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Utilisation of Tannery Wastes as Substrate for Tomato Growth

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ABSTRACT

Tannery industries create serious environmental problems especially in terms of polluting organic effluent and the hazardous solid wastes as a result of hides and skin processing. Tannery waste is categorised as toxic and hazardous waste in Malaysia due to the high content of Cr (in excess of 500 ppm) and other heavy metals. It is very important that tannery wastes in the form of sludge and shavings are managed in an environmentally sound manner. This study focused on utilisation of tannery wastes as substrate additives to grow tomatoes. The results showed that there was a significant difference between initial and final sample in terms of electrical conductivity (EC), pH, root to shoot ratio and plant height. However, % seed germination at 5 days was inhibited and significantly reduced at 14 days from sowing date with 100%, 75% and 50% of both sludge and shaving. The results also indicated that 50% and 25% treatments of both wastes provide more appropriate media for plant growth compared to other treatments.

Keywords: Tannery sludge, shaving, tomato, germination, growth, electrical conductivity

INTRODUCTION

The development of appropriate strategies for the treatment and disposal of waste is a major problem for all countries throughout the world. The common methods of disposal such as landfill, incineration and ocean dumping may not be adequate or suitable to accommodate the ever-increasing quantities of sludge. Disposal is costly and also depletes valuable landfill space and, therefore, it should be considered an option only if sludge cannot be recycled or reused. Thus, the challenge for sludge management is to find affordable, sustainable and safe approaches to sludge management, which are publicly accepted (Hall and Zmysloska 1998).

The leather industry is associated with the generation of huge amounts of liquid wastes (30-35 l/kg of raw material processed) and 150 000 tonnes of dry sludge annually and thus disposal of these wastes becomes a serious problem (US Environmental Protection Agency 1976). Basically, three types of by-products are

produced: solid wastes from splitting and trimming hides; sludge from liming, dehairing, pickling, and chrome tanning; and liquid wastes from each step in the operation (Hughes 1988).

The primary agricultural constraint on the use of byproducts from leather manufacturing has been the chromium (Cr) content of the sludge. Currently, most processing plants are recycling the chromium as waste before it leaves the plant. This recycling segregates high-chromium waste streams from the other waste streams. Chromium has been of concern due to its potential plant toxicity. Trivalent chromium (Cr^{+3} or chromic) is present in the sludge, but is not toxic to plants and is immobile in the soil system. However, hexavalent chromium (Cr^{+6} or chromate) is phytotoxic and mobile (Chaney 1983). The possible oxidation of trivalent Cr to the mobile form and the potential for phytotoxicity has been the primary focus of much of the research for agricultural use of leather manufacturing wastes (Chaney 1983).

Another potential problem is salinity which originates from salt present in the hides prior to tanning. Untreated, this wastewater is not suitable for agricultural use. Composting the wastewater and sludge may circumvent this problem.

Dewatered tannery sludge has nitrogen content ranging from 2.5–5%. When Cr has been adequately excluded from this sludge, the optimum application rates for this sludge should be based on nitrogen needs of the crops to be grown. This approach should prevent excessive nitrate from being in soil solution during times when they can be leached into ground water (Stromberg *et al.* 1984). The objective of this study, therefore, was to characterise and evaluate the use of tannery wastes (sludge and shaving) as substrate additives for plant growth. It was also aimed at checking on the superiority of the wastes as substrate for plant growth compared to peat.

MATERIALS AND METHODS

Collection and Preparation of Samples

Tannery wastes (sludge or shaving) were collected from a tannery plant in Malacca, Malaysia. The sludge and shaving were used as substrate for growing tomato. Two separate experiments were conducted (sludge and shaving) to use the above wastes separately and in combination with tropical peat in different ratios as shown below in Table 1. The sludge or shaving was mixed with tropical peat at application rates of 0, 25, 50, 75, and 100% (w/w). Germination pots were placed in a greenhouse in a complete randomised design (CRD) with five treatments and five replications at an average daily temperature of 28–38°C. Daily overhead irrigation was applied, and data was analysed according to SAS (1988) program.

The plants were grown in the commercial Hydroponics Unit, Universiti Putra Malaysia. An individual pot contained 18.5 cm^3 of media when filled. After filling, the pots were seeded with 5 seeds of tomato 'Red Rock F1' cultivars, and covered with additional materials appropriate to the treatment.

