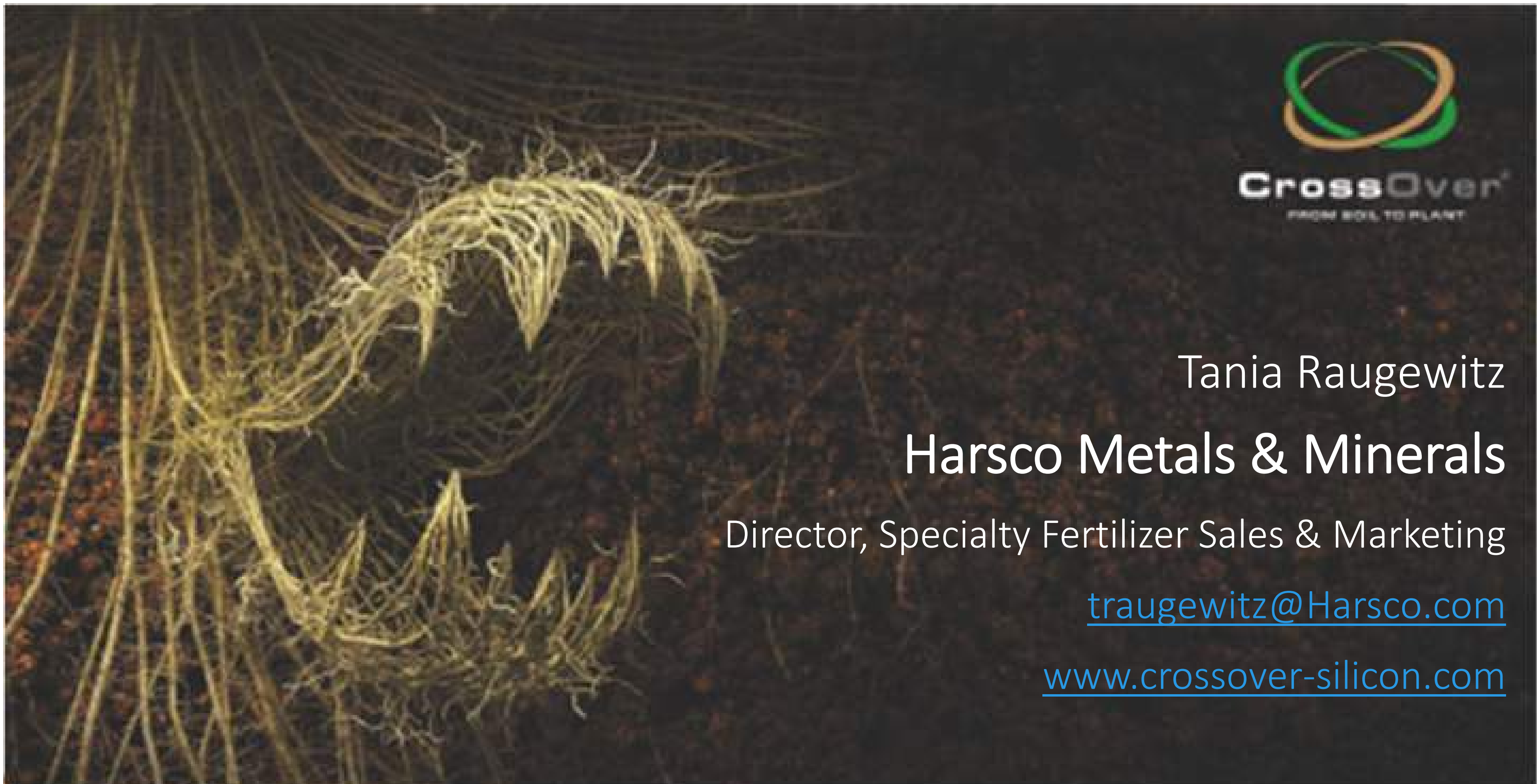
SILICON: A NONTRADITIONAL PRODUCT
AND THE PROCESS OF TAKING IT MAINSTREAM



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www.crossover-silicon.com

HARSCO

CrossOver®

FROM SOIL TO PLANT

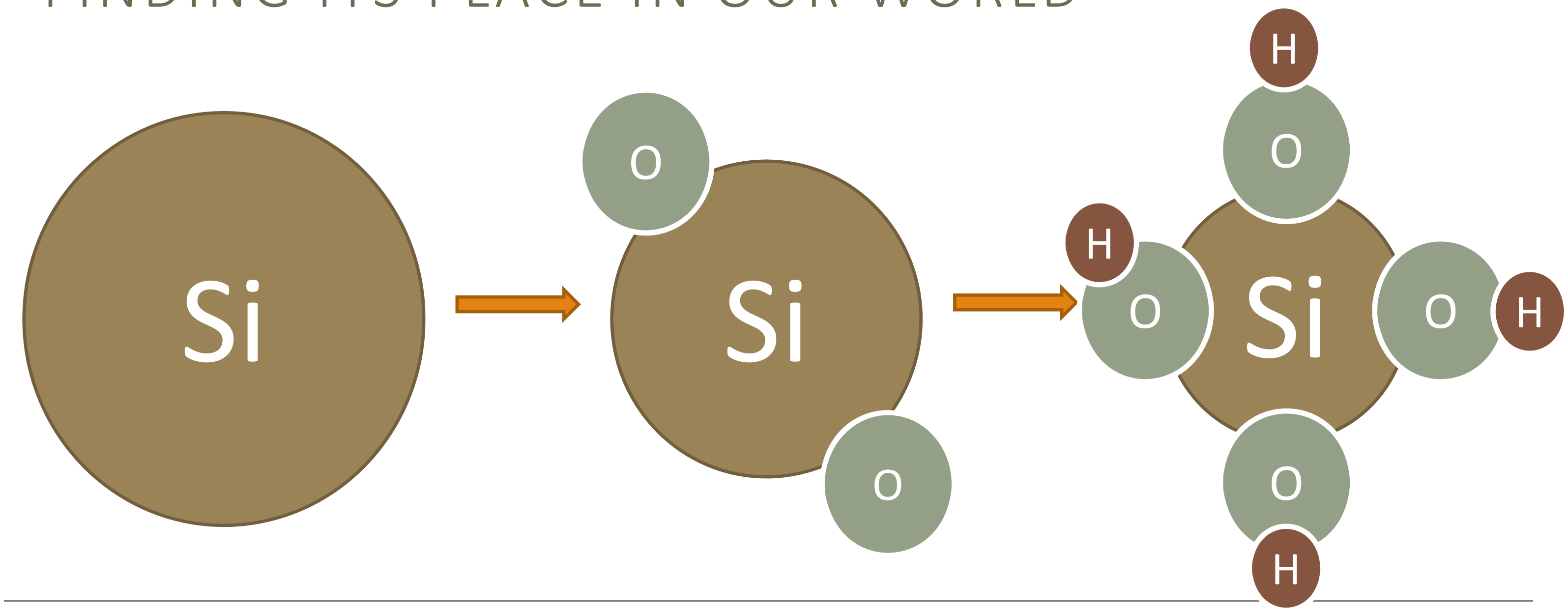
Forward-Looking Statements and Disclaimers

This presentation contains forward-looking statements based on management's current expectations, estimates and projections. The nature of the Company's business and the many countries in which it operates subject it to changing economic, competitive, regulatory and technological conditions, risks and uncertainties. In accordance with the "safe harbor" provisions of Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934, the Company provides the following cautionary remarks regarding important factors that, among others, could cause future results to differ materially from the results contemplated by forward-looking statements, including the expectations and assumptions expressed or implied herein. Forward-looking statements contained herein could include, among other things, statements about management's confidence in and strategies for performance; expectations for new and existing products, technologies and opportunities; and expectations regarding growth, sales, cash flows, and earnings. Forward-looking statements can be identified by the use of such terms as "may," "could," "expect," "anticipate," "intend," "believe," "likely," "estimate," "plan" or other comparable terms.

