CONFERENCE PROCEEDINGS

8th International Conference on Silicon in Agriculture

Sheraton New Orleans Hotel
New Orleans, Louisiana USA
May 23-26, 2022

LSU AgCenter
Research · Extension · Teaching

ISSAG
International Society for Silicon in Agriculture and Related Disciplines

8th International Conference on Silicon in Agriculture

Sheraton New Orleans Hotel
New Orleans, Louisiana, USA

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Dr. Clistenes Nascimento, Federal University of Pernambuco, Recife, Brazil
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ACKNOWLEDGEMENTS
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Foreword

We would like to welcome everyone to New Orleans, Louisiana, USA, the site of the 8th International Conference on Silicon in Agriculture (ICSA). After 23 years, the conference is once again hosted in the US. Since then, the conference is held every three years and has become the venue for the silicon scientific community and industry to meet and share the latest information on silicon research in agriculture as well as foster camaraderie among the participants from around the world. We also discuss issues and research opportunities, and collaborations. The 8th ICSA theme "Innovate and Integrate Silicon Research for Sustainable Agriculture" reflects our awareness as a community of the evolving needs and challenges in agriculture.

The conference proceedings consist of 53 research abstracts in oral (25) and poster (28) presentations. We have research topics on the role of silicon in alleviating biotic and abiotic stress in plants and updates on the analytical procedures for determining silicon in soils and plants. The presentations on the implications of silicon in agricultural systems and climate change are well in tune with the conference theme. Elucidating the function of silicon at the plant cellular level and the introduction of new silicon sources are the focus of several presentations. Graduate students are presenting highlights of their research through the 5-minute rapid oral and poster presentations. All these outcomes indicate our resiliency and determination to continue our work, despite all challenges encountered and set-backs during the peak of the worldwide COVID-pandemic.

We would like to thank our sponsors for their generous financial support and for working with us to ensure the success of this conference. We thank you all for your patience. Indeed, this conference has been long overdue, and the 8th ICSA organizing committee could not be more delighted to finally open the conference to everyone.

Sincerely,

8th ICSA Organizing Committee

TABLE OF CONTENTS

CONTENT **PAGE**

CONFERENCE PROGRAM

May 23, 2022

5:00 – 6:30	PM	**Early Registration**	Rhythms I
		Sponsors Table Set-up	Lagniappe
		Posters Set-up	Rhythms I
6:30 – 10:00	PM	**Reception**	Waterbury Ballroom

May 24, 2022

7:00 – 9:00	AM	**Continental Breakfast**	Waterbury Ballroom
		Registration	Rhythms I
		Sponsors Table Set-up	Lagniappe
		Posters Set-up	Rhythms I
		Upload Presentations	Waterbury Ballroom
9:00 – 9:10	AM	**Conference Opening** Dr. Brenda Tubana President ISSAG	Waterbury Ballroom
9:10 – 9:25	AM	**Welcome Remarks** Dr. Michael Salassi LSU AgCenter Associate Vice President Program Leader for Plant and Soil Sciences	Waterbury Ballroom
9:25 – 10:00	AM	**Plant Silicon Interactions between Organisms and the Implication for Agroecosystems** Dr. Scott Johnson Plenary Speaker	Waterbury Ballroom
10:00 – 10:30	AM	**Break/Poster Viewing/Exhibit**	
10:30 – 1:55 PM		**Program Theme I: Role in Biotic and Abiotic Stress** ***Moderator:*** *Dr. Miroslav Nikolic* ***Timekeeper:*** *Dr. Jelena Pavlovic*	Waterbury Ballroom
10:30 – 11:00	AM	**Keynote: Silicon-Facilitated Plant Defense Against Biotic Stress: Recent Advances** Dr. Olivia Reynolds Charles Sturt University	
11:00 – 11:20	AM	**Silicon Alleviates Antimony Phytotoxicity in Giant Reed** Dr. Marek Vaculik Comenius University in Bratislava	
11:20 – 11:40	AM	**The Effect of Foliar Application of Silicon on the Expression of Genes Involved in Plant Response to Stress** Dr. Anna Konieczy INTERMAG	

11:40 – 12:00	AM	**Effect of Silicon Application on Orange Rust Control in Different Sugarcane Varieties** Dr. Bruno Nicchio Federal University of Uberlandia	
12:00 – 1:00	PM	**Lunch**	Lagniappe
1:00 – 1:20	PM	**Effect of Soil Silicon Amendment on Rice Insect Pest Complex in Louisiana** Dr. James Villegas LSU AgCenter	
1:20 – 1:35	PM	**Benefits of Silicon Fertilization in Contrasting Sugarcane Cultivars to Drought-Tolerance Subjected to Late Water Deficit** Dr. Monica Camargo Agência Paulista de Tecnologia dos Agronegócios	
1:40 – 1:55	PM	**Program Theme I Panel Discussion** ***Moderator:*** *Dr. Miroslav Nikolic* ***Timekeeper:*** *Dr. Jelena Pavlovic*	
1:55 -3:00	PM	**5-Minute Rapid Oral Competition (Graduate Students)** ***Moderator:*** *Dr. Brenda Tubana* ***Timekeeper:*** *Dr. Marilyn Dalen*	Waterbury Ballroom
3:00 – 3:30	PM	**Break**	
3:30 – 4:30	PM	**Poster General Session** **Poster Graduate Student Presentation**	Rhythms I
4:30 – 6:30	PM	**Big Easy Ghost Tour** ***Coordinator****: Dr. James Villegas*	Meeting Place: Waterbury Ballroom
7:00 – 10:00	PM	**Cultural Night** ***Hosts:*** *Drs. Henk-Maarte Laane & Brenda Tubana* ***Music:*** *Dr. Jazz and the New Orleans Sounds*	Waterbury Ballroom

May 25, 2022

7:00 – 8:00	AM	**Continental Breakfast**	Waterbury Ballroom
8:00 – 9:45		**Program Theme II: Chemistry and Analysis of Silicon in Soils and Plants** ***Moderator:*** *Dr. James Villegas* ***Timekeeper:*** *Dr. Marilyn Dalen*	Waterbury Ballroom
8:00 – 8:30	AM	**Keynote: Extraction and Estimation of Si in Soils and plants: Downsides and Front-Line Appraisals** Dr. Nagabovanalli B. Prakash University of Agricultural Sciences	

8:30 – 8:50	AM	**The Correlation between Amorphous Content and Soluble Silica of Calcium Silicate Slags Using X-Ray Diffraction and Colorimetric Analysis** Jessica Lyza Edward C. Levy Corporation	
8:50 – 9:10	AM	**Effect of Slag Based Gypsum on Silicon Availability, Uptake and Yield of Rice, Maize, and Groundnut in India** Dr. Prabhudev Dhumgond University of Agricultural Sciences	
9:10 – 9:30	AM	**Condensed Silica as a New Source for Si-Fertilizer with Huge Potentials** Tor S. Hansen Elkem Materials	
9:30 – 9:45	AM	**Program Theme II Panel Discussion** ***Moderator:*** *Dr. James Villegas* ***Timekeeper:*** *Dr. Marilyn Dalen*	
9:45 – 10:15	AM	Break/Poster Viewing/Exhibit	
10:15 – 12:00	**Program Theme III: Plant Growth, Development and Metabolism** ***Moderator:*** *Dr. Fabricio Rodrigues* ***Timekeeper:*** *Dr. Marilyn Dalen*		Waterbury Ballroom
10:15 – 10:45	AM	**Keynote: Beyond Biosilicification and the Cell Wall: How Does Silicon Function as a Plant Nutrient?** Dr. Wendy Zellner The University of Toledo	
10:45 – 11:05	AM	**Genes Related to Silicon Transport and Accumulation in Selected Crops** Dr. Boris Bokor Comenius University in Bratislava	
11:05 – 11:25	AM	**Silicon Fertilization and Paddy Field** Dr. Chanchal Malhotra Baba Mastnath University	
11:25 – 11:45	AM	**Elucidating Silicon Responses with Nicotiana tabacum** Dr. Scott Leisner The University of Toledo	
11:45 – 12:00	AM	**Program Theme III Panel Discussion** ***Moderator:*** *Dr. Fabricio Rodrigues* ***Timekeeper:*** *Dr. Marilyn Dalen*	

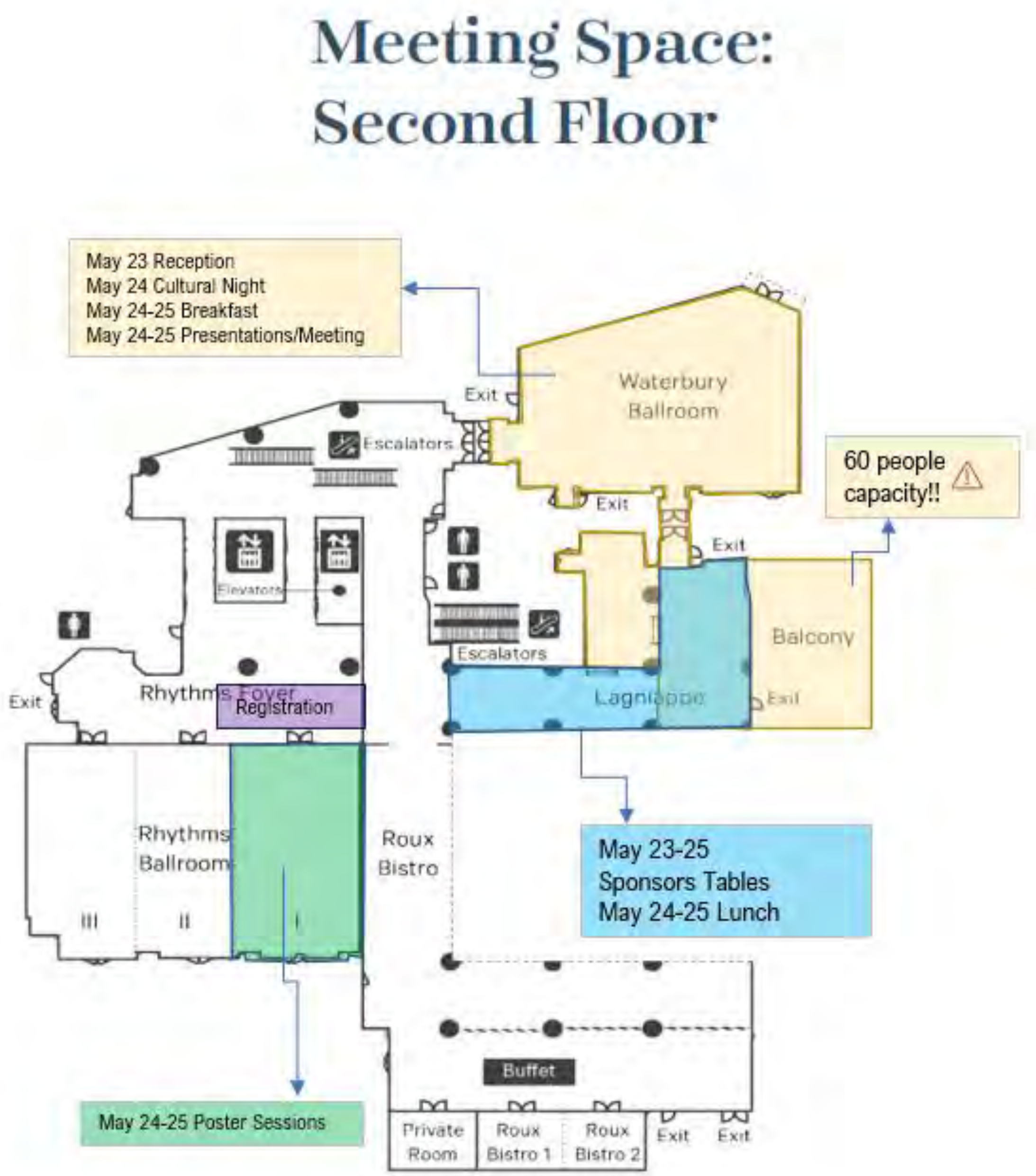
12:00 – 1:00	PM	**Lunch**	Lagniappe
1:00 – 2:35	**Program Theme IV: Agricultural Systems, Climate Change and Ecology** ***Moderator:*** *Dr. Brenda Tubana* ***Timekeeper:*** *Krizzia Guardado*		Waterbury Ballroom
1:00 – 1:30	PM	**Keynote: Silicon Soil-Plant Dynamics in Nutrient-Poor Environment** Dr. Miroslav Nikolic University of Belgrade	
1:30 – 1:45	PM	**Soil Application of Calcium Silicate Slag and the Effects on Soil pH, Crop Yield and Quality of Corn, Potatoes, Tomatoes and Cucumbers Grown in Michigan Soils** Dr. Patrick McGinnity Edward C. Levy Corporation	
1:45 – 2:00	PM	**The Effect of Particle Size on the Solubility and Release of Monosilicic Acid from Silicate Slag and Silicon Uptake by Wheat (*Tritium aestivum*)** Dr. Wooiklee Paye New Mexico State University	
2:00 – 2:15	PM	**The Effects of Stabilized Silicic Acid on Fish and Shrimps** Dr. Henk-Maarte Laane ReXil Agro	
2:15 – 2:30	PM	**Silica Uptake and Effects in Forest Tree Plants** Tommy Landberg Stockholm University	
2:30 – 2:40	PM	**Program Theme IV Panel Discussion** ***Moderator:*** *Dr. Brenda Tubana* ***Timekeeper:*** *Krizzia Guardado*	
2:40 – 2:55	PM	**Break/Poster Viewing/Exhibit**	
2:55 – 4:30	**Program Theme V: Biostimulant, Soil Amendment, and Fertilizer: What's New in the Industry** ***Moderator:*** *Dr. Wendy Zellner* ***Timekeeper:*** *Krizzia Guardado*		Waterbury Ballroom
2:55 – 3:25	PM	**Keynote: Crop Response to Silicon Fertilization in Northeastern Brazil** Dr. Clistenes Nascimento Federal University of Pernambuco	

3:25 – 3:40	PM	**Questions and Answers About Root Silicification** Dr. Alexander Lux Comenius University in Bratislava	
3:40 – 3:55	PM	**Alkali-Enhanced Biochar as a Soil Amendment for Providing Plant-Available Si** Dr. Jim Wang LSU AgCenter	
3:55 – 4:10	PM	**Magnesium Silicate and Its Potential Use for Agricultural Production in Colombia** Dr. Carlos Gauggel Mg12 ZOMAC SAS	
4:10 – 4:25	PM	**A New Alternative Source for Si-Fertilizer by Using Ground SiMn-Slag** Tor S. Hansen Eramet Norway	
4:25 – 4:35	PM	**Program Theme V Panel Discussion** ***Moderator:*** *Dr. Wendy Zellner* ***Timekeeper:*** *Krizzia Guardado*	
4:35 – 5:30	PM	**Business Meeting** **Presiding,** Dr. Brenda Tubana **ISSAG** (Financial Report, Board Members Nomination) **Recognition,** Dr. Lawrence Datnoff **Graduate Student Winners,** Dr. Clistenes Nascimento **Appointment New President & Site of 9th ICSA**	Waterbury Ballroom
5:30 – 6:30	PM	**ISSAG Officers and Board Members Meeting**	TBA
6:30	PM	**Dinner in the Big Easy (on your own)**	

