CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
FERTILIZER RESEARCH AND EDUCATION PROGRAM
2010 Interpretive Summary

Project Title: **Comparing the Efficiency of Different Foliarly-Applied Zinc Formulations on Peach and Pistachio Trees by Using ^{68}Zn Isotope**

Project Leader: R. Scott Johnson, Extension Specialist
UC Davis Department of Plant Sciences
Kearney Agricultural Center
9240 S. Riverbend Avenue
Parlier, CA 93648
(559) 646-6547
e-mail: sjohnson@uckac.edu

Cooperators: Robert H. Beede, Farm Advisor
UC Cooperative Extension, Kings County
680 North Campus Drive, Suite A
Hanford, CA 93230
(559) 582-3211, ext. 2737
e-mail: bbeede@ucdavis.edu

Kevin Day, Farm Advisor
UC Cooperative Extension, Tulare County
4437-B S. Laspina St.
Tulare, CA
(559) 685-3309 Ext. 211
e-mail: krday@ucdavis.edu

Patrick Brown, Professor
Department of Plant Sciences
University of California
One Shields Avenue
Davis, CA 95616
(530) 752-0929
e-mail: phbrown@ucdavis.edu

Supporters: Monterey AgResources
Contact: Lawrence Marais
P. O. Box 35000
Fresno, CA 93745
(559) 499-2100
e-mail: lmarais@montereyagresources.com

INTRODUCTION

This is the final year of a three year project funded by FREP. Therefore, this report will summarize results from all three years and thus some points from previous reports will be repeated. Since Zn deficiency is common in California fruit and nut orchards, many different approaches and materials have been tried by growers. Our first FREP project (see 2005-2007 reports) took a broad look at various approaches and we concluded that foliar applications are the most cost effective method of supplying Zn to trees. Therefore, this second FREP project has focused on evaluating the effectiveness of different foliarly-applied materials, additives and timings. There are literally hundreds of zinc formulations that vary greatly in cost, solubility, chemistry and phytotoxicity. Since we have not been able to test all materials, our emphasis has been on cost effectiveness. Thus our research has focused first on the less expensive formulations, but has expanded from there to include many of the other commonly used materials. Even though we determine biological effectiveness of each treatment, our eventual selection criteria has depended much more on cost effectiveness. The project has relied heavily on using labeled ^{68}Zn - an expensive approach, but very precise at measuring uptake efficiency.

OBJECTIVES

1. Incorporate the ^{68}Zn isotope into some commonly used zinc formulations such as sulfate, EDTA chelate, oxide, amino acid or poly amine complex, citrate, lignosulfonate, fulvic acid, neutral-52%, nitrate etc.
2. Test the foliar uptake efficiency of these formulations on peach and pistachio seedlings with and without different types of surfactants.
3. Using the best treatments from objective 2, treat young peach and pistachio trees with ^{68}Zn in the field.
4. Test the most efficient Zn treatments in commercial peach and pistachio orchards.

DESCRIPTION

Before incorporating the ^{68}Zn label into different formulations, we developed a greenhouse procedure for evaluating the effectiveness of zinc formulations (without the ^{68}Zn label) using peach and pistachio seedlings. Briefly, the procedure involves Nemaguard peach seedlings and Kerman pistachio seedlings grown under conditions that induce noticeable zinc deficiency. Foliar sprays of zinc formulations then overcome these symptoms within 20 to 30 days. The degree of recovery demonstrates the relative effectiveness of the material (for details of this procedure, see the 2008 and 2009 FREP reports).

The ^{68}Zn label has now been incorporated into five different zinc formulations. At the beginning of the project, we already had ^{68}Zn oxide and ^{68}Zn sulfate. Once we started getting results with the greenhouse seedling experiments, we had the chemist at Monterey AgResources produce ^{68}Zn EDTA in June 2008 and ^{68}Zn nitrate and ^{68}Zn chloride in July 2009. These different formulations have now been used to confirm results from the seedling experiments. In 2009 they were also used to compare zinc uptake from ^{68}Zn sulfate and ^{68}Zn nitrate sprays applied to nectarine trees in the fall. The procedure involved spraying 100 ml of solution to a section of leaves on full sized trees in an orchard. The next spring, flowers and new leaves were collected from the same section of the trees and analyzed for ^{68}Zn.

RESULTS AND DISCUSSION

Over the three years of this project we have conducted numerous experiments comparing different zinc formulations on both peach and pistachio seedlings. Details of these experiments were reported in previous FREP proceedings. The summary ranking of the formulations is shown in Table 1. These are based on the original peach seedling experiments with non-labeled formulations as well as follow-up experiments with ^{68}Zn. The experiments with pistachio have not been as extensive, but the same general ranking has been obtained.

