UTILIZING FOOD PROCESSING BY-PRODUCTS AS A SOIL AMENDMENT: SOIL NUTRIENT AVAILABILITY

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ABSTRACT

We studied the impact of food processing by-products which contain high moisture content, low pH, high total dissolved salts, and trace elements. The primary goal of this project was to develop best management practices for sustainable reuse of food processing by-products as a soil amendment on California farmlands. Quantifying soil nutrient availability from these by-products is critical to growers to carefully establish fertilizer replacement value to improve their crop nutrient use efficiency on their farms. We established a greenhouse study to evaluate a potential loading rate for land-application of food processing by-products. The current application rate (1X) of these by-products to farm soils prior to planting forage crops is at 1:8 v/v or 9.8 tons per acre (dry weight). The objective of this study was to assess soil nutrient mineralization after various application rates of peach by-products on two soil types (sandy loam and silt loam). These peach by-products were in semi-solid or slurry forms and contained as high as 90% moisture content. Each by-products were mixed with each soil type at the rate equal to none (control), 1:8, 3:8, and 5:8 v/v or 9.8 (1X), 29.4 (3X), and 49 (5X) tons per acre (dry weight), respectively. Macro- and micro nutrient, and trace element contributions from soil-byproduct mixtures were recorded at 0, 7, and 30 days after their applications. The application of peach by-products significantly increased selected macro- and micronutrients, and trace element on both soils. Additional soil nutrients after mixing soil and peach by-product applications will benefit forage crops often planted on these sites.

INTRODUCTION

Food processing facilities, especially those using raw fruit and vegetable-base materials, generate various types of by-products or non-hazardous wastes. The use of land-applied non-hazardous wastes as an agricultural soil amendment is projected to rise because of public concerns regarding environmental impact and economic constraint of their disposal in landfill or incineration, as well as because of presumed inherent agricultural benefits (O'Connor et al., 2005).

By-product constituents are dependent on the source of raw material utilized and the substances associated with processing. The application of food processing by-products (by-products) to agricultural farmlands, while certainly not new, has become increasingly widespread. Well-regulated practices are important not only for properly recycling nutrients back into the soil, but also for managing elements of concern (e.g. sodium, chloride, and trace elements) that would otherwise be concentrated elsewhere. In addition, there are other potential management options for these by-products, depending on their physical and chemical characteristics, available local infrastructure, market demand, and other economic considerations. The objectives of this study were to quantify plant nutrient release (macro- and micronutrients and trace elements) from the decomposition of soil-byproduct mixtures at three application rates at 0, 7, and 30 days after land application, and to establish potential maximum loading rate of peach by-products application on two soil types in California

METHODS

We conducted bench scale experiments under controlled conditions at the CSU Fresno Greenhouse facility. The range of air temperatures was observed between 74.1 and 93.3 °F during this study. We collected two soil types (sandy loam and silt loam) from sites not yet having received by-products in Stanislaus County (but are potential future application sites). Each soil type received three rates of by-products [9.8, 29.4, and 49 tons per acre (dry weight)] with a total of four replications under randomized complete block design. We prepared a total of 96 six-inch pots. Then, these soil and by-product mixtures were incubated for periods of 1, 7, and 30 days prior to an analysis where the whole pot was collected and submitted to an analytical laboratory certified by the Environmental Laboratory Accreditation Program (ELAP).

We compared three application rates of peach by-products to a control (no by-product application). The current loading rate under Stanislaus County Food Processing By-product Land-application Program is approximately one truckload or 9.8 tons per acre or 1X thereafter. We also included three truckloads (3X) or 29.4 tons per acre, and five truckloads (5X) or 49 tons per acre. Flesh and liquid of the peach by-products were homogenized for an even application rate. In addition, the ratio of the fruit pit weight to the slurry weight was also considered at each application. Each soil type was mixed and weighed at ~500 gm dry soil per pot. This weight was estimated based on an application rate of by-products per square inch at six inches depth with the soil bulk density at 1.4 Mg m^{-3}.

RESULTS AND DISCUSSION

We observed saturated soil conditions from 5X treatments on both soils during the first 24-hour period, however, these conditions diminished after 3 days as evaporation occurred. *The amount of water* contributed by an application of peach by-products at 1X, 3X, and 5X rates were equivalent to 0.63, 1.90, and 3.15 inches of irrigation water, respectively.

