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COMPOSTING RICE STRAW IN SEMI-ARID CONDITIONS

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Abstract

Five experiments were conducted, three with 10-kg lots (in cement cylinders/digesters) and two in heaps with 500-kg lots of rice straw. Results from three—one with cement cylinders and two with heaps—are reported here. All were conducted at Patancheru from 1998 to 2000 in the hot summer period (April–May). The use of 0.76% N (as urea) with or without added micro-organisms more quickly decomposed the rice straw (by a subjective visual rating scale and C:N ratio) by about 1 week than otherwise. Also, the compost of N-applied treatments had at least 40% more N than that from the non-applied control. But N loss, indicated by the odour of ammonia, was noticed only from the N-applied treatments. All the treatments, except the control, received 25% rock phosphate (RP), when composting was done in cement digesters. For heap composting, RP was reduced to 6% so that its concentration would not be excessive when the compost is applied to crops at high rates. Composting was accomplished within 45 days whether in the digesters or in heaps, even with a reduced use of N (0.36% in 1999 and 0.1% in the year 2000). Treatment effects due to N that were apparent in the final product, disappeared when N-application was reduced to 0.3% or 0.1%. It was only through the visual rating that amendment with N and micro-organisms was perceived to shorting composting time. The resultant compost, however, did not indicate differences in chemical characteristics (N, P, K, OC%) across treatments in heap composting. One apparent biological difference across treatments was the presence of fruiting bodies of *Sclerotium rolfsii* (causes root rots in many crops) in control treatments. This fungus was not seen in treatments receiving microbial inoculation. In the experiment in 1999, we composted over 6 t of rice straw in a single session, in multiple heaps of 500 kg. The composting protocol is proposed for a small-scale village-level enterprise and is not intended for individual farmers.

1. INTRODUCTION

Crop residues are an important source of soil organic matter, which is low to very low in most soils in the tropics. Large quantities of the crop stubble [1] and crop residues are burnt in the arid, semi-arid and wet tropics [2]. Rice straw is one of the major crop residues that is burnt in the Philippines, Viet Nam, Sri Lanka, Pakistan and India. Although it is an important cattle feed in certain regions of these countries, in other parts it is available in excess of demand and is burnt. For example, about 12 Mt of rice straw and wheat straw are burnt annually in Punjab, India. Thus, N worth US $17 million is lost. In addition, burning causes environmental pollution (smoke) and the annual production of 28 Mt of CO_2, a greenhouse gas [2]. Similar data for other countries/regions are not available.

Rice straw may be disposed of by incorporation in soil where it decomposes naturally [3]. But the short time between harvest of rice and sowing of the next crop can result in incomplete decomposition and reduced yield from the subsequent crop. Long-term experiments (7 to 11 years) on incorporation of rice straw in the region have not been encouraging [3]. Furthermore, farmers need to use extra water for decomposition, and extra tillage for appropriate incorporation. Also, the machinery needed for incorporation is not readily available to many farmers, therefore they find burning to be a convenient means of residue disposal [2]. The straw can be applied as mulch [4,5], but research is needed to evaluate the feasibility of this practice in the intensively cropped regions of tropical and sub-tropical Asia.

Banger et al. [6] composted rice straw in 10-kg batches in cement cylinders. Rock phosphate and pyrite were added to enhance its value. Cuevas [7] developed a protocol for rapid composting of rice straw in large quantities for use by farmers in the Philippines. We modify it for use in the semi-arid climate of Patancheru. This paper describes the development of the modified protocol for composting rice straw.

2. MATERIALS AND METHODS

2.1. Composting protocols

2.1.1. In cement cylinders/digesters (1996–1998)

The experiment, repeated three times (once each year), had three treatments and a control: T1 = control (no amendment); T2 = rock phosphate (RP) at 25% on a dry-mass basis in relation to the rice straw; T3 = N + RP, i.e. N at 0.76% as urea, RP at 25%; T4 = inoculation with micro-organisms, i.e. the activator fungus *Aspergillus awamori*, the P-solubilizing bacterium *Pseudomonas striata* (strain 303), *Paecilomyces fusisporus* and *Bacillus polymyxa* (strain 411) for straw decomposition, and *Azotobacter chroococcum* (strain MAC 27) an asymbiotic N_2-fixing bacterium, and 0.76% N as urea and 25% RP.

