Does silicon fertilization enhance creeping bentgrass resistance to insects?

Although silicon fertilizer may be beneficial to turf, it does not appear to make creeping bentgrass resistant to black cutworm or masked chafer grubs.

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Recently interest has grown in using silicon fertilization of turfgrasses to enhance plant performance and resistance to diseases and abiotic stress (1,3). Silicon is plentiful in most soils but is combined with other elements, forming insoluble silicates, so most of it is not in plant-available form (2). Plant-available silicon may be limiting in highly organic soils having little mineral matter and in soils that are heavily leached or that have high quartz sand content, conditions that may occur on greens, tees and other turfgrass sites (1).

Silicon fertilization may benefit turfgrasses by reducing water use, enhancing heat and drought tolerance, producing more erect growth with increased photosynthetic efficiency, promoting cleaner mowing cuts and making foliage less susceptible to fungal pathogens (1,3).

In some cases, the abrasiveness of silicon in plant cell walls may erode insects' mandibular teeth so that feeding ability is compromised and impaired growth or starvation ensues (6). However, when the silicon content of five species of potted warm-season turfgrasses was increased with applications of calcium silicate slag, the increase in silicon did not affect the growth and development of tropical sod webworms, *Herpetogramma phaeopteralis* (4).

No published studies have examined whether augmenting silicon enhances resistance to insects in cool-season turfgrasses. We tested that hypothesis in field and greenhouse trials using Penncross creeping bentgrass (*Agrostis stolonifera*) and the black cutworm, *Agrotis ipsilon*, a caterpillar that chews blades and stems. We also evaluated silicon fertilization effects on field densities of root-feeding masked chafer (*Cyclocephala* species) grubs.

Studies with field-applied silicon fertilizer

General materials and methods

Experimental field plots were Penncross creeping bentgrass grown on Maury silt loam (pH = 6.2) at the University of Kentucky Turfgrass Research Facility, Lexington. The turf was fertilized twice a year in October and December with 65.1 pounds/acre nitrogen from urea (73 kilograms/hectare), irrigated about 1 inch (2.5 centimeters) per week and mowed at 0.63 inch (16 millimeters) three times per week.

Does creeping bentgrass accumulate silicon?

To evaluate the capacity of creeping bentgrass to accumulate silicon, we applied a prilled calcium silicate fertilizer, Excellerator (39.3% total available silicon plus micronutrients), at the label rate (2,000 pounds of product/acre [2,242 kilograms/hectare]) and at one and a half, one-half and one-fourth times the label rate on April 19, 2005. Treatments included untreated controls. The 3-foot × 3-foot (0.91-meter × 0.91-meter) plots were in a randomized complete block with six replicates. Grass clippings (0.39 inch [1 centimeter] long; 0.35 ounce [10 grams] total wet weight) were harvested from the inner 5.4 square

To evaluate the capacity of creeping bentgrass to accumulate silicon, we applied a prilled calcium silicate fertilizer, Excellerator, to experimental plots at four different rates. **Photos by D. Potter**

feet (0.5 square meter) of each plot 30 days after treatment, dried at 104 F (40 C), and ground. Subsamples (100 milligrams) were autoclaved and analyzed for silicon.

As the level of silicon fertilizer was increased, leaf silicon content increased. Applications at the label rate increased leaf silicon content by 36.4%, and applications at one and a half times the label rate increased leaf silicon content by 40.3%.

Is silicon-fertilized grass unpalatable to cutworms?

Eight pairs of 6-foot × 6-foot (1.83-meter × 1.83-meter) plots were marked adjacent to the accumulation study in the same stand. One plot of each pair was treated with Excellerator at the label rate on April 19, 2005. Tillers were sampled 30 days after treatment and presented to first-instar black cutworms in choice tests to determine whether the larvae would avoid feeding on silicon-fertilized grass. For each replicate, six tillers, three each from treated and control plots, were arranged in an alternating, spokelike pattern on moist filter paper in petri dishes, and 10 larvae were added to each dish. Dishes were placed in a growth chamber, and numbers of black cutworms feeding on tillers were recorded after 24 hours. First instars did not discriminate between tillers from treated or untreated plots, causing comparable damage with a mean of 4.8 larvae feeding on treated tillers versus 4.3 on untreated tillers.

Is silicon-fertilized grass unsuitable for cutworms?

Starting 30 days after the field plots were treated, newly hatched black cutworms were reared on clippings from the plots used for choice tests to determine whether silicon fertilization reduced bentgrass suitability for growth and development. Initially 10 larvae per plot (160 total) were held individually in petri dishes and provided fresh clippings on moist paper every 48 hours. We measured larval weight and instar at seven and 14 days; pupal weight; days to pupation and moth emergence; and survival. We averaged the values for individuals reared on grass from a given plot and then compared the values for cutworms reared on treated and untreated grass. Silicon fertilization had little or no effect on grass suitability for black cutworm (Table 1).

