Journal of Industrial Microbiology (1996) 16, 237–240

A sawdust-derived soil conditioner promotes plant growth and improves water-holding capacity of different types of soils

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Sawdust, a bulky waste generated by wood processing industries, has very few profitable and ecofriendly uses and poses a problem of proper disposal. Treatment with the fungus *Volvariella volvaceae* and a dilute solution of urea converted sawdust from a phytoinhibitory material to a phytostimulatory soil conditioner. In different types of soils, the soil conditioner increased the moisture retention and facilitated the cohesive interaction of particles. Analyses of the major biopolymers of sawdust after fungal treatment indicated that levels of cellulose, hemicellulose and lignin decreased; however, these changes did not account for the plant growth stimulatory property attained by this material.

Keywords: moisture retention; sawdust; soil conditioner; *Volvariella volvaceae*

Introduction

Sawdust is a voluminous waste generated by the timber and wood processing industries. Due to its poor biodegradability and low bulk density, disposal of this solid waste is an economic and environmental problem. Although sawdust is used as a fuel, especially in the developing countries [10], its low bulk density and high surface area make energy recoveries poor and combustion incomplete, resulting in the generation of volatile pollutants [4]. Previous studies have shown that treatment of sawdust with the fungus *Volvariella volvaceae* removed the plant growth-inhibitory property of sawdust and imparted plant growth-promoting activity [12]. In this communication it is shown that the fungus-treated sawdust imparted beneficial attributes to different types of soils to make them suitable for agricultural purposes.

Materials and methods

Fungus treatment of sawdust

Eucalyptus sawdust and bagasse pith were obtained from a pulp mill in northern India. The sawdust (500 kg), with or without bagasse pith (85 kg), was mixed with a slurry of water (200 L) containing urea (10 kg) and an overnight culture of the fungus *Volvariella volvaceae*. In some experiments bagasse pith was omitted, a different amount of *V. volvaceae* culture was used or urea was omitted or replaced with an equivalent amount of nitrogen in the form of soybean meal. The mixed sawdust was placed in 1 m^3 pits, covered with jute cloth, moistened at weekly intervals by sprinkling with water and incubated for 10 weeks. The temperature in the pits ranged from 25° to 45°C, and moisture was 30–45% on a wet weight basis.

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Received 26 June 1995; accepted 24 January 1996

Analytical procedures

Samples were collected from several locations within the pit, mixed and analyzed. Moisture content was determined by drying the samples at 60°C to constant weight. Cellulose, hemicellulose and lignin content of the dried samples were analyzed using procedures described by Updegraff [13], Deschatelets and Yu [5] and Browning [3], respectively.

The physicochemical characterization of the soil conditioner and soil mixtures were analyzed according to the Indian Standards Code: dry density [6]; moisture content [7]; direct shear test [8]; coefficient of permeability [9].

Plant growth conditions

Treated sawdust was mixed with an equal volume of sterilized garden soil (soft textured medium black, pH 8.2), and placed in plastic containers. Twelve wheat seeds (HD-2329) were sown in each container at a depth of 4 cm; the containers were maintained in a well-lit area, watered (500 ml) twice a week, but no fertilizer was added. Analyses were done in triplicate and the averaged data are reported.

Results and discussion

Conversion of sawdust into a soil conditioner

Samples collected from treatment groups and from controls were mixed with soil and the ability to support the growth of wheat seedlings was evaluated (Figure 1). Beds containing sawdust treated with only water and urea inhibited the growth of wheat seedlings, whereas in the beds containing *V. volvaceae*-treated sawdust, the growth of wheat seedlings was not inhibited. Beds containing sawdust and bagasse pith treated with *V. volvaceae* exhibited enhanced growth of the wheat seedlings. These results indicated that treatment of sawdust with the fungus *V. volvaceae* and urea could remove the phytoinhibitory effect and impart plant growth-promoting properties to sawdust. The contribution of urea to the conversion process was tested (Table 1) by