Composting was done in cement digester tanks (75 cm diameter × 75 cm deep, with a lined base) buried in the soil and covered with galvanized iron lids. In each digester, 10 kg sun-dried rice straw (without chopping), moistened with a 15-L suspension of *A. awamori* and *B. polymyxa*, and 0.38% N as urea in water was placed as 10-cm-thick layers. Mats of *P. fusisporus* grown on potato dextrose agar plates, cut into 1-cm squares were placed randomly at every 10-cm depth in the digesters. Powdered Mussoorie rock phosphate (2.5 kg) was sprinkled between the layers. Eighty-two g of urea per digester were also added in the water used for soaking the rice straw. The surface of the rice straw in each cylinder was kept moist by sprinkling about 200 mL water at 2- to 3-day intervals. The contents of each digester were mixed at 20 days after starting the process. A second mixing was done at 30 days when 500-mL broths each of *A. chroococcum* and *P. striata* were sprayed onto the virtually composted straw. The final compost was analysed for traits such as pH, and inorganic nutrients using methods described by Jackson [8] and Page et al. [9].

2.1.1.1. Visual rating scale

Growth of fungi, strength of strands of rice straw and odour in heaps were used to assess composting: from 1 for least composted to 5 for most composted. Fungal growth was observed at at least ten spots per heap and at least once, between days 4 and 7, after setting up the composting. If fungal growth was seen at all spots, it was rated 5 and if growth was not visible or apparent at a few spots it was rated 1. The in-between ratings depended on the visibility of the fungal growth. Odour of the composting material was judged at the time of mixing the contents. Mature compost has a characteristic earthy smell, which was generally absent during composting. During composting the odour was like that of freshly wet straw or of fungi if it was progressing well. In some pockets, always associated with more than 80% moisture, generally at the base, hydrogen sulphide was detected and a rating of 1 assigned. This was associated with excessive watering. Dry pockets were obviously due to inadequate watering and did not compost. A well-composting heap was rated 4. Strength of the strands of rice straw was judged at days 30 and 45 or at termination of composting. If it was difficult to break a single strand of rice straw, as is the case with a fresh strand, it was rated 1. If it broke readily, it was rated 4 and if it broke and could be pressed like dough, it was rated 5. The intermediate ratings were subjective.

Mean ratings for a given digester or heap at the various times of observation, i.e. in the early stages, at mixing (day 30), and at maturity (day 45), were used to compare treatments. The composting rice straw changed from yellowish brown to dark grey. Application of rock phosphate disturbed the use of colour as a criterion for judging progress.

2.1.2. In heaps, phase I (1999)

The composting procedure was scaled up from 10-kg lots of rice straw to 500-kg heaps on the soil surface in a field. The experiment had three treatments including the control: i) control with no N, no P and no micro-organisms, with rice straw soaked in water; ii) bacterial inoculum with no N, no P and no fungi, with a previous batch of compost sprinkled into the moist rice straw as an inoculum, and, at the start of composting, rice straw was soaked in a water suspension containing an unidentified bacterium known to suppress the growth of several fungal species; iii) standard procedure with 0.3% N as urea, 6% Mussoorie rock phosphate (RP) and the activator fungus *A. awamori*.

The heaps were 5 m long × 1.5 m wide × 1.5 m deep, of 500 kg of sun-dried rice straw. Multiple heaps of this size allowed composting of large quantities of straw. The steps in the standard procedure (treatment iii) are described below. For the other treatments the relevant amendments were followed as described above.

A "soaking solution" was prepared in a large container: 150 L of water, 0.65 kg urea and 1 L of a blended suspension of *A. awamori* were mixed well. Sun-dried rice straw was weighed into convenient 5- to 10-kg bundles and dipped in the "soaking solution" for 2 to 3 min followed by draining for 5 to 10 min. The excess liquid was collected and reused. Each 10-kg bundle of straw absorbed some 15 L of soaking solution and, with it, 65 g urea, i.e. about 30 g N, i.e. 0.3% N on a dry-mass basis, and approximately 10^8 fungal propagules/spores. The moistened/inoculated straw aliquots was taken to a plastic sheet spread near the heaping point.