For *nitrogen application* in the case of existing dairies, the CVRWQCB has recognized and accepted an efficiency factor of 1.65 or 61% for the Whole Farm Nitrogen Balance in its General Order. Following this example, the amount of nutrients applied from peach by-products can be up to 1.65 times the amount harvested. When alfalfa is planted on sites receiving peach by-products, harvest alfalfa at 9 tons/acre can remove up to 600 lbs N/acre in Stanislaus County (Pasakdee and Dellavalle 2008). Applications of peach by-products at various rates will significantly substitute for the use of N fertilizer on these sites. Based on the 1.65 factor, according to the Dairy Order issued by the CVRWQCB, up to 990 lbs N/acre (1.65 multiplied by 600) of peach by-products can be applied to site planted with alfalfa. Our study showed the 1X (238 lbs N/A) and 3X (714 lbs N/A) loading rates of by-products containing 1.22% total N (dry weight) can be applied on these sites and water quality will be protected under accepted best management farming practices.

Soil *nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N)* concentrations from these sites significantly changed after by-product application (Tables 1 and 2). Applications of by-products at all rates on both soils encouraged soil N immobilization and denitrification processes (diminishing levels of soil NO3-N) and soil ammonification (rising levels of soil NH4-N) processes at 7 and 30 days after by-product application. The greatest immobilized rate occurred from 5X followed by 3X and 1X loading rates, respectively, and with a greater extent from sandy loam soil. The soil NO_3-N concentrations of sandy loam soil were significantly higher than silt loam soil. This may be because sandy loam soil was collected from sites containing greater soil microbial activities from decomposing grass stubbles, whereas silt loam soil was collected from a fallow field. Soil NH_4-N concentrations were slightly increased with applications of by-products at 1X, 3X, and 5X, respectively for sandy loam soil, whereas no significant change was observed for silt loam soil. The ranges of total soil N concentrations were from 4.2 to 4.4 g/kg and from 1.4 to 2.0 g/kg for sandy loam soil and silt loam soil, respectively. We observed immobilization of nitrogen for up to 30 days following the application of by-products at all rates. The soil NO_3-N is a plant-available form of nitrogen while soil NH_4-N will ultimately be transformed to soil NO_3-N by soil microbial activity. This allows time for pre-irrigation and possibly the first crop irrigation for mineralization of soil organic nitrogen to produce soil NO_3-N. A longer incubation period is needed to determine the release rate of plant- available nitrogen.

Soil *phosphorous (P)* levels in both soils were reported as sodium bicarbonate extractable orthophosphate (PO_4-P) (Tables 1 and 2). Overall, applications of by-products at 3X and 5X significantly increased soil P concentrations in both soils with no significant difference between control soil and 1X loading rate of by-products. When alfalfa is planted on sites receiving 1X loading rate of by-products, the crop removal rate of P is slightly greater than that input from by-products (Pasakdee and Dellavalle 2008). For sandy loam soil, growers may need additional P fertilizer to grow alfalfa with by-products applications at 1X, but an application rate of peach by-products greater than 3X will provide adequate P to fulfill crop P removal rate by alfalfa and substitute the need for additional P fertilizer. For silt loam, the control soil contained adequate levels of P to grow alfalfa. By-product application to this soil will help to maintain optimum level of soil P reservoir.

Overall, applications of by-products at all loading rates significantly increased soil *potassium (K)* concentrations in both soils, more for sandy loam soil than silt loam soil (Tables 1 and 2). Application of K fertilizer is often recommended for alfalfa growers in California (Hays 1998) and especially when soil K concentration is below 80 mg/Kg. Harvesting 9 tons/acre of alfalfa will remove up to 425 lbs K/acre. An application of by-products to these soils is necessary to sustain levels of soil K over time especially for alfalfa production where a single application of by-products is only applied at pre-plant, and harvesting alfalfa continues over three to five years.

Applications of by-products at all rates significantly reduced *soil pH* levels at day 0 but these differences were no longer apparent by 30 days (Tables 1 and 2). In addition, soil pH of soil-by-product mixtures were between 6.4 and 6.9, which is considered an optimal range for farming because the majority of essential plant nutrients become available for plant uptake. Alkaline soil would benefit from application of peach products or acidic by-products because their soil pH levels will be lowered to encourage a greater plant nutrient availability.

