Preparation and Evaluation of Rice-straw Compost

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Abstract

Rice-straw is an important cattle-feed in several Asian countries even though its quality is low. But in some areas of at least five countries it is burnt. A procedure for rapid composting of rice-straw in lots of 10 kg straw in the semi-arid tropics was standardised using *Aspergillus awamori*, *Pseudomonas striata* and *Bacillus polymyxa*. Rock phosphate (25%, dry straw weight basis) and nitrogen (0.76%, dry straw weight basis) were added at the beginning of composting that generally took 30 to 45 days. Olsen's phosphorus (P) increased from <4 mg kg^{-1} contents of a digester at the beginning of composting to at least 320 mg kg^{-1} contents (<2% of total P) at 30 days. The nitrogen (N) added at the beginning apparently hastened composting but 42-53% of the total N (the amended plus that contained in rice-straw) was lost when measured at 30 days. In the other treatment not receiving nitrogen its loss was 38%. More than 80% of both P and potassium (K) present at the beginning was recovered in the resultant compost that was named as "value-added rice-straw manure" (VARM).

One t of the VARM contained about 17 kg total N, 21 kg total P, 16 kg total K and 270-290 kg organic carbon. Yield of rice plus wheat with recommended fertilizers and VARM was among the highest (11.00 to 11.23 t ha^{-1}) in an on-going long-term field experiment. But it was only marginally superior to the plots receiving recommended levels of chemical fertilizers (10.90 t ha^{-1}). It is hoped that the beneficial effects of VARM will increase in subsequent years. Application of four t ha^{-1} VARM indicated a saving of 13 to 26 kg P ha^{-1}.

The process of composting is complicated for farmers to use but has a promise to become a village level enterprise and needs to be evaluated. For this, feasibility of decomposing large quantities of rice-straw needs to be studied.

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Introduction

Although rice-straw is an important animal feed in most Asian countries, it is commonly burnt in parts of Vietnam, Sri Lanka, Philippines, Indonesia and India. This is usually done because more preferred feeds are readily available and farmers are keen to vacate fields for sowing of the next crop. A recent survey in the present Punjab State of India, found that almost all farmers, who harvest rice using combines, burnt rice-straw (Sidhu et al. 1998). The extent of burning (varying between 50% and 90% on a farm) depended on dryness of straw. It also depended on whether a farmer chopped the standing stubble (generally 40-cm high) with a shredder that cuts stubble at ground level, thereby aiding its early drying and rapid burning. It has been estimated that at least 12 million t of rice and wheat residues are burnt in Punjab annually, resulting in a significant loss of volatile plant nutrients and organic matter. Nitrogen (N) lost with the burnt residues in Punjab is worth US $ 19.5 million annually (Sidhu et al. 1998). Burning crop residues has harmful environmental implications through global addition of carbon dioxide, a gas contributing to the greenhouse effect, and likely high health costs through increase in respiratory problems (as told by elderly farmers) in the local population. This paper describes the conversion of rice-straw into value-added compost that has the potential to improve productivity of the rice-wheat cropping system, and reduce the problem of environmental pollution.

Cuevas (1993) and Banger et al. (1989) have reported composting of rice-straw. The procedure of Cuevas (1993) has been demonstrated at farmers' fields in Philippines and required one part of loppings of leguminous trees and/or animal dung and poultry manure for every three parts of rice-straw. It also used *Trichoderma harzianum* as the microbial agent hastening the decomposition. Cuevas (1993) method at ICRISAT required at least 60 days and was perhaps due to low humidity conditions during March to May (14% to 34% during days and 38% to 80% during nights) in 1996 when it was tested. Work of Banger et al. (1989) was at research scale using *Aspergillus awamori* as activator. Judging from their data on C:N at least 60 days were required to get usable compost. This paper describes special conditions where a compost of C:N of about <20 was accomplished in <45 days in the semi-arid tropics.

