The benefits of silicon fertiliser for sustainably increasing crop productivity

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1. Introduction

Silicon (Si) exists in all plants grown in soil and its content in plant tissue ranges from 0.1 to 10% (Epstein, 1999). While its essentiality in plant growth has not yet been clearly established, Si is considered a nutrient of agronomic essentiality for high Si-accumulating crops such as rice and sugarcane, in that its absence causes imbalances of other nutrients resulting in poor growth, if not death of the plant (Savant et al, 1999).

Numerous laboratory, greenhouse and field experiments have shown the benefits of silicon fertilisers for agricultural crops and the importance of silicon fertilisers as a component in sustainable agriculture (Belanger et al, 1995; Laing et al, 2006; Ma and Takahashi, 2002, Matichenkov and Calvert, 2002). The beneficial effects of Si are mainly associated with its high deposition in plant tissues, enhancing their strength and rigidity. This increased mechanical strength reduces lodging and pest attack and increases the light-receiving posture of the plant, increasing photosynthesis and hence growth (Epstein, 1999). The deposition of Si in the culms, leaves and hulls is also purported to decrease transpiration from the cuticle thereby increasing resistance to low and high temperature, radiation, UV and drought stress (Ma et al, 2006). Indeed, the beneficial effect of Si is more evident under stress conditions. More recent studies suggest that Si also plays an active role in the biochemical processes of a plant and may play a role in the intracellular synthesis of organic compounds (Fawe et al, 1998; Ma et al, 2006).

Plants differ in their ability to accumulate Si (Ma et al, 2006) but in order for any plant to benefit from Si it must be able to acquire this element in high concentrations. Plants can only absorb Si in the form of soluble monosilicic acid, a non-charged molecule. Monosilicic acid, or plant available silicon (PAS), is a product of Si-rich mineral dissolution (Lindsay, 1979). Different Si sources have different dissolution rates (and therefore PAS); where the solubility of quartz is very low compared to soluble amorphous silica (Savant et al, 1999).

The presence of Si in nutrient solutions has also been reported to affect the absorption and translocation of several macro- and micro-nutrients (Epstein, 1999). More recently, Si-amendments were shown to reduce the leaching of phosphate, nitrate and potassium (NPK) (Matichenkov and Bocharnikova, 2010). This is of particular importance in Australia where leached phosphates and nitrates promote eutrophication in the Great Barrier Reef and Western Australian waterways. Nutrient leaching also results in soil nutrient deficiencies that require additional fertilisation. Given that the leaching of NPK fertilisers poses a significant environmental and economic concern, Si-amendments that are able to mitigate these risks are worthy of further investigation.

To date, a large amount of the reported research, field trials and commercial applications have been with calcium silicate slags, an easily obtained by-product of furnaces. Silicate slag has been used extensively in the USA; however, slags can be variable in composition and although they have high concentrations of total Si, often only a small proportion is easily solubilised (Gascho, 2001). An important consideration with silicate sources derived from industrial by-products is the possible high level of heavy metals associated with their origin or processing (Berthelsen et al,
2003). These are not only toxic to plants but leach into waterways causing environmental damage. Likewise, cement and cement building board waste can contain heavy metals (Muir et al, 2001).

Amorphous diatomaceous earth (DE) is known to be a good source of plant available silicon as amorphous silica is more easily solubilised than crystalline silica. Amorphous DE is also expected to exhibit soil-conditioning properties given its high water holding capacity, without the heavy metal contaminants of slags. The purpose of the analyses and trials presented here is to understand the efficacy of AgriPower Silica (which is rich in DE) in soil fertility and as a sustainable soil conditioner, while reducing the negative impacts of chemical fertilisers on the environment.

Gascho (2001) postulated that before a Si amendment can be considered useful for agricultural applications it should meet a number of criteria, such as solubility, availability, suitable physical properties and be free of, or have acceptably low levels of contaminants. AgriPower Silica meets these four criteria.

Furthermore, we set out to create a product with an enhanced level of plant available silicon and achieved this by creating an Enhanced Agripower Silica. This green Si amendment delivers a high level of plant available silicon while maintaining suitable physical characteristics (granular or powder and easy to apply) with none of the contaminants of heavy metals and cristobalite which are often present in silicate slags.