May 26, 2022

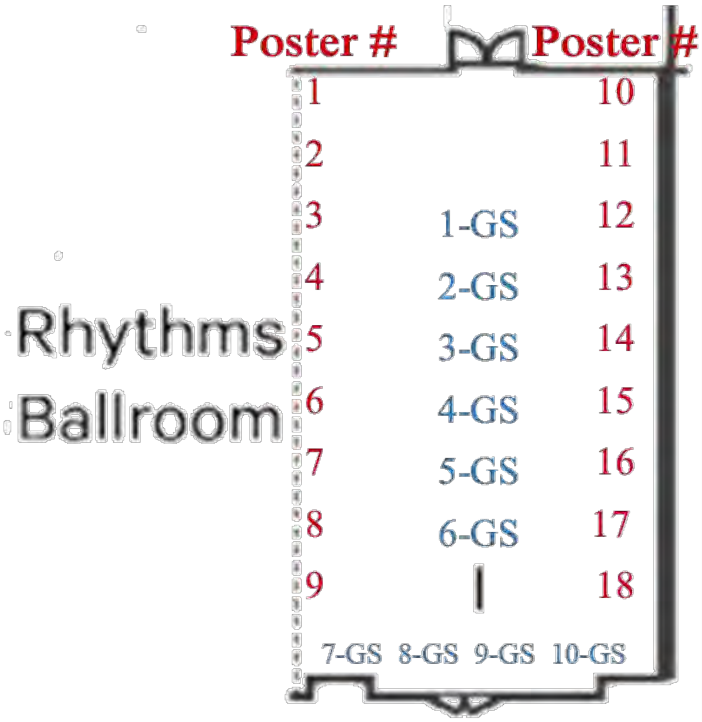
7:00 – 8:00	AM	**Continental Breakfast**	Waterbury Ballroom
8:30 AM – 7:00 PM		**Tour to Baton Rouge** **Coordinator:** Dr. Brenda Tubana LSU AgCenter Soil Fertility Team	Hotel Front Parking Area
8:00 – 8:30	AM	**Bus Boarding**	
8:30	AM	**Depart**	
10:00 – 11:30	AM	**LSU AgCenter Sugar Research Station** Dr. Collins Kimbeng, Sugarcane Breeding & Genetics Dr. Michael Pontiff, Plant Breeder	
12:00 – 2:30	PM	**Lunch @ LSU AgCenter Botanic Garden at Burden** Dr. Jeff Kuehny, Resident Director	
3:00 – 5:00	PM	**Baton Rouge Downtown**	
5:00	PM	**Depart for New Orleans**	
7:00	PM	**Arrive at Sheraton New Orleans Hotel** **Dinner (on your own)**	

Sheraton New Orleans Hotel
500 Canal Street, New Orleans
Louisiana, USA



Poster General Session and Graduate Student Competition

May 24, 3:00 – 4:30 PM, Rhythms I



Notes:

Using Velcro or push pins, attach poster beside the number assignment on the wall/easel

GS – Graduate Student Posters (Competition)

Last Name	First Name	Poster #
Etienne	Philippe	1
Artyszak	Arkadiusz	2
Gittins	David	3
Kostic	Ljiljana	4
Nicchio	Bruno	5
Cruz	Jayvee	6
Desher	Mohsen	7
Desher	Mohsen	8
Laine	Philippe	9
Artyszak	Arkadiusz	10
Carballo-Mendez	Fernando	11
Carballo-Mendez	Fernando	12
Gauthier	Nicole	13
Kostic	Igor	14
Nicchio	Bruno	15
Nikpay	Amin	16
Pavlovic	Jelena	17
Monoshyn	Dmytro	1-GS
Ajnum	Mohsina	2-GS
Chibesa	Mirriam	3-GS
Pallavi	Thimmappa	4-GS
Rivai	Reza Ramdan	5-GS
Trailovic	Maja	6-GS
Biru	Fikadu	7-GS
Islam	Tariku	8-GS
Jhonson	Leonard	9-GS
Mukarram	Mohammad	10-GS

PLENARY
May 24, 9:25 – 10:00 AM, Waterbury Ballroom

Plant Silicon Interactions Between Organisms and Implications for Agroecosystems

Scott Johnson

Hawkesbury Institute for the Environment, Western Sydney University, NSW Australia
Scott.Johnson@westernsydney.edu.au

ABSTRACT

Herbivorous insects account for 25% of multi-cellular species on the planet and can cause significant damage to many agricultural ecosystems. The accumulation of silicon in plant tissues is known to confer resistance to a broad range of invertebrate herbivores and is arguably the most important anti-herbivore defense in the Poaceae, of which just three species provide 42% of human calories globally. Silicified plant tissues are abrasive and can wear down mouthparts, inhibit feeding and reduce nutrient acquisition once ingested. Moreover, silicon can interact with plant secondary metabolite defenses to optimize the overall defensive response of the plant. This talk will consider how plant antagonists (*i.e.*, insect herbivores) and plant mutualists (*i.e.*, endophytes and mycorrhizal fungi) shape how grasses accumulate silicon and reflect on whether these ecological interactions could be exploited in agriculture. We work with the model grass *Brachypodium distachyon*, which is closely related to many cereal crops, forage grasses (tall fescue and perennial ryegrass) and the polyphagous megapest, the cotton bollworm (*Helicoverpa armigera*). Our recent work has shown that silicon is a rapidly induced and persistent anti-herbivore defence which can be quickly activated in plants previously deficient in silicon. Plant mutualists, in some instances, can facilitate silicon accumulation and potentially synergise this resistance to herbivores. Silicon supplemented plants may indirectly interact with natural enemies of the herbivores, either via increased attractiveness or, as we recently demonstrated, via compromising the immune system of herbivores to their antagonists. There are significant gaps in our understanding of these silicon-based interactions, but I argue that a better understanding these ecological interactions might provide a route to more effective pest management in some agroecosystems.

Keywords: Herbivorous insects, Silicified plant tissues, Pest management

Program Theme: Role in Biotic and Abiotic Stress
May 24, 10:30 – 1:55 PM, Waterbury Ballroom

KEYNOTE
10:30 – 11:00 AM

Silicon-Facilitated Plant Defence Against Biotic Stress: Recent Advances

Olivia L. Reynolds[1,2], Malcolm G. Keeping[3,4]

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[4]School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg, 2050 South Africa

ABSTRACT

Silicon (Si) is a ubiquitous element, comprising approximately 28% of the Earth's crust. Although a quantitatively major inorganic component of some plants, its accumulation in specific species is highly dependent on phylogenetic features and the availability of Si in the soil solution. It is reported to be beneficial for plant growth and crop yield, but it is the alleviation of both abiotic and biotic stress that defines this phenomenon and highlights the prospects for this element. However, the mechanisms that underpin this prophylactic effect are not yet fully implicit. Recent advances on Si uptake and accumulation in plants are discussed in the context of how we might increase plant resistance to biotic stress. Here we attempt to define common underpinnings that may assist in bringing together a unifying theory of how Si protects plants against arthropod pests, plant diseases and biotic stress in general.

Keywords: Phylogenetic features, Arthropod pests, Beneficial

Benefits of Silicon Fertilization in Contrasting Sugarcane Cultivars to Drought-Tolerance Subjected to Late Water Deficit

Mônica S. Camargo[1], Natalia G. Bozza[2], Marcelo A. Silva[2]

[1] APTA Regional, Agência Paulista de Tecnologia dos Agronegócios (APTA), Piracicaba, SP, Brazil. (Monica.Camargo@sp.gov.br)
[2] Faculdade de Tecnologia de Piracicaba, Piracicaba, SP, Brazil.
[3] Department of Crop Production, School of Agricultural Sciences, São Paulo State University (UNESP), Botucatu, SP, Brazil

Oral Presentation, 1:20 – 1:35 PM

ABSTRACT

Silicon (Si) is a beneficial element to plant growth, but there is still scarce information about the effects on water deficit in sugarcane, a major yield-limiting factor. Therefore, the objective of this study was to evaluate the effects of Si fertilization and water deficit at the maturation stage of sugarcane cultivars using Si concentration in the leaves, physiological evaluations, biomass, and sugar production. A greenhouse experiment was conducted following a completely randomized factorial design with 8 replications, two sugarcane cultivars (RB85-5536 = drought sensitive; RB86-7515 = drought tolerant), without and with Si (0 =, and 1000 kg^{-1} Si; -Si and +Si) applied as Ca-Mg silicate under well-watered (WW) or water deficit (WD) conditions imposed at maturing stage (11 months-old) during 28 days. Pots (20 L) were filled with samples of Quartizpsament and equal quantities of all nutrients were applied with or without silicate. The biometric, physiological, and gas exchange measurements were influenced ($p < 0.05$) by Si, water deficit, and cultivar independently, and no interaction between these factors was found. The application of Si increased Si content in the leaves, chlorophyll a (c*hla*), carotene, net CO_2 assimilation rate (A), electron transport rate (ETR), plant transpiration (E), stomatal conductance (g_s), and sugar content in stalks, and decreased electrolyte leakage, plant height, leaf area, and stalk fresh biomass. Water deficit enhanced A, ETR, and g_s, and increased Si content in leaves and sugar content in the stalks, but decreased leaf water potential (ψ), relative water content (RWC), and fresh biomass of leaves and leaf area. RB86-7515 showed higher leaf area, plant height, fresh biomass of stalks and leaves while RB85-5536 showed superior values of Si, c*hla*, and c*hlb*, carotene, A, ETR, E, and sugar, but higher electrolyte leakage, and lower ψ in the leaves were also shown for this cultivar. In conclusion, Si fertilization is an important tool to improve the physiological aspects of sugarcane, proving reduced damage to cell plants and increased sugar contents in stalks, independently of water deficit or drought tolerance of the sugarcane cultivar.

Keywords: Water deficit, Physiological evaluations, Plant biomass

The Effect of Foliar Application of Silicon on the Expression of Genes Involved in Plant Response to Stresses

Anna Konieczny, Krzysztof Ambroziak, Hubert Kardasz, Joanna Kardasz, Roksana Rakoczy-Lelek, Marlena Grzanka

INTERMAG sp. z o.o., Al. 1000-lecia 15G, 32-300, Olkusz, Poland
(Anna.Konieczny@intermag.pl)

Oral Presentation, 11:20 – 11:40 AM

ABSTRACT

The positive effect of silicon (Si) on increasing plant response to various environmental stresses has been known for a long time, but Si was mostly provided to plants via soil application in the form of hardly water-soluble solid formulations. Foliar application of Si is also an effective way of providing that element to plants. However, the effectiveness of foliar application of Si formulations depends on chemical form of Si and Si concentration in formulation as well as on the stability of formulation. Among commercially available Si products used in agriculture there are products either alkaline pH or acidic pH. Acidic Si products are characterized by relatively low content of Si whereas the alkaline ones are not well compatible with other agrochemicals. INTERMAG R&D Team developed Si liquid formulation, designed for foliar application, which is characterized by high content of plant available form of Si, high stability, excellent solubility, and compatibility with agrochemicals due to neutral pH. The effectiveness of this formulation has been proved in agriculture practice on various crops. In order to understand the effect of the formulation on plant metabolic pathways the gene expression analysis using the RNA-seq method was performed. Tomato, as a model plant, was used in the experiment. During the experiment tomato plants were exposed to drought stress and Si was applied via foliar spraying 3 times in 4-day interval since the growth stage 6-8 leaves unfolded. Leaf samples for analysis were collected 2 days after 3rd Si application. The results of the experiment demonstrated that foliar application of Si on tomato plants increased the expression of genes related to the synthesis of PR proteins and synthesis of cellulose and xyloglucan, which are compounds responsible for building plant cell walls. Additionally, Si increased expression of genes increasing plant tolerance to drought and cold stress and *Protein Detoxification* gene, which primary function is removing heavy metals and toxic compounds from plant cells. The studies demonstrated lower content of abscisic acid (ABA) in tomato leaves and decreased expression of genes from the ABA signaling pathway, which confirms the lower stress sensation by plants.

Keywords: Environmental stress, Formulation, Tomato

Effect of Silicon Application on Orange Rust Control in Different Sugarcane Varieties

Bruno Nicchio[1], Fernando César Juliatti[2], Hamilton Seron Pereira[2], Marlon Anderson Marcondes Vieira[3], Elber Alves Pereira Filho[4]

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[2]Institute of Agricultural Sciences, Federal University of Uberlandia, Brazil
[3]Graduate Student Program in Agronomy, Federal University of Uberlandia, Brazil
[4]School of Agronomy, UNIPAC, Uberlandia, Brazil

Oral Presentation, 11:40 – 12:00 NN

ABSTRACT

Brazil is the world's largest producer of sugarcane and the main supplier of clean energy such as biofuels and bioelectricity. Among the several factors limiting production, the occurrence and severity of diseases such as orange rust is the reason for replacing cultivars. In some situations, genetic improvement is one of the most suitable strategies for its control, however, it is important to use other forms of disease control depending on the time required to obtain new resistant varieties. The use of chemical control through fungicides can offer a greater possibility of disease control but the fungus has the ability to adapt to the production environment. That is why the use of alternative techniques is important, as the use of silicon (Si) that can provide more resistance to the plant making its less vulnerable. Assuming that the Si soil and foliar application can have an effect on orange rust control in sugarcane, three experiments under house conditions were been conducted using a Randomized Block Design in a 2 x 5 factorial scheme (with and without Si application in the soil x five leaf treatments), with three replications. Was used one variety per experiment (RB92-579, RB85-3250 and RB86-7515) with different levels of susceptibility and planted one pre-sprouted seedling per pot. The treatments with soil Si application indicated higher levels of Si content in plant (variety RB92-579) and soil. The foliar treatments showed higher numbers of height, dry mass and Si uptake but were not able to control rust disease. The area under disease progress curve in sugarcane leaves of variety RB85-3250/susceptible inoculated with *P. kuehnii* was higher than varieties RB92-579/susceptible and RB86-7515/resistant. The severity level on leaves of variety RB85-3250 with soil Si application was lower than treatments without soil Si. There was an incidence of aphids in this study and was observed that in treatments with soil Si the number of aphids were lower.

Keywords: Silicate, Phosphorous acid, Integrated management of plant diseases

Silicon Alleviates Antimony Phytotoxicity in Giant Reed

Marek Vaculík[1, 2], Rajpal Shetty[1, 2], Chirappurathu Sukumaran-Nair Vidya[2], Marieluise Weidinger[3]

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[2]Institute of Botany, Plant Science and Biodiversity Centre of Slovak Academy of Sciences, Bratislava, Slovakia
[3]Core Facility Cell Imaging and Ultrastructure Research, University of Vienna, Austria

Oral Presentation, 11:00 – 11:20 AM

ABSTRACT

Antimony (Sb) is a non-essential metalloid that causes various symptoms of toxicity to plants. Silicon (Si) has been reported to enhance the resistance of plants suffering under various kinds of biotic and abiotic stresses. Fast-growing plant, giant reed (*Arundo donax* L.) is a promising energy crop and can be suitable for use in phytoremediation. However, information regarding the tolerance capacity with respect to Sb toxicity and potential of Si to mitigate the Sb phytotoxicity in giant reed are very scarce. Rhizomes of giant reed were grown for ten weeks in hydroponics exposed to Sb, Si, and their combination wherein treatment without Sb/Si served as a control. Effect of these treatments on rate of net photosynthesis and photosynthetic pigments, phytoextraction ability of Sb, Si and Sb uptake, plant biomass, and lignification and suberization of roots along with localization of Sb and Si were analysed. We found that Si considerably improved the growth and biomass of giant reed under Sb toxicity. Antimony reduced the photosynthesis and decreased the content of photosynthetic pigments, which was completely alleviated by Si. Silicon amendment to Sb treated plants enhanced root lignification. Silicon enhanced lignification of root structures probably restricted the Sb translocation. However, co-localization of Sb with Si has not been observed either at the shoot nor at the root levels. Similarly, Sb was also not detected in leaf Si phytoliths. These findings suggest that Si treatment promotes overall plant growth by improving photosynthetic parameters and decreasing Sb translocation from root to shoot in giant reed. This work was supported by the Slovak Research and Development Agency (grant number APVV-17-0164) and by the VEGA Grant, Nr. VEGA 1/0472/22).