TABLE 1
Tannery wastes to peat combination used for plant growth

Material	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Sludge or shavings	0%	25%	50%	75%	100%
Peat	100%	75%	50%	25%	0%
Ratio	0:1	1:3	1:1	3:1	1:0

Chemical and Physical Analysis

Initial and final EC and pH (H_2O: substrate, 1:9 by W/V) of the different media combinations were determined using EC meter and pH meter, respectively. Total organic carbon, C/N ratio, total N, P, K, and Ca were determined according to the European International Substrate Manual (2000) for initial and final media combinations.

Percent germination after 5 and 14 days from sowing date were counted. Plant leaf area was measured in cm^2 using a leaf area meter (delta-T Cambridge, U.K.). Root-to-shoot ratio on dry a basis and average plant height for 5 plants per treatment was also determined after 6 weeks.

Heavy Metals Determination

Samples from sludge and shavings were dried at 105°C for 24 h. A 0.5 g of dried sample was transferred to the digestion flask, then 5 mL concentrated H_2SO_4 acid and 20 mL of 50% H_2O_2 were added to digested flask on a hot plate for 12 min; using finger cots, the fractioning head from the digestion flask was removed and flask was allowed to cool on the cooling pad. It was then diluted with distilled water to 100 mL (Stilwell and Graetz 2001). The digested samples were then analysed for measurement of total Cr, Pb, Cu, Mn, Zn, Fe and Cd by flame atomic absorption spectrophotometer (Varian Spectra AA220 Fast Sequential) (USEPA 1998, method 3051).

Bulk Density

An air-dried sample from sludge or shavings was packed in a core ring of known volume. The sample was allowed to settle under saturation. When the volume sample became stable, the ring sample was dried at 105°C for 24 h and weighed (Day 1965).

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{wt. of oven-dried sample}}{\text{volume of sample}}$$

TABLE 2
Chemical composition of the tannery wastes used in experiments

Parameter	Shavings (Sh)	Sludge (Sl)	Control (Peat)	Typical soil *
Organic –C, %	48.67	20.03	32.46	3.9
Nitrogen (N), %	11.44	0.9996	0.41	0.4
C/N	4.25	20.04	79.13	9.75
Potassium, %	0.41	0.415	0.224	0.4 -3
Phosphorus, %	0.002	0.097	0.07	0.05-0.2
Magnesium (mg/l)	788	1190	5450	0.06-6
Iron (mg/l)	68	1062	684	0.7-55
Sodium (mg/l)	1207	1006	-	0.04-3
Heavy metals (mg/l)				
Chromium	586	1404	-	100
Lead	1	93	-	15
Cadmium	0.83	3.23	-	0.5
Copper	18	41.4	20	20
Zinc	4.67	44.67	2	50
Manganese	8	70	14	850

* Mokhtaruddin *et al.* 2001

Water Retention Characteristics

Disturbed samples of sludge and shavings were used. Samples were placed in rubber rings on a pressure plate and saturated overnight. They were then subjected to different tensions by applying positive air pressure at 0.0, 1, 10, 33, and 1500 k Pa (Day 1965). On reaching equilibrium, normally at one week, moisture content was determined by the gravimetric method

RESULTS AND DISCUSSION

Chemical Properties of the Tannery Waste

The chemical properties of the sludge and shavings (Table 2) showed that it was low in C/N ratio (4.25 and 20.04, respectively) and high in total nitrogen content especially shaving (11.44%) and sludge (0.99%). The results were in line with previous work done by Reddy *et al.* (1977). Generally, organic wastes with lower C/N favors N-mineralization while those with high C/N may inhibit or slow down this process (Parker and Sommers 1983). C/N ratios in the sludge normally fall well below the threshold 25:1, above which nitrogen supply may limit decomposition (Reddy *et al.* 1977).

The phosphorus content (%) of the sludge was 0.097%, while that of shaving was 0.002%. Potassium content of the sludge and shaving was the same about 0.41%. Sommers (1977) showed that potassium level in sludge is usually low and

can range from 0.02 to 2.645% but is enough for plant uptake and is still sufficient for crop requirement.

Apart from plant nutrient, the waste contained high amounts of chromium, calcium, sodium, and lead, all of which have a negative impact on plant growth (Logan *et al.* 1997). The level of chromium was very high (1404 mg/kg for sludge and 586 mg/kg for shaving) which is above the typical level in the soil (100 mg/kg) (Chaney and Ryan 1993; Chaney 1990).

The lead content is high in sludge (93 mg/kg) and low in shavings (1 mg/kg), the typical level of lead content in the soil is 15 mg/kg (Chaney and Ryan 1993; Chaney 1990).