Factors that could cause actual results to differ, perhaps materially, from those implied by forward-looking statements include, but are not limited to: (1) changes in the worldwide business environment in which the Company operates, including general economic conditions; (2) changes in currency exchange rates, interest rates, commodity and fuel costs and capital costs;(3) changes in the performance of equity and bond markets that could affect, among other things, the valuation of the assets in the Company's pension plans and the accounting for pension assets, liabilities and expenses; (4) changes in governmental laws and regulations, including environmental, occupational health and safety, tax and import tariff standards; (5) market and competitive changes, including pricing pressures, market demand and acceptance for new products, services and technologies; (6) the Company's inability or failure to protect its intellectual property rights from infringement in one or more of the many countries in which the Company operates; (7) failure to effectively prevent, detect or recover from breaches in the Company's cybersecurity infrastructure; (8) unforeseen business disruptions in one or more of the many countries in which the Company operates due to political instability, civil disobedience, armed hostilities, public health issues or other calamities; (9) disruptions associated with labor disputes and increased operating costs associated with union organization; (10) the seasonal nature of the Company's business; (11) the Company's ability to successfully enter into new contracts and complete new acquisitions or strategic ventures in the time-frame contemplated, or at all; (12) the integration of the Company's strategic acquisitions; (13) the amount and timing of repurchases of the Company's common stock, if any; (14) the prolonged recovery in global financial and credit markets and economic conditions generally, which could result in the Company's customers curtailing development projects, construction, production and capital expenditures, which, in turn, could reduce the demand for the Company's products and services and, accordingly, the Company's revenues, margins and profitability; (15) the outcome of any disputes with customers, contractors and subcontractors; (16) the financial condition of the Company's customers, including the ability of customers (especially those that may be highly leveraged and those with inadequate liquidity) to maintain their credit availability; (17) implementation of environmental remediation matters; (18) risk and uncertainty associated with intangible assets; and (19) other risk factors listed from time to time in the Company's SEC reports. A further discussion of these, along with other potential risk factors, can be found in Part I, Item 1A, "Risk Factors," of the Company's Annual Report on Form 10-K for the year ended December 31, 2016. The Company cautions that these factors may not be exhaustive and that many of these factors are beyond the Company's ability to control or predict. Accordingly, forward-looking statements should not be relied upon as a prediction of actual results. The Company undertakes no duty to update forward-looking statements except as may be required by law.