Soil electrical conductivity (EC) levels were significantly increased with by-product application in both soils, at the greater extent on silt loam soil than sandy loam soil (Tables 1 and 2). Additional K, Mg, Ca, and Na from by-product application resulted in rising soil EC levels, which is expected from application of plant-based soil amendments. Although the concentrations of sodium (Na) in these soils were increased with by-product applications, the difference with respect to the control soil was comparatively small (<10%) for 1X and 3X loading rates (Tables 1 and 2). The application rates at 1X, 3X, and 5X loading rates will contribute ~10, 30, and 50 lbs Na/acre to these soils, respectively. An annual harvest of alfalfa removed about 16 Na/acre while the wheat-silage corn rotation removed about 6 lbs Na/acre (Pasakdee and Dellavalle 2008). In general, one-acre foot of good quality irrigation water with EC ~1 dS/m may deliver up to 2,000 lbs of salt per acre (Grattan, 2002). If Na content in this irrigation is ~10 meq/L, this irrigation water will transport ~627 lbs of Na per acre, and when comparing to Na contribution to these soils from by-product application, these amounts are de minimis.

Applications of peach by-products at all loading rates to both types of soils significantly increased other plant micronutrients such as calcium (Ca), magnesium (Mg), zinc (Zn), and manganese (Mn), but no significant change to levels of copper (Cu), iron (Fe), and boron (B) was observed (Tables 1 and 2). The concentrations of Ca, Mg, Zn, Mn, Cu, Fe and B obtained from the 5X loading rate to these soils were within or below average background soil concentrations reported in California (Chang and Page 2000). Growers will benefit from additional micronutrients to these soils by utilizing these by-products as soil amendments prior to planting crops.

SUMMARY

The application of peach by-products significantly increased macro- and micronutrients, and trace elements to sandy loam and silt loam soils, which are the potential sites for future by-product applications. The diminished levels of soil nitrate from a land-application event for up to 30 days may provide ground water protection during the period when pre-irrigation could cause nitrate leaching loss. In general, contribution of salt from by-products is minimal. Growing forage crops such as alfalfa or silage corn on these sites will remove significant amounts of these elements without posing risk to ground water quality from applications of by-products. However, other factors that may cause nutrient leaching or runoff may increase risk of ground water contamination which is beyond the scope of this research project. Growers are expected to benefit economically from a reduction in the use of chemical fertilizer inputs because they are replaced by applications of less-expensive by-products. Considering annual elemental inputs from by-products, harvest crop removal rate, crop selection and irrigation management, and proper site management, applications of by-products on these farmlands will pose minimal impacts to ground water quality.

REFERENCES

Chang, A. C. and A. L. Page (2000). "Trace Elements Slowly Accumulating, Depleting in Soils." California Agriculture 54(2): 49-55.

Grattan, S. (2002). "Irrigation Water Salinity and Crop Production" University of California Agriculture and Natural Resource Publication no. 8066.

Hays, T. (1998). "How much fertilizer do I need?" Soil testing and alfalfa fertilization. The 1998 California/Nevada Alfalfa Symposium, Reno, NV, University of California.

O'Connor, G.A., H.A. Elliott, N.T. Basta, R.K. Bastian, G.M. Pierzynski, R.C. Sims, and J.E. Smith, Jr. 2005. Sustainable Land Application: An Overview. Environmental Quality 34:7-17.

Pasakdee, S. and N. Dellavalle (2008). Crop Removal Rate of Food Processing By-products Constituents, Memo submitted to Stanislaus County, California Agricultural Technology Institute, California State University Fresno: 4.

Table 1. Sandy loam soil properties changed at 0, 7, and 30 days after peach by-products applied at various rates