Mandibular wear trial

For additional larvae concurrently reared on grass from the same plots, we measured the third mandibular incisor of 10 second instars and 10 sixth instars from each treatment. We found no excessive wear associated with feeding on silicon-fertilized grass.

Does silicon fertilization suppress white grubs?

Half of each treated plot was re-treated with Excellerator at half the label rate on July 20, 2005, to provide field plots that received one or two applications. Natural grub densities were sampled on Sept. 8, 2005. Sod strips, 3 feet × 1.5 feet (0.91 × 0.46 meter) and 2.4 inches deep (6 centimeters), were cut from both halves of each plot, and grubs were counted, identified and weighed. Samples from halves of each control plot were averaged, but portions of treated plots that received one or

Black cutworms vs. field plots

Parameter		Treated	Control
Larval weight (milligrams) attained by	7 days	15.9 ± 0.8	16.2 ± 0.6
	14 days	446 ± 17	484 ± 17
Larval instar attained by	7 days	3.9 ± 0.03	3.8 ± 0.05
	14 days	6.6 ± 0.1	6.7 ± 0.1
Days to reach	pupa	21.5 ± 0.2	21.4 ± 0.2
	adult	34.4 ± 0.2	34.2 ± 0.2
Pupal weight (milligrams)	females	519 ± 8	527 ± 6
	males	476 ± 13	479 ± 11
% survival	(to pupa)	87.5 ± 3.1	90.0 ± 2.7

Table 1. Mean weight, growth rate and survival of black cutworms reared on clippings from silicon-fertilized or nontreated creeping bentgrass field plots.

Masked chafer vs. silicon

Treatment plot	Masked chafer density/ 4.5 square feet	Masked chafer weight (milligrams)	Root silicon content (% dry weight)
Once-treated	11.7	367	7.0
Twice-treated	10.2	379	7.5
Control	8.3	390	6.5

Table 2. Density and grub weight of masked chafers were not affected by turf treated to augment plant silicon content. Root silicon content was also not elevated by the treatments.

Newly hatched black cutworms were reared on clippings from the plots used for choice tests to determine whether silicon fertilization reduced bentgrass suitability for growth and development.

two applications were considered separate treatments. Six core samples, 2 inches (5 centimeters) in diameter and 3 inches (8 centimeters) deep, were pulled from each plot concurrent with grub sampling and washed to remove soil. Roots were then cut off, dried, ground and analyzed for silicon content.

Density and grub weight of masked chafers, the predominant grubs present, were unaffected by silicon treatments, and root silicon content was not elevated by the treatments (Table 2).

Sodium silicate soil drench

Additional trials evaluated whether a silicon soil drench might be more effective than prilled calcium silicate for augmenting bentgrass resistance to black cutworm. Penncross bentgrass cores 7.9 inches (20 centimeters) in diameter and 4.7 inches (12 centimeters) deep were pulled from research plots in early December 2005, potted and grown in a greenhouse under sodium vapor lights to stimulate growth. They were watered every third day and cut at a height of 2 to 2.5 centimeters. Subdue GR (granular mefonoxem) at 12.5 ounces/1,000 square feet (3.82 grams/square meter) was applied once to discourage fungal diseases.

Treatment regimes (Table 3) were each replicated six times. Sodium silicate solution (14% NaOH, 27% SiO_2) was applied in 0.68 fluid ounce (20 milliliters) of water per pot. All treatments were applied to the surface and followed by 0.4 inch (1.0 centimeter) of irrigation.

Choice and rearing trials

At 35 days after treatment, harvested clippings were dried and analyzed for silicon content. At the same time, tillers harvested from each pot were presented to newly hatched black cutworms in paired choice tests, as above. Each treatment was tested versus untreated grass. Damaged tillers and larvae feeding on each tiller were counted after 24 hours.

A rearing trial, similar to the one for the field trial, also was initiated. Ten neonates were collectively reared on clippings from each pot. Survival, larval weight and instar were recorded after seven days. Because the quantity of grass clippings was limited, three representative larvae from each cohort (larvae whose weight deviated less than 10% from the group mean) were individually reared on clippings from that pot for another seven days, and weight and instar were recorded. Data were averaged to provide a single value per replicate pot and analyzed.

Low rates of sodium silicate produced a 2.4-fold increase in silicon content of bentgrass leaf blades, and high rates resulted in a five-fold increase (Table 4). Newly hatched black cutworms nevertheless did not discriminate between treated or untreated tillers. Mean numbers feeding on the respective choices were 3.7 and 4.8 for high silica (SiO_2) versus control, 4.7 and 3.7 for low silica versus control, 4.0 and 5.3 for Excellerator versus control. Numbers of tillers fed upon also did not differ (range, 2.0-2.7 out of 3 for all treatments).

