Zinc Product Movement in Garlic

Research Summary for

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Background

California produces over 99% of the garlic (*Allium sativum*) in the United States[2]. California garlic increased by 13% from 2016-2017 in California, with Fresno and Kern county responsible for 96.9% of the garlic produced[2]. In 2018, 32,800 acres of garlic were harvested, which yielded 175 cwt/acre[1]. The corresponding value was just under $452.6 million; fresh market garlic accounted for $381.7 million of the total[1].

Garlic grows best in well-drained soil rich in organic matter with a pH of 6.0-6.5. Garlic is planted 1-1.5 inches deep in the fall on raised beds. Drip irrigation is often used to provide about one inch of water each week during critical periods. Diseases that commonly affect garlic include *Botrytis*, basal rot (*Fusarium*), white rot (*Sclerotium*), and downy mildew (*Peronospora*). Heavy fertilization is necessary; 125 lbs of nitrogen, 150 lbs of phosphorus, and 150 lbs of potassium per acre each growing season are required.

Zinc is a regulatory, functional, or structural component of many cofactors and enzymes that drive metabolic reactions and is essential for optimal plant growth. It is taken up in the Zn^{2+} or the $ZnOH^{+}$ forms. It is thought to be only slightly phloem-mobile, with ZIP proteins enabling loading. It travels as a complex with organic acids or proteins when being remobilized to other regions of the plant.

The objective of this trial was to evaluate Helix and Oasis Zinc, along with competitor products, on garlic in the Central Valley of California. Zinc concentration throughout plant organs was measured.

[1] NASS. 2018. State Agriculture Overview: California. USDA, Washington DC.
[2] California Agricultural Production Statistics. 2018. California Agricultural Statistics Review 2018 Report. CDFA, California.

Materials and Methods

The trial was placed within a conventional California Early garlic field, planted October 20. Six zinc treatments were replicated four times each in a randomized complete block design (table 1). Rates were designed to deliver equivalent amounts of zinc. Plots were one bed wide and 20ft long, with one bed buffers. Products were applied with a CO_2 powered backpack sprayer calibrated to deliver 15 gal/ac spray volume. Application was made on April 14 (figure 1). No grower zinc applications were made for the duration of the trial.

Plants from each plot were randomly selected for composite treatment sampling pre-application and one, two, five, and ten days after application. Each plant was separated into individual organ classifications: scape, bulb, and roots (figure 2). These samples were then acid washed and taken to a commercial laboratory for determination of zinc content.

Trial Treatment Details			
Product	*Manufacturer*	*Zinc Content*	*Rate*
Zinc sulfate	Soil Basics	5%	1.33 qt/ac
Oasis Zinc	Soil Basics	6.5%	1 qt/ac
Helix Zinc	Soil Basics	6.5%	1 qt/ac
Metalosate Zinc	Albion	6%	1.08 qt/ac
Biolink Zinc	Westbridge	8%	0.81 qt/ac
Untreated control	n/a	n/a	n/a

Table 1. The product, manufacturer, and zinc percentage is noted for each treatment, along rate used in the trial.

Figure 1. Crop stage at application.

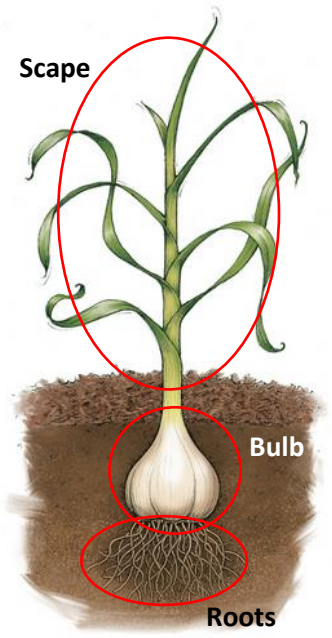

Figure 2. Plant organs separated for nutrient analysis.

Results

Within the leaf tissue, zinc concentrations ranged from 20-32 ppm (figure 3). Pre-application leaf zinc levels were quite variable between treatments; untreated and Oasis Zinc had lower initial contents and zinc sulfate a higher content. Helix Zinc, Oasis Zinc, and Metalosate Zinc all produced clear zinc increases one day post-application (each about 30% improvement over their respective pre-application values). Helix and Oasis Zinc saw decreasing zinc contents for the remainder of the sampling period, while Oasis Zinc slightly increased through day 2 before also declining through day 14. Zinc sulfate only moderately increased leaf zinc concentration one day after application and then zinc levels in this treatment fell. Biolink Zinc initially decreased in zinc before improving by day 5 and day 10. Untreated had less obvious swings in zinc concentration compared to the foliar zinc treatments, but did slightly increase day 1 to 2 and day 5 to 10.

