Plant Available Silicon in Agriculture

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NEW TRENDS

- Large number of research projects on Silicon was reported in 2016 **(> 2000 in the US)** (Tubana *et al*., 2016).
- Association of American Plant Food Control officially designated Si as a plant **"beneficial substance"** (Tubana *et al*., 2016).
- Official method for quantifying soluble Si in solid fertilizer products: **5-Day Na_2CO_3-NH_4NO_3–soluble Si extraction method** (Sebastian *et al*., 2013*)*.
- Method to quantify the concentration of Si in water, soil extracts, and plant samples: **Molybdenum blue colorimetry method** (Hallmark *et al*., *1982,as cited by* Tubana *et al*., 2016).
- International Plant Nutrition Institute recently highlighting the importance of Si in plant nutrition especially under **"Stress Conditions"** (http://www.ipni.net/nutrifacts-northamerican).

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IMPORTANT FACTS

- The earth's crust consists of **28%** Si, but only **dissolved Si** (as **monosilicic acid, H_4SiO_4**) is plant availible (Tubana *et al*., 2016).
- Absorption of H_4SiO_4 from soil by lateral roots via **active** and **passive** mechanisms (Cornelis *et al*., 2011). H_4SiO_4 is also absorbed via **leaves**.
- **High accumulators of Si: 10-100 g Si kg^{-1} DM** (monocotyledons such as Rice, Sugarcane, Wheat and Barley.

  Intermediate–Si-accumulators: 5- 10 g Si kg^{-1} DM (monocotyledons)
  Low accumulators of Si: < 5 g Si kg^{-1} DM (Liang *et al*., 2007).
- Accumulated leaf H_4SiO_4 becomes **hard polymerized silica gel** ($SiO_2.nH_2O$) known as phytoliths (Raven, 1983) and **cannot be translocated** to new growing leaves. **Frequent** supply of available Si required.

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SI SOIL-REMOVAL RATES OF VARIES CROPS

(Meyer and Keeping, 2001; Makabe *et al*., 2009; Blecker *et al*., 2006; Anderson, 1991)

Crop	Si removal (kg/ha/year)
Sugar cane	500 - 700
Rice	230 – 470
Cereals	100 – 300
Potatoes	50 – 70
Grasslands (U.S.)	22 – 67

SI SHOOT CONCENTRATIONS FOR DIFFERENT CROPS

(Hodson *et al.*, 2005)

High accumulators of Si

Crop	Production (MT)	Si Concentration in Shoots (% Dry Wt.)*
Sugar Cane	1.736	1.509
Corn	826	0.827
Rice	686	4.167
Wheat	683	2.455
Potatoes	326	0.4
Cassava	232	0.5
Soybeans	231	1.399
Sugar Beet	222	2.34-7
Barley	155	1.824
Tomatoes	136	1.55

MOST IMPORTANT BENEFICIAL EFFECTS OF SILICON

- H_4SiO_4 increases soil **pH** via release of OH- (Wallace, 1993)
- Precipitate **Heavy Metals** (Lindsay, 1979)
- H_4SiO_4 diminishing **Al** in soil solution (Baylis *et al*., 1994).
- Improve **mechanical strength** of plant structural components (Hayasaka *et al*., 2008).
- Activate unique **defensive (PR-proteins) & metabolic genes** in plant (Ghareeb *et al*., 2011).
- Enhances plants **antioxidant** systems (Inal *et al*., 2009).
- Prevent **Na-accumulation & salt-stress** (Yeo *et al*., 1999).
- Reduce the effect of **Abiotic stress** such as **Drought** (Hattori *et al*. 2005)

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MAIN ATTRIBUTES OF PLANT-AVAILIBLE SILICON FROM A ABIOTIC LITERATURE PERSPECTIVE

Greater tolerance towards:

- Drought stress
- Al-toxicity
- Salt stress
- Nutrient imbalances (such as > N & P)

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DROUGHT STRESS

(Hattori *et al.* 2005)

