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UTILIZATION OF BY-PRODUCTS FROM THE TEQUILA INDUSTRY. PART 6: FERTILIZATION OF POTTED GERANIUM WITH A SLAUGHTERHOUSE WASTE COMPOST

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ABSTRACT

A greenhouse pot study was conducted to evaluate the use of a slaughterhouse waste compost (SWC) as fertilizer for potted geranium plants. This SWC was mixed with agave bagasse compost (ABC) at rates of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% by volume. The effects of the SWC on the germination and initial growth of *Raphanus sativus* were also examined. Samples of SWC and ABC were used to prepare 6 different mixtures: (1), 50% sand, 25% bark and 25% peat, (2), 50% sand and 50% peat, (3), 50% sand, 25% bark and 25% SWC, (4), 50% sand and 50% SWC (5), 50% sand, 25% bark and 25% ABC and (6), 50% sand and 50% ABC. Samples of these mixtures and SWC and ABC, were analyzed for bulk density, easily available water (EAW) and water buffering capacity (WBC). Potted geranium plants grew well in mixtures of SWC and ABC with no additional fertilization. High volumes of SWC (70 to 100%) had no adverse effect on root growth, on subsequent plant growth and development, or on the flowering process. SWC had no detrimental effect on *Raphanus sativus* seeds germination ($p \leq 0.05$). Conditioning soils with SWC and ABC increased soil bulk density ($p \leq 0.05$). Easily available water and water buffering capacity results suggest that SWC and ABC can substitute peat.

Palabras clave: composta de desechos animales, desechos de rastros, geranio, fertilizante, substrato para macetas

RESUMEN

En el presente trabajo se realizó un estudio de invernadero para evaluar como fertilizante la utilidad de una composta a base de desechos de rastros (CDR) para el crecimiento de plantas de geranio. Esta composta se mezcló a su vez con otra a base sólo de bagazo de agave (CBA) en proporciones en volumen del 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% y 100%. También se evaluó el efecto de la CDR en la germinación y desarrollo inicial de *Raphanus sativus*. Por otro lado se utilizaron muestras de CDR y CBA para preparar 6 diferentes mezclas: (1), 50% de arena, 25% de corteza y 25% de turba, (2), 50% arena y 50% de turba, (3), 50% de arena, 25% de corteza y 25% de CDR, (4), 50% de arena y 50% de CDR (5), 50% de arena, 25% de corteza y 25% de CBA y (6), 50% de arena y 50% de CBA a las que se les determinó densidad, agua fácilmente asimilable y capacidad compensadora de agua. Los geranios se desarrollaron muy bien en las macetas sin la necesidad de una fertilización adicional. Proporciones altas de CDR (70 al 100%) en las macetas, no tuvieron efectos dañinos en la raíz, desarrollo y floración. No se presentaron efectos negativos al germinar semillas en CDR ($p \leq 0.05$). El acondicionamiento de suelos con CDR y CBA aumentó la densidad de los mismos ($p \geq 0.05$). Los resultados en términos de agua fácilmente disponible y capacidad compensadora de agua, sugieren que las compostas a base de desechos de rastros y de bagazo de agave pueden ser un sustituto de la turba.

INTRODUCTION

Pork is an important part of Mexican diet. Although waste by-products from the butchering of hogs are relatively small, the disposal of large intestines poses a challenge for Mexican swine slaughterhouses. Most unmarketable animal parts may be rendered without special handling. Intestinal material, however, must be cleaned to remove fecal matter before it can be rendered. Because cleaning requires special handling, the purchase of water, and leaves a polluted effluent, Mexican slaughterhouses landfill the large intestines that result from their operations.

The Mexican tequila industry also generates significant amounts of solid waste materials. To manufacture tequila, fermentable sugars are removed from the agave plant leaving a bagasse that must be disposed of. To dispose of the agave bagasse, distilleries typically burn the material as it is produced or they allow it to accumulate in piles that are eventually either intentionally or inadvertently burned. Air pollutants generated from the burning of agave bagasse are not controlled.