The acceptable concentration level of cadmium, copper, iron, manganese and zinc in the soil was 0.5 mg/kg, 20 mg/kg, 55 mg/kg, 850 mg/kg and 50 mg/kg, respectively (Chaney and Ryan 1993; Chaney 1990; and Mokhtarudin *et al.* 2001). From the above results it appears that the tannery wastes were on the acceptable concentration levels for heavy metals except for chromium (1404mg/kg), which was above the typical level.

Initial electric conductivity (EC) and pH (water: substrate, 1: 9 by W/V) of the different media combinations before and after treatment were determined. The results show that there was significant difference within the treatments in terms of EC and pH as shown in Table 3. The EC in 100 % and 75% sludge was high (Table 3), and it did affect the growth of these plants, while that of 50% and 25% sludge was moderately low and plant growth compared well to control (Plate 1). In the case of shavings, since the EC of these plants was low, all plants in the different treatments grew well compared to the sludge and the control (Plate 2). The pH of the sludge was higher (averaging 7.5), while that of shavings was slightly acidic (averaging 6.1). This high pH was due to addition of lime in the removal of hair during the tannery process.

Germination Studies

Table 4 shows that seed germination at 5 days was inhibited and significantly reduced at 14 days from sowing date with 100%, 75% and 50% of both sludge and shavings. This might be due to the high EC and heavy metals in the tannery waste. Previous studies concluded that exposure of tomato seeds to high salt level decreased germination (Shalhevet and Yaron 1973; Boscuk 1981). Numerous studies have described delayed or reduced seed germination due to the presence of phytotoxic substances in the media (Sterrett 2001).

Studies on Plant Height, Leaf Area Root-to-Shoot Ratio

Average plant height, leaf area and root-to-shoot ratio after 6 weeks of sowing date varied in response to sludge, shavings, and peat combinations (Table 5). However, 50% sludge gave the highest stem length, leaf area and root-shoot ratio followed by 25% sludge compared to the control, whereas 100% and 75% sludge decreased with no significant difference between them (Table 5). This indicates that sludge is rich in available macro- and micronutrients and thus has potential for use in potted media for production.

TABLE 3
Electrical conductivity and pH of each treatment

Treatment	EC in dS m^{-1}		pH	
	Initial	Final	Initial	Final
Sludge				
100% Sl, 0%P	(A) 8.56**	(A) 3.51**	A) 7.36**	(A) 7.85**
75% Sl, 25%P	(B) 6.37 **	(B) 2.35**	(B) 7.29**	(B) 7.44**
50% Sl, 50%P	(C) 5.85 **	(C) 1.27**	(C) 7.31**	(C) 7.77**
25% Sl, 75%P	(D) 4.15 **	(D) 0.85**	(D) 7.18**	(D) 7.37**
Control	(E) 0.49 **	(E) 0.03**	(E) 5.35**	(E) 5.79**
Shavings				
100% Sh, 0%P	(F) 3.16 **	(F) 1.08**	(F) 5.23**	(F) 5.63**
75% Sh, 25%P	(G) 2.11 **	(G) 0.98**	(G) 6.55**	(G) 6.89**
50% Sh, 50%P	(H) 1.13 **	(H) 0.86**	(H) 6.04**	(H) 6.41**
25% Sh, 75%P	(I) 0.92 **	(I) 0.07**	(I) 5.74**	(I) 6.83**
Control	(E) 0.49 **	(E) 0.03**	(E) 5.35**	(E) 5.79**
R -square	0.99	0.99	0.99	0.99
C.V.	0.281	0.818	0.155	0.358
F	<0.0001	<0.0001	<0.0001	<0.0001
Mean	3.64	1.22	6.45	6.89

Neans with the same letter were not significant with Duncan's multiple range tests at 0.05
Comparisons significant at 0.05 level indicated by**

TABLE 4
Effect of tannery wastes (sludge & shavings) on % germination of tomato

Treatment	% germination 5 days	% germination, 14 days
Sludge		
100% sludge+ 0% peat	(A) 0.00**	(A) 25**
75% sludge + 25% peat	(A) 0.00**	(B) 32**
50% sludge + 50% peat	(A) 0.00**	(C) 50**
25% sludge + 75% peat	(B) 33.00**	(D) 67**
Control (100% peat)	(C) 36.00**	(E) 64**
Shavings		
100% shavings + 0% peat	(A) 0.00**	(F) 35**
75% shavings + 25% peat	(A) 0.00**	(F) 40**
50% shavings + 50% peat	(A) 0.00**	(F) 55**
25% shavings + 75% peat	(A) 32.00**	(F) 60**
R-square	0.99	0.99
C.V.	6.03	2.79
Mean	7.81	26.65
F	<0.0001	<0.0001

Means with same letter were not significant with Duncan's multiple range tests at 0.05.
Comparisons, significant at 0.05 level indicated by**

Plate1: Effect of 100% Sl, 75% Sl, 50% Sl, 25% Sl and 0% Sl as substrate additives on production of 6-week-old organic tomato seedling.