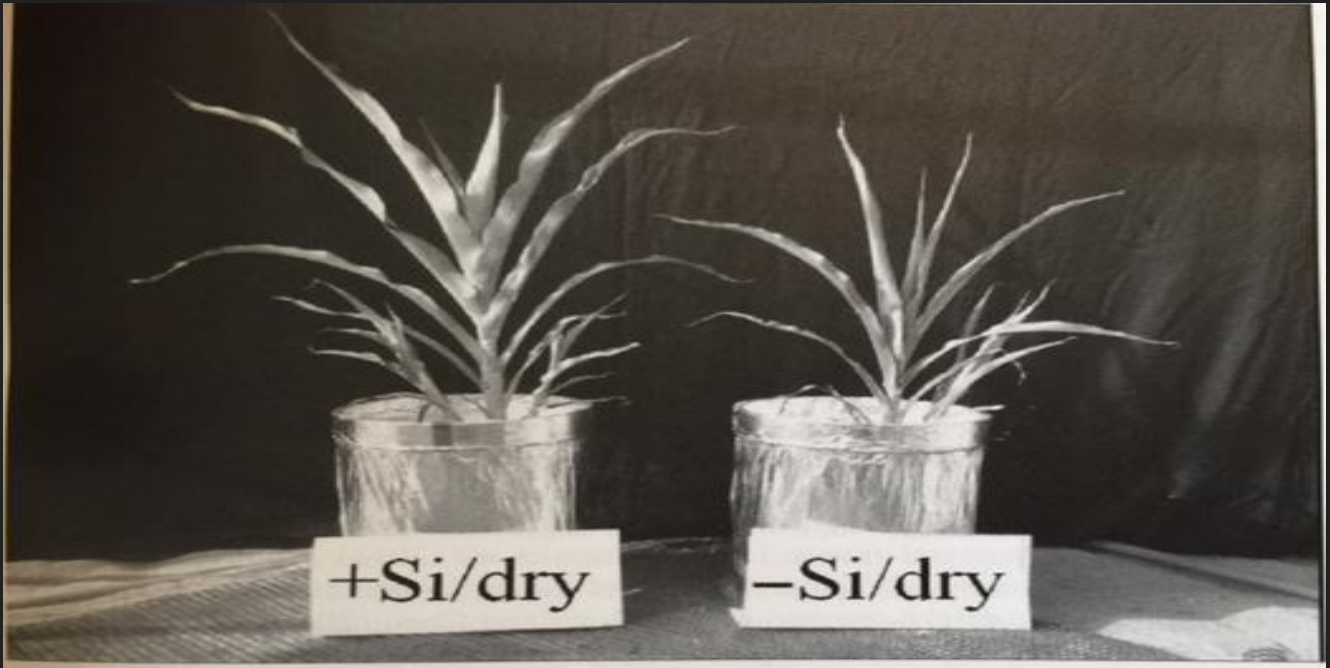

Fig. 7.2 Effect of Si application on the growth of sorghum under dry conditions (From Hattori et al. 2005). Sorghum plants (cv. Gadambalia) were grown in Si-applied soil (*left*) and non-applied soil (*right*). Plants were 47-day old (22 days after the initiation of dry treatment)

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Al & Si

(Silicon in Agriculture Handbook, 2015)

Table 5.3 Interactions between Al and Si in experiments

Plant species	Authors and/or references
Barley	Hammond et al. (1995), Liang et al. (2001), and Morikawa and Saigusa 2002
Sorghum	Galvez et al. (1987), Galvez and Clark (1991), Hodson and Sangster (1993), and Li et al. (1996)
Rice	Rahman et al. (1998), Hara et al. (1999), and Singh et al. (2011)
Mung bean	Yang et al. (1999)
Maize	Ma et al. (1997), Corrales et al. (1997), Kidd et al. (2001), and Wang et al. (2004)
Teosinte	Barceló et al. (1993)
Wheat	Cocker et al. (1998a, b) and Zsoldos et al. (2003)
Cotton	Li et al. (1989)
Soybean	Baylis et al. (1994)
Melastoma malabathricum	Watanabe et al. (1997)
Holcus lanatus	Kidd and Proctor (2001)
Norway spruce	Ryder et al. (2003)
Stylosanthes	Zhang et al. (2009)