A beneficial alternative is needed to current disposal practices for both of these waste products. This paper considers the use of a slaughterhouse waste compost (SWC) product derived from swine large intestines and agave bagasse. When agave bagasse is composted together with swine slaughterhouse waste, the intestinal material serves as a source of labile carbon and nitrogen while the bagasse works as an effective bulking agent. Composting serves as means of stabilizing the materials and inactivating pathogens associated with the swine wastes (Íñiguez and Vaca 2001). Composts can assist in agricultural crop production by improving soil physical properties, such as by lowering bulk density and increasing water holding capacity. To a limited extent compost may also assist crops by supplying essential nutrients (McConnell *et al.* 1993; Rosen *et al*. 1993; Raviv 1998). Compost quality is generally a function of particle size, pH, soluble salts, maturity and the absence of such undesirable components as weed seeds, heavy metals and phytotoxic compounds. The purpose of this investigation was to test for a possible SWC phytotoxicity and to evaluate the potential for SWC as a growth medium for potted geraniums as an example of the potential horticultural use of the material.

MATERIALS AND METHODS

This study considered a slaughterhouse waste compost (SWC) produced by mixing swine abattoir wastes (principally large intestines) with an agave bagasse bulking agent in a 2:3 wet mass ratio and then aerobically composted in turned windrows (Iñiguez and Vaca, 2001). Agave bagasse was also composted with 5% (dry basis) urea. The resulting agave bagasse compost (ABC) was mixed with the SWC during the growth experiments.

The SWC and ABC were analyzed for significant physical and chemical properties. Germination and seedling growth tests were used to test the SWC for potential phytotoxicity and the influence of different SWC ratios on plant production was evaluated. Finally, SWC and ABC were considered as possible replacements for materials such as peat and bark, which are commonly used to formulate potting soil mixtures.

Compost hydrologic and physiochemical characteristics

Samples of the SWC and ABC were analyzed for bulk density, saturation water content, easily available water (EAW) and water buffering capacity (WBC). EAW (g cm^{-3}) is a measure of the water released by the sample when the suction of a water column increases from 0 to –50 cm. It represents that portion of soil water that can be easily absorbed by the roots. The WBC (g cm^{-3}) is the volume of water released by the samples when suction increases from a water column measurement of –50 to –100 cm.

Samples were compacted in brass cylinders 5.4 cm in diameter and 6 cm high using a mechanical compactor to produce consistent soil cores (Richards *et al*. 1965) and saturated with water overnight. Saturation water content was determined by registering the differences in mass. Sample bulk densities (g cm^{-3}) were calculated by considering the brass cylinder volumes and the sample dry masses. To measure water retention capacity, saturated samples were subjected to a metric potential of –50 cm with a 5 bar ceramic plate extractor for 24 h. Afterwards, samples were weighed and placed again on the ceramic plate extractor at a metric potential of –100 cm for 24 h. Water retention capacity measurements were determined by mass differences. Percent of moisture was determined by drying a known amount of medium at 105°C for 24 h.

Germination and seedling growth tests

To test germination, 25 cm^3 of the SWC were placed 4-5 mm deep in 10 cm petri dishes and moistened to saturation with deionized water. A control was prepared with a medium speed filter paper set in a petri dish with 3 ml of deionized water. The experiment (one-way classification analysis of variance) included ten replications of all treatments. radish (*Raphanus sativus)* seeds were placed in each petri dish in the compost or filter paper and allowed to germinate at 22 ± 1°C. Petri dishes were kept covered with their lids until radish emerged. Each dish was watered as required. Germination percentages were calculated 7 days after germination started.

For the SWC seedling growth test, radish seeds were placed in petri dishes and kept moist with filter paper.

After their emergence (within 3 days), seedlings were planted in two polystyrene seedling flats (34 x 34 cm) with 100 cells (2.5 x 2.5 x 7 cm) each, one for growth with peat moss (as control) and one for growth with SWC. Plants grew with light conditions of 12 h per day. Seedling and root lengths were measured 10 days after planting.

Plant production experiments

The SWC was sieved with a 1=cm mesh and then mixed with ABC previously grounded to pass through a 7.5-mm mesh (**Table I**) to represent 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% of the total mixture volume. Hybrid geranium HF2 red plants germinated for twelve days in trays and were then transferred to pots. A completely randomized experiment was used with four replicates in a glass greenhouse using plastic pots 15 cm in diameter and 19 cm deep filled with 1.5 L of each mixture. Plants were watered daily with demineralized water to "container capacity" while avoiding leaching. During the experiment no additional fertilization was performed. Plants were harvested 120 days after planting. Leaves, stems, roots and flowers were dried at 65°C for 48 h and weighed. Leaves and flowers were counted and stems lengths measured.

