Bio-stimulants: Which Pure Compounds Have Reproducible Effects

If you have been exploring ways to improve crop performance in your hydroponic system, you have likely encountered the term “bio-stimulants.” The market is flooded with products making bold claims, but separating marketing hype from reproducible science can be challenging. In this post I am going to focus exclusively on **pure chemical compounds** that have demonstrated consistent effects in peer-reviewed research. I am deliberately excluding mixtures, proprietary blends, polymeric substances, and commercial formulations to help you understand which individual substances actually work.

After reviewing the scientific literature extensively, I have identified several categories of pure bio-stimulants with strong evidence from multiple independent studies: specific amino acids, silicon compounds, plant hormones, melatonin, and thiamine. Each compound discussed below has at least five peer-reviewed studies demonstrating consistent positive effects in controlled greenhouse or hydroponic systems.

Taken from this article, it shows the effect of some bio-stimulants, including melatonin, on calendula officinalis (one of my favorite plants). A layout of the experiment. Salinity levels (S), S0 = Tap water, S1 = 42.8 mM, S2 = 85.6 mM, S3 = 128.3 mM, Melatonin (M), M0 = 0 µM, M1 = 50 µM, M2 = 100 µM, Bacterial inoculation (B), B0 = non-inoculation, B1 = inoculation

What about humic and fulvic acids?

Before diving into the compounds that made the cut, I want to address a common question. Humic and fulvic acids are popular in hydroponics, but they do not qualify as pure substances. According to the International Humic Substances Society, these are “complex and heterogeneous mixtures of polydispersed materials" containing thousands of distinct organic compounds (1). Modern analytical chemistry has identified **5,000 to 7,000 unique molecules** in typical humic extracts. While they can be effective bio-stimulants, they fall outside the scope of this article because their variable composition makes reproducibility difficult to guarantee across different sources.

Amino acids with extensive research support

Two amino acid compounds stand out for having robust evidence across multiple independent studies: **glycine betaine** and **L-proline**.

Glycine betaine functions as an osmoprotectant, stabilizing protein structure and protecting photosystem II under stress conditions (2). Commercial greenhouse hydroponic lettuce production in Finland demonstrated reduced nitrate accumulation while maintaining yield (3). Hydroponic trials in chickpea showed significant improvements in chromium stress tolerance at 11715 ppm (4). Field applications at 700 ppm improved lettuce performance under water stress (5). Pot studies with maize demonstrated enhanced growth and chlorophyll content under drought at concentrations of 3650 to 3840 ppm (6). Hydroponic maize trials with 11.7 ppm showed improved salt tolerance through Na+ homeostasis regulation (7). Field trials in winter wheat at 5858 ppm demonstrated improved water use efficiency under limited irrigation (8).

L-proline operates through similar osmoprotective mechanisms while also acting as a reactive oxygen species scavenger. Greenhouse hydroponic studies in maize showed significant drought tolerance improvements at 576 to 1151 ppm application rates (9). Field trials conducted in Egypt during 2017-2018 demonstrated that foliar proline at 230 to 461 ppm significantly improved maize yield under drought stress with both surface and drip irrigation systems (10). Greenhouse tomato trials showed that 100 ppm proline application alleviated heat stress damage and increased fruit yield per plant (11). Tomato seedling studies demonstrated that 1151 ppm foliar proline provided protection against chilling stress through enhanced antioxidant enzyme activities (12). Hydroponic NFT tomato trials with 1151 ppm foliar proline application alleviated salinity stress effects on cell ultrastructure and photosynthesis (13). Multiple greenhouse studies confirmed proline improved stress tolerance across various crops at concentrations between 576 to 2878 ppm (14).

Silicon: the most extensively validated bio-stimulant

Potassium silicate (K_2SiO_3) is the most practical option for nutrient solution supplementation. At hydroponic pH levels, it hydrolyzes into monosilicic acid and potassium ions. Plants absorb the monosilicic acid through specialized aquaporin-type channels and deposit it as amorphous silica in cell walls (15). This creates physical barriers against pathogens while improving structural integrity.

An important point to understand about silicon sources: at the pH where plants are fed in hydroponics, acid-stabilized silicon products and potassium silicate sources generate the exact same monosilicic acid. Stabilized monosilicic acid products are not more plant available than potassium silicate. The advantage of stabilized products is that they remain stable longer in recirculating systems and do not require pH adjustment, while potassium silicate polymerizes relatively quickly at typical hydroponic pH values.

Multiple greenhouse trials demonstrated pronounced resistance to powdery mildew in cucumber at 477 ppm Si (16). Melon greenhouse studies showed 65 to 73 percent reduction in powdery mildew disease progress with root application (17).

Hydroponic barley trials at various concentrations confirmed growth improvements (18). Greenhouse cucumber studies demonstrated that silicon addition to nutrient solutions significantly reduced powdery mildew severity (19). Recent lettuce research showed silicon extended shelf life by 40 to 80 percent (20). Zucchini greenhouse trials confirmed silicon effectiveness against powdery mildew when applied both foliar and through roots (21).

Melatonin: an emerging bio-stimulant with strong evidence

Melatonin has emerged as a promising bio-stimulant with extensive research support across multiple crops. This compound functions as both an antioxidant and growth regulator.

Hydroponic tomato trials demonstrated that 11.6 to 46.5 ppm melatonin improved growth and photosynthetic characteristics under saline-alkali stress (22). Greenhouse cucumber studies at 23.2 ppm showed enhanced nitrogen metabolism and growth (23). Tomato fruit quality studies confirmed that 23.2 ppm melatonin promoted accumulation of sugars, amino acids, and secondary metabolites (24). Hydroponic wheat trials with 23.2 ppm enhanced drought tolerance through jasmonic acid and lignin bio-synthesis pathways (25). Cucumber seed priming with melatonin improved antioxidant defense and germination under chilling stress (26). Greenhouse tomato trials demonstrated that 116 ppm melatonin improved salt tolerance when applied as foliar spray (27). Multiple studies confirmed melatonin at 11.6 to 116 ppm enhanced photosynthesis, antioxidant systems, and stress tolerance across various crops (28).