Table 1. Ranking of effectiveness of zinc formulations based on peach seedling experiments. Phytotoxicity was evaluated on both peach seedlings and in stone fruit orchards sprayed with solutions containing 500 to 1,000 ppm zinc.

Ranking	Formulation	Anion Size (mol wgt)	Solubility (g/100 H_2O)	Phytotoxicity
Most Effective	Zinc Chloride	35	432	High (58*)
Almost As Good	Zinc Nitrate	62	324	High (54)
	Zinc Nitrate Mix	62 & 96	324	High (59)
Next Best	Zinc Sulfate	96	50	Moderate (12)
	Zinc Carbohydrate	96 & ?	High	Moderate
	Zinc Polyamine	96 & 75-204	High	Moderate
	Zinc Glycine	96 & 75		Moderate (15)
Less Effective	Zinc EDTA	292	High	Low
	Zinc Leonardite	1000+	High	Low
	Zinc Oxysulfate	16 & 96	1.3	None
Least Effective	Zinc Phosphite	79	?	Low (17)
	Zinc Oxide Suspension	16	Insoluble	None

* Percent of leaves showing obvious phytotoxicity in a controlled experiment on Summer Fire nectarine.

We conclude that soluble formulations are considerably more effective than insoluble materials. Experiments with labeled ^{68}Zn showed 3 to 10 times more uptake of Zn with Zn sulfate compared to Zn oxide. Therefore, even though Zn oxide can be somewhat less expensive than sulfate, the Zn sulfate formulation is still much more cost effective. Among the soluble formulations, we conclude that the greater the solubility and the smaller the anion size (molecular weight), the greater the uptake of Zn (Table 1). Thus, the ranking of the best formulations goes in the order of chloride>nitrate>sulfate>EDTA. Experiments with ^{68}Zn

showed sulfate to be much more effective than EDTA and it is also less expensive per unit of Zn. The same argument can be made for all the other formulations below Zn sulfate in the table. For the most effective formulations in the table (chloride, nitrate and sulfate), separation among them was not always clear. In some of the ^{68}Zn experiments there were no statistical differences among the three. In the field experiment comparing ^{68}Zn sulfate to ^{68}Zn nitrate, there was no difference between these two formulations (Table 2). Therefore, as we take these results to the field, our conclusion is that Zn sulfate is the most cost effective material to use. Both Zn nitrate and Zn chloride may be slightly better under some conditions, but are generally much more expensive than Zn sulfate and thus less cost effective.

Table 2. Recovery of ^{68}Zn applied to Summer Fire nectarine trees in early October, 2009. Labeled ^{68}Zn applied as either sulfate or nitrate in a 864 ppm Zn solution at 100 ml/tree. Recovery measured in flowers and new growth collected in March, 2010.

	Treatments			
Parameter	Untreated Control	^{68}Zn Sulfate	^{68}Zn Nitrate	Significance
^{68}Zn in Flowers (µg)	0 b*	18.0 a	17.8 a	.001
^{68}Zn in Young Leaves (µg)	0 b	7.3 a	5.5 a	.0001
Total ^{68}Zn Recovered (µg)	0 b	25.2 a	23.3 a	.0004
Percent of Applied (%)	0 b	0.03 a	0.03 a	.0004

*Different letters in a row indicate significantly different values at the significance level indicated.

The final step of this project will be foliar applications of ^{68}Zn sulfate to mature trees in the field. Experiments with young potted peach trees growing in a lath house indicated that early fall was more effective than the currently accepted practice of late fall. In 2010 this experiment will be repeated on mature trees in the field since leaf characteristics could be different from the potted trees. We will also attempt to evaluate the addition of a surfactant that showed slight improvements in Zn uptake on greenhouse seedlings.

The emphasis of this project has been on peach but similar experiments were conducted on pistachio along the way. The biggest difference between the two was that Zn was much more difficult to get into a pistachio plant. Often two to three times more Zn was taken up by peach compared to similar experiments on pistachio. Also, Zn seems to be less mobile in a pistachio plant. However, other aspects of the research such as response to formulations, timing and surfactants, was comparable between the two. Therefore, the final experiments on pistachio will be similar to those planned for peach.

CONCLUSIONS

Research during the three years of this project has shown that Zn sulfate is the most cost effective material to use for foliar applications that supply Zn to peach and pistachio trees. Most other formulations tested were both less effective and more expensive. Zn oxide is less expensive but much less effective than Zn sulfate. Zn chloride and Zn nitrate were more effective in some tests but not enough to justify the increased cost. The final step, that will be conducted in the fall of 2010, will be an evaluation of the optimum timing for a Zn sulfate spray and whether the addition of a surfactant might improve uptake efficiency.

ACKNOWLEDGEMENTS

Since FREP funding will end in December 2010, the authors would like to acknowledge the California Tree Fruit Agreement (CTFA) for funding support to help complete the project as it extends into the spring of 2011.