Investigating Silicon Nutrition to Decrease Pythium Root Rot Severity in Snapdragons and New Guinea Impatiens

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Abstract

Control of *Pythium* root rot in greenhouse production typically involves preventive fungicide applications that are costly, may run off to the environment, and are sometimes ineffective due to pesticide resistance. Adding silicon (Si) to the fertilizer regime has improved the *Pythium* response of several greenhouse vegetable crops. Anecdotal evidence suggests that Si may also improve the *Pythium* response of floriculture crops, but no research trials have been conducted. In this project we wanted to determine if silicon can reduce *Pythium* infection of snapdragons and New Guinea Impatiens.

A greenhouse experiment was conducted in which plants were monitored for five weeks in response to *Pythium* inoculation. Silicon was applied in two different forms (liquid or substrate-incorporated powder). Snapdragon plants showed increased wilting and decreased plant height within 10 days of exposure to *Pythium*. At this early stage silicon did show some promise in reducing severity of *Pythium*. However, by harvest at day 35, there was no improvement in *Pythium* response for silicon treated plants. It is interesting to note that for snapdragons not inoculated with *Pythium*, silicon improved plant size, flower number, and root system. New Guinea Impatiens plants began to show symptoms of *Pythium* infection 24 days after inoculation. Silicon did not improve response of New Guinea Impatiens to *Pythium*.

There does appear to be some promise for silicon in snapdragon. For plants not infected with *Pythium*, silicon improved several growth characteristics; and silicon may delay *Pythium* infection/severity early on. Silicon does not provide clear benefits for New Guinea Impatiens. Overall, this experimental system provided plants with heavy *Pythium* pressure to test for benefits. This system of inoculating each plant with a virulent strain is not representative of normal greenhouse disease pressure. With a lower level of *Pythium* inoculum more typical of contamination in a greenhouse, perhaps silicon would be able to delay disease symptoms or decrease their severity: this hypothesis should be tested.

Background and Justification

Silicon (Si) is not considered an essential plant nutrient; however, several plant species demonstrate improved disease resistance when silicon is supplied in the nutritional regimen. Si is readily available in most soils but soilless substrates and fertilizers used in commercial greenhouse production contain little available Si. For floriculture crops Si has been reported to reduce incidence of powdery mildew and black spot in roses, and to reduce Botrytis blight in sunflower.

In greenhouse floriculture production, several species of *Pythium* can infect roots causing decay of the root system and ultimately leading to stunted plants or plant death. Economic damage is incurred due to loss of saleable plant material and/or due to labor and product costs of applying fungicide drenches to control *Pythium*. Further, resistance to specific fungicide products (Subdue and Subdue MAXX) has occurred in 40% of *Pythium* isolates (Garzon and Moorman. 2009). Silicon is reported to reduce *Pythium* infection of cucumber (Cherif et al., 1994), lettuce (Utkhede et al., 2000), and bitter gourd (Heine et al., 2007). Anecdotally, silicon reduced *Pythium* infection in experiments with well-watered poinsettias and in snapdragons (Mattson and Roland Leatherwood, personal observations). However, these experiments were not conducted to evaluate disease resistance so there were not specific inoculated treatments and non-inoculated controls. Currently there are no research-based studies reporting on potential silicon benefits for control of Pythium root rot in floriculture species.

In this project we will address IPM needs by evaluating whether silicon applications are a useful strategy to delay or reduce *Pythium* infection. Recently, aqueous potassium silicate has been approved for use in certified organic production (USDA NOP AMS No. 239-10) – as potassium silicate is synthesized by joining together two naturally occurring compounds (silica sand and potassium carbonate).

Objectives

1. Conduct a greenhouse experiment to determine if silicon applied continuously in the fertilizer program or as a substrate-incorporated powder can reduce *Pythium* infection in two floriculture species
2. Evaluate the project to determine Si effectiveness and prepare final report
3. Distribute positive benefits (if found) via online newsletters and at greenhouse workshops

Procedures

A greenhouse experiment was conducted at Cornell University to determine if silicon is effective at improving tolerance of snapdragons and New Guinea impatiens to *Pythium irregulare*. These two species were chosen as they are among the top 10 bedding plants for economic value and both are quite susceptible to *Pythium*. Unrooted cuttings of New Guinea Impatiens 'Pure Beauty Salmon Pink' (Ecke Ranch) and seeds of Snapdragon 'Montego White' (Syngenta Flowers) were placed in 200 cell plug trays on April 28. A peat-based propagation mix was used as the substrate and trays were separated into 3 parts to provide for 3 silicon treatments:

- No silicon (treatments 1 and 2)
- Liquid potassium silicate (treatments 3 and 4), initially applied as a 100 ppm weekly drench; after transplanting on June 2nd, this was supplied daily in the irrigation water at 50 ppm Si
- Substrate incorporated potassium silicate powder (treatments 5 and 6), initially added to the propagation mix for this treatment and subsequently added to the transplanting mix, both times at the rate of 200 g Si m^{-3}

The young plants were grown under mist for five weeks and received weekly fertilizer drenches with 150 ppm N from Peter's 21-5-20 complete water soluble fertilizer. No fungicides were applied at any time during the production period. On June 2nd, plugs/liners were transplanted into 6” pots containing a commercial peat-perlite substrate (amended as described above for treatments 3 and 4). Three plants were transplanted into each pot. On June 4th, 6 mm agar plugs of *Pythium irregulare* from 4-wk old potato dextrose agar cultures were inserted into the containers near the root-zone of each plant. One agar plug was placed near each plant, and plugs were buried ca. 1 cm beneath the soil line. The *Pythium irregulare* isolate was cultured by M. Daughtrey; an isolate known to be virulent to New Guinea Impatiens was chosen. One-half of the plants were inoculated (treatments: 1, 3, and 5); the other half (treatments 2, 4, and 6) served as un-inoculated controls. The experiment was arranged as a completely randomized block design (CRD) with 3 levels of Si supply and two levels of inoculation equaling 6 treatments. For each cultivar, 90 plants were used, allowing for 5 replicates per treatment with 3 plants per container (experimental unit). Beginning 10 days after *Pythium* introduction, plants were monitored weekly to record the progression of disease symptoms in terms of: plant wilt index as noted below and degree of stunt as measured from plant height. During the experiment no plants died, so percent mortality was not recorded. At the experiment termination, July 9, plants were destructively harvested to determine root index (as noted below), root length, flower number, fresh weight, and dry weight.

Wilt Index

1 No visible symptoms of wilt
2 A few lower leaves (≤3) show wilting
3 Several lower leaves (>3) wilting
4 Lower and mid-leaves wilting
5 Leaves on nearly the entire plant are wilting

Root Index

1 Large/White root system – roots growing all the way out to the edge of the container
2 Large root system, may be slightly discolored, may not grow to edge of container
3 Moderate root system, does not fill out the container, somewhat discolored
4 Poor root system, a bit of root growth out of the plug ball, quite discolored
5 Very poor root growth / small and dark brown color, plant pulls away from soil easily

Results and Discussion

Weekly wilt index and plant height measurements were recorded beginning 10 days after inoculation; these can be thought of as early measures of the extent of *Pythium* infection. Snapdragons succumbed to *Pythium* infection earlier than New Guinea Impatiens. Inoculated snapdragons were wilting by June 14, while inoculated New Guinea Impatiens did not exhibit wilting until July 7 (Table 1). There appears to be some initial benefit of silicon to snapdragons, at June 14, silicon treated plants showed a wilt index of roughly 2, while plants not receiving silicon had a wilt index of 3 (Table 1). However, due to plant to plant variation the results were not statistically significant.

By July 7, all inoculated snapdragons exhibited the same degree of wilting and the same plant height regardless of silicon treatment (Table 1). Un-inoculated plants were taller and less wilted compared to their inoculated counterparts. Silicon did not affect height or wilting of un-inoculated snapdragons. By July 7, un-inoculated New Guinea Impatiens plants were taller and less wilted than their inoculated counterparts. Height of New Guinea Impatiens was greatest for those receiving substrate incorporated silicon but not inoculated. Interestingly, for inoculated plants, those receiving substrate incorporated silicon were more wilted than plants not receiving silicon.

On July 9, five weeks after *Pythium* inoculation final plant size measurements were recorded. For New Guinea Impatiens, height, root index and fresh and dry weights were unaffected by silicon treatment, inoculated plants were roughly three times smaller than their un-inoculated counterparts (Table 2). Liquid silicon did reduce root length of un-inoculated plants.

