Use of effective micro-organisms (EM) and urea in accelerating the decomposition of Rice Straw

[1]H.M.I.K. Herath, [2]W.M.D.B.Wickramasinghe and [1]R.B. Mapa
[1]Department of Soil Science, Faculty of Agriculture, University of Peradeniya
[2]Rice Research & Development Center, Bathalagoda, Ibbagamuwa

Accepted 30th June 2004

ABSTRACT

Slow decomposition rate of rice straw associated with its fibrous nature limits its use as organic manure even though it is widely available in Sri Lanka. Influence of effective microorganisms (EM) and urea on the decomposition of rice straw was tested using six treatments as control, EM, urea rate 1 (U1), urea rate 2(U2), EM+U1 and EM+U2. The rate of decomposition was evaluated using C:N ratio, weight loss and tensile strength throughout an eight-week period. The results showed that the EM treatment significantly reduced the C:N ratio only after 4th week of application. By the 8th week C:N ratio of the control was reduced from 50.3 to 18.5 whereas the others attained a similar value in shorter periods amounting to 6.5, 5.5, 5 and 4 weeks in EM, U1,U2, U1+EM and U2+EM treatments respectively. Urea applied treatments showed lower C:N ratio, higher weight loss and lower tensile strength than the EM applied and control, showing faster decomposition. This study reveals that EM increased the rate of decomposition of straw but when urea was applied the decomposition rate was higher. Using urea as N source and increasing the activity of indigenous microbial population seem to be more cost effective in straw decomposition, than applying EM of unknown composition.

Key Words: Effective microorganisms, decomposition, rice straw, urea, organic manure

INTRODUCTION

Among potential organic materials used in paddy cultivation, rice straw is a widely available resource in Sri Lanka (Kendaragama and Jayawardena, 2001). If straw from a 4 t/ha rice crop with a 1:1 grain to straw ratio is properly utilized, it could provide about 30% and 100% of N and K requirements, respectively (Wijesundara *et al.*, 1995). However, at present straw is not applied to paddy lands by most farmers due to practical difficulties. Among these, the fibrous nature and high tensile strength of straw make either surface application or soil incorporation difficult. Therefore, there is a need to pre-treat straw for improving its applicability. Among the pre-treatments, chopping straw into small pieces or accelerating the process of decomposition by additives prior to application are two fundamental strategies used. For these approaches, appropriate technologies have not been developed locally to practice chopping. Therefore, the most desirable approach is to accelerate the decomposition of rice straw by introducing suitable pre-treatments. The most popular pre treatment is mixing rice straw with a nitrogen source such as urea or animal manure. In the Philippines, *Trichoderma harziamum*, which is a cellulose decomposing fungus, has been used for rapid decomposition of plant residues (Cuevas, 1997). In many countries effective microorganisms (EM) are presently used to accelerate the decomposition rate of organic materials with high carbon to nitrogen ratios (Yadav, 1997).

Effective microorganisms (EM) is an inoculum of beneficial microorganisms, which can co-exist in a mixture. This mixture of microbes consists primarily of photosynthetic and lactic acid bacteria, yeast, actinomyceties and fermenting fungi (Kyan *et al.*, 1999). Many researchers have documented the beneficial and harmful effects of using EM. Chowdrey *et al.* (1993) showed that application of EM increased the photosynthetic capacity of plants by increasing the leaf chlorophyll content. Higa and Kinjo (1993) showed that soil physical and chemical properties, and environment improves with application of EM while suppressing pathogens and pests in plants. Higaa and Wididana (1989) showed the positive effects of EM on availability of soil P while Sangakkara (1993) documented the improvements of N and K. Tokeshi and Chagas (1997) have documented the effect of EM on enhancing seed germination and the vigor of seedlings. In contrast, Nagoratnapraporn and Vasuvat (2000) evaluated EM and EM products on agriculture and environment, and demonstrated that total aerobic and anaerobic bacteria counts were similar in the commercial microorganism mixture and in surface soil samples. They also documented that application of EM did not have a significant effect on phyto-pathogenic bacteria and fungi.

