# Effects of Different Treatments for the Soil Chemicals in the Application Field of Cannery Water

## --- A Case Study of Pacific Coast Producers, Inc., Oroville Ranch

## Introduction

Agricultural land application is a method commonly used by food processing companies to dispose of factory process liquid and solid-wastes (Overcash et al., 2005). These wastes very commonly contain oxygen-demanding organics, nitrogen, and salts, especially sodium (Na) salts (Crites et al., 2000). Land application of effluent and bio-solids can bring mixed remediation results depending on the amount of land available, the chemical nature of the waste applied, method of land application, and type of soils and crop production. The activities normally require crop production and harvest since the species “mine” the nutrients and water, and help to facilitate the biodegradation of chemical constituents of environmental concern. The significance of these disposal activities is seen especially in the Central Valley, CA, where it is estimated that 520 of 640 food processing companies utilize agricultural land application of food processing waste (California regional Water Quality Control Board, 2006).

Currently, most food processing companies have no economically feasible alternative to land application of their factory process water and solids. Agricultural land application research is needed to ensure that the effects to soil quality, crop health, and groundwater are acceptable with minimal impact to public health and environment. In addition, there remains a void in research that deals with alternative disposal methods and the economics of land application practices. The research is commensurate with the above needs as it will focus on the economic comparison among the economic analysis of different treatments for the application field of cannery water. The short-term research benefits include potential cultural and economic improvements in the management of land application activities for our industry partner, Pacific Coast Producers, Inc. Pacific Coast Producers is the largest employer in Oroville, CA at their fruit cannery, and employ several thousand more people at two other canneries at Lodi and Woodland, CA.

The research also provides long-term benefits to the economic sustainability of a myriad of food processing companies, and to the thousands of farmers and ranchers who provided the commodities to these industries. Lastly, this research is relative to and will benefit those farmers, ranchers, and irrigators who manage the thousands of acres of saline and alkali soils in California for agricultural production, irrespective of agricultural land application practices employed by food processing companies.

In practice, the chemistry of food processing water applied to land poses unique problems to soil quality and forage crops that are grown to utilize water and nutrients. This[LG1] is true for Pacific Coast Producers fruit cannery operation at Oroville, CA where fruit process water is piped during the July-Oct cannery season to a company ranch at Palermo, CA where the water is applied as irrigation.

In 2009 at the Pacific Coast Producers ranch 86 million gallons of cannery water was applied to 199 acres over an eighty day period. This equated to 1.3 acre feet of water applied. The cannery water contained high levels of organics, moderate levels of nitrogen, and salts, especially Na salts. This chemistry typifies most of the food processing wastewater applied throughout the Central Valley, CA. Our past research at Palermo, CA has indicated that the organics and nitrogen are effectively degraded or utilized by the forage crop. However, the Na salts have impacted both soil quality and plant health. The significance of a Na concern can be realized using the 2009 irrigation loading rate above. Based on an average irrigation application rate and Na concentration in the cannery water, Na is applied annually at a rate of 770 lbs per acre. This level of Na has resulted in alkali or sodic (exchangeable sodium percentage greater than or equal to 15), and high pH (greater than 8.0) soil conditions for the majority of the irrigated acres. Gypsum is regularly applied to control further increases in soil exchangeable sodium. Note that the native soil has a pH less than 7.0 and very little Na[LG2] .

The magnitude of the Na loading rate has negatively impacted forage plant health. One consequence has been that only a limited number of forage species are capable of growing in this high sodium, high pH, and moderate saline environment. Much of the recent and past research employing new forage species and plot trails have been unsuccessful. As a result, we are left with only a handful of forage species suited to the Palermo ranch during the summer cannery water irrigation season. These include in decreasing area of growth, Bermudagrass, tall wheatgrass, and Dallas grass. Other consequences of Na are that the yield (and quality) of hay production from these grasses remains low, and plant tissue nitrogen, phosphorus, and potassium are at deficient levels. The latter consequence is either direct caused by nutrient imbalances because of too much Na or indirect due to Na-induced poor soil physical conditions resulting in an inadequate rooting environment.