Silicon did not significantly improve growth response of the *Pythium* inoculated snapdragons (Table 2). However, it is interesting to note, that silicon did improve growth of un-inoculated plants. Both silicon treatments led to a better root index, root length, and flower number than plants not receiving silicon. Substrate incorporated silicon led to a greater plant fresh weight versus plants not receiving silicon. Liquid applied silicon led to a greater plant dry weight and height as compared to plants not receiving silicon. This promotion of growth by silicon (in the absence of *Pythium*) should be followed up in greater detail. A similar growth promotion has been reported for sunflower and zinnia.

Table 1. The effect of liquid silicon (50 ppm Si added to the irrigation water) and substrate incorporated silicon (200 g Si m^{-3}) on wilt index and plant height of New Guinea Impatiens and Snapdragons that were exposed/not exposed to *Pythium* inoculation on June 4, 2010. Numbers represent the mean ± SE of 5 containers each with 3 measured plants.

New Guinea Impatiens 'Pure Beauty Salmon Pink'

Trt	Silicon?	*Pythium* Inoc?	Wilt Index (1=good, 5=completely wilted)				Plant Height (cm)			
			June 14	June 21	June 28	July 7	June 14	June 21	June 28	July 7
1	no	yes	1.0 ± .0A	1.3 ± .2A	1.3 ± .2A	1.9 ± .2BC	5.5 ± .3A	5.9 ± .3B	6.9 ± .2BC	7.8 ± .8C
2	no	no	1.0 ± .0A	1.0 ± .0A	1.0 ± .0A	1.0 ± .0D	5.7 ± .3A	6.8 ± .3A	7.9 ± .2A	11.1 ± .3AB
3	liquid	yes	1.0 ± .0A	1.3 ± .2A	1.3 ± .2A	2.3 ± .3AB	5.6 ± .1A	6.2 ± .3AB	6.7 ± .1C	7.6 ± .3C
4	liquid	no	1.0 ± .0A	1.0 ± .0A	1.0 ± .0A	1.5 ± .5CD	5.5 ± .1A	6.8 ± .2A	7.7 ± .1A	10.0 ± .6B
5	substrate	yes	1.0 ± .0A	1.7 ± .7A	1.7 ± .7A	2.9 ± .2A	5.7 ± .1A	6.6 ± .2A	7.2 ± .2B	8.2 ± .2C
6	substrate	no	1.0 ± .0A	1.0 ± .0A	1.0 ± .0A	1.1 ± .1D	5.7 ± .2A	6.6 ± .1A	8.0 ± .1A	11.7 ± .2A

Snapdragon 'Montego White'

Trt	Silicon?	*Pythium* Inoc?	Wilt Index (1=good, 5=completely wilted)				Plant Height (cm)			
			June 14	June 21	June 28	July 7	June 14	June 21	June 28	July 7
1	no	yes	3.1 ± .7A	2.6 ± .5A	2.6 ± .5A	3.5 ± .6A	7.3 ± .2A	8.3 ± .7B	9.0 ± 1.1B	9.1 ± 1.1B
2	no	no	1.1 ± .1BC	1.0 ± .0B	1.0 ± .0B	1.6 ± .6C	7.7 ± .2A	11.1 ± .6A	12.6 ± .9A	13.3 ± .9A
3	liquid	yes	2.0 ± .4ABC	2.1 ± .2A	2.1 ± .2A	3.5 ± .2A	6.1 ± .4C	6.1 ± .4C	6.6 ± .4C	6.9 ± .6B
4	liquid	no	1.1 ± .1BC	1.0 ± .0B	1.0 ± .0B	1.4 ± .4C	7.0 ± .4AB	10.9 ± .6A	14.1 ± .7A	15.1 ± .9A
5	substrate	yes	2.2 ± .4ABC	2.2 ± .3A	2.2 ± .3A	3.1 ± .1AB	6.2 ± .2BC	6.8 ± .5C	7.2 ± .5BC	7.3 ± .6B
6	substrate	no	1.0 ± .0C	1.0 ± .0B	1.0 ± .0B	1.8 ± .8BC	7.1 ± .1A	10.6 ± .1A	13.8 ± .3A	14.7 ± .4A

Letters represent mean separation comparison based on Student's LSD. Within a column, treatments sharing the same letter are not significantly different from each other.

