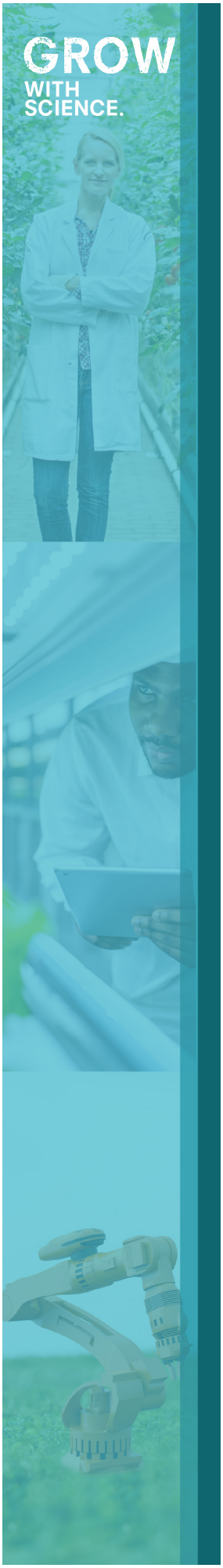

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Appendix Y

Guidance for Developing Best Management Practices to Reduce Cadmium Uptake by Spinach

Acknowledgements

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Richard Smith, UCCE Monterey County

Tim Hartz, University of California, Davis

Under the leadership of Hank Giclas, Western Growers.

Disclaimer

Background:

Crops vary considerably in their Cd uptake, with spinach accumulating much more Cd than other common crops grown in this region. Regulatory levels for plant tissue concentration of heavy metal elements like Cd are set on the basis of fresh weight, while most laboratory analysis is reported on a dry weight basis. A survey of vegetable fields showed that crop Cd uptake is roughly proportional to total soil Cd concentration, but crop differences in Cd accumulation are substantial (Fig. 1). Spinach accumulates 2-3 times the amount of Cd as romaine on a fresh weight basis, and broccoli accumulates even less than romaine. While soil Cd level is the primary factor determining crop Cd uptake, other factors can affect Cd uptake as well. The following is a brief summary of our research to date.

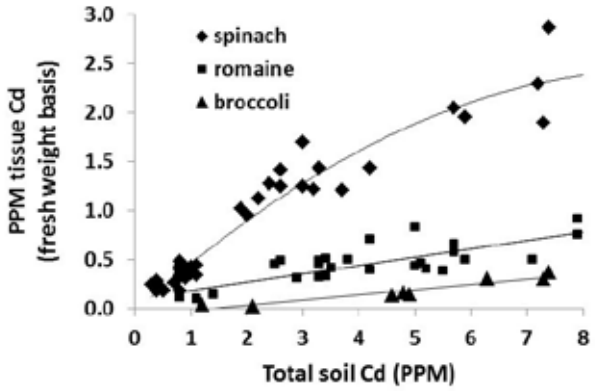

Fig. 1. Effect of total soil Cd concentration on tissue Cd concentration in spinach, romaine and broccoli (fresh weight basis).

Laboratory analytical techniques for Cd determination:

There are a number of laboratory techniques used to estimate soil Cd content. These techniques are highly correlated with each other, but they give very different numerical values. As an example, Fig. 2 shows the relationship between total soil Cd (determined by nitric acid extraction) and DTPA extractable soil Cd.

Across the range of Salinas Valley soils tested, total soil Cd concentration was approximately three times higher than soil Cd concentration determined by DTPA extraction.

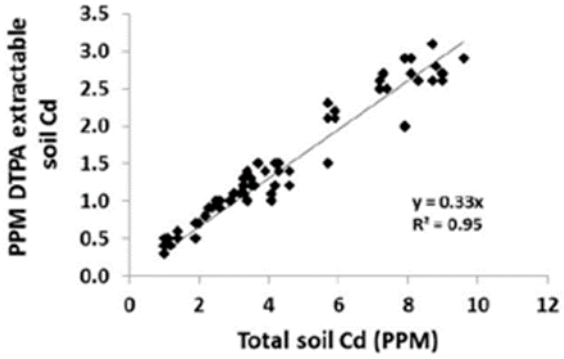

Fig. 2. Relationship between analytical techniques for soil cadmium determination.