The inoculated/moistened straw was spread and sprinkled with the required amounts of RP, mixed well and placed in a heap. Each heap was covered with a plastic net (hole size 1- to 2-cm square) then with a 20- to 30-cm layer of non-experimental rice straw. Wetness of the fermenting straw at the centre, sides and top of representative heaps of each treatment was monitored manually. Water was applied such that the straw remained at 60 to 80% moisture all through fermentation. Contents of a given heap were mixed twice, at day 10 to 15 and at day 30. The experiment was terminated at day 45. At day 30, 500-mL suspensions of *Azotobacter, B. polymyxa,* and *P. striata*, grown separately and mixed at application, were sprayed per heap.

2.1.2.1. Watering

When sprinkled on top of a heap, water generally ran down the sides and did not penetrate to where it was needed. Therefore, a watering lance was used: a 1.5-m long piece of galvanized iron pipe welded to a 20-cm long tapering metal piece with a sharp end (containing four holes, 10-mm diameter, half way). When connected to a hose with water under pressure, jets of water issued from the lance, which, when plunged inside a heap at close intervals effected thorough wetting. Output of water from the lance was calculated per unit time, allowing application of close-to-correct volumes of water. For the dry season, a watering schedule was developed: about 100 L of water through the lance at day 7, mixing and watering the straw with water (about 240 L) at day 15, about 150 L at day 20, plus 200 L at day 30.

2.1.2.2. Internal temperature

A data-logger, model CR 21 (Campbell Scientific Inc., USA) was used. Copper-constantan (T-type) thermocouples were placed at five points in three representative heaps, one of each of the three treatments. Three of the five points were at the centre (base, middle, surface) of a heap and the other two were at the two sides (at the middle). The data-logger was programmed to record readings once every 2. Temperature were recorded continuously for the first 36 days.

2.1.3. Composting in heaps, phase II (2000)

This experiment had three treatments including the control, and three replications: i) control, i.e., no N, no P, no fungi and no bacteria; ii) standard procedure, as described previously, but with modifications over that of 1999; iii) no-N treatment, i.e. the same as the standard procedure but without N. Modifications in the standard procedure were as follows: urea was reduced from 0.3% to 0.1% and the rate of inoculation with the fungus was 1 mL suspension per L of water.

Also, the amendment bacteria (*Azotobacter, B. polymyxa,* and *P. striata*) were added, where appropriate, at the end of 45 days.

3. RESULTS

3.1. Composting of rice straw in cement digesters

The experiments in the first 2 years (1996 and 1997) were exploratory and the results were used to develop the protocols described in Materials and Methods. Data generated in 1998 are presented. Initially the pH was about 8. At day 30, pH of compost samples from the different treatments ranged from 7.0 in T4 to 7.5 in T1. As composting progressed, weight of the straw decreased due to loss of C. Weight-loss determinations were made weekly; Table I shows weight-loss data at day 30. Treatments T3 and T4 were visually most decomposed with the former losing more weight (56%) than the latter (50%). By 30 days, the control (T1) had lost only 46% weight, obviously due to less decomposition. The C:N ratios agreed well with the visual ratings; the most decomposed treatments, T3 and T4, had lower C:N ratios. The total N per digester was maximal in T4 (116 g) followed by that in T3 (101 g) and T2 and T1 (72 g). The total P in T2, T3 and T4, all of which received 25% RP, ranged from 177 g in T3 to 189 g in T4. Total K ranged from 133 g in T4 to 113 g in T2. Nitrogen and P were available only in small amounts in all cases. Phosphorus was negligible (0.02 g) in T2, which received 25% RP only, and ranged from 3.6 g in T1 to 5.3 g in T4. Available P ranged from 1.1 g in T1 to 3.1 g in T2. Available K was maximal in T4 at 112 g and minimal in T1 at 34.5 g.

3.2. Composting in heaps

Based on visual ratings, five of the six replicated heaps of the standard procedure were among the most completely composted. The mean rating was 3.3 (Table II). The heaps of the bacterial-inoculum treatment also composted well, with a mean score of 3.2. The control heaps composted most slowly and had a rating of 2.6.