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SALT STRESS & Si

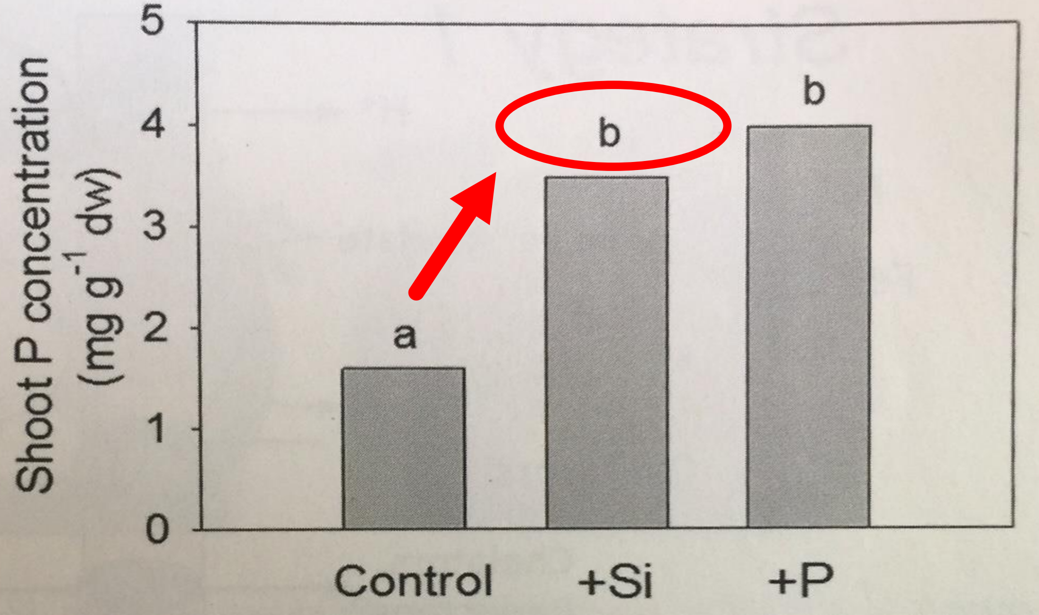
(HAGHIGHI & PESSARAKLI, 2013)

Fig. 6.1 Effect of 1.0 mM Si addition on the growth of salt-sensitive (cv. Kepin No. 7, *upper*) and salt-tolerant (cv. Jian No. 4, *lower*) barley cultivars grown hydroponically with 120 mM NaCl (Photography by Yongchao Liang)

P-availibility & Si

(Silicon in Agriculture Handbook, 2015)

Fig. 8.1 Effect of Si supply on shoot P concentration of wheat plants grown in the acid soil (Based on Kostic-Kravljanac 2015)



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TWO MAIN PLANT MECHANISMS

X

- **Physical**
  - Cuticle
  - Osmotic adjustments
- **Biochemical**
  - Photosynthesis
  - Abiotic stress

SilGro ™
SilCat ™
CibuSil™

Due to Large & Frequent crop need for Plant Available Si we need to look for more methods of application

SILGRO™ as an alternative Si source to increase Si application rates per hectare

SilGro™ is a powder product applied at **10 kg/ton** urea as a coating onto dry granules using CoatGro™ as sticking agent. **SilGro™** is mainly coated onto urea with the following main attributes:

- Supplies **Plant-Available Silicon** [$Si(OH)_4$].
- Keep urea **Dry** under high humidity conditions.
- Improve **Plant Vigour & Grain Yield.**

General notes:

- SilGro™ coated urea must preferable be worked into soil, especially on > pH soils.
- Relatively pH (>10), (> NH_3)
- Not 100% water soluble.
- Not be used with Zn, Cu, Mn, Fe, Ca & Mg.