Plate 2: Effect of 100%Sh, 75%Sh, 50%Sh, 25%Sh and 0%Sh as substrate additives on production of 6-week-old organic tomato seedling.

Shavings gave poor plant height, leaf area, and root shoot ratio compared to the control. This might be due to the lower nutrient content in the shavings (Table 2) or, to the low soluble salts, which affected the germination and subsequently the shoot length, leaf area and root to shoot ratio (Shalhevet and Yaron 1973; Boscuk 1981)(Table 3) (Plate 1 and 2). It may likely be that the media or mixture used in this study at high rates (100% and 75%) exerted a negative influence on plant growth (Argo 1998).

The actual extent of the effect may depend on C/N ratio, pH and EC of the different media combinations or to both water holding capacity and the ratio of water to air held in the root medium. However, these factors are important for production of quality transplants. Generally, very fine particle size is used in transplant production trays. Since water can be applied as needed, the primary concern is adequate aeration (Argo 1998).

TABLE 5
Average plant height, leaf area, and root-to-shoot ratio of tomato growth

Treatments	Plant height (cm)	Leaf area $(cm)^2$	Root-shoot ratio
Sludge			
100% Sl, 0%P	(A) 0**	(A) 0**	(A) 0
75% Sl, 25%P	(B) 2.5**	(B) 7.3**	(B) 0.3
50% Sl, 50%P	(C) 47.7**	(C) 26.5**	(C) 0.7**
25% Sl ,75%P	(D) 27.5**	(D) 25**	(D) 0.5**
Control (100%P)	(E) 20.9**	(E) 24.8	(B) 0.2**
Shavings			
100% Sh, 0%P	(F) 4.9**	(F) 1.6**	(D) 0.5
75% Sh, 25%P	(F) 4.7**	(G) 3.9**	(B) 0.4
50% Sh, 50%P	(G) 7.7**	(H) 9.8**	(B) 0.4**
25% Sh, 75%P	(H) 8.8**	(I) 16.1**	(B) 0.5**
R-square	0.99	0.99	0.86
C.V.	1.229	0.88	24.243
Mean	13.82	10.027	0.388
F	<0.0001	<0.0001	<0.0001

Means with same letter were not significant with Duncan's multiple range tests at level 0.05. Comparisons significant at 0.05 levels indicated with**.

TABLE 6
Physical properties of tannery wastes (by weight)

Parameters	Sludge (Sl)	Shaving (Sh)	Typical soil *
Bulk density	0.140	0.524	1.3
Total pore space	94.72	80.24	-
Available water	8.93	36.95	5.3
Water retention at pressure (Kpa) (%w/w, dry basis):			
0	153.41	709.10	33.40
1	117.5	191.60	32.20
10	89.50	147.35	22.80
33	78.50	136.00	21.20
1500	69.57	99.05	15.90

* Mokhtaruddin *et al.* 2001

Waste made from tannery sludge and peat have low water holding capacity compared to shaving and peat which have high ability to keep water for a long time in spite of its low bulk density and total pore space (Table 6).

More than 83% of the sludge is fraction <50μ and its equivalent texture is silty clay. The wet bulk density is close to that of mineral soil but when dry, it is

relatively light with bulk density close to peat soil (dry bulk density = 0.13 cm^{-3}) (Table 6). Generally, media made from bio-solids has a low water holding capacity relative to peat moss (Falahi-Ardakani *et.al* 1988; Gouin 1993). Proper water management may be needed when using organic materials in the growing medium.

CONCLUSION

The study concludes that treatment using 25% and 50% sludge provide better media for plant growth compared to other treatments (100% and 75%). It also showed that there was a significant difference between initial and final sample in terms of EC, pH, root-to-shoot ratio, plant height, and leaf area. However, percent seed germination at 5 days was inhibited and significantly reduced at 14 days from the sowing date using 100%, 75% and 50% of both sludge and shaving.

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