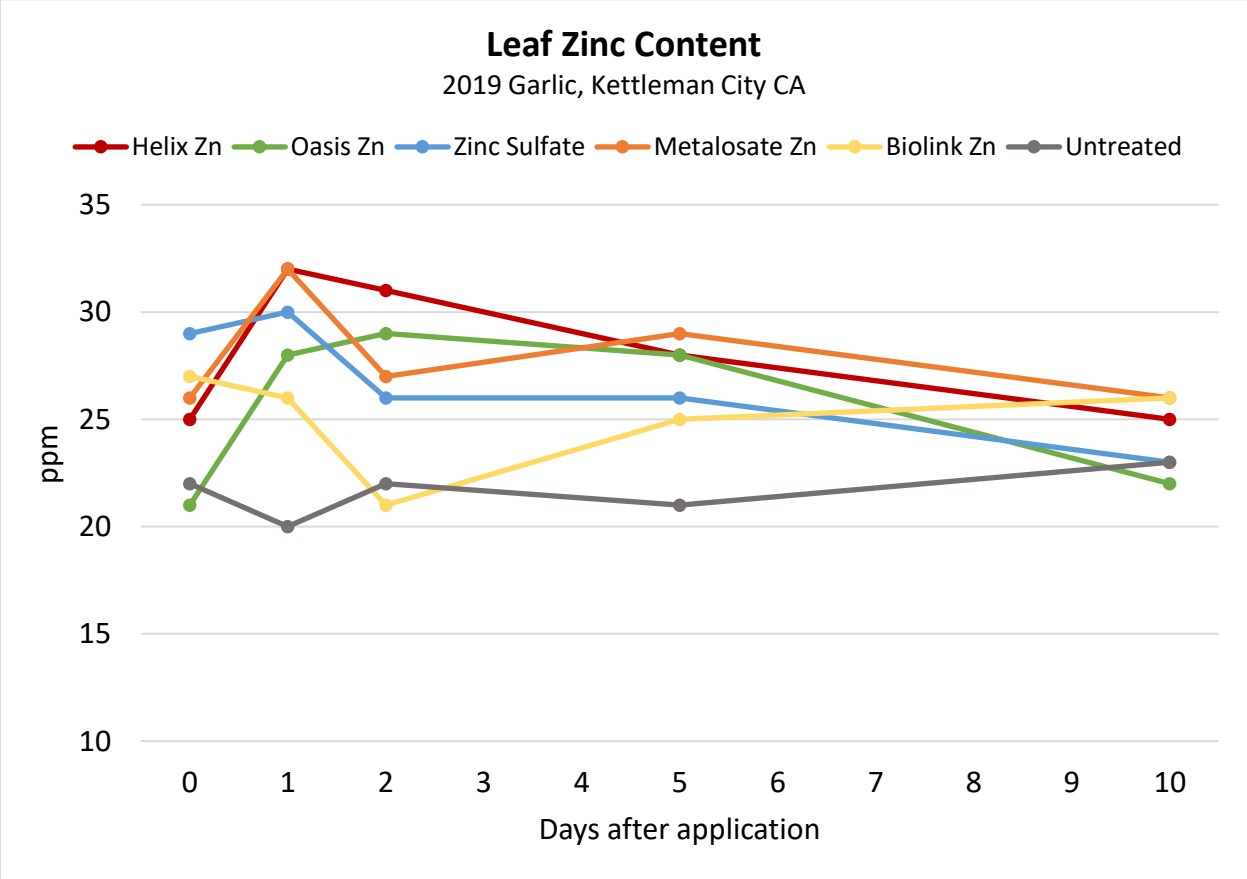

Figure 3. Zinc concentrations in parts per million within leaf tissue pre-application and 1, 2, 5, and 10 days post-application for all treatments.

Bulb tissue zinc concentrations ranged from 21 to 35 ppm across treatments and dates (figure 4). These samples showed more variation in results, and no general trend over time was evident. Excluding Biolink Zinc, all treatments showed a decrease in bulb zinc concentration through day 2. Zinc sulfate and Oasis Zinc improved by day 5 (28% and 38%, respectively), before declining again on day 10. Biolink Zinc-treated plots interestingly saw a large increase in bulb zinc one day after application, but decreased sharply one day later. The bulb zinc concentration under Helix Zinc decreased 36% on day 1 and never recovered. Metalosate Zinc echoed the bulb zinc trend seen in untreated plots.

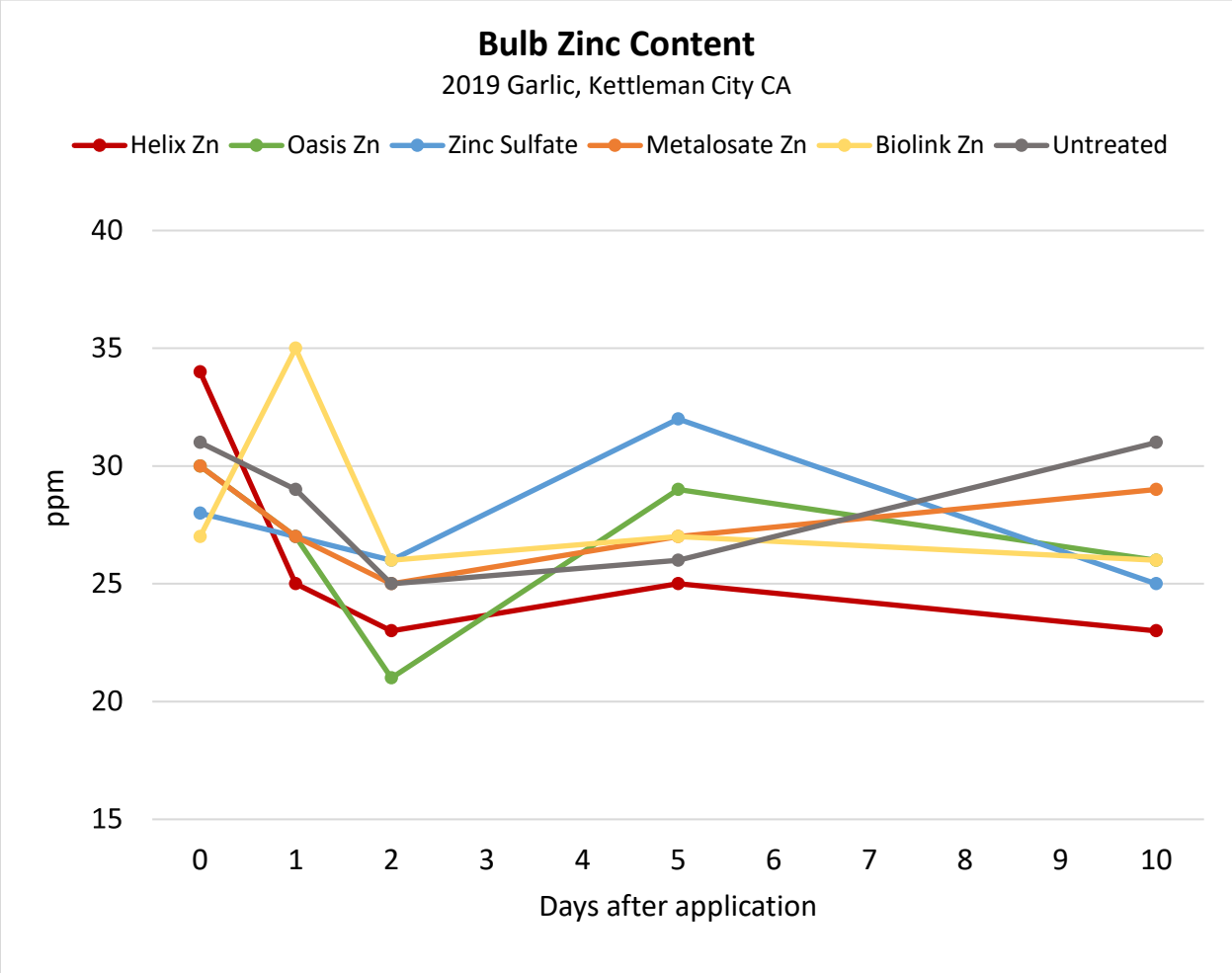

Figure 4. Zinc concentrations in parts per million within bulb tissue pre-application and 1, 2, 5, and 10 days post-application for all treatments.

