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Field and greenhouse experiments were conducted to determine the feasibility of utilizing tannery waste as a soil amendment for sweet corn (Zea mays L.), bush bean (Phaseolus vulgaris L.), and tall fescue (Festuca arundinacea Schreb.).

In 1978, waste was applied at rates to provide one, two and four times the N requirements of the test crops. Other treatments included waste or lime, plus NH_4NO_3, and an untreated plot. Treatments were arranged in a randomized block with four replications. In 1979, waste was reapplied to all plots except those treated with the largest amount of waste in 1978. Waste applications used in the greenhouse experiment were identical to those used in the field, with an additional treatment of twice the optimal amount of N.

The tannery waste contained: N, 2 to 12%; Ca, 1 to 26%; up to 4.7% Cr; K and SO_4-S, over 1%; Mg, P, Na and Mn, 0.04 to 0.9%; Cu and Zn, less than 0.03%; and Cd less than 0.08 μg/g.

Exchangeable Ca and Na, total and extractable N, total Cr and DTPA extractable Cu, Mn and Zn levels increased with waste application while exchangeable K and Mg and extractable Zn and Mg generally decreased with waste application. Migration of Na and NO_3-N beyond the amended surface

soil (0-15 cm) was noted, but no significant movement of other elements occurred. Soil organic matter content increased with waste treatment, but CEC (Cation Exchange Capacity) was not affected. Waste amendment caused soil pH to increase. At high rates of application, EC (Electroconductivity) increased to levels possibly detrimental to corn and beans.

Sweet corn yields were unaffected by waste additions in the field experiment. Contents of N, Mn and Zn in leaf and grain tissue increased with waste amendment, compared to plants grown on unamended soil. Leaf Mg content was not affected, but levels decreased in grain tissue with increased waste treatment. Plant Ca, Cr and Cu contents were unaffected.

In the greenhouse experiment, yield, Ca and Mg contents were higher while P was lower for corn grown on tannery waste treated soil, compared to plants grown on unamended soil. Nitrogen, Cu, Mn, Ca and Mg uptake by sweet corn also increased with waste amendment.

Yields of bean plants or pods, with tissue Ca, Mg, Cu and Cr contents were not affected by additions of tannery waste. Compared to levels in plants grown on untreated soil, Mn and Zn, and bean pod N contents were enhanced by waste treatment.

In greenhouse culture, a growth response to tannery waste was noted, and Ca, Mn, N and P uptake increased compared to that in plants grown on untreated soil. Manganese and Zn concentrations in bean tissue decreased with waste application.

In both field and greenhouse studies, fescue growth increased with waste application, relative to growth on untreated soil. Nitrogen, Ca, Mn and Cu concentrations increased in plants grown on waste treated soil in the field in 1978 and 1979. Manganese content decreased, but

uptake increased with waste application. Chromium content was unaffected, and uptake was not consistently related to treatment.

Nitrogen, P, Ca, and Mg content and uptake were increased in fescue grown on tannery waste treated soil in the greenhouse study. Compared to levels in tall fescue grown on unamended soil, Zn concentration and uptake decreased with tannery waste application. Copper and Cr contents were unaffected by tannery waste treatments.

Tannery waste application to agricultural soils is a feasible waste management option. The waste provided sufficient N for plant growth, when initially applied, and plant growth and N nutrition of subsequent crops suggest that considerable residual N was available from the waste. Metal accumulation in plant tissue grown on treated soil did not exceed normal levels. Waste additions may be limited primarily by salt accumulations in the soil following repeated waste application, and potentially by increased contents of metals in the waste treated soil.

Soil Reactions and Plant Growth After Tannery Waste Application to an Agricultural Soil

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SOIL REACTIONS AND PLANT GROWTH AFTER TANNERY WASTE APPLICATION TO AN AGRICULTURAL SOIL

INTRODUCTION

Leather tanning processes which utilize Cr to stabilize hide proteins are used extensively by the tanning industry in the United States. Wastes derived during the preparation, tanning and finishing processes contain lime, hair, salts, fats, and metals including Cr, Cu, Mn and Zn. Currently many of these wastes are disposed in landfills, but if they could be disposed on land and used as fertilizer materials, the potential of water and land contamination which may arise from markedly increased concentrations of metals and nutrients in a trench or landfill is reduced.

Accumulation of waste constituents, such as metals and salts, in soil which was repeatedly amended, however, could affect soil productivity. Acid soils which have received large quantities of waste such as sewage sludge may contain sufficient Cu and Zn so that plant yields are reduced (Cunningham et al., 1975; King and Morris, 1972). Hexavalent Cr is toxic to plants at low concentrations (Skeffington et al., 1976; Mortvedt and Giordano, 1975). The presence of salts can also create adverse physical and chemical conditions in the soil for plant growth (Russell, 1973), and may limit waste applications, or at least alter soil management programs.

Tannery waste has been utilized successfully as a nutrient source for potato (Solamum tuberosum, L.), barley (Hordeum vulgare L.), horsebean (Vicia faba L.), and winter wheat (Triticum aestivum L.) (Mazur and Koc, 1976). Corn (Zea mays L.) and tall fescue (Festuca arundinacea

Schreb.) yields increased when grown on soil treated with tannery waste, compared to the yield of plants grown on untreated soil (Wickliff et al., 1978).

The objective of this study was to test the suitability of tannery waste as a fertilizer material for sweet corn, bush bean (Phaseolus vulgaris L.) and tall fescue grown on Willamette silt loam by determining:

1) the effect of waste applications on the growth and elemental content of the plant;
2) the effect of waste additions on soil chemical properties;
3) the effect of waste treatments on the distribution of elements in the soil profile.

TANNERY WASTES: EFFECTS ON PLANT GROWTH, SOIL N AND pH

INTRODUCTION

Approximately 150,000 dry metric tons of waste are generated annually by the tanning industry (13). Most of these wastes contain hair, lime, oils and fats, and dye residues with smaller amounts of chromium, manganese, and other metals. Currently most of these wastes are deposited in trenches or landfills, and could thus create groundwater pollution problems.

Since tanning wastes contain from 3 to 15% N and considerable calcium carbonate, their addition to agricultural soils may benefit crop production. However, repeated applications of tannery waste may result in the accumulation of phytotoxic levels of heavy metals in the soil.

Barley (*Hordeum vulgare* L.) growth and N nutrition were enhanced by addition of 45 metric tons/ha tannery waste to Dayton and Steiwer soils.[3] Tannery waste applications to soils also increased potato (*Solanum tuberosum* L.) yield and the N content of barley, horsebeans (*Vicia faba* L.) and winter wheat (*Triticum aestivum* L.) (10); however, corn and sorghum (*Sorghum bicolor* L.) growth decreased with applications of 6.8 tons/ha tannery waste in field trials in Nigeria (14).

In greenhouse culture, corn growth on Amity soil increased with the addition of the equivalent of 12 tons/ha tannery waste compared to

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[3]Jarrell, W. M., and V. V. Volk. Unpublished data.

growth on untreated soil, but was not further increased by higher rates of waste application. Addition of 7 and 14 tons/ha or 11, 22 and 45 tons/ha waste to soils increased growth of bush beans and tall fescue, respectively, as compared to growth on untreated soils; however, growth did not exceed that on soils treated with an equivalent amount of N from commercial sources.[4]

Total N content of Dayton and Steiwer soils increased by 28 and 45%, respectively, with the addition of 45 metric tons/ha waste.[3] Soil pH in soil beneath 30 cm of tannery waste applied in a field drying experiment increased slightly, but in one instance, pH decreased from 6.4 to 5.7 (12).

This study was designed to evaluate the effects of tanning waste on soil properties and the growth and N nutrition of sweet corn, bush bean, and tall fescue.

MATERIALS AND METHODS

Tanning waste from the Legallet Wool Company in San Francisco, California and the A. K. Salz Tannery, Inc., of Santa Cruz, California was applied to irrigated field plots established on a Willamette silt loam (Pachic Ultic Argixeroll; fine-silty, mixed, mesic) at the North Willamette Experiment Station, Aurora, Oregon in 1978 and 1979, respectively.

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[4]Wickliff, C., V. V. Volk, D. T. Tingey, W. Griffis, M. Y. Trunk, and J. Witherow. 1978. Toxic and Beneficial Effects of Tanning Sludge on Crops. Progress Report to U.S. Environmental Protection Agency, Industrial Research Laboratory, Cincinnati, Ohio.

Waste from the Legallet Company was mixed filter-pressed tanyard and beamhouse waste. Wastes from the Salz Tannery were separated, dewatered beamhouse wastes, which consist of hair mixed with lime and manganese produced during hair removal, and tanyard wastes--lime-alum flocculated filter-pressed sludges containing chromium, dye residues, and oils from the tanning process.

Triplicate samples of each waste were collected, dried at 70C, and pulverized. The samples were analyzed for $CaCO_3$ equivalence (6) and total N (4). Extractable ammonium and nitrate were determined in filtrate from a 1:7.5, waste:2N KCl mixture that was shaken for one hour. The solids content of the waste was determined gravimetrically using a 10.0 g sample dried at 80C for 24 hours (Table 1).

Based on a waste content of 2.5% total N, 18% of which was estimated to be available as NH_4- and NO_3-N, or as readily mineralizable N, and a solids content of 50%, tannery waste was applied to soils such that N was added at rates of one, two and four times the Oregon Fertilizer Guide Sheet N recommendations for sweet corn, bush bean and tall fescue. Additional treatments included the intermediate tannery waste treatment plus NH_4NO_3, NH_4NO_3 plus lime, and an untreated check plot (Table 2). Lime equivalent to that present in the highest waste application was applied only in 1978.

The plots were arranged in a randomized block design with four replications. Because of inadequate amounts of waste, the fescue plots were replicated only three times in 1979. Corn and beans were planted in four rows spaced 76 cm apart in 3.0 by 6.1 m plots. Fescue plots were 2.3 by 4.6 m.

Table 1. Analysis of tannery wastes applied to Willamette silt loam in 1978 and 1979.

Waste type	Solids	$CaCO_3$ Equivalence	TKN	NH_4-N	NO_3-N
	----------%----------			------μg/g-------	
Mixed[+]	60	38	2.5	3390	60[≠]
Beamhouse[§]	30	10	7.7	604	116
Tanyard[§]	45	14	3.8	1549	127

[+]Applied in 1978.

[≠]Values ranged from 9 to 149 μg/g.

[§]Applied in 1979.

Table 2. Electroconductivity, pH and N content of Willamette silt loam treated with tannery waste.

Crop	Treatment, 1978			1978				
	Waste	Lime	N	EC	pH	TKN	NH_4-N	NO_3-N
	---tons/ha---		kg/ha	mmho/cm		%	-----μg/g-----	
Corn	0	0	0	0.4	5.9	0.13	2.6	7.3
	0	26	200	1.0	7.1	0.13	2.3	19.0
	48	0	0	0.9	6.0	0.14	3.1	14.4
	96	0	0	1.4	6.4	0.16	4.0	18.8
	96	0	56	1.7	6.6	0.17	4.6	20.0
	192	0	0	4.2	6.6	0.22	6.9	40.2
	LSD ($P \leq 0.05$)			1.7	0.6	0.03	1.4	9.8
Bean	0	0	0	0.9	5.8	0.14	2.3	6.5
	0	17.5	134	1.7	7.4	0.12	2.1	18.7
	32	0	0	1.5	5.9	0.15	5.2	7.6
	64	0	0	2.3	5.7	0.14	4.9	12.1
	64	0	56	NA	6.0	0.15	7.2	NA
	128	0	0	3.9	6.2	0.15	3.9	25.3
	LSD ($P \leq 0.05$)			1.4	0.3	NS	NS	11.4
Fescue	0	0	0	0.2	6.4	0.12	1.2	1.1
	0	0	180	0.2	6.4	NA	NA	NA
	0	22	180	0.3	7.2	0.13	2.6	1.5
	43	0	0	0.2	6.6	0.13	2.5	1.7
	86	0	0	0.3	6.8	0.13	2.3	1.5
	171	0	0	0.5	7.3	0.18	3.5	1.5
	LSD ($P \leq 0.05$)			0.1	0.2	NS	1.0	NS

Table 2. (Continued)

Crop	Treatment, 1979			1979				
	Waste	Lime	N	EC	pH	TKN	NH_4-N	NO_3-N
	---tons/ha---		kg/ha	mmho/cm		%	-----μg/g-----	
Corn	0	0	0	0.5	6.3	0.12	2.7	4.7
	0	0	200	1.3	7.3	0.11	2.4	18.3
	12	16	0	2.3	6.3	0.14	3.6	18.5
	24	32	0	3.0	6.7	0.18	4.5	36.9
	24[§]	32	56	2.3	6.7	NA[+]	NA	NA
	0	0	0	0.9	7.3	0.16	4.7	23.3
	LSD ($P \leq 0.05$)			1.1	0.3	0.05	NS[≠]	8.2
Bean	0	0	0	1.3	6.3	0.12	2.9	13.7
	0	0	134	2.5	7.2	0.10	2.1	24.7
	8	10	0	2.2	6.6	0.14	2.8	18.9
	16	20	0	3.4	6.8	0.17	4.0	25.5
	16[§]	20	56	3.6	6.8	NA	NA	NA
	0	0	0	1.6	7.6	0.16	3.5	23.1
	LSD ($P \leq 0.05$)			0.9	0.3	0.02	1.0	NS
Fescue	0	0	0	0.2	5.7	0.12	2.1	1.2
	0	0	180	0.3	5.5	0.12	2.6	1.6
	10	13	0	0.9	5.5	0.13	2.5	2.1
	21	25	0	1.9	5.2	0.14	5.6	3.6
	57	0	0	2.5	5.1	0.18	6.6	16.4
	LSD ($P \leq 0.05$)			0.5	0.2	0.05	1.6	5.4

[+]Not analyzed.

[≠]Not significant.

[§]Waste applied only in 1978.

Prior to application in 1978, the Legallet waste was rototilled to break up large filter-pressed blocks of mixed beamhouse and tanyard waste. The waste was then weighed and distributed on the appropriate plots. After waste and lime additions were incorporated by rototilling, the plots were fertilized and seeded to 'Jubilee' sweet corn, 'Bluelake' bush bean, and 'Fawn' tall fescue. In 1979, segregated tanyard and beamhouse wastes from the A. K. Salz Tannery in Santa Cruz, California were weighed and applied in a 2:1 wet weight ratio to the corn and bean plots. Corn and beans were seeded as in 1978. Additional plots for tall fescue were established using the same waste ratio (Table 2).

Leaf samples were collected from 15 corn and bean plants before tasseling and before flowering, respectively. The leaves were washed with distilled water, dried at 70 C, and stored in paper envelopes.

In August, the above ground portion of the bean plants from three meter sections of the center two rows in each plot were collected and weighed. Pods were separated and weighed. Subsamples of plants and pods were collected for chemical analysis and moisture determinations.

In September, mature corn plants were cut from two three meter sections in the center of the plots. Corn ears were separated and graded for maturity. Both stalks and corn ears were weighed and subsampled for analysis.

Fescue was harvested on 1 September and 19 October 1978, and on 28 April, 22 June and 22 August 1979. Plots established in 1979 were cut on 22 August, 21 September, and 9 November 1979. A one meter swath was cut from each fescue plot to determine yield. Samples were collected from the first two harvests of each set of plots for chemical analysis.

Plant samples were dried at 70 C, ground to pass a 20 mesh screen in a Wiley mill, and stored in paper envelopes. Total N was measured in a 0.3 g sample (4) which was analyzed on a Technicon AutoAnalyzer II.

A composite soil sample of fifteen surface (0-15 cm) soil samples was obtained from each corn and bean plot at planting and at harvest, and from both sets of fescue plots in the fall of 1979.

Soil samples from the plots used to grow corn which received the largest total waste applications and the untreated check plots were collected at 15 cm intervals between the depths of 15 and 90 cm after harvest in 1979. Two pits were dug in each plot to 60 cm, and samples were collected from each depth increment; a bucket auger was used to obtain the deeper samples. The samples from each increment from both pits in each plot were mixed and subsampled.

Soil samples were air dried, ground to pass a 2 mm sieve, and stored in plastic lined bags. Total Kjeldahl N (TKN) was analyzed by micro-kjeldahl distillation following sulfuric acid digestion and steam distillation (4). Soil pH was determined by glass electrode in a 1:2 soil:water mixture. Electroconductivity (EC) was determined from a saturated paste extract using an RD-26 Solubridge (3).

All parameters measured were analyzed statistically using analysis of variance (8). A least significant difference (LSD) was calculated at the five percent level of significance if significant F tests were obtained. Soil samples collected as a function of depth were analyzed as a strip block (8).

RESULTS AND DISCUSSION

Sweet corn yield and N content

No significant differences in final sweet corn stands among treatments were noted, but delayed germination and stunting were apparent in the corn grown on soils which received the largest waste applications in 1978. Some tip burn appeared in sweet corn grown on soils treated with the largest amount of waste in 1978. Immediately after waste application, the EC of a saturated paste extract from these soils averaged 4.2 mmho/cm (Table 2), sufficiently high to adversely affect seedling establishment. Corn yields may be reduced if the EC of soil in which corn is grown is 4.0 mmho/cm or greater (2).

Although no statistically significant differences in sweet corn ear or stover yield were observed in 1978, the highest yields were obtained from soils which received lime and NH_4NO_3 (Table 3). Corn yields from plants grown on soils amended with the intermediate amount of tannery waste, either with or without NH_4NO_3, were higher than yields from plants grown on soils amended with larger amounts of waste (Table 3). Even though more N was applied with the high levels of tanning waste, benefit at this level of application may have been offset by salts or other detrimental constituents of the waste.

The N content of corn leaf tissue in 1978 was higher in plants grown on soils which received lime and NH_4NO_3 than on either waste treated or untreated soils. However, tissue N from all plants sampled exceeded the 3.0% sufficiency level for corn at tassel stage (1) (Table 3). Nitrogen content in stover samples collected from plants grown on soil

Table 3. Total sweet corn yield and N content of leaf and stover tissue from corn grown in 1978 and 1979 on tannery waste amended soil.

Treatment, 1978				Nitrogen		Treatment, 1979			Nitrogen		
Waste	Lime	N	Yield[+]	Leaf	Stover	Waste	N	Yield	Leaf	Stover	Grain
--tons/ha--		kg/ha	tons/ha	-----%-----		tons/ha	kg/ha	tons/ha	-------%----------		
0	0	0	5.40	3.6	0.9	0	0	8.64	3.5	1.2	2.5
0	26	200	7.75	4.3	1.4	0	200	7.42	3.9	1.5	2.7
48	0	0	5.33	4.1	0.9	28	0	8.20	3.8	1.5	2.5
96	0	0	6.77	3.9	1.3	56	0	8.85	3.9	1.4	2.4
96	0	56	6.39	3.8	1.2	56	56	8.03	3.9	1.5	2.8
192	0	0	5.77	4.1	1.4	0	0[§]	8.09	3.9	1.5	2.7
LSD ($P \leq 0.05$)			NS[≠]	0.3	0.3			NS	0.3	NS	0.2

[+]Dry weight.

[≠]Not significant.

[§]Waste applied in 1978 only.

to which the largest waste applications were made in 1978 was equal to those in samples collected from soils which received commercial N (Table 3).

In 1979, higher sweet corn yields were obtained for plants grown on soils to which tannery waste had been applied, compared to commercially fertilized soils (Table 3). The N content of leaf and grain tissue of corn grown in 1979 on soils which received the largest waste treatments in 1978 were equal to or greater than the N content in tissue from corn grown on soils which received tannery waste both years. This suggests that at high levels of waste application, sufficient mineralization may occur to provide adequate N to corn grown one year after waste application (Table 3). In 1979, stover tissue of plants grown on waste treated soils had a higher N content than did tissue from plants grown on untreated soils, but differences in tissue N concentrations between waste and NH_4NO_3 treated plots were not apparent (Table 3).

Bush bean yield and N content

No significant differences in bush bean yield or plant stands were noted in 1978 or 1979, but the lowest yields on waste treated soils in 1978 and the highest yields in 1979 occurred for plants grown on soil amended with the maximum amount of waste in 1978 (Table 4).

Soil that received the largest quantity of waste in 1978 had an average EC of 3.9 mmho/cm at the time of planting (Table 2). A saturated paste EC of 3.5 mmho/cm has been related to significant bean yield reductions (2). The fact that highest yields were obtained in 1979 from these soils implies that the inhibitory effects of the waste were ameliorated with time, and that sufficient nutrients were available from tannery waste to support good growth.

Table 4. Total bush bean yield and N content of leaf and pod tissue from beans grown in 1978 and 1979 on tannery waste amended soil.

Treatment, 1978				Nitrogen		Treatment, 1979			Nitrogen	
Waste	Lime	N	Yield[+]	Leaf	Pod	Waste	N	Yield	Leaf	Pod
-tons/ha--		kg/ha	tons/ha	----%----		tons/ha	kg/ha	tons/ha	-----%----	
0	0	0	3.5	5.1	3.2	0	0	3.0	4.1	2.7
0	17.5	134	4.0	4.8	3.2	0	134	3.0	4.3	3.4
32	0	0	4.0	5.1	3.1	18	0	2.9	4.6	3.2
64	0	0	4.2	5.0	3.3	36	0	3.4	5.1	3.2
64	0	56	4.0	5.2	3.2	36	56	2.2	5.1	3.3
128	0	0	3.9	5.3	3.3	0	0[§]	3.5	4.4	3.3
LSD ($P \leq 0.05$)			NS[≠]	NS	NS			NS	NS	0.2

[+]Dry weight.

[≠]Not significant.

[§]Waste applied in 1978 only.

Leaf N content did not differ significantly among treatments in either year of the study (Table 4). Bean pod N content was not affected by waste treatment in 1978, but in 1979, significant ($P \leq 0.05$) differences in N content between plants grown on waste treated or commercially fertilized soils and those from untreated soils were noted. Since these values were within the range reported for fertilized pole beans (3.0 to 3.7% N), this suggests that sufficient N was supplied by the waste and fertilizer to maintain normal levels of N in the pod (A. P. Sidwell, 1954. The effects of nitrogen, phosphorus and potassium fertilization on the quality and chemical composition of pole beans. Ph.D. Thesis. Oregon State University, Corvallis) (Table 4).

Tall fescue yield and N content

The largest tall fescue yields in 1978 were obtained for plants grown on soils which received NH_4NO_3 without lime (Table 5). Fescue yields from plants grown on soils which received the largest amount of waste or lime and commercial fertilizer were similar. In 1979, total yield for tall fescue grown on soil which had been treated with maximum amount of tannery waste in 1978 was considerably greater than yield for plants grown on soils that had been treated with NH_4NO_3 or on untreated soils. This suggests significant benefit was being derived from the waste more than one year after application (Table 5).

From fescue plots established in 1979, the highest total yields were achieved on soils treated with the maximum amount of waste (Table 6). Yields of tall fescue grown on soil treated with the lower rates of waste were less than with commercial N except at the first harvest. Tall fescue response to the NH_4NO_3 treatment was greater than to the

Table 5. Dry matter yield of tall fescue established in 1978 on tannery waste amended soil.

Treatment, 1978			Dry matter yield				
			Harvest dates				
Waste	Lime	N	9-1-78	10-19-78	4-25-79	6-22-79	8-22-79
----tons/ha---		kg/ha	----------tons/ha----------				
0	0	0	3.72	0.67	0.28	0.75	0.19
0	0	180	4.90	2.27	1.16	0.97	0.23
0	22	180	4.89	2.05	1.40	1.05	0.28
43	0	0	4.30	1.03	0.76	1.00	0.17
86	0	0	5.01	1.60	1.36	1.36	0.33
171	0	0	4.91	2.00	2.28	1.81	1.07
LSD ($P \leq 0.05$)			0.64	0.52	0.54	1.02	0.25

Table 6. Dry matter yield of tall fescue established in 1979 on tannery waste amended soil.

Treatment, 1979		Harvest dates		
Waste	N	8-22-79	9-21-79	11-9-79
tons/ha	kg/ha	tons/ha		
0	0	1.45	1.93	0.97
0	180	2.16	3.53	1.34
23	0	2.33	2.53	1.16
46	0	2.42	3.20	1.27
57	0	2.00	3.33	3.01
LSD ($P \leq 0.05$)		NS[+]	0.57	1.01

[+]Not significant.

maximum application of waste for the first two harvests, but by the third harvest, benefit from the waste was clearly greater than from NH_4NO_3 (Table 6).

Tissue N levels from all samples collected at the first harvest in 1978 were within or above the critical range (2.8-3.4% N) (9), but were highest in plants grown on soils which received commercial N fertilizer, and lowest in plants from untreated plots (Table 7).

In 1979, the highest fescue N content at the first two harvests was in plants from plots to which the maximum amounts of waste were applied (Table 7).

Soil pH and N content

Application of tannery waste increased soil pH in plots established in 1978 (Table 2). At harvest in 1978, the pH of soil on which corn and beans were grown which had received the largest application of waste was significantly higher than the pH of soil from untreated plots, but lower than the pH of lime amended soils. By the autumn of 1979, the pH of soil which received the largest waste application in 1978 had reached a pH equal to or greater than that of the limed plots (Table 2). The higher pH achieved one year later suggests that reaction of lime contained in the waste with soil required more time than did reaction of commercial lime.

In contrast, waste application to soils seeded to fescue in 1979 decreased soil pH (Table 2). Nitrification coupled with the lower $CaCO_3$ equivalence of the waste applied in 1979 and the slow rate of reaction of applied waste could explain the lower pH in these soils. A drop of 0.7 pH units was observed in soil directly beneath tanning wastes that

Table 7. Nitrogen content of tall fescue grown on tannery waste amended soils.

Treatment, 1978			Nitrogen Harvest dates		Treatment, 1979		Nitrogen Harvest dates	
Waste	Lime	N	9-1-78	10-19-78	Waste	N	8-22-79	9-21-79
--tons/ha--		kg/ha	---------%---------		tons/ha	kg/ha	--------%--------	
0	0	0	3.2	1.9	0	0	2.4	2.2
0	0	180	4.6	NA[+]	0	180	2.6	2.6
0	22	180	4.8	NA	23	0	2.6	2.4
43	0	0	3.4	2.3	46	0	3.1	2.9
86	0	0	4.0	2.6	57	0	3.4	3.1
171	0	0	4.2	2.9				
LSD ($P \leq 0.05$)		0.5	0.4			0.3	NS[≠]	

[+]Not analyzed.

[≠]Not significant.

were applied during field drying experiments (12). This decrease in pH was attributed to CO_2 production or nitrification enhanced by the waste material.

Tannery waste increased the TKN and NH_4-N content of surface soils collected at harvest from corn and fescue plots established in 1978 (Table 2). The NO_3-N content of waste treated corn and bean plot soil was higher than that of untreated soil. The low NO_3-N concentrations observed in soil collected from the fescue plots in November, 1979 probably resulted from removal of N by the fescue, as well as seasonally depressed rates of mineralization and nitrification that may occur in late autumn (1).

At the highest rate of waste application (192 tons/ha), approximately 860 and 390 kg/ha N would be mineralized the first and second years, respectively, if mineralization rates of 18 and 10% are assumed for the first two years after waste application. Additionally, 490 kg/ha NH_4-N was available from the waste, even assuming volatilization of 25% of the NH_4-N present (7). Waste-borne hair decomposed slowly and was present in soil samples collected four months after waste application. Since dehairing wastes contain up to 15% N (5), release of N as the waste decomposes may contribute to the sustained high levels of total and inorganic N in surface soils treated with this waste.

Nitrate-nitrogen in soil samples collected to a depth of 90 cm in the fall of 1979 increased with waste application and decreased with depth. The highest NO_3-N levels were observed in soils which received applications of the intermediate amount of waste in 1978 and 1979. However, NO_3-N concentrations in soils that received the largest amounts of waste in 1978 were still elevated in 1979 compared to untreated soils

Table 8. Nitrate-N content of soils used in corn study, 0-90 cm depth, collected November, 1979.

	NO_3-N		
	Total waste application tons/ha		
Depth	0	152+	196≠
cm	µg/g soil		
0-15	4.7	36.9	23.3
15-30	1.5	47.6	16.1
30-45	3.2	43.1	17.5
45-60	1.0	34.1	18.0
60-75	1.4	10.7	10.1
75-90	2.3	18.2	8.3

+Ninety-six and 56 metric tons/hectare applied in 1978 and 1979, respectively.

≠Applied in 1978.

(Table 8). This suggests that degradation of organic compounds in the waste may enhance nitrification and release of NO_3-N for more than a year after waste incorporation.

Summary

Fescue growth and N content was enhanced by tannery waste additions, and growth was sustained on waste amended soils during a second season to a greater extent than on soils which received NH_4NO_3 when the plots were established. Sweet corn was not similarly benefited, but bean yield was increased one year after addition of 170 tons/ha waste compared to yield of beans grown on commercially fertilized soils or soils which received less tannery waste. The N content of bean leaves and pods increased with tannery waste additions to Willamette silt loam soil.

Slow mineralization of tanning waste organic matter may provide sufficient N for plant growth for at least one year after waste application. The high $CaCO_3$ equivalence of the waste indicates that it could be useful as a liming material and Ca source in acid soils.

At very high rates of application, NO_3-N released from the waste may present a groundwater pollution hazard, and high levels of salts could depress the yield of sensitive crops.

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HEAVY METALS IN SWEET CORN AND SOIL AFFECTED BY TANNERY WASTES

INTRODUCTION

Wastewater treatment sludges produced at tanneries which use Cr in the tanning process may contain several percent Cr, smaller quantities of other metals, and considerable lime and N (24). Potential for pollution of water sources arises when these wastes are disposed in landfills or trenches. An alternative to traditional disposal methods involves use of these products as amendments to agricultural soils. Benefits from nutrients contained in tannery waste may be similar to those derived from sewage sludges applied to agricultural land. Since Cr, Cu, Mn, Zn and other metals may be present in both sewage sludges and tannery wastes, the possible development of phytotoxic levels of metals in the soil and attendant decreases in crop production, as well as entry of harmful substances into the food chain are of concern (5, 17).

Metal concentrations found in tannery wastes are similar to those found in municipal waste water treatment sludges (1, 24), thus, the two waste products may react similarly when applied to agricultural soils. Plants do accumulate some metal ions when sewage sludges are applied to soils (4, 5, 17). Increased levels of Mn and Zn were noted in corn (*Zea mays* L.) plants grown on soil amended with sewage sludge compared to plants grown on untreated soil (7). Only concentrations of Zn increased in the grain of plants grown on the treated soil (7). No signs of toxicity were apparent.

