

Silicon shows promise for Fusarium wilt suppression

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The Fusarium wilt pathogen can survive for several decades in soil and once a farm is infested with Fov there is no commercially viable way to eliminate the pathogen from the soil. The fungus can infect cotton at all stages of growth and produces symptoms which include wilting, foliar chlorosis, vascular discolouration and plant death.

Fusarium wilt has caused severe losses in some districts, with loss estimates of \$57 million on the Darling Downs alone during the 1999–2000 season. Many industry personnel consider the disease to be the most significant recent constraint to sustainable cotton production.

Integrated control strategies have been devised that reduce the impact of Fusarium wilt. A combination of practices can help combat the disease:

- Using the most resistant varieties available;
- Limiting build up of the pathogen through agronomic practices (such as crop rotation, controlling weeds, planting later to avoid cold shock conditions); and,
- Keeping machinery and vehicles that enter or leave the farm free from mud or crop debris which could carry the fungus to clean ground.

We are currently investigating new strategies to control Fusarium wilt by using activators that stimulate the expression of natural defence reactions in plants. Linda Smith, in collaboration with Dr Elizabeth Aitken (University of Queensland), has shown that the application of potassium silicate to micropropagated bananas significantly increases the activity of the defence related enzyme chitinase, and reduces the severity of Fusarium wilt caused by the fungus *Fusarium oxysporum f. sp. cubense*.

Chitinases are enzymes that break down chitin, a structural component of the cell wall of pathogenic fungi, and are released by many plants as part of their defence mechanism against various pathogens.

Silicon (Si) is an important constituent of plants, comprising 0.1–15 per cent of plant dry matter. Some plants are regarded as 'high' accumulators (rice, sugarcane and cucurbits) as they contain at least 10 per cent silicon on a dry weight basis.

Beneficial effects on growth from silicon fertiliser have been reported for rice, sugarcane, wheat, barley and cucumber. Like most dicotyledons, cotton would be regarded as a 'low' silicon accumulator (less than one per cent silicon).

In China, the application of silicon fertiliser at the squaring and flowering stage of cotton was found to be beneficial. Squaring, cotton bolls per plant, boll weight and yield were improved in a high temperature and drought environment.

Silicon is taken up as silicic acid ($\text{Si}(\text{OH})_4$) by the root system of higher plants and moves upwards in the transpiration stream to sites of strong evapotranspiration where it is transformed into insoluble polymers. Once polymerised, silicic acid is no longer available as a source of silicon for any other part of the plant.

Improved resistance to disease and pathogenic fungal attack due to Si applications has been reported for a number of crops. As most parasitic fungi penetrate the host by boring through the epidermal cell wall, Si in these walls may act as a mechanical barrier.

Recent research indicates that the production and accumulation of antifungal phenolic compounds (including lignin) and activation of defence related enzymes



Glasshouse bioassay showing six week old untreated seedlings of Siokra 1–4.



Range of nutrient toxicity symptoms from the application of potassium silicate (40 ml/L) compared with an untreated plant (right).

(chitinase and 1,3-glucanase) may also be involved.

In addition to decreased susceptibility to fungal pathogens (and insects), the beneficial effects of adequate Si include reduced manganese and iron toxicity, reduced salinity and water stress, protection of leaves from ultraviolet radiation damage and increased growth in some plants.

Spore germination and growth rate of Fov

In the laboratory at Indooroopilly we mixed a conidial suspension of Fov with various rates of potassium silicate (0, 0.1, 0.25, 1, 5, 10 and 20 ml/L) and spread spores onto solid growth media. After five days, germination and growth were examined.

It appears that spore germination was not prevented, but growth rate of the pathogen was reduced at the higher rates (five, 10 and 20 ml/L). There was no effect at the lower rates. It is not known if the suppressive effect on fungal growth observed in this plate assay also occurs in the soil.

TABLE 1: The effect of potassium silicate (SiO₂-K₂O) and potassium sulphate (K₂SO₄) on infection of *Fusarium oxysporum* f. sp. *vasinfectum* in Siokra V17

Treatment	Vascular browning ^{AC}	% Seedlings infected ^{BC}	% Rating 0 & 1 ^{BC}
Control	1.8 c	63 (0.9) c	66 (0.9) a
5 g/L K ₂ SO ₄	0.6 ab	41 (0.7) bc	90 (1.5) abc
0.25 mL/L SiO ₂ -K ₂ O	0.9 abc	33 (0.6) ab	71 (1.0) ab
2 mL/L SiO ₂ -K ₂ O	1.3 bc	43 (0.7) bc	71 (1.0) a
5 mL/L SiO ₂ -K ₂ O	0.2 a	11 (0.3) a	93 (1.3) bc
10 mL/L SiO ₂ -K ₂ O	0.2 a	21 (0.5) ab	99 (1.5) c

A = Vascular browning where 0 = no infection, 1 = base of stem infected below soil level, 2 = infection up to node 0, 3 = infection above node 0, 4 = infection up to top node and 5 = dead plant.

B = Number in parentheses are transformed percentage data.

C = Data followed by the same letter are not significantly different from one another.