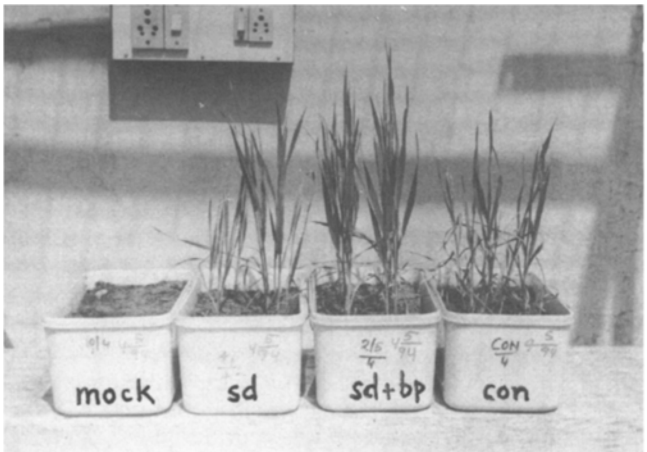

Figure 1 Effect of *V. volvaceae* treatment on the phytoinhibitory property of sawdust. Sawdust was treated with a dilute solution of urea with or without (mock) addition of *V. volvaceae*. While in one set only sawdust was treated (sd), in another, a mixture of sawdust and bagasse pith (sd + bp) was treated. Aliquots of these treatments were mixed with an equal volume of garden soil and used as growth beds for wheat seedlings. In the control (con) only soil was used as the growth bed. The seedlings were photographed after 6 weeks.

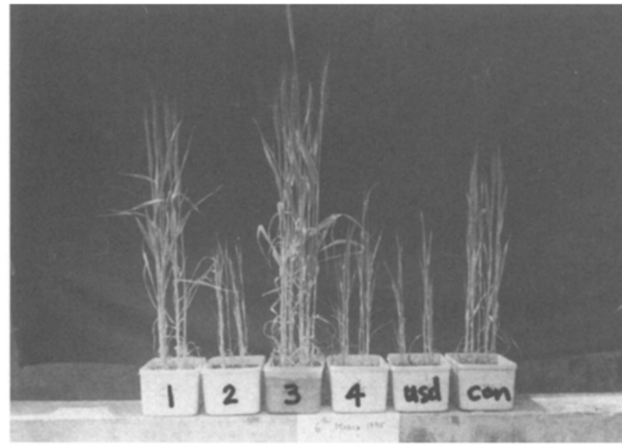

Figure 2 Effect of urea on the conversion of sawdust to soil conditioner. A mixture of sawdust and bagasse pith was treated with water containing urea and 40 ml *V. volvaceae* culture per kg sawdust (1), only *V. volvaceae* culture (2), urea and 80 ml *V. volvaceae* culture per kg sawdust (3), or soybean flour and *V. volvaceae* culture (4) to prepare soil conditioners. Soil conditioners from different treatment groups, or untreated sawdust (usd) were mixed with an equal volume of garden soil and used as growth beds for wheat seedlings while soil without amendment served as the control (con). The seedlings were photographed after 12 weeks.

Table 1 Test of parameters involved in conversion of sawdust to soil conditioner and their effect on wheat productivity

Treatment pit	Nutrient	Inoculum (ml kg^{-1})	Grain yield (g)
1	Urea	40	2.38
2	None	40	0.50
3	Urea	80	3.61
4	Soybean meal	40	0.81
Untreated sawdust	–	–	0.25
Soil only	–	–	0.55

omitting it from the treatment mixture (pit 2) or replacing it with an equivalent amount of nitrogen from soybean meal (pit 4). Whereas in pits 1, 2 and 4 the fungal inoculum was used at 40 ml kg^{-1} sawdust, in pit 3 it was used at 80 ml kg^{-1} sawdust. After 10 weeks of treatment, samples were collected from different pits and their effect on growth of wheat seedlings was examined (Figure 2). Poor growth of wheat seedlings in beds containing sawdust from pit 2 and untreated sawdust, compared to growth in soil alone (control), indicated that the suppressive effect of sawdust persisted. Comparison of growth in beds containing sawdust from pits 1 and 4 with the control suggested that soybean meal was only marginally effective in the conversion process, and the soil conditioner thus prepared did not promote the growth of wheat seedlings better than soil alone. Since the fungus is able to utilize nitrogen from soybean meal for growth in a laboratory growth medium, the ability of the fungus to utilize this nitrogen source could not have been the limitation, and other factors like the particulate nature of the meal and insufficient distribution of the nutrient within the milieu could have contributed to the failure of the conversion of sawdust. Urea, on the other hand, being soluble, could be better distributed within the mixture, and thus could be more effective in the conversion process. At the dose used in these experiments, no urea was detected after 3 weeks from the sawdust mixture (data not shown), and thus, the urea may not be available for promoting plant growth. Comparison of sawdust from pits 1 and 3 suggested that in both these cases the sawdust had lost its phytoinhibitory property and promoted growth of the wheat seedlings. Thus, this experiment indicated that by the action of the fungus *V. volvaceae* and urea, sawdust could be converted to a soil conditioner, useful for stimulating the growth of wheat seedlings. However, the growth of the seedlings was much better (Figure 2) and the yield of grains was also higher (Table 1) from plants growing in beds containing soil conditioner from pit 3 than pit 1. Previous results had shown that among the various organisms evaluated for conversion of sawdust, only *V. volvaceae* was effective in such a conversion [12].