**Methodology**

**1. Materials**

In this research, we selected five conventional and organic soil amendments to counteract the detrimental direct effects to soil, and direct or indirect effects to forage from the large amounts of Na applied by the cannery water. A high rate of gypsum based on the theoretical gypsum requirement (Ayers and Westcott, 1994), current rate of gypsum (control), N-P-K slow-release fertilizer to increase nutrient availability to forage, potassium sulfate, wood (100%) ash, and compost-gypsum mixture will be applied in a statistical sound design to plots comprising the 199 acres of irrigated cropland. Included in this amendment study is an economic analysis of the financial viability of employing one or more of these amendments. This analysis will include a value determination for increased environmental amenities (e.g., decreased soil Na and pH).
Gypsum is the common amendment for sodic or alkali soil reclamation that primarily involves increasing calcium ($Ca^{2+}$) on the soil cation exchange complex at the expense of $Na^{+}$ (Qadir et al., 2007). Wood ash is an excellent source of $Ca^{2+}$, low in heavy metals, and has been seen to increase soil potassium, phosphorous, and other nutrients that contributed to improving soil fertility and hay yields (Paterson et al., 2009; Perucci et al., 2008; Cabral et al., 2008). Care must be given in ensuring the ash is from 100% wood biomass and low in heavy metals. Wood ash is alkaline but will dissolve at the soil surface since the cannery water used in irrigation at Palermo, CA has a pH from 4 to 5. The combined application of compost and gypsum on saline and alkali soils increased crop yields to levels expected from good commercial fields (Avnimelech, 1994[LG3] ).
The second focus of this research involves livestock feed trials using fruit cannery bio-solid waste as a cattle feed supplement. Throughout the fruit canning process, residual waste is produced and must be disposed.  Currently, Pacific Coast Producers in Oroville truck their fruit

solid waste to their Palermo ranch. As stated above, considerable costs are incurred in transportation and disposal, and there are environmental concerns as well. Research to date at the CSU University Farm has determined that fruit bio-solids have excellent potential as cattle feed. We desire to pursue further cattle feeding trials at the University Farm initially. The latter stage of our research will involve direct feeding trials at the Pacific Coast Producers Palermo, CA ranch where agricultural land application of the fruit solids occurs[LG4] .

## 2. Experiment Design

The research employed a randomized complete block design with a selected field of 17 x 20 meters within the irrigated wheel lines that consists of homogenous growth of Bermudagrass. Homogeneity will be determined by biomass sampling. Seven blocks will be used with the six treatments (detailed above in "Purpose of the Research") resulting in 42 plots (1 $m^2$) per field. The plots will be separated by a 50 cm buffer. Soil sampling for chemical analysis (detailed below) in one-foot increments to two feet will be made to characterize the research blocks. See the figure 1 for the map of the experiment field.

Figure 1. Trial Plot Design

## 3. Application of Amendments

Amendments will be added before the start of the cannery water irrigation season (about July 15) the first and second years of the study. Treatment (amendment) rates are as follows: (1) Current rate of gypsum (Control) at 11.2 Mt/ha (5 tons/acre); (2) Wood ash (to be analyzed) based on Ca content equal to Control; (3) N-P-K slow release fertilizer using Endure (brand name, J.R.

Simplot Company) 15-15-15 fertilizer at “starter” N rate of 56 kg/ha. This rate will also provide 56 kg/ha each of $K_2O$ and $P_2O_5$, and 16.8 kg/ha of S; (4) Potassium sulfate at 1991 kg/ha which is equivalent on a 1:1 soil exchangeable basis to the annual addition of 863 kg/ha of Na added with the cannery water irrigation. This rate will also add 358 kg/ha S; (5) compost-gypsum 1:1 (wt.) mixture based on Control at 11.2 Mt/ha for each; and (6) a higher rate of gypsum (to Control) based on the theoretical gypsum requirement[sb5] (?).

**4. Sample Collection and Lab Analysis**

The research includes the following sampling activities. During the research period, we collected plant tissue samples and the soil samples 5 times on May 31, 2012, November 7, 2012, May 30, 2013, December 6, 2013, and May 21, 2014. Soil samples were analyzed for pH value, organic matter, exchangeable and soluble Na, K, Ca, and Mg by Olsen's Agricultural Laboratory, Inc.

**Data Analysis and Results**

During the experiment period, PCP changed their application of Sodium to Potassium in their production process in 2013. This change significantly affected the chemistry in the soil. During the analysis we have to take into consideration the influence from the conversion from Sodium to Potassium to the soil. After the lab results were available, graphs for pH value, OM%, exchangeable Na, K, Ca, and Mg are plotted in graph 1 to graph 6.