Keywords: Giant reed, Phytolith, Lignification

Effects of Soil Silicon Amendment on Rice Insect Pest Complex in Louisiana

James Villegas[1], Brenda Tubana[2], Michael Stout[1]

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[2]School of Plant, Environmental, and Soil Sciences, Louisiana State University AgCenter, Baton Rouge, Louisiana, USA

Oral Presentation, 1:00 – 1:20 PM

ABSTRACT

Rice plants are consistently subjected to various pressures by insect pests throughout the growing season. The main insect pest complex reported in Louisiana is composed of the rice water weevil (major early-season insect pest), fall armyworm (sporadic early-season pest), sugarcane borer and rice stalk borer (long-established but sporadic stem boring pest), Mexican rice borer (an invasive stem-boring pest), and rice stink bug (major late-season pest). Soil silicon amendment has been shown to enhance plant resistance against herbivorous pests. Rice is a typical silicon-accumulating graminaceous crop. Field and greenhouse experiments were conducted to investigate the effects of soil silicon amendment and nitrogen levels on the rice insect pest complex in Louisiana. In the greenhouse, we found that the force required to penetrate rice stem was higher on silicon-treated rice plants compared to untreated plants. Total phenolic content, on the other hand, decreased when the nitrogen rate was increased. In the field experiment, the effects of soil silicon amendment on rice water weevil densities, whitehead incidences (stemborer injury), stink bug population, and yields were found to be weaker than the effects of nitrogen fertilization. Furthermore, separate field experiments were conducted to investigate the effects of silicon fertilization and rice cultivars on rice insect pests. Results showed reductions in weevil larval densities in silicon treated plots compared to untreated plots in one sampling time only. Similarly, higher yields were observed in silicon-treated plots compared to untreated plots for one year only. Silicon amendment did not affect whitehead incidences and rice stink bug densities. The levels of infestations of rice water weevil, stemborers, and rice stink bugs were also found to vary among the rice cultivars evaluated in the study. Despite the weak effect of silicon on insect pests in this study, silicon could still play an important role in rice production considering the positive effects on yield and documented effects on disease suppression.

Keywords: Rice water weevil, Stemborers, Drill-seeded rice

The Effect of Various Forms of Silicon and Term Foliar Application on Yield and Technological Quality of Sugar Beet Roots

Arkadiusz Artyszak, Alicja Siuda

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Poster Presentation #10, Rhythms I

ABSTRACT

In Poland, silicon (Si) is used in foliar application more and more often not only in horticultural crops and vegetables, but in recent years also in the production of agricultural plants, including sugar beet. Sugar beet (*Beta vulgaris* L.) is cultivated in Poland on the area of approx. 250 thousand hectares ha. The sugar yield is often reduced as a result of increasing water shortages. One of the ways to reduce the harmful effects of drought is foliar application of Si. The beneficial effect of Si was also found to reduce the infestation of plants by *Cercospora beticola* Sacc. In the years 2017-2019 in Sahryń (south-eastern region of Poland, near the border with Ukraine), a strict field experiment was established in which products containing various forms of Si: Agriker® (potassium silicate), Optysil® (sodium metasilicate and iron chelate), SmartSil® (calcium silicate), and YaraVita Optysil® (choline stabilized orthosilicic acid with added calcium) were applied once in the 6-leaf phase of sugar beet (cultivar BBCH 16) at 7 and 14 days later in the doses recommended by the producers. The number of combinations, repeats, and plots were 12, 4, and 48, respectively. Years of research significantly differentiated the value of the assessed features. The highest yields of roots and sugar were obtained in 2017, which was characterized by the most favorable course of weather conditions, and the lowest one a year later, when they were the least favorable. On average, for the entire research period, it was found that the selection of the product had a significant impact on the content of sugar, α-amino nitrogen, potassium, sodium, and refined sugar in sugar beet roots as well as the biological sugar yield and the pure sugar yield. The selection of the product had no significant influence on the root yield. The term of application significantly influenced the content of sugar, potassium, and refined sugar in sugar beet roots. It did not significantly differentiate the root yield, the content of α-amino nitrogen, and sodium in sugar beet roots as well as the biological sugar yield. The highest biological and pure yield of sugar was obtained using Agriker®.

Keywords: Drought, Silicon sources, Sugar quality

Silicon Improves the Antioxidant Capacity in Leaves of *Moringa oleifera* Lam. Grown in Nutrient Solution with Different Levels of Electrical Conductivity

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Poster Presentation # 11, Rhythms I

ABSTRACT

Moringa oleifera Lam. has been called a multipurpose plant, since it is used for various activities such as human and farm animal feed. Particularly, moringa leaves, due to their content of antioxidant compounds can be considered as a product with potential application in the food, nutraceutical and pharmaceutical industries. Moringa seedlings were transplanted into polyethylene pots containing 10 L of pumicite and kept in a greenhouse. The treatments used arose from the combination of the base nutrient solution with the following three factors: first factor was electrical conductivity (EC): 3, 6, and 9 dSm^{-1}, these levels were achieved by the addition of NaCl; second factor was silicon (Si) concentration: 60 and 120 mg L^{-1}: while the third factor was two Si fertilizer sources (potassium silicate (K_2SiO_3) and Si dioxide (SiO_2)). Phenolic compounds and antioxidant capacity of moringa leaves were evaluated in two harvests, the first at six weeks after transplanting and the second at six weeks after the first harvest. The effect of EC and Si were significantly different, while Si fertilizers sources and the interactions between these factors did not show differences. At the first harvest, total flavonoids as well as antioxidant capacity DPPH and ABTS showed higher values with the 6 dS m^{-1}, where total flavonoids were the most benefited variables with an increase of 68%. Total phenols, total flavonoids, and ABTS antioxidant capacity showed increases of 26, 107, and 27%, on average, respectively, for both Si doses. At the second harvest, total phenols showed an increase of 13% at EC 6 and 9 dS m^{-1} and total flavonoids increased 15% at EC 9 dS m^{-1}. Total phenols increased by 22 and 32% at the 60 and 120 mg L^{-1} Si doses, respectively, while total flavonoids as well as antioxidant capacity DPPH and ABTS were benefited, regardless of Si dose, by 22, 12, and 27%, respectively. The results show that the addition of Si to the nutrient solution, independently of the EC, increased the concentration of phenolic compounds and the antioxidant capacity of leaves from moringa plants.

Keywords: Antioxidative metabolism, Moringa, Phenolics, Silicon sources

Duration of Priming with Silicon Modulates Antioxidative Response of Wheat to Salinity Stress

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Poster Presentation #12, Rhythms I

ABSTRACT

Priming with silicon (Si) may increase plant resistance to biotic and abiotic stresses, in particular in conjunction with its subsequent application. Yet, the very effect of the duration of priming with Si is less understood. Here, we investigated the effect of the duration of priming with Si on components of the antioxidative response of wheat exposed to a gradient of salinity stress. After priming with 1.5 mM $Si(OH)_4$ (0, 1, and 3 days), wheat seedlings were exposed to different NaCl levels (0, 30, and 60 mM) without (-Si) or with (+Si) supply of 1.5 mM $Si(OH)_4$. The activities of superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX), and the concentration of malondialdehyde (MDA) were measured in shoots and roots after 1 and 5 days of NaCl treatments. Interaction of priming duration and addition of Si on antioxidative variables were analyzed using general regression model. Overall, priming had no influence on -Si plants under salt stress. On the day 1 of NaCl exposure, priming duration did not affect SOD and APX activities neither in roots nor in shoots. However, on the day 5 of NaCl exposure longer priming with Si significantly increased the activities of APX and SOD in both roots and shoots. The activity of CAT showed no response to priming with Si and subsequent Si supply in both plant organs irrespectively of the duration of NaCl exposure. Interestingly, in both organs the concentrations of MDA as a proxy for oxidative damage of plant membranes were very clearly and consistently lower after 3 days of priming with Si (compared to 1 day or no priming) during the whole period of NaCl exposure. This study demonstrated that longer priming with Si can enhance the ameliorative effect of Si supply on the antioxidative response of wheat plants to a gradient of salinity stress.

Keywords: Abiotic stress, Antioxidative metabolism, Salt stress

Suppression of Hemp Powdery Mildew Using Root-Applied Silicon

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Poster Presentation #13, Rhythms I

ABSTRACT

Powdery mildew (*Golovinomyces spadiceus*) is the most common disease of greenhouse cannabis. Most hemp grown for cannabinoid production is propagated by cuttings or started from feminized seed in greenhouses and then moved outdoors, while most marijuana and some hemp are grown entirely indoors. To determine the effects of silicon (Si) on powdery mildew in the greenhouse, Si was applied to hemp roots in a peat-based soilless mix and evaluated for plant uptake and disease suppression over a six-week period. This study confirmed that there was a negative linear relationship between percent Si accumulation in leaf tissue and the percent powdery mildew per leaf area. Mildew severity in the upper canopy was significantly reduced at 300 kg ha^{-1} total Si, while 600 kg ha^{-1} was needed for the mid canopy. Results confirmed that Si may be a useful tool for the integrated management of powdery mildew. As the cannabis market expands, Si can serve as a viable option for greenhouse growers especially for plants grown in soils or soilless mixes low or limiting in soluble Si.

Keywords: Cannabis, Disease management, Plant uptake

Silicon Modulates Root Phenomics and Leaf Ionomics in Oak under *Phytophthora* Infection and Low Phosphorus Conditions

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Poster Presentation #14, Rhythms I

ABSTRACT

Pedunculate oak (*Quercus robur* L.) is the most abundant deciduous tree species in Europe with high economical and ecological importance. Different species of *Phytophthora* are considered as one of the most important factors responsible for deterioration of oak forest, causing serious root damage not only in the forest trees, but also in the nurseries. Oak seedlings were grown in plastic pots with extremely low phosphorus (P) soil (1.5 mg kg^{-1} total P; no available Olsen-P detected). Silicon (Si) and P were supplied as Na_2SiO_3 (300 mg Si kg^{-1} dry soil) and KH_2PO_4 (180 mg P kg^{-1} dry soil), respectively. Four treatments (-P/-Si, -P+/Si, +P/-Si, and +P/+Si) were used in the experiment. After two months of experiment, a half of the plants in each treatment were root-inoculated with *Phytophthora plurivora*. After further four weeks, the first symptoms of *P. plurivora* infection appeared in leaves (*e.g.*, leaf necrosis and wilting). Plants were then carefully removed from the pots, divided into roots and shoots, and the roots were scanned and analyzed by the WinRHIZO® software. Foliar concentrations of Si, P, K, Ca, Mg, B, Cu, Fe, Mn, and Zn were determined by ICP-OES, while the concentrations of N and S were determined by CHNS Analyzer. The addition of Si obviously improved root health status (*e.g.*, decreasing de number of lesions and necrosis intensity) in the infected plants grown under -P conditions, which was followed by an increased foliar P concentration. The Si supply significantly increased the root variables (*e.g.*, total root volume, root length, and area of thin roots) in both -P and +P plants inoculated with *P. plurivora*. Therefore, *P. plurivora* infection and supply of P and Si modulated the nutrient uptake and thereby changed the leaf ionomics, especially for infected -P plants supplied with Si (*e.g.*, significantly increased B, Cu, and Si foliar concentrations and decreased Fe, Mn, Ca, Mg, K, and S foliar concentrations). Furthermore, Si fertilization significantly declined loses in plant dry biomass caused by *P. plurivora* infection and/or P deficiency, showing biomass comparable to non-infected +P plants.

Keywords: *Phytophthora plurivora*, Plant nutrition, Root infection

Effect of Soil and Foliar Application of Silicon Sources to Control Orange Rust in Sugarcane

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Poster Presentation #15, Rhythms I

ABSTRACT

Brazil is the world's largest producer of sugarcane and the main supplier of clean energy such as biofuels and bioelectricity. Among the several factors limiting production, the occurrence and severity of diseases such as orange rust is the reason for replacing cultivars. In some situations, genetic improvement is one of the most suitable strategies for its control, however, it is important to use other forms of disease control depending on the time required to obtain new resistant varieties. The use of chemical control through fungicides can offer a greater possibility of disease control but the fungus has the ability to adapt to the production environment. That is why the use of alternative techniques is important, as the use of silicon (Si) that can provide more resistance to the plant making its less vulnerable. The objective of this study was to evaluate the effect of Si soil and foliar treatments to control *P. kuehnii* in sugarcane (variety IACSP-015503) plants cultivated in a sand soil. One experiment under house conditions was been conducted using a completed randomized design with 13 treatments (control, fungicide, solution I and II, K_2SiO_3 and Silicic Acid at 20, 40 and 60 mg, wollastonite, agrosilicio, wollastonite + fungicide, wollastonite + K_2SiO_3, agrosilicio + fungicide, and agrosilicio + K_2SiO_3,) and four replications. In this study was used one pre-sprouted seedling per pot with capacity of 6 kg of soil. Sugarcane plants without any treatment showed lower dry mass, Si content and uptake. Silicic Acid doses (20, 40 and 60 mg of Si L^{-1} H_2O) increased dry mass and Si uptake. Soil and foliar (K_2SiO_3 and Silicic Acid at 20, 40 and 60 mg L^{-1} H_2O) treatments were more effective than foliar treatments in increasing Si uptake in sugarcane plants. Foliar treatments and soil treatments combine with foliar treatments (agrosilicio, agrosilicio + fungicide, and agrosilicio + K_2SiO_3) were more effective to reduce orange rust severity on sugarcane leaves. However, K_2SiO_3 showed lower severity than the treatments with Silicic Acid at 20, 40 and 60 mg L^{-1} H_2O.