Root tissue zinc concentrations ranged from 17 to 39 ppm and were quite variable both between and within treatments (figure 5). The untreated root zinc concentration unexpectedly increased by 95% from 1 to 2 days after application, before decreasing throughout the remainder of the trial. Zinc sulfate steadily increased post-application. Metalosate Zinc-treated plots maintained fairly steady root zinc levels, with a slight increase through day 5. Oasis Zinc produced the greatest increase in root zinc content of any zinc treatment before declining between day 5 and 10. Root zinc in Biolink Zinc and Helix Zinc was variable and intermediate.

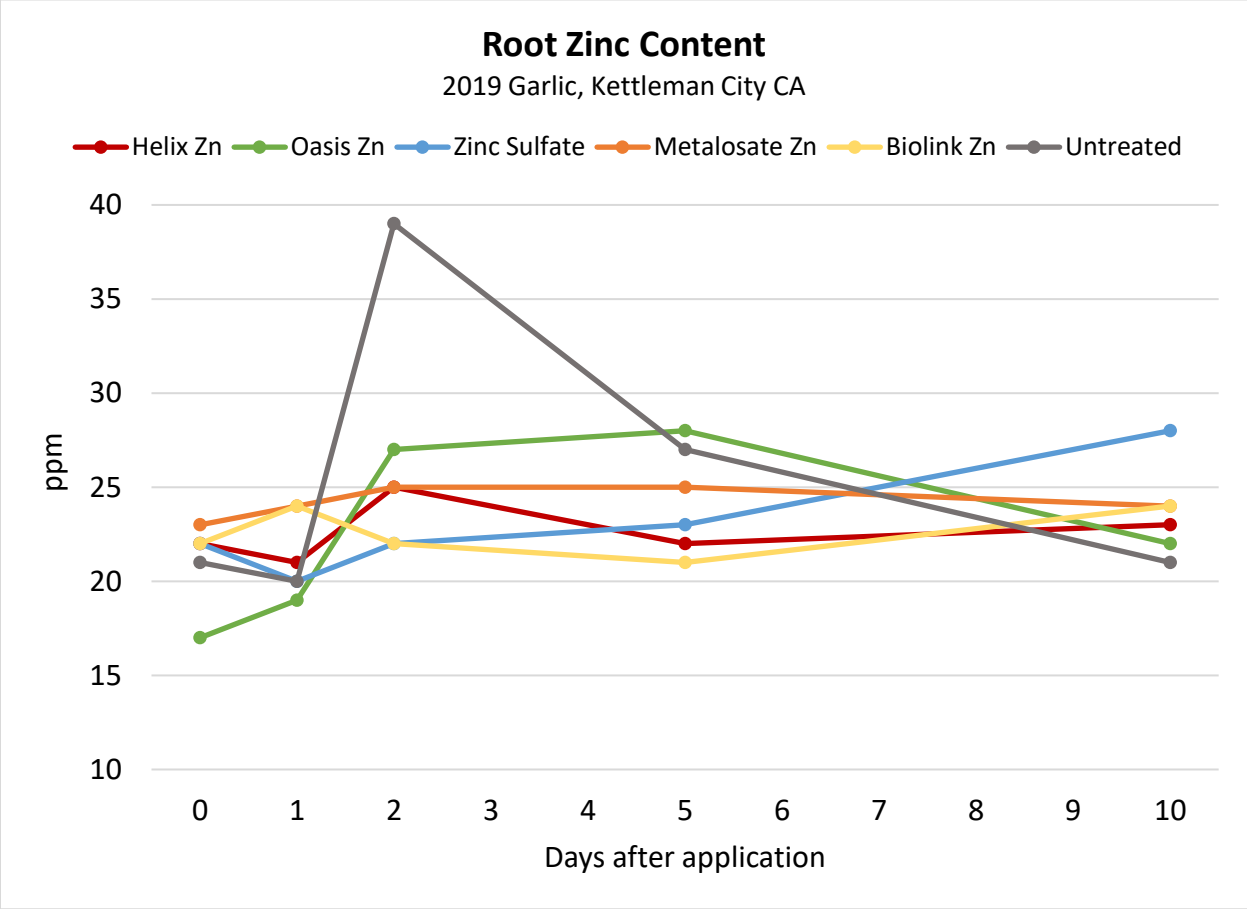

Figure 5. Zinc concentrations in parts per million within root tissue pre-application and 1, 2, 5, and 10 days post-application for all treatments.

There were no clear trends over time considering the cumulative zinc content from all sampled plant organs (figure 6). Untreated plots declined in measured zinc pre-application to 1 day post-application. These untreated plants then saw a large increase on day 2 before falling on day 5, remaining steady though day 10. Biolink Zinc produced the largest post-application total zinc increase, followed by Metalosate Zinc and Oasis Zinc. Metalosate Zinc then decreased on day 2 and remained fairly constant for the remainder of the trial. The Biolink Zinc total zinc level plummeted from day 1 to day 2, recovering slightly by day 10. Oasis Zinc maintained a nice increase in total zinc content though day 5 before decreasing on day 10. Zinc sulfate and Helix Zinc declined in total zinc content immediately post-application (though not as sharp a decrease as untreated); Helix Zinc treated tissue continued this decline though day 10, and zinc sulfate only saw an uptick between day 2 and day 5.

