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Volvariella-treated *Eucalyptus* sawdust stimulates wheat and onion growth

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Abstract

Conversion of sawdust, a major waste generated by the timber industry, to an agricultural supplement was explored. Beds made with a mixture of *Eucalyptus* sawdust and soil reduced the chlorophyll content and the growth rate of wheat seedlings. However, following treatment with *Volvariella volvaceae* and urea, the sawdust in growth beds enhanced both the chlorophyll content and growth of wheat seedlings. Application of treated sawdust to soil increased the biomass of both bulb and foliage of onion. This represents a small beginning in the conversion of an industrial solid waste into a soil conditioner for enhancing agricultural productivity.

Introduction

Sawdust is a voluminous waste generated by the timber industry. Due to its poor biodegradability and low bulk density, disposal of this solid waste is becoming an increasing economic and environmental problem for the generating mills. Although significant amounts of sawdust are incinerated in India and elsewhere for generating energy (Kandpal & Maheshwari 1993), its low bulk density and high surface area make energy recoveries poor due to inefficient combustion; it also generates volatile pollutants (Crystopher 1979). An alternate outlet to disposing of this solid waste was explored, which has a potential to yield useful and saleable products.

Increased production and application of inorganic fertilizers has greatly contributed to the pollution of air, water and soil. Besides, their production is capital- and energy-intensive. Several environmentally problematic products like the oxides of nitrogen and sulfur, fluorides and particulate matter arise during the manufacture of inorganic fertilizers. Continued application of fertilizers has contributed to increased soil acidity, alteration of microbial flora, pollution of groundwater and soil erosion. With the realization of these problems, there is a renewed interest in the development and use of organic nutrients for sustainable agriculture (Koepf 1989; Reganold et al. 1993). In this communication, we report the possibility of converting sawdust into a plant growth-stimulating soil conditioner, useful for augmenting the agricultural productivity and partially alleviating the dependence on inorganic fertilizers.

Materials and methods

Microbial treatment of sawdust

Sawdust from *Eucalyptus tereticornis* was obtained from Ballarpur Industries Limited, Yamunanagar, India. The trees were 8 to 9 years old from which sawdust of 2–3 × 5–8 mm was produced. The sample used for the studies was obtained in one mixed lot. The sawdust (500 kg) was mixed with a slurry-containing urea (2.5 kg) and one of the microbial inocula in 50 l water. The microbial inocula used were one of the following: 24 h-old cultures of *Phanerochaete chrysosporium* (ATCC 24725), or *Volvariella volvaceae* (Punjab Agriculture University, Ludhiana), activated lagoon sludge from a rayon mill in central India (Andhra Pradesh Rayons Limited, Kamalapuram, India), or no inoculum (mock-treated). The mixed sawdust was placed in 1 m^3 pit, covered with jute bags, moistened at weekly intervals by sprinkling water and incubated for three

Fig. 1. Growth of wheat seedlings in sawdust-containing beds. Seeds of wheat were sown in beds containing only soil (Con), or sawdust (1 kg) mixed soil (3 kg). The sawdust was treated with a mixed microbial inoculum (Mix), *P. chrysosporium* (Pc), *V. volvaceae* (Vv) or water (Mock). The seedlings were grown for five weeks and photographed.

months. The temperature in the pits ranged from 25° to 45° C and the moisture of the sawdust from 30 to 45% (wet weight basis). After this period, the sawdust was allowed to dry and used for efficacy evaluation.

Plant growth conditions

Treated sawdust was mixed with untreated garden soil (soft textured medium black, pH 8.0 ± 0.5), placed in earthen pots. Eighty wheat seeds (HD-2329) were sown in each pot at a depth of 4 cm. The pots were maintained in a well lit area, watered (500 ml) twice a week, but no fertilizers were applied. The germinated seedlings were counted on the eighth day. Height of the seedlings from the base of the stem were measured at weekly intervals. After five weeks of growth, the experiment was terminated. Growth rate was calculated as the rate of change in plant height. Chlorophyll content of the leaves was estimated as described in Tandeau de Marsac & Houmard (1988).

Outdoor trials on onion

Soil in 10 m^2 plots was mixed with none, 4 or 8 kg *V. volvaceae*-treated sawdust, to about 20 cm depth. An equal number of onion (Nasik Red N-53) seedlings from the nursery was planted in each plot, watered once or twice a week. No additional fertilizer was applied. The crop was harvested after 5 months.