Chromium is not readily translocated from the plant root to leafy tissue or grain (8). Chromium taken up by beans (*Phaseolus vulgaris* L.), corn, peas (*Pisum sativum* L.), wheat (*Triticum aestivum* L.), tomato (*Lycopersicon esculentum* Mill.), and potato (*Solanum tuberosum* L.) from nutrient solution was retained primarily in the root, and not transported to the aerial portions of the plant (3). The Cr concentration in corn leaves was not affected by application of up to 224 tons/ha sewage sludge containing 0.136% Cr to soils in greenhouse experiments (17).

Metals in waste products applied to soils generally are retained in the upper portion of the soil profile. Chromium and Zn applied in sewage sludge to soil columns which were leached with deionized water essentially did not move beyond the surface three centimeters of soil (6). Removal of most Cu, Mn, and Zn occurred in the upper few centimeters of soil irrigated with sewage sludge effluent in lysimeter studies; but some movement of Cu and Zn deeper into the profile occurred when effluent infiltration rates were high (12). In contrast, sewage sludge application to Blount silt loam resulted in increased concentrations of 0.1 *N* HCl extractable Cr, Cu, Zn and Mn at depths of 30 to 45 cm when compared to untreated soils (7).

Sand filters effectively removed Cr from tannery effluents, by physical entrapment of particulate matter containing Cr (20). However, vertical movement of Cr associated with silt sized particles increased the content of total Cr in material to a depth of over 6.1 m below old tannery waste dump sites (25). This mechanism could result in movement of metals associated with waste materials into water sources.

Oxidation of trivalent Cr to hexavalent Cr has been shown to occur in moist soils if oxidized Mn is present (2). Formation of this toxic,

mobile ion in soils to which Cr containing tanning wastes have been added could cause water contamination and plant injury.

The purpose of this study was to evaluate the effect of application of tannery wastes to an agricultural soil on Cr, Cu, Mn and Zn uptake by sweet corn, and to examine the accumulation and mobility of these metals in the soil.

MATERIAL AND METHODS

Irrigated field plots were established at the North Willamette Experiment Station, Aurora, Oregon, on a Willamette silt loam (Pachic Ultic Argixeroll: fine-silty, mixed, mesic) that was treated with tannery waste in both 1978 and 1979. In 1978, the waste was a mixed filter-pressed beamhouse and tanyard waste from the Legallet Wool Company, Inc., San Francisco, CA.

In 1979, two separate wastes, a filter-pressed tanyard waste and a dewatered beamhouse waste, were obtained from the A. K. Salz Tannery, Inc., Santa Cruz, CA. Wastes derived from beamhouse processes contain hair, lime, alum, and Mn, while tanyard wastes contain dye residues, alum, fats and oils, lime, Cr and other metals.

Based on a total N content of 2.5%, 18% of which was estimated to be available during the first growing season, waste was applied to plots in amounts providing approximately one, two and four times the Oregon Fertilizer Guide Sheet N recommendations for sweet corn. Additional treatments included tannery waste plus NH_4NO_3, lime plus NH_4NO_3, and an untreated check plot (Table 1). Lime, applied only in 1978, was added at a rate to equal that provided by the largest waste application.

Table 1. Total dry weight tannery waste application to sweet corn plots, 1978 and 1979.

1978			1979		
Mixed waste	Lime	N	Beam-house	Tan-yard	N
---tons/ha----		kg/ha	---tons/ha-----		kg/ha
0	0	0	0	0	0
0	26	200	0	0	200
48	0	0	12	16	0
96	0	0	24	32	0
96	0	56	24	32	56
192	0	0	0	0	0

In 1978, waste was mixed with a rototiller, weighed, and spread on the plots. The waste material and lime were incorporated by rototilling to a depth of approximately 20 cm. In 1979, segregated beamhouse and tanyard wastes (1:2 ratio) were similarly processed, applied and incorporated into the soil. Ammonium nitrate was broadcast after tilling.

The plots were arranged in a randomized block with four replications. Single plots were 3.0 by 6.1 m, planted with "Jubilee" sweet corn in four rows spaced 76 cm apart.

The uppermost mature leaf was collected from 15 plants prior to tasseling for plant analysis. Corn plants were harvested in September from 3.0 m sections of the center two rows in each plot. Graded, unshucked ears, and entire corn plants were weighed for yield determination, and subsampled for chemical analysis.

Leaf samples were washed with distilled water. Tissue samples were dried at 70 C, and ground in a Wiley mill to pass a 20 mesh screen.

The dry plant samples (1.0 g) were digested in HNO_3 (12.0 ml) followed by $HClO_4$ (6.0 ml). The samples were filtered, diluted to 100 ml with distilled water, and assayed for Cu, Cr, Mn and Zn. In 1979, additional plant samples (0.5 g) were digested, but the HNO_3-$HClO_4$ mixture was heated to dryness, after which 10 ml of 1.0 N HCl was added. The digests were filtered 12 hours later and assayed for Cu.

Fifteen soil samples (0-15 cm) were collected from each plot, mixed, and subsampled after corn harvest in both 1978 and 1979. Samples to a depth of 90 cm were collected in 1979 from the plots which received the largest total waste applications and the untreated check plots. Two pits were dug in each plot to a depth of 60 cm. Samples were collected

from each 15 cm increment starting at 15 cm. A bucket auger was used to obtain samples between 60 and 90 cm.

All soil samples were air dried, ground to pass a 2 mm sieve, and stored in plastic lined bags.

Soil organic matter was determined on all soils collected in 1979 by the Walkley-Black titration method (26). Triplicate 1.0 g samples of dried and ground waste and single samples (0.5 g) of soil were treated with HNO_3 (2.0 ml), HCl (3.5 ml), and HF (1.5 ml), shaken for 24 hours in a waterbath heated to 50 C, and diluted to 50 or 100 ml with 1.5% H_3BO_3.

Soil samples (10.0 g) were extracted with DTPA (diethylene-triaminepentacetic acid), and the filtrate assayed for Cu, Mn and Zn (14). After acid dissolution, waste and soil samples were assayed for total Cr content. Total Cu, Mn and Zn were determined in the waste digests (Table 2).

In 1978, plant and waste analysis was accomplished on an Applied Research Laboratory 20 element Inductively-coupled Plasma Spectrometer and DTPA extracts were analyzed with a Varian 6 Atomic Absorption Spectrophotometer. In 1979, all plant, soil and waste samples were analyzed with a Perkin-Elmer Model 306 Atomic Absorption Spectrophotometer.

The least significant difference (LSD) was calculated at the five percent level of significance if significant F tests were obtained after analysis of variance (15). A strip-plot design was used to analyze the soil samples taken to 90 cm, and Tukey's multiple comparison test was used for mean separation if a significant interaction term was obtained (18).

RESULTS AND DISCUSSION

Soil organic matter, pH, and trace element content

When sampled in 1979, tannery waste application significantly ($P \leq 0.05$) increased soil organic matter. The highest organic matter content occurred in soils which were amended with the intermediate amount of waste in both 1978 and 1979 (Table 3). Since organic matter forms stable complexes with micronutrients, changes in the organic matter contents of tannery waste treated soil could influence the form and stability of added metal ions (13).

The concentration of metals in the wastes varied, and actual metal applications differed in the two years of the study (Table 2). In 1978, the highest levels of extractable Cu, Mn, Zn and total Cr occurred in soils amended with the largest amount of waste (Table 3). Similarly, in 1979, the highest Cr, Cu, Mn and Zn concentrations were found in soils treated with waste both years (Table 3). The pH of the waste treated soils increased with waste application; an increase of 1.1 pH units occurred by the autumn of 1979 in soils amended with the largest amount of waste in 1978 (Table 3). Utilization of the waste on acid soils could reduce toxicity resultant from native or applied metals, and by supplying basic cations such as Ca (3, 9). Manganese and Zn availability decrease as soil pH increases (3).

Copper solubility also decreases with increased soil pH, but Cu-organic matter complexes probably regulate Cu availability more than does pH (22). More Cu was extracted from soils amended both years of the study than from soil treated only once. Since the organic matter content of soil treated with the intermediate amount of waste in both

Table 2. Elemental content of tannery waste and total metals applied at highest rate of application, 1978 and 1979.

Element	Metal content			Total applied	
	1978	1979			
	Mixed	Tanyard	Beamhouse	1978	1979
	----------μg/g----------			---------kg/ha---------	
Cu	24	65	4	5	2
Cr	6225	40750	20	1195	1302
Mn	3403	93	1043	653	28
Zn	1223	68	33	235	3

Table 3. Total Cr, DTPA extractable Cu, Mn and Zn, pH, and organic matter content of soil collected after corn harvest.

1978								1979								
Treatment			Total	DTPA extractable				Treatment			Total	DTPA extractable				
Mixed waste	Lime	N	Cr	Cu	Mn	Zn	pH	Beam-house	Tan-yard	N	Cr	Cu	Mn	Zn	pH	O.M.
--tons/ha--		kg/ha	----------μg/g------					-tons/ha-		kg/ha	------μg/g--------					%
0	0	0	45	0.68	110	0.9	5.8	0	0	0	54	0.49	88	0.7	6.2	3.09
0	26	200	NA[+]	0.62	56	0.6	7.2	0	0	200	48	0.48	43	0.6	7.2	2.61
48	0	0	64	0.65	120	0.9	6.0	12	16	0	217	0.53	130	1.0	6.7	2.86
96	0	0	92	0.68	128	1.0	6.4	24	32	0	555	0.66	156	1.7	6.8	3.40
96	0	56	NA	0.75	120	1.2	6.6	24	32	56	712	0.74	132	1.7	6.9	3.55
192	0	0	151	0.78	142	1.4	7.0	0[≠]	0	0	153	0.49	101	1.1	7.3	2.99
LSD ($P \leq 0.05$)			55	NS[§]	28	0.3	0.6				322	0.10	23	0.4	0.3	0.55

[+]Not analyzed.

[≠]192 tons/ha waste applied in 1978.

[§]Not significant.

1978 and 1979 increased relative to soil amended with the largest amount of waste in 1978 only, Cu availability might be expected to be higher in soils amended with waste both years (Table 3). The relatively higher pH of the soils which received waste in 1978 only could also have influenced the depressed Cu availability observed in these soils, compared to other soils with lower pH values (Table 3).

No statistically ($P \leq 0.05$) significant differences in total Cr or DTPA-extractable Cu, Mn or Zn content were found between soils collected at intervals between 15 and 90 cm (Table 4). Apparently, metals applied with tannery waste remained in a stable form in the upper 15 cm of the soil for the duration of the study. However, if soil pH and organic matter content are not maintained, some movement of metals into the soil profile might be anticipated.

Corn growth and trace element content

Corn plants grew satisfactorily, and no significant differences in stand among treatments developed in 1978 or 1979. No signs of nutrient deficiency or excess were apparent either year.

Leaf Mn and Zn levels in 1978 increased with tannery waste application, with highest concentrations occurring in tissue samples collected from plots which received the largest waste treatment (Table 5). In 1979, the highest concentration of both metals occurred in plants grown on soils which had received additional treatments of the intermediate amount of waste that year (Table 6). The levels of DTPA extractable Mn and Zn were also highest in these soils (Table 3).

Levels of Mn and Zn in leaves of plants grown in 1979 on plots treated with the largest amount of waste in 1978 were lower than in

Table 4. Total Cr and DTPA extractable Cu, Mn and Zn, 0-90 cm, in soil from corn plots treated with the maximum waste applications in 1978 and 1979.

Depth	Cu			Cr			Mn			Zn		
	0[+]	1[≠]	2[§]	0	1	2	0	1	2	0	1	2
cm	μg/g											
0-15	0.49	0.66	0.49	54	553	183	88	156	102	0.67	1.69	1.11
15-30	0.40	0.41	0.38	45	102	77	30	36	38	0.30	0.35	0.60
30-45	0.26	0.22	0.29	45	54	51	24	22	31	0.10	0.05	0.20
45-60	0.24	0.21	0.24	45	56	52	20	17	32	0.15	0.10	0.10
60-75	0.22	0.22	0.23	52	58	52	14	23	23	0.10	0.10	0.20
75-90	0.25	0.30	0.30	51	62	50	14	14	25	0.20	0.20	0.25

[+]No waste applied.

[≠]Applications of 96 and 56 tons/ha waste in 1978 and 1979, respectively.

[§]Application of 192 tons/ha waste in 1978.

Table 5. Chromium, Cu, Mn, and Zn content of sweet corn leaf and grain tissue collected in 1978.

Treatment			Leaf				Grain			
Mixed waste	Lime	N	Cr	Cu	Mn	Zn	Cr	Cu	Mn	Zn
--tons/ha--		kg/ha	----------μg/g----------							
0	0	0	9.1	4.3	47.3	29.2	3.0	6.9	9.6	34.5
0	26	200	10.7	NA[+]	53.0	28.2	3.0	7.0	10.1	38.4
48	0	0	10.4	4.0	63.5	37.1	2.8	6.4	8.5	32.8
96	0	0	9.7	5.1	60.7	36.8	2.7	6.8	9.9	34.9
96	0	56	9.3	NA	63.4	36.2	2.8	6.4	8.8	32.1
192	0	0	11.4	4.4	105.2	43.6	2.8	6.7	12.2	36.8
LSD ($P \leq 0.05$)			NS[≠]	NS	28.3	5.5	NS	NS	1.8	3.3

[+]Not analyzed.

[≠]Not significant.

Table 6. Chromium, Cu, Mn, and Zn content of sweet corn leaf and grain tissue collected in 1979.

Treatment			Leaf				Grain			
Beam-house	Tan-yard	N[≠]	Cr	Cu	Mn	Zn	Cr	Cu	Mn	Zn
--tons/ha--		kg/ha	----------μg/g----------							
0	0	0	9.7	5.1	45.0	29.5	10.5	4.3	11.3	38.2
0	0	200	NA[+]	NA	48.0	29.7	NA	NA	9.5	34.8
12	16	0	8.5	5.1	64.0	35.5	8.8	3.9	13.0	41.2
24	32	0	6.2	5.7	72.0	41.5	7.7	5.4	14.0	46.2
24	32	56	NA	NA	81.0	41.2	NA	NA	16.5	47.2
0	0	0[§]	9.6	4.7	51.5	25.7	7.1	3.3	11.5	38.2
LSD ($P \leq 0.05$)			NS[≠]	NS	14.6	4.9	NS	NS	3.0	NS

[+]Not analyzed.

[≠]Not significant.

[§]Application of 192 tons/ha waste in 1978.

plants grown on soils which received two waste applications (Table 6). This suggests that the availability of metals applied with the waste had decreased (Table 6). Similar effects were noted in the Zn content of corn stover in successive crops of corn grown on sewage sludge amended soil in field trials (10). This was attributed to plant removal, movement of metals out of the rooting zone, or reversion of nutrients to forms less available for plant assimilation. In samples from plants grown on all soils, leaf content exceeded critical nutrient levels for corn--15 μg/g for both Mn and Zn, and were within the range of values reported for fertilized sweet corn at tassel stage (16).

The Zn concentration in corn grain grown in 1978 significantly ($P \leq 0.05$) increased with the largest tannery waste application, compared to plants grown on untreated soil (Table 5). However, Zn concentrations in grain collected from plants grown on the limed and fertilized soil exceeded that in grain from plants grown on soils which received any other treatment, although DTPA-extractable Zn from limed and fertilized soils was lower than that extracted from any other soil (Table 3).

The highest grain Mn content was found in samples collected from plants grown on soils that were treated with the largest amount of waste. In 1979, the highest concentrations of Mn and Zn occurred in grain from plants grown on soils that were treated with waste that year. Grain samples collected in 1979 from plants grown on soils that received the largest amount of waste in 1978 had the lowest Mn and Zn content of any collected from soils to which waste was applied, again suggesting reduced availability of the nutrients that were applied the previous year (Table 6). Zinc and Mn contents were similar to those that were

found in corn grain from plants grown on sewage sludge amended soils, but fall within the range reported for normal corn grain (7, 11, 19).

Tannery waste had no significant effect on corn leaf or grain Cu in either 1978 or 1979 (Tables 5 and 6). Neither corn leaf nor grain Cr concentration responded consistently to increased concentrations of total Cr in waste treated soils (Tables 5 and 6). Levels of Cr in the plants were higher than have been reported for sweet corn grown on sludge amended soils (11, 17), but similar to levels found in corn grown on soils amended with sewage sludge to which Cr salts were added (5). Values of from 4.0 to 17.0 μg/g Cr have been detected in the leaf tissue of corn grown on serpentine soils high in Cr, and probably indicate toxic levels (21). Since corn grown on tannery waste amended soils contained from 6.2 to 11.4 μg/g Cr, but showed no sign of Cr toxicity, contamination of these samples with Cr is a more plausible explanation of these high levels than is actual plant uptake.

Summary

Soil application of tannery waste which contains Cr, Cu, Mn, and Zn produced no differences in corn stand, or visible or analytically detected toxicities in sweet corn grown in a two year field study. An increase in the Mn and Zn content of leaves and grain grown on treated soils was observed, relative to plants grown on untreated soils, but no consistant trend of increased Cu or Cr content in plant tissue was noted.

Soil organic matter content increased with high levels of waste application, compared to soils that received less waste, or that were fertilized with NH_4NO_3. Levels of DTPA-extractable Cu, Mn and Zn as well as total Cr increased in soils treated with waste relative to

untreated soils. Lower concentrations were found in soil samples collected one year after waste application, which may reflect removal of the metal from the sampled zone by plant uptake or by conversion of the metal to a less available form.

Metals applied in the tannery waste did not appear to migrate beyond the depth of incorporation.

Repeated applications of tannery waste could result in a substantial increase in soil pH. While this could mitigate the effect of the concurrent application of metals such as Mn and Zn, the availability of nutrients such as P and B could be limited (9, 23). An additional constraint to long term use of the waste in agricultural systems is the probability of development of high levels of trace metals in the soil, which, with changing management practices, could become available to plants or mobile within the soil profile. Thorough documentation of waste disposal on agricultural soils is therefore a crucial part of any waste management program.

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TALL FESCUE RESPONSE TO TANNERY WASTE APPLICATIONS

INTRODUCTION

Leather tanning processes which utilize Cr are used extensively in the United States to stabilize hides for use in leather products. The industry produces over 150,000 tons of waste each year (20). These wastes contain lime, hair, salts, and metals such as Cr, Cu, Mn, Zn, and Pb, as well as fats, oils, and dye residues.

Metal concentration in sludges generated at tanneries varies widely, according to an industry survey: 0.33 to 19,400 μg/g Cr, 0.12 to 8,400 μg/g Cu, 0.75 to 240 μg/g Pb and 1.2 to 147 μg/g Zn on a wet weight basis (20). These metals may have detrimental effects on plants if present in the soil at sufficiently high levels.

Current tannery waste disposal practices include land filling and trenching, but since the wastes contain both lime and N, utilization in crop production could be an alternative method of disposal. Applications to agricultural land, however, may be limited by the metal content of the waste.

Tannery waste applications have been shown to benefit tall fescue (*Festuca arundinacea* Schreb.).[3] Additions of the equivalent of 11, 22 and 45 tons/ha waste to an Amity soil increased tall fescue growth

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[3]C. Wickliff, D. T. Tingey, V. V. Volk, W. Griffis, M. Y. Trunk and J. L. Witherow. 1978. Toxic and Beneficial effects of tannery sludge on crops. Progress report to U.S. Environmental Protection Agency, Industrial Research Laboratory, Cincinnati, Ohio.

relative to growth on untreated soil. Total fescue yield, however, was slightly less than was obtained when commercial fertilizer was applied.

Since tannery wastes contain metals also present in sewage sludges, this waste product may be used to model expected reactions between tannery waste, soils, and plants (10, 20). Applications of 314 and 627 tons/ha sewage sludge to an agricultural soil increased soil pH an average of 0.7 pH units over a 28 month period, and decreased Mn concentrations in tall fescue compared to fescue grown on untreated soils (18). Applications of 45 and 90 tons/ha sewage sludge compost added to a Hayesville silt loam increased Cu and Zn uptake in tall fescue, relative to fescue grown on soils which were limed but did not receive sewage sludge. When lime was added to compost treated soils, Zn uptake decreased relative to compost amended, but unlimed, soils; however, Cu uptake was not consistently affected (19). The solubility of Mn and Zn compounds found in the soil decrease as pH is increased (7). Copper is maintained in solution in Cu-organic matter complexes, and is less affected by soil pH than are Mn or Zn (17). Organic matter added to soils treated with compost may have increased Cu in solution even though the soil pH increased.

With time, sewage sludges can cause decreases in soil pH, as a result of nitrification of NH_4-N or organic N compounds, oxidation of S, organic acid production, and release of CO_2 (2,3,6).

Trivalent Cr, such as is present in tannery waste, is less readily transported to the aerial portions of plants than the more toxic Cr VI (14, 16). In a greenhouse experiment fescue grown on soils amended with

627 tons/ha sewage sludge containing 0.7 μg/g Cr contained less than 0.2 μg/g Cr (18). Fescue grown on soils which received 215 mg Cr in sewage sludge contained only 0.05 μg/g Cr, to indicate low Cr availability to fescue (4).

In this study, the effect of Cr containing tanning waste on soil properties and the accumulation of Cr, Cu, Mn and Zn in tall fescue was evaluated.

MATERIALS AND METHODS

Tall fescue was planted on tannery waste amended Willamette silt loam (Pachic Ultic Argixeroll, fine-silty, mixed, mesic) in field plots established at the North Willamette Experiment Station, Aurora, Oregon in 1978 and 1979.

Filter pressed blocks of combined beamhouse and tanyard wastes were received from the Legallet Wool Company, Inc., of San Francisco, California in 1978. Separate dewatered beamhouse and lime-alum flocculated filter pressed tanyard wastes generated at the A. K. Salz Tannery, Inc., of Santa Cruz, California were utilized in 1979. Beamhouse process waste contains hair, mixed with lime and chemicals used in the dehairing process. Dye residues, Cr, fats, oils, and small amounts of Cu, Mn, Pb, and Zn are present in tanyard wastes.

Tannery waste was applied at rates designed to provide one, two and four times the Oregon Fertilizer Guide Sheet N recommendations for tall fescue, assuming 50% solids and a total N content of 2.5%, 18% of which was estimated to be available the first season. Ammonium nitrate,

180 kg/ha, with and without lime (21.5 tons/ha) was applied to separate plots. Applications of lime plus NH_4NO_3 were not repeated in 1979 (Table 1).

In 1978, four replications of six treatments were arranged in a randomized block design. Because of limited amounts of waste, only three replications were established in 1979. Plot size was 2.3 by 4.6 m.

Waste transported by truck in 1978 was mixed with a rototiller, weighed and spread on the plots. In 1979, beamhouse and tanyard wastes were applied in a 1:2 ratio. Waste and lime were rototilled to 20 cm depth. Ammonium nitrate was broadcast before seeding.

Fescue plots established in 1978 were cut on 1 September and 19 October, 1978, and on 28 April, 22 June and 22 August, 1979. Fescue planted in 1979 was cut on 22 August, 21 September and 9 November, 1979, moisture content determined, and total yield calculated. Fescue was cut from a 1.0 by 4.6 m strip in the center of each plot. Plant samples for chemical analysis were collected from the first two harvests each year.

Plant samples were dried at 70 C and ground in a Wiley mill to pass a 20 mesh screen. Plant samples (1.0 g) were digested in HNO_3 (12.0 ml) and $HClO_4$(6.0 ml), filtered and diluted to 100 ml with distilled water. The digests were analyzed for Cu, Cr, Mn and Zn. In 1979, Cu was determined in plant samples (0.5 g) digested with HNO_3 and $HClO_4$ and heated to dryness. Ten ml of 1N HCl was added, and the digests filtered 12 hours later for analysis.

Table 1. Dryweight tannery waste application to tall fescue, 1978 and 1979.

1978			1979		
Mixed waste	Lime	N	Beam-house	Tan-yard	N
ton/ha		kg/ha	ton/ha		kg/ha
0	0	0			
0	0	180	0	0	0
0	21.5	180	0	0	180
43	0	0	10	13	0
86	0	0	21	26	0
171	0	0	57	0	0

Fifteen surface (0-15 cm) soil samples were collected from all plots in November, 1979, mixed, air dried and ground to pass a 2 mm sieve. Soil samples (0.5 g) and triplicate dried and ground waste samples (1.0 g) were digested with HNO_3 (2.0 ml), HCl (3.5 ml) and HF (1.5 ml) acid. The digests were shaken for 24 hours at 50 C and diluted with 1.5% H_3BO_4 to a final volume of 50 or 100 ml.

Ten g soil samples were shaken for 2 hours with 20 ml of DTPA (diethylene-triaminepentacetic acid) solution to extract Cu, Mn and Zn (8).

Total Cr was determined in waste and soil samples. Total Cu, Mn and Zn were assayed in the waste digests, and extractable Cu, Mn and Zn were determined in the soil-DTPA extracts. Plant and waste analysis was accomplished with a 20 element Applied Research Laboratory Inductively-Coupled Plasma Spectrometer in 1978. Soil analysis in 1978 and all plant, soil and waste analysis in 1979 were done on a Varian Instruments 6 or Perkin-Elmer Model 30 Atomic Absorption Spectrophotometer. Soil pH was determined in a soil water slurry (1:10) by glass electrode.

All analysis were subjected to analysis of variance. If significant F tests were obtained, a least significant difference (LSD) was calculated at the 5% probability level (9).

RESULTS AND DISCUSSION

Tall fescue yields increased with waste applications in plots established in both 1978 and 1979, compared to the yield of untreated plots (Chapter 1).

Soil pH

Tannery waste increased the pH of soils treated in 1978 (Table 2). The pH of soils which received the largest amount of waste approximated that of soils treated with 21.5 tons/ha lime, about one unit higher than the pH of untreated soils. In 1979, the waste application decreased soil pH to levels below that of untreated soils (Table 2). Maximum depression of pH occured in the soils to which the largest amount of waste was applied. A similar pH decrease was observed in field drying experiments, where the pH of soil below tannery waste decreased 0.7 units, probably caused by CO_2 production or nitrification in the waste (15).

Soil and Plant Mn

The Mn concentration in the tall fescue grown on tannery waste treated soils increased relative to the concentration in plants grown on untreated soils in both 1978 and 1979 (Tables 3 and 4). Greatest total Mn uptake occured in plants grown on soils to which the largest or intermediate amounts of waste were applied (Tables 3 and 4). DTPA extractable Mn levels were lower in 1978 than in 1979, although approximately 20 times more Mn was applied to plots established in 1978, compared to 1979 (Tables 2 and 5). Lower levels of extractable Mn probably resulted from higher pH levels in those soils treated in 1978, relative to those amended in 1979 (Table 2). Evidence of increased uptake of Mn in fescue grown in 1978 indicates that a significant amount of Mn remained available despite the increased pH, whereas in 1979, enhanced uptake of Mn was related to a lower soil pH. Concentrations of Mn in plants

Table 2. Total Cr, DTPA-extractable Cu, Mn and Zn and pH of soil collected November 1979.[+]

1978								1979							
Treatment			Total	Extractable				Treatment			Total	Extractable			
Mixed waste	Lime	N	Cr	Cu	Mn	Zn	pH	Beam-house	Tan-yard	N	Cr	Cu	Mn	Zn	pH
---tons/ha--		kg/ha	--------μg/g--------					---tons/ha---		kg/ha	--------μg/g--------				
0	0	0	52	0.37	498	0.62	5.7	0	0	0	38	0.42	476	0.56	5.9
0	0	180	51	0.38	454	0.56	5.7	0	0	180	33	0.35	431	0.54	5.9
0	21.5	180	56	0.32	369	0.41	6.6	10	13	0	132	0.40	579	0.78	5.7
43	0	0	54	0.37	360	0.67	6.0	21	26	0	264	0.40	643	0.60	5.8
86	0	0	60	0.38	441	0.84	6.3	57	0	0	36	0.31	1429	1.18	5.3
171	0	0	160	0.51	538	1.01	6.7								
LSD($P \leq 0.05$)			28	NS[§]	158	NS	0.2				148	NS	133	NS	0.2

[+]Averaged over four and three replications in 1978 and 1979, respectively.

[§]Not significant.

Table 3. Concentration and uptake of Cu, Cr, Mn and Zn in tall fescue established in 1978, cut 1 September and 19 October, 1978.

Treatment			1 September 1978							
			Cu		Cr		Mn		Zn	
Mixed waste	Lime	N	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake
ton/ha		kg/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha
0	0	0	4.4	19.9	7.4	31.7	151	482	22.2	98.3
0	0	180	NA[+]	NA	12.1	55.3	122	572	24.8	114.8
0	21.5	180	4.2	17.3	10.9	45.0	81	335	22.0	91.4
43	0	0	5.4	22.9	8.8	37.5	106	472	22.0	93.9
86	0	0	5.0	24.2	12.4	59.3	114	545	23.2	111.2
171	0	0	5.7	26.2	10.3	51.3	131	600	23.8	110.1
LSD($P \leq 0.05$)				NS[‡]		18.2		NS		NS

Treatment			19 October 1978							
			Cu		Cr		Mn		Zn	
Mixed waste	Lime	N	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake
ton/ha		kg/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha
0	0	0	4.6	9.2	10.8	7.5	196	145	17.8	13.8
0	0	180	NA	NA	12.6	27.3	152	327	18.8	40.1
0	21.5	180	4.6	27.2	15.4	26.6	94	174	16.2	30.8
43	0	0	4.7	4.0	9.1	8.6	152	155	17.6	18.2
86	0	0	4.9	18.2	10.8	17.6	157	259	18.9	31.0
171	0	0	5.1	29.9	14.8	28.3	175	314	19.6	37.2
LSD($P \leq 0.05$)				13.2		12.9		87		10.6

[+]Not analyzed.

[‡]Not significant.

Table 4. Concentration and uptake of Cu, Cr, Mn and Zn in tall fescue established in 1979, cut 8 August and 21 September, 1979.

Treatment			8 August 1979							
			Cu		Cr		Mn		Zn	
Beam-house	Tan-yard	N	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake
ton/ha		kg/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha
0	0	0	8.1	15.7	10.9	20.5	141	327	13.1	41.8
0	0	180	NA+	NA	NA	NA	178	266	22.0	35.4
10	13	0	10.1	21.9	6.6	12.8	205	419	20.0	42.0
21	26	0	10.1	21.7	8.2	19.6	255	536	24.0	51.8
57	0	0	7.6	20.6	13.2	26.4	279	539	27.5	63.0
LSD($P \leq 0.05$)				NS‡		NS		NS		NS

Treatment			21 September 1979							
			Cu		Cr		Mn		Zn	
Beam-house	Tan-yard	N	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake	Concentration	Uptake
ton/ha		kg/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha	µg/g	g/ha
0	0	0	5.4	7.5	3.9	5.4	179	249	5.5	20.7
0	0	180	NA	NA	NA	NA	197	409	7.0	25.1
10	13	0	4.8	12.5	4.4	10.7	206	540	21.6	14.2
21	26	0	5.8	11.8	7.4	15.0	248	509	21.6	14.2
57	0	0	6.3	23.4	4.3	10.5	275	102	35.3	69.8
LSD($P \leq 0.05$)				NS		NS		179		22.6

+Not analyzed.