2. AgriPower Silica

AgriPower Silica is mined and processed in Australia and largely comprises the silica-rich Diatomaceous Earth (DE). Diatomaceous Earth is a naturally occurring substance, the fossilized remains of salt or freshwater organisms called diatoms. Diatoms are predominantly composed of amorphous Silica (SiO₂). The fossilised skeletal remains (a pair of symmetrical shells – frustules) vary in size but are typically 10 to 200 microns across and have a broad variety of shapes, from needles to discs or balls. The frustules present in AgriPower Silica has the ideal barrel shape (see Figure 1 below). The morphology and porosity of the DE present in AgriPower Silica are attributed with enabling large amounts of moisture to be absorbed from its surroundings.

Figure 1: Scanning electron microscopy images of samples of Agripower Silica showing the morphology of individual diatoms
Being free of crystalline silica (cristobalite) is an important consideration when sourcing DE products. It is often a specification required by occupational, health and safety (OH&S) regulations as the inhalation of crystalline silica is a health hazard for the lungs causing the deadly disease; silicosis.

Soon to be the largest producer of freshwater diatomaceous earth, Agripower sources their diatomaceous earth from its deposits that are free of cristobalite. Quantitative X-Ray Diffraction Analysis performed independently by AGR Science and Technology Pty Ltd confirmed that cristobalite was not present.

2.1 Soil Conditioning Properties

The soil conditioning properties of AgriPower Silica were evaluated in four different soils (in triplicate): clay, sand, potting mix and turf substrate. Containers were charged with these soils and AgriPower Silica was added at increasing concentrations: 0 (control), 3, 5 and 10% (Sadgrove, 2006):
2.1.1 Soil nutrient properties

The containers were pre-charged with a standard nitrogen, potassium and phosphorous fertiliser product followed by a standard application of water that was passed through each container at specific sampling intervals. The leachate volumes were analysed and subtracted from the total nutrient load in order to determine nutrient losses. It was found that AgriPower Silica facilitated a significant improvement in nutrient retention compared to the control in all soil types. Results for all four soils are shown in Figure 3:

![Figure 3: Percentage increase in nutrient retention above the control (at day 7) for soils amended with 5% Agripower Silica [measurements taken of the leachate using the Modified Morgan Technique]](image)

Figure 3 shows that there is an increase in the retention of all three nutrients (potassium, nitrate and phosphate) in all four soils amended with 5% AgriPower Silica. Sandy and deeply weathered soils usually have a low nutrient retention (Sims et al., 1998) therefore the increased retention of nutrients in the sandy soil due to the inclusion of AgriPower Silica is impressive.

It is well known that diatomaceous earth, a large constituent of AgriPower Silica, has a good cationic exchange capacity, and its this capacity which is attributed with retaining the cations; potassium and ammonium.

The improved retention (reduced leaching) of phosphate could potentially be attributed to the action of several mechanisms; including the formation of a complex between the phosphate ion and surface hydroxyls of the amorphous silica (Leung and Kamara, 1998).

The improvement in nutrient retention in various soils by AgriPower Silica demonstrated in Figure 3 has significant implications for reducing the environmental and economic impact of leached nutrients.
2.1.2 Soil moisture properties

Various cycles of watering and drying were executed using the same configuration as in Figure 2. Table 1 shows the moisture content of each soil type, as a percentage of the control.

Table 1: Percent moisture content compared to the control as a function of percent AgriPower Silica after 11 days drying phase

<table>
<thead>
<tr>
<th></th>
<th>Potting Mix</th>
<th>Clayey Soil</th>
<th>Turf Substrate</th>
<th>Sandy Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>105</td>
<td>103</td>
<td>158</td>
<td>101</td>
</tr>
<tr>
<td>5</td>
<td>104</td>
<td>84</td>
<td>203</td>
<td>116</td>
</tr>
<tr>
<td>10</td>
<td>114</td>
<td>91</td>
<td>274</td>
<td>141</td>
</tr>
</tbody>
</table>

In the potting mix, the turf substrate and sandy soil; moisture retention significantly increased with AgriPower Silica. In contrast, the clayey soil showed a decrease in retained moisture. The sandy soil and turf substrates improved the moisture retention by up to 41% and 174%, respectively.

During the 11 days of drying, the moisture content of each soil decreased at a similar rate and AgriPower Silica had the lowest percent moisture loss throughout the 11 days of drying, even though it held the greatest quantity of water.

In summary, AgriPower Silica improved water retention in two ways:

1) During watering events soils with AgriPower Silica held a greater bulk quantity of water, and
2) Soils with AgriPower Silica dried at a slower rate.