Results

V. volvaceae*-treated sawdust enhanced the growth of wheat seedlings*

In beds prepared with a mixture of soil and sawdust treated with *Volvariella volvaceae*, the growth of wheat seedlings was far superior to seedlings grown in other beds (Fig. 1). Use of sawdust without microbial treatment but only with urea (mock-treated) did not have any effect on the growth of the seedlings since they appeared similar to the seedlings grown in soil alone, suggesting that the urea-treated sawdust in itself did not promote the growth of the seedlings. Similarly, treating sawdust with a mixed microbial inoculum from the activated sludge of a rayon pulp manufacturing mill, or with the white-rot fungus *Phanerochaete chrysosporium*, did not sufficiently modify the sawdust to promote the growth of the wheat seedlings. Thus, it appeared that only on exposure to *V. volvaceae* the sawdust acquired the plant growth-promoting activ-

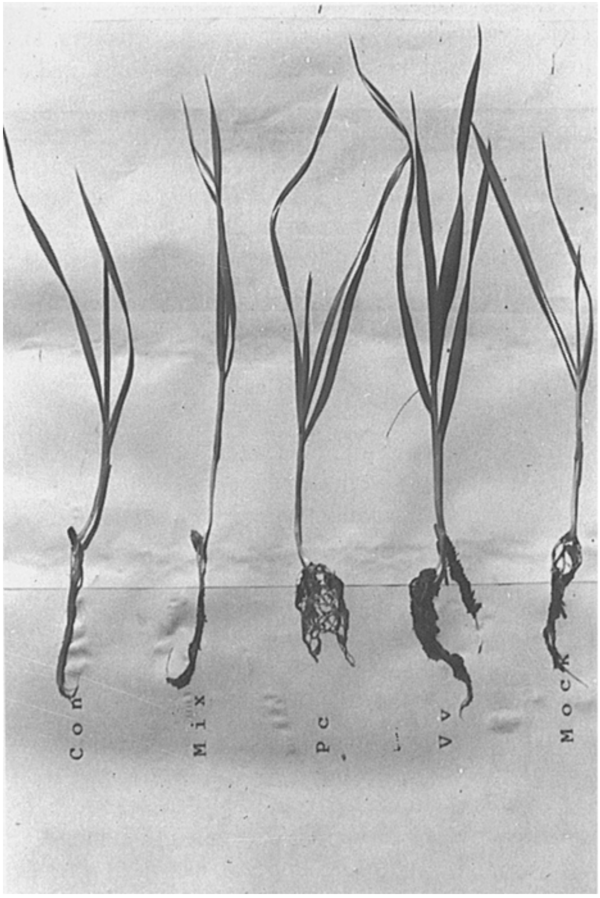


Fig. 2. Development of wheat seedlings grown in treated sawdust. Representative seedlings from pots as shown in Fig. 1 were completely removed from their bedding, all non-plant material washed and photographed. The symbols are as in Fig. 1.

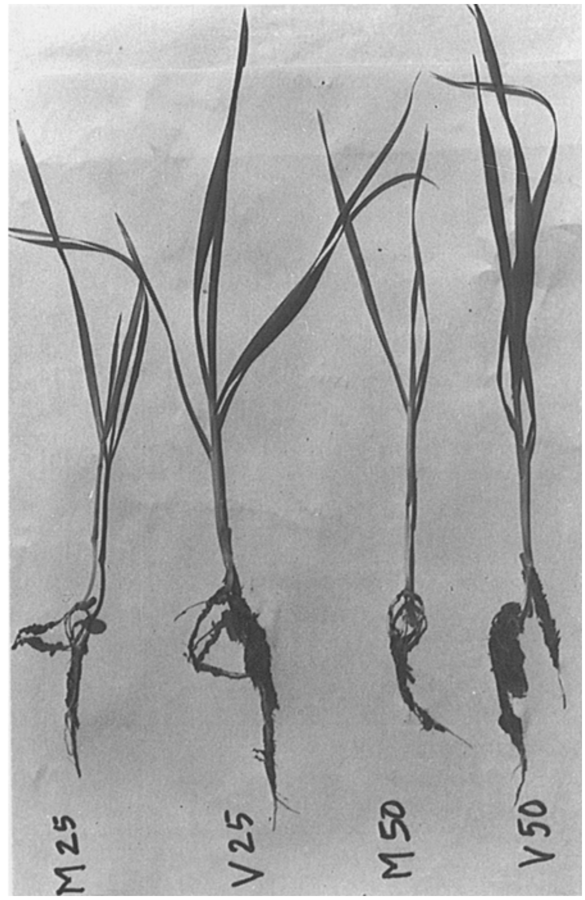


Fig. 3. Effect of different amount of sawdust on the development of wheat seedlings. Sawdust was mixed with soil at 25% or 50% ratio (by weight), wheat was sown and allowed to grow for five weeks. Individual seedlings grown in beds containing mock-treated (M) or *Volvariella*-treated (V) sawdust at 25% (25) or 50% (50) levels are shown.

ity. Preliminary results suggest that these beneficial effects on plant growth were not restricted to *Eucalyptus* sawdust alone, but also to other lignocellulosic material treated with *V. volvaceae* as well (unpublished results).