Keywords: Silicic acid, Accumulated silicon, Integrated management of plant diseases

Silicon Fertilization in Sugarcane for Management of Whitefly (*Neomaskellia andropogonis* Corbett (Homoptera: Aleyrodidae))

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Poster Presentation #16, Rhythms I

ABSTRACT

Sugarcane is grown extensively throughout the world including more than 120 thousand hectares in Khuzestan province, the principal area of sugarcane production in Iran. Sugarcane (interspecific hybrids of *Saccharum*) is a strategically important cash crop that has economic and social impact in many countries. Sugarcane is sensitive to a wide range of biotic stresses, including insect herbivores, pathogens, and weeds. The sugarcane whitefly (*Neomaskellia andropogonis* Corbett (Homoptera: Aleyrodidae)) becomes apparent in recent years and damage of this pest seems increasing continuously year by year. This pest spreads in all sugarcane agro industries and damage of it may worsen under humid conditions. Active nymphs of whitefly suck crop juice and phloem sap from under-side of leaves resulting in reduction of chlorophyll content, impart of photosynthesis and eventually in severe damage juice quality and purity. Therefore, sucrose content will be greatly reduced mostly in early-maturing commercial cultivars. Silicon (Si) has been considered as a beneficial agronomic nutrition for sugarcane production, which alleviates abiotic stressors. Moreover, Si has been successfully used for protection of sugarcane against different pests' species including stem borers, spittlebugs, leafhoppers and mites. Field trials were carried out during two consecutive years 2016 and 2017 at Salman Farsi Agro-industry Farms (48°35'E, 31º8'S), Ahwaz-Iran. The two varieties used in this research were CP57-614 and CP69-1062, which shown different rate of susceptibility to *N. andropogonis* infestation. For each planted variety, two experimental plots including 15 furrows 12 meter in length and 1.8 meter spaced between two furrows (324 m^2 for each plot) were used. The Si treatment (Silicic acid, Rexil-Agro Company, Netherlands) was applied to all varieties during four sprays (0.5 liter per hectare at early vegetative stage of plants with 8 to 10 leaves, 1 liter per hectare after first spray, 1 liter per hectare after second spray and finally 1 liter per hectare after third spray). In each sampling date (four sampling dates, late September to mid-November) 10 whole stalk of each variety (80 whole stalks for each variety) were selected randomly at different parts of plot for damage assessment. All infested leaves were placed in plastic bags and sent to laboratory for counting the number of eggs, adults, pupa, and nymphs. The results clearly showed that there were significant differences between control and Si-treated varieties in reduction of all life stages of *N. andropogonis*. We proposed that silicic acid is a promising component for management of *N. andropogonis* damage and can be incorporated with other management strategies in sugarcane IPM.

Keywords: Biotic stresses, Silicon source, Sugarcane IPM

Silicon Enhances Biosynthesis of Organic Acids in Zinc-Deficient Rice

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Poster Presentation #17, Rhythms I

ABSTRACT

Zinc (Zn), an essential micronutrient for crops, is involved in a variety of physiological processes. The Zn deficiency mainly affects generative growth and seed development and being a component of the antioxidant machinery (*e.g.*, Cu/Zn-SOD) is conductive to oxidative stress in plant tissues. Rice is a typical silicon (Si)-accumulating species, which is strongly affected by Zn deficiency in the alkaline, low Zn soils, especially high in phosphate and/or organic matter. Yet, little is known about the interaction between Si and Zn in rice plants under Zn-deficient conditions. We investigated the effect of Si nutrition on Zn tissue distribution and biosynthesis of organic acid in rice plants subjected to short-term (up to 7 days) and long-term (28 days) Zn deficiency. Tissue concentrations of organic acids by HPLC in parallel Zn and Si by ICP-OES were measured. The Si addition to the nutrient solution successfully mitigated visual symptoms of Zn-deficiency stress and significantly increased dry biomass of rice plants. Interestingly, during the short-term experiment, +Zn plants supplied with Si showed significantly lower Zn concentration in the shoots, but significantly higher Zn concentration in the roots. Also, in the -Zn plants supplied with Si, the concentration of Zn in root tissue rapidly decreased to the level of -Si/-Zn plants, which was followed by an increased concentrations of both organic acids and Zn in the shoots. In the long-term experiment, however, Si did not affect Zn concentration in roots nor in shoots of -Zn plants, but Si differently affected organic acid profile and their tissue accumulation depending on the plant organ and Zn status. In conclusion, Si supply enhanced root-to-shoot translocation of Zn mediated by organic acid ligands during the first 7 days of Zn deficiency.

Keywords: Silicon nutrition, Oxidative stress, Plant nutrition

Si Inhibits the Uptake of Cl^- Into Mesophyll Protoplasts of Wheat under Various Abiotic Stresses

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Poster Presentation #18, Rhythms I

ABSTRACT

Several investigators showed that silicon (Si) improved plant tolerance to abiotic stresses. through Si-increased root hydraulic conductivity and reduced uptake of toxic ions and heavy metals. The relationships between Si and various other inorganic ions have been extensively studied but the effect of Si on chloride (Cl) transport in plants under saline conditions is poorly understood. Chloride is an essential micronutrient that regulates several physiological processes and metabolic enzymes in plants. The Cl content in fresh plant/foliar extracts or dried and acid-digested plant samples was earlier determined using Cl electrodes or using an automatic Cl analyzer, respectively. The dynamic equilibrium between passive fluxes through membrane conductance and active transport mediated by importers and exporters determines the intracellular concentration of Cl. The intracellular Cl ion or Cl^- concentrations in the biological cells are an indicator of Cl^- channels and Cl^- transport. Therefore, exploring Cl homeostasis in plants treated independently with Si or combined with abiotic stresses is an important strategy to elucidate Si-mediated adaptive tolerance. The fluorescence imaging of intracellular Cl developed during the 1990s in biomedical sciences has little been used in plant science research. The major advantage of Cl imaging is to allow the temporal and spatial measurement of intracellular concentration. The cell-permeable Cl^- indicator dye MQAE [N-(ethoxy carbonyl methyl)-6-methoxy quinolinium bromide] specifically binds to Cl and an increase in Cl concentration is signaled by a decrease in fluorescence without any change in either the excitation (380 nm) or emission spectra (460 nm). In the present study with wheat, cv. Vinjette, we investigated the influence of Si on the cytosolic uptake of Cl under salinity and different heavy-metals treatments. Primary stressors namely NaCl (20, 40, and 50 mM), aluminum ($AlCl_3$ 2 µM), arsenite (As[III], 5 µM), arsenate (As[V], 50 µM), and cadmium ($CdCl_2$, 5 µM), which were added directly to the MQAE-labelled protoplasts isolated from wheat mesophyll cells and the kinetics of fluorescence quenching was monitored. Potassium silicate (5, 20, and 50 mM) was added when the fluorescence decline had attained a plateau level. Results revealed that salinity induced Cl^- uptake was dose-dependent. Similarly, salinity-increased Cl^- uptake was evidently reduced by Si also in a dose-specific manner and the maximal alleviative effect was observed at 25 mM Si. However, Si application was unable to decrease the KCl-induced Cl^- uptake. The pre-treatments of wheat mesophyll protoplasts with Si were also unable to reduce Cl^- uptake. Among the arsenic species, As[III] was more effective than arsenate and Si treatment was unable to reduce the increase in Cl^- intracellular concentrations. An opposite pattern was observed in arsenate treatments. Cadmium showed more rapid Cl^- uptake as compared with Al-treated protoplasts.

Keywords: Root hydraulic conductivity, Toxic ions, Heavy metals

Prior Herbivory Induced Si Defences Against Subsequent Herbivory but Elevated Atmospheric CO_2 Negates Si Defences

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5-Minute Rapid Oral, 2:30 – 2:35 PM
Poster Competition #8-GS, Rhythms I

ABSTRACT

Crop losses caused by insect herbivores is one of the major challenges facing the world agriculture. Plants in nature are attacked by multiple herbivores either simultaneously or sequentially. Specifically, prior feeding by one herbivore often alters host plant quality that can affect the performance of subsequent herbivores. Such prior effects typically resulted in induced plant defences that can potentially impact the successive herbivore. Silicon (Si) has been shown to induced in many grasses following herbivory, so could mediate such temporally separated insect herbivore interactions. In contrast, elevated atmospheric CO_2 (eCO_2) concentrations, predicted in the future, often decrease Si accumulation which could potentially weaken this interaction. We examined the effects of prior feeding by the generalist insect herbivore *Helicoverpa armigera* on the performance of house crickets (*Acheta domesticus*) that subsequently fed on the same host plant. We used the model grass *Brachypodium distachyon*, either supplied with Si (+Si) or untreated (-Si), grown in the glasshouse maintained at CO_2 concentrations of 410 and 640 ppm (eCO_2). We measured the effect of prior caterpillar herbivory and Si treatments on plant physical defences and cricket performance. Prior feeding by caterpillars induced Si accumulation. Despite eCO_2 reducing Si accumulation, initial herbivore induction of Si negated the effects of eCO_2. Both previous caterpillar herbivory and Si treatment reduced cricket performance. Silicon induction by successive herbivory was additive, initially increasing by 48% under aCO_2 and 47% under eCO_2 with caterpillar herbivory and then by 73% and 140% with both herbivores under aCO_2 and eCO_2, respectively. Plant biomass was similar in plants attacked by caterpillars alone or both herbivores, suggesting that initial Si induction by caterpillars deterred feeding by crickets. Our results suggest that Si induction by one herbivore negatively impacts successive herbivores. Moreover, Si induction is an irreversible defence and potentially a stronger, or perhaps longer-lasting mediator of such herbivore interactions in some plant taxa.

Keywords: Insect herbivore, Silicon induction, House crickets

Plant Silicon Disables Cryptic Colouration of an Insect Herbivore by Reducing Its Ability to Sequester Carotenoids

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5-Minute Rapid Oral, 2:35 – 2:40 PM
Poster Competition #9-GS, Rhythms I

ABSTRACT

Cryptic colouration in herbivorous insects is an effective strategy for evading their natural enemies; it requires sequestration of carotenoids derived from plant tissues in the insect haemolymph. Carotenoid and chlorophyll pigments can alleviate oxidative stress in plants imposed by insect attack. For grasses, silicon (Si) accumulation is the main deterrent to herbivory, but it is unknown whether Si defences inhibit carotenoid sequestration and cryptic colouration in insects and whether Si impacts pigment levels in plants following insect attack. Using the model grass *Brachypodium distachyon*, we demonstrated that the global insect cotton bollworm (*Helicoverpa armigera*) exhibited lower relative growth rates (RGRs) and brown to black colouration when feeding on Si-supplemented (+Si) plants, whereas larvae feeding on Si-free plants (−Si) exhibited higher RGRs and green cryptic colouration. Larvae sequestered lower levels of lutein (−53%) and total carotenoids (−44%) in the haemolymph when feeding on +Si plants than when feeding on −Si plants. Larvae partly excreted carotenoids and chlorophylls, regardless of plant Si status. Furthermore, Si reduced carotenoid and chlorophyll contents in *B. distachyon* leaves in the absence of insect attack. Insect attack subsequently induced increased pigment synthesis and Si accumulation in +Si plants. We provide novel evidence that Si fertilisation can disable insect cryptic colouration by inhibiting carotenoid sequestration in the haemolymph. Potential reduction in the degree of crypsis can make insects more detectable to visually hunting predators (*e.g.*, birds, spiders) and enhance their likelihood of being attacked and killed.

Keywords: Herbivorous insect, Natural enemies, Oxidative stress

Characterization of the Microbial Community of the Rice Rhizosphere Structured by Silicate Fertilization and Pathogen Infection

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5-Minute Rapid Oral, 2:40 – 2:45 PM
Poster Competition #10-GS, Rhythms I

ABSTRACT

Silicon (Si) is an important micronutrient for plant growth and resistance to abiotic and biotic stresses. Being a high Si accumulator, rice is benefited from silicate fertilization for growth and resistance to diseases, such as sheath blight caused by the rice pathogenic fungus *Rhizoctonia solani*. We hypothesized that Si fertilization would induce changes in the rhizosphere microbial structure of diseased rice plants. Our study aimed at profiling the microbiome of the rice rhizosphere in the soil in accordance with the application of silicate slag (a Si-fertilizing source) and the infection with *R. solani*. For this study, we conducted a field trial at the LSU AgCenter's H. Rouse Caffey Rice Research Station (Rayne, LA). For Si fertilization, silicate slag, an industrial by-product of iron production containing 5.4% Si, was applied manually to half the field at the rate of 500 kg ha^{-1}. For infection of rice to incite sheath blight, rice plots were inoculated with *R. solani* using the inoculum formulated with sterilized rice hulls. We observed that Si-fertilization significantly reduced the disease severity of sheath blight. To characterize the microbial profiles, the DNA of the rice rhizosphere from Si-treated and non-Si-treated plants, in combination with infected and non-infected conditions, were extracted and analyzed using Qiime 2 and R software. We detected Si fertilization-associated variation in the microbial communities of the rice rhizosphere in alpha diversity indices, bacterial phyla abundance, and differentially abundant amplicon sequence variants (ASVs). Si-treated plants showed increases in *Rhizobium* sp., *Methanobacterium oryzae*, and *Acidobacterium* sp., and decreases in iron-reducing enrichment bacteria. The beta diversity analysis revealed that the change in the most abundant bacterial species was primarily driven by the status of pathogen infection by *R. solani*. This study provides an insight into how Si-treated rice plants shape microbial communities of the rice rhizosphere in association with their enhanced disease resistance.

Keywords: Silicon accumulator, Microbiome, Disease resistance

Silicon Nanoparticles (SiNPs): A Potential Biotechnological Tool to Palliate the Negative Impact of Salinity Stress in Lemongrass Plants

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5-Minute Rapid Oral, 2:45 – 2:50 PM
Poster Competition #11-GS, Rhythms I

ABSTRACT

Lemongrass (*Cymbopogon flexuosus*) crops have acquired great relevance, mainly due to their essential oils which have multiple applications in medicine, food preservation, and the cosmetics industry. The increasing salinity in cropland is one of the most important environmental problems in the world that limits the growth and productivity of crops since it usually has associated oxidative stress. Using lemongrass grown under two concentrations of NaCl (160 and 240 mg L^{-1}), the present study analyses how salinity affects its growth and the metabolism of reactive oxygen species (ROS). Thus, 160 mg L^{-1} NaCl caused significant damage to the physiology parameters, essential oil content, and antioxidant system, however, the highest reduction in plant height (41%), chlorophyll fluorescence (23%), and essential oil production (50%) were observed with 240 mg L^{-1} NaCl. Furthermore, it was evaluated whether the foliar application of 150 mg L^{-1} SiNPs could palliate the observed negative impact of salinity on lemongrass plants. Under these experimental conditions, the data indicate that SiNPs trigger a general activation of growth, PSII activity and antioxidant system, as well as an increase in essential oil biosynthesis. Therefore, it is proposed that the SiNPs can be a useful biotechnological tool to palliate salinity stress on lemongrass crops.

Keywords: Antioxidant metabolism, *Cymbopogon*, Essential oil

Program Theme: Chemistry and Analysis of Silicon in Soils and Plants

May 25, 8:00 – 9:45 AM, Waterbury Ballroom

KEYNOTE

8:00 – 8:30 AM

Extraction and Estimation of Si in Soils and Plants: Downsides and Front-Line Appraisals

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ABSTRACT

In spite of abundance of silicon (Si) in the Earth's crust, its external application is gaining popularity due to its availability to the plants correlating primarily with the concentration of silicic acid in the soil solution. The precise gauging of Si availability in the soil has been a limiting factor for its effective utilization in agriculture since different Si sources exhibit complex dissolution chemistry in different soil environment. A number of chemical extraction procedures have been established to determine the plant-available Si (PAS) status across the world. Most of these methods apply an anion to replace adsorbed Si and have been tested by determining the correlations between Si analyzed in the extract with crop yield and uptake. This association between extractants was reinforced by the relativity between the critical levels established for the different extractants despite the fact that they were established in independent studies. The quantity of extractable Si varies depending on the extracting solution used to solubilize the soil Si. In general, the most successful extractants used are acid rather than neutral solutions, and dissolution is further increased by chelating agents. Other factors such as the method of equilibration, soil: solution ratio, temperature, and pH of extractant solution are also important. Dilute salt solutions provide a measure of readily available Si present in the soil solution, while results obtained using NH_4OAc and acetic acid indicated that the Si solubilized was likely to be more simple polymers affected by changes in pH, CEC and the ratio of soluble Si:Al in the soil solution. However, clay content and relationships between extractable Si and Fe and Al were more prominent factors in Si extracted by phosphate acetate, citric acid and 0.005M H_2SO_4. Moreover, the 1% Na_2CO_3 is the most commonly used methodology for the extraction of biogenic Si (BSi) in aquatic sediments. Although it is less often used, several Na_2CO_3 procedures have been developed to extract amorphous Si (ASi) from soils. Plant-available Si analysis is even more complicated when Si is added to soil, because it may react with amorphous surfaces; additionally, the sesquioxide content of the soil, soil pH and the presence of other anions can interfere with Si adsorption. The ability to determine Si in plant material accurately is a basic requirement when evaluating yield responses to applied Si products in the fields. Silicon dissolution and release from soils/applied source materials varied during different growth stages of crop and influences its plant uptake However, the relationship between the soil Si levels determined by different methodologies and the uptake of Si by plants is not always consistent. Hence, analytical protocols would over or underestimate the Si and poorly correlate with

yield or nutritional parameters. It is indispensable to develop common protocols or modification to the procedures for Si estimation at a global scale. Extraction and estimation of available Si in soils and plants need to be discussed for a better understanding of the subject especially on application of Si fertilizers on different crops in varied soil types.