EM had been used for waste degradation by biotechnology companies, as a compost accelerator, odour controller and to prevent pollution in prawn farms in many countries. Many researchers have documented concerns on the lack of information on risks involved in using microbial mixtures as EM and also the possibilities of the invasive nature of microbes in these mixtures. In addition, incorporation of EM to soils with low organic matter contents may enhance the organic matter decomposition and thereby reducing its beneficial effects as dry and wet aggregate stability (Mapa and Yaparathne, 2002). Therefore, the objective of this study was to investigate the impact of effective microorganisms (EM) and urea on increasing the decomposition of rice straw.

MATERIALS AND METHODS

Fresh rice straw was used as the starting material for this experiment. The decomposition pattern of rice straw was tested using six treatments including control, EM (10 cc/kg of straw), U1 (1.75 kg of urea/ tone of rice straw), U2 (3.5 kg of urea/ tone of rice straw) and combinations of EM+U1, and EM+U2. EM was applied at the rate recommended by the manufacturer (Kyan et al., 1999). Urea was dissolved in water and applied to dry straw. The higher rate of urea was used according to the recommendation by the Department of Agriculture (Anonymous, 1990). Three liters of water was added to each kg of dry straw to keep it moist and a level of 0.55 g/g moisture content was maintained throughout the experiment. The surface was covered using transparent polythene to minimize evaporation and a few holes were made to facilitate gas exchange. Treatments were arranged in a completely randomized design (CRD) with four replicates. A composite straw sample of starter material was analyzed for total carbon content, total nitrogen content, C/N ratio and tensile strength and considered as initial properties. After commencement of the treatments, samples were removed weekly for analysis up to eight weeks.

The total carbon was determined by the titrimetric method (Nelson and Sommers, 1982) and total N was determined using the Micro-kjeldahl procedure. From these values the C:N ratio was obtained. To determine the weight loss due to decomposition a sub- sample was removed weekly and the oven dry moisture content was determined.

The total dry mass remaining at each week was calculated using the moisture factor. The remaining percentage of dry weight was estimated as the ratio of dry weight of each week to initial dry mass (Wickramasinghe, 1994). The weight loss due to sampling at different times were considered when estimating the weight loss.

Tensile strength was measured using a device where one end of 10-15 cm length inter-node of straw was fixed while the other end was attached to a small container to facilitate adding of weights. Amount of weights added at the time of breaking was measured. The cross sectional area of straw was measured and the tensile strength was determined as the weight needed to break straw in kg/cm^2 as suggested by Kendaragama and Jayawardhana (2001).

The data obtained were analyzed statistically using the Statistical Analytical Software package (SAS, 1988) to obtain the least significant difference (LSD) for mean separation.

RESULTS AND DISCUSSION

Carbon to Nitrogen Ratio

The changing pattern of C: N ratio of differently treated rice straw at weekly intervals up to eight weeks is shown in Table 1. The mean value of the initial C: N ratio of the material used in the experiment was around 50. Wickramasinghe (1994) showed that the C:N ratio of straw may slightly change with the rice variety, and the amount of N fertilizer applied during cultivation. Yang (1997) documented that when

The C:N ratio is higher than 35 the micro organisms must go through many life cycles oxidizing off the excess carbon until a more convenient C:N ratio for their metabolism is reached.

Table.1 Mean C:N Ratio of decomposing rice straw in different treatments with time

Week	Control	EM	U1	U2	U1+EM	U2+EM
0	50.3 ^{a}	51.1^{a}	51.2^{a}	50.4^{a}	50.4^{a}	50.0^{a}
1	46.6 ^{a}	44.7^{a}	38.5^{b}	33.4^{c}	36.9^{b}	32.4^{c}
2	42.5 ^{a}	40.5^{a}	32.7^{b}	29.3^{b}	30.4^{b}	26.3^{c}
3	36.5 ^{a}	35.5^{a}	28.5^{b}	26.3^{b}	25.6^{b}	22.5^{c}
4	31.5 ^{a}	30.5^{a}	25.7^{b}	21.5^{c}	20.5^{c}	18.5^{c}
5	26.6 ^{a}	23.3^{b}	20.6^{c}	19.6^{c}	18.5^{c}	17.6^{c}
6	23.4 ^{a}	20.7^{b}	18.4^{c}	17.3^{c}	17.9^{c}	16.8^{c}
7	20.6 ^{a}	18.6^{a}	17.7^{b}	16.7^{b}	16.7^{b}	15.4^{b}
8	18.5 ^{a}	18.2^{a}	16.6^{a}	15.4^{b}	15.7^{b}	14.4^{b}