Development of the seedlings

Seedling grown in *V. volvaceae*-treated sawdust-containing bed showed thicker, longer and denser root systems and healthier and fleshier shoots (Fig. 2). Seedlings grown in the other sawdust-containing beds showed more branched roots but were not significantly different in the amount of shoot biomass when compared to the seedlings grown in soil alone (Fig. 2, Con). These results indicate that *V. volvaceae* changed the sawdust/urea mixture to stimulate plant growth.

Dose response of the seedlings to V. volvaceae-*treated sawdust*

The wheat seedlings were grown in beds containing 25 to 50% (w/w) of mock-treated or *V. volvaceae*-treated sawdust. Seedlings grown in beds containing different quantities of mock-treated sawdust were comparable in growth rate and biomass to each other and to those grown in beds containing only soil (Fig. 3). Thus, the amount of mock-treated sawdust in itself did not contribute either positively or negatively towards the overall development of the seedlings. In contrast, the seedlings in beds containing *Volvariella*-treated sawdust grew much better. The seedlings in beds containing 50% *V. volvaceae*-treated sawdust grew much better than those in 25% sawdust. These results indicate

Table 1. Effect of treated sawdust on the growth of wheat seedling.

Bedding	Germination (% ± sd)	Chlorophyll mg·g^{-1} ± sd)	Growth rate (cm·d^{-1})
Soil only	81 ± 5	1.27 ± 0.04	0.63
Treated sawdust (25% by weight)			
Mixed culture	80 ± 8	1.04 ± 0.06	0.49
P. chrysosporium	79 ± 8	0.97 ± 0.19	0.43
V. volvaceae	74 ± 5	1.41 ± 0.11	0.85
Mock-treated*	75 ± 3	0.92 ± 0.04	0.44
Treated sawdust (50% by weight)			
Mixed culture	78 ± 7	1.13 ± 0.09	0.47
P. chrysosporium	74 ± 6	0.90 ± 0.06	0.50
V. volvaceae	70 ± 7	1.82 ± 0.10	1.07
Mock-treated*	71 ± 6	1.00 ± 0.09	0.49

* Sawdust treated similar to other groups except there was no additional microbial inoculum.

Table 2. Effect of *Volvariella*-treated sawdust on onion productivity.

Bedding (kg sawdust per 10 m^2)	Height of plants after 75 days (cm)	Weight of harvested biomass (kg)	
		Bulb	Shoot
None	28	9.75	2.50
4	33	10.25	4.75
8	38	12.75	4.25

that there was a dose-dependent growth response of the wheat seedlings to *V. volvaceae*-treated sawdust.

Comparison of germination, chlorophyll content and growth rate of the wheat seedlings in various trial beds (Table 1) showed that (a) the germination of seeds sown in different beds were between 70 and 80%, and did not appear to be influenced by the beds used; (b) the chlorophyll content of the leaves and the growth rate of seedlings grown in sawdust-containing beds in general, was lower than that of the seedlings grown in soil alone; (c) the chlorophyll content and the growth rate of seedlings grown in beds containing *V. volvaceae*-treated sawdust were greater than those of seedlings grown in only soil or any of the other treatment groups; and (d) with higher amount of *V. volvaceae*-treated sawdust in beds, the chlorophyll content and the growth rate of the seedlings were also higher.

Although there was little difference in gross appearance and development of the seedlings grown in sawdust-containing beds vs non-sawdust beds (Fig. 1), lower chlorophyll levels and growth rates suggested a modest suppressive effect exerted by sawdust on the growth of wheat seedlings. On the contrary, higher chlorophyll content and growth rate of the seedlings with increasing amounts of *V. volvaceae*-treated sawdust indicated that the treated sawdust was beneficial to the overall growth of the plant, and that the effect was not saturated at the higher level tried in these trials.