Potting mixture physical properties

Six different mixtures were prepared by volume and examined (see **Table IV)**: Mix 1 (50% sand, 25% bark, and 25% peat), Mix 2 (50% sand and 50% peat), Mix 3 (50% sand, 25% bark and 25% SWC), Mix 4 (50% sand and 50% SWC), Mix 5 (50% sand, 25% bark and 25% ABC), and Mix 6 (50% sand and 50% ABC). These mixtures were analyzed for bulk density, EAW, and WBC with the same procedures used to evaluate the composts alone.

TABLE I. CHARACTERISTICS OF SLAUGHTERHOUSE WASTE (SWC) AND AGAVE BAGASSE COMPOSTS (ABC)

	SWC	ABC
pH	7.00	7.20
Dry matter (%)	88.80	67.30
Ash (%)[a]	62.20	31.90
Conductivity (mmhos cm^{-1})	9.98	6.49
Extractable NH_4^+- N (mg kg^{-1})[a]	473.00	15.00
Extractable NO_3^-- N (mg kg^{-1})[a]	1892.00	2481.00
Total N (%)[a]	3.10	3.70
Total C (%)[a]	25.30	63.00
C/N ratio	8.10	17.00
Total P (%)[a]	1.24	0.113
Total K (%)[a]	0.29	0.564
Total S (mg kg^{-1})[a]	4797.00	1545.00
Total Ca (%)[a]	4.15	6.55
Total Mg (%)[a]	0.495	0.386
Total Na (mg kg^{-1})[a]	1846.00	995.00
Total Zn (mg kg^{-1})[a]	459.00	67.00
Total Mn (mg kg^{-1})[a]	300.00	34.00
Total Fe (mg kg^{-1})[a]	6766.00	543.00
Total Cu (mg kg^{-1})[a]	214.00	14.00
Total Mo (mg kg^{-1})[a]	1.60	0.60

[a]Dry basis

Analytical methods

Mixture electrical conductivity and pH values were measured in a saturated pasted extract and in a saturated paste using a pH meter and a conductivity meter, respectively. Ash was measured after ignition at 550 °C for 2 h in a muffle furnace. Total nitrogen and total carbon were determined by analysis in a Carlo Erba ® NA 1500 Carbon-Nitrogen elemental analyzer. Analysis of extractable nitrate-N, and ammonium-N were based on an extraction with a solution of 2% acetic acid and determined according to the diffusion-conductivity method as described by Carlson *et al*. (1990). Total P, S, K, Ca, Mg, Na, Zn, Mn, Fe, Cu and Mo were measured using a nitric acid/hydrogen peroxide microwave digestion analysis by atomic absorption spectroscopy or inductively coupled plasma atomic emission spectrometry. All analytical methods were obtained from ALSOPM (2001) and results were subjected to one-way ANOVA analysis, followed by the LSD test at $p < 0.05$ (Montgomery 1991).

RESULTS AND DISCUSSION

Compost hydrologic and physiochemical characteristics

SWC and ABC pH values were 7.0 and 7.2, respectively (**Table I**), which are within the preferred range for most agricultural crops (Rynk 1992). Fitzpatrick *et al*. (1988) reported that values of commercially produced composts typically range from 6.7 to 7.7. C/N ratios for the SWC and ABC composts were 8.1 and 17.0, respectively. Composts with C/N ratios less than 20 are often considered best for plant production (Davidson *et al*. 1994). Composts with C/N ratios higher than 30 may result in nutrient immobilization (Zucconi *et al*. 1981). The SWC had greater fertility values than the ABC in terms of NH_4^+-N, P, S, Mg, Zn, Mn, Fe, Cu and Mo ($p > 0.05$) and the addition of SWC to soil would raise its overall nutrient content, particularly in regard to P. The relatively elevated nitrate-N and total N concentration in the ABC is possibly due to the fertilizer added during its composting and does not, therefore, represent a reclaimed nutrient. The ABC had a lower ash content than SWC ($p > 0.05$), however SWC and ABC had conductivity values of 9.98 and 6.49 mmhos cm^{-1}, respectively, values statistically different ($p > 0.05$).

