SHORT COMMUNICATION

Effects of Silicon on the African Stalk Borer, *Eldana saccharina* (Lepidoptera: Pyralidae) in Sugarcane

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Abstract

Sugarcane varieties, resistant and susceptible to *Eldana saccharina* Walker (Lepidoptera: Pyralidae) were grown in a pot trial, in silicon (Si) deficient river sand with and without calcium silicate as a source of silicon (Si). At nine months, the plants were artificially infested with *E. saccharina* and the larvae harvested seven (rind of sugarcane drilled; harvest 1) and 21 (rind not drilled; harvest 2) days after inoculation. For Harvest 2, fertilisation with Si significantly increased stalk length, total number of internodes, rind hardness and stalk mass for the susceptible variety N26 compared with the control. The same trend was observed for N11 (susceptible), N21 and N33 (both resistant), although differences in these varieties were not significant. The length of stalk bored was significantly less for the treated sugarcane compared with the control, although this was significant only for N26. Larvae were weighed prior to inoculation and at harvest. Mass of larvae at harvest was significantly less in N26 treated with Si compared with the control, and the same trend, although not significant, was recorded for N11, N21 and N33. Larval survival did not differ significantly between control and treatment (all varieties). Similar, but non-significant, trends were recorded for harvest 1. The application of Si shows a general trend of increased resistance of sugarcane to attack by *E. saccharina* consistent with the 'mechanical barrier hypothesis'.

Keywords: Eldana saccharina, calcium silicate, host plant resistance, mechanical barrier hypothesis, silicon, sugarcane.

Introduction

The sugarcane stalk borer, *Eldana saccharina* Walker (Lepidoptera: Pyralidae) is South Africa's major pest on sugarcane, costing the industry approximately R60 million during 2003-04, excluding losses due to early harvesting (Way, 2004). Grasses (Poaceae), to which family sugarcane belongs, display a number of characteristics that make the leaves and stems difficult to chew by both mammalian and insect herbivores. Many grasses are characterised by high levels of silica, the presence of which is thought to be partly due to selection pressure by herbivores, particularly grazing mammals (McNaughton and Tarrants 1983). Concentrations of 5% dry weight are common (McNaughton *et al.*, 1985) with dryland grasses such as wheat, rye, sorghum and sugarcane containing about 10 g/kg (Epstein, 1994, 1999; Jones and Handreck, 1967; Rodrigues *et al.*, 2001), with levels of up to 14% recorded in rice (Djamin and Pathak, 1967). In soil solution the range of Si concentration is generally 0.1-0.6 mM (Epstein 1994). Increasing evidence suggests that Si can enhance plant resistance to pests. For example, the application of silicon to corn plants increased the mortality and cannibalism of second instar larvae and mortality in sixth instar larvae of the fall armyworm, *Spodoptera frugiperda*, when fed on silicon-treated corn plant leaves (Goussain *et al.*, 2002). In this paper it is investigated, using potted sugarcane, whether Si increases mechanical resistance of external and/or internal stalk tissue of sugarcane to larval feeding by *E. saccharina*.

Methods

A total of 96 pots containing varieties N21, N33 (resistant) and N11, N26 (susceptible), treated (at 10 t/ha) and untreated with calcium silicate were set up in a shade house using a split-split plot design. At nine months, third instar *E. saccharina* larvae were placed onto the bud, root primordia or internode (referred to here as 'place') at each of three heights (top, middle and bottom) on two stalks per pot over a four-day period. For each harvest, only two varieties were inoculated each day, as the exercise was labour intensive. Eppendorph vials with the tips removed were used to restrict larval stalk penetration to the chosen place.

An additional treatment to bypass a possible Si layer in the stalk epidermis (i.e. Si 'barrier') and to therefore test for its effect on stalk penetration and larval performance in Si-treated plants, involved boring a small, shallow hole in the rind at the point of placement of vials. For the buds, the entire bud was removed. Artificially bored plants were harvested seven days ('harvest 1') after larval inoculation, and unbored (intact) plants at 21 days ('harvest 2'). The mass gain, survival, frequency of stalk penetration, and length of boring of individual larvae were recorded for all pots at each harvest. Soil and leaf samples were taken on four separate dates, approximately three months apart, and analysed for Si and pH. Stalk samples for Si analysis were taken at the time of harvest. Si and pH analysis employed standard techniques used by the Crop Nutrition and Soils Department at the South African Sugarcane Research Institute.