Thiamine (Vitamin B1): disease

resistance activator

Thiamine has a unique position among bio-stimulants due to its role in activating systemic acquired resistance in plants rather than direct nutritional effects.

Greenhouse studies demonstrated that foliar application of 5772 ppm thiamine induced systemic acquired resistance in rice, Arabidopsis, tobacco, and cucumber against fungal, bacterial, and viral infections (35). Wheat pot trials showed that 100 ppm thiamine improved growth, chlorophyll content, and yield under water stress (36). Research confirmed thiamine functions as an activator of plant disease resistance through salicylic acid and calcium-dependent signaling pathways (35). Greenhouse trials on multiple crops demonstrated that thiamine treatment at 50 to 100 ppm protects plants against biotic and abiotic stresses (37). Studies showed thiamine enhanced stress tolerance by improving thiamine bio-synthesis pathway regulation under osmotic and salt stress (37). Research on various plant species confirmed thiamine involvement in primary metabolism and stress response mechanisms (38). Soybean trials demonstrated that 50 to 100 ppm thiamine favors plant development and grain yield as a bio-stimulant (39).

Important note: Thiamine does NOT stimulate root growth or reduce transplant shock in whole plants despite common marketing claims. Its beneficial effects are limited to disease resistance and metabolic enhancement.

Plant hormones with consistent small-scale validation

Gibberellic acid (GA3) has extensive greenhouse and laboratory validation across multiple crops. Hydroponic lettuce and rocket floating system trials established tested concentrations around 0.35 ppm for enhanced growth and yield

(29). Hydroponic lettuce studies with 20 to 100 ppm GA3 showed improved morphological characteristics and yield (30). Greenhouse tomato seed treatment studies demonstrated that 300 to 900 ppm GA3 increased germination percentage and seedling vigor (31). Greenhouse trials on yellow cherry tomatoes showed that 25 to 75 ppm GA3 foliar applications increased stem diameter, branch number, and fruit biomass by up to 93.8% (32). Hydroponic cucumber studies confirmed that 1.7 ppm GA3 reversed growth inhibition caused by low root-zone temperatures (33). Greenhouse tomato seedling trials demonstrated that GA3 treatment improved growth and reduced heavy metal accumulation under stress conditions (34). The compound decreased nitrate accumulation in leafy vegetables while increasing dry weight. Concentrations around 0.35 ppm are widely used in research settings for various crops, though higher concentrations cause excessive elongation that reduces marketability.

Salicylic acid shows consistent benefits across greenhouse trials. Hydroponic cucumber studies demonstrated yield improvements at 69 ppm (40). Greenhouse tomato trials showed positive effects on plant growth and yield at 69 ppm applications (41). Greenhouse tomato trials with 250 ppm salicylic acid enhanced drought tolerance through improved antioxidant enzyme activity (42). Field tomato studies demonstrated 40 to 45 percent yield increases at 138 to 207 ppm under water stress (43). Greenhouse cucumber trials confirmed improved phenolic compounds and yield at 10.4 to 69 ppm (44). Hydroponic maize studies showed protection against chilling injury at 69 ppm (45).

Suggested test application rates and practical suggestions

Based on the evidence reviewed, here are some suggestions if you want to try pure compound bio-stimulants. As always, make sure to try on a small number of plants before making large scale applications:

For silicon supplementation, potassium silicate at 20 ppm Si (approximately 40 ppm SiO_2) offers excellent disease resistance and yield benefits. Add it to your nutrient solution at each reservoir change and adjust pH accordingly. Remember that low cost potassium silicates can provide readily available monosilicic acid when used properly. For more details on silicon use in hydroponics, see this previous article.

For stress tolerance, glycine betaine at 700 ppm in nutrient solution or L-proline at 575 ppm as foliar application can significantly improve crop performance under salt or drought conditions. For comprehensive guidance on glycine betaine applications, see this previous article.

For melatonin applications, use 25 ppm as foliar spray or in nutrient solution. This concentration has shown consistent benefits across multiple crops for stress tolerance and growth enhancement.

For disease resistance, thiamine at 100 ppm as foliar spray activates systemic acquired resistance. This is particularly useful for preventive disease management rather than direct growth promotion. For detailed information on thiamine applications, see this previous article.

For specialized applications, gibberellic acid at 0.35 ppm or salicylic acid at 30 ppm offer targeted benefits, though these require more careful application timing and concentration control. For more information on salicylic acid use, see this previous article.

Summary table: Pure compounds with

reproducible effects

Compound	Number of Studies	Tested Concentration	Primary Benefits
Glycine Betaine	7 studies (2, 3, 4, 5, 6, 7, 8)	12–5900 ppm	Osmoprotection, salt tolerance, reduced nitrate
L-Proline	6 studies (9, 10, 11, 12, 13, 14)	230–2900 ppm (foliar)	ROS scavenging, drought tolerance, salt stress
Potassium Silicate	7 studies (15, 16, 17, 18, 19, 20, 21)	14–42 ppm Si	Disease resistance, shelf life, structural integrity
Melatonin	7 studies (22, 23, 24, 25, 26, 27, 28)	11–116 ppm	Antioxidant activity, stress tolerance, growth regulation
Gibberellic Acid	6 studies (29, 30, 31, 32, 33, 34)	0.35–1.7 ppm	Fruit development, reduced nitrate, cell elongation
Thiamine (Vitamin B1)	5 studies (35, 36, 37, 38, 39)	50–100 ppm (foliar)	Disease resistance activation, stress metabolism
Salicylic Acid	6 studies (40, 41, 42, 43, 44, 45)	70–250 ppm	Stress tolerance, yield enhancement, disease resistance

The key advantage of using pure compounds rather than commercial blends is reproducibility. When you know exactly what you are applying and at what concentration, you can systematically optimize your system and troubleshoot problems effectively. Each of these compounds has been validated across multiple independent studies, giving you confidence that results can be consistent across different growing conditions.

However, keep in mind that crop conditions can be very variable and, while these bio-stimulants have been validated across various scenarios, effects can vary depending on the particular circumstances of each crop.

Have you tried any of these pure compound bio-stimulants in your hydroponic system? What were your results? Let us know in the comments below!