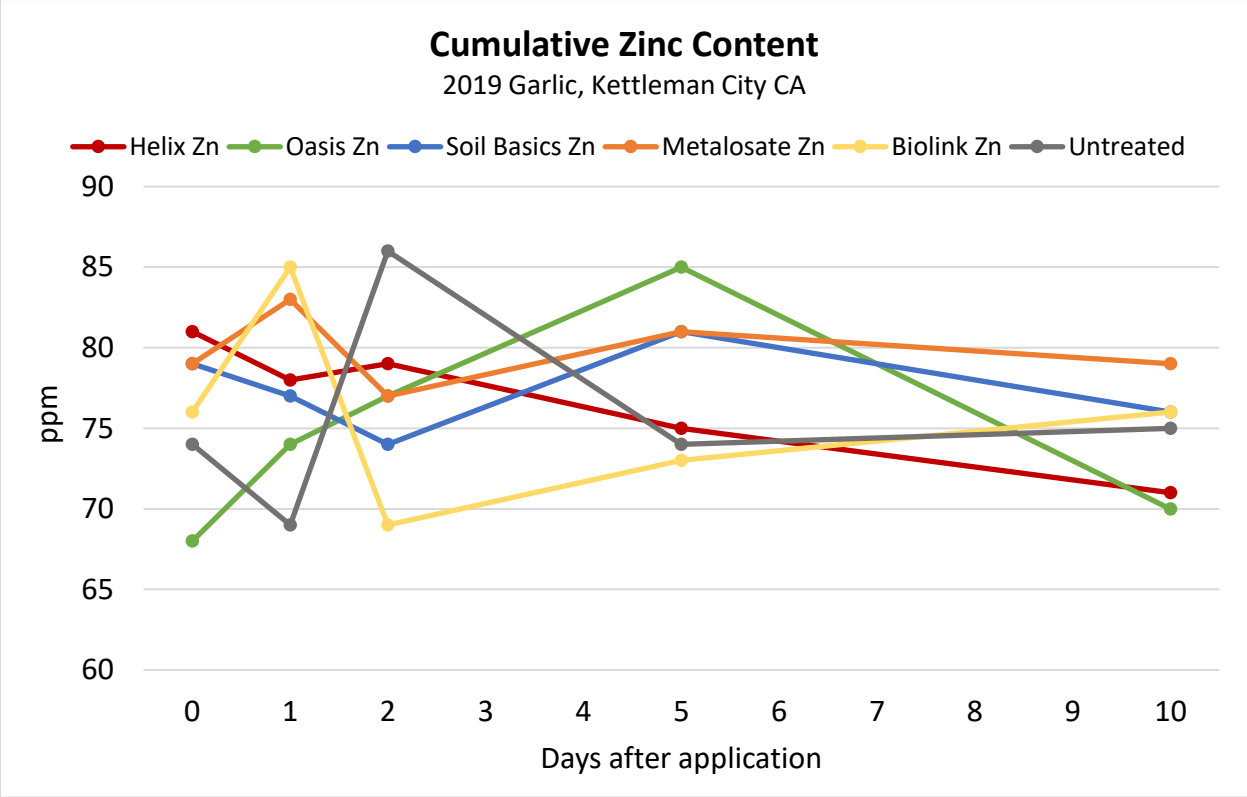

Figure 6. Total zinc concentrations in parts per million within all tissue samples 2, 5, and 10 days post-application for all treatments.

Initial zinc concentrations varied between treatments, so comparing percent change relative to each pre-application value can be beneficial (figure 7). Most treatments increased and decreased seemingly at random relative to the pattern in untreated. The stand-out product was Oasis Zinc, which consistently improved total zinc concentration in sampled tissues. Percent increase peaked on day 5.

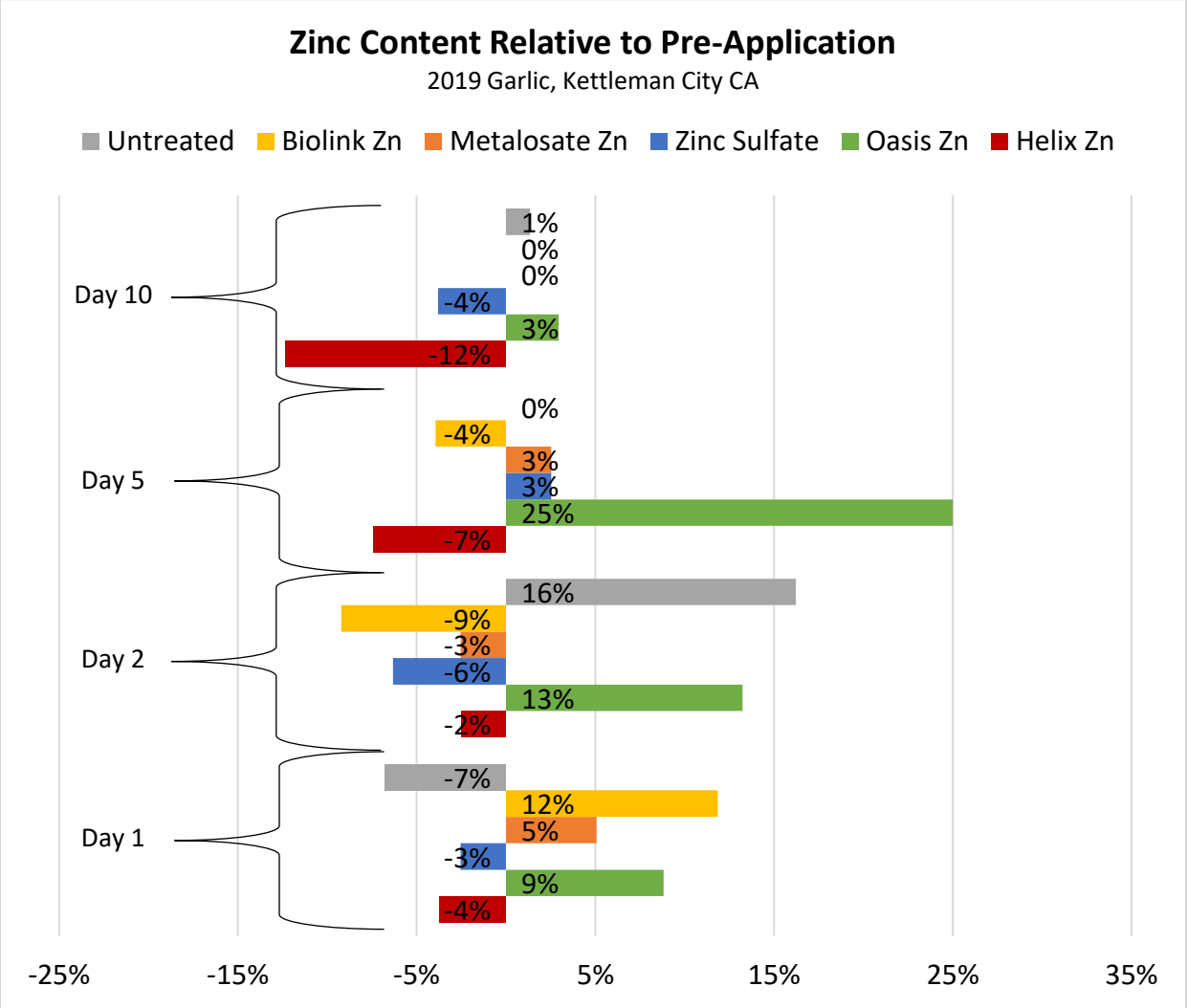

Figure 7. For each treatment, percent increase or decrease in zinc at each sampling date relative to the pre-application value.