Table 2. The effect of liquid silicon (50 ppm Si added to the irrigation water) and substrate incorporated silicon (200 g Si m^{-3}) on final growth measurements of New Guinea Impatiens and Snapdragons that were exposed/not exposed to pythium inoculation on June 4, 2010. Measurements were taken on July 9. Numbers represent the mean ± SE of 5 containers each with 3 measured plants.

New Guinea Impatiens 'Pure Beauty Salmon Pink'									
Treatment	**Silicon?**	***Pythium* Inoc?**	**Wilt Index**	**Height (cm)**	**Root Index**	**Root Length (cm)**	**Flower Number**	**Fresh Weight (g)**	**Dry Weight (g)**
1	no	yes	1.3 ± 0.1A	8.5 ± 0.2B	3.5 ± 0.1A	9.3 ± 1.2C	0.5 ± 0.3A	21.1 ± 2.0B	2.0 ± 0.2B
2	no	no	1.1 ± 0.1A	10.9 ± 0.2A	1.1 ± 0.1B	24.0 ± 0.6A	0.0 ± 0.0A	62.7 ± 0.9A	5.6 ± 0.2A
3	liquid	yes	1.2 ± 0.1A	8.3 ± 0.5B	3.5 ± 0.2A	10.5 ± 1.7C	0.0 ± 0.0A	19.9 ± 1.9B	1.6 ± 0.2B
4	liquid	no	1.3 ± 0.3A	11.3 ± 0.2A	1.5 ± 0.4B	20.0 ± 2.1B	0.0 ± 0.0A	61.0 ± 5.9A	5.7 ± 0.5A
5	substrate	yes	1.3 ± 0.2A	8.5 ± 0.3B	3.9 ± 0.1A	9.6 ± 0.5C	0.4 ± 0.4A	23.9 ± 1.7B	2.5 ± 0.1B
6	substrate	no	1.1 ± 0.1A	11.6 ± 0.1A	1.1 ± 0.1B	21.3 ± 0.6AB	0.0 ± 0.0A	63.9 ± 2.1A	5.8 ± 0.2A
Snapdragon 'Montego White'									
Treatment	**Silicon?**	***Pythium* Inoc?**	**Wilt Index**	**Height (cm)**	**Root Index**	**Root Length (cm)**	**Flower Number**	**Fresh Weight (g)**	**Dry Weight (g)**
1	no	yes	2.7 ± 0.4A	8.2 ± 0.4C	4.8 ± 0.2A	4.9 ± 0.4C	0.0 ± 0.0B	5.4 ± 0.6C	0.9 ± 0.1C
2	no	no	1.5 ± 0.5B	13.4 ± 0.9B	2.8 ± 0.2B	9.1 ± 0.6B	45.8 ± 11.4A	39.7 ± 6.6B	7.1 ± 0.2B
3	liquid	yes	2.5 ± 0.2A	7.1 ± 0.5C	4.9 ± 0.1A	4.5 ± 0.6C	0.8 ± 0.8B	4.0 ± 0.7C	0.7 ± 0.1C
4	liquid	no	1.0 ± 0.0B	15.4 ± 0.8A	2.3 ± 0.3C	9.5 ± 0.4B	58.2 ± 5.0A	46.8 ± 4.8AB	7.8 ± 0.2A
5	substrate	yes	2.5 ± 0.2A	7.4 ± 0.5C	4.8 ± 0.1A	5.4 ± 0.6C	1.0 ± 0.6B	4.0 ± 0.5C	1.0 ± 0.3C
6	substrate	no	1.0 ± 0.0B	15.2 ± 0.5AB	2.1 ± 0.1C	12.5 ± 1.1A	61.3 ± 3.3A	51.8 ± 2.2A	7.5 ± 0.2AB

Letters represent mean separation comparison based on Student's LSD. Within a column, treatments sharing the same letter are not significantly different from each other.

Figure 1. Representative New Guinea Impatiens plants taken from treatments 1 (left side) to 6 (right side). The 2nd, 4th, and 6th pots from the left were inoculated with *Pythium* four weeks prior to the photo. Pots 1 and 2 received no silicon, pots 3 and 4 received liquid potassium silicate in the irrigation water, pots 5 and 6 received substrate incorporated silicon.

Figure 2. Representative New Guinea Impatiens plants at experiment termination. Plants on the right were inoculated with *Pythium* 4 weeks prior to the photo; plants on the left side were not inoculated.

