	0.05	0.05	0.04	0.06	0.06	0.05	0.04	0.05

* Details as in Table 3

** Differences between treatments not significant (0.05) in all seasons

Table 6. Effect of rates and methods of N application on yield of rice at Ulpothagama*

Rate of N (kg/ha)	Method of** application	Grain yield*** (t/ha)
0	—	4.38 d
40	A	5.08 bc
80	A	5.59 a
120	A	5.81 a
160	A	5.64 a
40	B	4.75 c
80	B	5.47 ab
120	B	5.80 a
160	B	5.69 a
CV (%)		4.3
Variety		Bg 94–1

* A field adjoining the experiment on recycling of straw

** A—8% at planting, 49% at maximum tillering and 43% at primordia initiation
B—33% each at planting, maximum tillering and primordia initiation

*** DMRT at 5%

Table 7. The chemical analysis of *in situ* composed rice straw

Sample No.	*N* (%)	*K* (%)	*C/N*
1	1.84	0.36	14.3
2	1.42	0.18	18.9
3	0.99	0.12	13.8
4	0.99	0.45	15.9
5	1.10	0.30	12.0
6	1.23	0.05	17.8
7	1.23	0.19	13.7
8	1.94	0.09	10.3
9	0.84	0.25	15.0
10	1.42	0.30	13.3