Mean values indicating same letters along the rows are not significantly different at 95% probability level

The main factors that are important for decomposition of organic matter are oxygen supply, C:N ratio and moisture content (Yang, 1997). It has been shown that the main indicator of compost maturity is the C:N ratio (Yadev, 1977). Therefore, in evaluating the bio-stability of decomposing organic matter, it is important to determine C:N ratio with time. In the first week, urea alone and the combination with EM showed a significant decrease of C:N ratio compared to the control. The lowest C: N ratio was observed in U2+EM treatment throughout the experimental period (Table 1). After six weeks, significantly lower values of C:N ratios were observed in treatments U1, U2, U1+EM, U2+ EM which showed a reduction of 21%, 26%, 23% and 28% respectively, compared to the control. When different treatments were compared, U1, U2, U1+ EM and U2+EM treatments did not show significant differences between treatments in C: N ratio values of 5th ,6th and 7th weeks. The EM treatment showed a significantly higher C:N ratio than all treatment above but significantly lower values than the control after 4th and 5th weeks of study. During the eight weeks of study period, the C:N ratio of straw in the control treatment decreased to 18.5 which is an accepted ratio for mature compost. When the time taken to reduce the C: N ratio to the same level was considered, the treatments EM, U1, U2, U1+EM and U2+EM took 6.5, 6, 5.5, 5 and 4 weeks respectively. This showed that the quickest decomposition of straw was obtained by using the higher rate of urea and EM together. When the total of 8 weeks were considered the reduction of the C:N ratio in treatments U1, U1+EM and U2+EM were at a faster rate in the first four weeks than in the 4th to 8th week period.

Weight Loss of Decomposing Rice Straw

Due to release of carbon as carbon dioxide during decomposition, the dry weight of the initial material reduced with time. Changes of the dry weight of differently treated rice straw, as a percentage from initial dry mass and the standard error of the mean is shown in Figure 1. The amount of weight loss within a time period is an indirect measurement of the decomposition of organic matter. All the treatments showed a higher weight loss than the control through out he experimental period. The control and EM treatment showed a significantly higher remaining percentage of dry weight than all the other treatments from 2nd to 6th weeks.

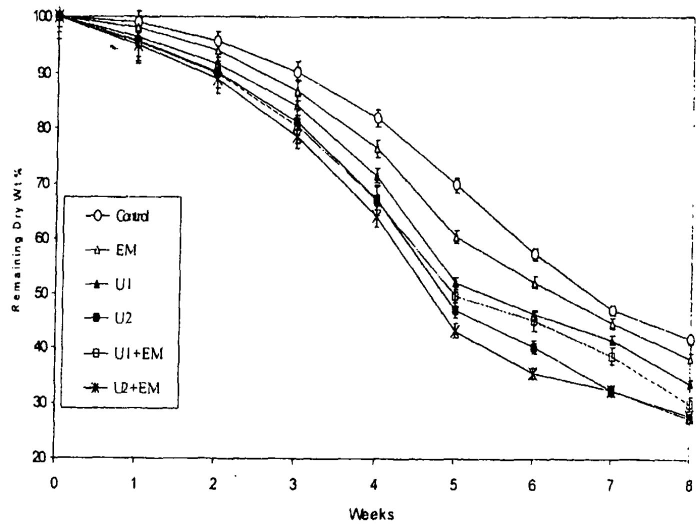

Figure 1. Remaining dry weight % and the standard error of the mean for different treatments up to 8 weeks

When compared to the control the EM treatment showed significantly lower values of remaining percentage values at 4th, 5th and 6th weeks respectively. Figure 1 shows that the weight loss related to the decomposition process was faster during the first four week period than the second four week period irrespective of the treatments. It has been reported that nearly 20% of the original weight of rice straw was lost in the control during the first four week time period in an incubation study of rice straw decomposition (Wickramasinghe, 1994). Kendaragama and Jayawardhana (2001) compared the decaying pattern of rice straw during a two months period and showed that it was faster during the first 30- day period than the 30-60 day period. Among all the treatments the lowest remaining percentage of dry weight was given by the U2+EM treatment at all sampling dates. At the 8th week it was 28% from the initial dry weight while control and EM treatment showed 42% and 38% remaining dry weight respectively. This is related to the loss of Carbon as CO_2 due to higher rate of decomposition in U2+EM treatment.