Germination test and seedling growth

Table II shows the effect of SWC on germination and on the stem and root length development of *Rhaphanus sativus* 10 days after planting. There was no statistical difference ($p \leq 0.05$) between the number of seeds germinated in deionized water (control) and the number germinated in SWC. Stem lengths and stem/root ratios of *Rhaphanus sativus* were 11.7 and 12.3% higher for seedlings grown on peat moss (control) than for seedlings grown on SWC, suggesting the possibility of limited phytotoxicity. However, root lengths were similar for seedlings grown on either peat moss or SWC.

Plant production

The plant production experiments were structured to examine SWC phytotoxicity compared to ABC. Phytotoxicity was believed to depend on the amount of SWC employed. Experimental results suggest, however, that the rich nutrient environment provided by the SWC compensates any potential phytotoxic compounds given by the ABC.

Plant tissue production (**Table III**) increased markedly when SWC ≥ 40% and were depressed when ABC ≥ 40%. Flower and leaves production was greatest when SWC ≥ 70%. By contrast, flower production was effectively curtailed when ABC ≥ 40% and overall tissue production was severely depressed when ABC ≥ 80%. Shoot dry weights (stems, leaves and flowers) were statistically significantly greater for SWC mixes than for either ABC alone or 10% SWC ($p > 0.05$). The amount of leaves was approximately half (an average of 9.2 with 100% ABC and 10.2 with 90% ABC) than that obtained when S in comparison to the other ABC-SWC containing pots.

TABLE II. EFFECT OF SWC ON GERMINATION AND ON THE STEM AND ROOT LENGTH OF *RAPHANUS SATIVUS* 10 DAYS AFTER PLANTING

	Treatment	
	Control	SWC
Germination (%)	95[a]	87[a]
Component[1]		
Stem length (cm)	3.38[a]	2.75[b]
Root length (cm)	5.73[a]	5.53[a]
Stem/root length ratio	0.65[a]	0.57[b]

[1] Each value represents the mean value of ten replicates. Each replicate represents the mean value of 10 seedlings

[a, b] Values followed by the same letter in a given row do not differ at $p \leq 0.05$

Media with high SWC volumes (70 to 100%) had no apparent adverse effect on root growth, subsequent plant growth and development, as well as on the flowering process. Root dry weights ranged from 0.697 g to 1.016 per plant as the SWC percentage rose from 30 to 100% of the growth media. The shoot/root ratio was not affected by the SWC increase in the growth media; it was consistently between 6.01 and 8.30 in the 10 to 100% SWC containing crops. Plant stem lengths were between 18.5 and 24.12 cm for the 40 to 100% SWC added plants. The highest yield of leaves was for the media containing 70 and 100% SWC. Pots with 70, 90 and 100% SWC had an average of 56.2, 41.5 and 40.2 flowers per plant, which correspond to 675, 745, and 688 g of flowers dry weight.

SWC appeared to be a superior potting mixture compared to ABC. ABC is deficient in many nutrients that

TABLE III. EFFECT OF THE SWC ADDITION ON THE SHOOT DRY WT, ROOT DRY WT, SHOOT:ROOT RATIO, STEM LENGTH, NUMBER OF LEAVES, NUMBER OF FLOWER AND FLOWERS DRY WEIGHT PER PLANT