Keywords: Extraction method, Critical levels, Plant-available silicon

Effect of Slag Based Gypsum on Silicon Availability, Uptake and Yield of Rice, Maize and Groundnut in India

Prabhudev Dhumgond, Shruthi Venkatesh, Pema Khandu Goiba, Laxmanarayanan M., Hamsa Nagaraju, Jahir Basha C R, Chikkaramappa T., Nagabovanalli B. Prakash

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Oral Presentation, 8:50 – 9:10 AM

ABSTRACT

Slag based gypsum (SBG) is a unique multi nutrient fertilizer produced from Linz-Donawitz (LD) slag which contains calcium, sulphur, silicon, iron and zinc. Application of gypsum is a common practice as a nutrient source and amendment in India. In general, natural gypsum or commercial gypsum (CG) contains less or no silicon. Field experiments were conducted at various locations of Karnataka, Southern India from 2018 to 2021, to study the effect of silicon fertilization through SBG on rice, maize and groundnut. For rice and maize crops, seven treatments consisting of three levels (450, 600 and 750 kg ha^{-1}) each of SBG and CG together with recommended dose of fertilizer (RDF) and one control (RDF alone) were used. Three rates of SBG (375, 500 and 625 kg ha^{-1}) was applied as two methods (basal and basal + split) and 500 kg CG ha^{-1} as basal is considered as control for groundnut. In all the experiments, treatments were arranged in randomized block design with three replications. Pooled analysis results of rice and maize crop revealed that application of 750 kg SBG ha^{-1} recorded significantly higher yield when compared to CG and RDF applied treatments. In groundnut, basal and basal + split application of SBG recorded significantly higher pod and haulm yield than basal application of CG. However, higher pod and haulm yield was recorded with basal + split application of 625 kg SBG ha^{-1}. Silicon uptake in rice, maize and groundnut significantly increased with the application of SBG when compared to CG application. However, total uptake of silicon by rice ($r = 0.84$), maize ($r = 0.76$) and groundnut ($r = 0.94$) was positively correlated with their economic yield. Regardless of the crop, increased rate of SBG, significantly increased the calcium chloride and acetic acid extractable silicon content in post-harvest soils and also significantly higher than CG applied treatments. In conclusion, silicon fertilization through SBG could be essential to improve the yield of crops, nutrient uptake and fertility status of soil.

Keywords: Sulfur, Fertilization method, Source

Condensed Silica as a New Source for Si-Fertilizer with Huge Potentials

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Oral Presentation, 9:10 – 9:30 AM

ABSTRACT

Elkem is world class company specialized on Si production and has several Si based specialty products. For years Elkem has been experimenting with new types of Si based soil amendments or fertilizers and have obtained very positive quality and yield results on crops like rice, banana, and sugarcane. These products are based on amorphous silica, with a purity of 95% SiO_2, surface area of 20 m^2/gr, is in the size-range from micro- to nanoparticles, that distributes with close proximity to the plant roots, and rapidly generates monosilicic acid when the plants need it. The products have been tested in several green house and field trials in China since 2014 in research programs, with the objective to improve rice yield and quality, especially on HM polluted rice-fields. Results are published in several papers. (One presentation was given on ISSAG conference no 7.). Banana is, after rice, no 2 in volume as a harvested crop in the world, and India is the most dominant country. Elkem's Si based products were tested by the University of Bangalore in India on two farm fields, with the aim to increase the yield by maintaining a healthy crop due to less stress caused by biotic stress. Results showed considerable reduced stress on tissue grown plants, increased plant height by 48%, increased leaf area index by 68% and banana yield by 26%. India is also ranked no 2 for sugarcane after Brazil and sugarcane fields were tested by Vasantdada Sugarcane Institute in Pune, India, over two seasons (2017-2019). The shoot borer was reduced by 40%, the plant heights were increased by 11%, number of stalks by 14%, volume of cane by 14%, and sugar yield by 26%. Benchmarking test showed our product to be superior to rice husk ash, diatomite and CaSi-slag.

Keywords: Diatomite, Banana, Soil amendment

The Correlation between Amorphous Content and Soluble Silica of Calcium Silicate Slags Using X-Ray Diffraction and Colorimetric Analysis

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Oral Presentation, 8:30 – 8:50 AM

ABSTRACT

A correlation between the amorphous content and the soluble silicon of calcium silicate slags used in fertilizer applications was observed by comparing results obtained with X-ray diffraction (XRD) and colorimetric analysis. The XRD is a useful tool that helps investigate the mineralogical and structural components of a material, including but not limited to qualitative/quantitative phase identification, percent crystallinity, percent amorphous material, and crystal structure. A subgroup of Plant Tuff calcium silicate blended slags was analyzed for quantitative phase analysis using the internal standard method for slags and cements. Samples were ground to a particle size of < 50 µm using a McCrone Micronizing Mill. A total of 8.000 grams (wt%) of internal standard zincite (ZnO) was added to each sample and then mixed with an agate mortar and pestle. The samples were then run on a benchtop XRD and analyzed using JADE Pro's whole pattern fitting software. A calcium silicate slag blend-specific database of powder diffraction files was used to regulate and normalize the analysis process. After analyzing a thirteen-sample subgroup, a correlation ($r^2 = 0.84$) was obtained between the 5-day colorimetric soluble silicon and the amorphous content, with the amorphous contents ranging between 25.2-45.8 wt%. This finding suggests that amorphous content analyzed by XRD may be an alternative option for determining available silicon.

Keywords: Amorphous silica, Silicon quantification, Soluble silica

Effect of N-forms on Silicon Mobilization in White Lupin Rhizosphere

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Poster Presentation #4, Rhythms I

ABSTRACT

Silicon (Si) is the major constituent of soil present in various fractions, *i.e.*, mobile, adsorbed, occluded (in pedogenic oxides and hydroxides), amorphous (biogenic and lithogenic) and crystalline (primary and secondary silicates, and quartz). Different soil factors such as pH, temperatures, microbial activity, the presence of cations, Al/Fe oxides and hydroxides and organic compounds, influence Si transformation, thereby modifying plant availably of Si. Silicon mobility and transformation in the soil have mainly been studied in the context of pedogenesis or biogeochemical Si cycling. However, research on Si mobility, transformation, and plant availability in the rhizosphere is still lacking. Here, we investigated the root potential of white lupine (*Lupinus albus* L.), known as a phosphorus (P)-efficient model plant (*e.g.*, root release of H^+ and carboxylates), to mobilize Si from the soil. Plants were grown in the rhizoboxes filled with low P soil (control) and fertilized with different N-forms (NO_3, NH_4 and NO_3NH_4). The control, NO_3- and NO_3NH_4-fertilized plants accumulated significantly lower amounts of Si than the NH_4-fertilized ones. All applied N-forms influenced Si availability in the bulk soil, but Si fractions have further been modified in the rhizosphere, what was crucial for Si accumulation in plants. For instance, NO_3 supply slightly decreased Si availability in the bulk soil, but lupine plants accumulated a similar amount of Si as the control plants. A strong gradient of decreasing Si concentrations between bulk and rhizosphere soils was observed in mobile, adsorbed, and amorphous biogenic Si pools in the control and in all N treatments, while occluded and lithogenic amorphous Si pools were recalcitrant. Interestingly, a gradient of increasing concentrations of the amorphous biogenic Si pool between bulk and rhizosphere soils was recorded in the NH_4 treatment, concomitantly with the strongest rhizosphere acidification.

Keywords: Biogeochemical cycling, Biogenic silicon, Phosphorus-efficient plant

The Use of Silicon Combined with Phosphorus and Sulfur on Flooded Rice Plants Cultivated in a Clay Soil

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Poster Presentation # 5, Rhythms I

ABSTRACT

Silicon (Si) is a beneficial element with great importance in rice cultivation. Additionally, to that, the use of environmentally sources (industry by-products) can be valuable for sustainable agriculture, such as hexafluorosilicic acid, from the phosphatic industry. This source in addition to making Si available to plants, can increase the efficiency of other fertilizers in providing nutrients such as phosphorus (P) in soil with tendency to fixate its element. The combination of Si and P sources can be effective to increase agronomy development of flooded rice in soil with high clay content. That is why the aim of this study was to evaluate the agronomic efficiency of the use of alternative source of Si combined with MAP with and without sulfur in a clay soil cultivated with flooded rice under greenhouse conditions. The experimental design used was a randomized blocks (DBC) in a triple factorial scheme (3x2x2+2) with four replications. The factorial design consisted of the use of three doses of P_2O_5 (50, 100 and 150 kg ha^{-1}) x two sources of MAP with and without sulfur (MAP and MAP + S) x with or without Si + two additional treatments, being control with and without Si (both without P_2O_5) on greenhouse conditions. The use of Si associated with P sources was more efficient than the use of P sources without Si in increasing dry mass, P and Si content and accumulated in flooded rice plants and Si level on a clay soil.

Keywords: Silicate, Residual effect, Hexafluorosilicic acid

A Study of Production of Phytolith Occluded Carbon in Intensively Cultivated Rice Ecosystem in India

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5-Minute Rapid Oral, 2:05 – 2:10 PM
Poster Competition #3-GS, Rhythms I

ABSTRACT

Traditionally, rice fields are considered as the largest source of carbon (C) emission but they can be turned into a possible sink under rational management. Monosilicic acid, taken up by plant roots, may polymerized in plant cells and cell walls as non-crystalline silica minerals to form phytoliths. During the formation, phytoliths occlude 0.2 to 5.8 % organic C called phytolith occluded carbon (PhytOC). Relative to other forms of C sinks, PhytOC is stable in soil for thousands of years depending on the morphology and chemical composition of phytoliths and environmental conditions. Quantification of the phytolith and PhytOC production in the intensively cultivated rice field is important to establish the magnitude of the PhytOC sink in the rice ecosystems. However, the magnitude and spatial distribution of PhytOC sequestration in intensively cultivated rice ecosystems of India are still unclear. In this study, we sampled above ground biomass from 22 intensively cultivated rice ecosystems to evaluate the rate of C sequestration through phytoliths. Depending on the rice varieties, there existed a great variability in above-ground net primary productivity (ANPP) from 5,174 to 13,394 kg ha^{-1} across the rice ecosystems. The phytolith and PhytOC content varied from 8.53 to 15.72 % and 0.09 to 0.26%, respectively. Spatial variability of PhytOC sequestration among the rice ecosystems exists depending on the crop variety, ANPP and nitrogenous fertilizer management. Our results suggested that the Indian rice ecosystems sequester 0.95 Tg CO_2 yr^{-1} through phytoliths, which is equivalent to the 15.5 % of PhytOC sink in the global rice field. Considering the PhytOC flux of relatively higher PhytOC accumulating varieties, the annual PhytOC sink rate in the Indian rice ecosystems can be increased to 4-fold over the current rate. Our findings suggest that the selection of higher PhytOC accumulating varieties may enhance the PhytOC sequestration.

Keywords: Nitrogen fertilizer, Sequestration, Polymerized

The Role of Root Exudate Compounds in Silicon Solubilisation in Soils

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5-Minute Rapid Oral, 2:10 – 2:15 PM
Poster Competition #4-GS, Rhythms I

ABSTRACT

Plant roots exude various compounds in response to limited nutrient supply. The exuded compounds play a role in nutrient solubilisation and plant acquisition. To date, many studies have focused on the solubilisation of essential nutrients, but not beneficial ones like silicon (Si). For this reason, this study aimed at exploring how model root exudate compounds (MRECs) can influence Si solubilisation in the soil. We extracted six Austrian soils varying in soil organic matter, pH, texture, mineralogy, $CaCl_2$- and NaOH- extractable Si using three different MRECs (catechol, citrate, oxalate). We also extracted primary (augite, labradorite, olivine, quartz) and secondary (kaolinite, montmorillonite, illite) soil minerals. A typical exudate concentration of 5 mmol L^{-1} found at the root tips was used for all compounds. We used NH_4NO_3 as a background electrolyte at a concentration of 5 mmol L^{-1}. The extracts were filtered and immediately analysed for Si, Al, Ca, Fe, Mg, Mn, P, and K using the inductively coupled plasma-optical emission spectroscopy (ICP-OES). Analysis of variance and linear regression analysis performed using R 4.1.1 to determine the differences among the extractants and the relationship between the extracted elements, respectively. We found that MRECs extracted up to 9.4 times more Si than NH_4NO_3 in soils and minerals. The MREC-enhanced Si extractability of all compounds was significant ($p < 0.05$) in almost all soils, with oxalate having the highest effect. However, the extractability varied between primary (catechol ≈ citrate > NH_4NO_3 > oxalate) and secondary (catechol > citrate > NH_4NO_3 > oxalate) minerals. As expected, some elements were co-solubilised, while the solubility of others decreased. The co-solubilisation effect of elements differed among the compounds. For example, citrate and catechol co-solubilised Ca and Mg, while oxalate decreased their solubility. The results suggest that the mechanisms and soil fractions from which individual compounds solubilise Si differ. Furthermore, the Si extractability of MRECs is influenced by the initial Si status and mineralogy. Measurement of $CaCO_3$ and Si fractionations, which are necessary for interpreting the results, are ongoing. Our study shows that root exudate compounds have the potential to solubilise Si, thereby increasing its availability to plants.

Keywords: Plant acquisition, Essential nutrients, Extractability

Evaluation of LD Slag and Potassium Feldspar Formulations as a Source of Silicon for Rice

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5-Minute Rapid Oral, 2:15 – 2:20 PM
Poster Competition #5-GS, Rhythms I

ABSTRACT

The study aims at elucidation of the solubility and availability of silicon (Si) from the Linz-Donawitz slag (LDS) in combination with potassium feldspar (PF) and evaluation of its efficacy on the performance of rice crop as a source of Si in acidic soil under submerged condition. The LDS and PF formulations of LDS 10 + PF 90, LDS 20 + PF 80, LDS 30+ PF 70, LDS 40 + PF 60 and LDS 50 + PF 50 showed a significant increase in the plant available Si content of soil over the control under the incubation study. Further, pot culture experiment with rice revealed significant response in terms of growth and yield irrespective of the LDS and PF combinations over the control. However, application of 500 kg ha^{-1} of LDS 10 + PF 90 formulation along with recommended dose of N and P_2O_5 recorded significantly higher plant height (92.57 ± 3.23 cm), number of tillers (13.67 ± 1.53), panicle length (24.11 ± 0.86 cm), test weight (24.91 ± 0.76 g) as well as yield attributes, *e. g.*, grain yield (22.32 ± 1.69 g pot^{-1}) and straw yield (18.36 ± 1.39 g pot^{-1}), of rice over the control. The Si content and uptake by grain and straw of rice increased linearly with the applied levels of Si and found to have significant correlation with grain and straw yield of rice. Our study has shown that the use of LDS along with PF could be a vital and highly novel way to meet the Si requirement of rice crop to achieve sustainable yields.