Tensile Strength

Changes in tensile strength as a percentage from the initial value in differently treated rice straw during the experimental period is shown in Table 2. The mean value of the tensile strength of rice straw used for the experiment at the beginning was 240 kg / cm ^{2}. Kendaragama and Jayawardhana (2001) in their experiments reported a tensile strength of 173 kg/ cm^2 in fresh rice straw, which is a lower value than reported here. This difference may be due to the varietial difference, the length of straw and inclusion of nodes in the sample used.

High tensile strength is one of the major limitations, which makes incorporation of rice straw difficult. One week after the experiment the tensile strength of the control reduced to 73 % from the initial value while U1, U2, U1+ EM and U2+ EM treatments reduced to 57%, 55 %, 55% and 52%, respectively. In the EM treatment there was a 59% reduction in the first week after incubation. In urea applied treatments, due to the rapid decomposition rate facilitated by lower C: N ratio, the tensile strength dropped markedly in comparison with that of control even at the initial stage of the study.

It has been shown that the reduction of tensile strength with decomposition of rice straw is higher under saturated moisture conditions. (Kendaragama and Jayawardhene, 2001). A rapid reduction in tensile strength was observed during the first four week time than in the second four week period (Table 2).

This is similar to a reduction of the remaining dry weight related to Carbon loss due to the rapid rate of decomposition in all the treatments including control. EM treatment showed 26 %, 43 %, 58 % and 65 % reduction in tensile strength than that of control in 2nd, 4th, 6th and 8th week of the experimental period, respectively.

As shown with the other parameters the lowest tensile strength could be observed in U2+EM treatment during the experimental period. This is related to rapid decomposition due to the lowest C:N ratio and introduction of microorganisms, which enhanced the rate of decomposition. During the 8th week of the study, treatments U1, U2, U1+EM and U2+EM showed 73 %, 83 %, 75 % and 83 % reduction in tensile strength compared to the control, which was 5.2 % of initial value.

Table. 2 Relative percentage of tensile strength of decaying rice straw in different treatments with time

Week	Control	EM	U1	U2	U1+EM	U2+EM
0	100	100	100	100	100	100
1	73.2	58.9	57.2	55.2	55.2	52.3
2	48.6	35.7	3 4.7	32.5	32.6	29.7
3	29.9	21.7	21.5	17.8	19.3	16.3
4	24.0	13.6	13.5	11.3	12.1	10.8
5	16.6	7.9	7.1	5.7	5.8	4.9
6	10.6	4.4	3.8	2.8	3.9	2.7
7	7.6	3.6	2.7	1.7	2.4	1.3
8	5.2	1.8	1.4	0.9	1.3	0.9