Materials and methods

Composting rice-straw

Aspergillus awamori was used for composting because it had been reported to effectively decompose rice-straw (C:N ratio of generally >38) and solubilise the insoluble P in rock phosphate (Banger et al. 1989). It was grown in 500 mL conical flasks containing 300 mL of potato-dextrose broth (Gaur 1984). The fungal growth along with the broth was blended in a Vortex mixer when it formed spores (in about 5 days when grown at 30 °C). Fifty mL of the suspension containing fungal spores and hyphae was used per 15 L water. One hundred and sixty four g urea (0.76% N, straw dry weight basis) was also added. Ten kg air-dried rice-straw (without chopping) was soaked in the 15 L solution. Next day, the inoculated straw was spread on a polyethylene sheet and powdered Musoori rock phosphate (RP, 2.5 kg per 10 kg dry straw) having 7 to 7.4% P, was sprinkled on it and mixed. The contents were then loosely placed in a digester (75 cm diameter, 75 cm deep cement cylinder with water proof base, buried in soil). A frame of iron bars was placed at base of each cylinder. This allowed collection of condensing water from wall of digester and prevented anaerobic conditions. The surface was covered with an additional 10 cm layer of rice-straw wrapped in a plastic net (having 2 mm^2 holes) to prevent its mixing with the experimental materials. Each digester was then covered with a metal lid to prevent animals from disturbing these. The composting rice-straw was kept moist (to 60 to 70% moisture) by applying about 200 mL water in the middle of digester where rice-straw generally went dry as the composting progressed. A knap-sack sprayer with a pointed nozzle having 1 mm six holes that could be pushed into the straw. The contents in a digester were mixed at about 20 days interval by emptying the contents on a polythene sheet. At this point, 50 mL broth of *Bacillus polymyxa* (strain 411) and *Pseudomonas striata* (strain 303) diluted to 500 mL with water was sprayed on the straw. The contents were replaced back in the digester after mixing. A second mixing was done at about 30 days. Decomposed rice-straw was passed through a heavy duty meat-mincer to reduce its volume. The compressed compost was dried in shade before use.

Determining need of nitrogen and microorganisms for composting

The following treatments were examined in a replicated (thrice) test to determine the need of adding nitrogen (N) and microorganisms for composting. The composting of rice-straw receiving all inputs as explained in the preceding section was the standard method (treatment T4) and the resultant product was named Value Added Rice-straw Manure (VARM). The other three treatments in the test were: control (T1, rice-straw soaked in water without any amendments), rock phosphate (RP, rice-straw soaked in water and next day 2.5 kg rock phosphate was mixed with it - T2), urea+RP (same as the standard method described in the preceding section but without microorganisms – T3). Procedure for composting was same in all the treatments as described in the preceding section. All microbiological care during composting was taken to avoid mixing of contents between digesters.

Characterisation of compost

Each type of treatment was rated visually on a "1" (poor decomposition) to "5" (best decomposition) scale. It involved judging growth of fungi on strands of rice-straw during first week, moisture content and smell in the second week, and strength of strands at day 30. Compost of rating "1" was late starter, had less growth of fungi and strands were difficult to break at day 30. And that of rating "3" had reasonably good fungal growth but the rice stems were still strong at day 30. Compost of rating "5" could be made into dough, at day 30, if pressed between the palms of two hands. And that of rating "4" showed good fungal growth from early on (as in the case of rating "5") and a bundle of straw could be pieced, by hand, into two halves, at day 30.

Air-dried 30 day old samples of compost from the four different treatments were characterised for pH, organic carbon, total N (Kjeldahl N plus 2 M KCl extractable N), total phosphorus (P), total potassium (K), available N (2 M KCl extractable N), Olsen's P and exchangeable K (Page et al. 1982).

Field evaluation of VARM

Rice-straw compost for the field evaluation received all inputs as described for VARM. About 250 kg

VARM (dry weight basis) was required for each rice and wheat and was prepared at ICRISAT Patanch..., in the digesters explained above and transported to the Punjab Agricultural University (PAU), Ludhiana for characterisation and evaluation in a long-term field experiment. The experiment was begun in June 1996, and the following ten treatments were applied each season to a Rice-Wheat cropping system:

C	Control (no amendment)
F	Recommended fertilizer (120 kg N ha^{-1} to rice; 120 kg N ha^{-1} and 26.2 kg P ha^{-1} to wheat)
FI	F + Incorporation of rice-straw (4 t ha^{-1}) to wheat
FB	F + Burnt rice-straw (equivalent to 4 t ha^{-1}) to wheat
F2V	F + VARM (2 t ha^{-1}, dry mass basis) to wheat
F2VV	F + VARM (2 t ha^{-1}) both to rice and wheat
½F4VV	Half F and 4 t ha^{-1} VARM both to rice and wheat
8VV	8 t ha^{-1} VARM both to rice and wheat
F(0P)4VV	F + 4 t ha^{-1} VARM to rice; 4 t VARM, 120 kg N ha^{-1}, no P to wheat
F(½P)4VV	F + 4 t ha^{-1} VARM to rice; 4 t VARM, 120 kg N ha^{-1}, 13.1 kg P ha^{-1} to wheat

Although the application of VARM was planned at rates of 2, 4, and 8 t ha^{-1} in the designated treatments, its short supply at sowing of the rice in 1996 dictated the application of 1.5, 3, and 6 t ha^{-1} instead. Wheat did receive the planned levels of VARM.

The field experiment in randomised block design was conducted on loamy sand (Typic Ustochrepts), with three replications for each of the ten treatments on plots of 8.5m × 4m (34 m^2). Rice (variety: PR 111) was sown on 20 Jun 1996 and harvested on 24 Oct 1996 from a net plot harvest area of 23 m^2. Wheat (variety: WL 343) was sown on 15 Nov 1996 and harvested on 6 May 1997 (net plot 23 m^2). Rice was transplanted in 20 x 15 cm spacing and wheat was sown in 22 cm rows. Weeds in rice were managed through application of 1.5 L ha^{-1} Butachlor, 4 days after transplanting (DAT). In wheat, 650 g ha^{-1} of 2-4-D was sprayed at 25 days after sowing (DAS). No manual weeding was done. Fifty kg zinc sulphate ha^{-1} was applied to rice at land preparation. There was no need of pesticides for wheat but rice received 15 L ha^{-1} of monocrotophos at 32 and 95 DAT each and 7.5 kg ha^{-1} of Thimet at 60 DAT. Rice received at least 20 irrigations such that the soil surface was maintained moist. Wheat received two irrigations, one each at 28, and 112 DAS. Harvesting of both rice and wheat was done manually but they were machine threshed. Representative sub samples were collected from each plot to determine moisture in grains (and used for normalising grain yield to 15% moisture). Total N, P and K in grains and stover (above ground plant parts minus grains) was determined as explained by Jackson (1973).

Results and discussion

Preparation of rice-straw manure

Rice straw generally has a pH of at least 8.0. At day 30, pH of compost samples from the different treatments ranged from 7.0 (in T4) to 7.5 (in T1).Weight of the rice-straw reduced (obviously due to carbon loss) as composting progressed (observations on weight loss in each digester were taken every week in previous experiments but Table 1 has weight loss data at 30 days). The treatment T3 and T4 were visually most decomposed with former loosing more (56.4%) than the later (49.8%). By 30 days, control (T1) lost only 46.2% weight and was obviously due to least decomposition (rating "1"). The C:N ratio agreed well with the visual rating. The most decomposed treatments (T3 and T4) also had least C:N ratio (Table 1).

Deducing from the information provided in the section on materials and method, each digester of T1 had 116 g N, 20 g P, 138 g K; T2 had 116 g N, 205 g P, 138 g K; T3 and T4 had 216 g N, 205 g P and 139 g K (total of both from amendment and that contained in rice-straw). From the total nutrient contents per digester at 30 day in Table 1, it was calculated that 42 to 53% of the total N was lost when N was amended in T3 and T4. In T1 and T2 where N was not added, 38% of that at the beginning was lost. Eighty-two to 93% of P and K present at the beginning of composting were recovered in the resultant compost.

At 30 days <1 to 5% N, 1 to 5% P and 30 to 84% K in the different treatments was in soluble form (Table 1). Water soluble forms of nutrients are liable to be leached with rain or excess watering if base of the digesters was not waterproof. Leaching losses of soluble nutrients may partly be the reason of a large variability reported in the concentration of N, P, K in the FYM at farmers' fields (0.17 to 1.79% total N, 0.05 to 0.28% total P, 0.12 to 1.70% total K; T J Rego Senior Scientist, ICRISAT Patancheru, personal communication; Motavalli and Anders (1991)).