Figure 3. Representative Snapdragon plants at experiment termination. Plants in the bottom row were inoculated with *Pythium* 4 weeks prior to the photo. Plants in the top row were not inoculated. Within each row, the pot on the left did not receive silicon, the pot in the middle received liquid silicon, and the pot on the right received substrate incorporated silicon.

Figure 4. Representative Snapdragon plants at experiment termination. Plants on the right were inoculated with *Pythium* 4 weeks prior to the photo, plants on the left side were not inoculated.

Discussion and Impact

In this experiment, silicon did not significantly improve the performance of New Guinea Impatiens or snapdragon plants. There may be several causes of the lack of silicon impact:

1) The conditions of the experiment i.e. challenging individual plants with a fairly virulent strain of *Pythium* and at only 2 days after planting, may have been too stressful. Perhaps Si may provide some benefits to NG Impatiens or snapdragon, but not under the severely stressful conditions of the experiment: lower rates of inoculum or inoculation of older plants should be tested. With a lower level of *Pythium* inoculum more typical of contamination in a greenhouse, perhaps silicon would be able to delay disease symptoms or decrease their severity: this hypothesis should be tested.

2) The specific application methods or doses of silicon may not have been enough to cause *Pythium* tolerance in our experiment. The rates used were similar to effective treatments used with other species and other disease organisms as recorded in the scientific literature, but perhaps these need to be adjusted for NG Impatiens and snapdragon.

3) NG Impatiens and snapdragons may indeed not respond to silicon in terms of their susceptibility to *Pythium irregulare*. According to the scientific literature, silicon does not improve disease tolerance of all plants in response to any disease organism. Cavins et al. (2010) reported that liquid potassium silicate decreased incidence of another water mold, *Phytophthora*, in Gerbera plants. However silicon delayed *Phytophthora* symptoms only during an initial 10 day period: by 14 days post-inoculation silicon plants were as diseased as untreated plants. In our experiment, snapdragons exposed to liquid or substrate silicon and to *Pythium* were less wilted than their untreated counterparts 10 days after inoculation; however, the results were not statistically different from plants not receiving silicon (Table 1). By 17 days post-inoculation plants were equally wilted.

There does appear to be some promise for silicon in snapdragon. For plants not infected with *Pythium*, silicon improved the fresh weight, root length, and root index compared to plants not receiving silicon. The wilt index results indicate that silicon may delay early responses to *Pythium*: more experimentation is necessary to reproduce and understand this phenomenon. It's possible that silicon could be a tool to delay *Pythium* infection slightly, which would increase the window of time that a grower has to detect and solve the problem. That positive results with silicon have been found for *Pythium* tolerance in cucurbits supports the need to further screen a variety of plant materials for any silicon benefits. We estimate the cost of the silicon material in this experiment to be 2¢ per pot for the liquid potassium silicate and 0.2 ¢ per pot for the powdered form incorporated into the substrate. In the end silicon may be found to be a low-cost product adopted by some growers as “insurance” to reduce low-level disease incidence. The fact that potassium silicate is made from naturally occurring compounds and that the liquid form is now eligible for organic production underscores the need for more silicon research for organically produced transplants.

A final benefit of this project was developed from collaboration between the project leaders. This is the first time they have worked together on a research project involving the intersection of plant mineral nutrition and diseases. Further, the *Pythium* culture system developed by M. Daughtrey was found to be useful experimentally: the strain was able to infect both NG Impatiens and snapdragons. Snapdragons, known to be very susceptible to *Pythium,* expressed infection symptoms within a week of inoculation, while NG Impatiens required 3-4 weeks to show clear infection. The experimental culture system would be useful for future work among the project leaders, such as testing other materials or cultural practices.

Project Location

The greenhouse project was conducted at the Kenneth Post Lab greenhouses at Cornell University. The *Pythium* cultures were prepared in the lab of M. Daughtrey at the Long Island Horticultural Research and Extension Center.

Project findings are applicable to greenhouse bedding plant producers nationwide.

Samples of Resources Developed

A fact sheet prepared as part of a related New York Farm Viability Institute project on silicon and poinsettias is available online at:

http://www.greenhouse.cornell.edu/crops/factsheets/silicon_poinsettia.pdf

The fact sheet provides introductory information on silicon and application information applicable to this project. It is planned that the fact sheet will be adapted to provide information specific to use of silicon on spring bedding plants.