Silicon

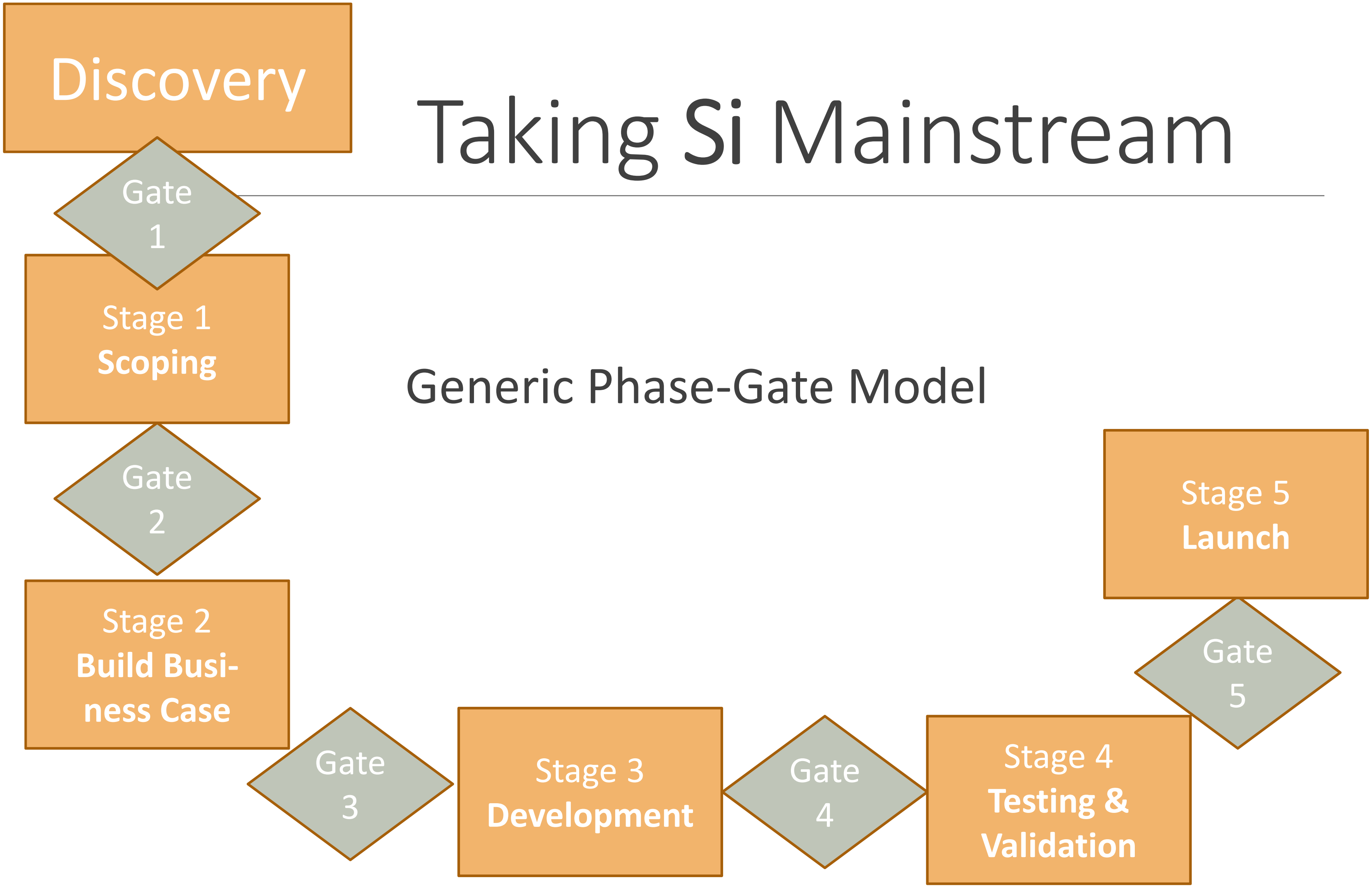
FINDING ITS PLACE IN OUR WORLD



A NON-TRADITIONAL PRODUCT AND THE PROCESS OF BECOMING ESSENTIAL

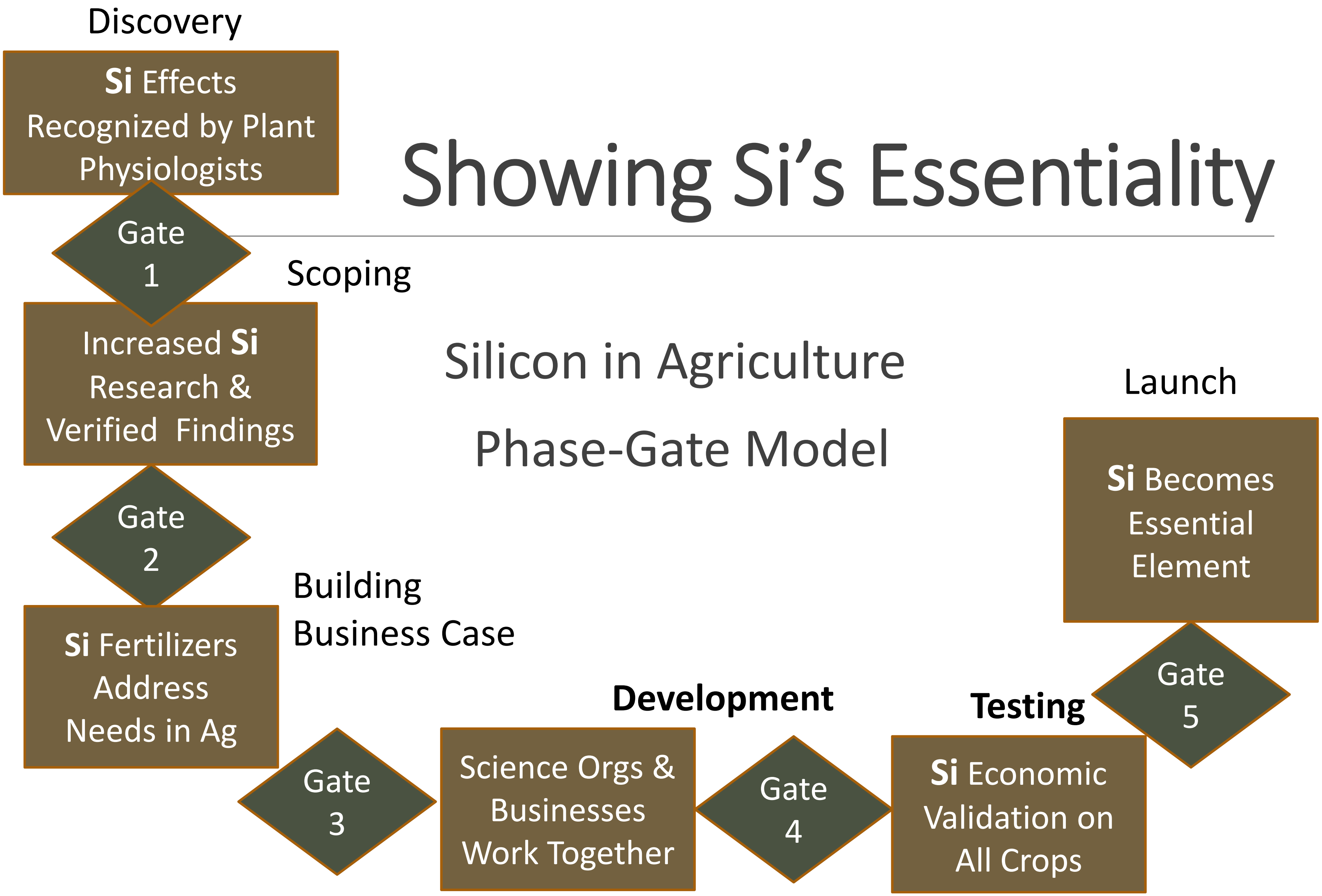
Taking Si Mainstream

Generic Phase-Gate Model



DRIVING NEW PRODUCTS TO MARKET

Showing Si's Essentiality



Recognizing **Si** as Essential

Discovering Silicon

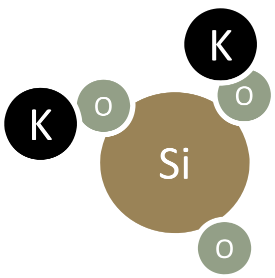
Discovery

Effects of **Si** as Discovered by Plant Physiologists

Discovering Silicon: Relevant Terminology

Not Plant-Available Silicon

- **Silicon:** (silikən,ˈsiləˌkän) The chemical element, a nonmetal with semiconducting properties, used in making electronic circuits



Silicate

- **Silicate**: (sĭl'ĭ-kāt') Any of a large class of chemical compounds composed of silicon, oxygen, and at least one metal. *Most rocks and minerals are **silicates***

Silica

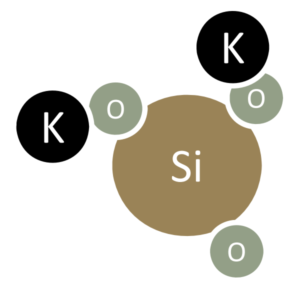
- **Silica:** (silikə) a hard, unreactive, colorless compound *that occurs as the mineral quartz and as a principal constituent of sandstone and other rocks*
- ***Silicone – not relevant here***

Discovering Silicon

Laying the Groundwork

- The second most abundant element in the soil after oxygen.
- Approximately 28% of earth's crust
- Most widely distributed as silica or alumino-silicates (i.e. rocks and sand)
- Ubiquitous… It's everywhere
- Silicas and silicates are not plant available

Silica



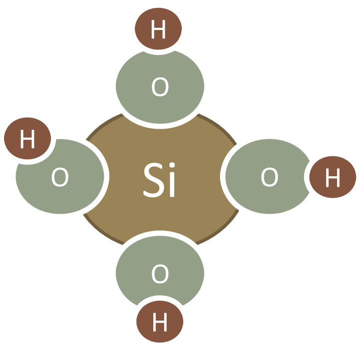
Silicate

PHASE 0: DISCOVERY

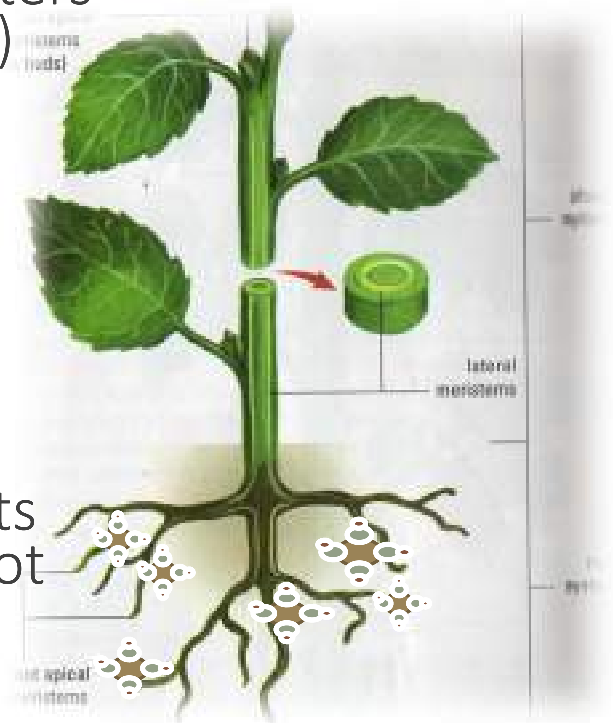
Discovering Silicon

Plant-Available Silicon: Roots to Shoots

- Plants can only absorb silicon as monosilicic acid (H_4SiO_4)



- H_4SiO_4 uses specific Si transporters only found in roots (not in leaves)
- Si-Accumulators & Si-Nonaccumulators: misleading terminology
- Si is found in ALL terrestrial plants ranging from 0.1% to 10% of shoot dry weight



PHASE 0: DISCOVERY

Discovering Silicon

Plant Accumulation of Essential Elements

- Si is found in ALL terrestrial plants ranging from 0.1% to 10% of shoot dry weight

- Silicon uptake occurs by
  - Active (faster uptake than H_2O)
  - Passive (similar to H_2O)
  - Rejective (slower than H_2O)

Typical concentrations sufficient for plant growth. After E. Epstein. 1965. "Mineral metabolism" pp. 438-466. in: Plant Biochemistry (J.Bonner and J.E. Varner, eds.) Academic Press, London.

