# Delay of Expression of Powdery Mildew on Zinnia Grown Hydroponically in Hoaglands Solution Fortified with Silicon

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## Abstract

Powdery mildew, caused by the fungus *Erysiphe cichoracearum*, is a major foliar disease that occurs on greenhouse bedding plants during commercial production. Zinnia plants (*Zinnia elegans* cv. 'Oklahoma White') were grown either in liquid (hydroponic) culture or in peat-based potting mix to study the effect of silicon on subsequent disease development. Dilute Hoaglands solution was employed as a defined nutritional solution with or without fortification with soluble silicon. Plants subjected to both nutritional regimes were subsequently inoculated with *E. cichoracearum* and evaluated for powdery mildew development. Initially, characteristic white, pubescent powdery mildew growth appeared on the upper leaf surfaces of control plants (non-fortified with silicon) but colonies on silicon-fortified plants required two additional days to appear. Disease continued to progress on all infected plants under both nutrient treatments, but plants receiving silicon-fortified solution failed to develop symptoms as extensively as the plants grown in non-fortified solution. Better understanding of this phenomenon could lead to new approaches for controlling this widespread greenhouse production disease.

**Fig. 1**. Five-week-old zinnia seedlings grown in 5 L tubs containing control or silicon-fortified nutrient solutions.

## Introduction

Foliar fungal diseases of herbaceous bedding plants, caused by fungal plant pathogens, pose a serious challenge to the disease management efforts of greenhouse growers. The intensive nature of greenhouse bedding plant production is inherently conducive to the development of many foliar plant diseases. In addition, facility design, crop diversity, worker protection issues, economics, and accelerated production schedules all limit the selection and efficacy of disease management strategies. Although powdery mildews are somewhat host specific, *E. cichoracearum* is reported to have a broad host range including the commonly grown bedding plants begonia, phlox, salvia, sunflower, verbena, and zinnia. We have previously reported begonia, verbena, and zinnia to accumulate silicon when grown in silicon-fortified nutrient solution. Supplemental silicon applications have been reported to be associated with reduction of several other powdery mildew diseases (1). The research reported here is part of a larger project designed to comprehensively evaluate numerous parameters of greenhouse crop production, including nutritional factors, which can potentially reduce dependence on synthetic fungicide applications. The objectives of this research are to 1) quantify the presence of silicon in bedding plant species previously unreported to be accumulators, 2) determine if the presence of silicon in plant tissues affects the development and severity of powdery mildew, and 3) determine the most efficient method of application of silicon to achieve control of powdery mildew.

**Table 1**: Nutrient concentrations of modified Hoaglands solutions.

| Element | Concentration (mM) | |
|---|---|---|
| | starter | growth |
| N | 4.5 | 7.5 |
| P | 0.35 | 0.5 |
| K | 1 | 3 |
| Ca | 1.25 | 2.5 |
| Mg | 1 | 1 |
| S | 0 | 1 |
| Fe | 0.071 | 0.071 |
| Mn | 0.003 | 0.009 |
| Cu | 0.0005 | 0.0015 |
| Zn | 0.0005 | 0.0015 |
| B | 0.015 | 0.045 |
| Mo | 0.00003 | 0.0001 |
| Cl | 0.008 | 0.024 |
| Na | 0.00006 | 0.0002 |

## Materials and Methods

Zinnia seedlings (Z. elegans cv. 'Oklahoma White') were grown by sowing individual seeds into Oasis cubes (Smithers-Oasis, Kent, OH) moistened with high purity distilled water to reduce the potential for silicon contamination. Once germinated, the seedlings were nourished with a modified Hoaglands "starter" solution (Table 1) until they were placed either into 4-inch pots of peat-based media or into five liter hydroponic tubs (Fig. 1 ) at approximately three weeks of age. Seedlings transplanted to peat-based media were grown in a greenhouse and fertigated with a modified Hoaglands growth solution (Table 1) until visual evaluation of disease development. The Si-fortified zinnias were grown in modified Hoaglands growth solution with 1 mM silicon (Si) supplement (supplied as $K_2SiO_3$), for four to six weeks before harvesting for scanning electron microscope (SEM)/energy dispersive x-ray analysis (EDXA) to determine Si content and location (Fig. 2 ) or exposure to powdery mildew inoculum. All plants were maintained in renewed (weekly) modified Hoaglands growth solution until powdery mildew symptoms developed. Disease assessment was made visually on a daily basis, documented with digital photography and analyzed using Assess Image Analysis Software (APS Press, St. Paul, MN) to determine the area of powdery mildew development. Silicon content in leaf tissue at the time of harvest was determined using inductively coupled plasma atomic emission spectrometry (ICP-AES, Thermo Electron, Waltham, MA).