‡Not significant.

sampled were within the range of reported values, and were less than the 500 μg/g level considered toxic (5, 11, 12).

Soil and Plant Cu

Tannery waste applications generally increased the Cu uptake by fescue harvested in 1978 and 1979, compared to the uptake by plants grown on untreated soils (Tables 3 and 4); however, DTPA-extractable Cu did not increase (Table 2). Levels of extractable Cu were greater than the 0.2 μg/g level suggested as critical for good plant growth (8). Applications of from 1 to 10 kg/ha Cu to mineral soils is considered adequate to correct Cu deficiency in many crops (13). Amounts of Cu applied with tannery waste (4.1 kg/ha in 1978 and 1.7 kg/ha in 1979; Table 5) could, with repeated applicatons to soil, result in toxic levels; however, all plant samples collected had Cu contents less than 20 μg/g, a level considered toxic to many plants (1).

Soil and Plant Cr

Chromium content and uptake appeared to increase with waste application compared to uptake and concentration in fescue grown on untreated soils at the time of the first harvest in 1978 (Table 3). However, levels of Cr in fescue grown on untreated soils were considerably higher than has been reported for fescue grown on sewage sludge amended soils, and, therefore, probably represent contamination of the plant tissue rather than accumulation of Cr (4, 18).

Application of 197 kg/ha Cr in 1978 significantly ($P \leq 0.05$) increased the total Cr concentration of the treated soils compared to the Cr concentrations in other soils (Table 2). The higher Cr content of the

Table 5. Maximum application of Cu, Cr, Mn and Zn to tannery waste treated soils, 1978 and 1979.

Metal	1978	1979
	----------kg/ha----------	
Cu	4.1	1.7
Cr	197.0	1058.0
Mn	582.0	24.2
Zn	11.8	2.6

tanyard wastes applied to soil in 1979 is reflected in the higher concentration of Cr in soils that received these wastes (Table 2).

Soil and Plant Zn

The Zn concentration in plants collected during the second harvest of fescue in both 1978 and 1979 differed significantly ($P \leq 0.05$) between treatments (Tables 3 and 4). In 1978, plants grown on soil to which the two highest rates of waste or fertilizer were applied accumulated more Zn than plants grown on untreated soils, or soils to which lime and NH_4NO_3 or the least amount of waste was applied (Table 3). In 1979, the greatest Zn uptake occured in fescue grown on the soils which received the greatest amount of waste (Table 4). Levels of DTPA-extractable Zn were greatest in soils amended with the largest quantities of waste both years (Table 2).

Since very little Zn was applied with the waste in 1979, (2.6 kg/ha, compared to 11.8 kg/ha in 1978; Table 5), increased uptake in 1979 may have been predominantly influenced by the lowered pH of the waste treated soils (Table 2). Higher Zn concentrations in plants grown on unlimed fertilized soils may have resulted from increased Zn availability as the ammonium in NH_4NO_3 nitrified and caused a localized decrease in pH. Similar effects were noted in uptake of Zn in fescue following the application of sulfur-coated urea and heavy metals to soil columns, and was attributed to acidification accompanying S oxidation (4).

SUMMARY

The pH of soils amended with tannery waste in 1978 increased relative to the pH of untreated soils, whereas in 1979, the pH of amended soils decreased in plots established that year. Total Cr and DTPA-extractable Mn and Zn increased in soils treated with waste, compared to untreated soils.

Tall fescue grown on amended soils exhibited increased uptake of Cu, Mn and Zn, but toxicity due to increased levels of metals in the waste amended soils was not evident. Concentrations of Cu, Mn and Zn in plant tissue were similar to levels found in normal plants. No apparent increase in plant Cr concentration or uptake related to increased Cr concentration in the soil was noted.

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THE ELEMENTAL CONTENT OF BUSH BEANS GROWN ON WILLAMETTE SILT LOAM TREATED WITH TANNERY WASTE

MATERIALS AND METHODS

Experimental plots were established to evaluate the effect of tannery waste on bush bean (Phaseolus vulgaris L., cv Bluelake 274). Waste characterization, design of field plots and waste application, sampling, analytical, and statistical procedures have been outlined previously.

Approximately 15 bean leaves from each plot were collected prior to flowering each year, and samples of plant and pod tissue were collected at the time of plant harvest. Leaf and pod tissue was washed with distilled water and prepared for analysis as was described for corn tissue.

Surface (0-15 cm) soil samples were collected after plant harvest both years from each plot. Total Cr, and trace element analysis was accomplished after acid digestion or DTPA extraction was previously detailed. Soil pH was determined in a 1:2 soil to water mixture by glass electrode.

RESULTS AND DISCUSSION

Soil pH

Tannery waste increased soil pH, but did not react as rapidly as agricultural lime (Table 1). Limed soil reached a pH of 7.4 within 3 months after lime application, while soil treated with the highest rate of tannery waste reached a pH of 6.3 after one growing season, and 7.3

Table 1. Total Cr, DTPA-extractable Cu, Mn and Zn and pH of soil samples from bush bean plots collected after plant harvest in 1978 and 1979.

1978								1979							
Treatment			Total	DTPA extractable				Treatment			Total	DTPA extractable			
Mixed waste	Lime	N	Cr	Cu	Mn	Zn	pH	Beam-house	Tan-yard	N	Cr	Cu	Mn	Zn	pH
-- tons/ha -		kg/ha	---------- μg/g --------					-- tons/ha -		kg/ha	---------- μg/g -------				
0	0	0	31	0.28	205	0.58	5.7	0	0	0	63	0.37	75	0.88	6.3
0	17.5	134	NA[1]	0.21	51	0.29	7.4	0	0	134	53	0.36	57	0.61	7.4
32	0	0	59	0.31	233	0.69	5.6	8	10	0	123	0.38	123	1.07	6.2
64	0	0	49	0.29	240	0.68	5.8	16	20	0	194	0.43	125	1.26	6.7
64	0	56	NA	0.30	230	0.64	6.0	16	20	56	253	0.44	131	1.13	6.8
128	0	0	43	0.28	195	0.59	6.3	0	0[3]	0	207	0.39	86	1.32	7.3
LSD ($P \leq 0.05$)			NS[2]	0.05	44	0.20	0.3				98	0.05	29	0.38	0.3

[1] Not analyzed.

[2] Not significant

[3] One hundred twenty-eight tons/ha waste applied in 1978.

one year after waste incorporation.

Copper in plant tissue and soil

Copper applied with the tannery waste had little effect on Cu content in bean leaf or pod tissue in 1978 or 1979 (Table 2). The Cu concentration in the leaf tissue ranged from 1.6 to 4.4 μg/g, considerably less than the 20 μg/g level considered toxic to many plants (Allaway, 1968).

DTPA extractable Cu levels were not significantly affected by waste applied in 1978, but the lowest concentration occurred in soil which had been limed and fertilized (Table 1). Concentrations of DTPA extractable Cu in soil treated with waste in both 1978 and 1979 increased significantly relative to that in untreated soil, or soil which received only one waste application (Table 1).

Chromium in plant tissue and soil

The Cr concentration in bean leaf and pod tissue was not consistently affected by waste, fertilizer or lime application in either year of the study (Table 2). Since levels of Cr in bean tissue were similar to those found in corn and fescue tissue discussed earlier, contamination of bean plant samples probably occurred.

The total Cr concentration of the soil was not altered significantly by the application of tannery waste in 1978 (Table 1); however, in 1979, Cr levels in the soil which received the intermediate amount of waste both years increased significantly relative to the untreated soil (Table 1). Soils which received the largest waste application in

Table 2. Copper, Cr, Mn and Zn concentration in bush bean leaf and pod tissue, 1978 and 1979.

1978

Treatment			Leaf				Pod			
Mixed waste	Lime	N+	Cu	Cr	Mn	Zn	Cu	Cr	Mn	Zn
--tons/ha --		kg/ha	----------	----------	----------	μg/g	----------	----------	----------	
0	0	0	4.3	7.9	124	25	3.6	5.4	32	38
0	17.5	134	NA[1]	7.4	109	22	NA	5.3	27	33
32	0	0	4.1	7.9	119	28	4.1	5.2	34	38
64	0	0	4.4	7.7	142	27	3.4	5.4	36	39
64	0	56	NA	7.9	120	26	NA	5.7	34	39
128	0	0	4.4	7.8	144	27	4.1	5.6	32	42
LSD ($P \leq 0.05$)			NS[2]	NS	20	3	NS	NS	NS	NS

1979

Treatment			Leaf				Pod			
Beam-house	Tan-yard	N	Cu	Cr	Mn	Zn	Cu	Cr	Mn	Zn
--tons/ha --		kg/ha	----------	----------	----------	μg/g	----------	----------	----------	
0	0	0	2.5	6.1	53	21	3.7	4.6	31	33
0	0	134	NA[1]	NA	66	22	NA	NA	32	34
8	10	0	1.6	2.4	60	45	3.8	4.3	39	41
16	20	0	2.9	3.4	74	40	4.5	6.4	40	38
16	20	56	NA	NA	NA	26	NA	NA	37	42
0	0	0	2.4	5.3	64	15	3.9	6.0	31	39
LSD ($P \leq 0.05$)			NS	2.7	11	NS	NS	NS	NS	NS

[1] Not analyzed.

[2] Not significant.

[3] One hundred twenty-eight tons/ha waste applied in 1978.

1978 contained considerably less Cr than soil from those plots sampled in 1979 (Table 1). Uneven distribution of waste on the plots and inadequate initial sampling could account for this disparity.

Manganese in plant tissue and soil

The concentration of Mn in bean leaf tissue from plants grown on soil to which 64 or 128 tons/ha waste was applied in 1978 increased significantly compared to tissue from plants grown on soil which received other treatments (Table 2). The lowest leaf Mn concentration occurred when fertilizer and lime were applied. DTPA extractable Mn levels were highest in soil amended with the two lowest rates of waste, and lowest on the limed and fertilized soil (Table 1). The Mn concentration in soil amended with the greatest amount of waste was lower than all but the limed and fertilized soil. At the highest rate of waste application in 1978, soil pH increased 0.6 units, and the pH of the limed soil rose 1.7 units, compared to the pH of the untreated soil. The pH increase probably reduced the solubility of soil Mn compounds and the resultant Mn availability (Lindsay, 1972).

In 1979, significantly ($P \leq 0.05$) higher leaf Mn contents existed in plants grown on soil treated with the intermediate amount of waste in 1978 and 1979, or those which had received 128 tons/ha waste in 1978, compared to plants grown on untreated soil (Table 2).

Extractable Mn concentrations in 1979 were highest in soil that was treated with waste that year (Table 1). Lesser amounts extracted from the soil which received 128 tons/ha waste only in 1978 probably resulted from conversion of Mn to less available forms, as influenced

by increased soil pH, plant uptake, or movement of Mn out of the root zone.

All leaf and pod Mn concentrations fell within the range of concentrations found in normal plants and did not approach the level of 500 μg/g considered to be phytotoxic (Chapman, 1966; Bear et al., 1948).

Zinc in plant tissue and soil

In 1978, all plants grown on tannery waste treated soil contained higher leaf and pod Zn concentrations than plants grown on limed and fertilized soil (Table 2). Since the availability of Zn decreases with increased pH, less uptake by plants of waste applied Zn would be expected as lime in the waste reacts with soil to increase pH. In 1979, the lowest leaf Zn levels were in samples collected from plants grown on the soils treated with 128 tons/ha waste in 1978, which had a pH of 7.3 (Tables 1 and 2). The pH of this soil was significantly higher than the pH of the other waste amended or untreated soil, and could have depressed Zn uptake by plants. No consistent differences in pod Zn contents were noted.

Zinc levels were within reported limits for bush bean and did not approach levels associated with toxicity or yield decreases (Geraldson et al., 1973; Boawn and Rasmussen, 1971).

SUMMARY

Bean leaf Mn content increased significantly with waste application, but levels of other metals in the plant were unaffected by the waste, when compared to plants grown on untreated soils. No significant

differences in the contents of Cr, Cu, Mn or Zn in pod tissue were noted.

The pH of soil treated with the intermediate and highest rates of waste increased compared to untreated soil. The pH of the limed soil and soil which received the highest waste application increased the most and were approximately equal after two years.

Increased amounts of Cr, Cu, Mn and Zn were extracted from waste treated soil compared to those which were untreated. Lime application depressed extractable Cu, Mn and Zn to levels below those observed in unlimed soil.

Tannery waste could be utilized as a source of lime, N and trace elements such as Mn and Zn. At the rates of waste applied, no apparent toxicities or deficiencies were observed in bush bean.

CALCIUM AND Mg CONTENT OF SWEET CORN, BUSH BEAN AND TALL FESCUE, AND EXTRACTABLE BASES AND CEC OF WILLAMETTE SILT LOAM AMENDED WITH TANNERY WASTE

MATERIALS AND METHODS

The Ca and Mg contents were assayed in sweet corn, bush bean and tall fescue grown in 1978 and 1979 on tannery waste amended soil. Plant samples were collected and analyzed as described previously.

Soil samples collected from the surface 15 cm after corn and bean harvest, and in November, 1979, from soil on which fescue was grown were extracted with 1N ammonium acetate and assayed for Ca, Mg, Na and K by atomic absorption spectrophotometry (Pratt, 1965). Samples were also collected between the depths of 15 and 90 cm from corn plots after plant harvest in 1979.

The CEC of soil used to grow sweet corn was determined by 1N ammonium acetate extraction followed by displacement of NH_4 with 0.1 N HCl and steam distillation (Berg and Gardner, 1978).

Calcium and Mg in plant tissue

Sweet Corn

In 1978, the Ca content of all plant leaves exceeded the critical level of 0.4%, but in 1979, Ca deficiency, based on tissue analysis, was noted (Melsted, 1969). Magnesium in leaf tissue both years was below the critical level for corn sampled at the tasseling stage (Melsted, 1969; Table 1).

The Ca content of corn grain in 1978 was below the detection

Table 1. Calcium and Mg content of sweet corn and bush bean grown on Willamette silt loam, amended with tannery waste in 1978 and 1979.

Crop	Treatment, 1978			Leaf		Grain		Treatment, 1979			Leaf		Grain	
	Mixed waste	Lime	N	Ca	Mg	Ca	Mg	Beam-house	Tan-yard	N	Ca	Mg	Ca	Mg
	--tons/ha	--	kg/ha	----------	%	----------		--tons/ha	-	kg/ha	----------	%	----------	
Sweet corn	0	0	0	0.58	0.14	>0.5	0.18	0	0	0	0.19	0.17	0.006	0.22
	0	26	200	0.70	0.18	>0.5	0.18	0	0	200	0.19	0.19	0.006	0.22
	48	0	0	0.59	0.17	>0.5	0.15	12	16	0	0.21	0.19	0.005	0.21
	96	0	0	0.60	0.16	>0.5	0.16	24	32	0	0.22	0.19	0.006	0.21
	96	0	56	0.63	0.16	>0.5	0.19	24	32	56	0.21	0.18	0.007	0.23
	192	0	0	0.64	0.17	>0.5	0.17	0	0	0[2]	0.21	0.18	0.006	0.24
	LSD ($P \leq 0.05$)			NS[1]	NS	NS	0.02				NS	NS	NS	NS
	Treatment			Leaf		Pod		Treatment			Leaf		Pod	
Bush bean	0	0	0	3.49	0.32	0.86	0.20	0	0	0	2.98	0.35	0.49	0.27
	0	17.5	134	3.44	0.32	0.91	0.25	0	0	134	2.68	0.28	0.54	0.29
	32	0	0	3.40	0.33	0.92	0.21	8	10	0	2.56	0.31	0.53	0.28
	64	0	0	3.38	0.33	0.86	0.21	16	20	0	3.45	0.36	0.55	0.27
	64	0	56	3.48	0.31	0.87	0.21	16	20	56	3.21	0.32	0.59	0.27
	128	0	0	3.60	0.31	1.00	0.20	0	0	0[3]	2.89	0.32	0.52	0.27
	LSD ($P \leq 0.05$)			NS	NS	NS	NS				0.58	NS	NS	NS

[1] Not significant.

[2] One hundred ninety-two tons/ha waste applied in 1978.

[3] Ond hundred twenty-eight tons/ha waste applied in 1978.

limit of the inductively-coupled plasmolizer (0.5 μg/g). In 1979, all values were less than 0.007%, and were similar to levels in corn grain grown on commercially fertilized soil (Pietz et al., 1978; Table 1).

In 1978, no consistent relationship between grain Mg content and waste application was apparent. The highest grain Mg concentration in 1979 was in tissue from plants grown on soil treated with the largest amount of waste in 1978 (Table 1). Contents of Mg were within levels listed for grain grown with commercial fertilizers (Pietz et al., 1978).

Bush Bean

The Ca content of bush bean leaves collected in 1978 from plants grown on soil which received the largest amount of waste was higher than, but did not differ significantly from, that of all other plants (Table 1). No consistent trends in Mg content were apparent. In 1979, the Ca content was greatest in tissue from plants grown on soil which had been treated with the intermediate amount of waste both years, and differed significantly from the Ca content of plants grown on soil which received the lowest rate of waste each year (Table 1). Both Ca and Mg contents were within the range found in normal plants (Geraldson et al., 1973).

Bean pods collected from plants grown on soil amended with largest amount of waste in 1978 contained the greatest amount of Ca (Table 1). No effects on the Mg content of bean pods in 1978 or on Ca or Mg in samples collected in 1979 were noted (Table 1). The content of Ca in bean pods was generally higher than has been found in pods grown on

untreated or commercially fertilized soil. Magnesium contents, however, were within the range found in plants grown in this soil (Furr et al., 1976; Sidwell, 1954).

Tall Fescue

The content and uptake of Ca in tall fescue tissue harvested in September, 1978 increased in plants grown on soil treated with the largest amount of tannery waste, compared to plants grown on soil which received other treatments (Table 2).

The Mg concentration in tall fescue collected during the first harvest in 1978 increased in plants grown on soil which received the intermediate and high rates of waste treatment, compared to plants grown on other waste treated or untreated soil, but uptake was not affected (Table 2). At the subsequent harvest, in October, 1978, both Mg content and uptake increased with application of the two highest rates of waste.

The Ca content of tall fescue samples from the first harvest in 1978 was lower than the level normally found in fertilized tall fescue in all but the plants grown on the most heavily amended soil. The Ca content in plants cut during the second harvest, and Mg at both harvests, were typical for fescue grown on fertilized soil - 0.4 to 0.5% Ca, and 0.20 to 0.27% Mg (Reid et al., 1970; Price and Moschler, 1970).

In fescue grown on plots established in 1979, the greatest Ca content and uptake, and greatest Mg concentrations occurred in plants gorwn on soil amended with the intermediate or largest amounts of waste, compared to other waste treated, or untreated soil (Table 2).

Table 2. Concentration and uptake of Ca and Mg in tall fescue grown on Willamette silt loam, amended with tannery waste, in 1978 and 1979.

Treatment, 1978			Concentration				Uptake			
			9-1-78		10-19-78		9-1-78		10-19-78	
Mixed waste	Lime	N	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg
--tons/ha --		kg/ha	%				kg/ha			
0	0	0	0.22	0.24	0.47	0.26	9.92	10.7	3.4	1.9
0	0	180	0.27	0.29	0.50	0.27	12.21	13.7	6.6	5.8
0	22	180	0.30	0.29	0.48	0.27	12.51	11.9	8.8	5.1
43	0	0	0.21	0.24	0.59	0.26	9.7	10.2	5.0	2.6
86	0	0	0.29	0.28	0.46	0.26	14.1	13.6	7.7	4.2
171	0	0	0.45	0.28	0.50	0.28	20.9	13.0	9.1	5.1
			0.12	0.03	NS[1]	0.01	5.67	NS	2.34	1.6

Treatment, 1979			8-22-79		9-21-79		8-22-79		9-21-79	
Beam-house	Tan-yard	N	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg
--tons/ha --		kg/ha	%				kg/ha			
0	0	0	0.43	0.18	0.42	0.17	9.92	3.1	5.8	2.8
0	0	180	0.38	0.18	0.48	0.19	12.21	5.2	9.8	5.4
10	13	0	0.54	0.19	0.49	0.18	9.70	3.5	12.1	3.4
21	25	0	0.65	0.21	0.63	0.20	14.10	4.3	12.8	4.5
57	0	0	0.67	0.20	0.76	0.21	21.00	4.1	20.5	5.6
			0.15	0.01	0.08	0.02	5.67	NS	5.45	NS

[1] Not significant.

Magnesium uptake was not significantly affected by treatment at either harvest (Table 2). Calcium and Mg contents in fescue tissue collected during both harvests were generally within the range found in normal fescue tissue (Reid et al., 1970).

Soil extractable bases

Soil collected from the plots used to grow sweet corn and tall fescue in 1978 which were treated with the largest amount of tannery waste contained significantly ($P \leq 0.05$) increased levels of Ca compared to other waste treated or untreated soil. The Na levels also increased significantly in the corn plot soil treated with the largest quantity of waste (Table 3).

Less Mg and K were extracted from soil which received the largest amount of waste than from untreated soil, or the soil which received smaller amounts of waste (Table 3). Extractable Ca levels increased greatly as Mg and K levels decreased, to suggest replacement of Mg and K with Ca on soil exchange sites.

In soil used to grow bush beans in 1978, the highest levels of extractable Ca were found in soil amended with lime and commercial N. The extractable Na content of the soil increased in the soil which received the largest waste treatment, compared to untreated soil (Table 3). The Mg content of the soil on which beans were grown was not significantly affected by waste treatment.

Extractable K was not influenced significantly by waste application to soil used to grow corn or beans, but decreased in treated soil from the fescue plots relative to all soil but that which

Table 3. Extractable Ca, Mg, Na and K in Willamette silt loam amended with tannery waste, collected after plant harvest in 1978 and 1979.

Crop	Treatment, 1978			Extractables				Treatment, 1979			Extractables			
	Mixed waste	Lime	N	Ca	Mg	Na	K	Beam-house	Tan-yard	N	Ca	Mg	Na	K
	--tons/ha --		kg/ha	------ meq/100 g -----				--tons/ha --		kg/ha	------ meq/100 g -----			
Sweet corn	0	0	0	7.7	0.9	0.2	0.6	0	0	0	8.5	1.0	0.1	0.5
	0	26	200	24.8	0.9	0.2	0.6	0	0	200	17.2	1.0	0.1	0.6
	48	0	0	10.5	1.0	0.4	0.7	12	16	0	13.2	0.9	0.3	0.5
	96	0	0	11.6	0.9	0.5	0.7	24	32	0	20.0	0.9	0.4	0.5
	96	0	56	12.7	1.0	0.5	0.6	24	32	56	20.3	0.9	0.3	0.5
	192	0	0	23.1	0.7	0.9	0.6	0	0	0[2]	18.1	0.8	0.2	0.5
	LSD ($P \leq 0.05$)			7.1	0.1	0.3	NS[1]				3.2	0.1	0.1	NS
Bush bean	0	0	0	7.1	0.9	0.1	0.8	0	0	0	8.4	1.0	0.1	0.6
	0	17.5	134	25.3	0.8	0.1	0.6	0	0	134	15.1	0.9	0.1	0.6
	32	0	0	9.2	0.9	0.4	0.6	8	10	0	12.0	0.9	0.4	0.6
	62	0	0	10.1	0.9	0.4	0.7	16	20	56	15.4	0.8	0.3	0.6
	64	0	0	9.1	0.9	0.4	0.7	16	0	0	15.0	0.8	0.4	0.6
	128	0	0	9.9	0.9	0.5	0.8	0	0	0[3]	19.0	0.8	0.2	0.6
	LSD ($P \leq 0.05$)			10.2	NS	NS	NS				2.4	0.1	NS	NS

Table 3. Continued

Crop	Treatment, 1978			Extractables				Treatment, 1979			Extractables			
	Mixed waste	Lime	N	Ca	Mg	Na	K	Beam-house	Tan-yard	N	Ca	Mg	Na	K
	--tons/ha --		kg/ha	------ meq/100 g ----				--tons/ha --		kg/ha	------ meq/100 g -----			
Tall fescue	0	0	0	8.2	1.0	0.1	0.6	0	0	0	5.7	1.0	0.1	0.6
	0	0	180	7.5	1.0	0.1	0.5	0	0	180	5.7	1.0	0.1	0.5
	0	22	180	17.7	0.9	0.1	0.5	0	0	0	5.7	1.0	0.1	0.6
	43	0	0	9.6	0.9	0.1	0.6	10	13	0	7.4	0.8	0.1	0.5
	86	0	0	12.1	0.9	0.1	0.6	21	25	0	9.4	0.8	0.2	0.5
	171	0	0	22.2	0.8	0.1	0.5	57	0	0	18.2	0.7	0.2	0.5
	LSD ($P \leq 0.05$)			4.3	0.1	NS	0.1				1.4	0.1	0.7	NS

[1] Not significant.

[2] One hundred ninety-two tons/ha waste applied in 1978.

[3] One hundred twenty-eight tons/ha waste applied in 1978.

received lime or N (Table 3).

In 1979, extractable Ca, Mg and Na levels were generally highest in soil from corn plots treated with waste that year. The Ca content increased significantly in soil from the corn plots which were treated with the intermediate amount of waste both years, although less Ca was present in the two applications than was applied with the highest level of tannery waste in 1978 (Tables 3 and 4). The highest level of extractable Ca in the soil used to grow bush bean, however, occurred in the soil which received the largest amount of Ca in the waste applied in 1978 (Tables 3 and 4).

Levels of Mg and Na in waste treated soil were lowest in the soil which was treated with the largest amount of waste only in 1978, compared to other waste amended soil, and probably reflects the smaller quantity of Mg present in the waste applied in 1978 compared to that which was used in 1979, and movement of Na out of the sampled depth (Tables 3 and 4). The Mg content of all waste treated soil was less than the content of the untreated soil, and some replacement of Mg with Ca in the soil may have occurred (Table 3).

The extractable Ca content in soil from fescue plots established in 1979 increased significantly ($P \leq 0.05$) with the highest two rates of waste treatment, compared to the other soils; Na content also increased with waste application. Magnesium content, however, was significantly lower in waste amended soil than in fertilized or untreated soil (Table 3). Extractable K was not significantly affected by waste treatment.

The extractable Ca, Mg, and K content between 15 and 90 cm depth

Table 4. Applications of Ca, Mg, Na and K applied in tannery waste in 1978 and 1979.

Crop	Year	Ca	Mg	Na	K
		---------- kg/ha ----------			
Sweet corn	1978	27800	460	307	466
	1979	1700	830	260	5
Bush bean	1978	18560	307	204	311
	1979	1090	522	170	5
Tall fescue	1978	24960	410	273	416
	1979	1750	79	22	7

Table 5. Exchangable bases in Willamette silt loam collected in November, 1979, from plots used in corn study.

Treatment				Ammonium acetate Exchangable			
Mixed waste	Beam-house	Tan-yard	Depth	Ca	Mg	Na	K
------- tons/ha ----			cm	--------- meq/100 g --------			
0	0	0	0-15	8.5	0.8	0.1	0.5
			15-30	6.9	1.1	0.1	0.3
			30-45	6.6	1.3	0.2	0.7
			45-60	6.9	2.5	0.1	0.6
			60-75	7.6	3.0	0.1	0.6
			75-90	8.3	3.1	0.1	0.6
96	24	32	0-15	20.0	0.9	0.4	0.5
			15-30	10.2	1.1	0.5	0.7
			30-45	7.5	1.8	0.3	0.7
			45-60	7.6	2.7	0.2	0.7
			60-75	8.6	3.4	0.2	0.6
			75-90	9.2	3.5	0.1	0.5
192	0	0	0-15	18.1	0.8	0.2	0.5
			15-30	13.3	1.0	0.2	0.6
			30-45	7.8	2.1	0.2	0.6
			45-60	7.5	2.6	0.3	0.4
			60-75	8.4	3.4	0.2	0.6
			75-90	8.6	3.6	0.2	0.5

in the soil from plots used to grow corn were not affected by waste applications (Table 5). The Na content in the 15 to 30 cm increment in soil from plots which received the intermediate amount of waste in 1978 and 1979, however, increased significantly compared to soil at the corresponding depth collected from plots amended with the largest amount of waste in 1978, or left untreated. Although some contamination may have occurred during tillage, the fact that less Na was extracted from the 0 to 15 cm depth increment than was extracted from the 15 to 30 cm interval suggests that movement of Na occurred.

Cation exchange capacity

The cation exchange capacity of waste amended soil used to grow sweet corn did not change significantly with treatment (Table 6).

SUMMARY

Tannery waste applied to Willamette silt loam soil increased Ca concentrations in bush bean leaf and tall fescue tissue, compared to concentrations in plants grown on untreated soil. The total Ca uptake by tall fescue also increased with waste application. The Mg content increased in tall fescue grown on soil amended with the highest rate of waste compared to other treated or untreated soil; however, Mg uptake was unaffected by tannery waste treatment.

Application of tannery waste increased the content of exchangable Ca in treated soils, compared to untreated ones. A concurrent decrease in exchangable Mg or K suggests that replacement of these cations with Ca occurred. No significant movement of cations other than Na into

Table 6. Cation exchange capacity of Willamette silt loam amended with tannery waste, collected September, 1979.

Treatment					Cation exchange capacity
Mixed waste[1]	Beam house[2]	Tan-yard[2]	Lime	N	
tons/ha				kg/ha	meq/100 g
0	0	0	0	0	14.6
0	0	0	26	200	NA[3]
48	12	16	0	0	14.7
96	24	32	0	0	15.2
96	24	32	0	56	NA
192	0	0	0	0	15.5
LSD ($P \leq 0.05$)					NS[4]

[1] Applied in 1978.

[2] Applied in 1979.

[3] Not analyzed.

[4] Not significant.

the soil profile was noted.

Tannery waste could be utilized as a nutrient source for crops; however, decreases in exchangable soil Mg and K related to increased contents of Ca may necessitate supplemental application of Mg and K if repeated heavy application of waste are made.

GROWTH AND ELEMENTAL CONTENT OF SWEET CORN, BUSH BEAN AND TALL FESCUE GROWN ON TANNERY WASTE AMENDED SOIL IN A GREENHOUSE STUDY

MATERIALS AND METHODS

A greenhouse experiment was established at the Corvallis Environmental Research Laboratory, March through November, 1979, to evaluate the effect of tannery waste on sweet corn, bush bean, and tall fescue germination, growth, and elemental content.