Keywords: Sustainable yield, Plant growth, Fertilizer efficacy

Program Theme: Plant Growth, Development and Metabolism
May 25, 10:15 – 12:00 NN, Waterbury Ballroom

KEYNOTE
10:15 – 10:45 AM

Beyond Biosilicification and the Cell Wall: How Does Silicon Function as a Plant Nutrient?

Wendy Zellner

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ABSTRACT

The majority of plants accumulate silicon (Si) as a macronutrient, containing 0.1% Si or higher in their foliar tissue. Plants that accumulate in the micronutrient range, have Si concentrations at or above those of iron and manganese. What is most profound is that plants grown in the absence of Si show reduced vigor whether they accumulate Si at macro- or micronutrient ranges. Moving out of the realm of rice, wheat, and other grasses, we can take advantage of the micro-accumulating species to understand how Si might influence water relations, nutrient toxicities and deficiencies, and disease tolerance in the absence of biosilicification pathways. As shown with tobacco, these plants contain Si transporter proteins and respond well to reduction in disease and environmental stress with Si fertilization and may provide insight into unique Si-responsive genes involved in metal homeostasis within *Solanaceae*. Additionally, enhanced endodermal barrier formation in roots of monocots first identified in 1976 and more recently described by researchers in China, Germany, Israel, Syria, and the Slovak Republic, supports exploring its role in periderm formation and structure in potato tubers. Data collected from these studies could demonstrate how Si treatment leads to enhanced post-harvest fruit-quality in orchards and vineyards. Working together as an organization to fill in the gaps or expand the knowledge of cellular responses of Si in plants will help in the effort to recognize Si as a plant nutrient here in the United States and throughout the world.

Keywords: Macronutrient, Accumulating species, Responsive genes

Genes Related to Silicon Transport and Accumulation in Selected Crops

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Oral Presentation, 10:45 – 11:05 AM

ABSTRACT

Silicon (Si) uptake, translocation, and accumulation is the result of many Si transport genes that were discovered in different crop plants including monocots (wheat, rice, maize, etc.), dicots (soybean, pumpkin, cucumber, etc.) and recently in species belonging to palms (Arecaceae, monocots). Besides the well-known genes responsible for Si transport such as *Lsi1*, *Lsi2*, *Lsi3*, *Lsi6,* and their homologous genes, another specific gene coding for Slp1 protein that plays a key role in silica precipitation in leaves was published very recently in *Sorghum* species. According to the level of Si accumulation in plants, palms belong to Si accumulator species with the content of silica slightly exceeding 1% of dry shoot biomass. The RNA sequencing (transcriptome analysis) of coconut palm plants revealed identification of several genes/transcripts related to Si uptake, transport, accumulation, and silica precipitation differently expressed in leaves and roots. Monocots show great diversity of silicified cells. The coconut palm plants accumulate silica in form of phytoliths (Si-aggregates) in the specific cells called stegmata, similarly to date palm plants. These stegmata containing phytoliths are associated with sclerenchyma fibres of leaves. In comparison, grasses, including cereals, are characterized by impregnation of epidermal cell walls by Si and specialized silica cells. Study of Si transport and accumulation in plants and especially crops, is of great importance, because Si plays an important role in plant protection against biotic (e.g., powdery mildew in wheat) and/or abiotic (e.g., toxicity of heavy metals/metalloids) stress. Functional role of Si in plant defence against stresses represents another field of our study. This work is supported by Slovak Research and Development Agency (APVV-20-0246), bilateral project (APVV SK-PT-18-0020) and by the Slovak Grant Agency VEGA (VEGA 1/0352/21).

Keywords: Silicon Uptake, Transporter Genes, Grasses, Dicots

Elucidating Silicon Responses with *Nicotiana tabacum*

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Oral Presentation, 11:25 – 11:45 AM

ABSTRACT

For the past several years, our lab has worked to establish *Nicotiana tabacum* (tobacco) as a model system for studying the role of silicon (Si) in stress mitigation at the cellular and molecular level. We mainly have been examining the processes by which Si supplementation permits plants to better tolerate copper (Cu) toxicity. We discovered that the timing of the stress exposure and sampling is very important to elucidating the beneficial effects of Si. Tobacco exposed to toxic levels of Cu showed induction of genes involved in salicylic acid (SA) responses in roots after one week of treatment. This induction was enhanced further by Si treatment, even though Si-supplemented plants did not show alleviation of Cu toxicity. After three weeks of treatment, Si alleviated Cu toxicity symptoms in tobacco. SA-related gene expression was still induced by Cu toxicity in tobacco roots. However, Si supplementation caused a dramatic reduction in transcript levels for genes involved in SA responses. In contrast, Si caused increased ethylene biosynthetic gene expression in roots grown under Cu toxicity conditions. During the course of these experiments, we discovered a gene in tobacco roots that was strongly induced by Si, but not Cu toxicity, or the combination thereof. This gene was originally annotated as *Defensin19-like*. Further analysis of the tobacco genome identified thirteen additional *Definsin19-like* genes. These genes are rich in the amino acid histidine, suggesting that they are members of a newly-identified family within the plant defensin superfamily called the Histidine-Rich Defensins (HRDs). The HRDs in general are diverse in their functions, some possessing metal-binding properties, while others may additionally be antimicrobial polypeptides. Which functions our recently-discovered tobacco *NtHRD1* gene family exhibits is currently under investigation. Expression of all but one of the fourteen *NtHRD1* genes is induced by Si in tobacco roots. We previously reported the discovery of a tobacco aquaporin-type Si transporter termed NtNIP2;1. We are currently examining the subcellular localization and potential binding partners of this Si transporter to elucidate the regulation of this polypeptide. Overall, our data indicate that tobacco is a useful plant to study Si-mediated responses and has led to some important insights into how this element may act to help plants better tolerate stress.

Keywords: Tobacco, Copper toxicity, Transporter

Silicon Fertilization and Paddy Field

Chanchal Malhotra

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Oral Presentation, 11:05 – 11:25 AM

ABSTRACT

Paddy is farmed all over the world and is one of the most significant cereal crops. Usually husk and straw of rice, accumulator of silicon (Si), are removed from the field and are used as animal fodder, fuel etc. Due to this, Si recycling is hampered resulting in no replenishment of Si in soil. Worldwide reports indicate the importance of Si fertilization in rice crop production. The current study was designed with the objective to evaluate the effect of Si fertilizer on growth parameters and yield attributes (plant height, panicle leaf length, leaves length, leaf area, tiller number, effective tillers, spikelets per grain weight, and harvest index) of rice variety Karan Bhog-521 grown in the soil of village Timarpur, District Rohtak, Haryana, India from July to October 2021. This village is situated at 28°47'38"N latitude and 76°29'49"E longitude with arid to semi-arid climate and soil with loam to clay loam texture. In this period, the average temperature ranged from 29.2 and 25.9°C with cumulative rainfall of 659 mm, 50-74% relative humidity, and an average photoperiod of 10 hours. In the current study, the application of 125 kg Si ha^{-1} using Agrisilica granular as source + basal fertilizer was compared with a control (basal fertilizer only). Silicon fertilization significantly increased rice grain yield by 39% that was attributed to the following: 89% higher tillers number, 20% higher in effective tiller, 89% higher tiller number per hill, 93% higher effective tiller number per hill ,4% higher number of spikes per panicle, 99% higher total spike per plant, 182% higher total spikelets per hill, 43% higher 1000-grain weight, 35% higher number of grain per panicle and 161% higher number of grain per hill. In addition, the husk yield and overall harvest yield were increase by 31% and 3.4%, respectively. The beneficial effects of Si fertilization such as alleviation of rice blast disease and uniform maturity of grain leading to better quality and quantity of crop were also documented. Thus, Si fertilizer application can be recommended as an agronomic practice to improve growth and yield productivity of rice in the soil of District Rohtak, Haryana, India.

Keywords: Straw, Husk, Recycling, Rice productivity

Identification and Profiling of Silicate-Solubilizing Bacteria in Louisiana Soils

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Poster Presentation # 6, Rhythms I

ABSTRACT

Chemical fertilizers used in excess can have a severe impact on soil health and the environment. Alternative technologies must be developed in order to achieve competitive agricultural yields while also maintaining soil ecological balance. In agriculture, the use of soil microorganisms as microbial inoculants is seen as an alternative way to boost crop growth. Soil is a good source of microorganisms that may produce a variety of useful substances like silicase, phosphatase, and other growth-promoting enzymes that are essential for crop growth. Beneficial microorganisms in the soil, such as silicate-solubilizing bacteria, play a critical role in the solubilization of insoluble forms of silicates that are critical for crop growth. The goal of this study was to identify and characterize silicate-solubilizing bacteria (SSB) in Louisiana soils as well as to document SSB's ability to colonize rice plants. Bacterial isolates were spot-inoculated inoculated on silica agar medium and incubated for 48 h at 37°C. The clearing zone around colonies was measured and used to calculate the solubilization index (SbI), which was defined as the halo diameter (mm) divided by the colony diameter (mm). Despite the quantity of microorganisms discovered in these soils, only 20 bacterial isolates were able to solubilize silicates; 16 had low (SbI < 2.0) and 4 had intermediate (2.00 < SbI < 4.00) solubilization capacity. Further analysis showed that three of the isolates with intermediate silicate solubilization capacities also produced plant growth-promoting compounds such as phosphatase, 1-aminocyclopropane-1-carboxylic acid deaminase, and indole-3-acetic acid enzyme. The potential SSB were identified into four genera based on sequencing data and phylogenetic tree: *Aeromonas, Bacillus, Enterobacter*, and *Pseudomonas*. Fluorescence microscopy revealed that the GFP-tagged SSB may colonize the roots of young rice seedlings which is a solid indicator of SSB's potential as a seed treatment for scaling up its utilization in the field. Data on the survival of SSB inoculates in different soil-plant systems in Louisiana as well as the impact of management practices on SSB activity and population is required to fully develop this bio-based method to increase silicon nutrition in soil and plants.

Keywords: Bio-inoculant, Growth-promoting enzymes, Rice, Silicon

Effects of Foliar and Soil Applications of Silicic Acid (Silicon 0.8%) on the Growth and Yield of Tomato under Greenhouse Conditions

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Poster Presentation #7, Rhythms I

ABSTRACT

Tomato is an important vegetable crop in Iraq. Experiments have been carried out to evaluate the effects of foliar and soil (drench) application of silicic acid (silicon 0.8%) on the growth and yield of tomato plants under greenhouse condition. The concentrations of silicic acid (AB Yellow®, silicon content 0,8%) used were 0 (control), 0,5, 1, and 2%. The growth variables were studied weekly during the growing season. The results showed a high leaf area of 355.8 cm^2 at 0.5 ml L^{-1} and 435.3 cm^2 at 0.5 ml L^{-1} for spraying and soil drench application at the sampling event, respectively. The total chlorophyll content was 11.9 and 11.9 mg 100 g^{-1} for 1- and 2- ml L^{-1} at spraying and soil drench application at the end of the sample-taking date, respectively. Results showed a significantly high wet and dry weight (4 leaves per plant) with an average of 12.8 and 1.7 g of spraying application for 2 ml L^{-1} treatments at the end of the experiment, respectively. The high significant value of wet and dry weight (4 leaves per plant) with an average of 16.6 and 2.4 g of soil drench application for 2 ml L^{-1} treatment at the end of the sample-taking date, respectively. There was significant vitamin C content in tomato fruits with average value of 15.8 mg per 100 g of fruit for the treatment 2 ml L^{-1} of spraying application, while no significant difference was obtained for soil drench application. Early yield results showed highest average value 2.38 Kg at 2 ml L^{-1} of spraying application, while no significant differences for silicon levels occurred for soil drench application. However, the total yield showed a considerable value at 2 ml L^{-1} with an average weight of 4.35 Kg of spraying application.

Keywords: Foliar silicon application, Silicic acid, Soil drench, Tomato production

Effect of Different Applications of Silicon Fertilizer on Growth Properties and Yield of Tomato Plants under Greenhouse Conditions in the South of Iraq

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Poster Presentation #8, Rhythms I

ABSTRACT

An experiment was conducted under greenhouse condition during the grown season of 2019-2020 in Silty clay soil in an Agricultural Research Station south of Iraq - Basrah province weather to evaluate the effects of silicon (Si) fertilization on some growth properties and yield of tomato plants. Treatments comprised two types of Si applications (surface watering treatment and foliar spraying) with four Si concentrations (0, 0.5, 1, and 2 ml L^{-1}) of AB Yellow® silicic acid formulation. The variables measurements were studied weekly during the grown season. The results showed a high leaf area of 355.8 cm^2 at 0.5 ml L^{-1} and 435.3 cm^2 at 0.5 ml L^{-1} for spraying and surface watering application in the third date (3 weeks) of sample-taking, respectively. There was significant total chlorophyll content at average of 11.9 and 11.9 mg 100 gm^{-1} for 1 and 2 ml L^{-1} at spraying and surface watering application at the end of the sample-taking date, respectively. There was a significant increase for wet and dry weight (4 leaves per plant) with an average of 12.8 and 1.7 g of spraying application for 2 ml L^{-1} treatment at the end of the sample-taking date, respectively. Wet and dry weight (4 leaves per plant) significantly increase with an average of 16.6 and 2.4 g of surface watering application for 2 ml L^{-1} treatment at the end of the sample-taking date, respectively. A significant vitamin C content in tomato fruits with average value of 15.8 mg per 100 g of fruit for treatment 2 ml L^{-1} of spraying application was obtained, while no significant difference occurred for surface watering application. Same results in early yield showed highest average value of 2.38 kg at 2 ml L^{-1} of spraying application, while no significant difference for silicon level in surface watering application occurred. For total yield, there was considerable value at 2 ml L^{-1} with an average weight of 4.35 kg of spraying application.

Keywords: Foliar silicon application, Silicon source, Tomato production

Genes Related to Ribosomes and Photosynthesis were Upregulated by Silicon Treatment in *Brassica napus* L.

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Poster Presentation #9, Rhythms I

ABSTRACT

For a long time, the mechanical role of silicon (Si) on the cell wall reinforcement was mainly considered to explain its beneficial effect to alleviate biotic and abiotic stress in plants. More recently, some studies suggest that a low part (around 1%) of Si taken up is present in soluble form in cells and would modulate the expression of genes related to some metabolic pathways. This assumption is supported by a recent study which reported that Si modulates the expression of numerous genes in roots of *Brassica napus* L. and in particular those related to cell wall synthesis, phytohormone metabolism, and defense responses. Moreover, the same authors from the previous study have demonstrated that Si benefit affects also physiological responses in the shoot (maintenance of chlorophyll content and photosynthesis activity, delay of leaf senescence), the present study aimed to verify whether Si was also able to modify the transcriptome of the shoot. To achieve this goal, an RNA sequencing approach was performed in the shoot of *Brassica napus* L. plants grown with Si (root feeding for 7 days with 1.7 mM of Si). The main results showed that the expression of 296 genes (DEGs) was modulated in shoot of *Brassica napus* L. treated with Si. Among them, 19 and 31 up-regulated genes were related to ribosomes and photosynthesis pathways, respectively. Taken together, these results suggest that Si root supply leads to a metabolic enhancement in the whole plant that would be efficient to alleviate the biotic and abiotic stresses faced by plants.