Changes in the polymeric constituents of sawdust during conversion

In order to better understand the changes that are brought about during the conversion of sawdust into soil conditioner, its major constituents, ie, cellulose, hemicellulose and lignin, were analyzed (Table 2). The cellulose content of the sawdust decreased by about 18% in samples from all the treatment groups, while lignin levels showed a decrease of about 30%. Hemicellulose content decreased the most. There was a uniform decrease in the level of these three polymers in all the treatment groups in spite of the vast difference between these sawdust samples on the wheat growth-promoting activity (Figure 2). The decrease in the level of these polymers occurred perhaps as a result of general decomposition of the sawdust and bagasse pith under the conditions of treatment, and were neither affected by the presence (or absence) of urea nor the amount of fungal inoculum. These results suggested that the plant growth-promoting activities were the result of effects of

Table 2 Profile of the polymers of sawdust as a function of microbial treatment

Treatment pit	Cellulose (%) after (weeks):				Hemicellulose (%) after (weeks):				Lignin (%) after (weeks):			
	1	2	3	4	1	2	3	4	1	2	3	4
0	47.0	47.6	47.6	48.5	19.5	18.3	18.0	18.5	38.0	37.0	36.0	35.5
2	44.5	44.7	45.4	46.6	18.0	17.0	14.5	17.0	36.0	36.0	36.0	35.5
6	42.0	42.7	41.9	43.6	12.8	13.0	13.3	14.0	33.5	29.5	28.5	29.5
10	38.4	39.3	39.6	39.9	9.0	9.3	8.8	11.5	26.2	27.0	25.5	28.8

the fungal growth and metabolism which were not directly related to the major polymers of the sawdust. Thus, the changes in the level of the major polymers of wood were not indicative of the process of conversion from sawdust to soil conditioner.

Physicochemical changes brought about by soil conditioner in soil

To get an insight into the alterations in soil structure and properties resulting from the addition of the microbially treated sawdust (soil conditioner), the conditioner was mixed with sandy, loamy or clay soils and the properties of the mixtures studied. The physicochemical interactions between soil conditioner and different types of soil were tested by measuring the changes in permeability to water, compaction of matter and the cohesion within particles as measured by direct shear test (Table 3). While the maximum dry density of the mixtures decreased, the moisture content increased in all types of soils by the addition of soil conditioner. Addition of the soil conditioner increased the degree of cohesiveness in sandy soil but decreased it in loamy and clay soils. Thus, the permeability to liquids (water) decreased in the case of mixtures with sandy soil and increased with loamy and clay soils. These alterations in the physical properties in different soil types may be independent of *V. volvaceae* treatment of the sawdust. Improvement in porosity in tightly packed soils rich in loam and clay by the addition of sawdust could be beneficial for root growth and the ability to retain moisture could also be beneficial, especially under arid and semi-arid conditions. However, due to the phytoinhibitory nature of untreated sawdust it will be difficult to exploit these beneficial alterations to soil properties brought about by sawdust unless the inhibitory properties are removed or reduced. Some of our previous data had indicated that plants growing in soil conditioner-containing beds had better root development [12], consistent with the physicochemical properties of the soil conditioner-soil mixtures.