Tannery waste from the Legallet Wool Company, San Francisco, CA, lime and N fertilizer were mixed with Willamette silt loam (3800 g) (Tables 2, 3, and 4). The treated soils were placed in black plastic covered one gallon pots and arranged by crop in a randomized block design with four replications. Corn and bean seeds, 6 or 7 per pot, were planted twice, on 5 April and 9 August or 26 March and 27 August, respectively. Fescue was seeded only once, on 2 April, 1979. Germination was checked daily for 15 days after the first planting, after which corn and bean plants were thinned to two per pot. The tall fescue plants were not thinned.

Corn plants were watered with approximately 180 mls of reverse-osmosed water twice weekly. Bean and tall fescue plants received 185 or 145 mls, respectively, twice a week, to approximate the amount of water applied to plants grown in the field experiment. Lighting was supplemented by sodium vapor lamps 16 hours a day.

Entire corn plants were harvested on 17 May and 20 September, and bean plants were harvested on 4 June and 5 November, 1979. Fescue was cut on 18 June, 27 August, and 11 November, 1979.

All soils which received the same amendment were mixed and subsampled after plant harvest.

Soil samples and plant tissue were prepared for analysis as described previously. Five samples of the tannery waste were also analyzed after acid digestion (Table 1).

RESULTS AND DISCUSSION

Sweet corn yield and elemental content

Sweet corn seed germination did not differ significantly between treatments, and plants showed no sign of salt burn or stunting with waste application. The first corn crop grew normally, but reduced plant height and vigor were observed in the second crop grown on the fertilized and untreated soil.

Greatest sweet corn yields at both harvests were obtained from plants grown on soil treated with the largest amount of tannery waste (Table 2). Corn yield on soil amended with the highest rate of waste was greater than yield of plants grown on untreated soil at the first harvest. Nitrogen concentration and uptake were greatest in plants grown on soil amended with the two highest rates of waste. Yield and N uptake from the second planting of corn grown on soil amended with the intermediate and greatest amounts of waste were elevated significantly compared to other plants (Table 2). More total and extractable N were present in waste amended soil than in the fertiilized or untreated soil, a fact reflected in the greater yield and N content of plants grown on waste treated soil. The N concentration in the sweet corn was lower than the 3.0% critical level (Melsted, 1969).

Table 1. Analysis of tannery waste from the Legallet Wool Company used in greenhouse study.

Sample	Moisture	Ca	Mg	Na	K	P	Cr	Cd	Cu	Mn	Zn	Total N	KCl extractable NH_4-N	KCl extractable NO_3-N
	%							μg/g				%		
1	68	26	0.6	0.3	0.16	0.017	2.03	NA[1]	33	2840	320	4.2	1.48	0.117
2	68	25	0.7	0.3	0.17	0.019	1.96	0.06	34	2920	310	4.2	1.00	0.016
3	68	29	0.7	0.3	0.19	0.020	1.79	0.07	36	2980	320	5.9	NA	NA
4	NA	27	0.7	0.7	0.18	0.019	1.66	0.08	35	3030	320	NA	NA	NA
5	NA	26	0.8	0.3	0.19	0.019	1.82	NA	37	3000	320	NA	NA	NA

[1] Not analyzed.

The concentration of P in corn tissue harvested from the first planting decreased significantly with waste application (Table 2). The total P uptake by the sweet corn was not significantly affected by waste treatment (Table 2). Plants grown on soil treated with the two highest rates of waste were deficient in P if 0.25% is considered to be the critical level for corn (Melsted, 1969), but sweet corn grown as the second crop contained adequate P (Table 2).

The Ca concentration and uptake was increased significantly ($P \leq 0.05$) in sweet corn grown on waste treated soil compared to corn grown on untreated soil (Table 2). Plants grown on soil treated with the two highest levels of waste and the highest level of waste at the first and second planting, respectively, exceeded the critical concentration of Ca (0.4%, Melsted, 1969).

Plants grown on waste treated soil contained the highest concentrations of Mg; uptake was also greatest by sweet corn grown on the waste amended soil (Table 2). All sweet corn plants contained sufficient Mg, if 15 μg/g dry weight plant tissue is considered to be critical for good growth (Melsted, 1969).

Although incorporation of tannery waste increased the total Cr content of soil treated with the largest amount of waste approximately 500% above untreated soil, the concentration and uptake of Cr in sweet corn was not affected (Tables 2 and 5).

Copper uptake in sweet corn increased significantly ($P \leq 0.05$) with waste application (Table 2), however, levels of DTPA extractable Cu did not differ significantly between treatments (Table 5).

Concentration and uptake of Mn were not significantly different

Table 2. Yield and elemental content of sweet corn grown in greenhouse studies on Willamette silt loam amended with tannery waste.

Treatment				Concentration								Uptake						
Waste	Lime	N	Yield	Cu	Cr	Mn	Zn	N	P	Ca	Mg	Cu	Mn	Zn	N	P	Ca	Mg
----- g/pot -----			g/pot	------ μg/g --------				---------- % ----------				----μg/pot ----			--------mg/pot ---------			
Sweet corn, 1st crop																		
0	0	0	4.20	2.4	3.6	69	40	0.71	0.26	0.29	0.11	10.1	290	168	29.6	10.8	12.2	4.5
0	0	0.24	3.62	NA[1]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.47	5.97	NA	NA	NA	NA	0.73	0.25	NA	NA	NA	NA	NA	43.0	13.8	NA	NA
0	31.0	0.24	3.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	0	0	3.37	2.4	7.5	134	45	0.84	0.29	0.37	0.16	8.1	452	152	27.6	9.8	12.3	5.2
37	0	0	6.20	2.6	3.8	117	38	1.37	0.18	0.53	0.17	16.1	725	236	64.0	10.5	33.1	13.6
75	0	0	7.47	2.4	3.7	96	60	1.21	0.08	0.69	0.21	17.9	717	448	88.0	5.7	51.9	15.5
LSD ($P \leq 0.05$)			2.08	NS[2]	NS	NS	NS	NS	0.13	0.13	0.02	7.8	NS	212	32.6	NS	19.2	NS
Sweet corn, 2nd crop																		
0	0	0	3.09	4.5	5.8	67	39	0.36	0.39	0.24	0.13	12.9	195	117	5.8	8.9	7.4	3.9
0	0	0.24	2.48	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.47	2.44	NA	NA	NA	NA	0.24	0.37	NA	NA	NA	NA	NA	4.1	11.8	NA	NA
0	31.0	0.24	3.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	0	0	3.95	3.6	3.9	39	36	0.28	0.28	0.21	0.14	12.7	155	146	9.6	10.3	8.3	5.3
37	0	0	6.61	2.3	6.2	38	43	0.35	0.26	0.29	0.15	14.2	256	266	23.0	18.3	19.5	10.1
75	0	0	9.46	2.2	2.6	41	46	0.39	0.28	0.43	0.18	20.1	384	436	37.2	26.1	25.6	17.4
LSD ($P \leq 0.05$)			1.54	NS	NS	14	NS	NS	NS	0.04	0.02	5.56	110	177	15.7	NS	7.5	3.1

[1] Not analyzed.

[2] Not significant.

between treatments in the first corn crop. The Mn concentration in the second crop of corn grown on waste treated soil was significantly lower than that in plants grown on untreated soil, reflecting the higher pH of the waste treated soil. Manganese uptake significantly increased with tannery waste application compared to uptake in plants grown on untreated soil (Table 2). This suggests dilution of Mn by greater growth of plants grown on waste treated soil. The Mn concentration in corn tissue exceeded the critical level for sweet corn, but never approached levels considered toxic (Table 2; Allaway, 1968).

The extractable soil Mn content did not notably differ between waste treated and fertilized soils, but was depressed on the limed soil (Table 5).

Zinc concentrations in corn tissue were adequate for normal plant growth (Melsted, 1969), and did not differ significantly between treatments (Table 2). Zinc uptake, however, increased markedly with waste application, and plants grown on soil treated with the largest amount of waste accumulated more Zn than did plants grown on other treated or untreated soil (Table 2). Levels of DTPA extractable Zn decreased with waste application (Table 5). The soil pH increased with waste additions (Table 5), and, compared to other fertilized or untreated soil, would be expected to decrease Zn solubility.

Soil pH and EC

The pH and EC of all waste treated soil increased relative to the fertilized or untreated soil (Table 5). The EC of the treated soil did not increase to a level expected to cause a decrease in sweet corn yield (Table 5; Berstein, 1964).

Bush bean yield and elemental content

Bush bean seeds germinated and grew normally. No significant differences in seedling emergence were noted, and no symptoms of nutrient deficiency or toxicity were observed.

The yield of both crops of beans increased with waste application (Table 3). Yield of bean plants grown on soil fertilized with twice the optimal amount of N was slightly less than the yield of plants grown on soil which received the intermediate amount of waste. Bean plants grown as the second crop on soil amended with the intermediate amount of waste had a greater yield than plants grown on any of the fertilized soil (Table 3).

Tissue N concentration did not differ significantly between treatments for either crop of bush beans, but N uptake was greatest in plants grown on soil treated with the largest amount of tannery waste (Table 3). Nitrogen levels were lower than are considered optimal for snapbeans (5.1%, MacKay and Leefe, 1962).

No significant differences in P concentration between treatments were noted in samples collected from the first or second crop of beans. Uptake of P increased with waste addition, and was generally greatest at higher levels of waste amendment (Table 3).

Calcium and Mg concentrations in bean plants were not affected by waste addition (Table 3). Calcium concentration was higher, and Mg lower than has been reported for beans grown on unfertilized soil (0.27 to 0.38% Ca and 0.34 to 0.38% Mg; Sidwell, 1954), but these values are for edible portions only, and may not be representative of the whole plant. Calcium uptake in plants grown on soil treated with the

intermediate and high levels of waste increased significantly when compared to uptake in plants grown on untreated soil, or soil amended with the least amount of waste (Table 3). Greatest Mg uptake occurred on soil treated with the largest amount of waste (Table 3).

The concentration and uptake of Cr and Cu were unaffected by waste or fertilizer application (Table 3). The total Cr concentration of the soil increased with waste application, but extractable Cu levels were unaffected, and were, in fact, about 100 times lower than levels that have been shown to induce Cu toxicity (Table 5; Walsh et al., 1962).

The Mn concentration in bean tissue decreased significantly with waste additions, but was within the range of values reported for snapbeans grown on fertilized soil (Table 3; Geraldson et al., 1973). Manganese uptake did not differ significantly between treatments, but was notably higher in plants grown on untreated soil, compared to treated soil. Extractable soil Mn decreased with waste and lime additions, a reflection of the higher pH of these soils compared to the untreated or N fertilized soil (Table 5).

The first crop of beans grown on waste treated soil contained significantly ($P \leq 0.05$) lower Zn concentrations than did plants grown on unamended soil, which also reflects the higher concentration of DTPA extractable Zn in the unamended soil (Tables 2 and 5). No differences were noted in tissue Zn concentration of the second crop of beans (Table 3). Total Zn uptake was greatest in plants grown on soil treated with the highest level of waste, and from the untreated soil in plants initially grown (Table 3).

Table 3. Yield and elemental content of bush bean grown in greenhouse studies on Willamette silt loam amended with tannery waste.

Treatment				Concentration								Uptake						
Waste	Lime	N	Yield	Cu	Cr	Mn	Zn	N	P	Ca	Mg	Cu	Mn	Zn	N	P	Ca	Mg
	Bush bean, 1st crop																	
------ g/pot -----			g/pot	------ µg/g --------				---------- % ----------				----- µg/pot----			------- mg/pot ----------			
0	0	0	6.04	4.7	3.9	133	45	1.95	0.19	1.86	0.27	28.1	815	270	118	11.7	113.2	16.4
0	0	0.16	6.97	NA[1]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.32	7.51	NA	NA	NA	NA	1.90	0.19	NA	NA	NA	NA	NA	143	14.5	NA	NA
0	20.5	0.16	7.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	0	0	6.86	6.7	9.6	90	31	1.86	0.18	1.74	0.24	46.0	592	205	129	12.4	116.4	15.8
23	0	0	7.68	6.4	8.8	89	32	2.23	0.21	2.01	0.28	51.2	653	242	173	15.7	150.2	20.7
47	0	0	8.59	4.3	4.3	70	29	1.93	0.19	1.86	0.26	39.6	653	275	177	17.2	170.0	24.1
LSD ($P \leq 0.05$)			NS[2]	NS	NS	37	6	NS	NS	NS	NS	NS	NS	47.2	NS	3.1	32.6	3.4
	Bush bean, 2nd crop																	
0	0	0	5.74	4.6	4.2	105	36	1.78	0.19	1.47	0.22	26.6	611	208	104	10.9	86.0	13.4
0	0	0.16	5.21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.32	5.13	NA	NA	NA	NA	1.63	0.17	NA	NA	NA	NA	NA	96	8.8	NA	NA
0	20.5	0.16	6.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	0	0	6.37	6.3	3.2	64	38	1.75	0.17	1.34	0.18	39.3	386	333	112	10.9	84.5	10.9
23	0	0	7.04	5.6	3.9	57	35	1.72	0.19	1.47	0.23	38.9	410	247	121	13.8	102.3	15.9
47	0	0	7.70	4.5	3.2	55	36	1.89	0.25	1.75	0.24	33.8	425	284	146	14.3	135.6	18.1
LSD ($P \leq 0.05$)			1.28	NS	NS	20	NS	NS	NS	NS	NS	NS	NS	NS	30.8	NS	NS	3.6

[1] Not analyzed.

[2] Not significant.

Soil pH and EC

Tannery waste additions resulted in an increased soil pH compared to the pH of soil which was untreated or treated with fertilizer (Table 5). The saturated paste EC of the soil also increased with waste application, but did not appear to interfere with germination or growth of the plants (Table 5). Since decreases in bush bean yields are not noted until soil EC is 3.5 mmho/cm or greater, the maximum level of 0.8 mmho/cm observed on waste treated soil would not be expected to affect bean seed germination or growth (Berstein, 1964).

Tall fescue growth and elemental content

Tall fescue germination was unaffected by waste or fertilizer application. Normal growth and visual appearance of the plants suggested that no deficiencies or toxicities developed with the tannery waste additions.

Tall fescue yields did not differ significantly at the first clipping, but greatest growth occurred on the soil treated with the largest amount of tannery waste, and on soil that received twice the optimal amount of N as NH_4NO_3 (Table 4). Yield of plants grown on the soil treated with the maximum and intermediate amounts of waste were significantly greater than yield of plants from other waste treated or untreated soils at the second and third clipping. The yield of fescue grown on N treated soil was less than with the two highest rates of waste at the second and third harvests, indicating that more residual benefit was derived from the tannery waste than from the commercial fertilizer (Table 4).

The N concentration in tall fescue tissue from every harvest was highest in plants grown on soil treated with the largest amount of waste, compared to other waste treated or untreated soil, but was statistically significant only in plants collected during the third clipping (Table 4). The highest total uptake of N occurred in plants grown on soil treated with the largest amount of waste, although this difference was only significant at the last harvest (Table 4).

The total N in the soil collected after the last plant harvest varied only slightly between all treatments, but NH_4-N extracted from soil treated with the largest amount of waste exceeded that extracted from all but the limed and fertilized soil (Table 5). Extractable NO_3-N content was greatest on the limed and fertilized soil, but the NO_3-N content in soil amended with the two highest rates of waste was also elevated.

Phosphorus concentrations in tall fescue decreased with waste addition and, in plants from both the second and third harvests, were lower in the tissue of plants grown on waste treated soil than in fescue grown on untreated soil (Table 4). Since P uptake was greater in plants grown on treated soil than untreated soil, dilution of P by greater plant growth on waste amended soil occurred. Phosphorus concentration in tall fescue is generally within the range of 0.23 to 0.45% (Reid et al., 1970). No P deficiencies were apparent upon visual inspection, but since concentrations of P in plants grown on waste treated soils were generally lower than the above values, P deficiencies may have occurred.

Calcium and Mg concentrations increased significantly with tannery

Table 4. Yield and elemental content of all fescue grown in greenhouse studies on Willamette silt loam amended with tannery waste.

Treatment				Concentration								Uptake						
Waste	Lime	N	Yield	Cu	Cr	Mn	Zn	N	P	Ca	Mg	Cu	Mn	Zn	N	P	Ca	Mg
g/pot			g/pot	µg/g				%				µg/pot			mg/pot			
Tall Fescue, 18 June 1979																		
0	0	0	3.37	2.6	5.8	120	36	1.07	0.08	0.45	0.24	9.3	436	130	37.9	2.8	54.2	8.6
0	0	0.21	2.93	NA[1]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.42	3.86	NA	NA	NA	NA	1.16	0.13	NA	NA	NA	NA	NA	37.8	5.0	NA	NA
0	25.2	0.21	3.55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15	0	0	2.50	3.4	6.3	145	19	0.84	0.19	0.53	0.31	8.3	352	46	20.6	4.6	13.1	7.6
31	0	0	2.89	4.1	7.4	117	20	1.00	0.16	0.58	0.33	11.8	230	102	29.1	4.3	16.7	9.4
62	0	0	3.86	2.8	4.9	79	24	1.23	0.11	0.61	0.28	13.1	304	87	47.9	4.1	70.8	10.9
LSD ($P \leq 0.05$)			NS[2]	NS	NS	35	NS	NS	0.07	NS	0.06	NS	NS	NS	NS	NS	NS	NS
Tall Fescue, 27 August 1979																		
0	0	0	6.00	2.4	8.7	488	56	0.80	0.79	0.33	0.18	7.6	1521	181	24.9	2.6	10.5	5.9
0	0	0.21	4.42	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.42	6.01	NA	NA	NA	NA	1.03	1.08	NA	NA	NA	NA	NA	33.2	3.3	NA	NA
0	25.2	0.21	5.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
48	0	0	5.21	3.9	6.0	432	15	0.85	0.20	0.37	0.23	12.2	1261	74	25.1	5.5	10.4	7.1
96	0	0	8.14	2.9	6.8	280	43	0.98	0.16	0.46	0.23	11.9	1241	172	39.9	6.2	21.2	10.4
194	0	0	11.18	3.6	7.4	194	25	1.14	0.10	0.48	0.22	20.4	1002	139	64.4	5.4	27.3	12.1
LSD ($P \leq 0.05$)			0.95	NS	NS	95	NS	NS	0.06	0.09	0.04	NS	NS	NS	NS	NS	9.5	2.6

Tall Fescue, 11 November 1979

Treatment				Concentration		Uptake	
Waste	Lime	N	Yield	N	P	N	P
g/pot				%		mg/pot	
0	0	0	1.71	0.58	0.96	10.2	1.6
0	0	0.21	2.46	NA	NA	NA	NA
0	0	0.42	2.78	0.77	0.13	22.3	3.7
0	25.2	0.21	1.99	NA	NA	NA	NA
15	0	0	2.18	0.48	0.22	10.6	4.4
31	0	0	3.58	0.55	0.15	17.8	5.3
62	0	0	4.89	1.19	0.11	60.1	5.3
			1.23	0.24	0.01	17.6	1.9

[1] Not analyzed.

[2] Not significant.

waste additions, and in all cases, concentrations of these nutrients were greater in plants grown on waste treated soil than in plants grown on untreated soil (Table 4). The Ca and Mg concentrations observed were similar to those reported (0.48 and 0.27% for Ca and Mg, respectively) in studies designed to compare the effects of residual lime treatments on elemental composition of tall fescue (Price and Moschler, 1970). Uptake of both nutrients in plant samples collected at the initial clipping was greatest in fescue grown on soil treated with the largest amount of waste (Table 4). By the time of the second harvest, uptake of Ca and Mg by plants grown in soil treated with the two highest rates of waste were significantly ($P \leq 0.05$) higher than uptake by plants grown on any other soil (Table 4).

Chromium and Cu applied with tannery waste did not increase the concentration or uptake of either metal in fescue tissue (Table 4). The total Cr content of the soil increased considerably with waste additions (Table 5). No marked differences in DTPA extractable Cu occurred (Table 5).

Manganese concentrations in tall fescue were not consistently related to extractable soil Mn, but tissue Mn content decreased with waste application, probably in response to the increased soil pH associated with waste additions, and concurrent decrease in soil Mn solubility. The greatest Mn concentration and uptake was observed in plants grown on the untreated soil, and those grown on soil that received the least waste (Table 4). No consistent trends in DTPA extractable Mn were present, although extractable Mn in all waste treated soil was lower than in fertilized or untreated soil (Table 5).

Table 5. Total Cr, extractable trace elements, total and extractable N, pH and electroconductivity of Willamette silt loam used in greenhouse studies.

Crop	Treatment			Total	DTPA extractable			Total	KCl extractable		pH	EC
	Waste	Lime	N	Cr	Cu	Mn	Zn	N	NH_4-N	NO_3-N		
	---- g/pot -----			---------- μg/g -------				%	---- μg/g ----			mmho/cm
Sweet corn	0	0	0	NA[1]	0.26	51	2.5	0.11	0.7	2.3	5.7	0.2
	0	0	0.24	35	0.30	51	1.8	0.11	1.9	1.5	5.8	0.2
	0	0	0.47	29	0.24	47	1.8	0.08	0.9	1.8	5.8	0.2
	0	31.0	0.24	NA	0.24	13	1.8	0.10	0.4	0.5	7.4	0.2
	18	0	0	85	0.30	49	3.2	0.11	1.6	2.4	6.1	0.4
	37	0	0	261	0.28	51	2.5	0.12	2.1	3.9	6.2	0.8
	75	0	0	231	0.22	47	1.7	0.13	4.0	9.2	6.4	1.2
Bush bean	0	0	0	41	0.30	71	2.3	0.09	2.5	1.8	5.7	0.7
	0	0	0.16	38	0.30	54	2.5	0.11	2.2	1.5	5.9	0.2
	0	0	0.32	37	0.28	100	2.8	0.11	1.8	2.6	NA	NA
	0	20.5	0.16	50	0.22	12	1.5	0.11	2.6	1.8	7.0	0.2
	10	0	0	NA	0.32	51	1.7	0.11	0.4	1.5	6.0	0.2
	23	0	0	67	0.30	32	1.3	0.12	0.9	3.2	6.1	0.4
	47	0	0	70	0.28	26	1.2	0.11	3.2	8.5	6.1	0.8
Tall fescue	0	0	0	22	0.34	73	1.7	0.11	1.0	1.6	5.7	0.2
	0	0	0.21	NA	0.38	60	2.8	0.11	0.5	0.6	6.0	0.2
	0	0	0.42	31	0.36	65	2.9	0.10	0.7	1.9	5.9	0.2
	0	25.2	0.21	36	0.44	77	2.2	0.12	1.8	8.5	7.2	0.2
	15	0	0	111	0.34	27	1.6	0.10	0.4	0.9	5.8	0.2
	31	0	0	105	0.38	54	1.2	0.09	0.7	2.0	6.0	0.8
	62	0	0	273	0.42	60	1.3	0.12	1.8	6.7	6.3	1.2

[1] Not analyzed.

Zinc concentration and uptake was lowest in plants grown on waste treated soil compared to untreated soil (Table 4). Since Zn compound solubility decreases with increased soil pH, the higher pH of waste amended soil probably depressed the availability of Zn. Extractable Zn content in the waste treated soil was lower than in the fertilized or untreated soil, and again probably refelcts the higher pH of these soils (Table 5). The relatively large amount of Zn extracted from the limed and fertilized soil, which had the highest pH of any soils, is unexpected, and may represent contamination (Table 5).

Soil pH and EC

Soil pH increased with waste additions, compared to the pH of untreated soil (Table 5). Soil EC also increased, and reached a maximum of 1.2 mmho/cm in the soil that received the largest waste amendment (Table 5). A decrease in growth of fescue would not be expected until soil saturated paste electroconductivity exceeded 7.0 mmho/cm (Berstein, 1964). Levels of waste application that appear to benefit fescue would thus not be expected to cause injury to plants.

SUMMARY

The yield of sweet corn, bush bean and tall fescue increased with tannery waste application compared to the yield of plants grown on untreated soil.

The concentration of Ca in bean and corn tissue and Mg in corn and fescue tissue increased with waste addition. Concentrations of Mn decreased in all crops grown on waste amended soil. Phosphorus

concentrations in corn and fescue plants, and Zn in bush bean grown on waste treated soil were lower than concentrations in plants grown on untreated soil.

Tannery waste additions increased total N, Ca and Mg uptake in all crops, relative to uptake in plants grown on untreated soil. Phosphorus uptake in bean and fescue plants, and Mn in corn plants were also enhanced by waste additions. Zinc uptake in sweet corn was increased by waste amendment, compared to Zn uptake in plants grown on unamended soil.

Extractable NH_4- and NO_3-N levels in waste treated soil increased when compared to fertilized or untreated soil, although total N levels did not change with waste addition.

Total Cr content of the soil increased with tannery waste amendment. No marked differences in Cu content between waste treated and untreated soils were noted, while extractable Zn and Mn generally decreased in waste treated soil relative to untreated soil.

Soil pH and EC increased with waste addition, compared to untreated soil. With the increase in soil pH, the effects of trace metals contained in the waste on plant growth and metal uptake would be mitigated. Although corn is considered to be moderately tolerant to salts, and beans sensitive (Russell, 1963), the increased EC of waste treated soils did not appear to inhibit germination or growth of these plants.

SUMMARY

Field study

Yields of sweet corn and bush bean were not significantly increased by tannery waste applications, but the yield of tall fescue plants was enhanced by waste treatment in plots established in 1978 and 1979.

Concentrations of nutrients were generally similar to those normally observed in the test crops. Plant growth was normal, and no deficiencies or toxicities were visually apparent.

Waste applications resulted in increased N concentrations in the tissue of the three crops grown on waste treated soil. Similarly, Mn and Zn concentrations or uptake were increased in plants grown on soil treated with waste. Calcium, Mg and Cu contents in sweet corn and bush bean were not affected by waste amendments, but concentrations of these elements were increased in tall fescue grown on waste treated soil, relative to concentrations in plants grown on untreated soil. Chromium concentrations were not consistently related to waste treatment for any of the test crops.

In general, applications of tannery waste increased contents of soil total and extractable N, total Cr, extractable Mn, Zn and Cu, and exchangable Ca and Na. Levels of exchangable Mg and K were observed to decrease as the exchangable Ca content of the soil increased. Soil pH and EC also increased with waste treatment. Levels of extractable metals in the treated soils were noted to have decreased one year after waste application.

In soil collected to 90 cm depth, only the NO_3-N and Na contents

increased with depth and treatment. No movement of other metals or nutrients was noted.

Greenhouse study

In the greenhouse study, a growth response to tannery waste application was evident in sweet corn, bush bean and tall fescue. Growth on tannery waste treated soil was sustained through multiple harvests to a greater extent than on soil fertilized with commercial N.

Nitrogen concentration in plant tissue increased with waste treatment, and was generally higher at all harvests in plants grown on waste treated soil than in those grown on commercially fertilized soil. Phosphorus concentration, but not uptake, was decreased in sweet corn and tall fescue grown on waste treated soil. Phosphorus uptake was significantly increased in bush bean grown on waste amended soil, relative to untreated soil.

The concentration and uptake of Ca and Mg in all crops were increased by waste treatment. Concentrations and uptake of Mn and Zn in sweet corn plants increased with increased waste amendments, but decreased in both bush bean and tall fescue with increased waste treatment. Copper uptake by sweet corn was elevated in plants grown on waste treated soil, relative to plants grown on untreated soil; concentrations and uptake of Cu in bush bean and tall fescue were unaffected. In none of the test crops did Cr concentration or uptake relate consistently to waste additions to Willamette silt loam.

Total or extractable N levels increased with waste treatment. Levels of extractable Cu in the soil were not affected by waste

amendment; Mn and Zn concentrations were generally lower than found in the untreated soil. The total Cr content of all waste treated soil increased in relation to increased waste addition. Soil pH and Ec were also elevated in waste amended soil, relative to unamended soil.

RECOMMENDATIONS

Tannery waste utilization as a soil amendment may be limited by increases in the salt content of soil affected by waste additions based upon crop N needs. Applications of 192 tons/ha waste increased soil EC to levels that were detrimental to corn. Cultivation of more tolerant plant species, such as tall fescue, is recommended.

Potential for phytotoxic levels of metal accumulation in soil repeatedly amended with tannery waste exists; however, damage to plants from excessive salt accumulation is likely to occur before metal toxicity is exhibited.

Utilization of tannery waste as a slow release N or micronutrient source, or as a liming agent is feasible within the constraints of the salt tolerance of a crop, and crop sensitivity to heavy metal concentrations.

FUTURE RESEARCH NEEDS

The concentration of trivalent Cr contained in tannery waste could, under certain soil conditions, be oxidized to the soluble, toxic ion Cr VI. The chemistry of Cr in the soil needs to be further clarified to understand the effects of additions of this element to soil.

Movement of NO_3-N from the waste treated surface soil into the soil profile indicates that groundwater contamination could occur with repeated applications of waste. Determinations of the optimal level of waste additions to reduce NO_3-N loss should be made. Additionally, the effects of the increased pH of the waste treated soil on nutrient availability should be clarified.

New waste treatment technologists at tanneries utilizing Cr in the tanning process permit separation of waste streams, and production of two waste types, one characterized by high metal and Cr concentrations, the other by high lime and N contents. Trials to determine the effect of these different waste types on soil and plants could be fruitful in developing workable waste disposal programs.

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APPENDICES

Table Ia. Analysis of waste from the Legallet Wool Company used in field studies, 1978.

Sample	Moisture	$CaCO_3$ equivalence	Organic C	Ca	Mg	Na	K	P	S	Cr	Cd	Cu	Mn	Zn	KCl extractable NO_3-N	KCl extractable NH_4-N	Total N
	%	%	%	%	%	%	%	%	%	%	μg/g	μg/g	μg/g	μg/g	%	%	%
1	43	33.9	2.9	14.5	0.25	0.16	0.22	0.18	1.2	0.61	0.04	26	3420	260	0.0009	0.105	2.8
2	54	44.0	7.9	14.5	0.22	0.16	0.23	0.18	1.2	0.34	0.04	20	3520	41	0.0022	0.350	2.5
3	38	NA[1]	NA	14.6	0.25	0.17	0.28	0.18	1.2	0.44	0.04	27	3270	119	0.0149	0.055	2.1
4	40	NA	5.6	NA	NA	NA	NA	0.18	1.4	NA	NA	NA	NA	NA	NA	0.115	2.8
5	36	NA	4.0	NA	NA	NA	NA	0.19	1.1	NA	NA	NA	NA	NA	NA	0.045	2.4

[1] Not analyzed.

Table Ib. Analysis of waste from the A. K. Salz Tannery used in field studies, 1979.