## Results

Initial observation of powdery mildew colonies occurred on greenhouse grown zinnias on control (Si -) plants approximately seven to ten days (3 to 4 days under ideal conditions in a growth cabinet) after exposure to inoculum. Colonies appeared as characteristic, white pubescent growth on the upper leaf surfaces. After an additional two days, minute colonies could be detected on the silicon-fortified (Si +) plants but these colonies did not develop as quickly or to the extent of the colonies on the Si - plants (Fig. 3). Both experimental approaches of introducing silicon to zinnia (hydroponics or fertigation) resulted in similar delay in appearance and reduced powdery mildew development. SEM/EDXA analysis identified silicon accumulation specifically around the base of trichomes (Fig. 2). Silicon levels in zinnia leaves, grown in hydroponic tubs containing silicon-fortified growth solution have been determined to contain 1.05 percent silicon based on dry weight. Selected leaves, representing an average amount of mildew infection, had 72 percent (control) vs. 5 percent (silicon-fortified) of the leaf area covered.

## Discussion

Because of the success in finding silicon present in the leaf tissues of most of the bedding plant species studied, we will continue to survey additional species to determine if accumulation is common in the majority of species or if there is some taxonomic relationship to this observation. SEM/EDXA analysis of bedding plant species positive for silicon accumulation will be continued to further define the site and/or mechanism of accumulation. ICP-AES analysis will be used to quantify the amounts of silicon accumulated in various tissues and its distribution across taxonomically diverse plant species. Laboratory and greenhouse inoculation studies with powdery mildew will be continued to ascertain the potential of silicon nutrition in reducing/controlling the disease on bedding plant crops that are particularly prone to disease development in greenhouse production. Application methods and rates are being evaluated to determine the best approach to exploiting the potential of silicon to control this endemic greenhouse production problem. Since our findings of delayed powdery mildew development and reduced severity parallels the report of a similar delay in black spot on rose (2) and are supportive of the active defense mechanism proposed by others (3), we are continuing to evaluate the possibility of silicon becoming a viable alternative to current fungicide-based management programs to combat this disease in greenhouse production.

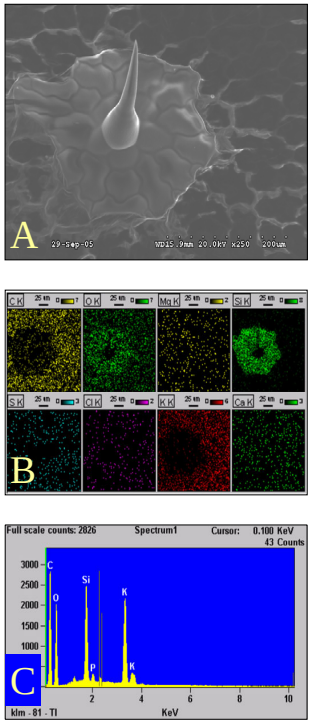


**Fig. 2**. A. Scanning electron microscopic image of a zinnia trichome, 250 X; B. Corresponding EDXA distribution maps; C. EDXA spectrum corresponding to maps above.

## References

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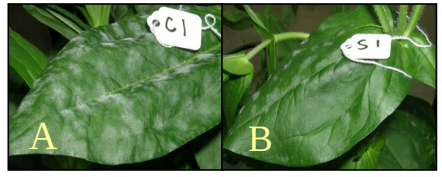


**Fig. 3**. Leaf surfaces of zinnia grown hydroponically in (A) control treatment and (B) silicon treated, modified Hoaglands growth solution 14 days after inoculation.