Element	Symbol	mg/kg	percent	Relative number of atoms
Nitrogen	N	15,000	1.5	1,000,000
Potassium	K	10,000	1.0	250,000
Calcium	Ca	5,000	0.5	125,000
Magnesium	Mg	2,000	0.2	80,000
Phosphorus	P	2,000	0.2	60,000
Sulfur	S	1,000	0.1	30,000
Chlorine	Cl	100	--	3,000
Iron	Fe	100	--	2,000
Boron	B	20	--	2,000
Manganese	Mn	50	--	1,000
Zinc	Zn	20	--	300
Copper	Cu	6	--	100
Molybdenum	Mo	0.1	--	1
Nickel	Ni	0.1	--	1

PHASE 0: DISCOVERY

Recognizing **Si** as Essential

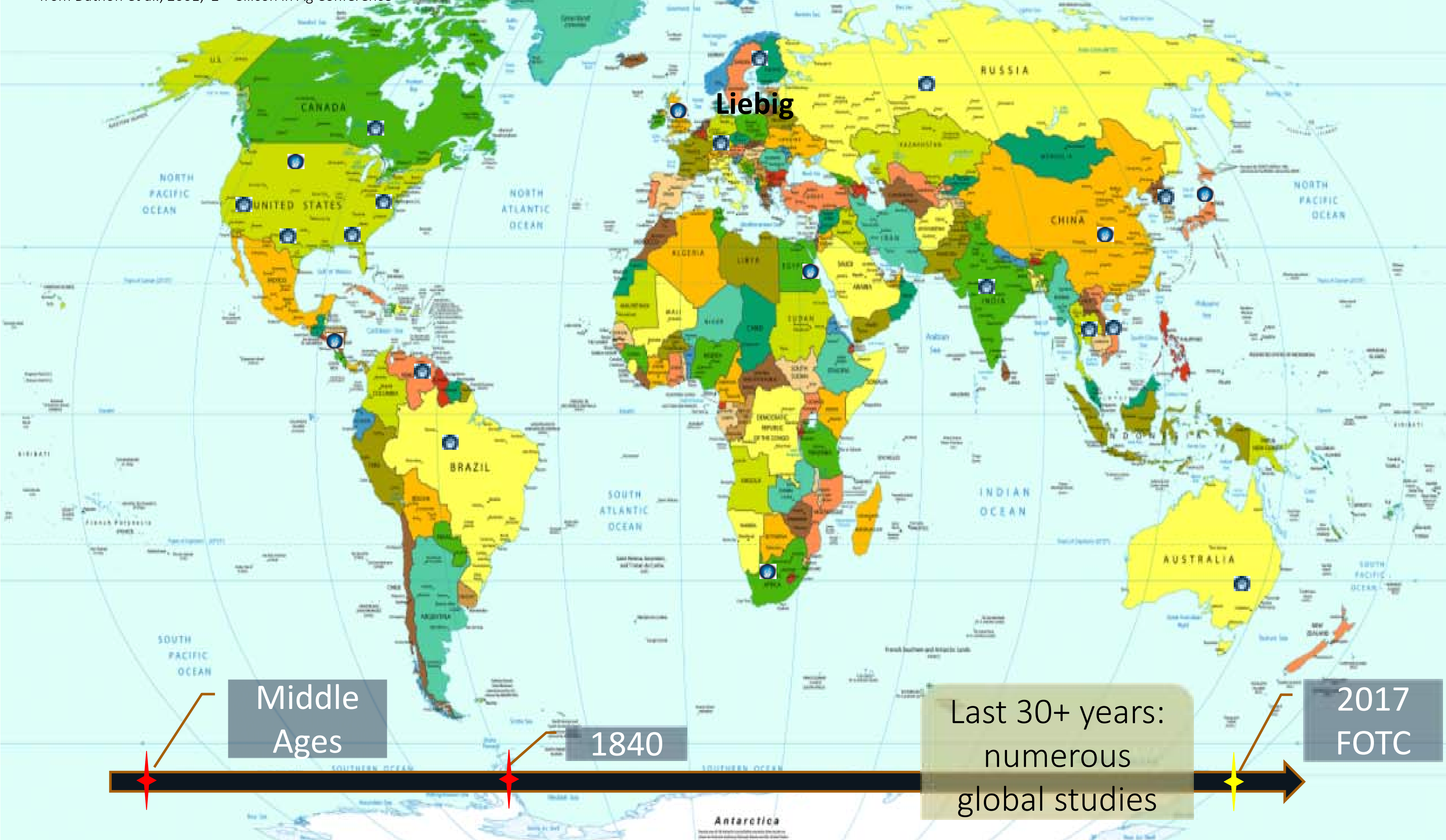
Gate 1

Scoping

Global Research on **Si** in Agriculture Show Consistent Beneficial Effects

Silicon Researched on Global Scale

- from Datnoff et al., 2001; 2ND Silicon in Ag Conference



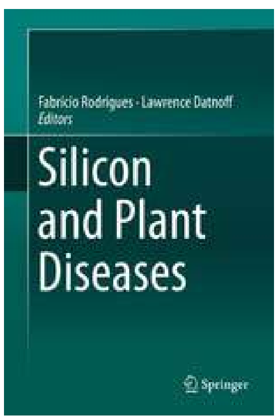
PHASE 1: SCOPING

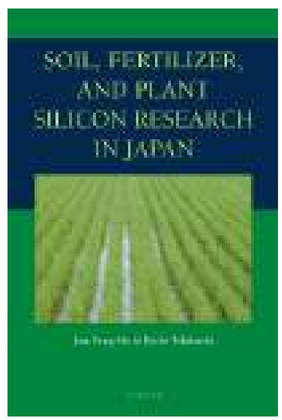
Compilation of Si Research
IN THE PLANT

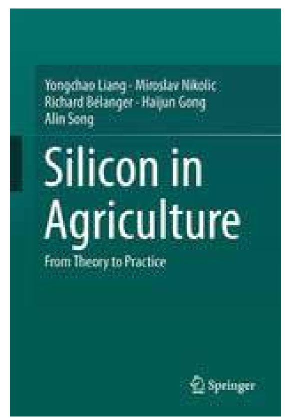
- Enhancement of growth, yield, and quality
- Promotion of mechanical strength
- Promotion of photosynthesis
- Resistance to insufficient sunshine or shading
- Resistance to drought stress and therefore efficient water use
- Resistance to biotic stress (disease, pest)
- Promote nutrient use efficiency
- Alleviation of stress from mineral toxicity

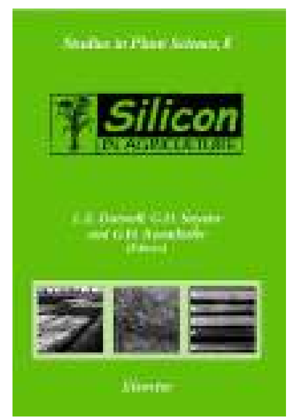
Compilation of Si Research
IN THE SOIL

- Enhance soil stability
- Improve soil structure
- Improve phosphorous availability
- Resistance to metal toxicity









PHASE 1: SCOPING

Recognizing **Si** as Essential

Gate 2

Building the Business Case

Si Fertilization Addresses Needs in Agriculture

Si FERTILIZATION ADDRESSES AGRICULTURAL NEEDS

What are the Basic Needs in Agriculture?