Zinc concentrations in untreated samples were initially highest in the bulbs at 41.9% followed by the leaves (29.7%) and roots (28.4%) (figure 8). The proportion of total zinc in the leaves stayed relatively steady throughout the trial. However, changes occurred in the roots and bulbs. From day 1 to day 2, root zinc levels increased by 16.3%, while zinc levels in other areas declined - 12.9% in the bulbs and 3.4% in the leaves. From day 2 to day 10, zinc partitioning returned to a level that was very similar to the pre-application zinc levels. Because it is unlikely for zinc to move out of the bulb into the roots, these results indicate root uptake of zinc on day 2 and subsequent re-allocation throughout the plant by day 10.

When measured pre-application, Helix Zinc had a very similar zinc allocation to untreated (figure 9). A large increase in the zinc proportion found in leaves was evident one day after application. From day 1 to day 10, this leaf zinc allocation decreased slightly (still remaining above pre-application values). Bulb levels remained fairly steady, while root percentages slightly increased. Overall, it appears that the foliar zinc application and potential root uptake increased zinc proportions in the scapes and roots, without much movement into the bulbs.

Compared to untreated, Oasis Zinc plots had slightly more zinc in the bulbs and leaves and less in the roots when measured pre-application (figure 10). As expected, the zinc proportion in the above-ground biomass clearly increased following the foliar application, peaking on day 2. Leaf zinc level returned to near pre-application allocation by day 10. Root zinc contribution increased though day 5 and then declined though day 10. It appeared that both foliar and soil zinc sources were reflected in the distribution profile, before remobilization to the growing bulbs in days 5 and 10.

Initially, zinc sulfate plots had more of their zinc in the scape and less in the bulbs than untreated (figure 11). After application, the increase in scape zinc proportion was only slight – and then declined for the next 10 days. Root zinc percentages remained similar though day 5, while bulb zinc increased. On day 10, however, the root proportion increased with bulb proportion accordingly smaller. These results may indicate movement of zinc from the leaves to first the bulbs and ultimately the roots, or possible root uptake on day 10.

Similar to zinc sulfate plots, the Biolink Zinc plots had more zinc portioned in the bulbs and less in the scapes compared to untreated (figure 12). Interestingly, the foliar application did not immediately increase leaf zinc proportion (although slight increases were achieved day 5 and day 10). Rather, bulb zinc proportions increased 1 day post-application before slightly declining. Root zinc levels were fairly steady. No clear evidence of zinc movement was apparent.

Metalosate Zinc plots had the smallest zinc allocation in leaves pre-application (figure 13). The expected bump in scape zinc was observed 1 day after application. Scape zinc slowly declined back to pre-application levels by day 10. Root zinc levels were slightly higher on day 2 but remained relatively steady. Zinc proportion in the bulbs decreased then increased. Overall, the foliar zinc addition appeared to be reallocated to below-ground organs, reestablishing the pre-application balance.

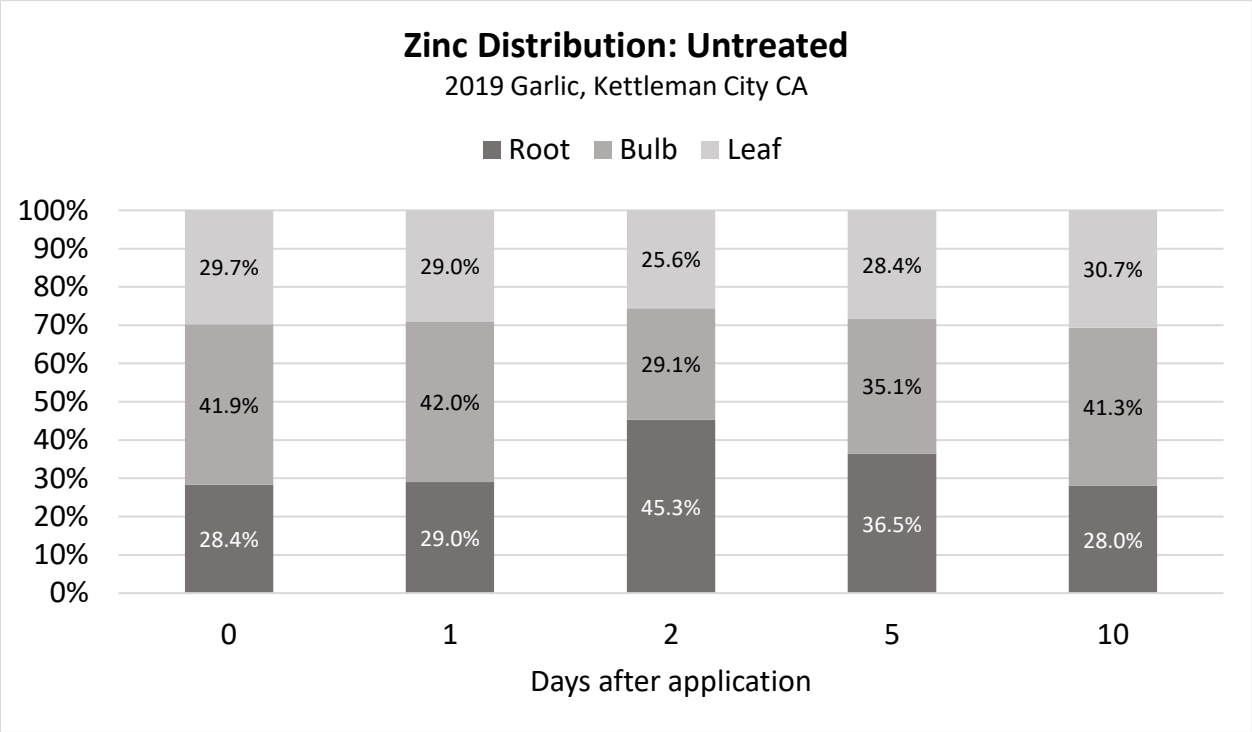

Figure 8. Total zinc distribution in percent within all tissue samples for untreated plants pre-application and 1, 2, 5, and 10 days post-application.