Waste type	Sample	Moisture	$CaCO_3$ equivalence	Ca	Mg	Na	K	P	S	Cr	Cd	Cu	Mn	Zn	KCl extractable NO_3-N	KCl extractable NH_4-N	Total N
		%	%	%	%	%	%	%	%	%	μg/g	μg/g	μg/g	μg/g	%	%	%
Beam house	1	57	9.7	3.0	0.06	0.23	0.015	0.05	0.03	0.0022	0.007	4	1190	31	0.009	0.07	2.4
	2	57	9.7	3.3	0.05	0.23	0.015	0.06	0.03	0.0029	0.014	4	950	32	0.017	0.06	7.3
	3	54	11.6	3.2	0.04	0.68	0.017	0.04	NA[1]	0.0012	0.006	4	940	28	0.008	0.05	NA
	4	57	NA	2.8	0.05	0.45	0.012	NA	NA	0.0010	NA	5	1180	32	NA	NA	NA
Tan-yard	1	70	21.9	3.0	0.2	0.90	1.90	0.23	0.15	4.7	0.04	60	101	62	0.014	0.22	12.5
	2	70	10.0	3.0	0.4	0.30	0.80	0.26	0.17	4.1	0.03	64	114	67	0.011	0.21	8.5
	3	71	10.0	3.0	0.2	0.70	1.30	0.28	NA	4.0	0.05	67	92	73	NA	0.22	10.3
	4	71	NA	1.0	0.2	0.30	0.60	NA	NA	3.5	NA	68	66	69	NA	NA	NA

[1] Not analyzed.

Table Ic. Analysis of tannery waste used in greenhouse study.

Sample	Moisture	Ca	Mg	Na	K	P	Cr	Cd	Cu	Mn	Zn	Total N	KCl extractable NH_4-N	KCl extractable NO_3-N
	%							μg/g				%		
1	68	26	0.6	0.3	0.16	0.017	2.03	NA[1]	33	2840	320	4.2	1.48	0.117
2	68	25	0.7	0.3	0.17	0.019	1.96	0.06	34	2920	310	4.2	1.00	0.016
3	68	29	0.7	0.3	0.19	0.020	1.79	0.07	36	2980	320	5.9	NA	NA
4	NA	27	0.7	0.7	0.18	0.019	1.66	0.08	35	3030	320	NA	NA	NA
5	NA	26	0.8	0.3	0.19	0.019	1.82	NA	37	3000	320	NA	NA	NA

[1] Not analyzed.

Table IIa. Yield of sweet corn grown on tannery waste amended soils in 1978.

Treatment			Replication	Ear[1]			Stover[1]	Moisture	
Mixed waste	Lime	N		Mature	Immature	Total		Ear	Stover
--tons/ha --		kg/ha		---------- tons/ha ----------				--- % ------	
0	0	0	1	0.0	8.3	8.3	52.8	82	93
			2	8.5	3.2	11.7	40.9	75	95
			3	5.8	4.1	9.9	55.5	78	96
			4	5.2	1.8	17.0	47.7	74	94
0	26	200	1	5.3	9.9	15.2	51.9	59	86
			2	5.6	3.6	9.2	54.8	80	94
			3	3.6	12.1	15.7	53.5	81	92
			4	20.8	2.9	23.7	44.3	78	93
48	0	0	1	4.8	3.6	8.4	39.0	78	88
			2	15.5	1.9	17.4	48.4	77	94
			3	5.6	3.6	9.2	37.0	80	96
			4	4.4	1.7	6.1	45.3	77	93
96	0	0	1	10.9	3.4	14.3	49.2	77	88
			2	13.6	3.4	17.0	46.0	72	95
			3	11.9	2.2	14.1	46.3	77	95
			4	15.8	3.4	19.2	55.3	78	95
96	0	56	1	12.1	4.9	17.0	38.9	79	95
			2	11.6	3.6	15.2	46.0	77	93
			3	12.6	5.1	17.7	47.2	78	93
			4	8.3	5.8	14.1	49.2	80	93
192	0	0	1	9.7	1.9	11.6	52.8	78	89
			2	9.2	5.1	14.3	47.7	81	97
			3	2.9	10.5	13.4	27.5	80	96
			4	13.6	4.1	17.5	51.6	77	94

[1] Wet weight

Table IIb. Yield of sweet corn grown on tannery waste amended soil in 1979.

Treatment			Replication	Ear[1]			Stover[1]	Moisture	
Beam-house	Tan-yard	N		Mature	Immature	Total		Ear	Stover
-- tons/ha --		kg/ha		---------- tons/ha ----------				---- % -----	
0	0	0	1	9.5	1.9	11.4	21.4	77	84
			2	16.1	7.3	23.4	50.6	80	88
			3	13.3	3.2	16.5	38.9	78	86
			4	11.2	2.9	14.1	33.1	78	86
0	0	200	1	9.7	12.2	10.9	26.3	80	85
			2	8.0	2.2	10.2	34.1	83	86
			3	9.5	5.3	14.8	41.8	80	90
			4	11.7	5.6	17.3	42.8	80	85
12	16	0	1	9.4	5.3	14.8	29.2	79	85
			2	13.4	4.6	18.0	47.7	79	86
			3	7.5	3.6	11.2	34.1	80	84
			4	9.5	4.4	13.9	37.0	81	88
24	32	0	1	9.2	2.4	11.7	35.1	79	83
			2	9.7	5.8	15.6	37.9	78	81
			3	9.7	4.4	14.1	47.7	80	87
			4	9.2	5.3	14.6	32.1	82	86
24	32	56	1	6.8	4.4	11.2	29.2	83	92
			2	12.4	3.6	16.1	42.8	80	85
			3	9.98	7.3	17.7	49.7	80	85
			4	11.6	4.8	16.5	41.8	81	88
0	0[2]	0	1	12.6	2.9	15.6	39.9	81	85
			2	6.6	4.6	11.2	38.9	82	86
			3	13.4	2.9	16.3	35.1	86	85
			4	6.6	5.3	11.9	35.1	84	86

[1] Wet weight [2] One hundred-ninety two tons/ha waste applied in 1978.

Table IIc. Elemental composition of corn leaf, 1978.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				μg/g					
0	0	0	1	3.9	0.29	0.64	0.16	14.3	17.5	9.9	208	54	32
			2	NA[1]	NA	NA	NA	NA	NA	NA	NA	NA	NA
			3	3.3	0.26	0.48	0.12	13.2	9.2	9.2	210	39	22
			4	3.7	0.28	0.62	0.15	9.3	8.1	8.1	244	49	33
0	26	200	1	4.4	0.36	0.69	0.18	11.9	18.2	10.3	207	48	31
			2	4.4	0.38	0.64	0.18	15.2	11.1	11.7	222	59	31
			3	4.3	0.30	0.72	0.20	14.9	12.0	12.0	304	58	22
			4	4.0	0.30	0.63	0.16	12.7	8.7	8.7	247	47	30
48	0	0	1	4.1	0.36	0.63	0.22	16.6	18.3	9.9	268	76	38
			2	4.3	0.36	0.67	0.15	13.2	17.6	10.0	213	62	39
			3	4.0	0.34	0.48	0.17	15.4	22.8	13.1	181	53	28
			4	4.0	0.36	0.60	0.14	15.7	15.4	8.7	194	62	43
96	0	0	1	4.2	0.35	0.62	0.15	14.3	18.3	10.3	171	62	43
			2	3.6	0.33	0.64	0.14	17.9	18.5	10.6	205	56	38
			3	3.7	0.30	0.58	0.15	17.3	16.6	9.7	206	57	30
			4	4.1	0.32	0.58	0.18	15.1	14.8	8.2	237	68	36
96	0	56	1	3.9	0.35	0.68	0.17	15.4	18.5	10.9	203	70	41
			2	3.9	0.33	0.64	0.16	16.4	9.3	9.3	219	57	31
			3	3.8	0.30	0.67	0.16	16.2	9.2	9.2	198	66	33
			4	3.7	0.30	0.53	0.16	16.8	7.8	7.9	253	61	41

Table IIc. Continued.

Treatment			Repli-										
Mixed waste	Lime	N	cation	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		%				μg/g					
192	0	0	1	4.2	0.34	0.66	0.18	15.7	20.1	11.2	208	81	41
			2	4.1	0.31	0.70	0.15	11.4	9.1	9.1	204	89	46
			3	4.1	0.27	0.63	0.18	29.6	15.5	15.5	540	167	44
			4	4.1	0.28	0.57	0.16	14.4	9.6	9.6	237	84	43

[1] Not analyzed.

Table IId. Elemental composition of corn grain, 1978.

Treatment			Repli-									
Mixed waste	Lime	N	cation	Ca	Mg	K	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		--------- % ------			---------- μg/g ----------					
0	0	0	1	0.05	0.19	0.88	7.5	7.3	3.2	58	10	38
			2	0.05	0.17	0.71	4.4	6.4	3.1	57	8	33
			3	0.05	0.19	0.86	5.3	7.3	3.3	40	10	38
			4	0.05	0.15	0.68	7.1	6.8	2.6	36	10	29
0	26	200	1	0.05	0.18	0.82	5.6	6.5	2.8	58	10	37
			2	0.05	0.19	0.84	9.2	7.3	2.9	60	9	38
			3	0.05	0.20	0.97	7.2	8.4	3.8	41	11	40
			4	0.05	0.17	0.71	8.2	5.7	2.6	48	11	38
48	0	0	1	0.05	0.18	0.82	6.9	6.8	3.0	55	9	36
			2	0.05	0.14	0.73	5.4	5.6	2.6	53	7	31
			3	0.05	0.15	0.75	5.8	6.7	2.7	56	9	32
			4	0.05	0.15	0.70	4.8	6.5	3.1	33	9	33
96	0	0	1	0.05	0.16	0.73	5.4	7.3	2.7	56	11	35
			2	0.05	0.16	0.75	6.5	6.6	2.4	64	10	34
			3	0.05	0.18	0.78	6.6	7.0	3.1	48	9	35
			4	0.05	0.17	0.70	5.7	6.5	2.6	34	10	36
96	0	56	1	0.05	0.15	0.70	5.3	5.5	2.4	53	8	31
			2	0.05	0.16	0.72	4.9	6.3	2.6	63	8	32
			3	0.05	0.17	0.76	5.8	6.9	3.0	34	8	33
			4	0.05	0.16	0.67	7.7	7.0	3.1	37	10	32

Table IId. Continued.

Treatment			Repli-									
Mixed waste	Lime	N	cation	Ca	Mg	K	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		---------- % ------			---------- μg/g ----------					
192	0	0	1	0.05	0.16	0.74	5.9	6.5	2.7	55	10	37
			2	0.05	0.18	0.84	4.9	6.8	2.7	61	14	39
			3	0.05	0.17	0.80	6.9	7.0	2.9	45	14	36
			4	0.05	0.15	0.73	5.2	6.4	2.9	30	11	35

Table IIe. Elemental composition of corn stover, 1978.

Treatment			Repli-											
Mixed waste	Lime	N	cation	N	P	Ca	Mg	K	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		%					μ g/g					
0	0	0	1	1.1	0.27	0.52	0.21	1.3	8.9	5.0	3.6	229	67	24
			2	0.7	0.25	0.27	0.12	1.5	9.5	5.7	5.3	187	44	18
			3	0.7	0.18	0.26	0.11	0.8	5.9	4.1	3.4	257	46	13
			4	1.0	0.28	0.44	0.17	1.4	9.9	6.5	4.8	239	70	20
0	26	200	1	1.3	0.28	0.34	0.15	0.8	6.5	3.7	NA[1]	143	48	15
			2	1.4	0.23	0.48	0.19	1.7	9.4	7.0	5.8	219	53	28
			3	1.6	0.29	0.50	0.20	1.2	9.1	6.6	5.2	298	69	23
			4	1.3	0.26	0.43	0.15	1.8	10.5	7.0	6.3	189	52	17
48	0	0	1	0.9	0.24	0.29	0.18	1.9	8.6	5.7	6.9	214	52	22
			2	1.0	0.27	0.31	0.14	1.3	9.4	5.3	3.6	148	57	19
			3	1.0	0.25	0.30	0.15	1.4	7.7	5.9	4.3	141	52	22
			4	0.9	0.26	0.34	0.15	1.2	7.4	5.3	4.0	218	60	22
96	0	0	1	1.3	0.27	0.41	0.18	1.6	10.9	6.3	6.4	272	87	26
			2	0.9	0.22	0.36	0.17	1.5	9.4	5.9	5.0	184	74	25
			3	1.3	0.24	0.46	0.19	1.5	10.9	7.0	6.4	334	88	26
			4	1.6	0.37	0.62	0.22	1.6	13.8	8.2	7.9	547	102	27
96	0	56	1	1.3	0.33	0.39	0.16	1.1	7.8	5.1	NA	180	78	24
			2	1.3	0.28	0.39	0.15	1.2	9.4	5.9	4.3	146	64	19
			3	1.2	0.26	0.47	0.18	1.2	11.3	6.2	5.1	178	69	19
			4	1.0	0.27	0.36	0.15	1.2	10.3	6.6	5.2	223	61	21

Table IIe. Continued.

Treatment			Replication	N	P	Ca	Mg	K	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N												
- tons/ha -		kg/ha		%					μg/g					
192	0	0	1	1.4	0.27	0.40	0.16	1.5	8.6	NA	6.0	197	99	29
			2	1.2	0.30	0.43	0.15	1.1	8.4	4.7	3.6	191	93	31
			3	1.5	0.32	0.37	0.16	1.3	13.7	6.2	4.6	202	102	27
			4	1.3	0.29	0.40	0.22	1.3	10.2	5.6	4.7	196	98	29

[1] Not analyzed.

Table IIf. Elemental composition of corn leaf, 1979.

Treatment			Replication	N	P	Ca	Mg	Cd	Cu	Cr	Fe	Mn	Zn
Beam-house	Tan-yard	N											
- tons/ha -		kg/ha		%				μg/g					
0	0	0	1	3.0	0.26	0.18	0.17	0.3	5.7	10.9	207	64	30
			2	3.9	0.36	0.25	0.20	0.4	4.6	12.8	288	40	28
			3	3.5	0.38	0.16	0.17	0.9	6.1	3.8	244	41	29
			4	3.6	0.37	0.17	0.15	0.4	3.8	11.5	275	35	31
0	0	200	1	3.9	0.37	0.21	0.20	NA[2]	NA	NA	251	45	24
			2	4.0	0.39	0.19	0.19	NA	NA	NA	329	52	33
			3	4.0	0.39	0.19	0.20	NA	NA	NA	352	49	24
			4	3.8	0.40	0.16	0.18	NA	NA	NA	272	46	38
12	16	0	1	3.7	0.34	0.19	0.19	0.5	5.7	10.9	225	61	28
			2	3.8	0.37	0.23	0.20	0.5	4.2	6.4	299	61	36
			3	4.0	0.38	0.19	0.19	0.6	6.1	6.4	254	57	31
			4	3.8	0.36	0.22	0.19	0.5	4.2	10.2	305	77	37
24	32	0	1	4.0	0.36	0.19	0.18	0.7	4.8	5.1	230	83	41
			2	3.9	0.39	0.17	0.18	0.5	7.6	12.2	248	64	47
			3	3.8	0.39	0.19	0.18	0.5	6.5	3.8	287	58	37
			4	4.0	0.34	0.31	0.22	0.6	3.8	3.8	316	82	41
24	32	56	1	4.2	0.40	0.19	0.17	NA	NA	NA	285	84	42
			2	4.1	0.39	0.20	0.19	NA	NA	NA	310	79	41
			3	3.7	0.37	0.19	0.18	NA	NA	NA	238	62	38
			4	4.2	0.39	0.23	0.2	NA	NA	NA	270	100	44

Table IIf. Continued.

Treatment			Replication	N	P	Ca	Mg	Cd	Cu	Cr	Fe	Mn	Zn
Beam-house	Tan-yard	N											
- tons/ha -		kg/ha		%				μg/g					
0	0[1]	0	1	3.7	0.36	0.19	0.18	0.3	4.6	3.8	272	48	24
			2	3.9	0.40	0.18	0.17	0.4	4.2	12.8	304	50	21
			3	3.9	0.38	0.26	0.21	0.3	6.1	10.2	281	53	23
			4	4.0	0.39	0.19	0.18	0.1	3.8	11.5	327	55	23

[1] One hundred ninety-two tons/ha applied in 1978.

[2] Not analyzed.

Table IIg. Elemental composition of corn grain, 1979.

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha -		kg/ha		%				μg/g			
0	0	0	1	2.3	0.40	0.006	0.22	2.6	11.4	14	36
			2	2.6	0.54	0.006	0.22	2.6	9.1	10	42
			3	2.4	0.42	0.004	0.19	3.0	12.5	9	35
			4	2.5	0.49	0.006	0.23	9.1	9.1	12	40
0	0	200	1	2.5	0.46	0.005	0.22	NA[2]	NA	10	34
			2	2.9	0.53	0.007	0.21	NA	NA	9	34
			3	2.8	0.54	0.006	0.22	NA	NA	10	34
			4	2.6	0.56	0.006	0.21	NA	NA	9	37
12	16	0	1	2.6	0.46	0.005	0.20	4.0	12.5	13	37
			2	2.4	0.45	0.005	0.19	4.0	9.1	9	38
			3	2.4	0.41	0.007	0.25	4.6	9.1	17	50
			4	2.5	0.49	0.006	0.21	3.0	4.6	11	40
24	32	0	1	2.5	0.41	0.006	0.19	4.0	10.3	13	41
			2	2.4	0.46	0.005	0.19	3.6	4.6	12	40
			3	2.5	0.42	0.007	0.21	4.0	5.7	13	54
			4	2.5	0.47	0.008	0.25	10.1	10.3	17	50
24	32	56	1	2.6	0.49	0.008	0.26	NA	NA	19	51
			2	NA	0.54	0.006	0.21	NA	NA	13	39
			3	3.1	0.60	0.008	0.24	NA	NA	18	49
			4	2.7	0.51	0.008	0.22	NA	NA	16	50

Table IIg. Continued.

Treatment											
Beam-house	Tan-yard	N	Repli-cation	N	P	Ca	Mg	Cu	Cr	Mn	Zn
- tons/ha -		kg/ha		---------- % ----------				---------- μg/g ----------			
0	0[1]	0	1	2.7	0.46	0.004	0.24	2.6	10.3	12	41
			2	2.8	0.56	0.006	0.22	3.8	6.8	9	34
			3	2.6	0.46	0.005	0.23	2.6	6.8	11	39
			4	2.9	0.53	0.006	0.25	4.2	4.6	14	40

[1] One hundred ninety-two tons/ha waste applied in 1978.

[2] Not analyzed.

Table IIh. Elemental composition of corn stover, 1979.

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha -		kg/ha		%				μg/g			
0	0	0	1	1.1	0.17	0.43	0.16	<9	<10	47	15
			2	1.4	0.28	0.62	0.19	<9	<10	39	32
			3	1.0	0.28	0.29	0.15	<9	<10	31	19
			4	1.2	0.24	0.27	0.13	<9	<10	21	50
0	0	200	1	1.5	0.21	0.48	0.21	<9	<10	32	15
			2	1.5	0.22	0.52	0.21	<9	<10	33	17
			3	1.6	0.22	0.51	0.21	<9	<10	32	12
			4	1.6	0.22	0.77	0.23	<9	<10	34	18
12	16	0	1	1.5	0.20	0.60	0.20	<9	<10	84	20
			2	1.5	0.23	0.80	0.21	<9	<10	82	30
			3	1.7	0.22	0.59	0.25	<9	<10	69	29
			4	1.2	0.19	0.54	0.17	<9	<10	44	26
24	32	0	1	1.5	0.19	0.56	0.18	<9	<10	73	26
			2	1.0	0.17	0.35	0.24	<9	<10	38	20
			3	1.6	0.20	0.65	0.20	<9	<10	77	25
			4	1.6	0.19	0.29	0.20	<9	<10	74	22
24	32	56	1	1.5	0.22	0.50	0.18	<9	<10	78	29
			2	1.5	0.23	0.70	0.22	<9	<10	65	29
			3	1.6	0.22	0.62	0.18	<9	<10	70	22
			4	1.6	0.22	0.67	0.21	<9	<10	59	28

Table IIh. Continued.

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha -		kg/ha		%				μg/g			
0	0[1]	0	1	1.5	0.29	0.24	0.18	<9	<10	25	21
			2	1.5	0.23	0.41	0.18	<9	<10	24	14
			3	1.5	0.21	0.46	0.20	<9	<10	45	16
			4	1.6	0.25	0.65	0.22	<9	<10	49	22

[1] One hundred ninety-two tons/ha waste applied in 1978.

Table IIIa. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in June, 1978.[1]

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed Waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3-N		
-- tons/ha -		kg/ha		------- meq/100 g -----				%	-- μg/g --			mmho/cm
0	0	0	1	7.4	0.94	0.23	0.74	0.13	3	12	5.8	0.7
			2	17.5	0.98	0.35	0.82	0.18	14	19	6.2	0.8
			3	NA[3]	NA	NA	NA	NA	NA	NA	NA	NA
			4	23.8	1.03	0.51	0.90	0.20	17	16	6.5	1.3
0	26	200	1	23.0	1.04	0.16	0.79	0.11	6	36	6.5	1.1
			2	7.4	0.95	0.20	1.02	0.14	15	50	5.1	1.2
			3	30.1	0.89	0.18	0.66	0.12	18	52	6.6	2.0
			4	28.4	1.09	0.77	0.95	0.20	61	31	6.5	3.2
48	0	0	1	22.4	1.04	0.66	0.82	0.21	33	33	6.6	2.7
			2	23.9	0.96	0.66	0.77	0.23	37	29	6.4	2.4
			3	17.6	0.99	0.52	0.78	0.18	38	33	6.4	NA
			4	25.2	0.98	0.18	1.05	0.14	33	37	6.4	1.3
96	0	0	1	15.0	0.93	0.59	0.82	0.22	39	23	6.5	2.7
			2	7.2	1.00	0.18	0.92	0.14	10	44	5.1	1.0
			3	20.6	0.98	0.55	0.77	0.27	23	27	6.6	2.1
			4	38.9	1.06	1.56	0.90	0.39	66	29	6.8	4.9
96	0	56	1	7.7	0.98	0.19	0.84	0.16	49	68	5.2	1.1
			2	23.6	0.95	NA	0.92	0.22	80	52	6.7	3.3
			3	33.1	1.03	0.95	0.74	0.34	42	27	6.9	2.5
			4	24.0	1.06	0.66	1.00	0.24	39	31	6.5	2.7

Table IIIa. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3[2]-N		
- tons/ha --		kg/ha		------- meq/100 g -------				%	- μg/g ---			mmho/cm
192	0	0	1	36.8	1.11	1.65	0.88	0.44	4	68	7.4	4.8
			2	27.4	0.95	1.12	0.99	0.25	57	89	6.6	4.2
			3	7.1	0.92	0.22	0.77	0.14	3	11	5.3	0.4
			4	35.0	0.94	1.08	0.77	0.31	75	66	6.8	3.8

[1] From plots used in sweet corn study.

[2] Includes NO_2- and NO_3-N.

[3] Not analyzed.

Table IIIb. Trace element content of Willamette silt loam collected in June, 1978.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Mixed waste	Lime	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		µg/g					
0	0	0	1	0.42	41	2.2	262	0.4	18.1
			2	0.36	82	0.6	216	0.5	17.7
			3	NA[2]	NA	1.4	NA	NA	NA
			4	0.19	NA	1.1	238	0.5	30.1
0	26	200	1	0.25	20	1.5	72	0.3	12.1
			2	0.39	41	1.0	153	0.5	16.0
			3	0.18	57	0.9	60	0.2	7.3
			4	1.91	NA	0.5	238	0.5	22.3
48	0	0	1	0.67	143	0.7	262	0.5	18.9
			2	0.72	163	0.9	400	0.9	21.2
			3	0.43	82	0.7	216	0.3	14.0
			4	0.37	132	1.0	168	0.7	16.2
96	0	0	1	0.74	118	0.6	286	0.6	18.0
			2	0.50	41	1.2	NA	0.5	15.4
			3	2.20	448	0.8	238	0.5	34.1
			4	1.31	408	0.5	108	0.9	32.2
96	0	56	1	0.70	69	1.0	192	0.4	13.7
			2	0.66	163	1.1	310	0.6	38.1
			3	2.50	510	1.0	250	0.9	45.9
			4	1.48	220	1.2	274	0.8	36.2
192	0	0	1	1.21	353	0.5	310	0.7	30.2
			2	0.55	163	0.8	298	0.6	26.1
			3	0.29	NA	3.6	120	0.4	32.2
			4	0.85	224	0.5	358	0.9	24.2

[1] From plots used in sweet corn study.

[2] Not analyzed.

Table IIIc. Exchangeable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in September, 1978.

Treatment				Ammonium acetate exchangable				Total	KCl-extractable			
Mixed waste	Lime	N	Replication	Ca	Mg	Na	K	N	NH_4-N	NO_3-N	pH	EC
--tons/ha --		kg/ha		------- meq/100 g ------				%	-- µg/g --			mmho/cm
0	0	0	1	7.0	0.98	0.22	0.62	0.12	2.2	5.7	5.7	0.4
			2	10.0	0.96	0.25	0.72	0.13	3.2	7.8	6.1	0.4
			3	6.0	0.86	0.11	0.52	NA[3]	2.6	6.2	5.8	0.2
			4	8.0	0.83	0.18	0.72	0.15	2.5	9.4	5.9	0.4
0	26	200	1	29.0	0.98	0.13	0.54	0.11	2.0	8.3	7.3	0.6
			2	27.0	1.03	0.15	0.72	0.14	2.2	22.0	7.1	1.3
			3	31.0	0.76	0.10	0.50	0.12	1.9	24.0	7.4	0.8
			4	12.5	0.83	0.34	0.72	0.16	3.3	22.0	6.5	1.2
48	0	0	1	8.5	1.03	0.40	0.62	0.13	2.8	9.6	5.8	0.7
			2	12.5	1.06	0.50	0.66	0.15	3.9	17.0	5.6	1.2
			3	10.5	1.00	0.41	0.56	0.13	2.9	16.0	6.3	0.8
			4	10.5	0.91	0.34	0.77	0.16	4.2	15.00	6.3	0.9
96	0	0	1	10.5	0.90	0.70	0.62	0.15	3.5	15.0	6.9	1.9
			2	10.0	1.14	0.42	0.79	0.17	4.9	14.0	6.0	0.9
			3	11.5	0.83	0.52	0.50	0.15	3.4	12.0	6.1	0.7
			4	14.5	0.80	0.54	0.72	0.19	4.3	34.0	6.7	2.2
96	0	56	1	12.5	1.03	0.64	0.55	0.16	4.7	14.0	6.4	1.5
			2	16.5	1.06	0.57	0.62	0.17	5.1	22.0	6.7	1.7
			3	8.5	0.86	0.31	0.50	0.17	4.4	27.0	6.6	1.8
			4	13.5	0.93	0.56	0.72	0.18	4.1	17.0	6.6	1.7

Table IIIc. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3[2]-N		
--tons/ha --		kg/ha		------- meq/100 g ------				%	-- μg/g --			mmho/cm
192	0	0	1	25.7	0.60	0.83	0.62	0.21	6.8	35.0	5.8	2.6
			2	31.0	0.73	1.30	0.62	0.28	7.4	53.0	7.2	3.6
			3	22.5	0.73	1.24	0.52	0.21	8.6	41.0	6.9	7.9
			4	13.5	0.73	0.40	0.49	0.19	4.6	32.0	6.5	2.7

[1] From plots used in sweet corn study.

[2] Includes NO_2- and NO_3-N.

[3] Not analyzed.

Table IIId. Trace element content of Willamette silt loam collected in September, 1978.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Mixed waste	Lime	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		µg/g					
0	0	0	1	0.11	43	0.7	110	0.5	0.8
			2	0.15	46	0.7	122	0.3	1.0
			3	0.10	34	0.7	106	0.3	0.9
			4	0.17	57	0.6	102	0.4	1.1
0	26	200	1	0.10	NA[2]	0.6	30	0.3	0.4
			2	0.10	NA	0.7	62	0.2	0.7
			3	0.10	NA	0.6	28	0.2	0.4
			4	0.59	NA	0.6	104	0.2	1.0
48	0	0	1	0.24	50	0.6	130	0.2	0.8
			2	0.33	55	0.8	136	0.5	1.0
			3	0.23	50	0.6	96	0.2	0.7
			4	0.65	100	0.6	120	0.2	1.0
96	0	0	1	0.34	73	0.6	134	0.2	0.8
			2	0.27	51	0.9	152	0.5	1.3
			3	0.41	130	0.6	104	0.2	0.9
			4	0.54	115	0.6	120	0.2	1.0
96	0	56	1	1.01	NA	0.6	124	0.3	1.0
			2	0.68	NA	0.8	142	0.3	1.2
			3	1.08	NA	0.6	102	0.2	1.0
			4	1.03	NA	1.0	114	0.2	1.4
192	0	0	1	0.46	155	0.8	166	0.4	1.0
			2	0.55	190	1.0	124	0.5	1.8
			3	0.59	175	0.7	134	0.3	1.4
			4	0.25	83	0.6	144	0.2	1.0

[1] From plots used in the sweet corn study.

[2] Not analyzed.

Table IIIe. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in June, 1979.[1]

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3^2-N		
-- tons/ha -		kg/ha		------- meq/100 g ------				%	-- µg/g ---			mmho/cm
0	0	0	1	6.9	1.00	0.07	0.63	0.12	8.3	34.4	5.8	0.6
			2	10.2	0.96	0.13	0.76	0.14	13.9	31.5	6.6	0.6
			3	6.7	0.97	0.05	0.63	0.13	7.5	80.1	6.0	0.3
			4	9.2	0.89	0.06	0.82	0.13	6.9	34.1	6.2	2.1
0	0	200	1	13.8	1.06	0.07	0.65	0.12	22.3	83.1	6.6	1.5
			2	16.8	0.96	0.05	0.75	0.14	7.5	87.6	6.9	1.1
			3	11.2	0.98	0.04	0.71	0.12	13.2	64.5	6.5	1.4
			4	16.0	0.87	0.05	0.86	0.15	17.2	126.3	6.9	1.1
12	16	0	1	20.1	1.09	0.43	0.73	0.20	125.3	51.8	6.7	3.7
			2	16.4	0.88	0.28	0.68	0.17	11.0	65.1	6.8	1.3
			3	15.5	1.02	0.30	0.66	0.12	45.7	71.5	6.4	2.7
			4	14.0	0.96	0.37	0.76	0.18	39.2	48.4	6.5	1.8
24	32	0	1	19.8	1.09	0.77	0.68	0.23	52.2	51.9	6.8	3.8
			2	20.8	1.13	0.63	0.43	0.22	46.2	77.9	6.8	1.6
			3	19.4	1.07	0.74	0.73	0.20	71.2	118.0	6.7	3.0
			4	13.3	0.71	0.37	0.67	0.19	26.6	50.8	6.7	1.3
24	32	56	1	26.2	1.07	0.63	0.67	0.17	33.6	62.1	6.9	3.5
			2	26.7	1.07	0.75	0.73	0.26	38.4	47.3	7.0	4.0
			3	18.9	1.07	0.51	0.73	0.23	34.7	66.1	6.9	3.5
			4	22.1	1.10	0.68	0.84	0.25	45.8	56.2	6.9	3.6

Table IIIe. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3[2]-N		
-- tons/ha -		kg/ha		------- meq/100 g ------				%	-- μg/g --			mmho/cm
0	0[3]	0	1	21.5	0.94	0.15	0.66	0.17	7.5	59.4	7.4	1.2
			2	13.9	0.87	0.11	0.66	0.14	6.7	55.6	6.6	0.4
			3	17.4	0.75	0.25	0.64	0.17	9.4	69.5	7.2	1.2
			4	19.0	0.77	0.15	0.69	0.18	8.1	56.2	7.0	1.5

[1] From plots used in sweet corn study.