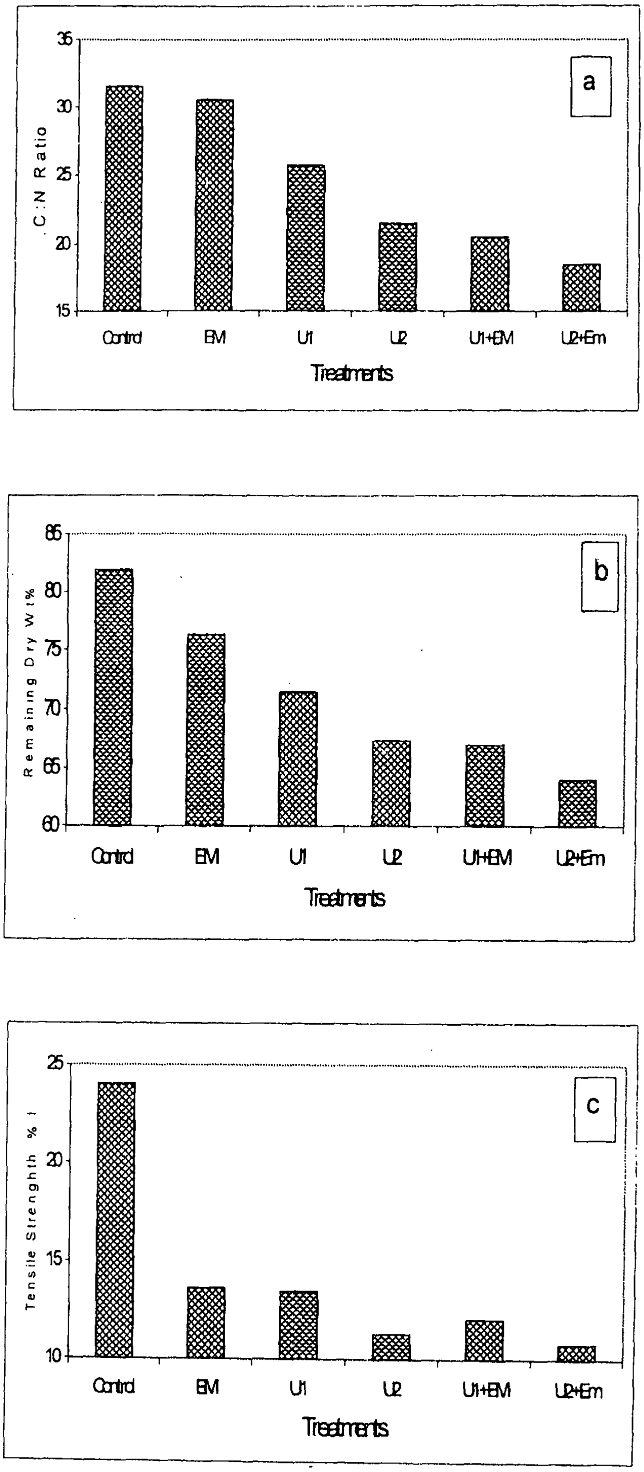

Figure 2. The C:N ratio (a), weight loss as % of initial weight (b) and tensile strength as % of initial value (c) at 4 weeks of the experimental period.

Figure 2a, 2b and 2c show the summary of all three parameters of decomposition, the C:N ratio, tensile strength and weight loss at 4th week after incubation. Tensile strength showed a significant reduction in the EM applied treatment than in the control. A similar pattern of gradual reduction in the order of control, U1, U2, U1+ EM and U2 +EM was shown in all three parameters. When all three parameters were considered, the highest rate of decomposition was observed in U2+ EM treatment. When EM treatment in compared with control, EM treated straw showed a higher rate of decomposition than the control but less than the urea applied and urea + EM applied treatments. The rate of decomposition among urea applied and urea + EM applied treatments did not show significant differences in most of the weeks. Seeding or inoculation using microorganisms have been effective in some composting procedure (Chen *et al.*, 1997) and on the other hand negative results have been reported (Bertoldi *et al.*, 1980). It has been shown that the rate of decomposition of sewagesludge was mainly controlled by the solids in their substrate than the microorganisms inhabiting in the compost (Yang, 1997).

This study revealed that effective micro-organism (EM) solution applied at the rate of 10 ml/ kg of straw increased the decomposition rate when compared to the control. This was evident from the three parameters measured, the decrease in C: N ratio, the decrease in tensile strength and increase of weight loss. This may be because the application of EM increased the microbiological population and enhanced the straw decomposition. When urea was applied at the rate of 1.75 kg/t and 3.5 kg /t of straw the decomposition rate was higher than the rate achieved by EM as the urea increased the N content and thereby enhanced the activity of the native microbiological population. Among all the treatments tested the highest decomposition rate of straw was observed when EM was applied in combination with urea. This combination supplied the N needed and also increased the microbiological population. In all treatments the decomposition rates were high from 1st to 4th week period than the 5th to 8th week period showing the bio-stability of the product.

According to the rates used in this study, using 3.5 kg of urea per ton of straw cost Rs 60/= which was economical than using 10 liters of EM solution per ton of straw at a cost of Rs 1360/= In addition using urea resulted in a faster decomposition rate. Therefore using urea as a N source which increases the activity of indigenous microbial population seems to be more cost effective and environmentally safer than applying EM of unknown composition, which may contain invasive or harmful micro organisms.

CONCLUSIONS

The results revealed that EM applied at a rate of 10 cc/kg of straw increased the decomposition rate when compared to control. When urea was added at the rate of 1.75 kg/t the decomposition rate was higher than the rate achieved by EM. The highest decomposition rate was observed when EM was applied in combination with urea. When the cost was compared using EM at the recommended rate, cost Rs 1360/ton of straw while urea cost only Rs. 60/= for same amount of straw. Therefore, adding urea as a nitrogen source and increasing the indigenous microbiological population seems to be more cost effective than applying EM of unknown composition, which may contain invasive micro flora or fauna.