The maximum weight loss at 30 days was 46%, recorded in the standard-procedure heaps (fungal inoculation, urea and RP) (Table II). The weight loss in the in the control heaps was close to that (45%). The heaps with bacterial inoculum registered minimum weight loss, although the progress in composting (indicated by visual ratings) was similar to that of the standard-procedure heaps The heaps receiving bacterial inoculum had low C:N ratios, indicating good decomposition.

There was an intense odour of ammonia around the standard-procedure heaps, indicating volatilization of N. However, there was no advantage in terms of shortening the number of days for composting over the bacterial treatment. Therefore, it seems possible that N application could be reduced (from 0.3%).

Table I. Composition of rice-straw compost at 30 days in cement digesters

Treatment	pH	H_2O (%)	Wt. loss (%)	Rating	OC (%)	C:N	Total per digester N (g)	Total per digester P (g)	Total per digester K (g)	Available per digester N (g)	Available per digester P (g)	Available per digester K (g)
T1, control	7.5	70	46	1	45	33	72	23	117	3.6	11	35
T2, 25% RP	7.5	61	45	2	29	29	72	179	113	0.02	3.1	92
T3, N+RP[a]	7.0	63	56	4	27	19	101	177	115	4.7	2.2	89.5
T4, inoculation[b]	7.0	62	50	4	29	19	116	189	133	5.3	2.6	112
SE (±)	0.2	1.8	5.6	—	1.2	1.4	7.6	14	6.2	1.8	0.14	6.5
CV (%)	5	5	19	—	7	8	15	17	9	90	10	14

[a]0.76% as urea, 25% RP. [b]Microorganisms, 0.76% N as urea, 25% RP.

Table II. Heap composting of rice straw, April–May 1999, at 30 days

Treatment	Rating	Weight loss (%)	C:N	$CaCl_2$-extractable P (ppm)
Control	2.6	45	11	72
Standard procedure	3.3	46	12	146
Bacterial inoculum	3.2	38	11	129
Mean	3.0	43	11	116
SE (±)	0.19	2.9	0.4	15
CV (%)	15	17	7.9	31

In all three treatments maximum temperatures were recorded at the centre of the heaps and minimum at the base (Fig. 1). Temperatures at the tops of the heaps fluctuated greatly. Overall, the highest mean temperature (for 36 days) was recorded at the centre of the heap of the control heaps (mean: 53.7°C, range: 25.5–63.2°C), followed by the standard-procedure (mean: 51.2°C, range: 24.6–68.2°C) and bacterial-inoculum heaps (mean: 47.0°C, range: 13.5–64.1°C).

Chemical analyses for N, P and organic C (OC) were done at 30 and 58 days. At 30 days, the bacterial compost had 33% more Kjeldahl N over the control and 15% more than the standard-procedure compost. Even N in the standard-procedure compost was significantly greater than in the control (Table III). However, these differences disappeared at 58 days and all three types of compost had 20.1 to 20.7 kg N t^{-1}. The total P was greatest when prepared with the standard procedure because it received 6% rock phosphate at the start of composting. Organic C measured by slow ignition in a muffle furnace was more in the bacterial and standard procedure composts than in the control. It was 29 to 30% greater in the bacterial compost and 13 to 34% greater in standard-procedure compost than in the control (Table III).

In the year 2000, the N concentration at composting was further reduced (from 0.3% N in 1999 to 0.1% N in 2000). Except for the N concentration, the standard procedure was the same in both years. The bacterial-inoculum treatment in 1999 was replaced by the fungus plus RP treatment in 2000. Composting in 2000 was terminated at 39 days. The total N values were similar in the two treatments at 12 kg t^{-1}, with the control having marginally higher at 14 kg t^{-1} (Table III). As in 1999, the total P was significant higher where RP had been added. Total K and OC were similar in all cases. Weight loss was significantly less in the standard procedure than in the control. The only apparent difference across treatments was the presence of fruiting bodies of the pathogenic fungus *Sclerotium rolfsii* (causes root rot in seedlings of several crops) in the control heaps in both years.