SWC:ABC (%)	Shoot[1] Dry wt (g)	Root dry wt (g)	Shoot[2]:root ratio	Stem length (cm)	No. of leaves per plant	No. of flowers per plant	Flowers dry wt (g)
0:100	0.319[a]	0.281[a]	3.65[a]	0.50[a]	9.2[a]	0[a]	0[a]
10:90	1.164[a]	0.190[a]	6.01[b]	4.12[ab]	10.2[a]	0[a]	0[a]
20:80	3.347[b]	0.503[ab]	6.59[bc]	11.12[bc]	18.0[b]	0[a]	0[a]
30:70	4.443[bc]	0.697[bc]	6.40[bc]	13.62[cd]	20.0[bcd]	0[a]	0[a]
40:60	6.114[cde]	1.016[c]	6.13[b]	18.50[cde]	20.7[bcde]	0[a]	0[a]
50:50	5.100[bcd]	0.844[bc]	6.17[b]	18.62[de]	21.0[bcde]	6.7[ab]	0.095[a]
60:40	5.523[cd]	0.862[bc]	6.86[bc]	19.75[de]	18.2[bc]	0[a]	0[a]
70:30	6.136[cde]	0.945[c]	6.98[bc]	21.90[e]	28.2[f]	56.2[d]	0.675[b]
80:20	6.171[cde]	0.967[c]	6.57[bc]	20.50[de]	22.5[cde]	28.5[bc]	0.413[b]
90:10	7.437[e]	0.980[c]	8.30[c]	24.12[e]	22.7[de]	41.5[cd]	0.745[b]
100:0	6.860[de]	0.971[c]	7.35[bc]	19.90[de]	24.5[ef]	40.2[cd]	0.688[b]
LSD	1.859	0.384	1.560	7.436	4.253	24.629	0.418

[1] Stems with leaves and flowers

[2] Stems and leaves

[a, b, c, d, e, f] Values followed by the same letter in a given column do not differ at $p \leq 0.05$ by LSD test

TABLE IV. PHYSICAL PROPERTIES OF LABORATORY PREPARED MIXTURES

Measurement	Mixtures[1] 1[2]	2[3]	3[4]	4[5]	5[6]	6[7]	SWC[8]	ABC[9]
Bulk density (g/cm^3)	0.93^{ab}	0.95^{bc}	0.97^{cd}	0.98^{d}	0.92^{a}	0.91^{a}	0.51^{e}	0.35^{f}
Easily available water (EAW) (g water/g sample)	0.20^{a}	0.32^{b}	0.25^{c}	0.33^{b}	0.20^{a}	0.33^{b}	0.93^{d}	1.34^{e}
Water buffering capacity (WBC) (g water/g sample)	0.19^{ab}	0.26^{cd}	0.23^{bc}	0.31^{d}	0.19^{a}	0.28^{d}	0.90^{e}	1.26^{f}

[1]Percentages by volume
[2]50% sand, 25% bark and 25% peat. Standard University of California mix used as reference
[3]50% sand and 50% peat. Standard University of California mix used as reference
[4]50% sand, 25% bark and 25% SWC
[5]50% sand and 50% SWC
[6]50% sand, 25% bark and 25% ABC
[7]50% sand and 50% ABC
[8]Slaughterhouse waste compost
[9]Agave bagasse compost
Values followed by the same letter in the same row do not differ at $p \leq 0.05$ by LSD test

are contained in SWC, including Zn (34 vs. 300 mg kg^{-1}), Cu (14 vs. 214 mg kg^{-1}), Mo (0.6 vs. 1.6 mg kg^{-1}), and S (1545 vs. 4797 mg kg^{-1}), and most particularly P (0.113% vs. 1.24%). Several factors may therefore be contributing to the differences observed in the germination experiments. It is likely that the available phosphorus in the SWC was high relative to the ABC and that much of the difference in performance between the two materials may be explained by the difference in availability of this important macronutrient.

Potting mixture physical properties

Both SWC and ABC (**Table IV**) showed similar physical properties to peat when mixed with sand and bark in the potting soil mixtures. SWC contains significant ash (0.51 g/cm^3) and is heavier than ABC (0.35 g cm^{-3}). Bulk densities of SWC mixtures were therefore slightly greater than those with ABC or peat. The EAW and WBC of ABC (1.34 g/g and 1.26 g/g, respectively) were significantly greater than those of SWC (0.93 g/g and 0.90 g/g), but this differences were not apparent in the mixtures. Mixtures without bark did not show differences in either EAW or WBC. With bark, SWC mixture EAW values were an average of 25% greater than the ABC or peat mixtures. WBC values were 21% greater, although the difference in WBC between the peat and SWC mixtures with bark were not statistically significant.

CONCLUSIONS

According to these results, it seems that geranium plants could be grown satisfactorily with no florescence problems in SWC but that ABC alone would not be a good growth medium. When SWC is mixed with ABC, 70-100% SWC is required to produce acceptable plants. In terms of physical properties, both ABC and SWC could substitute for peat in potting soil mixtures. However, SWC provides a more fertile growth environment than ABC.

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