These relationships were proportional to the amount of AgriPower Silica that was added to the soil.

2.2 Plant available Silicon properties

With the recognition that Si is an important element for the growth of plants, many methodologies have been used to determine the plant available Si of Si amendments, although there has been no systematic survey of these methodologies (Sauer et al, 2006). The chemical extractant methods used to estimate the PAS of the Si source often do not correlate well with the plant uptake of Si once applied to the soil therefore it is important to carefully select the extraction method.

Three commonly used extractants were used to measure the extractable Si of AgriPower Silica and other Si amendments:

- Alkaline extractant: NH₄NO₃ and Na₂CO₃ (Pereira et al, 2003)
- Acid extractant: 0.005M H₂SO₄ (described in Berthelsen et al, 2001)
- Neutral extractant: 0.01M CaCl₂ (described in Berthelsen et al, 2001)

The extractions were carried out at different extraction ratios as the availability of monosilicic acid (PAS) varies with dilution, a soil phenomenon attracting much attention in the literature.

The various Si amendments that are discussed later in this article are compared in Figures 4, 5 and 6 below via these three different extraction techniques. The description of the Si amendments is given below:
Table 2: Description of products analysed in Figures 4-7

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Lab grade calcium silicate</td>
<td>Riedel-de Haën product 13703</td>
</tr>
<tr>
<td>Slag 2</td>
<td>Phosphorous furnace byproduct</td>
</tr>
<tr>
<td>Enhanced AgriPower Silica</td>
<td>Described in following section</td>
</tr>
<tr>
<td>Slag 1</td>
<td>Sourced from Asia</td>
</tr>
<tr>
<td>AgriPower Silica</td>
<td>Described in preceding section</td>
</tr>
<tr>
<td>Wollastonite</td>
<td>A natural calcium silicate</td>
</tr>
</tbody>
</table>

An acid extraction was carried out on all the Si amendments listed in Table 2, given its historic popularity as a chemical extractant:

The sulphuric acid (H$_2$SO$_4$) attacks silicates, dissolving calcium silicates and any clay minerals present in the sample or soil. Sauer et al (2006) also suggests that this extractant acts both mechanically and chemically so that levels of plant available Si are highly overestimated. Therefore it is not surprising that the slags show such high extractable silicon via this method compared to the AgriPower Silica given that calcium silicates are soluble in acid, however, this level of extractable silica is unlikely to be indicative of the plant available silicon.
An alkaline extraction was also performed on these same Si amendments, following the method of Pereira et al (2003):

Figure 5: mg Si extracted per kg product by alkaline extraction as a function of extraction ratio for various Si amendments

The method of Pereira et al (2003) was developed for measuring extractable silica from calcium silicate, where slag was one of the test products. Therefore not surprisingly the pure, lab grade calcium silicate shows the highest level of extractable silicon, followed by the Enhanced AgriPower Silica product and the other Si amendments.

And finally, extractions were performed using a neutral extraction of 0.01M CaCl₂:

Figure 6: mg Si extracted per kg product by neutral extraction as a function of extraction ratio for commonly used extractants
In order to focus on the Si amendments of practical relevance, the scale of Figure 6 was adjusted, which excludes the data points for the lab grade calcium silicate (the extractable Si of the lab grade went from 7,400 mg Si/kg product at an extraction ratio of 100 to 59,300 mg Si/kg product at an extraction ratio of 980).

The Enhanced AgriPower Silica yields the highest extractable silica of the Si amendments, followed by AgriPower Silica. The two slags and the wollastonite have significantly lower levels than these two products across all the extraction ratios.

The neutral extraction method measures the easily soluble silica and is therefore cited as being a closer approximation to plant available silicon compared to the other methods (Sauer et al, 2006 and Berthelsen et al, 2001).

Figures 4 to 6 clearly demonstrate that is important to carefully choose the extraction method as the extraction process itself may solubilise more Si compounds in the Si amendment and/or soil than usually available to plants in the natural environment (Muir et al, 2001). Also, Figures 4 to 6 demonstrate the variability in extractable Si that is possible between slags of different sources.

The neutral extraction result in Figure 6 confirms that AgriPower Silica has a significant level of extractable silicon. The high availability of plant available silicon measured in AgriPower Silica is attributed to the diatomaceous earth, which is composed of amorphous silica.