Calcium silicate (wollastonite) in soilless crops

Silicon in media is not a magic switch. In soilless systems it can help, it can do nothing, and at the wrong rate or pH it can hurt. Calcium silicate sources such as wollastonite release plant-available Si into inert substrates and typically raise pH, which is useful in peat but potentially more risky in coir or already alkaline systems. A recent substrate study quantified this clearly: wollastonite steadily released Si for months and increased media pH about 0.5 to 1 unit depending on substrate composition (1). With that in mind, here is the evidence for tomatoes and cucumbers grown without soil, focusing only on media or root-zone applications.

Vansil CS-1, one of the most common forms of calcium silicate (wollastonite) used as an amendment in soilless crops.

Tomatoes

Two independent Brazilian groups that amended substrate with calcium silicate found quality benefits but also rate-sensitivity. In a factorial test across Si sources and doses, calcium silicate treatments improved postharvest durability and maintained physicochemical quality of fruits; the effect size depended on the source and the dose used (2). A protected-environment pot study that mixed calcium silicate into the substrate before transplanting reported reductions in gas exchange and chlorophyll at midcycle at higher rates, a warning that more is not always better (3). Earlier yield work that compared sources also detected response to silicon fertilization in tomatoes, but the magnitude varied with rate and material (4).

Cucumbers

When wollastonite was incorporated into the soilless substrate, 3 g L^{-1} increased yield by ~25% under moderate moisture restriction, with no penalty to soluble solids or fruit size. Lower doses or excessive irrigation did less (5). A separate work that applied a calcium-silicate solution into the substrate showed small gains in biomass under specific moisture regimes and no change in soluble solids, again pointing to context and dose as the deciding factors (6).

Practical takeaways for media use

1. Treat calcium silicate like a weak liming Si source. Expect a pH rise. In peat this can be helpful, in coir or high-alkalinity waters it can push you out of range (1).
2. Dose conservatively, then verify with tissue Si or leachate pH before scaling. Tomatoes show rate-sensitive physiology (3).
3. Target crops and situations with the strongest evidence. Cucumbers under moderate moisture restriction and strawberries in organic substrates show the clearest yield and quality benefits (5), (7).

Summary table – media or root-zone Si only

Crop	Medium and Si source	Application rate	Positive effects on yield or quality	Reported negatives	Ref
Tomato	Substrate mix, calcium silicate among Si sources	Field-equivalent 0 to 800 kg SiO_2 ha^{-1} mixed pre-plant	Improved postharvest durability and maintained physicochemical quality vs control; effect depended on dose and source	None specified at optimal rates	(2)
Tomato	Substrate, calcium silicate mixed before transplant	0, 150, 300, 450, 600 kg ha^{-1}	–	Reduced gas exchange and chlorophyll at midcycle at higher rates, indicating potential performance penalty	(3)
Tomato	Substrate, silicon sources including calcium silicate	Multiple rates	Yield responded to Si fertilization depending on source and rate	–	(4)
Cucumber	Soilless substrate, wollastonite	3 g L^{-1} of substrate under 75-85% container capacity	+24.9% yield vs untreated; fruit size and soluble solids unchanged	None noted at that rate	(5)
Cucumber	Substrate drench, calcium silicate solution	50-100 mg L^{-1} SiO_2 applied to substrate	Biomass gains under specific moisture regimes; quality unchanged	No quality gain at tested doses; response moisture-dependent	(6)
Any	Peat or coir mixes, wollastonite	~1 g L^{-1} media typical in study	Steady Si release over months supports long crops	Raises media pH by about 0.5-1 unit depending on substrate	(1)

Bottom line

Use calcium silicate where the crop and context justify it, not by default. For cucumbers and strawberries the upside on yield and quality is most consistent when Si is in the root zone. For tomatoes, treat calcium silicate as a quality tool with a narrow window and verify plant response; higher rates can backfire physiologically. If you want to try calcium silicate, mix wollastonite with your media at a rate of 3g L^{-1}, then test the effect on pH and Si in tissue.

Common questions about silicon in nutrient solutions

Introduction

We know that silicon can be a very beneficial element for many plant species (see some of my previous posts here and here). It mainly enhances disease resistance and increases the structural integrity of plant tissue. Because of these advantages, you will want to add silicon to your nutrient solution. However, there are a lot of misconceptions and questions about the use of Si in plants and the exact form of Si that you should use. In this post I am going to address some of the most common questions about silicon sources and how to use them properly.

Alkali metal silicates are the most common sources of soluble silicon used. They also have the lowest cost by gram of Si.

What sources are available?

To use silicon in nutrient solutions, we will generally have 3 types of sources available.