Results and Discussion

Analysis of the stalk Si content for harvest 1 (Figure 1) and harvest 2 (Figure 2) showed that, within each variety, stalk Si content was significantly higher in Si-treated plants than in controls (Holm-Sidak test; p<0.05).

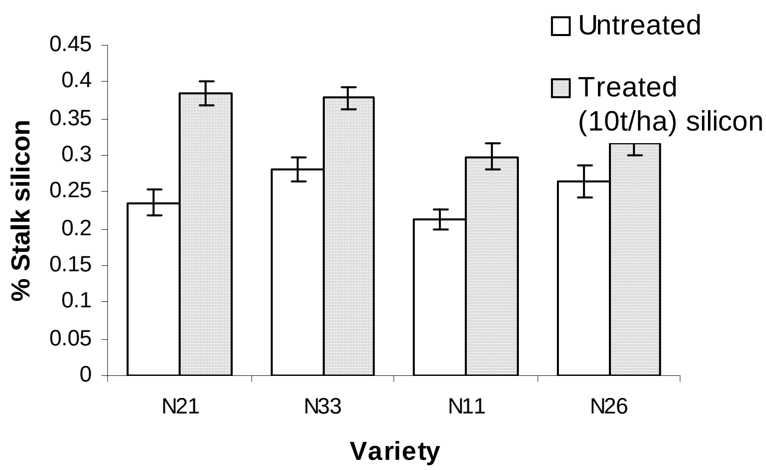

Figure 1. Percentage of stalk Si of four varieties of sugarcane, treated and untreated with Si, at age 9 months for the 7-day harvest (artificially bored plants). Bars are SE.

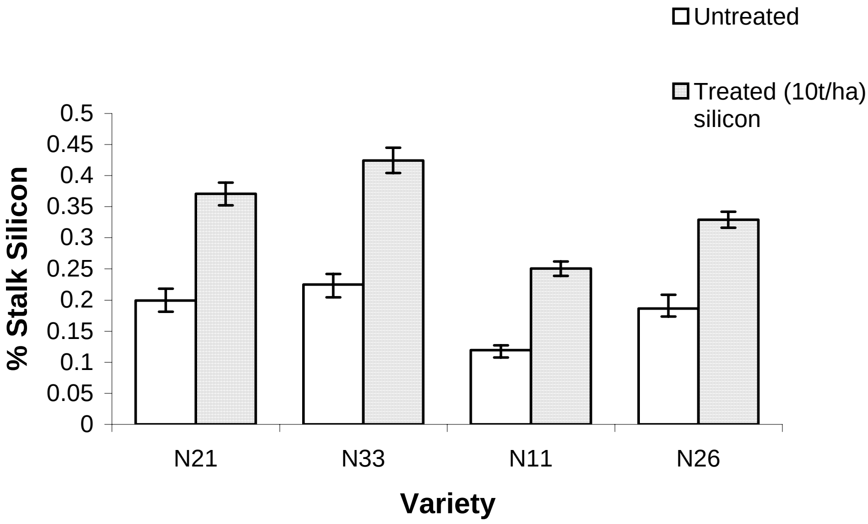

Figure 2. Percentage of stalk Si of four varieties of sugarcane, treated and untreated with Si at age 9.5 months for the 21-day harvest (unbored plants). Bars are SE.

For harvest 1, a general, but non-significant, reduction in mass gain (larval weight at harvest minus larval weight at inoculation) and boring length in artificially bored Si-treated plants compared with artificially bored controls (no Si) was evident for all varieties. This indicates a general reduction in internal feeding efficiency due to Si (i.e. Si deposited in internal stalk tissues).

For harvest 2, a general reduction in larval mass gain in Si-treated (unbored) plants compared with controls was evident for all varieties, although the difference was significant only for N26 (LSD; $p<0.05$). The same trend was evident for boring length, and again significant only for N26 (LSD; $p<0.05$). This suggests a combined external and internal reduction in feeding efficiency due to Si.

Across both harvests, larvae that fed on untreated sugarcane gained significantly more weight than those that fed on Si treated sugarcane (ANOVA; $p<0.05$). Similarly, length of stalk bored was significantly less in Si-treated cane compared with controls across both harvests (ANOVA, $P<0.05$). Across both harvests, there was a significant effect of 'place' on larval weight gain, which decreased from root primordia through bud to internode (ANOVA, $p<0.05$). Similarly, length of stalk bored was significantly greater (ANOVA, $p<0.05$) across both harvests in the bud and root primordia compared with the internode.