The true test of plant available Si is through plant tests, described in the next section.
2.3 The efficacy of AgriPower Silica in Field Trials

AgriPower Silica was included in a strawberry demonstration trial in Queensland, Australia at 250, 500 and 1000 kg/ha. The AgriPower Silica was applied in addition to the normal fertiliser application (control) and was found to yield significant improvements in growth and yield compared to the control, with the following observations:

- Significantly increased root development/root mass by 100-200%
- Increase in flowers, foliage, crown size and fruit
- Brix was increased and maintained later in the season
- Increase in survival rates of runners
- Significantly increased soil moisture while not being water logged.
- Ability to increase uptake of key nutrients (N, P, K) during wet period when nutrients are typically leached away from the root zone
- Increased yields by an average of 35%

Recommended application rates would be from 200 - 500 kg / ha pre plant depending on the soil condition.

![Figure 7: Comparison between the control and AgriPower Silica (Treated) grown strawberries](image)

An analysis of the soil showed significant improvements in the level of nutrients retained in the soil treated with AgriPower Silica compared to the control:
Table 3: Soil analysis comparison [ASPAC Accredited lab]

<table>
<thead>
<tr>
<th></th>
<th>Treated 500kg/ha</th>
<th>Untreated control</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate – N (mg/kg)</td>
<td>84</td>
<td>59</td>
<td>42% increase</td>
</tr>
<tr>
<td>Colwell P (mg/kg)</td>
<td>145</td>
<td>90</td>
<td>61% increase</td>
</tr>
<tr>
<td>K (mg/kg)</td>
<td>295</td>
<td>209</td>
<td>41% increase</td>
</tr>
<tr>
<td>Si² (mg/kg)</td>
<td>168</td>
<td>145</td>
<td>16% increase</td>
</tr>
<tr>
<td>ECEC* (cmol/kg)</td>
<td>6.4</td>
<td>5.9</td>
<td>Increased</td>
</tr>
</tbody>
</table>

* soil cationic exchange capacity

The improved retention of nutrients in the AgriPower Silica treated soil resulted into an increased uptake of these key nutrients by the strawberry plants compared to the control:

Table 4: Sap analysis (initial flower/fruit) comparison [ASPAC Accredited lab]

<table>
<thead>
<tr>
<th></th>
<th>Treated 500kg/ha</th>
<th>Untreated control</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate (ppm)</td>
<td>4,291</td>
<td>3,812</td>
<td>13% increase</td>
</tr>
<tr>
<td>Phosphate (ppm)</td>
<td>441</td>
<td>308</td>
<td>43% increase</td>
</tr>
<tr>
<td>Potassium (ppm)</td>
<td>4,983</td>
<td>4,430</td>
<td>12% increase</td>
</tr>
<tr>
<td>Silicon (mg/l)</td>
<td>27</td>
<td>15</td>
<td>80% increase</td>
</tr>
</tbody>
</table>

A demonstration study was carried out in Queensland, Australia on sweet potato. AgriPower Silica showed significant improvements over the control:

✓ The inclusion of DE into the nutrition program as a base soil conditioner pre plant delivered a 47% improvement in yield and gross margin
✓ This is a significant result given this crop received approx 60 inches of rain (most unusual) resulting in a highly leached growing environment.
✓ The increased retention and uptake of nutrients by the plant is evident in the yield increase.

The recommended rate would depend on the silicon content of the soil. The above results were obtained at 200kg/ha of AgriPower Silica.

And finally observations from Table Grape field trials in Victoria and Queensland, Australia reported:

✓ A revised nutrition program that now replaces 300kg/ha of superphosphate (SSP) with 200kg/ha AgriPower Silica and 75kg/ha SSP, yielding an economic and environmental benefit
✓ Increased root zone and no fruit split

2.3.1 Summary

The improved crop growth and yield observed in these field trials can be attributed to diatomaceous earth’s ability to:

○ Increase nutrient retention and plant uptake (Figure 3, Tables 3 & 4),
○ Improve moisture retention (Table 1), and
○ Deliver plant available silicon (Figure 6, Tables 3 & 4)

The improved soil retention and plant uptake of key nutrients indicate the potential for AgriPower Silica to displace a significant portion of NPK fertilisers. In particular, AgriPower Silica can help reduce urea and phosphate inputs thereby reducing costs and significantly reducing the environmental impact of these fertilisers.