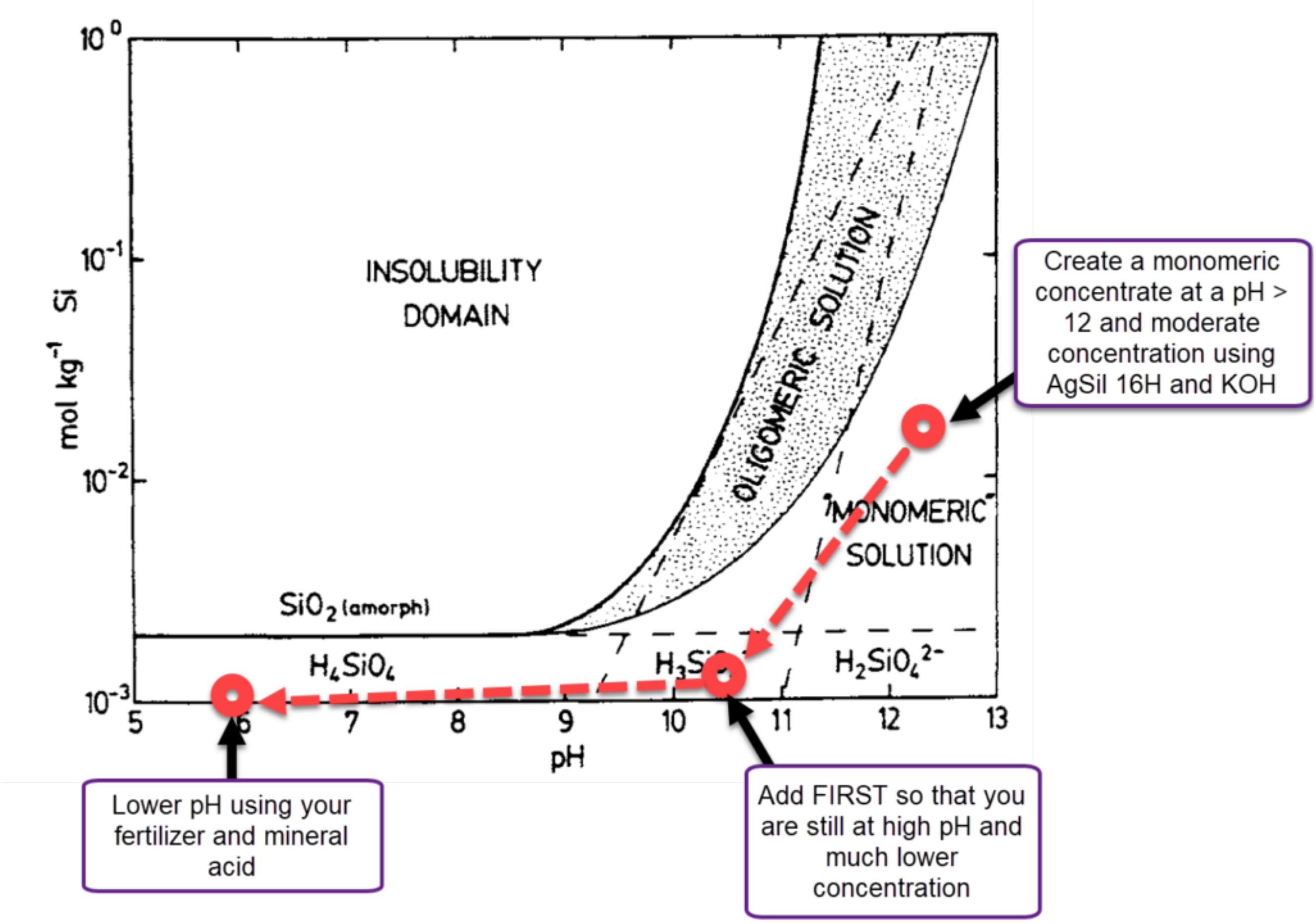
First, we have **basic potassium silicates**, which are solids or solutions derived from the reactions of silica with potassium hydroxide. In this category you have popular products like AgSil 16H and liquid concentrates like Growtek Pro-Silicate. These products have a very basic pH.

Second, we have **acid stabilized silicon products**. These are products like PowerSi Classic and OSA28. These products are always liquids and contain monosilicic acid in an acidic environment, with stabilizing agents added to prevent the polymerization of the monosilicic acid.

Third, we have **non-aqueous products with organosilicon reagents**, like Grow-Genius. These products do not contain water and are derived from reagents like TEOS (tetraethyl ortho-silicate) and other Si containing compounds, mainly Si containing surfactants. They are not in forms that are plant available but will generate these forms when in contact with water.

Do potassium silicates contain "less available" silicon?

When you dissolve a potassium silicate at high concentration, it forms silicate oligomers. These are large silicon chains that get stabilized in basic solutions because of their high negative charge. This is why you can create highly concentrated potassium silicate solutions in basic pH. As a matter of fact, making the solutions more basic with added potassium hydroxide often enhances the solubility of potassium silicate solids like AgSil16H (see here for a procedure on how to do this). However, when the molar concentration decreases the silicate hydrolyzes into monomeric silicate anions.



Create a monomeric concentrate at a pH > 12 and moderate concentration using AgSil 16H and KOH

Add FIRST so that you are still at high pH and much lower concentration

Lower pH using your fertilizer and mineral acid

Original background image taken from here. To create a monomeric solution you need high pH and low concentration.

Then you lower the pH to get to monosilicic acid.

When potassium silicate is diluted in nutrient solutions, this is exactly what happens. The reduction in concentration hydrolyzes the Silicates into monomers. If the solution pH is *then* lowered, the final form present will be monosilicic acid. If you properly prepare a nutrient solution with potassium silicate, the end form will be monosilicic acid, the form that is mostly available to plants.

It is a misconception that potassium silicates are somehow less “plant available”. They end up producing monosilicic acid and being perfectly available, when used properly.

How do I properly use a potassium silicate?

First, if using a solid, you need to prepare a stock solution no more concentrated than 45g/L. The recommendation with AgSil 16H would be to prepare a stock solution at 15g/gal and then using this solution at a rate of 38mL/gal of final solution (injection rate of 1%). To increase the stability of your AgSil 16H concentrate you can add 1g/gal of KOH. The end addition to your solution will be +9.8ppm of Si as elemental Si and +11.55ppm of K. The KOH addition and low 15g/gal concentration ensures that silicate will already be largely present as monomeric silicate anions.

Second, make sure to add this solution to your water first. If you add this solution after nutrients, the Si will come into contact with Ca and Mg in its concentrated form, which will cause problems with its stability in solution. Add it first, then add your lowest pH fertilizer concentrate, then your Ca containing concentrate, then finally decrease the pH with an acid to the desired level if needed.

This procedure ensures you get a final solution containing monosilicic acid that will be stable. If you increase the Si in the stock solution, change the injection order, or increase the Si in the end solution beyond 20ppm of Si as elemental Si you might end up with precipitated and unavailable Si forms.