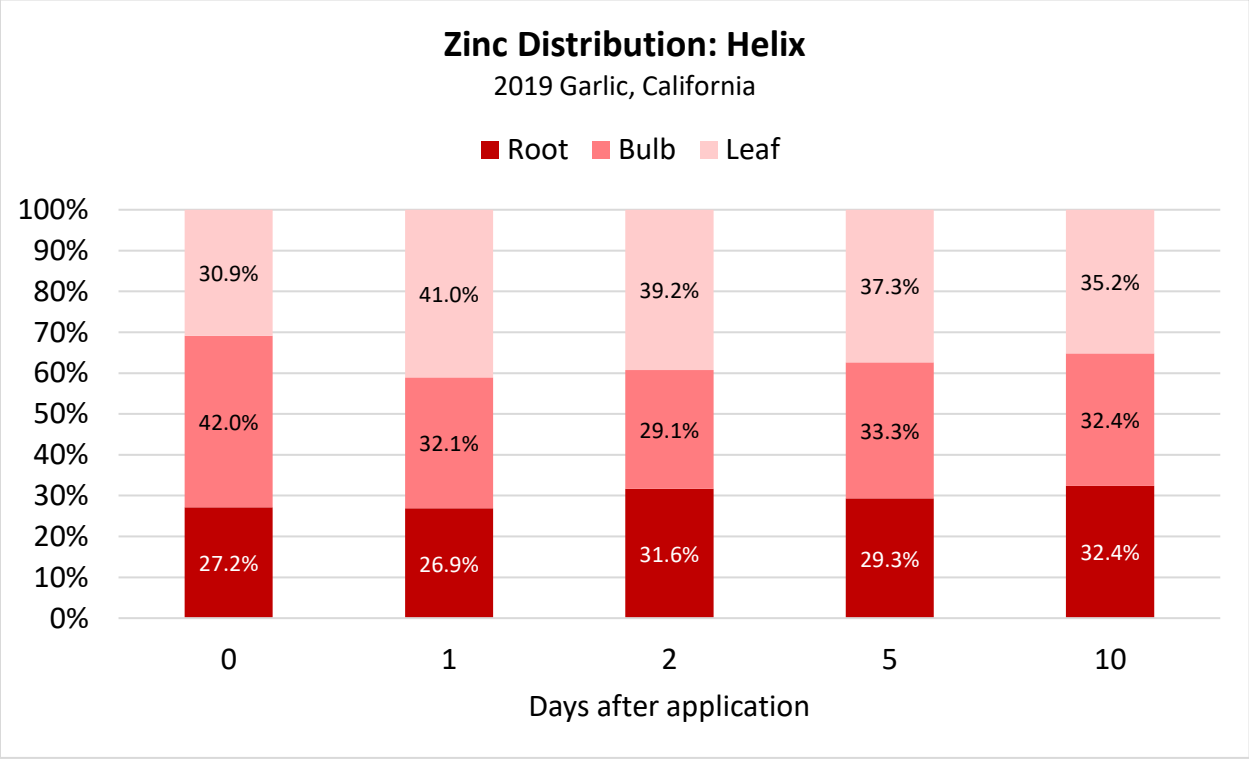

Figure 9. Total zinc distribution in percent within all tissue samples for Helix Zinc pre-application and 1, 2, 5, and 10 days post-application.

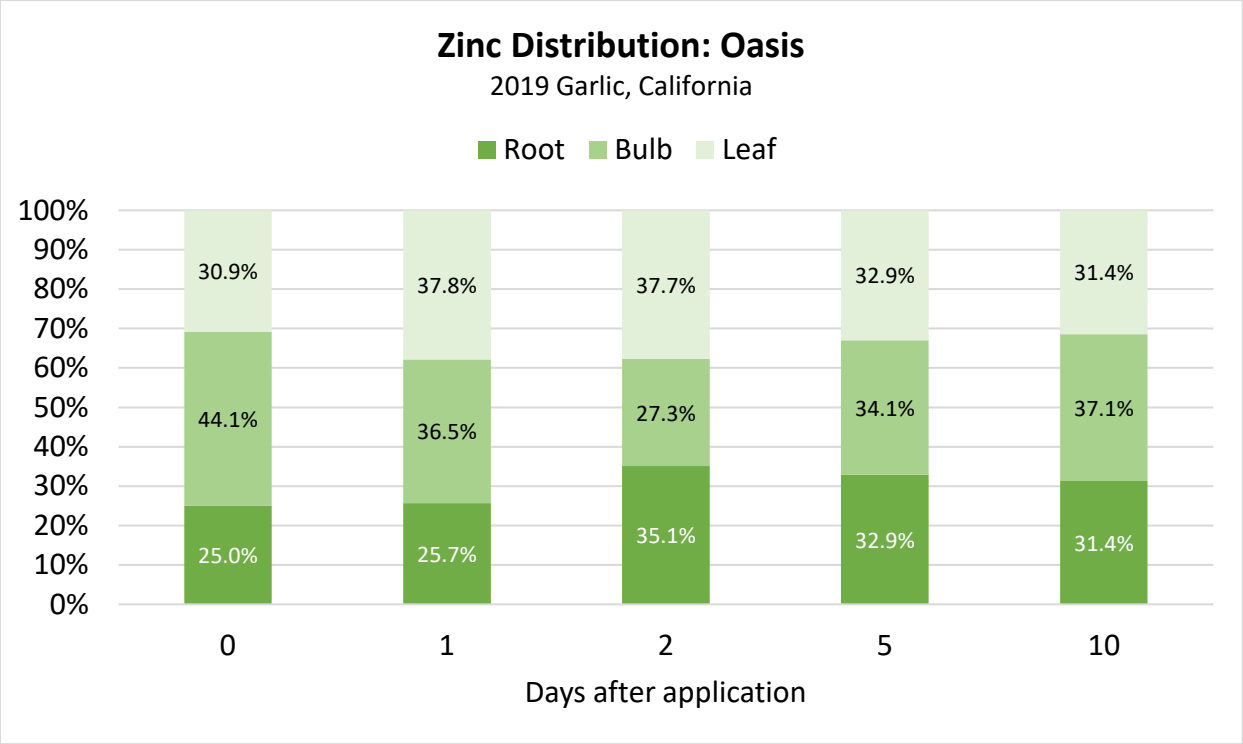

Figure 10. Total zinc distribution in percent within all tissue samples for Oasis Zinc pre-application and 1, 2, 5, and 10 days post-application.