Lignocellulosic materials cannot be directly applied to soil used for agricultural purposes since they sequester soil nutrients [1], exhibit significant phytotoxicity and suppress seed germination [2]. These antagonistic effects seemed to be persistent in sawdust treated with *V. volvaceae* in the absence of urea (pit 2) or in the presence of soybean meal (pit 4). Treatment with urea but not *V. volvaceae* did not remove the phytoinhibitory effect of sawdust (Figure 1). Thus, both these components were necessary for the conversion to soil conditioner. Although the sawdust appeared to be partially degraded, as the decrease in the level of the polymers suggested, this was not sufficient for the loss of its phytoinhibitory property. This is not surprising since composting of wood residues usually takes several years [11]. It is possible that the plant growth-promoting activity was attained as a consequence of *V. volvaceae* growth and metabolism. Further, the converted sawdust might facilitate plant growth through the changes in the physicochemical properties such as moisture retention and increased porosity of the soil.

Table 3 Effect on the properties of different types of soils as a function of adding soil conditioner

Soil type	Soil conditioner (% w/w)	Maximal dry density (g cm^{-3})	Optimum moisture content (% w/w)	Degree of cohesiveness (N cm^{-2})	Coefficient of permeability (cm s^{-1})
Sand	0	1.55	14.2	0.05	1.28×10^{-3}
	5	1.47[a]	16.8[b]	0.30[c]	1.28×10^{-3a}
	10	1.40[b]	19.1[c]	0.50[c]	1.28×10^{-3a}
Loam	0	1.60	14.6	1.90	4.37×10^{-5}
	5	1.52[a]	17.0[b]	1.60[b]	8.25×10^{-5c}
	10	1.47[b]	19.0[c]	1.33[c]	7.37×10^{-5c}
Clay	0	1.56	15.0	4.95	2.62×10^{-6}
	5	1.51[a]	16.6[b]	4.55[b]	6.01×10^{-6c}
	10	1.43[b]	20.4[c]	4.00[c]	8.01×10^{-6c}

The values were analysed by paired *t*-test. The statistical significance of the difference between control and experiment is reported as: [a], not significant; [b], $P < 0.05$; [c], $P < 0.01$.

Acknowledgements

We thank the Director, TIET for providing facilities, Dr RM Kothari for useful discussion and Mr AK Sappal for secretarial services. Financial assistance from Ministry of Human Resource Development, Government of India, is gratefully acknowledged.

References

1 Beauchemin S, A N'Dayegamiye and MR Laverdieve. 1992. Nitrogen recovery after application of wood wastes to a sandy soil under potato production. Can J Soil Sci 72: 89–95.

2 Beauchemin S, A N'Dayegamiye and MR Laverdieve. 1992. Phytotoxicity of fresh and composted wood wastes applied as organic amendments in soil. Can J Soil Sci 72: 177–181.

3 Browning BL. Methods of Wood Chemistry Vol II. 1967. Interscience Publication, New York.

4 Crystopher L. 1979. Efficiency improvement in bioenergy conversion system. Energy Conservation 19: 125–131.

5 Deschatelets L and EKC Yu. 1986. A simple pentose assay for biomass conversion studies. Appl Microbiol Biotechnol 24: 379–385.

6 Indian Standards Code 2720. 1974. Dry density. Part VII, Indian Standard Institution Publications, New Delhi.

7 Indian Standards Code 2720. 1973. Moisture content. Part II, Indian Standard Institution Publications, New Delhi.

8 Indian Standards Code 2720. 1972. Direct shear test. Part XIII, Indian Standard Institution Publications, New Delhi.

9 Indian Standards Code 2720. 1975. Coefficient of permeability. Part XXXVI, Indian Standard Institution Publications, New Delhi.

10 Kandpal JB and RC Maheshwari. 1993. A decentralized approach for biocoal production in a mud kiln. Bioresource Technol 43: 99–102.

11 N'Dayegamiye A and D Irfan. 1991. Chemical and biological changes in compost of wood shavings, sawdust and peat moss. Can J Soil Sci 71: 475–484.

12 Ramamurthy V, RK Sharma, KR Yadav, J Kaur, D Vrat and RM Kothari. 1996. Volvariella treated eucalyptus sawdust enhances wheat and onion growth. Biodegradation (in press).

13 Updegraff DM. 1969. Semi-microdetermination of cellulose in biological material. Anal Biochem 24: 420–424.