[2] Includes NO_2- and NO_3-N.

[3] One hundred ninety-two tons/ha waste applied in 1978.

Table IIIf. Trace element content of Willamette silt loam collected in June, 1979.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Beam-house	Tan-yard	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	μg/g	----------	----------	----------
0	0	0	1	0.27	53	0.50	156	2	0.5
			2	0.40	129	0.54	184	4	1.0
			3	0.27	48	0.54	166	2	0.7
			4	0.34	66	0.50	152	4	0.9
0	0	200	1	NA[3]	60	0.40	104	NA	0.5
			2	NA	52	0.52	106	NA	0.8
			3	NA	45	0.42	104	NA	0.6
			4	NA	75	0.54	104	NA	0.9
12	16	0	1	0.53	347	0.52	334	2	1.5
			2	0.45	196	0.52	240	2	1.1
			3	0.40	154	0.54	248	2	0.8
			4	0.53	335	0.74	248	2	1.1
24	32	0	1	0.67	900	0.66	376	2	1.3
			2	0.64	900	0.72	374	8	1.7
			3	0.78	1120	0.72	396	3	1.5
			4	0.62	420	0.54	336	2	1.2
24	32	56	1	NA	750	0.66	328	NA	1.9
			2	NA	475	0.62	290	NA	2.2
			3	NA	700	0.70	248	NA	1.8
			4	NA	980	0.80	376	NA	1.8
0	0[2]	0	1	0.57	155	0.58	182	2	1.1
			2	0.35	90	0.50	150	4	0.9
			3	0.63	141	0.46	208	4	1.1
			4	0.54	148	0.51	NA	4	1.1

[1] From plots used in sweet corn study.

[2] One hundred ninety-two tons/ha applied in 1978.

[3] Not analyzed.

Table IIIg. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in September, 1979.[1]

Treatment			Replication	Ammonium acetate Exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3^2-N		
--- tons/ha		kg/ha		-------- meq/100 g			------	%	-- µg/g ---			mmho/cm
0	0	0	1	6.9	1.02	0.09	0.51	0.10	2.8	3.2	6.0	0.2
			2	9.8	0.97	0.10	0.53	0.12	1.2	4.4	6.3	0.8
			3	6.9	0.99	0.04	0.54	0.12	2.0	7.2	6.2	0.2
			4	10.3	0.99	0.08	0.50	0.13	4.8	4.0	6.5	0.5
0	0	200	1	13.9	1.07	0.05	0.47	0.11	2.4	17.6	7.0	0.6
			2	21.1	0.98	0.06	0.67	0.12	2.4	12.8	7.6	0.6
			3	15.6	0.96	0.10	0.44	0.10	2.4	20.8	7.4	2.9
			4	18.3	0.91	0.01	0.62	0.11	2.4	22.1	7.5	0.9
12	16	0	1	12.6	0.95	0.38	0.48	0.14	2.8	26.8	6.2	2.7
			2	14.5	0.94	0.24	0.56	0.14	4.0	14.8	6.2	2.4
			3	11.4	0.94	0.29	0.48	0.13	4.0	12.4	6.2	2.0
			4	14.2	0.81	0.17	0.52	0.16	3.6	20.0	6.6	2.0
24	32	0	1	19.3	0.91	0.36	0.51	0.07	6.4	36.8	6.7	3.0
			2	21.9	0.96	0.35	0.54	0.23	4.8	41.2	6.9	3.0
			3	20.5	0.95	0.50	0.53	0.23	4.0	43.6	6.7	3.3
			4	18.3	0.81	0.40	0.46	0.19	2.8	26.0	6.6	2.9
24	32	56	1	20.5	0.85	0.31	0.54	NA[3]	NA	NA	6.7	2.8
			2	22.9	0.98	0.34	0.57	NA	NA	NA	6.9	2.9
			3	19.9	0.88	0.34	0.50	NA	NA	NA	6.8	2.9
			4	17.8	0.93	0.38	0.56	NA	NA	NA	6.4	2.8

Table IIIg. Continued.

Beam-house	Tan-yard	N	Repli-cation	Ammonium acetate exchangable Ca	Mg	Na	K	Total N	KCl-extractable NH_4-N	NO_3[2]-N	pH	EC
-- tons/ha --		kg/ha		------- meq/100 g -------				%	-- μg/g ---			mmho/cm
0	0[4]	0	1	20.1	0.91	0.21	0.53	0.16	3.6	22.8	7.3	0.9
			2	15.1	0.83	0.11	0.60	0.14	4.0	21.6	7.2	0.7
			3	18.3	0.67	0.30	0.49	0.18	4.0	24.0	7.3	1.2
			4	18.8	0.66	0.19	0.42	0.18	7.2	24.8	7.4	0.8

[1] From plots used in sweet corn studies.

[2] Includes NO_2- and NO_3-N

[3] Not analyzed.

[4] One hundred ninety-two tons/ha waste applied in 1978.

Table IIIh. Trace element content of Willamette silt loam collected in September, 1979.[1]

Treatment			Replication	Total	DTPA-extractable			
Beam-house	Tan-yard	N		Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	μg/g	----------	----------
0	0	0	1	47	0.44	106	5	0.4
			2	62	0.52	98	6	0.8
			3	38	0.52	70	3	0.6
			4	69	0.48	74	2	0.8
0	0	200	1	49	0.42	52	4	0.4
			2	50	0.52	40	5	0.7
			3	45	0.40	42	3	0.4
			4	50	0.58	38	2	0.8
12	16	0	1	142	0.53	124	5	0.8
			2	136	0.52	130	6	1.0
			3	163	0.50	90	5	0.8
			4	428	0.58	172	4	1.2
24	32	0	1	341	0.58	146	5	1.4
			2	449	0.76	140	3	1.8
			3	1020	0.70	130	5	1.9
			4	411	0.60	160	4	1.6
24	32	56	1	479	0.84	130	5	1.8
			2	1250	0.74	150	4	1.0
			3	780	0.74	118	3	2.2
			4	340	0.64	132	6	1.6
0	0[2]	0	1	190	0.52	106	2	1.3
			2	255	0.54	104	3	0.9
			3	135	0.44	98	2	1.1
			4	153	0.48	98	2	1.1

[1] From plots used in sweet corn study.

[2] One hundred ninety-two tons/ha waste applied in 1978.

Table IIIi. Organic matter and cation exchange capacity of Willamette silt loam amended with tannery waste, collected in September, 1979.

Treatment							
Mixed waste	Beam house	Tan yard	Lime	N	Replication	Organic matter	Cation exchange capacity
------ tons/ha		----------		kg/ha		%	meq/100 g
0	0	0	0	0	1	2.7	13.8
					2	3.2	14.1
					3	3.4	14.2
					4	3.2	16.5
0	0	0	26	200	1	2.6	NA[1]
					2	3.0	NA
					3	2.5	NA
					4	2.3	NA
48	12	16	0	0	1	2.7	13.7
					2	2.7	15.4
					3	3.0	14.2
					4	3.1	15.4
96	24	32	0	0	1	3.3	14.3
					2	3.4	15.0
					3	3.3	16.2
					4	3.6	15.3
96	24	32	0	56	1	3.4	NA
					2	3.2	NA
					3	4.0	NA
					4	3.5	NA
192	0	0	0	0	1	2.5	15.5
					2	2.8	15.5
					3	2.7	15.0
					4	4.0	15.9

[1] Not analyzed.

Table IIIj. Exchangable bases, extractable trace elements and extractable NH_4- and NO_3-N in Willamette silt loam collected in November, 1979, from plots used in corn study.

Treatment			Replication	Depth	Ammonium acetate exchangable				Total	DTPA extractable			KCl-extractable	
Mixed waste	Beam house	Tan yard			Ca	Mg	Na	K	Cr	Cu	Mn	Zn	NH_4-N	NO_3-N
-----tons/ha------				cm	------ meq/100 g ------				--------			μg/g	----------	
0	0	0	1	15-30	5.8	1.13	0.12	0.60	41	0.32	31	0.2	2.4	1.2
				30-45	7.5	1.41	0.26	0.76	52	0.16	12	0.0	1.6	4.4
				45-60	7.3	2.50	0.13	0.50	49	0.30	27	0.2	2.8	0.4
				60-75	6.5	2.01	0.12	0.46	48	0.10	9	0.0	1.6	2.4
				75-90	6.4	1.90	0.12	0.43	46	0.25	4	0.0	0.8	2.4
			2	15-30	8.1	1.25	0.16	0.64	56	0.42	34	0.2	1.9	1.5
				30-45	8.4	1.55	0.23	0.65	46	0.26	48	0.2	1.8	3.2
				45-60	7.5	2.88	0.12	0.71	46	0.26	27	0.2	0.0	1.6
				60-75	8.7	3.49	0.11	0.96	50	0.28	17	0.2	1.8	2.0
				75-90	9.9	3.9	0.13	0.97	50	0.30	19	0.4	1.2	2.0
			3	15-30	6.7	0.95	0.10	0.79	38	0.42	35	0.4	1.2	1.8
				30-45	6.9	1.49	0.09	0.83	41	0.26	24	0.0	1.8	3.2
				45-60	7.5	3.13	0.17	0.69	42	0.22	13	0.2	2.4	1.2
				60-75	8.4	3.35	0.11	0.63	43	0.24	14	0.2	2.4	0.8
				75-90	9.6	3.63	0.12	0.46	49	0.22	17	0.2	0.8	3.2
			4	15-30	6.8	1.08	0.12	0.52	43	0.42	23	0.4	2.0	1.6
				30-45	3.6	0.72	0.07	0.56	41	0.26	13	0.0	2.0	2.0
				45-60	5.4	1.39	0.10	0.53	44	0.20	12	0.0	1.2	0.8
				60-75	6.6	3.00	0.10	0.50	68	0.24	18	0.0	2.0	0.4
				75-90	7.2	3.10	0.12	0.50	58	0.24	16	0.2	1.2	1.6

Table IIIj. Continued.

Treatment			Replication	Depth	Ammonium acetate exchangable				Total	DTPA extractable			KCl-extractable	
Mixed waste	Beam house	Tan yard			Ca	Mg	Na	K	Cr	Cu	Mn	Zn	NH_4-N	NO_3-N
----- tons/ha ----				cm	----- meq/100 g ------				---------- μg/g ----------					
96	24	32	1	15-30	6.9	1.27	0.86	0.64	51	0.40	32	0.4	2.0	40.0
				30-45	6.7	2.28	0.42	0.73	45	0.18	15	0.0	2.8	56.8
				45-60	8.8	3.80	0.22	0.62	63	0.24	19	0.2	2.0	30.0
				60-75	9.5	3.80	0.22	0.64	50	0.20	31	0.0	2.2	10.8
				75-90	10.2	3.90	0.15	0.58	49	0.18	8	0.0	2.6	14.0
			2	15-30	11.2	1.32	0.33	0.69	88	0.50	45	0.4	1.2	64.2
				30-45	7.5	1.66	0.22	0.60	62	0.32	24	0.2	1.6	43.8
				45-60	6.1	1.83	0.19	0.64	56	0.24	21	0.2	1.6	40.8
				60-75	6.5	2.66	0.12	0.59	60	0.20	15	0.2	1.6	12.8
				75-90	7.5	3.63	0.11	0.62	56	0.24	14	0.2	1.2	5.6
			3	15-30	9.3	0.93	0.51	0.80	180	0.42	36	0.0	2.8	38.8
				30-45	8.0	1.94	0.32	0.75	60	0.20	20	0.0	1.2	32.8
				45-60	8.4	3.17	0.17	0.93	60	0.18	11	0.0	1.2	16.4
				60-75	10.6	3.77	0.15	0.79	70	0.26	19	0.2	1.6	8.4
				75-90	10.5	3.19	0.18	0.70	69	0.46	17	0.4	1.6	15.2
			4	15-30	13.5	0.90	0.40	0.72	90	0.32	33	0.6	2.0	47.6
				30-45	7.8	1.20	0.37	0.71	49	0.16	26	0.0	2.8	38.8
				45-60	7.0	2.08	0.25	0.62	45	0.18	16	0.0	0.8	49.2
				60-75	7.7	3.26	0.20	0.61	50	0.22	29	0.0	1.8	10.7
				75-90	8.8	3.47	0.18	0.52	72	0.30	19	0.2	0.0	38.0

Table IIIj. Continued.

Treatment			Replication	Depth	Ammonium acetate exchangable				Total	DTPA extractable			KCl-extractable	
Mixed waste	Beam house	Tan yard			Ca	Mg	Na	K	Cr	Cu	Mn	Zn	NH_4-N	NO_3-N
---- tons/ha ------				cm	------ meq/100 g ------				----------			μg/g	----------	
192	0	0	1	15-30	14.8	1.29	0.28	0.58	92	0.32	54	0.8	1.6	18.8
				30-45	8.4	2.99	0.27	0.61	58	0.30	36	0.2	1.2	14.0
				45-60	6.6	2.36	0.19	0.46	59	0.18	44	0.2	2.8	2.8
				60-75	6.1	2.35	0.14	0.46	55	0.20	36	0.4	2.4	4.8
				75-90	6.8	3.11	0.12	0.53	56	0.30	38	0.4	1.2	3.6
			2	15-30	19.0	0.87	0.18	0.52	92	0.42	47	0.8	1.6	11.2
				30-45	7.5	1.74	0.11	0.60	48	0.32	39	0.2	2.4	10.8
				45-60	7.9	2.20	0.24	0.68	44	0.24	39	0.2	0.8	19.2
				60-75	8.9	3.54	0.17	0.63	49	0.28	27	0.4	1.6	10.8
				75-90	9.3	4.10	0.17	0.53	48	0.34	25	0.2	2.8	9.6
			3	15-30	7.7	1.15	0.34	0.63	48	0.24	19	0.2	2.2	11.2
				30-45	7.7	2.32	0.36	0.75	47	0.22	22	0.2	2.0	4.8
				45-60	7.4	3.22	0.33	0.71	47	0.18	15	0.0	2.0	26.0
				60-75	9.9	3.75	0.18	0.72	46	0.16	8	0.0	3.2	8.8
				75-90	9.1	3.45	0.15	0.59	47	0.26	19	0.2	2.0	4.0
			4	15-30	11.6	0.83	0.17	0.59	77	0.56	32	0.6	2.0	23.2
				30-45	7.6	1.21	0.22	0.56	50	0.32	28	0.2	1.9	9.8
				45-60	8.0	2.80	0.32	0.52	59	0.34	30	0.0	2.4	22.0
				60-75	8.8	3.82	0.24	0.55	57	0.28	22	0.0	2.0	16.0
				75-90	9.3	3.89	0.19	0.46	47	0.30	18	0.2	0.8	16.0

Table IVa. Yield of bush bean grown on tannery waste amended soil in 1978.

Treatment			Replication	Yield		Moisture	
Mixed waste	Lime	N		Pod[1]	Plant[1]	Pod	Plant
-- tons/ha --		kg/ha		--- tons/ha ----		----- % -------	
0	0	0	1	7.6	13.7	89	78
			2	5.2	9.8	86	76
			3	6.3	10.9	86	76
			4	5.7	10.6	83	74
0	17.5	134	1	7.1	14.5	89	76
			2	6.2	12.5	84	72
			3	6.8	12.7	87	73
			4	4.4	9.6	86	75
32	0	0	1	10.6	18.9	87	77
			2	6.6	13.3	90	71
			3	5.5	9.7	86	77
			4	4.2	8.2	87	74
64	0	0	1	5.1	13.7	88	76
			2	9.7	17.7	87	80
			3	5.5	11.0	85	76
			4	7.9	14.6	87	76
64	0	56	1	5.1	11.0	86	73
			2	6.3	13.2	86	77
			3	7.5	13.3	87	73
			4	5.9	11.7	88	77
128	0	0	1	3.1	10.6	87	71
			2	4.8	11.1	88	79
			3	4.1	9.8	84	75
			4	2.9	7.5	86	76

[1] Wet weight.

Table IVb. Yield of bush bean grown on tannery waste amended soil in 1979.

Treatment				Yield		Moisture	
Beam-house	Tan-yard	N	Replication	Pod[1]	Plant[1]	Pod	Plant
-- tons/ha --		kg/ha		--- tons/ha ---		----- % ------	
0	0	0	1	10.8	24.3	93	84
			2	6.2	14.6	93	84
			3	4.7	11.2	93	81
			4	5.4	11.4	93	81
0	0	134	1	3.9	12.5	93	86
			2	6.2	19.8	94	85
			3	7.9	23.6	94	87
			4	6.9	20.4	94	86
8	10	0	1	7.9	23.5	93	87
			2	7.3	18.5	93	86
			3	7.1	16.9	93	85
			4	5.2	12.9	94	86
16	20	0	1	7.3	21.3	93	86
			2	9.9	28.3	94	86
			3	3.9	10.1	93	84
			4	7.7	19.5	93	86
16	20	56	1	2.2	6.9	94	84
			2	6.0	17.8	93	87
			3	3.2	9.0	93	85
			4	7.1	18.5	94	85
0	0[2]	0	1	6.2	20.8	94	85
			2	7.3	21.9	94	85
			3	6.2	18.7	94	91
			4	7.3	24.5	94	86

[1] Wet weight. [2] One hundred twenty-eight tons/ha waste applied in 1978.

Table IVc. Elemental composition of bean leaf, 1978.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				μg/g					
0	0	0	1	5.2	0.24	3.5	0.35	20.4	4.5	8.3	840	120	28
			2	5.2	0.21	3.5	0.35	17.6	4.7	7.9	507	126	24
			3	4.9	0.18	3.4	0.29	20.2	3.6	7.6	720	123	24
			4	5.0	0.21	3.5	0.30	20.9	4.3	7.7	510	127	26
0	17.5	134	1	5.1	0.21	3.6	0.34	20.3	NA[1]	7.3	540	133	23
			2	4.7	0.20	3.5	0.34	18.4	NA	7.9	690	105	23
			3	4.6	0.20	3.4	0.29	18.8	NA	6.9	395	109	22
			4	4.9	0.20	3.4	0.31	19.9	NA	7.2	526	89	20
32	0	0	1	5.0	0.25	3.8	0.34	19.1	4.2	8.2	545	117	28
			2	5.6	0.24	3.5	0.36	20.3	3.6	7.7	400	133	29
			3	4.6	0.21	3.1	0.32	22.3	3.9	7.4	514	116	27
			4	5.3	0.26	3.2	0.31	17.6	4.5	8.4	465	112	36
64	0	0	1	4.3	0.16	3.6	0.34	23.9	7.2	7.7	510	160	24
			2	5.0	0.22	3.6	0.34	22.8	3.6	7.5	501	152	27
			3	5.5	0.25	3.2	0.33	22.5	4.5	8.4	550	128	29
			4	5.2	0.24	3.2	0.31	24.4	5.2	7.4	610	128	28
64	0	56	1	5.2	0.20	3.6	0.29	22.7	NA	8.3	460	137	25
			2	5.0	0.23	3.6	0.34	21.6	NA	7.9	495	129	28
			3	5.2	0.25	3.5	0.29	23.1	NA	8.4	448	108	25
			4	5.3	0.24	3.3	0.31	18.6	NA	7.0	385	106	25

Table IVc. Continued.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				μg/g					
128	0	0	1	5.0	0.19	3.5	0.32	24.8	3.5	7.5	450	143	25
			2	5.4	0.24	3.9	0.32	24.5	5.3	8.6	610	129	30
			3	5.0	0.20	3.9	0.31	22.7	4.4	7.8	541	170	27
			4	5.7	0.25	3.1	0.29	26.4	4.5	7.4	466	134	26

[1] Not analyzed.

Table IVd. Elemental composition of bean plant, 1978.

Treatment													
Mixed waste	Lime	N	Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		%				μg/g					
0	0	0	1	2.9	0.31	0.30	0.34	20.4	14.4	7.3	532	90	37
			2	3.4	0.23	0.32	0.31	17.6	13.1	7.1	509	126	32
			3	3.1	0.25	0.31	0.30	18.8	12.1	6.4	309	111	29
			4	3.0	0.20	0.37	0.34	31.1	10.6	6.4	532	171	28
0	17.5	134	1	2.7	0.24	0.33	0.35	18.9	11.3	6.2	450	103	20
			2	3.1	0.26	0.51	0.45	15.7	14.3	6.5	328	49	24
			3	3.4	0.22	0.38	0.34	21.8	12.6	6.7	396	124	28
			4	3.0	0.26	0.34	0.33	20.5	10.7	6.2	424	68	23
32	0	0	1	2.4	0.24	0.32	0.39	21.3	9.4	4.9	385	83	27
			2	3.1	0.25	0.28	0.32	22.3	12.3	6.6	394	108	31
			3	2.7	0.25	0.31	0.34	20.8	11.5	6.7	494	104	28
			4	2.9	0.23	0.30	0.26	20.9	6.2	6.2	366	98	23
64	0	0	1	2.6	0.23	0.30	0.30	18.4	9.7	4.4	303	94	25
			2	3.1	0.23	0.33	0.30	20.7	11.5	6.1	272	171	32
			3	3.4	0.30	0.28	0.28	22.5	14.7	7.3	456	91	37
			4	3.2	0.25	0.34	0.29	19.2	11.9	6.7	362	141	34
64	0	56	1	2.9	0.22	0.34	0.29	23.1	12.3	6.4	536	123	28
			2	3.5	0.28	0.39	0.37	25.5	14.0	7.7	465	155	32
			3	2.7	0.30	0.14	0.28	22.5	10.7	6.6	330	87	19
			4	3.5	0.29	0.32	0.32	21.5	9.9	5.4	372	100	31

Table IVd. Continued.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				μg/g					
128	0	0	1	2.7	0.27	0.27	0.29	20.0	8.9	5.0	242	108	24
			2	3.3	0.25	0.33	0.34	18.9	12.6	6.6	311	85	29
			3	3.2	0.25	0.35	0.35	20.7	13.1	6.3	296	146	31
			4	3.0	0.28	0.28	0.29	21.1	13.4	6.7	362	100	29

Table IVe. Elemental composition of bean pod, 1978.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				μ g/g					
0	0	0	1	3.0	0.40	0.98	0.21	24.5	3.8	5.0	145	37	40
			2	3.1	0.38	0.79	0.21	26.5	4.4	5.5	128	32	38
			3	3.5	0.36	0.88	0.21	28.1	3.2	5.1	132	31	39
			4	3.4	0.30	0.79	0.18	22.6	3.2	5.2	125	31	36
0	17.5	134	1	3.2	0.35	0.90	0.22	23.8	NA[1]	4.7	69	33	35
			2	3.4	0.39	0.97	0.25	19.2	NA	5.0	103	21	31
			3	2.9	0.33	0.91	0.31	17.6	NA	5.8	120	31	31
			4	2.9	0.37	0.86	0.21	23.8	NA	5.6	141	25	34
32	0	0	1	3.1	0.41	0.87	0.22	23.8	6.2	4.9	238	28	39
			2	3.2	0.37	0.98	0.23	20.3	3.6	5.2	148	37	37
			3	3.1	0.39	0.88	0.21	22.0	2.8	5.4	134	34	37
			4	3.0	0.37	0.96	0.19	20.8	3.8	5.0	117	35	39
64	0	0	1	3.1	0.39	0.91	0.20	24.4	3.2	5.3	79	33	37
			2	3.4	0.35	0.68	0.20	22.6	2.4	5.2	71	45	41
			3	3.2	0.38	0.95	0.22	24.2	4.4	5.6	122	33	38
			4	3.4	0.40	0.91	0.21	22.6	3.6	5.4	126	34	39
62	0	56	1	3.2	0.39	0.69	0.21	27.5	NA	5.8		35	45
			2	3.5	0.41	0.85	0.21	23.6	NA	5.3	119	34	39
			3	3.1	0.35	0.96	0.18	21.5	NA	5.8	148	35	33
			4	2.9	0.35	0.97	0.22	23.2	NA	6.1	137	33	40

Table IVe. Continued.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				μg/g					
128	0	0	1	3.2	0.39	1.06	0.22	24.0	3.0	5.6	97	34	44
			2	3.5	0.39	1.18	0.18	28.9	3.8	5.5	72	26	44
			3	3.3	0.37	0.71	0.22	26.4	4.4	5.6	106	35	38
			4	3.3	0.39	1.07	0.21	30.0	5.0	5.8	166	38	40

[1] Not analyzed.

Table IVf. Elemental composition of bean leaf, 1979.

Treatment			Replication	N	P	Ca	Mg	Cd	Cu	Cr	Fe	Mn	Zn
Beam-house	Tan-yard	N											
- tons/ha -		kg/ha		%				μg/g					
0	0	0	1	5.02	0.15	2.10	0.34	0.14	2.8	9.4	455	45	33
			2	3.61	0.15	2.44	0.35	0.12	2.8	3.8	547	56	15
			3	4.43	0.15	2.77	0.35	0.12	2.8	3.8	626	56	19
			4	3.52	0.16	2.30	0.36	0.15	1.4	7.5	542	56	17
0	0	134	1	3.02	0.13	3.33	0.33	0.04	NA[2]	NA	661	72	35
			2	4.55	0.19	2.36	0.34	0.07	NA	NA	615	59	17
			3	4.69	0.17	2.25	0.31	0.11	NA	NA	411	58	21
			4	4.93	0.15	2.84	0.33	0.12	NA	NA	604	75	13
8	10	0	1	4.14	0.18	2.15	0.31	0.11	3.8	3.8	477	50	67
			2	4.46	0.16	3.16	0.37	0.11	1.6	0.9	653	71	18
			3	4.62	0.17	2.14	0.30	0.11	0.9	1.9	410	57	32
			4	5.25	0.16	2.73	0.33	0.12	0.2	2.8	560	63	64
16	20	0	1	5.16	0.17	3.11	0.32	0.07	3.8	4.7	560	75	23
			2	5.08	0.16	3.74	0.39	0.13	3.8	3.8	488	76	48
			3	4.98	0.16	3.08	0.34	0.13	3.8	3.3	480	73	34
			4	5.11	0.14	2.84	0.33	0.11	0.2	1.9	540	74	54
16	20	56	1	4.93	0.17	3.00	0.34	NA	NA	NA	879	NA	16
			2	4.93	0.19	3.24	0.35	NA	NA	NA	547	NA	46
			3	5.06	0.18	1.54	0.20	NA	NA	NA	425	NA	22
			4	5.34	0.17	3.75	0.36	NA	NA	NA	622	NA	18

Table IVf. Continued.

Treatment			Replication	N	P	Ca	Mg	Cd	Cu	Cr	Fe	Mn	Zn
Beam-house	Tan-yard	N											
- tons/ha -		kg/ha		%				μ g/g					
0	0[1]	0	1	4.52	0.15	2.56	0.30	0.08	2.8	9.4	430	59	21
			2	4.93	0.20	2.73	0.33	0.14	2.8	2.8	465	64	13
			3	4.55	0.16	3.50	0.34	0.12	2.8	3.3	556	75	15
			4	3.81	0.16	2.14	0.29	0.13	0.9	5.6	380	57	11

[1] One hundred twenty-eight tons/ha waste applied in 1978.

[2] Not analyzed.

Table IVg. Elemental composition of bush bean plant, 1979.

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha -		kg/ha		%				μ g/g			
0	0	0	1	3.78	0.25	3.78	0.34	<9	<10	108	13
			2	2.61	0.23	2.54	0.30	<9	<10	56	4
			3	3.28	0.21	2.74	0.35	<9	<10	55	119
			4	3.50	0.28	2.87	0.40	<9	<10	68	13
0	0	134	1	2.02	0.17	2.73	0.28	<9	<10	86	108
			2	3.11	0.22	2.66	0.25	<9	<10	51	3
			3	3.05	0.28	2.46	0.30	<9	<10	42	18
			4	3.08	0.25	2.87	0.31	<9	<10	63	52
8	10	0	1	3.28	0.25	2.61	0.31	<9	<10	71	23
			2	2.82	0.30	2.32	0.29	<9	<10	51	30
			3	2.84	0.24	2.71	0.33	<9	<10	47	24
			4	2.17	0.24	2.52	0.30	<9	<10	56	17
16	20	0	1	3.14	0.21	3.70	0.34	<9	<10	93	11
			2	2.87	0.25	2.95	0.35	<9	<10	59	9
			3	3.50	0.23	3.78	0.36	<9	<10	102	15
			4	3.05	0.30	3.89	0.38	<9	<10	75	16
16	20	56	1	2.96	0.29	3.37	0.33	<9	<10	85	10
			2	3.49	0.24	3.62	0.38	<9	<10	95	67
			3	3.28	0.25	2.66	0.29	<9	<10	59	51
			4	3.49	0.25	3.19	0.29	<9	<10	80	31

Table IVg. Continued.

Treatment											
Beam-house	Tan-yard	N	Repli-cation	N	P	Ca	Mg	Cu	Cr	Mn	Zn
- tons/ha -		kg/ha		%				μg/g			
0	0[1]	0	1	2.90	0.24	3.32	0.32	<9	<10	74	33
			2	3.34	0.27	3.05	0.36	<9	<10	64	10
			3	2.35	0.24	1.98	0.27	<9	<10	44	39
			4	3.12	0.24	3.24	0.33	<9	<10	94	59

[1] One hundred twenty-eight tons/ha waste applied in 1978.

Table IVh. Elemental composition of bean pod, 1979.

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha -		kg/ha		%				μ g/g			
0	0	0	1	2.6	0.35	0.52	0.29	3.1	3.7	31	33
			2	2.9	0.41	0.39	0.28	3.9	5.6	30	32
			3	2.9	0.37	0.52	0.27	2.9	4.3	31	34
			4	2.5	0.35	0.53	0.27	4.9	4.9	31	32
0	0	134	1	3.6	0.44	0.52	0.31	NA[2]	NA	32	32
			2	3.3	0.36	0.55	0.28	NA	NA	29	35
			3	3.3	0.41	0.52	0.29	NA	NA	37	35
			4	3.3	0.41	0.56	0.30	NA	NA	31	32
8	10	0	1	3.3	0.43	0.49	0.27	3.9	6.2	38	37
			2	3.0	0.42	0.49	0.28	4.9	4.3	38	36
			3	3.0	0.39	0.60	0.27	3.4	11.8	37	48
			4	3.2	0.39	0.54	0.28	2.9	4.9	41	43
16	20	0	1	3.3	0.40	0.55	0.26	3.9	11.2	42	37
			2	3.3	0.43	0.47	0.28	5.8	7.4	39	41
			3	3.1	0.37	0.63	0.27	4.5	4.3	41	37
			4	3.2	0.39	0.56	0.26	3.9	4.9	39	69
16	20	56	1	3.2	0.37	0.65	0.27	NA	NA	39	45
			2	3.5	0.42	0.54	0.28	NA	NA	36	38
			3	3.0	0.36	0.63	0.26	NA	NA	37	41
			4	3.4	0.42	0.55	0.28	NA	NA	35	45

Table IVh. Continued.