Keywords: Cell wall, Metabolic enhancement, Phytohormone

Limitation of Silicon Supply Modifies Cell Wall Lignin Structures of Sorghum

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5-Minute Rapid Oral, 2:20 – 2:25 PM
Poster Competition #6-GS, Rhythms I

ABSTRACT

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most promising biomass crops for bioenergy production. The structures of lignin and other constituents in the cell wall are important factors affecting the quality of biomass as the feedstock for bioenergy. The structures of lignin in cell walls can be modulated by various factors including nutritional conditions. One of the nutrients possibly affecting the lignin structures is silicon (Si), as both lignin and Si as silica contributes to the mechanical strength of the plant body. However, limited information is available on the impacts of Si supply on lignin properties in this species. Therefore, we investigated the effects of Si limitation on lignin in the cell walls of sorghum grown hydroponically with or without Si supplementation (hereafter referred to as low Si and +Si treatment, respectively). The results from chemical, histochemical, and two-dimensional short-range ^{1}H-^{13}C correlation heteronuclear single quantum coherence nuclear magnetic resonance (2D HSQC NMR) analyses of the whole shoot showed that low Si plants contained more lignin than +Si plants. The lignin-aromatic composition was also altered significantly, as revealed by an increased thioacidolysis-derived syringyl/guaiacyl (S/G) monomer ratio in low Si plants. Gene ontology (GO) enrichment analysis of RNA-sequencing data suggested that Si limitation could enhance phenylpropanoid biosynthetic and metabolic processes. A reverse transcription-quantitative PCR analysis confirmed that the expression of phenylpropanoid biosynthetic-related genes was upregulated in low Si plants. The result suggests that Si status is thus one of the factors affecting the cell wall properties of sorghum plants.

Keywords: Biomass quality, Feedstock, Lignin-aromatic composition

Phosphorus Deficiency Induced Silicon Mobilization in Grapevine Rhizosphere: A Field Study

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5-Minute Rapid Oral, 2:25 – 2:30 PM
Poster Competition #7-GS, Rhythms I

ABSTRACT

Silicon (Si) uptake by crops is well studied and Si transporters have been characterized in various crop species, including grapevine. However, information on the rhizosphere mobilization of Si is still lacking and virtually no information is available on grapevine. Our previous study showed that grapevine is a phosphorus (P)-efficient species with a high root capacity to mobilize P from the rhizosphere by the released of organic anions (mainly citrate). The field experiment was established in 12-y-old vineyard with the cultivar 'Chardonnay', grafted on 5BB rootstock under extremely low P conditions (Olsen P < 3 mg kg^{-1}). Four own-designed rhizotrons (80 cm depth) were installed in a vineyard enabling easy access to the new intact roots. The following treatments were performed: –P/–Si, +P/–Si, –P/+Si (soil application) and –P/+Si (foliar application). The samples of rhizosphere and bulk soils, root exudates from intact root tips and vine tissues (root and leaves) were collected at different growth stages according to Eichhorn-Lorentz (E-L) system: flowering (E-L stage 23), berries pea-size (E-L stage 31), and veraison (E-L stage 35). In addition to Si and P concentrations in the tissues, the expressions of *VvALMT*, *VvMATE (*encoding efflux transporters for malate and citrate, respectively*)*, and *VvNIP2.1* (encoding Si influx transporter) were also determined. Phosphate fertilization decreased, while low soil P and Si fertilization increased Si availability in the rhizosphere. At the flowering stage, –P plants accumulated more Si than the P-fertilized ones and was comparable to the Si-fertilized plants. Foliar application of Si was less effective in comparison with soil application unless at the veraison stage. The leaf Si concentrations showed a clear seasonal pattern being the highest at the veraison stage. Exudation rate of citrate also showed a clear seasonal pattern and was significantly higher in the –P/–Si than in +P/–Si plants, which was followed by an increased Si availability in the vine rhizosphere. Overall, low P conditions induced Si accumulation in the leaves due to increased exudation of organic anions that can also mobilize Si in the rhizosphere, thereby increasing Si uptake by grapevine.

Keywords: Transporters, Root exudates, Uptake

Program Theme: Agricultural Systems, Climate Change, and Ecology
May 25, 1:00 – 2:35 PM, Waterbury Ballroom

KEYNOTE

1:00 – 1:30 PM

Silicon Soil-Plant Dynamics in Nutrient-Poor Environment

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ABSTRACT

Silicon (Si) is a beneficial plant mineral, improving plants' resilience to several abiotic stresses, including nutrient limitations. In the context of climate-change scenarios, Si even becomes more important for plants coping with extreme environmental conditions. Recent research highlights the potential of Si to increase nutrient availability in the rhizosphere and root uptake through the complex mechanisms, also including transcriptional regulation of nutrient transporters. However, growing high-yielding genotypes of Si-accumulating crops (*e.g.*, rice, maize, wheat, sugarcane) greatly depletes available Si in intensive agriculture systems. So far, soil-plant Si dynamics has been considered mostly in relation to soil conditions such as weathering and pH, whilst role of rhizosphere processes, especially root exudates, has been overlooked. Here, we compile recent information about increased Si mobilization under nutrient-poor conditions and discuss possible mechanisms on how Si mediates mobilization, uptake and utilization of nutrients. In particular, concomitant mobilization of Si and phosphate by root-released carboxylates will be evaluated. We further hypothesize possible Si mobilization by the other root-released LMW compounds under low (micro)nutrient availability. In addition, the relationship between soil nutrient availability and potential of phytolith-occluded carbon (C) in rice straw biomass for long-term storage of soil C will also be discussed. Finally, our keynote aims to emphasize the importance of sustainable crop cultivation practices (*e.g.*, intercropping) for Si soil-plant dynamics.

Keywords: Nutrient availability, Climate change, Mobilization

The Effects of Stabilized Silicic Acid on Fish and Shrimps

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Oral Presentation, 2:00 – 2:15 PM

ABSTRACT

At the third world conference of ISSAG in Brazil (2005), we presented for the first time the effects of SAAT (Silicic Acid Agro Technology), supplied as a foliar spray on plants. Until then there was almost no knowledge that foliar sprays containing silicic acid (SA) could be effective. At that time Dr. N.B. Prakash, a soil scientist at the University of Bangalore, India, showed interest in our results. It was the start of many trials conducted in India since 2006, which showed that SAAT was even more effective than presented in 2005. At the 4th International Conference of ISSAG in South Africa (2008), the effects of SA on both plants and humans were presented. Gradually, SAAT was accepted and is now an agricultural technique in some countries. In 2001 and 2002, research was done on the effect of stabilized silicic acid (sSA) on fungal infections in rainbow trout. When sSA was applied, the infections disappeared completely, and all fish survived in good health. Unlike treated fish, many of the non-treated fish died of fungal infection. What could be the role of sSA for aquaculture? Since 2005 there is a growing awareness of the role of silicon (Si) in increasing the production levels in aquaculture. It was shown that Si products like silica or silicates can stimulate the growth of diatoms to some extent. But silica/silicates are barely converted into SA, so hardly any SA is formed. But when sSA is added to the pond water, many aquatic lifeforms will profit including diatoms/plankton, water plants, shrimps, and fish. Since 2017 trials are done with Silifish® (a liquid with SA, boron, zinc, and manganese) on shrimp and fish in India, Bangladesh, and Vietnam. Silicic acid is an important nutrient/biostimulant for diatoms/phytoplankton. Phytoplankton is the usual food for zooplankton and filter-feeding fishes, the beginning of the food chain. Unfortunately, the concentration of SA in the surface layer of large areas of the oceans is very low (< 1 μM). This results in a decreased uptake of SA and consequently a (much) lower growth rate of many diatom species. So, this is a rationale to increase the SA concentration resulting in a higher growth rate of diatoms, and other aquatic lifeforms including shrimp and fish. The initial (and confidential) trials on shrimp were done with the application of Silifish® in Gujarat (India). In the first experiments, the average weight gain of the shrimps (harvested biomass) increased by 26% and 17.5%, respectively. The survival rate of shrimps in both trials increased by 19% and 35%. The overall health status improved. Other parameters showed that the zooplankton and phytoplankton levels increased substantially in the treated ponds. The dissolved oxygen rate and pH values were improved as well, while the concentration of N (ammonia) decreased significantly compared to control ponds. The results of trials in Bangladesh show a significant increase in growth rates of several fish species, like Rohu, Tilapia and Catfish, compared to control. Based on all research it has been proven that the application of soluble sSA is capable to enhance the growth of fish and shrimp. sSA improves survival rates, increases the FCR (food conversion rate) and improves water quality including a significant decrease in the ammonia level. SiliFish® is user-friendly, fully biodegradable, and eco-friendly.

Keywords: Aquaculture, Phytoplankton, Fungal infection

Silica Uptake and Effects in Forest Tree Plants

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Oral Presentation, 2:15 – 2:30 PM

ABSTRACT

The aim of this study was to investigate the silica uptake and distribution in spruce, pine, and birch and its effect on pine weevil *(Hylobius abietis)* attacks, fiber content, and cell wall thickness. Plants were grown from seeds or 1.5-year-old plantlets. Plants were treated with 0, 0.1, and 1 mM K_2SiO_3 or SiO_2 nanoparticles (SiNP). Results showed that Si is taken up in all three plant species, the more added the more was accumulated. In the conifers, the highest accumulation was found in wood and less in needles. More is accumulated in wood than in bark. In birch, the highest accumulation was found in roots and stems. In all species, the biomass increased at the lowest Si addition, 0.1 mM. In conifers, the fiber amount and the cell wall thickness of wood cells (tracheary elements) increased twice. No such effects were seen in birch. Conifer plants are exposed to pine weevils during the first years of establishment in the forest regeneration sites. In our experiments, pine weevil feeding damage on the stem bark decreased to the greatest extent at the lower Si addition. Highest effect was seen in spruce. In spruce, Si treatment declined the emission level of the attractant a-pinene, while the repellent methyl salicylate increased compared with the control at day zero (before the insect's introduction). In contrast, pine responded to Si treatment by increased emission of a-pinene and limonene. Similar effects were found when treated with SiNP´s, however, the effect on weevil attacks was much less with SiNP´s than with K_2SiO_3. The difference in effect might be due to the accumulated Si-form in the bark. A high portion of SiNP´s accumulates as SiNP´s in the bark while K_2SiO_3 accumulates as a hardbound fraction of SiO_2 in the external layer of the bark, and the latter is probably the one influencing the weevils. The study shows also that it would be favorable to continue to fertilize with Si even after plantation since the concentration of Si in the bark decreases with time and growth.

Keywords: Conifer, Cell wall thickness, Pine weevil

Soil Applications of Calcium Silicate Slag and the Effects on Soil pH, Crop Yield and Quality of Corn, Potatoes, Tomatoes and Cucumbers Grown in Michigan Soils

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Oral Presentation, 1:30 – 1:45 PM

ABSTRACT

Silicon (Si) has been shown to be an important nutrient for plant growth and helps to alleviate abiotic and biotic stresses that can reduce yield and improve many quality parameters. An available source of Si, calcium silicate slag, when applied to agricultural soils raises the soil pH which results in improvements in soil nutrient availability. Calcium silicate slag raises the soil pH when applied at rates of 0.5–2 t acre^{-1}, application rates similar to those of Hi-Cal agricultural lime. Abiotic and biotic stresses that field crops are exposed to throughout a growing season usually are the most limiting factors when it comes to yield and crop quality. Field trials were established from 2018 to 2021 in a range of typical Michigan soils. Treatments included broadcast treatments of the calcium silicate slag and Hi-Cal agricultural lime applied at rates of 0.5, 1.0, and 2.0 t acre^{-1}. Soils treated with calcium silicate slag and planted to corn showed increased yields from 154 bu acre^{-1} for the 1 t acre^{-1} Hi-Cal ag-lime treatment to 172 bu acre^{-1} for the calcium silicate slag at the 1 t acre^{-1} rate. Soils planted to potatoes were treated with calcium silicate slag at the 3 application rates. Treated potatoes showed an increase in number of tubers, improved sizing, and an overall increase in yields. Yield increases in 2016 ranged from 591 hundredweight (cwt) acre-1 for Hi-Cal Ag lime to 640 cwt acre^{-1} for calcium silicate slag at 1 t acre^{-1}. In 2017, yield increase ranged from 666 cwt acre^{-1} for Hi-Cal Ag lime to 718 cwt acre^{-1} for calcium silicate. Soils treated with calcium silicate and then planted to tomatoes and cucumbers also showed an increase in overall yield and fruit number when compared to soils treated with Ag lime. Results suggest that calcium silicate slag is an excellent source of plant available silicon and calcium that reduces the impact of abiotic and biotic stress on overall crop yields and quality parameters.

Keywords: Agricultural soils, Nutrient availability, Fruit, Tuber

The Effect of Particle Size on the Solubility and Release of Monosilicic Acid from Silicate Slag and Silicon Uptake by Wheat (*Triticum aestivum*)

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Oral Presentation, 1:45 – 2:00 PM

ABSTRACT

Silicate slag is used to adjust soil pH and supply silicon (Si) to crops, but the effect of source and particle size on its release of monosilisic acid (H_4SiO_4) has not been fully elucidated. A greenhouse study evaluated the effect of source and particle size of silicate slag on the release of H_4SiO_4 in soil and Si uptake by wheat (*Triticum aestivum*). Treatments include four particle sizes (fine, ungraded, coarse and pellet) of two silicate slag sources: Slag-1 (from a steel plant in Detroit, USA), Slag-2 (from a steel plant in Wisconsin USA) and Wollastonite applied at 125, 250, 500, and 1000 kg Si ha^{-1} and a control (no slag or Wollastonite), applied to pots containing 5 kg of Cancienne silt loam soil. Following Si application, the pots were separated into two groups, half was planted with wheat, and half was left unplanted. Soil samples were taken periodically at 30, 60, 90, 120 and 150 days after application; and analyzed for H_4SiO_4. Plant samples were also taken before and at physiological maturity and analyzed for Si. The release of H_4SiO_4 from the particle sizes of the two silicate slags and wheat biomass Si uptake were similar; and in the order of fine > ungraded > coarse > pellet. Wheat Si uptake and total yield were significantly higher under Wollastonite than the silicate slag treatments. However, fine, ungraded, coarse and pellet silicate slag increased wheat grain yield by 22, 19, 8 and 6% respectively in comparison to the control. Our results show that the effectiveness of silicate slag to supply Si to crop could be improved by using fine or ungraded granular sizes.

Keywords: Granular size, Source, Grain yield

A Supply of Silicon Improves Agronomic Performances of Rapeseed Grown in Field Conditions

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Poster Presentation #1, Rhythms I

ABSTRACT

Alternative cropping practices are new way to limit the environmental pollution linked to intensive nitrogen (N) fertilizer used for crops requiring high N inputs such as rapeseed. In this context, the effects of a silicic acid supply [12 kg silicon (Si) ha^{-1}] on the agronomic performances of rapeseed grown in field conditions with two levels of N fertilizer (60 and 160 kg N ha^{-1}) were undertaken. Our study showed that supply of Si had no effect on the agronomic performance of plants cultivated with the lowest N input (60 kg N ha^{-1}). On the other hand, the positive effects of Si supply were shown in plants fertilized with 160 kg N ha^{-1}, especially on the preservation of green leaves (at least until the flowering stage) but also on the improvement of growth and yield. Through the use of agronomic indexes such as nitrogen harvest index (NHI), agronomic efficiency (AE) and agronomic nitrogen recovery (ANR), it has been shown that these beneficial effects are related to a better uptake of N from the soil but not to an increase of the endogenous N mobilization toward seeds. These results demonstrated that a Si supply leads to a better N fertilizer efficiency only when plants are cultivated with the highest N level (160 kg N ha^{-1}). In addition, this study shown that Si supply also promoted biofortification of seeds, especially by increasing their micronutrient concentrations (especially Co and Fe).