GLASSHOUSE BIOASSAYS

Glasshouse experiments were conducted to examine the effect of potassium silicate on disease development. In the initial experiment, seed of the highly susceptible cultivar Siokra 1-4 was sown into seedling flats filled with pasteurised potting mix. Seedlings were drenched weekly with potassium silicate at 10, 20 and 40 ml/L or left untreated.

After two applications of potassium silicate at 40 ml/L, signs of nutrient toxicity were observed and these plants were excluded from the trial. After five weeks, the remaining seedlings were transplanted into 20 cm pots containing pasteurised potting mix that had been inoculated with Fov colonised millet.

After two weeks, typical symptoms of *Fusarium* wilt were clearly seen in the untreated control treatment. Very little wilting was observed in plants treated with silicon, particularly at 10 ml/L. When plants were harvested, roots of silicon treated plants were white and healthy, whereas roots of the untreated control plants were much thinner and darker in colour.

When examined internally, vascular discolouration was significantly reduced in plants treated with all rates of silicon. These results were very encouraging, particularly since disease suppression was observed in a cultivar that is highly susceptible to *Fusarium* wilt.

As mentioned previously, nutrient toxicity was observed in seedlings treated with 40 ml/L of potassium silicate. Symptoms included plant death, stunting and development of brown necrotic lesions on cotyledons and first true leaves.

Silicon is known as an element that does not cause severe injury to plants when

present in excess. So the nutrient toxicity observed is most likely due to excessive potassium.

It is not known at this stage the quantity of Si that is required for disease control and further work is required to determine this. Some researchers suggest that there exists a threshold level of Si needed for enhancing host resistance, beyond which application of Si will have no further effect on reducing disease.

A second glasshouse bioassay was conducted to investigate the potential of Si to reduce disease severity in field soil naturally infested with Fov. Field soil was collected from Graham and Wendy Clapham's property near Cecil Plains in Queensland and mixed 50:50 with sand.

Two cultivars were examined — the highly susceptible cultivar Siokra 1-4 that

had been used previously and the more resistant cultivar Siokra V17. Seeds were sown directly into seedling flats filled with the soil mix and covered with vermiculite to reduce moisture loss.

Seedlings received weekly application of potassium silicate at the rates of 0.25, 2, 5 and 10 ml/L. The untreated control treatment consisted of seedlings drenched with water only. It is possible that both elements in potassium silicate are involved in disease suppression.

It has been reported that the severity of most diseases caused by *Fusarium oxysporum* were reduced by the addition of potassium, but in cotton there were conflicting reports. So potassium sulphate was included as an additional control treatment to examine the potential of potassium to reduce disease severity.

Results of the glasshouse bioassay showed that although potassium silicate reduced disease severity in Siokra 1-4 when grown in pasteurised potting mix, in field soil none of the treatments reduced disease severity in this cultivar after six weeks.

After nine weeks, Siokra V17 was harvested and disease severity was assessed. Results were very encouraging as potassium silicate significantly reduced vascular browning and percentage of seedlings infected with Fov, and increased the percentage of seedlings with low disease ratings when applied at 5 and 10 ml/L.

But at 10 ml/L plants, showed signs of potassium toxicity such as small and distorted leaves, some with necrotic patches.

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Interestingly, vascular browning was significantly reduced following weekly application of potassium sulphate, but there was no effect on percentage of seedlings infected or percentage of low disease rating plants (Table 1). These results suggest that both Si and potassium may play a role in disease suppression in cotton.

Results of the glasshouse experiments have encouraged us to investigate the potential of Si (and potassium) to reduce disease under commercial field conditions. In October 2004, a field trial commenced on Graham and Wendy Clapham's property investigating the potential of various silicon products and potassium sulphate to reduce severity of Fusarium wilt. The trial is due for harvest in April-May this year when disease severity, yield and quality of cotton will be assessed.

For the successful adoption of silicon for disease control in cotton, further study is required. We need more detailed knowledge of the following:

- Is Si being deposited in the epidermal cell walls of cotton roots and acting as a physical barrier to Fov? Or does it have an active role by being able to stimulate the natural defence mechanisms (phenolics, plant resistant proteins) in cotton?
- Information on what source of Si yields the best results and how best to apply it.



Reduced growth rate of Fov after five days when a conidial suspension was mixed with potassium silicate at five, 10 and 20 ml/L and spread onto solid growth media. There was no effect at 0.1, 0.25 and 1.0 ml/L compared to the untreated control.

If Si is playing an active role in inducing resistance, a continuous feeding of the element in the soluble and mobile state (monosilicic acid) may be necessary. Will slow release formulations applied at sowing provide sufficient silicon over a

long enough period for disease control? Will foliar applications of soluble Si control soil-borne diseases?

- What rate to apply. In this study Si was applied weekly as a drench. This may not be practical or appropriate in the field. We do not know how well Si is absorbed through the roots and where it is deposited and in what quantities.

Once we have acquired this knowledge there is the possibility that Si could be added to the integrated disease management program for cotton to further enhance host plant resistance.

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We thank CRDC for funding this research. We particularly thank Graham and Wendy Clapham for their continued support and use of their property for trials and providing soil for glasshouse bioassays. We thank John Marsden of PQ Australia Pty Ltd for supply of the potassium silicate.



Reduction in disease severity in seven-week-old seedlings treated with potassium silicate. The seedlings on the left received a weekly application of potassium silicate (10 ml/L), while the seedlings on the right were untreated.