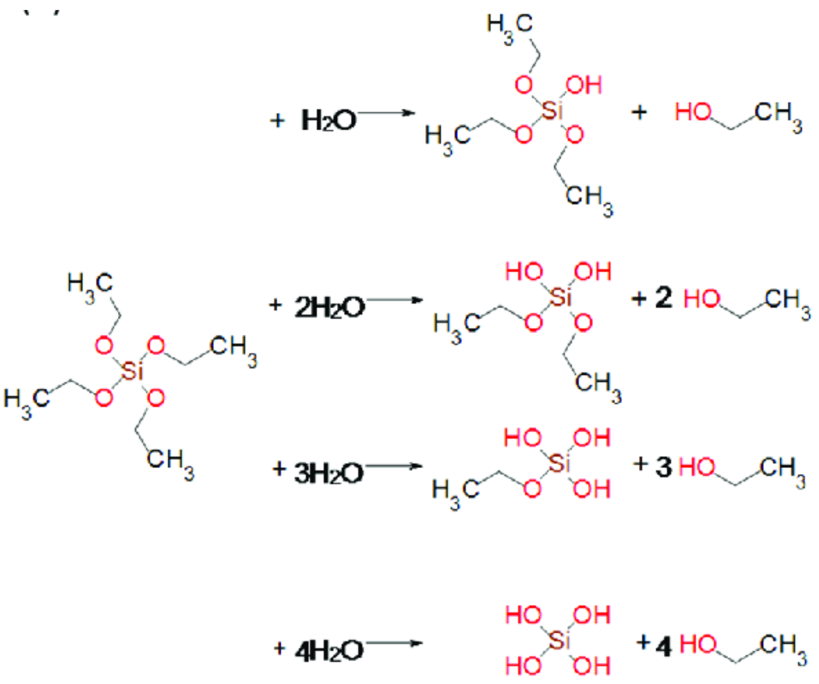
Why would you use acid-stabilized Si products?

Acid stabilized silicon sources are *not* more plant available. However, their starting pH is usually low and their mineral composition can also be minimal (depending on the preparation process). This means they can lower the need for acid additions and can help lower the pH of hard water sources when used. They can also contain stabilizing agents that could be beneficial for plants. However, the exact stabilizers used and the exact mineral composition used will vary substantially by product, since there are a wide array of choices available to manufacturers.

In the end, at the pH where plants are fed, acid stabilized Si and potassium silicate sources generate the exact same monosilicic acid. **Plant availability is *not* an advantage of using this sort of product**.

Why would you use non-aqueous Si products?

These products can be much more highly concentrated than either basic silicon or acid stabilized liquid silicon products by mass. This is because they are made from Si forms that are highly stable under water-free conditions. This means you can buy a small amount and add a small amount to your reservoir per gallon of solution prepared. Another advantage is that they are pH neutral and do not alter the pH of nutrient solutions at all. The formation of the silicic acid from these products requires only reactions with water, so no mineral addition, stabilizer additions or pH modifications happen.



Reaction of TEOS with water to produce different silicic acids (plus ethanol)

A significant point however is that the reaction of a product like TEOS with water releases other substances into solution. *For each 10 ppm of Si as elemental Si that you add from TEOS you will in fact be adding ~66pm of ethanol to your solution*. These alcohols can be very detrimental for root and plant growth, reason why the use of these non-aqueous Si products needs to be carefully considered. When using a product containing non-aqueous Si sources, it’s important to consider that these substances can accumulate in your root zone and may cause problems. Which organics are present and whether they will cause problems will depend on the exact formulation. **When using these organosilicon sources, passing the nutrient solution through a carbon filter to remove these organics before contact with plant roots would be ideal.**

Is the final Si in solution from

any product type more stable?

No, all three types of products, when used properly, will end up as stable monosilicic acid in your solution. The stabilizing agents in acid-stabilized products will be so dilute that any additional stabilizing effect will be relatively non-existent. If Si is dilute enough (<20ppm of Si as elemental Si), then it will be stable in solution indefinitely (I measured 5 weeks with no changes in concentration). At higher Si concentration, the Si will tend to polymerize (no matter which source it comes from) which will create problems with stability. To have stable Si in solution make sure that you prepare it properly and that you keep the concentrations low enough.

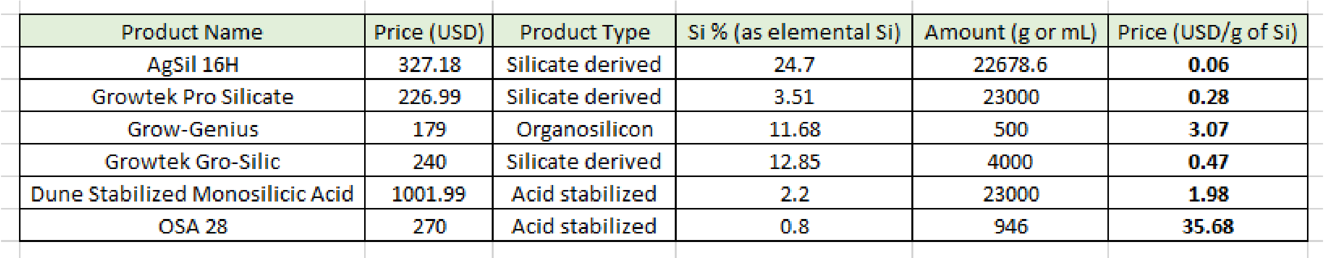
If they are mostly the same in terms of Si availability, why do I see differences between different products at an equivalent Si application rate?

Despite all of the different Si products leading to the same form of Si in the final solution, acid-stabilized Si products will contain a wide array of additional substances that are going to be active nutritionally. For example, Boron and Molybdenum are very commonly used stabilizing agents. Products, like PowerSi bloom, also contain “exotic plant extracts” (according to their website). Commonly used stabilizing agents include glycerol, carnitine, choline and sorbitol. All of these could potentially have an effect on the plants at the concentrations added with these products. Some of these stabilizing agents are usually added at 10-50x the amount of Si present by mass, meaning that your Si supplement might be adding way more of these stabilizing agents than what you’re adding in terms of Si.

What product is more cost effective per delivered mole of monosilicic acid?

There is a lot of space in labeling regulations to allow fertilizer manufacturers to trick people into believing a product might be more concentrated or dilute than another. First of all, labeling a product as “% of monosilicic acid” does not mean that the product contains that percentage of monosilicic acid, it means that the product contains Si, such that if that silicon was all converted to mono-silicic acid, it would give that percent. The only products that contain monosilicic acid in its actual form from the start are acid-stabilized Si containing products, which are usually limited to low concentrations due to the reactivity of this molecule when present.

Both non-aqueous silicon products and soluble potassium silicate products contain precursors to monosilicic acid. One in the form of organosilicon compounds and the other in the form of silicate chains. As mentioned above, both precursors can lead to very high conversions to mono-silicic acid when properly used.