- Restore soil tilth and fertility
- Improve crop yield
- Protect crops once planted

Under Less than Ideal Growing Conditions:

- Certain silicon products **can** restore soil tilth and fertility
- Silicon products **can** Improve crop yield
- Silicon products **can** protect crops once planted

Si FERTILIZATION ADDRESSES AGRICULTURAL NEEDS

Lastly, But Most Importantly: What do Growers Want?

- Minimize environmental risks
- Improve crop economics
- Generally, make life easier for them

Si PRODUCTS COMMERCIALIZED

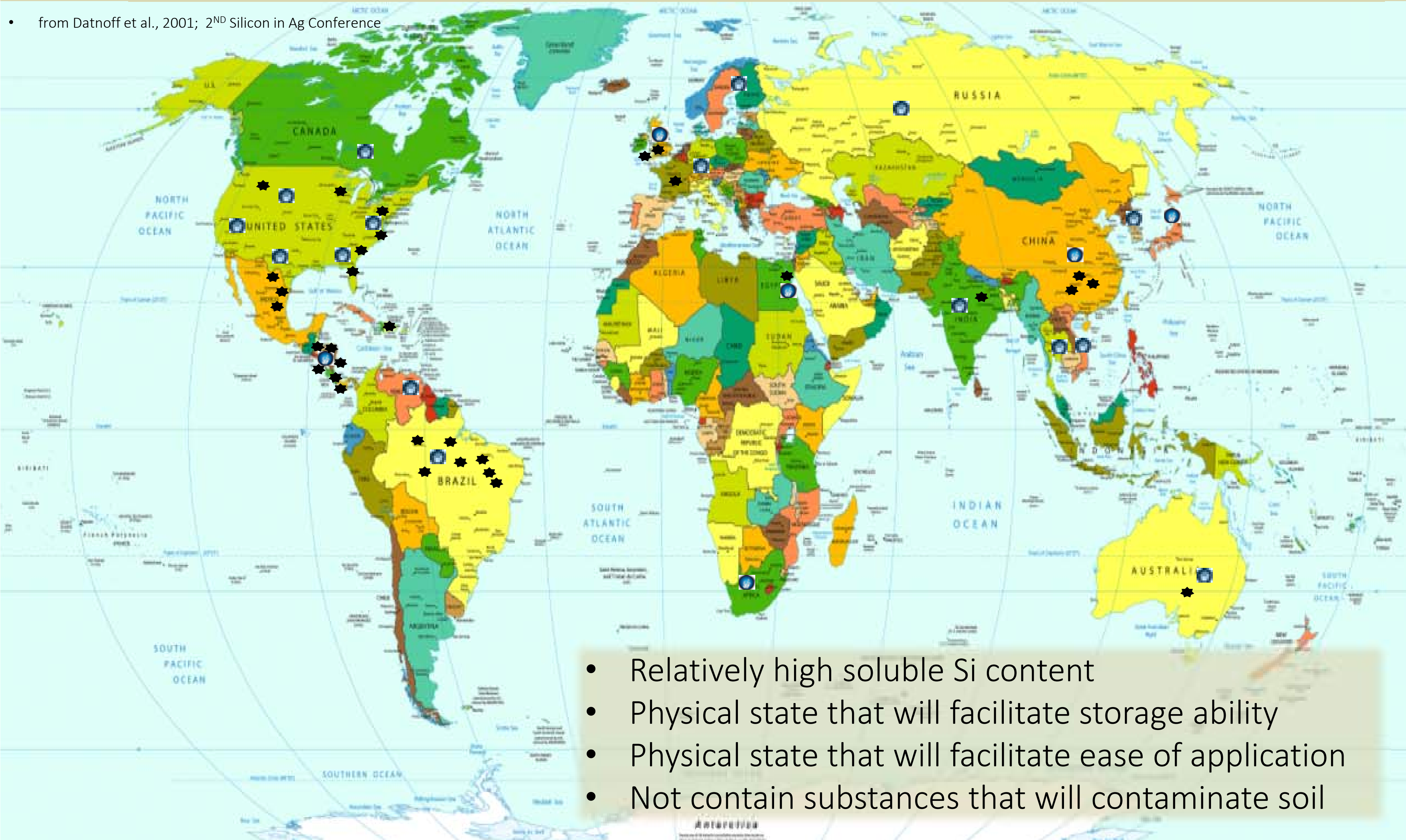
Various Si Sources used in the Market

- Calcium silicate
- Calcium magnesium silicate
- Crop residues – rice hull ash
- Diatomaceous earth
- Orthosilicic acid
- Potassium silicate
- Sodium silicate

PHASE 2: BUILDING THE BUSINESS CASE

Silicon-Based Products Sold Globally

- from Datnoff et al., 2001; 2[ND] Silicon in Ag Conference



- Relatively high soluble Si content
- Physical state that will facilitate storage ability
- Physical state that will facilitate ease of application
- Not contain substances that will contaminate soil

PHASE 2: BUILDING THE BUSINESS CASE

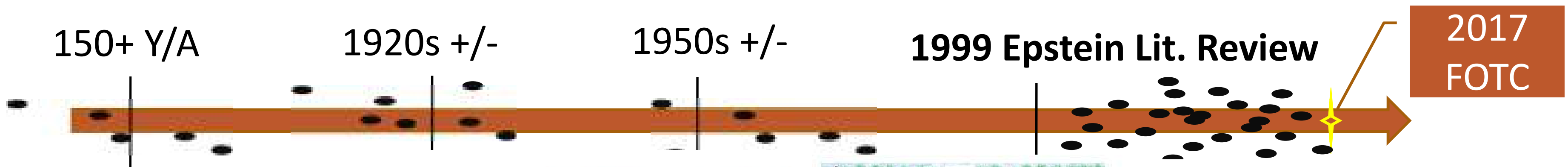
Recognizing **Si** as Essential

Gate 3

Development

Science Orgs & Businesses Work Together

Silicon: Validating its Value



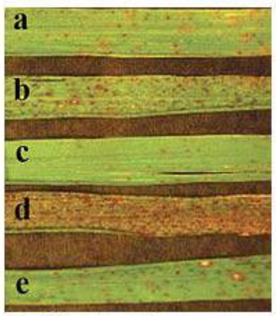
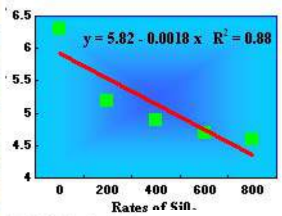