With addition of N, rock P and microorganisms (T4) it took about 40 days to decompose rice-straw at ICRISAT Patancheru during hot periods of Feb–Jun (average minimum temperature 17 to 24°C and average maximum temperature 29 to 39°C). Addition of microorganisms did not influence rapidity of composting in this experiment but in a previous experiment (one of the three experiments conducted so far) the difference in the comparable treatments was at least 10 days. A small advantage of T4 (7 to 16% over T3) in nutrient (N, P, K) concentrations was recorded due to the amendment with microorganisms (Table 1). Amendment with rock P and without N and microorganisms (T2) delayed the decomposition by about 7 days. Control treatment (T1) took about 60 days to decompose.

Advantage of using microorganisms for rapidity in composting was not consistent between the three experiments. The difference in number of days taken for decomposition (to make a usable compost, at least of rating "4" on the "1" to "5" scale), with and without N, in three different experiments (only one of the three reported here) ranged from nil to about 15 days, and was puzzling. Recently recorded large differences in N content (0.6 N in the rice-straw used for the batch of data in Table 1, but N was not determined in the straw used for the other two experiments) in different batches of rice-straw (0.5% to 0.9%) seem to be the reason. Perhaps straw of different N concentration influenced enrichment of different microorganisms during composting.

Characteristics of VARM and its effect on rice-wheat

On chemical analysis, the batch of VARM used for the field experiment at PAU contained 0.07% mineral N, 1.72% total N, 0.032% water-soluble P, 2.13% total P, 1.09% exchangeable K

1.60% total K, and 25.4% organic C. Its C:N ratio was 14.8. Thus, one t of VARM contained about 17 kg total N, 21 kg total P, 16 kg total K and 270 to 290 kg organic carbon.

Rice yield with full fertilizer treatment (5.69 t ha^{-1}) and with the various treatments involving the use of fertilizer and VARM were similar. Maximum wheat yield (5.52 t ha^{-1}) was obtained with the treatment receiving the recommended level of fertilizers and 2 t ha^{-1} VARM each to wheat and rice (F2VV) and was significantly superior to F2V (4.74 t ha^{-1}) and ½F4VV (4.43 t ha^{-1}, Table 2). Control treatment (no fertilizer, no VARM) produced lowest rice (2.58 t ha^{-1}) and wheat (2.66 t ha^{-1}) yield. The treatment receiving only organic sources of nutrients (6 t ha^{-1} VARM to rice and 8 t ha^{-1} VARM to wheat) yielded 64% greater rice (4.23 t ha^{-1}) and 45% greater wheat (3.26 t ha^{-1}) yield over control treatment. This is a significant observation because in the work of Sidhu and Beri (1989), cereal residue incorporation (4 t ha^{-1} annually for 4 years) even with N fertilizer (0, 40, 80, and 120 kg N ha^{-1}) generally suppressed yield (except in two of the 4 years when 120 kg N ha^{-1} was applied) of the following wheat crop. In the first cycle of rice-wheat, the organic treatment received a total of 224 kg N i.e. similar to that received by F (recommended doses of fertilizers) but produced significantly lower yields than F. This may be due to low mineralization of nutrients perhaps partly due to pelleting of VARM. The pellets generally do not dissolve until well after rice harvest and we have seen a coat of fungal growth on some pellets. From the rainy season 1998, it is proposed to use pulverised VARM.

Generally, rice and several other crops grown in rainy season do not respond to applied P in Punjab whereas wheat does (Gill and Meelu 1983). Therefore, wheat was expected to respond better to VARM application than rice but it was not apparent in the year 1 and perhaps was due to the fact that almost all quantity of P in the VARM was in insoluble form. Still, the yield of the treatments with 4 t ha^{-1} VARM along with half of recommended P, or with nil P (the last two treatments in the Table 2) was similar to that receiving recommended fertilizers. This indicates the potential of VARM saving significant quantities of fertilizers.

Straw yield and uptake of N, P, K, both by rice and wheat, generally followed the trends of the grain yield (Table 2). Addition of significant quantities of K through VARM, did not result in increased quantities of K in grains or stover in relevant treatments. This was due to sufficiency of K at the experimental site (1341 kg ha^{-1} in top 120 cm profile).