Product Name	Price (USD)	Product Type	Si % (as elemental Si)	Amount (g or mL)	Price (USD/g of Si)
AgSil 16H	327.18	Silicate derived	24.7	22678.6	**0.06**
Growtek Pro Silicate	226.99	Silicate derived	3.51	23000	**0.28**
Grow-Genius	179	Organosilicon	11.68	500	**3.07**
Growtek Gro-Silic	240	Silicate derived	12.85	4000	**0.47**
Dune Stabilized Monosilicic Acid	1001.99	Acid stabilized	2.2	23000	**1.98**
OSA 28	270	Acid stabilized	0.8	946	**35.68**

These prices were the lowest prices I could find for each product in Feb 2023. To find current prices, I suggest searching any products you’re interested in. Composition values taken are those provided by the manufacturer, converted to Si as elemental Si. Prices do *not* include shipping.

To compare the actual concentration of products, it is best to always convert the amounts to elemental Si percentage values. To convert monosilicic acid % values to Si, multiply the value by 0.2922, to convert SiO_2 values to Si, multiply the value by 0.4674. For example, 40% Si as monosilicic acid is equivalent to 11.68% Si as elemental Si. Soluble potassium silicates like AgSil 16H can be around ~24% Si as elemental Si by mass, making them the most highly concentrated and lowest cost form of bioavailable silicon when used properly. More highly soluble potassium silicates than AgSil16H will usually be lower in Si, as higher K proportions lead to better solubility and a lesser need to add KOH when preparing stock solution. The table above, showcases the price differences per gram of Silicon of different products as of Jan 2023. **When purchased in bulk (50 lbs) AgSil16H can be up to two orders of magnitude lower cost than other alternatives.**

I have done lab tests measuring molybdenum reactive Si that show all the Si in AgSil16H can be quantitatively converted to monosilicic acid when following the preparation guidelines mentioned in this post.

What is your recommendation?

After studying the subject for years, using different products with different growers and testing the chemistry myself (preparing stabilized silicic acids and measuring active Si concentrations). Given the price of Si products and the chemistry involved, I would suggest anyone interested in Si supplementation in nutrient solutions to use a potassium silicate solid product. I would suggest to prepare a suitable stock with potassium silicate and potassium hydroxide to increase pH and stability and then prepare their nutrient solutions from dilutions of this stock. If a solid product like AgSil 16H is not available, then using a basic silicate concentrate product would be the next best choice. Usually preparing a more dilute stock from these products is recommended to ensure the stock already contains monomeric silicate.

I don’t think acid-stabilized silicon products or non-aqueous Si products are worth the price premium. If you’re having better results with a non-potassium silicate product compared to potassium silicate, bear in mind that this is likely because either the potassium silicate stock preparation and dilution were not done correctly or the product you’re using contains a substance different from Si that is giving you those effects. The stabilizing agents themselves are going to be much lower cost, so testing the eliciting effects of these agents might be more economical for you than using these expensive products long term.

In cases where mixing stocks and handling basic reagents is problematic or there is limited availability to adjust pH, then the use of non-aqueous Silicon reagents might be desirable. Non-aqueous silicon forms are also the most robust to mixing errors – wrong mixing order, mixing at variable pH, etc – because the hydrolysis reactions happen readily under a wide variety of conditions. However, my recommendation is to always couple these with carbon filtration to avoid potential issues from their organic side-products.

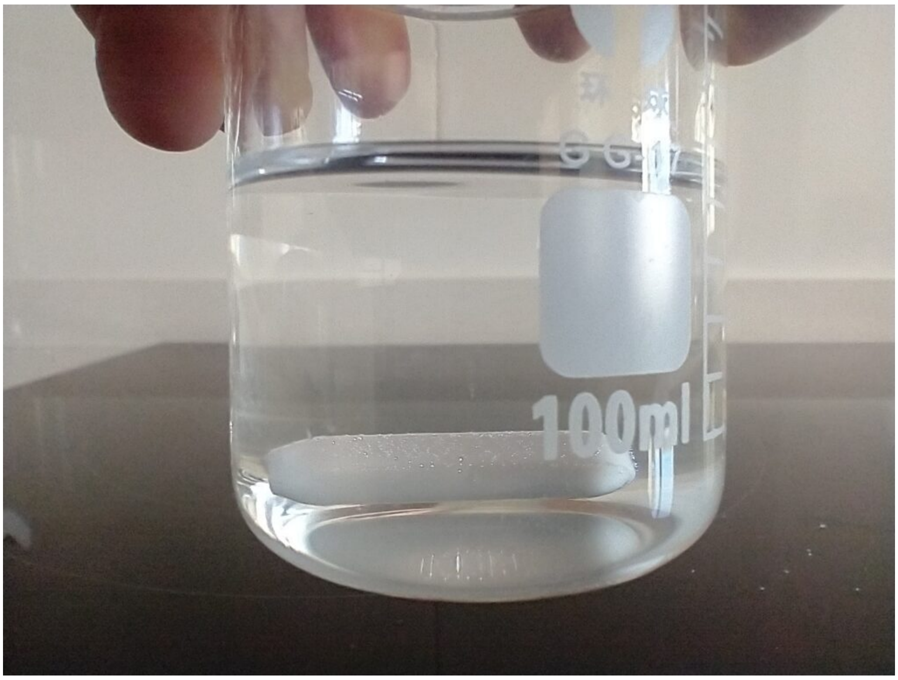
If you have issues with the use of soluble silicon sources – because of your initial water composition, injector limitations, cost, etc – and your media supports amending, I would also suggest considering using solid amendments to supplement Si (watch this video I made for more information). Amending can be a great choice, much more economical than soluble Si supplementation.

Do you have any questions about Si in nutrient solutions not addressed above? Feel free to leave a comment and I might also add it to the post!

How to make a stabilized ortho-silicic acid solution with only 3 inputs

In a previous post, which you can read here, I gave a procedure for the preparation of a stabilized mono-silicic acid using from potassium silicate. The procedure called for the usage of several stabilizing agents, including carnitine and propylene glycol, with phosphoric acid being used as the acidifying agent.