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha -		kg/ha		%				μg/g			
0	0[1]	0	1	3.5	0.45	0.56	0.22	4.9	2.5	32	35
			2	3.5	0.45	0.52	0.29	3.9	3.7	30	40
			3	3.2	0.39	0.48	0.27	1.9	9.9	31	44
			4	3.2	0.46	0.50	0.29	4.9	8.1	32	37

[1] One hundred twenty-eight tons/ha waste applied in 1978.

[2] Not analyzed.

Table Va. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in June, 1978.[1]

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3^2-N		
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- μg/g --			mmho/cm
0	0	0	1	25.6	1.01	0.24	0.79	0.13	54	78	NA	1.2
			2	21.7	1.13	0.25	0.82	0.15	180	240	6.0	0.7
			3	9.0	1.12	0.48	0.77	0.14	51	6	5.4	1.4
			4	6.6	0.90	0.22	0.82	0.13	5	25	6.4	0.6
0	17.5	134	1	32.2	1.02	0.86	0.82	0.31	38	61	5.7	NA
			2	32.6	1.20	1.33	1.02	0.26	210	7	6.2	NA
			3	21.0	0.85	0.22	0.69	0.14	8	35	6.2	NA
			4	26.1	0.96	0.37	0.69	0.16	17	72	6.6	NA
32	0	0	1	NA[3]	NA	NA	NA	NA	NA	NA	6.8	NA
			2	10.5	0.99	0.33	0.69	0.14	5	16	6.1	NA
			3	7.1	0.96	0.18	0.56	0.13	7	29	6.5	NA
			4	13.8	0.98	0.32	0.72	0.17	6	20	7.1	NA
64	0	0	1	9.6	1.02	0.35	0.77	0.14	11	37	6.9	1.0
			2	17.4	1.01	0.68	0.74	0.18	56	38	7.0	2.4
			3	16.2	0.90	0.61	0.77	0.18	23	49	6.7	NA
			4	21.8	0.95	0.84	0.77	0.21	13	20	6.8	1.2
64	0	56	1	24.0	0.80	1.16	0.82	0.31	72	71	6.7	2.9
			2	35.1	1.24	2.08	0.82	0.33	210	43	7.0	1.9
			3	21.3	0.85	0.63	0.74	0.33	27	40	6.8	1.4
			4	16.0	0.99	0.63	0.77	0.21	160	5	7.0	3.0

Table Va. Continued.

Treatment			Replic-	Ammonium acetate exchangable				Total	KCl-extractable			
Mixed waste	Lime	N	cation	Ca	Mg	Na	K	N	NH_4-N	NO_3^2-N	pH	EC
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- µg/g --			mmho/cm
128	0	0	1	26.0	1.14	1.67	0.71	0.22	160	6	6.8	3.3
			2	15.2	0.94	0.57	0.77	0.19	21	34	6.7	5.3
			3	10.6	0.97	1.03	0.79	0.16	8	19	6.0	1.4
			4	33.4	1.14	1.72	0.72	0.40	32	22	5.5	3.2

[1] From plots used in bush bean study.

2 NO_2^- and NO_3-N.

[3] Not analyzed.

Table Vb. Trace element content of Willamette silt loam collected in June, 1978.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Mixed waste	Lime	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	µg/g	----------	----------	----------
0	0	0	1	0.38	60	4.55	19800	0.4	30.2
			2	0.28	70	0.64	18500	0.3	17.6
			3	0.57	80	0.65	62600	0.5	13.3
			4	0.43	60	0.84	32700	0.5	16.4
0	17.5	134	1	1.19	250	0.79	90300	0.6	26.3
			2	1.21	280	0.55	182	0.5	16.8
			3	0.25	70	0.85	21700	0.4	21.6
			4	0.56	150	0.64	46400	0.3	11.9
32	0	0	1	NA[2]	NA	NA	NA	NA	NA
			2	0.48	80	0.54	38500	0.4	10.7
			3	0.47	50	0.64	26870	0.4	9.7
			4	0.28	140	2.45	66200	0.5	32.0
64	0	0	1	0.81	160	0.59	26800	0.5	14.0
			2	0.54	160	0.64	58400	0.5	14.6
			3	0.77	160	0.69	66500	0.4	40.1
			4	1.07	300	0.64	74200	0.4	28.2
64	0	56	1	1.62	800	0.59	161	0.5	24.2
			2	1.28	440	0.59	158	0.5	24.4
			3	0.61	510	0.59	162	0.4	15.3
			4	0.54	130	0.59	86400	0.4	18.5
128	0	0	1	1.32	170	0.64	185	0.5	16.2
			2	0.63	130	0.79	62200	0.5	14.4
			3	0.57	90	0.59	74500	0.4	10.3
			4	1.57	1000	0.49	161	0.6	45.9

[1] From plots used in bush bean study.

[2] Not analyzed.

Table Vc. Exchangable bases, total and extractable nitrogen, pH and electroconductivity of Willamette silt loam collected in September, 1978.[1]

Treatment				Ammonium acetate exchangable				Total	KCl-extractable			
Mixed waste	Lime	N	Replication	Ca	Mg	Na	K	N	NH_4-N	NO_3-N	pH	EC
- tons/ha --		kg/ha		------- meq/100 g -----				%	-- μg/g --			mmho/cm
0	0	0	1	6.8	0.96	0.15	0.61	0.14	2.4	5.5	5.8	0.2
			2	6.8	0.96	0.10	0.77	0.13	2.0	15.0	5.6	0.2
			3	7.7	0.90	0.13	0.85	0.11	3.0	8.6	5.9	0.3
			4	7.2	0.82	0.15	0.95	0.13	2.0	12.0	5.8	0.4
0	17.5	134	1	25.9	0.86	0.07	0.66	0.13	2.5	13.0	7.2	0.5
			2	25.9	0.93	0.08	0.56	0.13	2.0	31.0	7.4	1.1
			3	26.4	0.65	0.09	0.62	0.12	2.0	14.0	7.5	0.7
			4	22.9	0.86	0.19	0.56	0.12	2.0	18.0	7.3	1.2
32	0	0	1	9.1	0.84	0.42	0.66	0.18	10.5	9.4	6.1	0.8
			2	9.1	0.96	0.38	0.51	0.16	3.7	16.0	5.8	1.2
			3	10.1	0.93	0.38	0.56	0.14	3.8	9.5	6.0	0.9
			4	8.4	0.82	0.29	0.69	0.12	2.8	6.4	5.9	0.5
64	0	0	1	8.1	0.83	0.49	0.74	0.14	3.3	9.2	5.8	1.1
			2	10.6	0.96	0.62	0.62	0.16	9.0	19.0	5.9	1.2
			3	9.9	0.86	0.29	0.62	0.13	2.7	11.0	5.6	1.1
			4	7.8	0.83	0.36	1.21	0.13	4.5	31.0	5.6	1.5
64	0	56	1	9.9	0.85	0.50	0.69	0.16	4.6	26.0	5.7	1.4
			2	10.8	0.96	0.55	0.66	0.17	15.5	14.5	6.3	1.2
			3	10.7	0.73	0.38	0.66	0.14	5.5	12.0	6.3	3.3
			4	9.0	0.92	0.27	0.59	0.15	3.2	27.0	5.9	1.4

Table Vc. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3[2]-N		
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- μg/g --			mmho/cm
128	0	0	1	9.3	0.86	0.54	0.56	0.19	2.0	15.0	6.3	1.0
			2	10.2	0.95	0.51	0.72	0.14	2.0	26.0	6.2	0.6
			3	11.7	0.83	1.67	1.07	0.13	8.4	23.0	6.5	1.0
			4	8.5	0.93	0.49	0.66	0.15	3.1	15.0	5.6	1.0

[1] From plots used in bush bean study.

[2] Includes NO_2- and NO_3-N.

Table Vd. Trace element content of Willamette silt loam collected in September, 1978.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Mixed waste	Lime	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		µg/g					
0	0	0	1	0.14	21	0.33	210	0.4	0.6
			2	0.14	14	0.23	196	0.2	0.4
			3	0.15	19	0.27	212	0.3	0.6
			4	0.12	69	0.31	202	0.2	0.7
0	17.5	134	1	0.21	NA[2]	0.21	62	0.2	0.3
			2	0.12	NA	0.21	36	0.3	0.2
			3	0.12	NA	0.23	44	0.2	0.3
			4	0.12	NA	0.22	62	0.2	0.3
32	0	0	1	0.39	54	0.24	200	0.3	0.6
			2	0.24	130	0.33	NA	0.3	0.6
			3	0.23	24	0.37	272	0.2	0.9
			4	0.21	26	0.29	188	0.3	0.6
64	0	0	1	0.35	24	0.27	218	0.2	0.5
			2	0.41	71	0.31	292	0.3	0.9
			3	0.17	76	0.29	234	0.2	0.6
			4	0.17	26	0.29	218	0.3	0.7
64	0	56	1	0.35	NA	0.35	264	0.2	0.7
			2	0.48	NA	0.28	260	0.3	0.7
			3	0.21	NA	0.27	208	0.2	0.7
			4	0.14	NA	0.31	190	0.2	0.5
128	0	0	1	0.38	40	0.25	190	0.2	0.5
			2	0.24	36	0.27	192	0.3	0.5
			3	0.53	71	0.29	208	0.2	0.9
			4	0.35	24	0.31	218	0.2	0.5

[1] From plots used in bush bean study.

[2] Not analyzed.

Table Ve. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in June, 1979.[1]

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3^2-N		
- tons/ha --		kg/ah		-------- meq/100 g -----				%	-- μg/g --			mmho/cm
0	0	0	1	9.9	0.97	0.06	0.65	0.11	3.2	20.8	6.4	0.7
			2	9.0	1.12	0.05	0.62	0.12	4.0	9.9	6.1	0.6
			3	11.7	0.89	0.14	0.61	0.12	2.4	17.8	6.4	0.6
			4	8.3	0.85	0.04	0.61	0.13	4.4	8.5	6.2	0.5
0	0	134	1	13.5	0.85	0.03	0.63	0.12	5.4	34.7	6.7	0.7
			2	16.2	1.02	0.05	0.62	0.12	3.9	17.9	7.0	0.7
			3	10.0	0.90	0.06	0.66	0.14	9.3	24.4	7.2	0.6
			4	17.5	0.82	0.06	0.61	0.11	4.0	21.9	7.0	0.8
8	10	0	1	13.0	0.99	0.25	0.63	0.14	7.8	31.2	6.7	2.1
			2	12.7	1.07	0.23	0.67	0.14	6.2	20.6	6.7	2.3
			3	14.0	0.83	0.18	0.66	0.16	13.8	22.9	6.7	0.9
			4	13.1	0.86	0.22	0.67	0.16	6.9	25.1	6.4	1.4
16	20	0	1	18.9	0.92	0.34	0.62	0.18	8.7	25.1	6.8	3.1
			2	20.0	1.05	0.53	0.73	0.19	11.6	36.8	6.8	3.0
			3	17.7	0.81	0.29	0.63	0.16	14.4	49.9	6.8	2.4
			4	14.7	0.81	0.36	0.69	0.17	7.8	19.9	6.8	0.6
16	20	56	1	24.2	0.99	0.51	0.65	0.21	38.9	21.2	6.8	3.2
			2	17.8	1.01	0.45	0.70	0.17	13.4	36.7	6.9	2.8
			3	19.4	0.78	0.04	0.61	0.17	25.9	18.1	6.9	2.1
			4	18.6	0.87	0.41	0.67	0.19	14.3	40.1	6.8	1.8

Table Ve. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3^{2}-N		
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- μg/g --			mmho/cm
0	0[3]	0	1	19.3	0.75	0.11	0.58	0.17	3.0	16.7	7.3	1.1
			2	21.4	0.91	0.13	0.62	0.18	3.3	18.3	7.6	0.9
			3	19.1	0.86	0.44	0.62	0.17	7.4	28.7	7.1	1.0
			4	19.5	0.75	0.11	0.59	0.12	5.8	16.5	7.4	0.9

[1] From plots used in bush bean study.

[2] Includes NO_2- and NO_3-N.

[3] One hundred twenty-eight tons/ha waste applied in 1978.

Table Vf. Trace element content of Willamette silt loam collected in June, 1979.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Beam-house	Tan-yard	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	µg/g	----------	----------	----------
0	0	0	1	0.32	68	0.52	198	1.0	0.7
			2	0.32	53	0.56	182	1.8	0.6
			3	0.36	60	0.52	174	2.2	0.7
			4	0.32	48	0.60	362	1.8	0.8
0	0	134	1	NA[3]	51	0.44	110	NA	0.5
			2	NA	54	0.54	106	NA	0.5
			3	NA	65	0.56	130	NA	0.6
			4	NA	63	0.48	106	NA	0.5
8	10	0	1	0.41	179	0.56	270	1.0	1.0
			2	0.41	101	0.56	230	1.8	0.8
			3	0.33	120	0.54	220	2.2	0.8
			4	0.36	196	0.60	356	2.2	0.9
16	20	0	1	0.49	267	0.56	258	1.0	1.3
			2	0.65	421	0.70	338	1.8	1.2
			3	0.49	234	0.56	306	1.8	1.0
			4	0.40	192	0.72	354	1.6	1.0
16	20	56	1	NA	217	0.61	NA	NA	1.4
			2	NA	477	0.60	350	NA	1.2
			3	NA	208	0.72	478	NA	1.0
			4	NA	285	0.52	256	NA	0.8
0	0[2]	0	1	0.64	174	0.54	154	1.0	1.1
			2	0.61	257	0.58	158	1.8	0.9
			3	0.53	150	0.48	182	1.0	1.0
			4	0.72	178	0.52	162	2.2	1.1

[1] From plots used in bush bean study.

[2] One hundred twnety-eight tons/ha waste applied in 1978.

[3] Not analyzed.

Table Vg. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in August, 1979.[1]

Treatment				Ammonium acetate exchangable				Total	KCl extractable			
Beam-house	Tan-yard	N	Repli-cation	Ca	Mg	Na	K	N	NH_4-N	NO_3-N[2]	pH	EC
- tons/ha --		kg/ha		--------- meq/100 g ----				%	-- μg/g --			mmho/cm
0	0	0	1	9.6	1.12	0.15	0.55	0.11	2.0	12.8	6.5	1.6
			2	7.1	1.07	0.25	0.62	0.11	2.4	15.6	6.0	1.7
			3	8.9	1.01	0.12	0.58	0.12	4.0	15.6	6.5	1.4
			4	7.8	0.95	0.06	0.57	0.12	3.2	10.8	6.3	0.5
0	0	134	1	12.9	0.84	0.18	0.53	0.09	2.4	32.4	6.9	2.9
			2	15.0	1.01	0.20	0.60	0.11	0.4	21.4	7.2	2.9
			3	16.9	0.85	0.06	0.63	0.10	2.4	20.0	7.5	2.9
			4	15.6	0.87	0.10	0.54	0.08	3.2	25.2	7.2	1.4
8	10	0	1	11.6	0.86	0.92	0.55	0.13	2.4	9.2	6.6	3.2
			2	12.3	0.97	0.23	0.55	0.14	2.4	20.2	6.5	1.5
			3	12.5	0.84	0.29	0.64	0.15	3.2	28.0	6.7	2.4
			4	11.7	0.80	0.18	0.55	0.14	3.2	18.2	6.6	1.9
16	20	0	1	16.9	0.85	0.82	0.55	0.17	3.6	21.2	7.0	4.0
			2	15.7	0.89	0.30	0.62	0.17	4.0	26.4	6.6	2.9
			3	13.8	0.75	0.18	0.53	0.16	4.0	23.2	6.5	4.1
			4	15.9	0.76	0.17	0.59	0.17	4.4	31.2	7.0	2.4
16	20	56	1	16.9	0.85	0.50	0.56	NA[3]	NA	NA	6.8	5.5
			2	17.8	0.89	0.20	0.61	NA	NA	NA	6.9	3.1
			3	14.1	0.77	0.16	0.53	NA	NA	NA	6.9	2.7
			4	12.9	0.81	0.19	0.59	NA	NA	NA	6.6	3.2

Table Vg. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3[2]-N		
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- μg/g --			mmho/cm
0	0[4]	0	1	18.9	0.78	0.50	0.53	0.17	2.8	28.8	7.7	1.9
			2	21.2	0.96	0.14	0.56	0.16	3.6	20.8	7.6	1.2
			3	17.2	0.70	0.09	0.52	0.15	4.4	23.2	7.4	2.3
			4	18.8	0.68	0.11	0.47	0.17	3.2	19.6	7.5	1.0

[1] From plots used in bush bean study.

[2] Includes NO_2- and NO_3-N.

[3] Not analyzed.

[4] One hundred twenty-eight tons/ha waste applied in 1978.

Table Vh. Trace element content of Willamette silt loam collected in August, 1979.[1]

Treatment			Replication	Total	DTPA-extractable			
Beam-house	Tan-yard	N		Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	μg/g	----------	----------
0	0	0	1	100	0.38	110	2	0.7
			2	49	0.37	NA[3]	2	0.5
			3	55	0.36	102	2	0.8
			4	51	0.37	88	2	1.5
0	0	134	1	41	0.32	54	2	0.6
			2	49	0.40	62	2	0.6
			3	43	0.38	40	2	0.6
			4	80	0.34	130	2	0.7
8	10	0	1	125	0.36	106	2	0.9
			2	98	0.40	136	4	1.1
			3	155	0.40	128	3	1.3
			4	115	0.44	122	2	1.1
16	20	0	1	188	0.42	116	2	1.0
			2	200	0.48	130	2	1.2
			3	170	0.38	128	2	1.6
			4	226	0.44	128	2	1.1
16	20	56	1	230	0.44	140	2	1.2
			2	254	0.44	140	2	1.3
			3	344	0.46	114	2	1.1
			4	185	0.44	130	2	0.9
0	0[2]	0	1	296	0.40	82	2	1.4
			2	202	0.40	86	2	1.5
			3	156	0.36	94	2	1.1
			4	275	0.38	80	2	1.3

[1] From plots used in bush bean study.

[2] One hundred twenty-eight tons/ha waste applied in 1978.

[3] Not analyzed.

Table VIa. Dry weight yield of tall fescue grown on tannery waste amended soil in 1978 and 1979.[1]

Treatment			Replication	Harvest dates				
Mixed waste	Lime	N		9-1-78	10-19-78	4-25-79	6-22-79	8-22-79
-- tons/ha --		kg/ha		tons/ha				
0	0	0	1	3.72	1.07	0.39	0.73	0.12
			2	2.06	1.00	0.20	1.08	0.19
			3	4.66	0.53	0.15	0.60	0.29
			4	4.43	0.42	0.39	0.60	0.14
0	0	180	1	5.12	2.44	0.74	0.60	0.11
			2	4.34	1.44	0.94	0.69	0.12
			3	5.12	2.38	1.48	1.12	0.27
			4	4.99	2.35	1.48	1.12	0.41
0	21.5	180	1	5.35	2.47	1.43	1.29	0.11
			2	3.90	1.95	0.78	1.08	0.17
			3	5.67	1.67	1.92	0.60	0.61
			4	4.66	1.39	1.48	0.60	0.23
43	0	0	1	4.54	0.88	0.69	1.12	0.11
			2	3.58	1.35	1.03	1.42	0.22
			3	4.89	0.99	0.69	0.47	0.11
			4	4.10	0.88	0.65	0.47	0.22
86	0	0	1	5.25	1.86	1.28	1.55	0.16
			2	4.44	1.43	1.68	1.55	0.32
			3	5.23	1.79	1.32	1.12	0.41
			4	5.12	1.54	1.18	1.12	0.45
171	0	0	1	5.12	1.56	1.82	1.79	0.55
			2	4.66	1.57	2.95	1.81	1.40
			3	4.74	2.66	2.02	1.98	1.09
			4	5.12	1.54	2.31	1.98	1.26

[1] From plots established in 1978.

Table VIb. Dry weight yield of tall fescue grown on tannery waste amended soil in 1979.[1]

Treatment				Harvest dates		
Beam-house	Tan-yard	N	Repli-cation	8-22-79	9-21-79	11-9-79
-- tons/ha --		kg/ha		---------- tons/ha ----------		
0	0	0	1	2.63	1.74	4.13
			2	0.86	1.56	3.96
			3	2.42	0.86	3.41
0	0	180	1	2.72	2.96	7.40
			2	2.76	2.69	8.90
			3	2.01	1.56	2.30
10	13	0	1	1.67	2.17	2.08
			2	2.01	1.74	6.06
			3	2.47	2.98	5.68
21	25	0	1	1.44	2.54	8.53
			2	2.63	2.00	6.25
			3	2.39	1.60	11.11
57	0	0	1	1.28	2.78	12.30
			2	2.72	2.61	11.60
			3	0.21	1.36	6.60

[1] From fescue plots established in 1979.

Table VIc. Elemental composition of tall fescue harvested 9-1-78.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				µg/g					
0	0	0	1	3.3	0.35	0.23	0.22	14.9	4.6	7.8	153	149	22
			2	3.6	0.40	0.14	0.24	13.5	4.3	8.8	119	119	22
			3	3.1	0.41	0.18	0.26	11.6	4.6	6.8	240	195	22
			4	3.0	0.35	0.33	0.23	8.1	4.3	6.5	218	142	23
0	0	180	1	4.2	0.37	0.24	0.28	14.2	NA[1]	10.4	112	141	22
			2	5.1	0.41	0.14	0.30	15.4	NA	12.4	131	122	26
			3	4.7	0.37	0.23	0.29	13.1	NA	10.9	128	102	24
			4	4.6	0.40	0.48	0.30	14.9	NA	14.6	143	125	27
0	21.5	180	1	5.0	0.34	0.26	0.28	16.7	3.9	11.6	183	81	21
			2	4.4	0.42	0.14	0.28	16.3	3.9	10.4	137	75	22
			3	5.4	0.42	0.28	0.31	14.6	4.6	10.9	196	94	23
			4	5.3	0.42	0.53	0.28	16.3	4.3	10.7	169	74	22
43	0	0	1	3.4	0.43	0.33	0.23	16.1	5.4	10.1	179	91	22
			2	3.7	0.40	0.14	0.24	14.7	5.4	9.1	171	107	22
			3	3.0	0.37	0.18	0.23	13.8	6.3	6.9	143	121	21
			4	3.7	0.41	0.22	0.26	13.9	4.3	8.9	132	106	23
85	0	0	1	3.8	0.39	0.39	0.30	16.0	5.4	12.8	121	105	21
			2	4.5	0.45	0.14	0.28	17.7	5.4	14.6	110	118	26
			3	4.4	0.43	0.24	0.28	15.9	4.6	9.9	118	105	22
			4	3.5	0.38	0.39	0.27	11.1	4.7	NA	253	127	24

Table VIc. Continued.

Treatment													
Mixed waste	Lime	N	Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		%				μ g/g					
171	0	0	1	4.5	0.42	0.59	0.31	14.7	6.3	11.2	115	131	25
			2	4.7	0.41	0.34	0.27	21.0	6.3	14.1	125	130	28
			3	3.7	0.42	0.45	0.29	15.1	5.4	8.2	135	143	21
			4	3.7	0.37	0.43	0.26	9.6	4.7	7.9	123	119	21

[1] Not analyzed.

Table VId. Elemental composition of fescue harvested 10-18-78.

Treatment			Repli-										
Mixed waste	Lime	N	cation	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
- tons/ha -		kg/ha		%				μg/g					
0	0	0	1	2.1	0.24	0.43	0.26	10.3	4.6	6.6	110	214	19
			2	2.1	0.26	0.43	0.24	12.9	4.7	10.5	526	162	19
			3	2.2	0.29	0.50	0.27	13.4	4.7	13.6	493	202	18
			4	1.3	0.18	0.52	0.28	12.5	4.3	12.7	110	205	15
0	0	180	1	NA[1]	NA	0.37	0.25	14.7	NA	6.7	494	147	19
			2	NA	NA	0.15	0.27	16.0	NA	12.0	483	152	20
			3	NA	NA	0.33	0.26	14.0	NA	11.5	455	139	19
			4	NA	NA	0.32	0.30	14.8	NA	20.5	110	170	17
0	21.5	180	1	2.8	0.28	0.44	0.26	12.8	4.3	7.5	486	86	18
			2	2.7	0.28	0.48	0.28	15.5	4.7	14.4	110	105	16
			3	3.2	0.29	0.50	0.27	15.9	4.7	20.3	110	92	15
			4	3.3	0.31	0.49	0.28	16.6	4.7	19.3	110	91	16
43	0	0	1	2.3	0.26	0.47	0.25	11.2	4.7	4.4	548	130	16
			2	2.6	0.27	0.47	0.26	14.2	4.7	7.7	440	148	19
			3	2.2	0.28	0.48	0.26	11.2	4.7	10.3	428	166	18
			4	2.3	0.26	0.55	0.26	13.5	4.7	14.0	508	162	18
85	0	0	1	2.4	0.25	0.47	0.26	13.7	4.7	1.8	110	152	18
			2	2.8	0.28	0.45	0.25	14.9	4.7	8.4	411	160	22
			3	2.5	0.28	0.47	0.25	14.4	4.7	16.4	519	141	17
			4	2.7	0.29	0.47	0.26	13.1	5.4	16.8	110	176	18

Table VId. Continued.

Treatment			Replication	N	P	Ca	Mg	B	Cu	Cr	Fe	Mn	Zn
Mixed waste	Lime	N											
- tons/ha -		kg/ha		%				µg/g					
171	0	0	1	2.9	0.29	0.51	0.27	15.0	5.4	7.1	110	171	22
			2	3.2	0.31	0.50	0.28	15.4	5.4	14.0	520	171	20
			3	2.8	0.28	0.48	0.28	14.8	4.7	19.0	454	152	18
			4	2.7	0.27	0.52	0.29	NA	5.0	19.3	110	206	NA

[1] Not analyzed.

Table VIe. Elemental composition of tall fescue harvested 8-22-79.[1]

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha --		kg/ha		%				μg/g			
0	0	0	1	2.6	0.35	0.44	0.19	6.6	9.4	181	19
			2	2.2	0.25	0.44	0.19	8.1	12.6	174	15
			3	2.5	0.29	0.41	0.17	9.5	10.7	147	16
0	0	180	1	2.3	0.33	0.49	0.19	NA[2]	NA	170	20
			2	2.4	0.31	0.40	0.19	NA	NA	209	21
			3	2.5	0.34	0.34	0.18	NA	NA	140	16
10	13	0	1	2.4	0.35	0.41	0.19	7.6	9.5	188	21
			2	2.9	0.32	0.67	0.20	7.6	6.6	247	23
			3	2.8	0.35	0.53	0.20	15.2	3.9	182	23
21	25	0	1	2.2	0.31	0.63	0.21	9.5	7.5	285	27
			2	3.0	0.32	0.66	0.21	7.6	12.6	232	25
			3	3.3	0.32	0.67	0.21	13.3	6.3	248	32
57	0	0	1	3.5	0.33	0.59	0.20	7.6	12.6	284	28
			2	3.3	0.37	0.58	0.21	7.6	13.9	274	29
			3	3.4	0.29	0.83	0.20	31.3	17.6	340	44

[1] From fescue plots established in 1979.

[2] Not analyzed.

Table VIf. Elemental composition of tall fescue harvested 9-21-79.[1]

Treatment			Replication	N	P	Ca	Mg	Cu	Cr	Mn	Zn
Beam-house	Tan-yard	N									
- tons/ha --		kg/ha		%				μg/g			
0	0	0	1	2.2	0.29	0.44	0.18	5.7	4.3	189	5
			2	2.2	0.25	0.39	0.17	5.7	3.7	170	8
			3	2.0	0.25	0.44	0.17	4.7	3.7	178	7
0	0	180	1	3.0	0.38	0.49	0.20	NA[2]	NA	175	12
			2	2.4	0.29	0.49	0.21	NA	NA	219	11
			3	2.1	0.27	0.47	0.19	NA	NA	180	13
10	13	0	1	2.4	0.27	0.49	0.17	5.7	4.3	206	7
			2	2.4	0.29	0.47	0.17	4.2	4.9	203	14
			3	2.5	0.32	0.49	0.18	6.0	4.9	207	13
21	25	0	1	2.9	0.35	0.62	0.20	5.7	4.3	267	22
			2	2.3	0.33	0.63	0.19	6.0	13.4	230	11
			3	3.4	0.39	0.64	0.21	5.7	4.6	247	20
57	0	0	1	4.0	0.41	0.66	0.20	6.6	4.3	410	22
			2	2.6	0.33	0.86	0.22	6.0	4.3	440	25
			3	2.8	0.37	0.75	0.20	6.3	4.3	470	61

[1] From fescue plots established in 1979.

[2] Not analyzed.

Table VIIa. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in June, 1978.[1]

Treatment				Ammonium acetate exchangable				Total	KCl-extractable			
Mixed waste	Lime	N	Replication	Ca	Mg	Na	K	N	NH_4-N	NO_3^2-N	pH	EC
- tons/ha --		kg/ha		------- meq/100 g ------				%	-- μg/g --			mmho/cm
0	0	0	1	10.0	1.58	0.62	1.12	0.12	4.1	35	5.6	0.9
			2	12.2	1.00	0.49	0.82	0.17	18.0	77	6.0	2.1
			3	8.2	0.88	0.33	0.82	0.13	3.4	49	5.7	1.0
			4	9.1	0.98	0.34	0.82	0.15	4.0	34	5.5	1.2
0	0	180	1	8.5	1.02	0.17	0.77	0.11	3.1	28	5.8	0.6
			2	9.1	0.96	0.25	0.77	0.16	7.2	30	5.9	0.9
			3	8.9	1.04	0.31	0.72	0.15	6.9	47	5.6	1.0
			4	7.9	0.95	0.24	0.62	0.14	5.9	41	5.3	1.0
0	21.5	180	1	15.2	1.04	0.19	0.82	0.11	2.4	36	6.4	1.0
			2	26.1	1.04	0.32	1.02	0.13	5.2	52	6.7	1.9
			3	28.2	0.95	0.28	0.77	0.14	6.2	54	6.7	1.6
			4	15.2	0.94	0.14	0.82	0.14	2.6	30	6.3	1.2
43	0	0	1	21.6	1.12	0.10	0.64	0.22	95.5	76	6.6	4.0
			2	14.2	1.04	0.64	0.82	0.19	25.0	76	6.1	NA[3]
			3	9.2	0.97	0.36	0.77	0.15	11.0	56	5.7	1.6
			4	16.0	0.95	0.49	0.87	0.16	34.0	86	6.1	3.1
56	0	0	1	27.2	1.10	0.87	0.77	0.26	130.0	100	6.5	4.5
			2	14.2	1.02	0.93	0.87	0.17	93.0	89	5.7	4.3
			3	15.1	1.07	2.4	0.87	0.34	290.0	130	6.8	7.3
			4	25.9	1.05	1.4	0.77	0.26	190.0	58	6.7	7.3

Table VIIa. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3^{2}-N		
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- µg/g --			mmho/cm
171	0	0	1	39.1	1.10	2.65	0.82	0.38	360	69	7.1	8.2
			2	33.2	1.04	3.08	0.77	0.29	240	90	6.7	8.6
			3	32.2	1.02	2.30	0.82	0.44	350	100	7.0	6.8
			4	10.2	1.00	1.37	0.97	0.16	130	120	5.8	5.6

[1] From fescue plots established in 1978.