Fig. 12. Symptoms of brown spot as influenced by applications of silicon (a and e), propiconazole (b), the combination of silicon + propiconazole (c), and the nontreated control (d). Reprinted from Crop Protection, Vol. 16, Datnoff, L. E., Deren, C. W., and Snyder, G. H., Silicon fertilization for disease management of rice in Florida, p. 529, 1997, with permission from Elsevier.



ig. 9. Effect of wollastoı
e severity of grain disc
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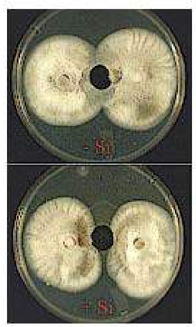
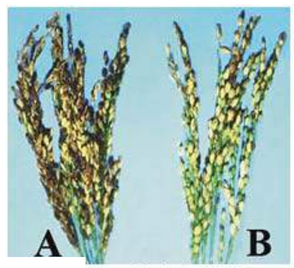
ean grain discoloration
enotypes. Source: Prat





ptoms of grain discoloration on
of the rice cultivar BG 367-4
-treated control plants (0 kg/ha
(B) plants grown at the highest
800 kg/ha). Photo from Dr. Anne

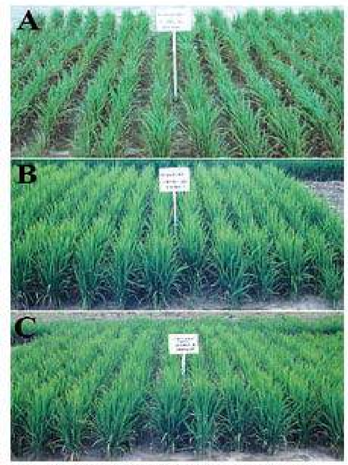
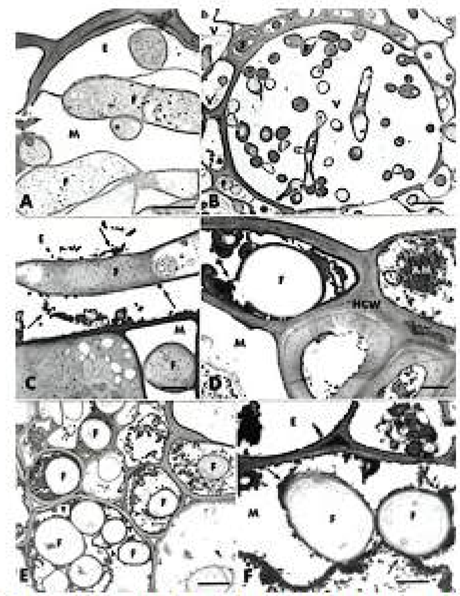
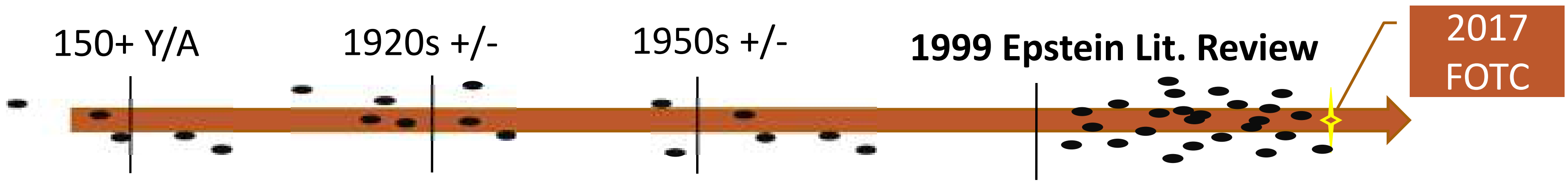


Fig. 14. Overall symptoms of blast on the lower leaves of the rice cultivar Oryzica 1 for the non-amended control (A) in comparison to plants amended with Si (B) or treated with fungicides (C). Note the clear difference in plant vigor between the non-amended control and the treatments receiving either Si or fungicides.



PHASE 3: DEVELOPMENT

Silicon: Marketing its Value



Harsco Metals & Minerals uploaded a video

The Benefits of Soluble Silicon for plant health and growth - Professor

Harsco Metals & Minerals • 4.5K views • 3 years ago

Professor Lawrence Datnoff, Dpt Head for Plant Pathology and Crop Physiology at Louisiana State

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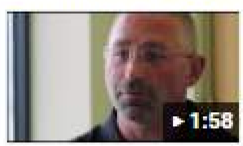
Benefits of Silicon - YouTube

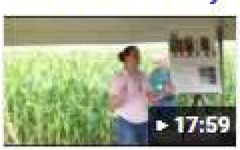


https://www.youtube.com/watch?v=RzYnmfy4Yb8

May 26, 2016 - Uploaded by Plant Tuff Inc.

Dr. Brenda Tubana and Agronomist Rob Schaefer go in depth on the benefits of **Silicon**. **Plant Tuff** 3 in 1 ...

Silicon Wendy Zellner - YouTube



https://www.youtube.com/watch?v=...

Sep 30, 2015 - Uploaded by Plant Tuff Inc.

Dr. Wendy Zellner of the USDA presents on the benefits of **Silicon** at Center For Excellence. Dr. Zellner's ...

PHASE 3: DEVELOPMENT

DEVELOPING A PLACE FOR Si FERTILIZERS IN AGRICULTURE

PHASE 3: DEVELOPMENT

Recognizing **Si** as Essential

Gate 4

TESTING

- Continued Economic Validation of **Si** on More Crops
- Continued Progress with Test-Method Development
- Consistent Regulatory Oversight

PHASE 4: TESTING THE MARKET

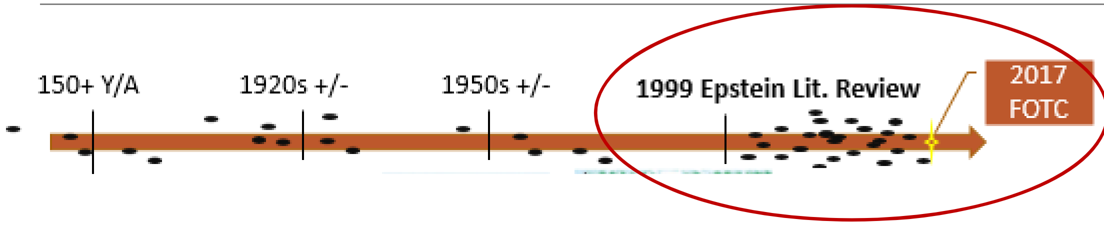
PANEL DISCUSSION: Future Scenario of Silicon in Agriculture

"Why is silicon still not used routinely for managing plant health and enhancing plant growth under greenhouse and field conditions?"

- Dr. Datnoff Department of Plant Pathology & Crop Physiology, LSU AgCenter, ldatnoff@agcenter.lsu.edu

PHASE 4: TESTING THE MARKET

What is holding producers and growers back from using silicon?