After trying this synthesis myself and talking with other people who tried this process, it seemed clear that the success rate was low and that the process was just too complicated and imprecise for most people to carry out (especially for the patience needed for the addition of the solid potassium silicate). There is a detailed discussion about this procedure, as well as mono-silicic acid synthesis in this forum thread.



Stabilized mono-silicic acid solution created using the procedure below. Note that mono-silicic acid and ortho-silicic acid are the exact same thing, they are two names for the same molecule (H_4SiO_4). Another molecule with the same nomenclature is ortho-phosphoric acid (H_3PO_4), which is also called mono-phosphoric acid.

Given these issues, I decided to look for a potentially easier synthesis starting from cheaper, more readily available materials, avoiding the use of Propylene Glycol (which concerned some people) and trying to simplify the steps involved.

The procedure I came up with simplifies the process by relying on the interaction of silicic acid with sorbitol as a stabilizing agent. This stabilization process is well documented in the literature (see here) and is caused by the formation of highly stable polyolate complexes between mono-silicic acid and molecules like sorbitol. These complexes form because molecules like sorbitol have adjacent hydroxy groups in what we call a *threo* configuration. These do not exist in sugars like glucose or sucrose, reason why these do not work for this process.

The raw inputs you will need are as followed

1. A potassium silicate with a high K/Si ratio, such as AgSil 16H. You can also use a liquid potassium silicate, such as Grotek Pro-silicate.
2. Sulfuric Acid (>90%)
3. Sorbitol
4. Distilled water.

If using AgSil16H follow this process first. In a 1000mL beaker, add 70g of AgSil16H and 450mL of distilled water. Stir – ideally with magnetic stirring – until the silicate has all dissolved. This will be the silicate solution.

This is now the procedure to prepare the stabilized ortho-silicic acid solution (700mL):

1. In a 1000mL beaker, add 500mL of distilled water and a magnetic stirrer.
2. Weigh 200g of Sorbitol and add them to the water.
3. Start the magnetic stirring.
4. After the sorbitol has completely dissolved, during a period of 30 seconds add 100mL of the silicate solution (either as prepared above or a commercial silicate equivalent to the Grotek suggestions above (around 7.5% Si as SiO_2)).
5. Stir the silicate and sorbitol solution for 10 minutes.
6. Add 10mL of >90% sulfuric acid and stir for 5 minutes. The pH should now be lower than 2.
7. The solution can now be stored.

The above process creates a stable mono-silicic acid solution that has an Si concentration of around 1% of Si as SiO_2 and around 0.6% K as K_2O. **Used at 8mL gal it should provide around 20ppm of Si As SiO_2 and 10 ppm of K.**

A previous version of this procedure used 50mL of 80-85% phosphoric acid. However, phosphoric acid seems to generate solutions that are unstable after 1-2 weeks of preparation. Solutions prepared per the above process have been confirmed *to be stable for at least 1 month.*

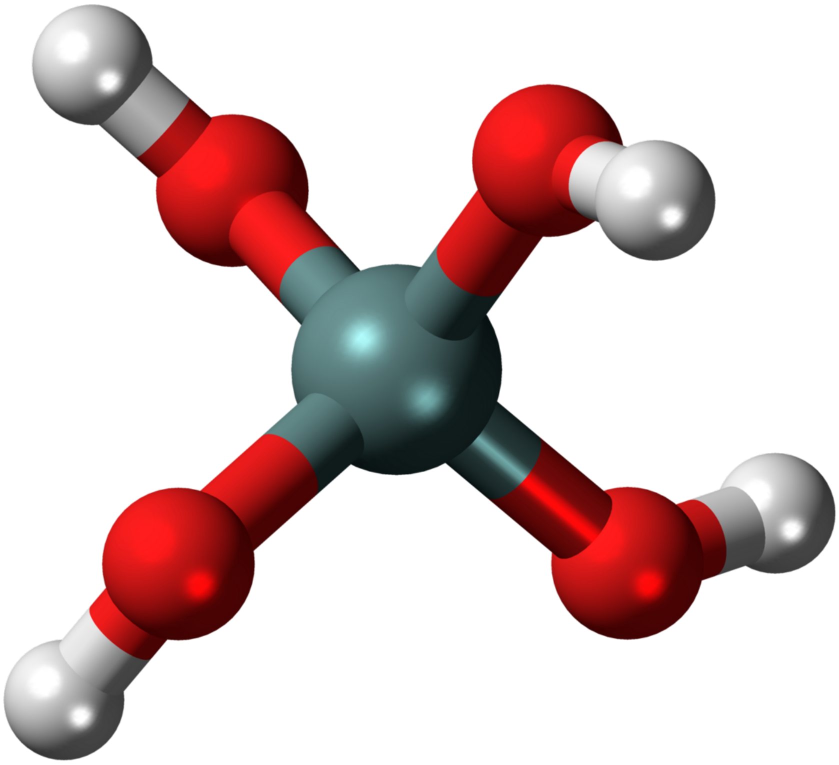
Did you try it? How were your results? Let us know in the comments below!

How to make your own stabilized mono-silicic acid for use in hydroponics

Please follow this link, for an updated an easier process for the synthesis of mono/ortho-silicic acid.

During the past several years, there have been a lot of “mono-silicic acid” products being marketed for their use in hydroponic culture. These differ from the traditional potassium silicate based products in that they are very acidic in their concentrated form and are stable in solution for longer periods of time at the pH values used in hydroponics. While a hydroponic nutrient solution that has potassium silicate added to it and the pH adjusted to 5.5-6.5 will generally see extensive polymerization of the silicon-containing molecules within 24 hours, these stabilized mono-silicic acid products will be stable for far longer periods of time. They are therefore ideal for use in recirculating systems, where potassium silicate additions can be less effective.

If you watched my youtube video on silicon in hydroponics, you’ll know that the most common way to produce these stabilized products is quite complicated and involves the use of silicon chloride and very specific reaction conditions. These are unavailable to hydroponic growers, reason why it is not easy to produce a home-made version of choline stabilized ortho-silicic acid (ch-OSA). However, choline is not the only reagent that can be used to stabilize silicic acid in solution, and research in industry has shown us that it is actually possible to form stabilized silicic acid products starting from potassium silicate itself.