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1 ASPAC: Australasian Soil and Plant Analysis Council
2 BSES method: H₂SO₄ extraction
3 Normal fertiliser applications, broadcast basal dressing pre-planting
3. An enhanced silicon amendment

Calcium Silicate (CaSiO$_3$) from slag has been used by the Hawaii sugar industry for years (Medina-Gonzales, 1988) and to increase sustainable rice production in Japan (Ma, 2009).

Kato and Owa (1997) proposed several possible reactions occur in the soil after the addition of calcium silicate. Calcium silicate (readily released fraction) is dissolved in the soil, which generally has a low/neutral pH, producing monosilicic acid (or plant available silicon - PAS) for plant uptake. The Ca resulting from this dissolution will be continuously absorbed onto the soil colloids, releasing protons from the hydroxylated surfaces, gradually making the system more acidic, which in turn enhances the dissolution of Si (slowly released fraction) from the calcium silicate. These dissolution kinetics potentially favour the delivery of an enhanced level of PAS. Calcium silicate is also hypothesized to assist in improving soil acidity, a more effective method than liming, which reduces the uptake of Si from the soil.

Calcium silicate occurs naturally as wollastonite although the availability and solubility of wollastonite is variable and can be low compared to slag silicates (Muir et al, 2001). However, slag has its downfalls. It can also be quite variable in composition in terms of its plant available silicon and most importantly silicate sources derived from industrial by-products such as slag can contain high level of heavy metals associated with their origin or processing (Berthelsen et al, 2003).

We set out to synthesize an Enhanced AgriPower Silica product that mirrored the performance of calcium silicate, without the contaminants of slag.

**Synthesis of the Enhanced AgriPower Silica**

The Enhanced AgriPower Silica was characterized via several techniques to identify its morphology and composition. Thermogravimetric Analysis (TGA) is a technique used to characterise materials as a function of temperature and measures when phase changes occur. As interpreted from the TGA spectra below, the Enhanced AgriPower Silica maintains its amorphous form up to 761°C, above which the product transforms to a crystalline product. This result coupled with an X Ray Diffraction Analysis confirmed that the Enhanced AgriPower Silica is not crystalline.

![Figure 8: TGA spectrum of the Enhanced AgriPower Silica](image-url)
A lack of crystallinity is important for two reasons:

- Avoids the formation of cristobalite, and
- Amorphous products are expected to be more plant available

A Scanning Electron Microscope (SEM) image of a sample of the Enhanced AgriPower Silica in Figure 9 below reveals a product consisting predominantly of flocs with a porous structure and large specific surface. The average particle diameter of the reaction product is about 10 microns. Residual frustules of diatomaceous earth are evident in the micrograph as well and would lend soil-conditioning properties to the product.

Figure 9: SEM images of a sample of Enhanced AgriPower Silica
3.1 Plant Available Silicon

Figure 10 reports results using the direct chemical extraction via the neutral extraction method (0.01M CaCl\textsubscript{2}) described previously in regards to Figure 6. This extraction method provides a measure of the readily available silicon that is present at the pH and conditions of the soil and is therefore unlikely to overestimate the plant available silicon.

The extractable Si of the Enhanced AgriPower Silica was measured in an iterative process to develop an optimised product. Figure 10 compares the optimised Enhanced AgriPower Silica to several other Si amendments.

![Comparison of extractable Si of various Si amendments](image)

**Figure 10: Comparison of the extractable Si in various Si amendments using the neutral extraction method (0.01M CaCl\textsubscript{2}) [data selected from Figure 6 at an extraction ratio of 100]**

The extractable Si of The Enhanced AgriPower Silica as shown in Figure 10 is significantly higher compared to wollastonite, slag 1 and slag 2. This compelling result warranted further investigation into the soils themselves in order to quantify the improvement in soils amended with The Enhanced AgriPower Silica.

While many chemical extractants may provide the first estimate of the potential value of a Si source, the more reliable method of determining the PAS of a Si source is through indirect chemical extraction after soil incubation (Savant et al, 1999). Soil incubation trials were carried out in 4 different soils typical of Queensland, the properties of which are reported in Table 5 below.

