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Conceptual Paper

Silicic Acid Agri Technology (SAAT): The Benefits of Stabilized Silicic Acid

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Introduction

The Silicic Acid Agri Technology (SAAT) is the application of stabilized silicic acid (SA) as foliar spray or hydroponically. SAAT is developed because silicon has beneficial effects on the plant. Almost any plant needs silicon. Although silicon (Si) is not recognized an essential element for plants, Si shows positive effects on growth- and yield parameters in many plant species.

Silicon (Si) is the second most abundant element in the earth's crust (28%) and in the soil (< 2 - > 45%). Silicon is present in the soil as silicate minerals, aluminosilicates (clay) and various forms of silica (silicon dioxide, SiO_2) including biogenic silica. These solid Si-compounds are not plant available. The only biological active and bioavailable Si compound is (liquid) mono-silicic (= ortho-silicic) acid: $Si(OH)_4$. This molecule is taken up by the roots, transported to the xylem and next distributed throughout the plant.

Silicon content in plants

The amount of Silicon in the biomass of the plant ranges from 0,1% to 15% by weight. The content is dependent on the species: monocots have high concentrations, while the amount in dicots is low. Especially terrestrial grasses such as wheat, oat, rye, barley, sorghum, corn, sugarcane and turf grass contain about > 1 - 2% Si, aquatic grasses have Si content up to 5% and rice up to 10%. Dicots such as soybean, tomato and tobacco are considered as poor Si accumulators because their Si values are lower than 1% dry weight.

Effects of Silicon related to the uptake of silicic acid

Silicon's beneficial effects on growth, development, yield and disease resistance have been observed in a wide variety of plant species, so Si is important for the plant. The beneficial effects of Si are even more pronounced in case of abiotic (salinity stress, drought and high temperature stress, etc).and biotic stress conditions (plant disease and pest damage). These effects are mostly attributed to the accumulation of Si in plant shoots. However, the level of Si accumulation in the shoots differs greatly among plant species. Physiological studies have shown that the differences in Si accumulation results from the capacity of the roots to absorb Si. In most monocots the uptake is an 'active' process being facilitated by membrane transporters (aquaporin proteins) resulting in significant higher concentrations compared to dicots being dependant on 'passive' diffusion of silicic acid.

Rice mutants with a smaller number of membrane transporters accumulate much lower Si resulting in significant lower grain yields, also showing the importance of a sufficient silicic acid uptake.

In case of sufficient silicon uptake, leaves, stems and culms of plants show a more erect growth, with more tillers (for example in rice), larger leaves with more chlorophyll resulting in yield increases with higher quality.

The Silicon dilemma

Silicon has an abundant presence in the soil as solid Si compounds. Despite this abundance of silicon, the plants aren't able to absorb these Si compounds. Only the liquid monosilicic acid is absorbed by the roots, but its concentration in the soil is (very) low. Fertilization with silicon compounds (like silicates) can increase the concentration of monosilicic acid, but repeated cropping, repeated applications of chemical fertilizers (N, P, K's) and agrochemicals (pesticides) have a negative effect on the production of silicic acid from silicates and biogenic silica. Moreover, monosilicic acid is a (very) instable molecule, which high tendency to polymerize, especially with increasing concentration. This results in a silicic acid deficiency despite the abundance of silicon in the soil. And, a silicic acid deficiency is a major limiting factor for optimal plant growth and crop production.

SAAT (Silicic Acid Agri Technology)

To overcome the issue of the instability of SA, stabilized silicic acid has been developed being a technology to prevent the polymerization of silicic acid. Next, to overcome the limited uptake of silicic acid by the roots, due to low silicic acid concentrations in the soil, and the low capacity of dicots to absorb silicic acid, foliar applications were used to investigate if this routing could be an alternative for the growth of as well monocots as dicots. Since beginning of this millennium, experiments with foliar applications of silicic acid showed the effectiveness of this routing: increases of growth -, yield - and quality parameters.

In our earlier research it was found that (mono) silicic acid is absorbed by leaves being an alternative uptake routing instead of the complicates uptake by the roots. In our research, the application schedules for the foliar sprays was optimised like concentration, the growth stage(s), the timing of the sprays, etc.