The compost prepared in 2000 was also analysed for four micronutrients. Concentrations of Zn and Cu were similar in compost of all three treatments (11.5 to 12.4 ppm and 0.5 to 0.7 ppm, respectively) (Table IV). Manganese was lowest at 85 ppm in the compost prepared following the standard procedure and highest at 112 ppm in the treatments receiving the fungal inoculum and RP, but the difference was not statistically significant. Iron was significantly higher (41.8 to 42.8 ppm) in composts receiving RP than in the control (11 ppm).

4. DISCUSSION

4.1. Composting of rice straw in cement digesters

In the initial studies we used 25% RP, then reduced it to 6% (on a straw dry-weight basis); with 7.0 to 7.4% total P, an application of 2 t ha^{-1}compost would provide 25 to 30 kg P. Although, less than 10% of the total P would be available, it is hoped that it would increase the P pool of the soil and become available in the long term through increases in populations of P-solubilizing micro-organisms added with the compost.

Table III. Nitrogen, P, K, and organic C per ton of rice-straw compost prepared in heaps (and weight loss at 45 days)

Treatment	Total N	Total P	Total K	OC	Weight loss
	(kg)				(%)
1999, at 30 days					
Control	13.9	2.1	ND[a]	153	45
Standard procedure	16.1	9.8	ND	206	46
Bacterial inoculum	18.5	2.9	ND	200	38
Mean	16.2	4.9		186	43
SE (±)	0.79	0.20		8.8	2.9
CV (%)	12	10		12	17
At 58 days					
Control	20.4	2.9	ND	251	ND
Standard procedure	20.7	15	ND	284	ND
Bacterial inoculum	20.1	3.8	ND	325	ND
Mean	20.4	7.1		287	
SE (±)	0.26	0.17		1.99	
CV (%)	2	4		1	
2000, at 39 days					
Control	14.1	2.0	19.7	172	39
Standard procedure[b]	12.4	5.8	21.5	185	31
Fungus+RP	11.8	7.2	18.8	195	41
Mean	12.8	5.0	20.0	184	37
SE (±)	0.49	0.72	0.69	4.3	6.2
CV (%)	7	25	6	4	28

[a]Not determined. [b]Urea+fungus+RP.

Table IV. Micro-nutrient content of rice-straw compost prepared in heaps, 2000

Treatment	Mn	Cu	Fe	Zn
	(ppm)			
Control	105	0.5	11.0	12.4
Standard procedure	85	0.6	41.8	11.5
Fungus + RP	112	0.7	42.8	11.7
Mean	101	0.6	31.9	11.8
SE (±)	17.9	0.10	2.47	1.71
CV (%)	31	29	13	25

With addition of N, RP and micro-organisms (T4) it took about 40 days to decompose rice straw during the hot period, February to June during which the average monthly minimum temperature were 17 to 24°C and average maximum temperature were 29 to 39°C. Addition of micro-organisms did not influence rapidity of composting in this experiment, whereas in a previous experiment (one of the three experiments conducted in cement cylinders) the difference in the comparable treatments was at least 10 days. Amendment with RP without N and micro-organisms (T2) delayed decomposition by about 7 days as judged by the visual rating scale. The controls (T1) took about 60 days to decompose.

The advantage of using micro-organisms was not inconsistent from experiment to experiment. The difference in number of days for decomposition (at least of rating "4" on the "1" to "5" scale), with and without N, in three different experiments, one of which is reported here, ranged from nil to about 15 days, which was puzzling. Large differences in N content from batch to batch of rice straw (0.5% to 0.9%) seem to be the reason (0.6% N for the batch in Table I). Perhaps the micro-organisms are differentially affected according to N content, during composting.

4.2. Composting in heaps

Our previous experience suggested that maintaining 70% moisture inside the heaps was the most difficult part in the composting process. Adding water once a week and mixing was satisfactory, but labour intensive. It was manageable for 10-kg lots, but mixing 500-kg lots, was not practical. A watering lance (see Materials and Methods) proved very effective and obviated mixing the contents of compost heaps at weekly intervals. Only one mixing, at day 30, may be enough, but this needs further investigation.