Since 1999 when the first silicon in agriculture conference was held:

- At least five books,
- Over 60 book chapters,
- Numerous reviews and 100s of refereed articles published

Clearly, the science for silicon is well-documented and comprehensive

PHASE 4: TESTING THE MARKET

What is holding producers and growers back from using silicon?

No current soil tests for gauging the amounts of PAS have been calibrated for many agronomic or horticultural crops

Lack of analytical laboratories to test plant tissue for Silicon

- Current procedures used would render silicon insoluble

Many scientist still state that plants are either silicon accumulators OR non-accumulators

- reality all plants accumulate Silicon is not recognized as being necessary for plant development,

Lack of economic studies to show the benefits of applying silicon

Continued Progress with Test-Method Development

Table 1. Methods used to determine soluble and extractable soil Si

Extractant	Soil : Solution Ratio (or recommended weights and volumes)	Method	Suggested critical level	Reference
H_2O	pre-wet air-dry soil at a matric suction of 0.1 bar	incubate at 25°C for 1 day and centifuge at 900g (RCF) for 1 hr.		Gillman and Bell, 1978; Menzies and Bell, 1988
H_2O	saturated paste		2 mg/kg	Fox and Silva, 1978
H_2O	1g :1 mL	allow to stand 2 weeks with repeated shaking, filter and centrifuge		Clements *et al.*, 1967
H_2O	10 g : 100 mls	continuous shaking for 4 hrs. and centrifuge at 24,000g (RCF)	< 0.9 mg/kg (deficient) < 2.0 mg/kg (marginal) 8.0 mg/kg	Fox *et al.*, 1967; Elawad et al., 1982
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible] shaker at 25° C		[illegible]
0.005 M H_2SO_4	1 : 200	continuous shaking for 16 hrs and centrifuged	< 100 mg/kg (deficient-marginal)	Hurney, 1973
0.5 M Acetic acid	1:10	1 hr shake, rest 15 minutes, decant and filter, rest 12 hrs before analysis	< 15 mg/kg (deficient)	Snyder, 1991; Korndorfer, G. (per. comm.)
0.1 M Citric acid	1:50	2 hr shake, rest O/N, 1 hr shake, centrifuge		Acquaye and Tinsley, 1964

"It is possible that there is not a universal extractant that is suitable for determining available Si that will cover all types of materials, and for all soils and soil conditions (Gascho, 2001).

PHASE 3: DEVELOPMENT

Continued Progress with Test-Method Development

J AOAC Int. 2013 Mar-Apr;96(2):251-9.

A 5-day method for determination of soluble silicon concentrations in nonliquid fertilizer materials using a sodium carbonate-ammonium nitrate extractant followed by visible spectroscopy with heteropoly blue analysis: single-laboratory validation.

Sebastian D[1], Rodrigues H, Kinsey C, Korndörfer G, Pereira H, Buck G, Datnoff L, Miranda S, Provance-Bowley M.

Standards catalogue

ISO/TC 134

Fertilizers and soil conditioners

ISO/CD 19747 [Under development]

Determination of Soluble Silicon Concentrations in Nonliquid Fertilizer Materials

PHASE 3: DEVELOPMENT

Si ECONOMIC VALIDATION ON ALL CROPS (India Speech)

Table 6. Assumptions and resulting economic benefits from yield increases due to silicon applications in the base case and two alternate cases.

Assumptions	Base case	Alternate case 1	Alternate case 2
Average yield w/o silicon (kg/h			
Application rate (ton/ha)			

Other benefits and costs combined: the base case. This section duplicates what was done with yield increases but combining all other potential benefits from Si applications. In addition to the base case, alternative cases 1 and 2 are also discussed (Table 7).

Table 2. Influence of calcium silicate and mercuric fungicide alone and in combination at two different nitrogen levels on% neck blast incidence and grain yield[1].

Treatments	% Neck blast		Grain weight ($g/2.9\ m^2$)	
	50 kg/ha	75 kg/ha	50 kg/ha	75 kg/ha
Silicon (Si)*	12	11.2	1398.7	1415.7
Fungicide (Fu)**	10.1	7.4	1302.0	1357.3
Si + Fu	1.7	2.5	1425.0	1504.7
Control	26.5	42.5	1016.0	1012.7

1 Adapted from Kitani et al. (1960).
* Calcium silicate applied at 2.35 ton/ha
** Mercuric fungicide = phenyl mercuric acetate: calcium carbonate mixture (1:8) applied at 40 kg/ha

'otential benefits ($/ha/year), other than yield increases, due to silicon 1s in the base case and two alternate cases.

tial benefits	Base case	Alternate case 1	Alternate case 2
olling blast and other diseases	74.69	37.34	0.00
discoloration	61.60	30.80	30.80
management	21.00	10.50	10.50
...ing phosphorus applications	12.75	6.37	8.92
Eliminating lime applications	101.81	50.90	0.00
Extra net revenue ($/ha/year)	271.85	135.91	50.22

STAGE 4: TESTING

Effect of Silicon on Plant Yield and Quality

Agronomic / Vegetable Crop	Yield increase (%)		Hort Crop	Improved quality
Cucumber	9-26		Apple	Soluble solids/ Vitamin C
Maize	6-10		Cucumber	Sugar/Vitamin C
Rice	4-28		Grape	Soluble solids, sugars, acids
Soybean	8-14		Gerbera	Flower traits
Sugarcane	5-50		Rose	Flower traits
Tomato	8-16		Tomato	> Sugar content
Wheat	5-12		Zinnia	Flower traits

Chapter 11. Effect of silicon on crop growth, yield and quality, Silicon in Agriculture: Theory to Practice

REGULATORY CONSISTENCY ON NUTRIENT LABELING

Examples

Contains Beneficial Substances
Soluble Silicon.......................__% Si
Derived from: (i.e. Calcium Silicate, Calcium Magnesium Silicate)
Purpose: Soluble Silicon from Monosilicic acid has been shown t
tolerance to abiotic stre
heat, drought, and sali
improve plant structura

O

Contains Beneficial Co
Available Silicon........
Derived from: (i.e. Calc
Magnesium Silicate)

Granulated Premium Greens Fertilizer
plus Soil Conditioner

GUARANTEED ANALYSIS:

Calcium (Ca)	21.00
Total Magnesium as (Mg)	2.50
2.00 % Water Soluble Magnesium (Mg)	

Derived From: Calcium Silicate and Magnesium Sulfate

SOIL CONDITIONER

Guaranteed Analysis Silicone Dioxide (SiO2) ...	29.00
Total Other Ingredients:	71.00

Derived From: Calcium Silicate

KiS organics

AgSil 16 H

Potassium silicate

Benefits include stronger cell walls, increased stem strength, increased heat, drought, and cold tolerance, and longer lasting leaves and blooms!