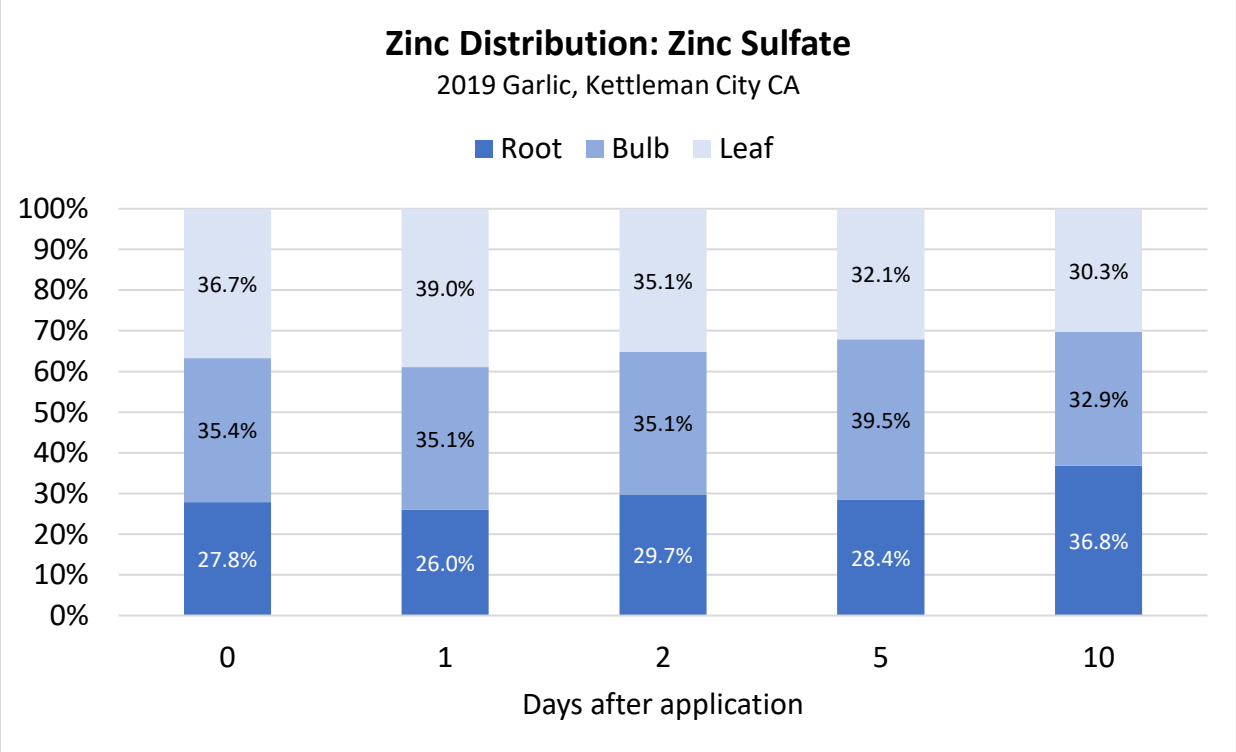

Figure 11. Total zinc distribution in percent within all tissue samples for Soil Basics Zinc pre-application and 1, 2, 5, and 10 days post-application.

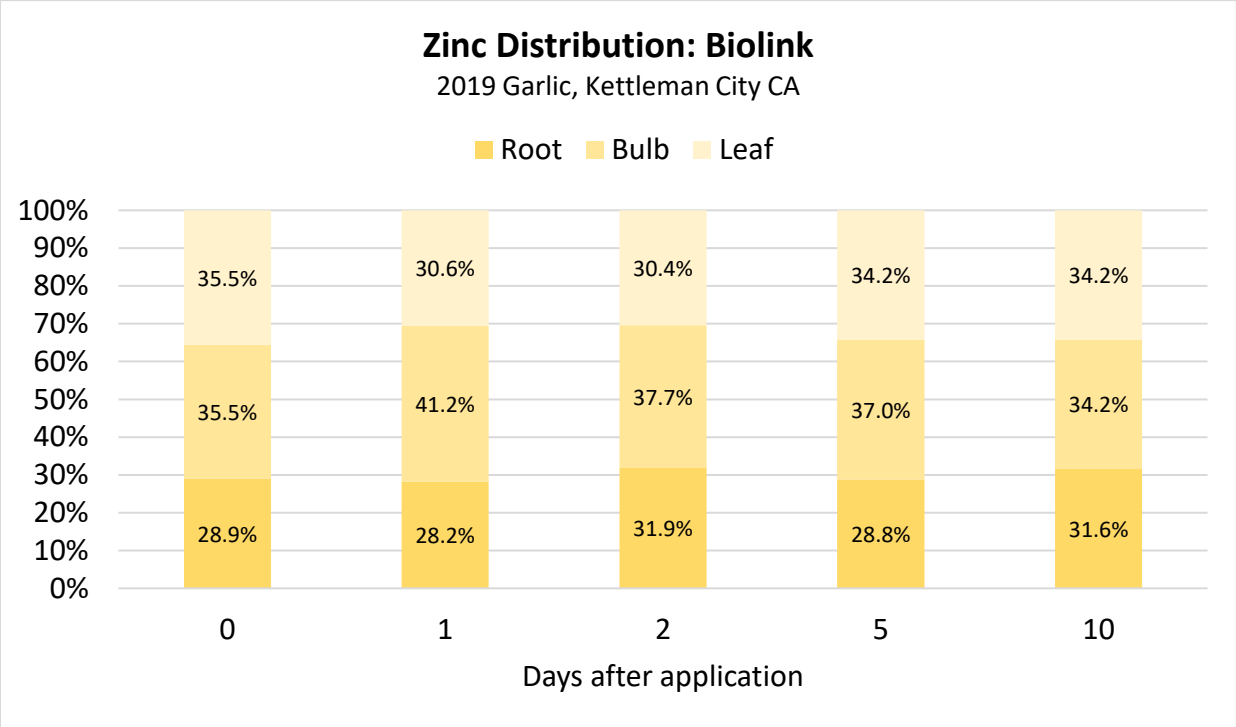

Figure 12. Total zinc distribution in percent within all tissue samples for Biolink Zinc pre-application and 1, 2, 5, and 10 days post-application.