Black cutworms fed clippings from pots drenched with sodium silicate gained less weight than controls during the first week, but there was high survival in all treatments, and differences were not significant by 14 days (Table 4).

Greenhouse study

Treatment	Silicon rate (grams/square meter)	No. weekly applications‡	Silicon/pot/ application (grams)	Total silicon/pot (grams)
Excellerator	88.0	1	1.76	1.76
Sodium silicate solution (low)†	10.0	4	0.05	0.20
Sodium silicate solution (high)	100.0	4	0.50	2.00
Control	—	—	—	—

†Contains 14% NaOH, 27% SiO_2.
‡First application Jan. 5, 2006; subsequent applications Jan. 12, 19 and 26, 2006.

Table 3. Silicon sources and amounts applied to pots of creeping bentgrass in the greenhouse study.

Black cutworms vs. greenhouse plots

		Larvae after 7 days			Larvae after 14 days	
Treatment	Foliar silicon (%)	Weight (milligrams)	Instar	% survival	Weight (milligrams)	Instar
High silica	2.5 ± 0.3 a	11.3 ± 0.8 a	2.7 ± 0.1 a	97 ± 2 a	256 ± 25 a	6.2 ± 0.2 a
Low silica	1.2 ± 0.1 b	13.9 ± 1.7 ab	2.9 ± 0.1 b	98 ± 2 a	278 ± 12 a	6.4 ± 0.2 a
Excellerator	0.7 ± 0.1 c	17.1 ± 1.4 bc	3.0 ± 0.0 b	97 ± 2 a	284 ± 29 a	6.4 ± 0.2 a
Control	0.5 ± 0.0 c	20.4 ± 1.9 c	3.0 ± 0.0 b	98 ± 2 a	320 ± 37 a	6.4 ± 0.2 a

Table 4. Mean weight, growth rate and survival of black cutworms reared on clippings from creeping bentgrass treated with sodium silicate soil drenches or prilled calcium silicate (Excellerator) in the greenhouse.

Treating turf with calcium silicate fertilizer did not affect the density and grub weight of masked chafers.

Mandible wear

Mandibles of larvae reared on silicon-augmented grass again did not show excessive incisor wear. No phytotoxicity was apparent three days after treatment, but by 35 days after treatment, some grass plants treated with the high-rate sodium silicate drench showed substantial yellowing and browning. We used only green, apparently healthy tillers in the bioassays.

Discussion and recommendations

Fertilizing with prilled calcium silicate increased foliar silicon content in our creeping bentgrass field plots by 36% to 40%, and sodium silicate soil drenches gave 2.5 to five-fold increases in the greenhouse. Our results differ from those of other researchers (7) who, on the basis of their finding that spray-applied potassium silicate did not affect leaf silicon in USGA sand-based putting greens, suggested that creeping bentgrass may be a silicon excluder. Foliar silicon in their untreated plots averaged 0.85% dry weight, compared to 0.57% in our control plots on silt loam soil.

In our study, black cutworms, a key pest of bentgrass putting greens and tees, suffered no reduction in their growth or survival after readily consuming foliage from field plots fertilized with calcium silicate. Masked chafer grubs also suffered no adverse effects on abundance or weight.

In our greenhouse trial, the growth of black cutworm maintained on grass with a high silicon content was initially retarded and could translate to higher mortality from invertebrate predators (for example, ants) that focus on early instars (5). However, larvae had compensated by 14 days. Because the high sodium-silicate rate caused some phytotoxicity, changes in leaf quality unrelated to silicon may have occurred in the apparently healthy tillers provided to the larvae.

In conclusion, although silicon doubtless contributes to the general structural defense of turfgrasses by lowering food quality for insects and other herbivores, our data suggest that augmenting silicon is unlikely to enhance resistance of creeping bentgrass to two of its major insect pests. Other researchers (4) have reached a similar conclusion for warm-season grasses and tropical sod webworms. Research concerning how silicon affects other grass species and insect feeding guilds (for example, stem-burrowers, sucking pests) is nevertheless warranted.

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The research says

→ We evaluated whether fertilization with silicon enhances resistance of Penncross creeping bentgrass to black cutworms and masked chafer grubs.

→ Prilled calcium silicate fertilizer (Excellerator) applied to fairway-height turf on silt loam soil elevated leaf silicon by as much as 40% without reducing palatability or suitability for cutworms.

→ Rates as high as 3,000 pounds of product/acre (3,363 kilograms/hectare) also did not reduce density or weight of naturally occurring chafer grubs.

→ Sodium silicate drenches that elevated leaf silicon content of greenhouse-grown bentgrass from 0.5% to 2.5% did not reduce cutworm feeding or survival and had only small effects on larval growth rates.

→ Our results suggest that silicon fertilization is unlikely to enhance creeping bentgrass resistance to key insect pests.