There was no significant difference in larval survival for harvest 1 at the three points of placement on the stalk (internode, bud, root primordia; $\chi^2=2.64$, $P=0.27$, df=2). For harvest 2, successful larval boring was dependent on point of placement of larvae ($\chi^2=39.48$, $P<0.001$, df=2). The number of larvae boring into the stalk was significantly lower than expected for the internode and significantly higher than expected for both bud and root primordia. For harvest 2, significantly more larvae survived on both the bud and root primordia than expected, while significantly less survived on the internode ($\chi^2=24.8$, $P<0.001$, df=2). This demonstrates that the internode is more difficult for larvae to penetrate, and that the root primordia and bud are more favourable for larval penetration and survival.

Djamin and Pathak (1967) found that rice grown in silica impeded feeding and boring by *Chilo suppressalis*, and reduced larval survival and number of dead hearts. Moreover, mandibles of larvae fed on a variety with high silica content were severely worn compared with those that fed on a low silica variety. The same authors also found that among five day old larvae caged on the node of the rice stem, 71% bored into a high silica content variety compared with 96% on the low silica content variety. On the internode, 0.4% of larvae bored into the high silica content variety compared with 17.5% for the low silica content variety (Djamin and Pathak 1967). As in the current study, this demonstrated that Si can form an external barrier in the plant that reduces the success rate or speed of larval stalk penetration. In concurrence with *E. saccharina* in sugarcane, Djamin and Pathak (1967) also found that in both varieties, larvae penetrated the nodal area more readily than the internode. Generally less silica was found in the nodal area than the internodal area (Djamin and Pathak 1967).

Si application has also decreased borer survival in sugarcane elsewhere in the world. For example, in Florida, fewer *Diatraea saccharalis* larvae were recovered from Si-treated sugarcane cultivars compared with untreated controls (Anderson and Sosa, 2001).

Contrary to the findings of the present and other studies, Korndorfer *et al.* (2004) found no effect of Si application to five species of turfgrass on larval weight of the tropical sod webworm, *Herpetogramma phaeopteralis*, after four days of feeding. However, the authors highlighted that the insect-plant-Si response is complex and not always predictable, a point that undoubtedly applies in the *E. saccharina*-sugarcane-Si interaction.

REFERENCES

Anderson DL and Sosa O Jr (2001). Effect of silicon on expression of resistance to sugarcane borer (*Diatraea saccharalis*). *J Am Soc Sug Cane Technol* 21: 43-50.

Djamin A and Pathak MD (1967). Role of silica in resistance to Asiatic rice borer, *Chilo suppressalis* Walker, in rice varieties. *J Econ Entomol* 60: 347-351.

Epstein E (1994). The anomaly of silicon in plant biology. *Proc Nat Acad Sci USA* 91: 11-17.

Epstein E (1999). Silicon. *Ann Rev Plant Physiol & Plant Mol Biol* 50: 641-664.

Goussain MM, Moraes JC, Carvalho JG, Nogueira NL and Rossi ML (2002). Efeito da aplicacao de silicio em plantas de milho no desenvolvimento biologico da lagarta-do-cartucho *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae). *Neotropical Entomology* 31: 305-310.

Jones LHP and Handreck KA (1967). Silica in soils, plants and animals. *Ad Agron* 19: 107-149.

Korndorfer AP, Cherry R, and Nagata R (2004). Effect of calcium silicate on feeding and development of tropical sod webworms (Lepidoptera: Pyralidae). *Fla Entomol* 87: 393-395.

McNaughton SJ and Tarrants JL (1983). Grass leaf silification: natural selection for an inducible defense against herbivores. *Proc Nat Acad Sci USA* 80: 790-791.

McNaughton SJ, Tarrants JL, McNaughton MM, and Davis RH (1985). Silica as a defence against herbivory and as a growth promoter in African grasses. *Ecology* 66: 528-535.

Rodrigues FÁ, Korndörfer GH, Corrêa GF, Buki GB, Silva OA, and Datnoff LE (2001). Response of six gramineae species to application of calcium metasilicate. Page 378 in: Silicon in Agriculture. LE Datnoff, GH Snyder and GH Korndörfer (Eds) *Studies in Plant Science*, Vol. 8. Elsevier Science BV, Amsterdam, The Netherlands.

Way MJ (2004). Annual Local Pest, Disease and Variety Control Committee Pest Report. South African Sugarcane Research Institute, Mount Edgecombe, South Africa.