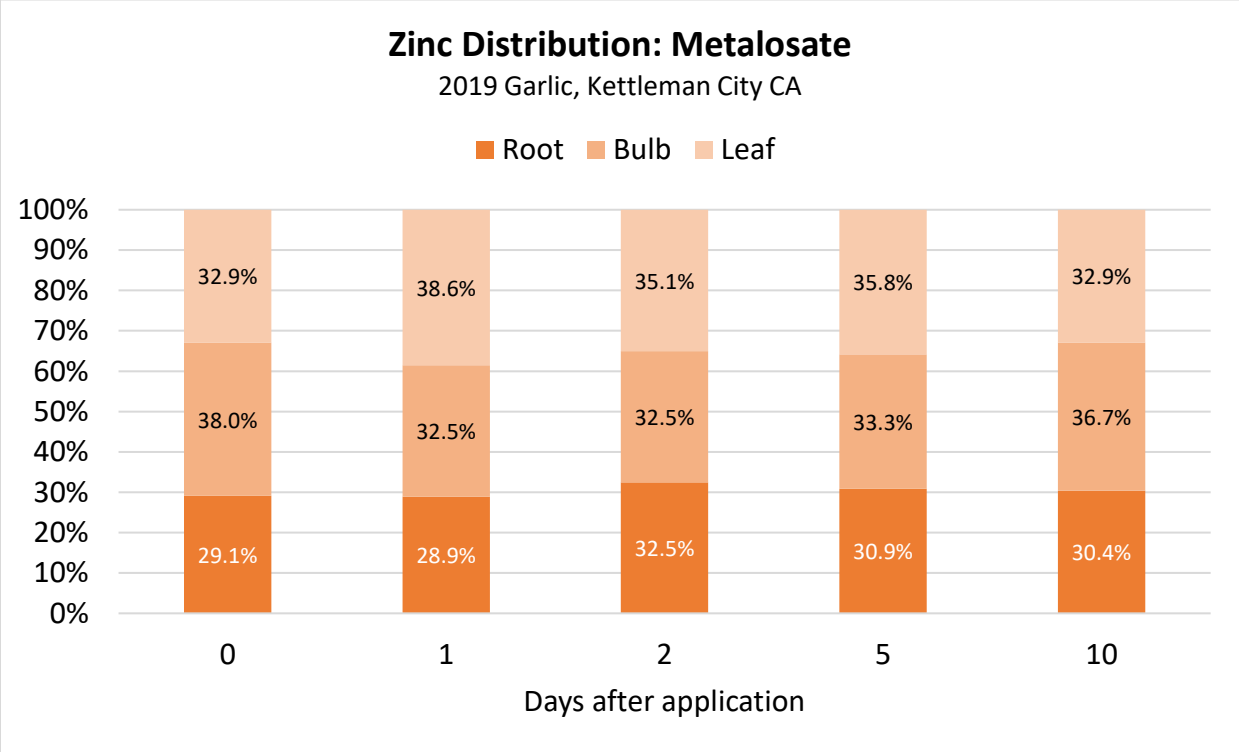

Figure 13. Total zinc distribution in percent within all tissue samples for Metalosate Zinc pre-application and 1, 2, 5, and 10 days post-application.

Conclusions

The individual tissue sample results were variable among treatments and across sampling dates. Generally, the leaf zinc contents peaked 1 day after application, with days 2, 5 and 10 showing lower levels. Untreated and Biolink Zinc were the exception, with leaf proportions peaking on day 10. Root zinc contents trended towards peaking on day 2 and decreasing throughout the remainder of the sampling period, and no clear pattern was discernable with the bulb samples. On average, Helix Zinc had the highest zinc concentrations within the leaves, while no treatment clearly dominated the bulb or root results.

Although the summation approach is not technically valid because each individual result indicates a concentration, it does provide a metric for assessing relative product assimilation efficiency. Most treatments increased and decreased seemingly at random relative to the pattern in untreated. The stand-out product was Oasis Zinc, which consistently improved total zinc concentration relative to its pre-application value.

When considering movement, zinc in each plant organ was translated to a proportion of total zinc in order to normalize the actual values between treatments. Additionally, it was assumed that the treatment foliar source of zinc was the primary contributor to plant zinc levels throughout the sampling period, as no other zinc fertilization had occurred. In the untreated plants, zinc percentage in the bulbs decreased while zinc proportion in the roots increased, but by day 10 the balance returned to levels similar to day 0. Because it is unlikely for zinc to move out of the bulb into the roots, these results probably indicate root uptake of zinc on day 2 and subsequent re-allocation throughout the plant by day 10. For Helix Zinc, it appears that the foliar zinc application and potential root uptake increased zinc proportions in the scapes and roots, without much movement into the bulbs. Under Oasis Zinc, both foliar and soil zinc sources were reflected in the distribution profile before remobilization to the growing bulbs in days 5 and 10. With zinc sulfate, the percentages may indicate movement of zinc from the leaves to first the bulbs and ultimately the roots, or possible root uptake on day 10. No clear evidence of zinc movement was apparent after Biolink Zinc treatment, unless zinc moved to bulbs before the 24-hour sampling. In the Metalosate Zinc plots, the foliar zinc addition appeared to be reallocated to below-ground organs, reestablishing the pre-application balance.

With only one data set and no statistical backing, the observed results could be due to variation. More research should be conducted in order to clarify conclusions from this year's analysis.

Raw Data

Zinc concentrations in ppm

Pre-application

	Helix	*Oasis*	*Soil Basics*	*Metalosate*	*Biolink*	*Untreated*
Root	22	17	22	23	22	21
Bulb	34	30	28	30	27	31
Leaf	25	21	29	26	27	22

1 day post-application

	Helix	*Oasis*	*Soil Basics*	*Metalosate*	*Biolink*	*Untreated*
Root	21	19	20	24	24	20
Bulb	25	27	27	27	35	29
Leaf	32	28	30	32	26	20

2 days post-application

	Helix	*Oasis*	*Soil Basics*	*Metalosate*	*Biolink*	*Untreated*
Root	25	27	22	25	22	39
Bulb	23	21	26	25	26	25
Leaf	31	29	26	27	21	22

5 days post-application

	Helix	*Oasis*	*Soil Basics*	*Metalosate*	*Biolink*	*Untreated*
Root	22	28	23	25	21	27
Bulb	25	29	32	27	27	26
Leaf	28	28	26	29	25	21

10 days post-application

	Helix	*Oasis*	*Soil Basics*	*Metalosate*	*Biolink*	*Untreated*
Root	23	22	28	24	24	21
Bulb	23	26	25	29	26	31
Leaf	25	22	23	26	26	23