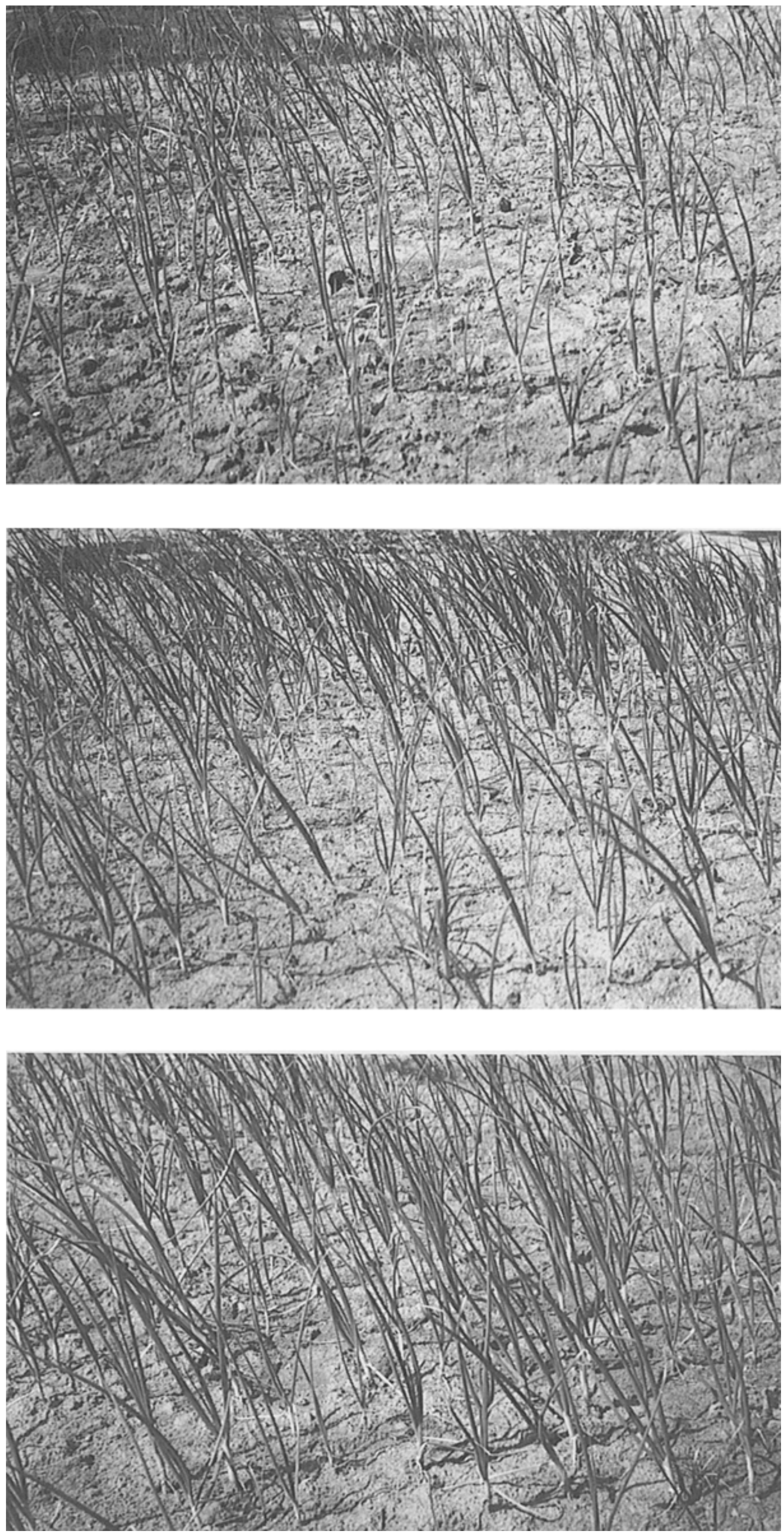
The initial studies on wheat seedlings were conducted in small pots. In this setup, the limited nutrient availability restricted the complete development of the plant, and hence the impact of the sawdust on crop productivity could not be assessed. To overcome this limitation and to determine the usefulness of *V. volvaceae*-treated sawdust on other crops, field studies were conducted with onion crop.

Volvariella volvaceae-*treated sawdust increased biomass yield of onion*

In experimental plots of 10 m^2, 4 or 8 kg of *V. volvaceae*-treated sawdust was applied, while in control plots no sawdust was applied. From the initial growth of the onion crop, it was evident that *V. volvaceae*-treated sawdust had a growth stimulatory effect (Fig. 4). When the crop was harvested after 5 months, the initially observed difference in plant size between the treated and control groups was not as vivid. However, there was a significant increase in the weight of bulbs and shoots (Table 2), indicating that the treated sawdust can be used as a soil amendment. It appeared that application of 8 kg was more beneficial than 4 kg per 10 m^2 plot.