Zinc Fertilization:

Zinc (Zn) and Cd are closely related ions. Zinc is an essential plant nutrient, but Cd is not. However, plants are not able to distinguish well between these ions, and substantial uptake of Cd can occur if a high

level of Cd is present in soil. Increasing the ratio of plant-available soil Zn to Cd suppresses Cd uptake. However, to significantly decrease Cd uptake much higher levels of Zn application are needed than would typically be used to remedy a soil Zn deficiency. Across numerous field and pot trials we have observed that applying 25-50 PPM elemental Zn on a soil dry weight basis (equivalent to approximately 100-200 lb elemental Zn per acre foot of soil) suppressed crop Cd uptake by roughly 4060%. However, the effectiveness of Zn application was affected by the following factors:

Zinc form:

- Zinc sulfate and zinc chelate were more effective in reducing Cd uptake than zinc oxide. Zinc sulfate was more economical than zinc chelate.
- Granular forms of zinc sulfate were less effective in reducing Cd uptake than powdered forms, or zinc solutions. We presume that Zn from the granules did not disperse thoroughly through the soil.

Zinc incorporation:

- To be maximally effective, Zn must be distributed throughout the primary rooting zone of spinach (the top 8-12 inches of soil).
- Disking incorporates Zn to a depth of approximately 6 inches and is therefore more effective than mulching, which incorporates Zn only to about 3 inches. Where practical, incorporation of Zn even deeper than 6 inches would be ideal.

Zinc foliar applications:

- Foliar applications of zinc sulfate or zinc chelate were not effective at reducing Cd uptake in spinach.

Zinc longevity:

- When Zn is applied to soil it slowly becomes less plant-available over time, as chemical compounds of low solubility are formed. However, high-rate incorporation of Zn will have measurable effects over several years at least. In a field trial, in the first crop following an application of 280 lbs. of zinc sulfate per acre we observed a 40% reduction in Cd uptake by spinach; after two years the Zn-treated area still showed a 15% reduction in crop Cd uptake. In pot trials the reduction in Cd uptake of four successive spinach crops was 66%, 66%, 51% and 49%. Based on these observations, it is clear that Zn applications can be effective across years, but additional Zn application may be needed to maintain maximum efficacy.

Soil pH:

Cadmium is more plant-available at lower soil pH, and liming may therefore decrease crop Cd uptake. In the Salinas Valley soils are frequently limed to maintain soil pH above 7.2 to reduce the incidence of club root in cole crops, so low soil pH is seldom encountered. We have observed variable response to liming in our trials, with some trials showing a modest decrease in crop Cd uptake while in other trials no effect was observed.

Other soil amendments:

Soil application of organic materials such as compost, biochar, and humic acid have been evaluated; in theory the high cation exchange capacity of these materials may sequester heavy metal ions such as Cd, making them less plant available. In a field trial, combining zinc sulfate with compost application resulted in greater reduction in spinach Cd uptake than with zinc sulfate alone. In a pot trial, biochar provided an inconsistent result, suppressing Cd uptake in one soil but not in another. Humic acid materials did not reduce Cd uptake.

Impact of chloride on Cd uptake:

Chloride (Cl) in irrigation water, and from fertilizers, can increase crop Cd uptake. In a pot study we observed that spinach Cd uptake increased with increasing Cl in irrigation water, with Cl concentration above 100 PPM (approximately 3 meq/liter) causing the largest increase. This suggests that fertilizers containing Cl should be avoided in fields where crop Cd uptake may be a problem, and use of low Cl irrigation water, if available, would be ideal for spinach production in such fields.

Summary:

Zinc application appears to be the most effective and practical approach to amending elevated-Cd soils. It appears that Zn applications can be effective in limiting spinach Cd concentration, but Zn form and application rate, incorporation technique and other factors can all influence spinach Cd uptake, so achievement of lower Cd concentration is not guaranteed.