	Control			1X			3X			5X		
	Day 0	**Day 7**	**Day 30**	**Day 0**	**Day 7**	**Day 30**	**Day 0**	**Day 7**	**Day 30**	**Day 0**	**Day 7**	**Day 30**
pH	6.7 abcd	6.4 cd	6.3 d	5.6 e	6.5 bcd	6.8 abc	5.2 ef	6.3 d	6.9 ab	5.1 f	6.4 cd	6.9 ab
EC (dS/m)	1.4 d	1.7 d	2.1 cd	3.3 bc	2.1 cd	3.0 bc	5.7 a	3.6 b	3.4 b	6.1 a	4.2 b	3.4 b
Ca (meq/L)	5.5 e	6.6 e	8.2 de	15.7 b	9.7 cde	13.8 bc	24.2 a	15.0 b	12.8 bcd	23.3 a	14.5 bc	10.0 cde
Mg (meq/L)	3.7 ef	4.5 ef	9.2 bc	10.1 bc	6.5 cde	5.3 def	15.1 a	10.3 b	8.2 bcd	14.7 a	10.6 b	6.5 def
Na (meq/L)	2.3 e	2.5 e	3.2 cde	2.9 de	3.1 cde	4.1 bc	3.7 bcd	4.2 b	5.3 a	3.9 bcd	4.4 ab	5.2 a
NO_3-N (mg/kg)	76 b	89 a	89 a	32 c	40 d	32 d	15 e	11 ef	15 e	8 f	5 f	8 f
NH_4-N (mg/kg)	8 b	8 b	6 b	6 b	11 b	8 b	14 b	9 b	17 b	35 ab	41 a	47 a
PO_4-P (mg/kg)	33 f	27 f	26 f	48 d	33 f	30 f	74 b	42 de	40 e	90 a	61 c	57 c
K (mg/kg)	257 d	285 d	240 d	417 c	384 c	374 c	674 b	664 b	654 b	870 a	935 a	878 a
Zn (mg/kg)	3.1 d	3.4 cd	3.2 d	3.6 bcd	3.8 bc	3.4 cd	4.1 b	3.9 bc	3.4 cd	5.0 a	4.9 a	3.7 bcd
Mn (mg/kg)	26 e	23 e	22 e	62 b	40 cd	34 d	71 a	49 c	42 cd	71 a	73 a	48 c
Cu (mg/kg)	0.7 a	0.8 a	0.8 a	0.8 a	1.0 a	0.8 a	0.9 a	0.8 a	0.8 a	0.9 a	0.9 a	0.8 a
Fe (mg/kg)	119 b	122 b	128 b	134 b	137 b	117 b	145 b	151 ab	115 b	160 ab	211 a	144 b

[a]Each number represents mean values based on four replications.
[b]Values in a row followed by the same letter are not significantly different, *P<0.05*, using Tukey-Kramer multiple-comparison test.

Table 2. Silt loam soil properties changed at 0, 7, and 30 days after peach by-products applied at various rates

	Control			1X			3X			5X		
	Day 0	**Day 7**	**Day 30**	**Day 0**	**Day 7**	**Day 30**	**Day 0**	**Day 7**	**Day 30**	**Day 0**	**Day 7**	**Day 30**
pH	7.2 a	7.1 a	7.3 a	6.5 b	6.4 b	6.6 b	6.0 c	6.4 b	6.4 b	5.6 d	6.4 b	6.4 b
EC (dS/m)	2.3 f	3.2 ef	4.6 de	5.6 bc	4.7 de	6.2 bcd	9.5 a	6.4 b	9.2 a	9.2 a	6.4 b	9.5 a
Ca (meq/L)	5.6 e	7.3 e	11.0 de	19.0 bc	15.2 cd	19.2 bc	34.6 a	22.6 b	32.8 a	34.2 a	23.6 b	30.1 a
Mg (meq/L)	4.6 f	6.3 f	9.3 ef	15.4 cd	12.8 de	16.0 cd	27.1 a	18.5 c	26.8 a	26.7 a	20.0 bc	25.1 ab
Na (meq/L)	11.4 d	15.1 cd	21.2 bcd	17.1 bc	18.8 bc	22.6 bc	20.5 bc	22.0 bc	28.0 ab	18.1 bc	21.1 bc	35.1 a
NO_3-N (mg/kg)	22 a	23 a	22 a	18 b	11 c	8 d	5 de	3 ef	1 f	3 ef	2 f	1 f
NH_4-N (mg/kg)	4 bc	8 bc	5 bc	<0.1 c	6 bc	4 bc	1 c	4 bc	4 bc	15 a	6 bc	10 ab
PO_4-P (mg/kg)	71 d	64 ef	59 f	76 cd	63 ef	62 ef	85 b	69 de	69 de	97 a	80 bc	75 cd
K (mg/kg)	244 de	248 de	216 e	269 d	273 d	253 de	338 c	363 c	327 c	446 a	415 ab	378 bc
Zn (mg/kg)	1.2 b	1.1 b	1.0 b	1.4 a	1.1 b	1.2 b	1.5 a	1.2 b	1.2 b	1.8 a	1.4 a	1.3 a
Mn (mg/kg)	17 e	18 e	21 e	55 de	47 de	51 de	119 b	74 cd	70 cd	171 a	184 a	106 bc
Cu (mg/kg)	1.9 b	1.9 b	2.0 b	2.0 b	1.9 b	2.0 b	2.2 b	1.8 b	2.0 b	2.2 bc	2.0 b	3.1 a
Fe (mg/kg)	31 f	28 f	28 f	37 de	29 f	32 ef	50 b	37 de	38 de	60 a	47 bc	42 cd

[a]Each number represents mean values based on four replications.
[b]Values in a row followed by the same letter are not significantly different, *P<0.05*, using Tukey-Kramer multiple-comparison test.

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