[2] Includes NO_2- and NO_3-N.

[3] Not analyzed.

Table VIIb. Trace element content of Willamette silt loam collected in June, 1978.

Treatment			Replication	Soluble	Total	DTPA-extractable			
Mixed waste	Lime	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		---------- μg/g ----------					
0	0	0	1	0.53	70	0.59	122	0.46	10.7
			2	0.56	100	0.64	30800	0.37	11.3
			3	0.58	60	0.59	30800	0.50	9.9
			4	0.54	50	0.64	34700	0.29	11.5
0	0	180	1	0.46	50	0.64	70000	0.45	11.6
			2	0.49	95	1.47	199	0.63	24.2
			3	0.67	60	NA[2]	NA	NA	16.0
			4	0.61	50	0.65	26900	0.37	11.7
0	21.5	180	1	0.52	60	0.59	82600	0.33	9.1
			2	0.41	70	<0.50	202	0.25	12.0
			3	0.37	80	0.79	22800	0.37	9.7
			4	0.43	40	0.54	19800	0.25	8.9
43	0	0	1	0.77	210	<0.50	173	0.37	15.0
			2	0.68	150	<0.50	217	0.50	16.9
			3	0.54	90	0.59	38800	0.33	10.5
			4	0.43	60	0.65	28800	0.46	11.3
86	0	0	1	0.98	390	<0.05	209	0.37	17.6
			2	0.88	150	<0.05	177	0.42	16.2
			3	1.46	350	0.67	50700	0.59	24.3
			4	1.61	310	0.67	87500	0.33	26.3
171	0	0	1	1.79	490	<0.05	165	0.71	30.0
			2	2.20	280	<0.05	187	1.23	21.4
			3	2.30	1200	0.67	114	0.67	30.3
			4	1.12	130	0.84	62600	0.38	14.1

[1] From fescue plots established in 1978.

[2] Not analyzed.

Table VIIc. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in November, 1979.[1]

Treatment				Ammonium acetate exchangable				Total	KCl-extractable			
Mixed waste	Lime	N	Replication	Ca	Mg	Na	K	N	NH_4-N	NO_3-N	pH	EC
- tons/ha --		kg/ha		------- meq/100 g ------				%	-- μg/g --			mmho/cm
0	0	0	1	7.0	1.01	0.07	0.56	0.11	4.0	2.0	6.3	0.2
			2	8.1	1.03	0.06	0.66	0.12	4.1	1.0	6.3	0.3
			3	11.2	0.91	0.08	0.57	0.12	2.8	0.8	6.5	0.4
			4	6.6	0.99	0.07	0.61	0.13	2.8	0.4	6.4	0.2
0	0	180	1	5.2	1.06	0.07	0.51	NA[2]	NA	NA	6.3	0.2
			2	5.8	0.96	0.07	0.53	NA	NA	NA	6.1	0.2
			3	8.9	1.10	0.08	0.52	NA	NA	NA	6.5	0.2
			4	10.2	0.83	0.07	0.56	NA	NA	NA	6.7	0.2
0	21.5	180	1	23.6	0.78	0.05	0.42	0.12	1.6	0.4	7.4	0.4
			2	13.6	0.96	0.07	0.56	0.12	3.6	2.8	7.0	0.3
			3	18.7	0.80	0.05	0.45	0.14	2.8	2.0	7.3	0.3
			4	14.9	0.89	0.07	0.57	0.13	2.4	0.8	7.1	0.4
43	0	0	1	9.8	1.05	0.07	0.57	0.13	1.6	1.2	6.6	0.2
			2	8.8	0.89	0.10	0.56	0.12	2.8	0.4	6.6	0.2
			3	8.1	0.86	0.07	0.53	0.12	3.2	2.0	6.6	0.2
			4	11.5	0.88	0.06	0.60	0.14	2.4	3.2	6.8	0.2
86	0	0	1	9.3	0.91	0.12	0.46	0.11	1.6	0.8	6.7	0.2
			2	14.0	0.85	0.10	0.57	0.14	3.2	1.2	6.7	0.4
			3	10.6	0.89	0.07	0.58	0.13	1.6	1.6	6.8	0.2
			4	14.9	0.89	0.13	0.59	0.14	2.8	2.4	7.1	0.4

Table VIIc. Continued.

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Mixed waste	Lime	N		Ca	Mg	Na	K	N	NH_4-N	NO_3-N		
- tons/ha --		kg/ha		-------- meq/100 g -----				%	-- μg/g --			mmho/cm
171	0	0	1	21.3	0.78	0.04	0.44	0.18	3.6	2.0	7.3	0.4
			2	23.5	0.87	0.09	0.56	0.20	4.0	1.6	7.2	0.5
			3	23.2	0.67	0.13	0.40	0.18	2.4	1.6	7.3	0.4
			4	20.8	0.74	0.15	0.49	0.18	4.0	0.8	7.3	0.4

[1] From fescue plots established in 1978.

[2] Not analyzed.

Table VIId. Trace element content of Willamette silt loam collected in November, 1979.[1]

Treatment			Repli-	Total	DTPA- extractable			
Mixed waste	Lime	N	cation	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	µg/g	----------		
0	0	0	1	44	0.44	363	0.60	2.7
			2	50	0.36	514	0.60	0.5
			3	68	0.38	630	0.28	0.9
			4	44	0.32	584	0.54	0.5
0	0	180	1	41	0.28	299	0.48	0.4
			2	34	0.46	454	0.38	0.7
			3	49	0.34	389	0.36	0.5
			4	79	0.44	674	0.48	0.7
0	21.5	180	1	80	0.34	350	0.24	0.5
			2	36	0.28	208	0.36	0.3
			3	47	0.32	247	0.30	0.4
			4	59	0.34	311	0.28	0.4
43	0	0	1	71	0.38	363	0.22	0.4
			2	46	0.38	454	0.56	1.5
			3	44	0.42	234	0.32	0.3
			4	63	0.32	389	0.40	0.5
86	0	0	1	46	0.36	337	0.50	0.9
			2	56	0.40	519	0.46	0.8
			3	58	0.36	389	0.36	1.0
			4	80	0.40	519	0.36	0.8
171	0	0	1	140	0.36	519	0.22	0.8
			2	134	0.38	571	0.42	1.3
			3	205	0.40	493	0.30	1.0
			4	162	0.40	571	0.30	1.0

[1] From fescue plots established in 1978.

Table VIIe. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in June, 1979.[1]

Treatment			Replication	Ammonium acetate exchangable				Total	KCl-extractable		pH	EC
Beam-house	Tan-yard	N		Ca	Mg	Na	K	N	NH_4-N	NO_3-N		
-- tons/ha -		kg/ha		------- meq/100 g -------				%	-- μg/g --			mmho/cm
0	0	0	1	6.2	1.05	0.03	0.53	0.11	6.9	12.6	5.5	0.4
			2	6.3	0.96	0.04	0.61	0.10	9.1	12.1	5.7	0.4
			3	6.2	1.03	0.03	0.69	0.1	6.4	13.7	5.4	0.5
0	0	180	1	14.4	0.97	0.36	0.78	0.19	278.7	10.2	5.8	3.0
			2	19.5	1.03	0.52	0.69	0.23	390.0	11.6	5.8	3.8
			3	14.7	1.08	0.58	0.68	0.11	3.5	30.1	5.6	3.7
10	13	0	1	8.0	1.01	0.12	0.73	0.13	42.7	15.0	5.2	0.8
			2	5.9	0.91	0.04	0.66	0.11	11.6	15.0	5.4	0.4
			3	6.8	1.26	0.03	0.75	0.11	3.6	50.8	5.5	0.4
21	25	0	1	12.5	0.99	0.28	0.74	0.16	214.5	9.7	5.5	2.8
			2	6.0	0.99	0.05	0.72	0.11	11.0	5.4	5.4	0.7
			3	14.2	1.04	0.40	0.76	0.19	13.9	6.4	5.5	0.3
57	0	0	1	11.0	0.97	0.31	0.70	0.15	93.3	10.8	5.5	2.6
			2	13.4	1.07	0.43	0.73	0.18	246.3	18.8	5.8	3.0
			3	24.7	1.02	0.55	0.84	0.30	41.1	4.0	6.2	4.0

[1] From fescue plots established in 1979.

Table VIIf. Trace element content of Willamette silt loam collected in June, 1979.[1]

Treatment			Replication	Water soluble	Total	DTPA-extractable			
Beam-house	Tan-yard	N		B	Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	µg/g	----------	----------	
0	0	0	1	0.25	45	0.64	79	4	0.5
			2	0.26	42	0.62	104	5	0.3
			3	0.27	43	0.54	72	5	0.3
0	0	180	1	NA[2]	206	0.76	535	NA	0.6
			2	NA	47	0.54	525	NA	0.5
			3	NA	43	0.86	280	NA	0.4
10	13	0	1	0.24	62	0.72	212	6	0.4
			2	0.24	40	0.58	104	4	0.4
			3	0.26	42	0.66	112	5	0.5
21	25	0	1	0.27	75	0.76	476	3	0.5
			2	0.24	106	0.52	86	3	0.3
			3	0.27	98	0.48	168	5	0.5
57	0	0	1	0.26	182	0.78	388	3	0.5
			2	0.35	279	0.78	494	6	0.5
			3	0.35	45	0.52	298	5	1.0

[1] From fescue plots established in 1979.

[2] Not analyzed.

Table VIIg. Exchangable bases, total and extractable nitrogen, pH, and electroconductivity of Willamette silt loam collected in November, 1979.[1]

Treatment				Ammonium acetate exchangable				Total	KCl-extractable			
Beam-house	Tan-yard	pN	Repli-cation	Ca	Mg	Na	K	N	NH_4-N	NO_3-N	pH	EC
tons/ha --		kg/ha		------- meq/100 g ------				%	-- μg/g --			mmho/cm
0	0	0	1	5.7	1.23	0.06	0.58	0.10	2.0	2.0	5.8	0.3
			2	5.4	0.91	0.05	0.56	0.17	2.0	0.8	5.9	0.2
			3	6.2	0.87	0.09	0.69	0.08	2.4	0.8	5.9	0.2
0	0	180	1	5.8	1.11	0.06	0.52	0.11	2.0	0.8	6.0	0.2
			2	5.5	0.89	0.04	0.51	0.11	2.8	1.2	5.6	0.6
			3	5.6	0.85	0.05	0.50	0.13	3.2	2.8	6.1	0.2
10	13	0	1	6.7	0.99	0.13	0.46	0.12	1.6	0.8	5.7	0.7
			2	6.8	0.84	0.11	0.49	0.13	2.4	2.0	5.7	0.8
			3	8.7	0.68	0.18	0.59	0.13	3.6	4.8	5.8	1.2
20	25	0	1	9.5	0.84	0.11	0.47	0.16	4.4	5.2	5.8	2.1
			2	8.0	0.77	0.10	0.45	0.12	6.8	2.0	5.8	1.4
			3	10.8	0.69	0.26	0.65	0.13	7.6	3.6	5.8	2.2
57	0	0	1	19.1	0.70	0.14	0.51	0.18	8.0	10.8	5.4	2.6
			2	16.1	0.65	0.16	0.44	0.20	6.0	10.8	5.4	2.8
			3	19.3	0.68	0.28	0.64	0.18	7.2	22.0	5.3	2.2

[1] From fescue plots established in 1979.

Table VIIh. Trace element content of Willamette silt loam collected in November, 1979.[1]

Treatment			Replication	Total	DTPA-extractable			
Beam-house	Tan-yard	N		Cr	Cu	Mn	Ni	Zn
- tons/ha -		kg/ha		----------	----------	µg/g	----------	
0	0	0	1	53	0.42	526	0.52	0.7
			2	43	0.44	486	0.36	0.5
			3	20	0.42	418	0.34	0.6
0	0	180	1	33	0.34	338	0.48	0.4
			2	46	0.38	472	0.44	1.9
			3	19	0.28	392	0.36	0.4
10	13	0	1	200	0.38	714	0.40	0.6
			2	84	0.40	458	0.32	1.0
			3	113	0.44	522	0.40	0.8
21	25	0	1	500	0.34	634	0.32	0.6
			2	136	0.46	634	0.42	0.8
			3	156	0.42	662	0.30	1.0
57	0	0	1	36	0.32	1470	0.34	1.3
			2	50	0.34	1416	0.38	0.9
			3	24	0.28	1402	0.29	1.3

[1] From fescue plots established in 1979.

Table VIIIa. Yield and elemental content of sweet corn grown on Willamette silt loam amended with tannery waste, in a greenhouse experiment.

Treatment					1st Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				------- µg/g ----------			
0	0	0	1	7.8	0.7	0.28	0.28	0.11	2.4	3.2	66	30
			2	5.6	0.8	0.29	0.46	0.15	2.4	3.2	84	38
			3	5.6	0.7	0.29	0.44	0.15	2.4	4.0	69	64
			4	4.8	0.7	0.17	0.36	0.16	2.7	3.6	56	27
0	0	0.24	1	3.8	NA[1]	NA	NA	NA	NA	NA	NA	NA
			2	2.9	NA	NA	NA	NA	NA	NA	NA	NA
			3	4.7	NA	NA	NA	NA	NA	NA	NA	NA
			4	3.0	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.47	1	7.8	0.7	0.13	NA	NA	NA	NA	NA	NA
			2	5.6	0.9	0.13	NA	NA	NA	NA	NA	NA
			3	5.6	0.6	0.36	NA	NA	NA	NA	NA	NA
			4	4.8	0.7	0.37	NA	NA	NA	NA	NA	NA
0	31.0	0.24	1	3.5	NA	NA	NA	NA	NA	NA	NA	NA
			2	2.6	NA	NA	NA	NA	NA	NA	NA	NA
			3	2.2	NA	NA	NA	NA	NA	NA	NA	NA
			4	3.8	NA	NA	NA	NA	NA	NA	NA	NA
18	0	0	1	3.7	0.8	0.30	0.25	0.16	2.4	5.8	156	71
			2	2.9	0.9	0.30	0.46	0.15	2.4	3.2	93	25
			3	3.7	0.8	0.31	0.44	0.15	2.4	16.4	178	34
			4	3.0	0.8	0.26	0.36	0.16	2.4	4.8	111	49

Table VIIIa. continued.

Treatment					1st Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	--------- % ---------				-------- μg/g ---------			
37	0	0	1	7.7	0.7	0.14	0.36	0.16	2.4	5.8	54	32
			2	0.7	2.6	0.19	0.53	NA	2.4	3.8	NA	38
			3	9.1	1.4	0.08	0.69	0.18	3.2	3.2	244	65
			4	7.2	0.8	0.31	0.53	0.17	2.4	2.6	54	18
75	0	0	1	8.2	0.9	0.07	0.67	0.20	2.4	2.2	106	71
			2	6.1	1.5	0.08	0.57	0.19	2.4	6.6	40	68
			3	8.9	1.1	0.05	0.82	0.24	2.4	3.2	120	76
			4	6.6	1.3	0.12	0.69	0.19	2.4	2.6	119	25

[1] Not analyzed.

Table VIIIb. Yield and elemental content of sweet corn grown on Willamette silt loam amended with tannery waste in a greenhouse experiment.

Treatment					2nd Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	--------- % ---------				-------- µg/g ---------			
0	0	0	1	2.9	0.6	0.44	0.20	0.13	8.4	6.0	65	41
			2	4.2	0.2	0.35	0.27	0.12	2.4	7.2	49	24
			3	2.9	0.4	0.39	0.23	0.12	2.4	2.0	66	64
			4	2.2	0.3	0.39	0.26	0.16	4.8	8.0	88	28
0	0	0.24	1	2.1	NA[1]	NA	NA	NA	NA	NA	NA	NA
			2	3.0	NA	NA	NA	NA	NA	NA	NA	NA
			3	2.6	NA	NA	NA	NA	NA	NA	NA	NA
			4	2.2	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.47	1	2.7	0.3	0.34	NA	NA	NA	NA	NA	NA
			2	2.1	0.2	0.35	NA	NA	NA	NA	NA	NA
			3	2.2	0.2	0.38	NA	NA	NA	NA	NA	NA
			4	2.7	0.3	0.42	NA	NA	NA	NA	NA	NA
0	31.0	0.24	1	3.8	NA	NA	NA	NA	NA	NA	NA	NA
			2	3.0	NA	NA	NA	NA	NA	NA	NA	NA
			3	2.9	NA	NA	NA	NA	NA	NA	NA	NA
			4	4.3	NA	NA	NA	NA	NA	NA	NA	NA
18	0	0	1	2.6	0.6	0.36	0.21	0.13	6.2	2.0	36	40
			2	5.2	0.2	0.18	0.23	0.13	2.4	3.2	32	61
			3	4.1	0.2	0.28	0.33	0.15	2.4	7.2	45	29
			4	3.9	0.2	0.28	0.28	0.17	3.2	3.2	36	35

Table VIIIb. continued.

Treatment					2nd Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				-------- µg/g ---------			
37	0	0	1	6.6	0.7	0.13	0.24	0.15	2.4	8.0	38	46
			2	4.6	0.2	0.10	0.30	0.14	2.4	5.6	45	29
			3	9.1	0.2	0.37	0.33	0.15	1.4	4.0	36	35
			4	6.1	0.3	0.43	0.28	0.17	2.8	7.2	32	61
75	0	0	1	10.1	0.7	0.14	0.43	0.18	2.4	0.0	43	59
			2	9.4	0.2	0.42	0.47	0.19	2.4	7.2	37	18
			3	9.9	0.2	0.28	0.43	0.19	1.4	1.2	40	58
			4	8.3	0.4	0.28	0.41	0.18	2.4	2.0	43	49

[1] Not analyzed.

Table VIIIc. Yield and elemental content of bush bean grown on Willamette silt loam amended with tannery waste, in a greenhouse experiment.

Treatment					1st Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				-------- μg/g --------			
0	0	0	1	6.4	1.9	0.18	2.03	0.26	4.2	2.2	158	42
			2	5.8	2.0	0.18	1.58	0.25	4.8	1.8	98	50
			3	6.3	1.7	0.22	2.11	0.31	4.8	8.4	172	44
			4	7.8	2.2	0.19	1.73	0.26	4.8	3.2	105	43
0	0	0.16	1	6.0	NA[1]	NA	NA	NA	NA	NA	NA	NA
			2	6.7	NA	NA	NA	NA	NA	NA	NA	NA
			3	7.2	NA	NA	NA	NA	NA	NA	NA	NA
			4	8.0	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.32	1	8.1	1.8	0.18	NA	NA	NA	NA	NA	NA
			2	7.1	1.7	0.21	NA	NA	NA	NA	NA	NA
			3	7.4	2.2	0.21	NA	NA	NA	NA	NA	NA
			4	7.4	1.9	0.18	NA	NA	NA	NA	NA	NA
0	20.5	0.16	1	6.9	NA	NA	NA	NA	NA	NA	NA	NA
			2	7.6	NA	NA	NA	NA	NA	NA	NA	NA
			3	6.9	NA	NA	NA	NA	NA	NA	NA	NA
			4	7.8	NA	NA	NA	NA	NA	NA	NA	NA
10	0	0	1	6.2	1.9	0.18	1.77	0.25	14.2	17.8	97	34
			2	6.7	1.6	0.19	1.86	0.22	3.4	3.2	94	32
			3	5.4	1.8	0.19	2.08	0.28	2.6	6.2	106	33
			4	9.0	2.2	0.17	1.32	0.20	6.6	11.2	63	24

Table VIIIc. continued.

Treatment					1st Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				-------- μg/g ---------			
23	0	0	1	7.0	2.2	0.21	2.45	0.32	5.2	9.8	106	36
			2	6.7	1.9	0.22	2.11	0.27	5.2	9.8	101	33
			3	6.8	2.3	0.19	1.97	0.30	5.6	11.2	93	31
			4	10.2	2.4	0.19	1.51	0.22	9.4	4.4	55	28
47	0	0	1	8.9	1.9	0.17	1.61	0.23	2.4	7.2	59	29
			2	9.9	2.0	·0.18	1.93	0.26	5.2	4.4	66	34
			3	9.7	1.9	0.20	1.86	0.26	4.8	3.2	65	24
			4	8.2	1.9	0.20	2.03	0.30	4.8	2.2	88	33

[1] Not analyzed.

Table VIIId. Yield and elemental content of bush bean grown on Willamette silt loam amended with tannery waste, in a greenhouse experiment.

Treatment					2nd Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				--------- µg/g --------			
0	0	0	1	7.5	1.9	0.20	1.79	0.26	5.6	4.8	116	35
			2	4.8	1.6	0.18	1.58	0.19	5.6	2.0	90	42
			3	5.5	1.3	0.21	1.65	0.22	2.4	8.0	110	32
			4	5.1	2.2	0.18	0.87	NA	4.8	2.0	105	38
0	0	0.16	1	3.6	NA[1]	NA	NA	NA	NA	NA	NA	NA
			2	5.7	NA	NA	NA	NA	NA	NA	NA	NA
			3	5.3	NA	NA	NA	NA	NA	NA	NA	NA
			4	6.2	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.32	1	4.5	2.1	0.18	NA	NA	NA	NA	NA	NA
			2	5.2	2.0	0.17	NA	NA	NA	NA	NA	NA
			3	5.7	2.0	0.18	NA	NA	NA	NA	NA	NA
			4	5.2	2.0	0.15	NA	NA	NA	NA	NA	NA
0	20.5	0.16	1	6.9	NA	NA	NA	NA	NA	NA	NA	NA
			2	6.7	NA	NA	NA	NA	NA	NA	NA	NA
			3	5.8	NA	NA	NA	NA	NA	NA	NA	NA
			4	6.4	NA	NA	NA	NA	NA	NA	NA	NA
10	0	0	1	5.2	1.4	0.18	1.52	0.23	7.2	4.0	68	102
			2	7.6	1.8	0.18	1.34	NA	5.2	2.0	64	NA
			3	6.1	1.7	0.13	1.34	0.15	4.2	4.0	56	47
			4	6.5	2.0	0.20	1.15	0.18	8.4	2.8	56	28

Table VIIId. continued.

Treatment					2nd Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				-------- µg/g --------			
23	0	0	1	7.0	1.5	0.21	1.26	0.23	5.6	8.0	45	31
			2	6.4	1.8	0.17	1.75	0.25	5.2	2.0	76	35
			3	7.1	2.0	NA	1.63	0.24	6.6	2.8	69	32
			4	7.6	1.9	0.21	1.27	0.19	4.8	2.8	46	42
47	0	0	1	7.1	2.2	0.19	1.84	0.26	4.8	2.0	67	29
			2	7.4	1.7	0.18	1.75	0.23	4.2	4.0	58	37
			3	8.1	1.8	0.20	1.54	0.23	4.8	4.0	42	47
			4	8.3	1.8	0.18	1.89	0.22	4.2	2.8	55	33

[1] Not analyzed.

Table VIIIe. Yield and elemental content of tall fescue grown in Willamette silt loam amended with tannery waste, in a greenhouse experiment.

Treatment					1st Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				--------- μg/g --------			
0	0	0	1	4.0	1.0	0.09	0.50	0.28	2.4	1.8	131	29
			2	4.0	0.9	0.07	0.49	0.21	2.4	8.0	133	45
			3	3.5	2.2	0.08	0.32	0.22	3.2	8.0	102	34
			4	2.9	1.3	0.07	0.50	0.25	2.4	5.2	115	36
0	0	0.21	1	3.7	NA[1]	NA	NA	NA	NA	NA	NA	NA
			2	2.8	NA	NA	NA	NA	NA	NA	NA	NA
			3	3.4	NA	NA	NA	NA	NA	NA	NA	NA
			4	1.8	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.42	1	2.3	NA	0.14	NA	NA	NA	NA	NA	NA
			2	4.8	0.9	0.13	NA	NA	NA	NA	NA	NA
			3	4.4	0.9	0.09	NA	NA	NA	NA	NA	NA
			4	3.9	1.7	0.18	NA	NA	NA	NA	NA	NA
0	25.2	0.21	1	4.0	NA	NA	NA	NA	NA	NA	NA	NA
			2	3.2	NA	NA	NA	NA	NA	NA	NA	NA
			3	2.2	NA	NA	NA	NA	NA	NA	NA	NA
			4	4.0	NA	NA	NA	NA	NA	NA	NA	NA
15	0	0	1	2.5	0.8	0.18	0.51	0.30	5.2	6.6	139	14
			2	2.7	0.8	0.15	0.46	0.31	2.4	6.6	128	22
			3	2.8	0.8	0.18	0.62	0.35	2.8	8.0	131	20
			4	1.9	0.9	0.25	0.52	0.28	3.2	2.9	183	18

Table VIIIe. continued.

Treatment					1st Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				-------- µg/g ---------			
31	0	0	1	3.4	1.0	0.10	0.51	0.32	5.2	7.2	87	14
			2	2.9	0.9	0.18	0.64	0.31	3.8	7.6	126	20
			3	1.9	1.0	0.25	0.58	0.36	4.1	7.2	142	26
			4	3.4	1.1	0.12	0.59	0.32	3.2	7.6	114	75
62	0	0	1	3.9	1.2	0.11	0.42	0.22	2.8	8.4	56	20
			2	3.7	1.2	0.09	0.57	0.24	2.4	2.2	79	12
			3	3.1	1.1	0.16	0.87	0.33	2.8	2.6	89	44
			4	4.7	1.3	0.09	0.56	0.34	5.2	6.2	92	19

[1] Not analyzed.

Table VIIIf. Yield and elemental content of tall fescue grown on Willamette silt loam amended with tannery waste, in a greenhouse experiment.

Treatment					2nd Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				--------- µg/g --------			
0	0	0	1	4.1	0.6	0.10	0.32	0.22	2.4	8.4	490	70
			2	2.8	0.8	0.07	0.30	0.17	2.4	9.8	620	27
			3	2.9	0.8	0.08	0.33	0.15	2.4	8.8	390	69
			4	2.9	1.0	0.07	0.38	0.19	2.4	7.6	450	56
0	0	0.21	1	3.1	NA[1]	NA	NA	NA	NA	NA	NA	NA
			2	2.9	NA	NA	NA	NA	NA	NA	NA	NA
			3	2.0	NA	NA	NA	NA	NA	NA	NA	NA
			4	1.9	NA	NA	NA	NA	NA	NA	NA	NA
0	0	0.42	1	3.9	1.5	0.11	NA	NA	NA	NA	NA	NA
			2	2.6	0.9	0.11	NA	NA	NA	NA	NA	NA
			3	3.2	0.9	0.10	NA	NA	NA	NA	NA	NA
			4	2.7	0.8	0.11	NA	NA	NA	NA	NA	NA
0	25.2	0.21	1	3.3	NA	NA	NA	NA	NA	NA	NA	NA
			2	2.9	NA	NA	NA	NA	NA	NA	NA	NA
			3	2.2	NA	NA	NA	NA	NA	NA	NA	NA
			4	2.6	NA	NA	NA	NA	NA	NA	NA	NA
15	0	0	1	2.9	0.7	0.17	0.38	0.23	3.9	8.4	440	11
			2	3.6	1.0	0.16	0.34	0.24	7.0	6.2	470	21
			3	2.9	0.8	0.18	0.40	0.23	2.4	4.8	390	55
			4	2.2	0.8	0.28	0.31	0.23	2.4	4.4	430	13

Table VIIIf. continued.

Treatment					2nd Harvest							
Waste	Lime	N	Replication	Yield	N	P	Ca	Mg	Cu	Cr	Mn	Zn
----- g/pot -----				g/pot	---------- % ----------				-------- µg/g ---------			
31	0	0	1	6.1	0.7	0.12	0.55	0.22	2.4	3.2	220	10
			2	3.3	1.3	0.14	0.41	0.23	3.4	7.2	340	66
			3	3.2	0.8	0.25	0.52	NA	3.4	8.0	NA	NA
			4	4.5	0.9	0.11	0.47	0.23	2.4	8.8	280	53
62	0	0	1	6.9	0.9	0.10	0.42	0.20	4.8	9.8	140	14
			2	4.9	1.3	0.10	0.41	0.20	2.4	7.6	174	24
			3	4.4	1.0	0.11	0.48	0.25	4.8	7.6	270	33
			4	6.5	1.4	0.08	0.60	0.21	2.4	4.4	NA	30

[1] Not analyzed.

Table VIIIg. Yield and elemental content of tall fescue grown on Willamette silt loam amended with tannery waste, in a greenhouse experiment.

Treatment					3rd Harvest	
Waste	Lime	N	Replication	Yield	N	P
------- g/pot ------				g/pot	---- % ----	
0	0	0	1	1.34	0.5	0.11
			2	1.62	0.6	0.09
			3	1.65	0.6	0.09
			4	2.24	0.7	0.10
0	0	0.21	1	2.18	NA[1]	NA
			2	1.82	NA	NA
			3	1.35	NA	NA
			4	4.50	NA	NA
0	0	0.42	1	4.55	1.0	0.15
			2	1.84	0.7	0.14
			3	2.76	0.7	0.13
			4	1.98	0.7	0.12
0	25.2	0.21	1	2.10	NA	NA
			2	2.13	NA	NA
			3	2.05	NA	NA
			4	1.69	NA	NA
15	0	0	1	2.35	0.6	0.23
			2	2.17	0.4	0.22
			3	1.96	0.5	0.21
			4	2.24	0.5	0.19
31	0	0	1	4.50	0.5	0.11
			2	2.30	0.6	0.14
			3	3.14	0.5	0.20
			4	4.40	0.6	0.15
62	0	0	1	5.76	1.7	0.13
			2	4.94	1.0	0.10
			3	3.58	1.0	0.12
			4	5.31	1.1	0.08

[1] Not analyzed.