Measuring temperature inside the heap and moisture content in straw were considered important to keep track of the progress of composting in heaps. Temperature differences across treatments suggested that different micro-organisms were involved in composting in the three treatments in 1999. Presence of fruiting bodies of the fungus *Sclerotium rolfsii*, which causes seedling death in many crops, was generally noted in control heaps, but not after microbial inoculation. This indicates the importance of inoculation.

A total of 6.6 t of rice straw was composted at one time. The process was aimed at a village-level enterprise. It was apparent that, even in large scale, composting can be accomplished in about 45 days. Even by 30 days the C:N ratio in all three treatments was similar (11 to 13). It should be possible to decompose any number of 500-kg lots. Further studies should address issues related to adaptability of the composting protocols at village level and its economics.

4.3. Other observations

Preparation of rice-straw compost involved use of RP and P-solubilizing micro-organisms. The RP had less than 4 mg kg^{-1} Olsen's P and rice-straw compost was assessed to have less than 8% Olsen's P (available-P; Table III), which may be due to these micro organisms and organic acids produced during composting. The micro-organisms used in the study have been developed through screening in laboratory cultures [10,11] where all growth requirements of the organisms are met. Under such conditions, less than 11 mg of the total 100 mg of P in the growth medium (which contained glucose and yeast extract) were dissolved by the six different bacteria and *Aspergillus awamori* in three weeks [11]. Thus, the micro-organisms were more efficient under the laboratory conditions than in the composting environment reported here. Also, the laboratory medium changed from pH 7 to pH <3 in three weeks. These micro-organisms were generally seven-times less effective [11] in solubilizing P in rock phosphate than in solubilizing P in tricalcium phosphate, which is also an insoluble form of P. There seems to be potential to identify P-solubilizing micro-organisms that are more efficient under composting conditions of high pH (>7) and poor nutritional content.

All available nutrients in compost are liable to leaching loss (in addition to their assimilation by micro-organisms) if a heap is not protected from excess watering or rain. About 0.2% of N, 6 to 23% P and 72 to 80% of K are susceptible. With high N addition (0.76%) at composting (see Table I) the loss of N could be 42 to 53%. Thus, addition of 0.1% N at composting, which resulted in less available N but completion of composting in about 42 days seems to have utility.

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REFERENCES

[1] RIHAWI, S., Stubble—a burning issue, ICARDA Caravan **Winter/Spring** (1997) 18–19.

[2] SIDHU, B.S., et al., Sustainability implications of burning rice- and wheat-straw in Punjab, India Econ. Political Weekly **26 September** (1998) A-163 to A-168.

[3] SIDHU, B.S., BERI, V., Effect of crop residue management on the yields of different crops and on soil properties, Biological Wastes **27** (1989) 15–27.

[4] ADISARWANTO, T., et al., Agronomic Survey of MK I Soybean on Sawah in East Java (Jember to Madiun), 21–24 June, Malang Research Institute for Food Crops, Malang, Indonesia (1989).

[5] BHAGAT, R.M., et al., Tillage and residues management effects on soil physical properties and rice yield in north-western Himalayan soils, Soil Tillage Res. **29** (1994) 323–334

[6] BANGER, K.C., et al., (1989) Preparation of nitrogen and phosphorus-enriched paddy-straw compost and its effect on yield and nutrient uptake by wheat (*Triticum aestivum* L.), Biol. Fertil. Soils 8 (1989) 339–342.

[7] CUEVAS, V.C., Rapid composting fits rice farmers, ILEIA Newsletter **9** (1993) 11–12.

[8] JACKSON, M.L., Soil Chemical Analysis, Prentice-Hall, New Delhi (1973).

[9] PAGE, A.L., et al., (Eds.), Methods of Soil Analysis Part 2, American Society of Agronomy, Madison (1982).

[10] BARDIYA, M.C., GAUR, A.C., Isolation and screening of microorganisms dissolving low grade rock phosphates, Folia Microbiologica **19** (1974) 386–389.

[11] ARORA, D., GAUR, A.C., Microbial solubilization of different inorganic phosphates, Ind. J. Exp. Biol. **17** (1979) 1258–1261.