1.6 weight ratio hydrous potassium silicate powder with 32% K2O and 52.8% SiO2 and 14.8% H2O

gallon will give you 7.6% silicon (SiO2), which is
. 0.7 grams in one gallon of water yields 98ppm
ppm K

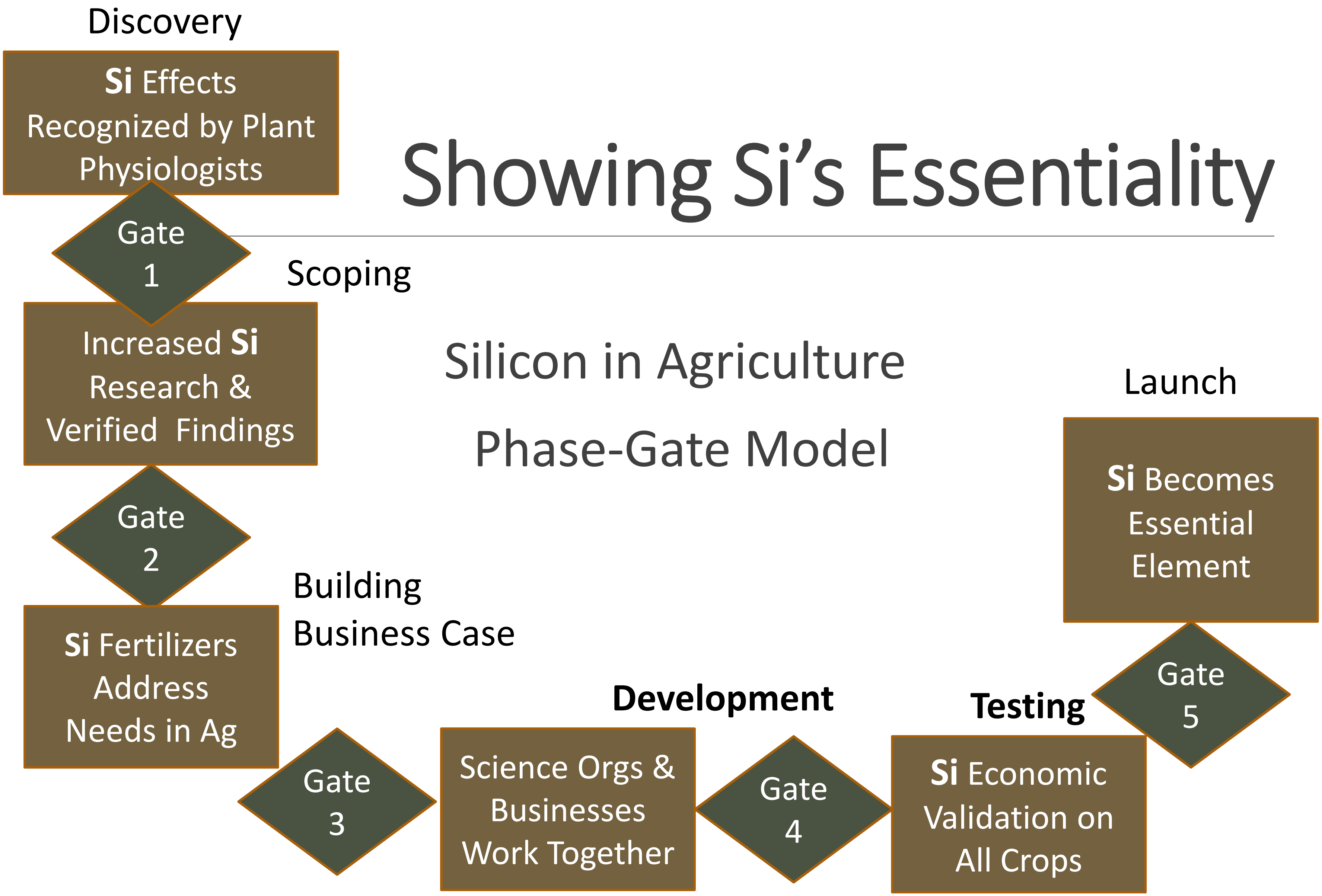
d silica solutions with other concentrated fertilizers. It
tion first or add water prior to mixing the powder with

STAGE 4: TESTING

Showing Si’s Essentiality

Silicon in Agriculture

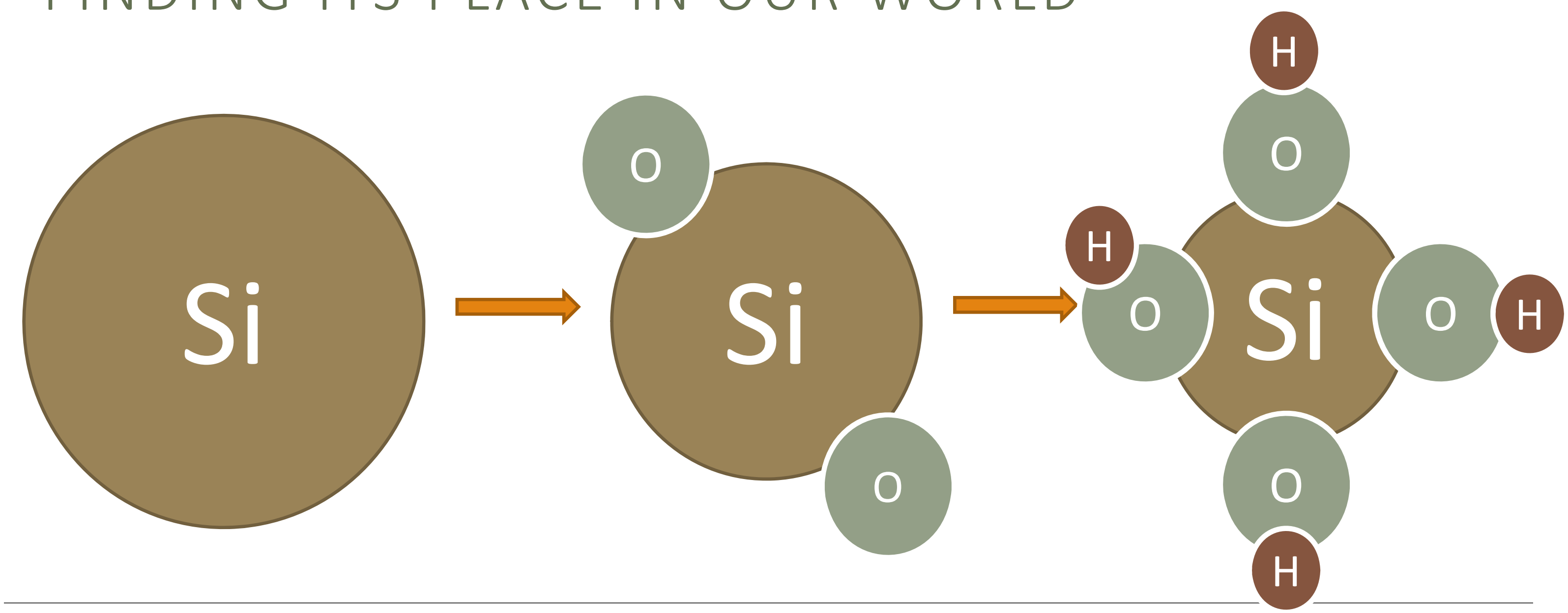
Phase-Gate Model



Recognizing **Si** as Essential

Silicon

FINDING ITS PLACE IN OUR WORLD



A NON-TRADITIONAL PRODUCT AND THE PROCESS OF BECOMING ESSENTIAL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FROM SOIL TO PLANT
ABOUT CrossOver®
INDUSTRIES SERVED
RESOURCES
CONTACT
GIVE YOUR PLANTS
WHAT THEY CRAVE
ELEVATES STRESS TOLERANCE
EXPLORE THE BENEFITS