ACKNOWLEDGMENTS

The financial support for this work was provided by the University of Peradeniya research grant scheme. The authors wish to thank Mr. K.L.N. Rajapaksha and P.R. Idemakorale for their assistance and to Dr. Harsha Liyanage of Survodaya for providing the EM solution.

REFERENCES

Anonymous 1990 Fertilizer Recommendations for Rice. Department of Agriculture, Sri Lanka.

Bertoldi MD U Citemesi and M Griselli 1980 Bulking agent in sludge composting Compost Science 21: 32-36

Chen KS YG Lo CH Chang and SS Yang 1997 Utilization of thermophilic actinomycetes in agricultural waste treatment. In N.M. Tahir (Ed.) Abstracts of the 2nd International conference on Environmental Chemistry and Geo-Chemistry in the tropics.' Kuala Lumpur, Malaysia p 24.

Chowdry AR MM Islam and J Hider 1993 Effect of EM on growth and yield of crops. Proc. 3rd International conference on nature farming for sustainable agriculture. California, USA.

Cuevas VC 1997 Rapid decomposing technology in the Philippines: Its role in producing good quality organic fertilizers. Extension Bulletin 444. Food and Fertilizer Technology Center, Taiwan.

Higa T and S Kinjo 1993 Effect of lactic acid bacteria on plant growth and soil fermentation. Proc. 1st International Conference on Kyusei Nature Farming, Khon Khan University, Thailand. 140-147.

Higa T and GN Wididana 1989 Concepts and theories of EM. Proc. 1st International Conference on Kyusei Nature Farming, Khon Khan University, Thailand. 112-118.

Kendaragama KMA and Jayawardana SN 2001 Effect of moisture content and nitrogen application on tensile strength of rice straw. SLAAS. Proceedings of 57th Annual Session Part 1. 85p.

Kyan T Shinthani M, Kanda S and Sakurai M 1999 Kyusei nature farming and the technology of effective micro-organisms. Guideline for practical use. Asia Pacific Natural Agricultural Network, Bangkok, Thailand. 45 p.

Mapa RB and Yaparathne YMW 2002 Influence of effective microorganisms on soil organic matter and aggregate stability. Sri Lankan Journal of Agricultural Science 39:51-61.

Nagoratnapraporn N and Vasuvat Y 2000 Feasibility of testing and effects of using EM on agriculture and environment. Research Report. Kasetsart University Research and Development Institute. Bangkok.

Nelson DW and Sommers L E 1982 Total Carbon and Organic Matter. In : A. L.Page(Ed). Methods of Soil Analysis. Part II. 2nd Ed. Amer. Soc. Agron. 539-577.

Sangakkara UR 1993 Research on the technology of EM in Sri Lanka. Proc. 3rd International Conference on Nature Farming for Sustainable Agriculture. California, USA. 15-25.

SAS 1988 SAS/ STAT User's Guide. Release.

6.03. SAS Institute Inc. , Cary, North Carolina, USA.

Tokeshi H and Chagas PRR 1997 Germination of citrus as effected by the hormonaleffects of EM. Proc. 5th International Conference on Nature Framing, Bangkok.Thailand. 25-30.

Wickramasinghe W M DB 1994 Solubility of Rice Straw Silica and Their Availability in Rice Cultivation. PhD thesis, University of Reading .UK.

Wijesundara, SM, Wickramasinghe WMADB and Wijesundara C. 1995. Chemical and bio fertilizers for rice. Pp 73-102. In Amarasiri SL, Nagarajah S and Perera BMK (ed.) Rice Congress. Papers presented at a symposium 3-4 September 1990.Hotel Tourmaline, Kandy. Department of Agriculture, Peradeniya.

Yang SS 1997 Preparation of Compost and Evaluation of Its Maturity, Extension Bulleting No 445, Food and Fertilizer Technology Center, Taiwan; PP 23-25.

Yadav SP 1997 The Technology of EM in Nepal, An Update on Success. Proc. fifth International Conference on Nature Farming, ed. Senanayake, Y. D. Thailand. PP 241-288.