Figure 1. pH Value for Different Treatments

Figure 2. OM% for Different Treatments

Figure 3. Ex. Na for Different Treatments

Figure 4. Ex. K for Different Treatments

Figure 5. Ex. Ca for Different Treatments

Figure 6. Ex. Mg for Different Treatments

Based on the above graphs, single factor ANOVA analysis were conducted between the control and different treatments for both summer samples and winter samples, and the single ANOVA analysis before and after PCP changed the sodium to potassium in 2013 summer for all the 6 treatments (including the control) for pH value, organic matter, exchangeable and soluble Na, K, Ca, and Mg. The results are follows:

Table 1. Single Factor ANOVA Results between the Control and 5 Treatments before and after Changing from Sodium to Potassium

| F Test Results* (5% Sig. Level) | Before Changing from Sodium to Potassium | | | | | | After Changing from Sodium to Potassium | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH Value | OM % | Na | K | Ca | Mg | pH Value | OM % | Na | K | Ca | Mg |
| Gypsum | No** | No | No | No | No | No | No | No | Yes | No | No | Yes |
| NPK | No | No | No | No | Yes | No | No | No | No | Yes | No | No |
| $K_2SO_4$ | No | No | No | Yes | Yes | No | No | No | No | Yes | Yes | No |
| Wood Ash | No | No | No | Yes | No | No | Yes | No | No | Yes | Yes | No |
| Compost-Gypsum | No | No | No | No | No | No | Yes | No | Yes | No | No | Yes |

* To avoid too many tables in the paper we just provide a summary table here. Detailed results are available upon request.

**Yes: Significant difference exists;   No:  No significant difference.

Table 1 shows that before changing from Sodium to Potassium there is no any difference for pH value, OM%, exchangeable Na, and Mg between the control and the other 5 treatments. But for exchangeable K, the $K_2SO_4$ and Wood Ash Treatments show significant difference compared to the control. For exchangeable Ca, the NPK and $K_2SO_4$ treatments show significant difference compared to the control. The test results indicate that different treatments did not show any significant difference compared to the control.  This result is kind of surprising to us. One possible explanation is the way PCP applying cannery water to the ranch.  Because of the facility and equipment constraint, PCP will let the cannery water running 24 hours without stop, flooding the field.  This can probably explain the test results.

After PCP changed from Sodium to Potassium, for pH value, the Wood Ash and Compost-Gypsum treatments show significant difference compared to the control. While for OM%, there is any difference between the control and other treatments. For Na, the Gypsum and Compost-Gypsum treatments show significant difference compared to the control. For K, the NPK, $K_2SO_4$, and Wood Ash treatments show significant difference compared to the control. For Ca, the $K_2SO_4$ and Wood Ash treatments show significant difference compared to the control. For Mg, the Gypsum and Compost-Gypsum treatments show significant difference compared to the control. The above results indicate that the application of Potassium did change the chemistry of the soil.

Table 2. Single Factor ANOVA Results for the Control and 5 Treatments before and after Changing from Sodium to Potassium for Summer and Winter Samples

| F Test Results* (5% Sig. Level) | Summer Samples | | | | | | Winter Samples | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH Value | OM % | Na | K | Ca | Mg | pH Value | OM % | Na | K | Ca | Mg |
| Control | Yes** | Yes | Yes | Yes | Yes | Yes | No | No | Yes | Yes | No | Yes |
| Gypsum | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| NPK | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| $K_2SO_4$ | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Wood Ash | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Compost-Gypsum | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

* To avoid too many tables in the paper we just provide a summary table here. Detailed results are available upon request.

**Yes: Significant difference exists;   No:  No significant difference.

Table 2 shows that for summer samples, all the treatments and the control show significant differences before and after changing from Sodium to Potassium for all the variables of interest. While for winter samples, there are few exceptions. For pH value, the Control and the $K_2SO_4$ treatments did not have significant difference before and after changing to Potassium. For OM%, only the Control does not show any difference before and after changing to Potassium. For Ca, the Control, NPK, and Wood Ash treatments show no difference before and after changing to Potassium.

**Further Discussion**

Among different treatments, there are no significant difference observed for the soil chemicals of the application field of the cannery water.  The possible reason for these results can be the way the watering practice currently adopted by the company, sprinkling water for over 24 hours on the same filed, and it can affect the treatments.

But changing from Sodium to Potassium does have significant influence on the soil chemistry. The operating practice of using Potassium in the canning process is an environmental friendly m

[LG1]This is where we need some historical context of this site with a range of rate and load conditions – Setting the stage for the change from NA to K.

[LG2]We could provide some historical data here with a range of conditions – range of between irrigation and winter flushing.

[LG3]Where did the wood ash come from?

[LG4]Is there any chance to have animals at the ranch?

[sb5]Need more information.