Model representation of orthosilicic acid, also called mono-silicic acid.

This patent describes how to prepare mono-silicic acid solutions that are stabilized by carnitine and several other additives, in the region from 0.01 to 8% silicic acid by weight. The great thing about this process is that we can start from potassium silicate, which is readily available. The concentration of Si obtained will be significantly lower than what is possible when generating ch-OSA – where solutions can reach 40% mono-silicic acid – but the fact that we can prepare it from readily available materials might compensate for this to some extent. **It is also worth noting that this process comes from an unexpired patent, so it should not be used commercially without licensing the technology from the owner**

of the intellectual property.

Extrapolating from the contents of the patent and the examples given, we can come up with a process to brew our own mono-silicic acid at an 8% concentration. Here are the things you will need:

Note the amazon links below are affiliate links. This means that, if you choose to purchase through these links, I get a commission for your purchase, at no extra cost to you.

1. Potassium silicate (at least 32% K as K_2O)
2. Carnitine hydrochloride
3. Phosphoric acid (85%)
4. Propylene glycol
5. Distilled water
6. Scale to weight the materials (precision of at least +/- 0.1g, max at least 500g)

To prepare around 425g of stabilized mono-silicic acid, you could follow this process.

Before continuing please make sure you understand what you're doing. Wear adequate eye and body protection, carry this out in a place with enough ventilation and make sure you read the material safety data sheet (MSDS) of all the materials used. These instructions are provided for educational purposes only, follow them at *your own risk.*

1. Add 10g of carnitine hydrochloride to a clean 1000mL beaker
2. Add 65g of distilled water to the mix.
3. Stir until all the carnitine hydrochloride dissolves
4. Add 10g of propylene glycol.
5. Add 240g of 85% phosphoric acid.
6. Put the mixture on an ice bath with ample ice.
7. Wait for 15 minutes, so that the mixture cools down.
8. During the course of an hour, *slowly* add 125g of potassium silicate to the mixture with constant

stirring. Add more ice to the ice bath if needed to keep the solution cool. Note that predissolving the silicate in 150mL of distilled water and adding it as a liquid makes this process easier, although KOH additions might be required to complete its dissolution.

After this, you should be left with an acidic, completely translucid, carnitine and propylene glycol stabilized mono-silicic acid solution that should be around 7-8% w/w of Si as elemental Si. If there’s any precipitate in the solution then the stabilization process did not go well and the silicic acid formed polymerized into silica. **This solution should then be used at around 1g/gal, which will provide ~18-20ppm of Si as elemental Si in your hydroponic solution**. When using this solution,. the silicon present at the pH used in hydroponics should be much more stable than when derived from direct addition of potassium silicate.

If you go through the above process, leave a comment and let us know how it went.

Is ortho-silicic acid worth the additional expense in hydroponics?

Silicon is all the rage right now and different silicon product manufacturers are racing to produce commercial products that contain more and more biologically active silicon. The idea is mainly that potassium silicate – the most commonly used form of silicon in hydroponics – has some problems maintaining high bioavailability at the pH levels used in hydroponics and therefore more stable silicon sources are needed to meet plant needs. However we need to ask ourselves if this is actually true and whether it is actually worth it to go to much more expensive Si sources when supplementing plants with silicon products. Today I want to talk about the Si research up until now and what it tells us about silicon and stabilized silicon products.

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Without a doubt there are some proven benefits to using silicon supplementation. As explained within this recent literature review from 2015 about silicon's role in plants the benefits from silicon application include increased photosynthesis, resistance to abiotic stress as well as increased resistance to several fungal pathogens. It is also clear that foliar application of Silicon does not lead to large increases in tissue concentration and root applications tend to yield the biggest benefits. The above image shows some of the benefits of high (1mM) and low Si (0.1mM) treatments under different conditions for hydroponically grown Zucchini plants. The review also mentions the exploration of stabilized silicon forms and the current lack of scientific evidence regarding their efficacy when compared with traditional non-stabilized forms of silicon.

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So if silicon from potassium silicate can show benefits why may we need a better form of silicon? The problem with silicates is that under low pH values the silicate ion gets protonated and converted into silicic acid but silicic acid is unstable and will tend to polymerize and form molecules with limited bioavailability under these conditions. If we use a form of silicon that does not suffer from this problem then we might be able to get some additional benefits. There are indeed a few studies in lettuce and tomatoes showing that choline stabilize orthosilicic acid (ch-OSA) can indeed improve plant responses under Mn stress and even a study about the use of ch-OSA improving seedling growth but these results lack controls against potassium silicate so we don’t know if the response would simply be equal than that of a traditional silicate application. Below you can see a graphical representation of a choline molecule’s structure, choline is basically a beta aminoacid that is able to stabilize silicic acid by binding to its oxygen atoms through the positive trimethyl amine group, inhibiting polymerization.

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We know however that not all forms of stabilized silicon sources would work well. For example there is a study involving alkyl silicic acids (another form to stabilize silicon) that shows that the application of these compounds produces even worse results than controls with no silicon supplementation. Plants do not seem to deal well with this type of stabilized compounds, where the silicon is stabilized by the introduction of simple alkyl groups. Some of these forms of silicon – dimethyl silicic acid – were even highly toxic to plants at low concentrations.

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Up until this point there is basically no scientific evidence that shows how stabilized silicon sources like ch-OSA may provide a benefit over using a simpler and cheaper source of silicon like potassium silicate in higher plants. If potassium silicate is dissolved at the appropriate concentration and in an adequate manner then there is no doubt that it can provide significant benefits at a fraction of the cost. Companies producing ch-OSA and similar silicon stabilized sources generally say that they contain “more bioavailable silicon” and while it may be true that they may allow for the larger abundance of some silicon species in solution, what they should show is an increase in benefits when compared with a potassium silicate control since this is in the end what interests most hydroponic growers. While this evidence is lacking it is certainly not worth it to pay the extra cost, given that benefits using potassium silicate have been proven while benefits using ch-OSA haven’t been proven to be greater than those obtained with these cheaper Si sources.