Keywords: Nitrogen, Cropping practices, N mobilization

The Effect of Earthworm Activity on Silicon Uptake by Wheat

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5-Minute Rapid Oral, 2:00 – 2:05 PM
Poster Competition #2-GS, Rhythms I

ABSTRACT

Earthworm activity can promote the weathering of soil minerals, which is often associated with changes in silicon (Si) solubility. However, the impact of earthworms on Si solubility in soils and related changes in plant Si uptake have hardly been studied. In this study, the effect of earthworms belonging to different ecological groups, namely surface dwellers (*Dendrobaena veneta)* and vertical burrowers *(Lumbricus terrestris*), on Si uptake by spring wheat (*Triticum aestivum*) was investigated. Experimental pots (2.8L) were filled with soil having either a high or low content of $CaCl_2$-extractable Si. Either 4 specimen of *D. veneta*, 2 specimen of *L. terrestris*, or no worms (control) were added to the soils. Half of the pots received wheat straw (22 mg g^{-1} Si, dried and ground to ≤0.5 cm) as feeding material. For *D. veneta*, 10 g of litter were mixed with the top 10 cm of soil at the beginning of the experiment. For *L. terrestris*, litter was provided weekly on the soil surface. The pots were kept in a greenhouse at 15-20°C with a 14/10-hour day-night cycle. The soil was incubated with the earthworms and litter for 8 weeks before wheat was planted. The plants were harvested after 16 weeks of growth, weighted and analysed for Si as well as macro- and micronutrients by ICP-OES._Si uptake of wheat varied significantly ($P \leq 0.05$) in the low Si soil but was unaffected in high Si soil. The observed differences were not related to earthworm activity, but to the addition of wheat straw, which lead to a ~2-fold increase in wheat Si uptake. Our results suggest that earthworm activity had little direct effect on wheat Si uptake. However, the twofold increase in Si uptake after straw addition suggests that soil biological activity plays an important role in making litter a highly available and important Si source when incorporated in low Si soils. Further experiments are running to investigate more directly the effect of earthworms on soil Si solubility in soil.

Keywords: Solubility, Feeding material, Calcium chloride

Program Theme: Biostimulant, Soil Amendments, and Fertilizers: What's New in the Industry
May 25, 2:55 – 4:30 PM, Waterbury Ballroom

KEYNOTE
2:55 – 3:25 PM

Crop Responses to Silicon Fertilization in Northeastern Brazil

Clístenes Nascimento

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ABSTRACT

The northeast region of Brazil covers 1,558,000 km². It is characterized by two climatic settings: a) the coastal zone, in which sugarcane is the main crop, and the semiarid, where horticultural (grapes, mango, melon, onions) and row crops (soybean, maize, cotton, beans) are grown thanks to large-scale irrigation projects. The soils in NE Brazil are characteristically sandier and hence more silicon (Si) depleted than other regions of the country. These soil traits and the stressful environment crops face in the semiarid region hold a high potential for Si crop responsiveness. Yet, Si field trials in the region are still incipient. This presentation will show how applying an amorphous-silica-based fertilizer (ASF, Agrisilica) improved the yield and quality of sugarcane and table grapes in Si-depleted soils of northeastern Brazil. For sugarcane, The Si concentrations in leaves and stalks were 5- and 8-fold higher in ASF-amended plants (750 kg ha^{-1}) than in control. Sugarcane height, stalk diameter, and dry leaf biomass were 50, 58, and 71% higher than the control. ASF also increased the contents of fiber, total sugar, and recoverable sugar. The accumulation of Si in the stalk significantly reduced the damage caused by the stalk borer. The ASF rates increased the yield of stalks, total and recoverable sugar, and the stalk borer's resistance. Regarding table grapes, applying 350 kg ha^{-1} of the ASF to the cultivars Arra-15 and Vitoria in two harvests increased fruit yield (6-22%), bunch mass (11%), number of berries (20-34%), crunchiness (20%), Brix (13-20%), titratable acidity (13%), nutrient accumulation (13-45%), and photosynthesis efficiency (5-33%).

Keywords: Row crops, Horticultural crops, Amorphous silica

Magnesium Silicate and Its Potential Use for Agricultural Production in Colombia

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Oral Presentation, 3:55 – 4:10 PM

ABSTRACT

Very frequent occurrence of droughts, floods, high and low temperatures, and reduced sunshine hours present climatological stresses in several crops in Colombia. Such conditions are becoming more extreme due to the fast pace of climate change. Furthermore, soil acidity, sodicity, and salinity pose significant edaphic stresses to crops. Plant disease incidence usually increases under suboptimal climatic and soil conditions. Major crops in Colombia are coffee, sugar cane, rice, bananas, plantains, cocoa, cut-flowers, and vegetable crops. Widely published literature indicates that magnesium silicate can significantly decrease the negative impact of climatic and edaphic stresses that substantially reduce yields and affect fruit quality. Large magnesium silicate (MgO_3Si) deposits occur in Central Colombia with the capability of mining far over 15 000,000 MT that can be used to reduce the negative impact of the stresses indicated above substantially. The magnesium silicate from the Campamento District, Antioquia Department in Colombia, has 36 to 40 and 31 to 37 % of SiO_2 and MgO, respectively. The ore analysis shows 0.54, 0.45, and 0.01 % of $Cr_2 O_3$, NiO, and $V_2 O_5$, respectively. Chemical analyses also report 818, 3.81, and 307.5 mg kg^{-1} of Cr, Pb, and Ni, respectively. The quality of this ore makes it very suitable for agricultural use as long as it can be made relatively soluble for plant uptake.

Keywords: Edaphic stress, Plant disease, Agricultural crops,

A New Alternative Source for Si-Fertilizer by Using Ground SiMn-Slag

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Oral Presentation, 4:10 – 4:25 PM

ABSTRACT

Ground slag from the steel industry (blast furnace slag) has for decades been used as Si-fertilizer, especially in Japan, South Korea, and China. The chemistry of the slag shows typically 40% CaO and 35% SiO_2, mostly amorphous. Different types of other smelting processes have slag of many kinds, but few of these have found their application in the treatment of soil as a Si-fertilizer or for yield increase of crops. In the production of SiMn, by Eramet in Norway, a slag is also produced, (SiGS®), containing typically 25% CaO and 45% SiO_2, >90% amorphous, and has been tested in the greenhouse to show good plant-available values and effects. It has a liming effect on soil besides having potential as Si-fertilizer and Mn supplement (7% Mn). Molten slag is either air-cooled like lava or quickly cooled directly in water forming sandy granules. These two types were ground down and tested in a sugar beets field in SE Poland close to Ukraine where rich soil is dominant. The soil was treated with dosage rates of 100, 300, and 1000 kg ha^{-1} with 4 replications. Normal NPK and insect treatment were applied. Half of the fields were additionally treated with foliar Si-solution. Unfortunately, the weather was abnormal and variable during the season. Root yields ended between 89,2 and 106,5 t/ha. Water-cooled slag alone showed no significant increase in yield for the applied dosage rates but was not tested with foliar Si. The air-cooled material alone gave a root yield increase of 9.0 % for the 300 kg/ha treatment without Si-foliar application. Applying Si-foliar treatment additionally, the yield increased by 11.7%; or to 106.5 t ha^{-1}. Pure sugar yield for 300 kg/ha treatment without Si-foliar showed a 3.6% increase, but when also applying Si-foliar, the pure sugar yield was 12.3 % higher than control. Si-foliar treatment alone gave a root yield increase of 5.2%, but pure sugar yield was 1.4% less than control. This shows that there is an important synergy effect using both Si-treatment methods. Approximately 12.0% yield increase gives around 12 tons extra sugar beets per ha, worth 460 USD. Testing will continue in 2022.

Keywords: Sugar beets, Soil amendment, Mn supplement

Questions and Answers About Root Silicification

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Oral Presentation, 3:25 – 3:40 PM

ABSTRACT

On the base of hundreds of studies analysing silicon (Si) uptake, translocation, and accumulation in plants, high, intermediate, and low Si accumulators can be distinguished. These differences are attributed mostly to various strategies of the plant roots during its uptake. This plant classification is based on Si accumulation in the shoot and often does not correspond to Si retention in the root. Some of the high Si accumulators (*e.g.*, rice, wheat, and bamboo) deposit high amounts of Si also in roots. Others, like horsetail, not. From this aspect, the root is less studied organ. Barrier function or checkpoints between roots and shoot are most probably responsible for this difference from an anatomical aspect. On the other hand, the discovery of membrane transport proteins for Si and their localisation in individual root tissues might be linked with the difference between root and shoot Si concentration. Plant species with increased root Si accumulation are mostly monocotyledonous. Two major places of Si deposits in the roots can be characterized: endodermal cells and stegmata. In endodermis, two basic forms can be present. It is eighter impregnation of the endodermal cell walls (*e.g.,* rice or wheat) or Si aggregates in the endodermal walls (*e.g.*, sorghum and sugar cane). The phenomenon of Si cell wall impregnation, which is more energy-efficient than its lignification, is, however, studied very poorly in the roots. Stegmata are specific Si containing cells associated with sclerenchyma and sclerenchyma fibres (*e.g.*, in date palm roots). In addition, more places of Si deposition in roots can be found. The function of Si in plants is intensively studied in the last decades and several thousand reports show a positive effect of Si mainly for plants exposed to stress. We have recently summarized the alleviation mechanisms of metal(loid) stress in plants by Si. The Si-enhanced resistance allowing plants to cope with various types of abiotic and biotic stresses has been developed at multiple levels in plants. In this aspect, there are still many questions which will be discussed and should be answered, especially to explain the role of Si for the plant root structure and function.

Keywords: Endodermal cells, Silicon accumulators, Silicon deposition, Stegmata

Alkali-Enhanced Biochar as a Soil Amendment for Providing Plant-Available Si

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Oral Presentation, 3:40 – 3:55 PM

ABSTRACT

Biochar, produced from silicon (Si)-rich waste biomass through pyrolysis, has been shown as a possible soil amendment to supply bioavailable Si for plant growth while simultaneously increasing soil carbon sequestration. Research has demonstrated that the Si-releasing behavior of biochar is closely related to pyrolysis temperature. In addition, alkali-enhanced biochar has been developed to further increase bioavailable Si through pretreatment of waste biomass with alkali regents during production. Depending on the total Si content of feedstock used for producing alkali-enhanced biochar, it results in varying amounts of the release of plant-available Si. Scanning electron microscope (SEM) analysis showed that alkali pretreatment tends to bleach phytolith-Si to cause increased Si release from biochar. Potting studies based on application to soil growing perennial ryegrass showed that alkali-enhanced biochar increased tissue Si content and suppressed gray leaf spot development. Trials with rice growth in the greenhouse also illustrated that the application of alkali-enhanced biochars, especially those made from rice husk, increased Si uptake and rice grain yields compared to lower temperature and non-enhanced biochars. Alkali-enhanced biochars from rice straw or husk yielded the higher extractable Si as determined by 5-day sodium carbonate and ammonium nitrate when the pyrolysis temperature was increased from 350^{o}C to 550^{o}C. More soluble Si was also released in unbuffered weak acid over 30n days and neutral salt solutions for alkali-enhanced biochars produced at 550^{o}C pyrolysis temperature. Overall, alkali-enhanced-biochar could be used as a plant-available Si source as well as a carrier for additional nutrients for plant growth.

Keywords: Feedstock, Plant available silicon, Pyrolysis

The Effect of Modified Digestate from Biogas Plants with Silicon on the Yield and Technological Quality of Sugar Beet Roots

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Poster Presentation #2, Rhythms I

ABSTRACT

Sugar beet (*Beta vulgaris* L.) is the only raw material for sugar production in Europe. Modern methods of increasing sugar yields are systematically searched for. It is important that they are also environmentally friendly. In the years 2020-2021 in Sahryń (south-eastern region of Poland, near the border with Ukraine), a strict field experiment was carried out to evaluate the impact of the Ceressil® product on yield and technological quality of sugar beet roots. Ceressil® is a material formulated for both the solid and liquid fraction of digestate from a biogas plant modified with an environmentally friendly gelling agent and potassium silicate (K_2O_3Si). Ceressil® was used in early spring, before pre-sowing cultivation, at the doses of 15, 22.5, and 30 Mg ha^{-1}, and then mixed with the soil using a cultivating unit. The effects were compared with the control combination (without using the product). The total number of combinations, repetitions, and plots were 4, 4, and 16, respectively. On average, for two years of research, it was found that the use of the product caused, depending on the combination, an increase in the yield of sugar beet roots by 11.9-18.01%, the sugar content in the roots by 0.19-0.72 pp, and the biological sugar yield with 13.2-19.3%, and the pure yield sugar by 12.2-19.5% in relation to the control treatment. The highest yield of roots and biological sugar yield was obtained with Ceressil® at the dose of 30 Mg ha^{-1}, and the sugar content in roots and the pure sugar yield at the dose of 15 Mg ha^{-1}.

Keywords: Digestate, Potassium silicate, Sugar quality, Silicon sources

Biostimulation via Plant Available Silicon: Results and Conclusions from Multi-year, Multi-Crop Studies

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Poster Presentation #3, Rhythms I

ABSTRACT

Plant Available Silicon (PAS) has been approved by the Association of American Plant Food Control Officials (AAPFCO) as a Beneficial Substance since 2012 and shown to improve plant tolerance to abiotic stresses such as cold, heat, drought, and salinity, as well as improve plant structural strength. Products delivering PAS are considered biostimulant under draft legislation with the USDA. In general, commercial PAS products have either been coarse post-industrial slags designed for soil broadcasting, or chemical solutions stabilized at extreme pH for niche horticultural applications. Here we present the results on a new highly efficient PAS product, designed for blending into growing media (at 3 kg MT^{-1}), or applied via fertigation or irrigation (at 6kg ha^{-1}) delivering the grower a return-on-investment (ROI) greater than 5X. PAS elutes from the mineral additive and is present in leaching water after each irrigation. Depending on plant genetics, PAS is absorbed either passively or actively and triggers a physiological effect. Increasing PAS from a typical background level of 5-15 ppm to >20 ppm triggers this effect. Higher levels provided no added benefit. Our trials included 3 business areas: growing media, horticulture, and agriculture. Growing media: pre-blended into coco-peat media in the dose 3 kg m^{-3}, this PAS product boosted germination, increased plant's biomass and showed positive effect on reduction of water stress. Horticulture: fertigation of strawberries with 20 kg ha^{-1} of this PAS product during three weeks after transplantation increased product yield by 11%. Agriculture: 12 ha of soybean fields were fertigated with this PAS product 3 x 2 kg to fit with the regular spraying schedule, the dose was 6 kg ha^{-1}. This increased the soybean yield valued at US$55 ha^{-1}.

Keywords: Plant Available Silicon, Beneficial Substance, Fertigation

Authors Index