Further studies

Thirty eight to 53% of the total N present in the beginning was lost during decomposition irrespective of N amendment. Using reduced N concentration (from 0.76% N in this report to 0.38% N in further studies) for amendment did hasten composting in further studies. Also, in further work we plan to use 6% rock P (on straw dry weight basis) having 7.0 to 7.4% total P, so that 2 t VARM provides about 25 to 30 kg P ha^{-1} that is recommended for wheat. Although only <2% of the total P will be in available form, it is hoped that it will build up the P pool of the soil and become eventually available in the long-term through the P-solubilizing microorganisms whose population is expected to increase with time.

Preparation of VARM involved the use of rock phosphate and P-solubilizing microorganisms. The rock P had <4 mg kg^{-1} Olsen's P and VARM was assessed to have 320 mg kg^{-1} Olsen's P and 2130 mg kg^{-1} total P. Only <2% of the total P was solubilized by these microorganisms and the organic acids produced during composting. The microorganisms involved in the study have been developed through screening in liquid cultures (Bardiya and Gaur 1974, Arora and Gaur 1979) where all growth requirements of the organisms are met. Under such conditions <2 to 11 mg of the total 100 mg provided in the growth medium (had glucose and yeast extract) was dissolved by the six different bacteria and *Aspergillus awamori* in three weeks (Arora and Gaur 1979). Thus the microorganisms under the laboratory conditions were more efficient than in composting environment used in this study. Also, pH of the laboratory medium changed from 7 at the beginning to <3, in three weeks. These microorganisms were generally 7-times less effective (Arora and Gaur 1979) in solubilizing P in rock-P than in solubilizing P in tricalcium-P (also an insoluble form of P). There seems a scope to identify P solubilizing microorganisms that should be efficient under composting conditions of high pH (>7) and poor nutrients.

Yield of rice plus wheat with recommended fertilizers and VARM was among the highest but only marginally superior to fertilizer application alone. It is hoped that the effect of VARM will increase in subsequent years. Rice in year 2 (data not shown) indicated 6% improvement in N-use efficiency in relevant treatments. Composting of rice-straw into a value-added product (and its use) is thus a highly promising alternative to its burning and can potentially increase present productivity of rice-wheat cropping systems. It will also reduce the problem of environmental pollution. However, the complicated process of preparing compost is unlikely to be practised by farmers. It was observed that significant number of farmers in the area have not adopted composting of cattle dung (extended in 1960's 70's) in a scientific way (Sidhu et al. 1998) despite significant efforts in India (including in the Punjab) in collaboration with FAO (Gaur 1984, FAO 1986). Rupela (1985) opined that if farmers have not adopted a relatively simple protocol of composting cattle dung, the composting of crop residues should not be targeted to farmers. He, however, saw a great scope of success if composting of rice-straw was promoted as a village level enterprise provided its economic feasibility has been evaluated. This will require scaling-up studies on composting from its present small scale.

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Table 1. Major nutrients and other characters of rice-straw compost at 30 days age.

		Moist-	Weight	Rat-	OC		Total nutrients per digester (g)			Available nutrients per digester (g)		
T. eatment	pH	ure (%)	loss (%)	ing	(%,	C:N	N	P	K	N	I	K
T1: Control	7.5	69.9	46.2	1	45.1	32.9	72	23	117	3.61	1.10	34.5
T2: Rock phosphate 25% (RP)	7.5	61.3	54.7	2	29.3	29.3	72	179	113	0.02	3.14	92.0
T3: N+RP (0.76% as urea, 25% RP)	7.0	63.0	56.4	4	27.1	19.4	101	177	115	4.70	2.22	89.5
T4: Inoculation (Microorganisms, 0.76% N as urea, 25% RP)	7.0	62.1	49.8	4	28.8	19.1	116	189	133	5.27	2.60	111.8
SE	±0.2	±1.80	±5.56	ND	±1.23	±1.42	±7.63	±13.9	±6.19	±1.764	±0.136	±6.49
CV%	5	5	19	ND	7	8	15	17	9	90	10	14