<table>
<thead>
<tr>
<th>Soil</th>
<th>Description**</th>
<th>Si* (CaCl\textsubscript{2})</th>
<th>Si* (H\textsubscript{2}SO\textsubscript{4})</th>
</tr>
</thead>
<tbody>
<tr>
<td>PinGin (Innisfail)</td>
<td>Acidic Dystrophic Red Ferrosol</td>
<td>14.4</td>
<td>284</td>
</tr>
<tr>
<td>Galmare (Mena Creek)</td>
<td>Acidic Dystrophic Red Kandosol</td>
<td>3.7</td>
<td>4</td>
</tr>
<tr>
<td>Hawkins (Ingham)</td>
<td>Fluvic Stratic Rudosol</td>
<td>4.4</td>
<td>93</td>
</tr>
<tr>
<td>Bundaberg</td>
<td></td>
<td>23.7</td>
<td>214</td>
</tr>
</tbody>
</table>

*measured in mg extractable Si per kg product  

Queensland sugarcane soils are considered deficient in Si if the concentration is less than 10-15mg Si/kg dry soil following extraction with 0.01M CaCl\textsubscript{2} (Muir et al, 2001). Therefore the Galmare and Hawkins soils are classified as being deficient in Si and are expected to be responsive to Si amendment.
Soil incubation trials were carried out on the Enhanced AgriPower Silica using a CaCl$_2$ extraction given that this extractant has a similar ionic strength to the soil solution and only extracts the easily soluble Si fraction. The Enhanced AgriPower Silica was run at rates from 100 to 750 kg/ha$^4$ in all four soils and the soils were incubated for at least one week before the extractions were carried out.

There is a significant increase in the extractable Si (or plant available silicon) in all four soils amended with the Enhanced AgriPower Silica. The extractable Si generally increases with the application rate, and a similar trend was found for acid extractable Si$^5$. There is a significant increase of up to 120% extractable Si from the Galmara and Hawkins soils. These soils are the most deficient in Si (Table 5) and therefore stand to benefit significantly from the Enhanced AgriPower Silica.

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$^4$ The rate experienced in a field trial could be different depending on how deep the product is incorporated into the top layer

$^5$ The CaCl$_2$ extraction method is preferred by the authors of this paper given its close approximation to soil solution conditions. The acid extraction method (H$_2$SO$_4$) tends to exaggerate the extractable Si as it dissolves other minerals, clays, in the soil
4. Conclusion

The inclusion of AgriPower Silica into the nutrition program of several crops as a base soil conditioner ahead of planting delivered significant improvements in crop productivity and the gross margin per hectare grown. This was attributed to diatomaceous earth’s ability to increase nutrient retention and plant uptake, improve moisture retention and deliver plant available silicon.

NPK (Nitrogen, Phosphorous, Potassium) based fertilisers are often considered a necessary part of intensive crop cultivation to improve crop production. Problematically, these fertilisers are a major source of water pollution due to Australian soils’ susceptibility to leaching. The initial results presented in this paper support the argument that AgriPower Silica could improve the soil retention and plant uptake of these key nutrients, indicating the potential for AgriPower Silica to displace a significant portion of NPK fertilisers. A reduced requirement of urea and phosphate inputs would provide an economic benefit and reduce the environmental impact of these fertilisers. AN improved crop yield due to the application of AgriPower Silica similarly provides an economic benefit.

Calcium Silicate slag as an industrial by-product is a proven Si-rich amendment, however, it carries the risk of polluting soils and natural waters. An Enhanced AgriPower Silica was developed based on the natural AgriPower Silica. This product is free of the contaminants typically found in slags and delivers a significant amount of plant available silicon in all the four soils tested. The level of Si in the most Si-deficient soils was increased by 120% and therefore stands to benefit significantly from the Enhanced AgriPower Silica.
5. Acknowledgements

We are immensely grateful to Suzanne Berthelsen for her analysis and insight into plant available silicon and to John Provis for his assistance and interpretation of mineral analyses.
6. References


Berthelsen, S., Noble, A.D., Garside, A., 2003, “Improving yield and ccs in sugarcane through the application of silicon based amendments”, SRDC Project CLW009


Ma J.F., 2009, “Silicon uptake and translocation in plants”, The proceedings of the International Plant Nutrition Colloquium XVI, Department of Plant Sciences, UC Davis’


Medina-Gonzales, O.A., Fox, R.I. and Bosshart, R.P., 1988, Solubility and availability to sugarcane of two silicate materials”, Fertilizer Research, 16, 3-13

Muir et al, 2001, “Plant available Silicon as a protectant against fungal diseases in soil-less potting media”,
horticultural research and Development Corporation, project number NY97046