Discussion

Previous studies suggest that the direct application of lignocellulosic materials in soil sequesters soil nutrients (Beauchemin et al. 1992a), exhibiting significant phytotoxicity and suppressing seed germination (Beauchemin et al. 1992b), and hence was not beneficial for the crops. In the present study also, *Eucalyptus* sawdust, although it appeared not to inhibit the growth at the gross level (Fig. 1), decreased the chlorophyll content and growth rate of wheat seedlings (Table 1), and hence would not be useful for direct application in agriculture. In these experimental pots, the seedlings never attained maturity, and thus were useful only in



a

b

c

Fig. 4. Effect of *V. volvaceae*-treated sawdust on onion. Plots (10 m^2) containing none (*a*), 4 (*b*), or 8 (*c*) kg *V. volvaceae*-treated sawdust were employed. Equal number of onion samplings were planted in each plot. Photographs were taken 80 days after plantation.

evaluating the initial effects on growth and development.

The microbiology and chemistry involved in composting is poorly understood, perhaps due to the heterogeneity of the substrate and the process. Generally a consortium of microbes is used to initiate the conversion process (Crawford 1983; Davis et al. 1992; Poggi-Varaldo & Oleszkiewicz 1992; Kakezawa et al. 1992). Moreover, composted material may suppress plant pathogens (Hoitnk & Fahy 1986) and be suitable for the growth of vegetable and forestry seedlings (Davis et al. 1992). A mixed microbial population from rayon mill sludge, presumably enriched for its ability to grow on lignin- and hemicellulose-rich substrates, did not impart to the sawdust any beneficial attributes. Similarly, the ligninolytic fungus *P. chrysosporium* also did not convert sawdust into a beneficial product. While sawdust did not adversely affect the development of shoots, it reduced the chlorophyll content and the growth rate of leaves and thereby the overall growth rate of seedlings. Since the growth rate was measured by the rate of change in the shoot height, and a major part of the shoots was leaves, it appeared that sawdust suppressed leaf development. This suggested that under the conditions of sawdust treatment, neither these microbes nor the microbes from the environs of the pit were able to bring about desired changes, or perhaps the changes they brought about (presumably to the lignin part of the sawdust) were insufficient to impart any beneficial attributes. However, treatment with *V. volvaceae* not only eliminated the suppressive effect but also imparted value to sawdust; it then promoted the growth of wheat seedlings. Since *V. volvaceae* treatment was done under field conditions where no particular step was taken to prevent growth of other microbes, the changes brought about in the sawdust was due to the interaction between the sawdust and *V. volvaceae*, which was over and above the normal degradation or changes brought about by the soil microbes, as in other treatment groups. The beneficial attributes could be generation of plant growth stimulants, increased porosity of soil substratum, consistent moisture availability to the roots, drainage of excess water, prolonged release of nutrients to the roots, suppression of phytopathogens, destruction of inhibitory compounds, etc., resulting in improved root development. Another possibility is that the sawdust served as a carrier for some of the phyto-stimulatory metabolites produced by *V. volvaceae*. Preliminary data from microscopic analyses of the sawdust suggest structural changes upon *V. volvaceae*-treatment. In a related study, treatment of *Brassica* with water extracts of composted bark resulted in improved root development (Chiou et al. 1991). Alternatively, chlorophyll biosynthesis could have been enhanced resulting in higher photosynthetic rates and growth.

The growth-promoting effects of *V. volvaceae*-treated sawdust was evident with onion (Fig. 4, Table 2) suggesting that the effect was not limited to wheat seedlings alone. Study in outdoor plots had the advantage of testing the response of plants under their normal condition of growth for agronomic purposes. We tested the response of plants from germination to harvest and processing. The data collected so far indicate an increase in the overall biomass, and since the value of most crops is directly related to the amount of biomass recovered, the commercial benefit accruing from the sawdust application could be directly correlated with the increase in biomass. The cost-benefit analysis of using soil conditioner for agronomic purpose should also involve the costs of the burning of sawdust and the ensuing environmental problems, the long-term effects of the soil conditioner on soil structure, erosion, microbial flora, etc., and the reduction envisaged in fertilizer and pesticide application. These are some of the areas this technology would impact, which will have to be analyzed from long-term studies.

In conclusion, a microbial treatment process, relatively inexpensive and applicable for converting large volumes of sawdust into a soil conditioner, has been identified. The beneficial effects of this soil conditioner are encouraging further evaluation of its applicability to other commercially valuable crops and its long term economic and environmental effects.

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