Methodology of foliar spray application

The foliar applications start in the early vegetative stage when 3 - 4 leaves have appeared, with 2 weeks interval. For most monocots 4 sprays are sufficient and 3 sprays for most dicots.

The foliar spray can be combined with other micronutrients, like boron, zinc and molybdenum.

The sprays are effective from the early vegetative stage on when several leaves (3 - 5) have appeared. Only relatively low concentrations are effective. When the concentration is raised or when applied in later stages, the foliar sprays aren't effective any more.

An average a total of 3 litres of the concentrated SA product is sufficient for four sprays per hectare per crop cycle.

Effects and some results

The sprays induce a cascade of effects starting with an increased root growth resulting in higher uptake of nutrients (as recorded in xylem and sap concentration), more and longer tillers, larger leaves, increase in chlorophyll content (30 -95%) and in biomass. The plants are strengthened/healthier resulting in a higher resistance to biotic (virus, fungi, bacteria) and abiotic (heat, drought, frost, acidity, salinity) stress factors.

Trials in India showed an increase of grain yield of rice (+ 15-45%), sugarcane (+ 28%), grapes (+35%), tobacco, soy and others. Due to the strengthening of the plants, pesticides were reduced with at least 50% or even abandoned. For example, in rice the yield increase without pesticides: + 26% and in case of the application of half dose of pesticide: + 32%.

In experiments on grapes it was found that after he foliar application of silicic acid, the quantities of Si found in the plant, were much higher than the quantities applied by foliar sprays. This shows that the foliar applied silicic acid had a positive effect on the uptake of all nutrients including Si, by the roots.

SAAT is now used for monocots and dicots with significant increases in growth, yield and quality parameters (like brix, sugar content in sugarcane, lycopene in tomato, intensive colouring of flowers, etc.). In grapes a significant reduction in physiological loss in bunch weight and percentage rotten berries was observed. The postharvest losses are reduced and the self-life is increased.

Overview

The use of silicon fertilizers needs more attention worldwide. The multiple benefits of the use of silicon compounds are underestimated. The first important effect is the increase of the root system resulting in better anchoring (more resistant to heavy winds), in a higher uptake of nutrients including the applied fertilizers (higher quality and more efficacy of the applied fertilizers) and higher uptake of water, important in case of drought. The higher uptake of nutrients has positive effects on the growth, biomass and yield parameters. Silicon optimizes the growth and development of the plant especially in stress conditions. Due to the climate change, the stress factors are increasing worldwide. The problems with the instability of silicic acid can be overcome by using stabilized silicic acid (sSA). Using sSA in foliar sprays the efficacy of Si in dicots is enhanced significantly compared to the limited uptake of silicic acid by the roots. It shows that silicic acid can have the same efficacy in dicots compared with monocots.

Stabilized silicic acid is very safe for the plant, the soil, surface water, insects and men. This can be illustrated by the fact that stabilized silicic acid is used as dietary supplement for humans and animals.

The yield increases, higher quality and less postharvest losses, result in lower cost expenditure on farming and production. The use of sSA increases the efficacy of fertilizers allowing a significant reduction. Due to the plant fortification the use of pesticides can be reduced as well with at least 50%.

SAAT can be used as well in drip irrigation and hydroponic systems. The first results show promising effects. So far silicates are used showing some effects but much less effective compare to sSA.

SAAT can be used for aquatic life as well. Experiments with the application of sSA showed significant increases in the growth of Diatoms (70% of the phytoplankton) resulting in, amongst others, enhanced growth of fish and shrimps (+ 21 - + 49%). Because Diatoms are extremely important for the absorption of carbon dioxide, sSA could play a role in the carbon dioxide problem realizing that Diatoms absorb at least the same amount of CO2 compared to all terrestrial plants.

The use and application of Si compounds need much more attention for a safer and more effective agriculture and aquaculture. SAAT is a multidimensional, effective and high yielding technology, maybe one of the most promising Agri-technologies for 21st Century.

Figure 1: *The effects of SAAT on rice (left) and control (right).*

Figure 2: *The effects of SAAT on the leaves of sugarcane (right) and control (left).*

Trials at the University of Agricultural Sciences, Bangalore, India have shown an increase in cane yield (25 - 30%) and NRS (+ 7%).

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