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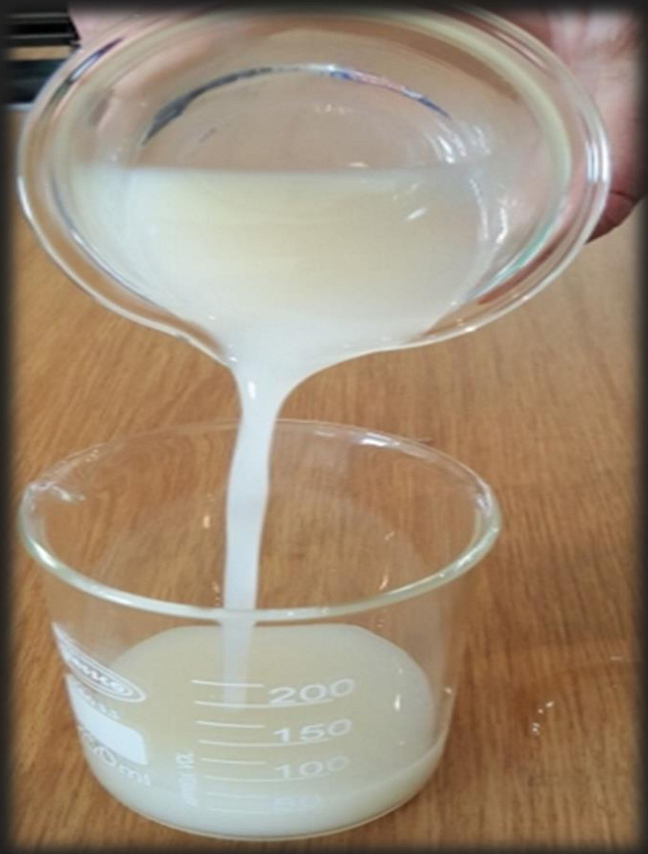
CoatGro - natural polymer

CoatGro™ is an adhesive bio-polymer that is used to coat SilGro™ onto dry granular urea.



CoatGro™ is a product of BioPher (Pty) Ltd.

Pictures illustrating the coating of SilGro powder onto urea granules

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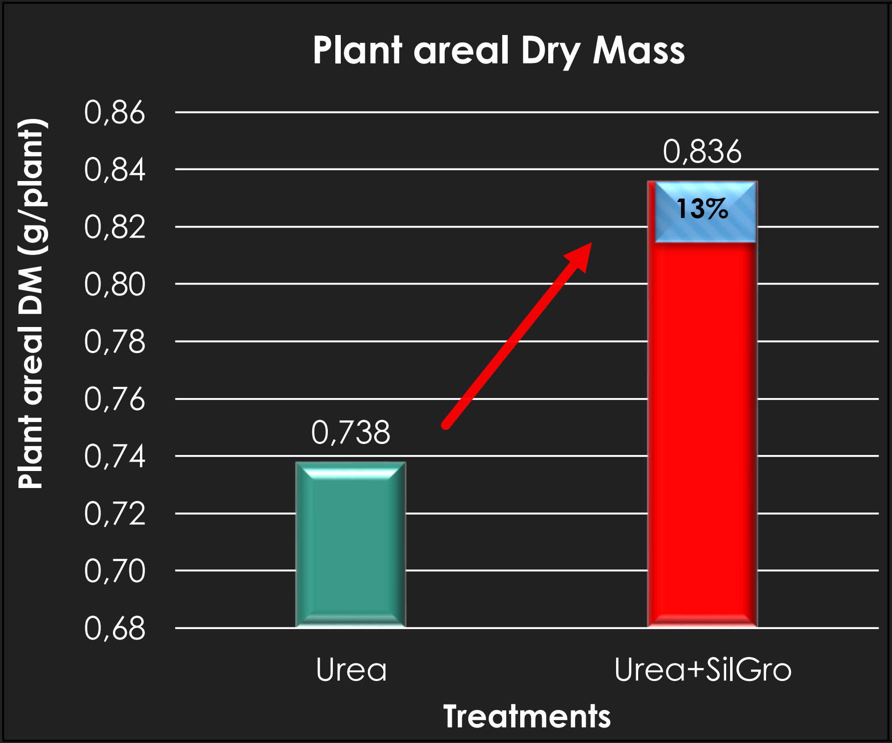
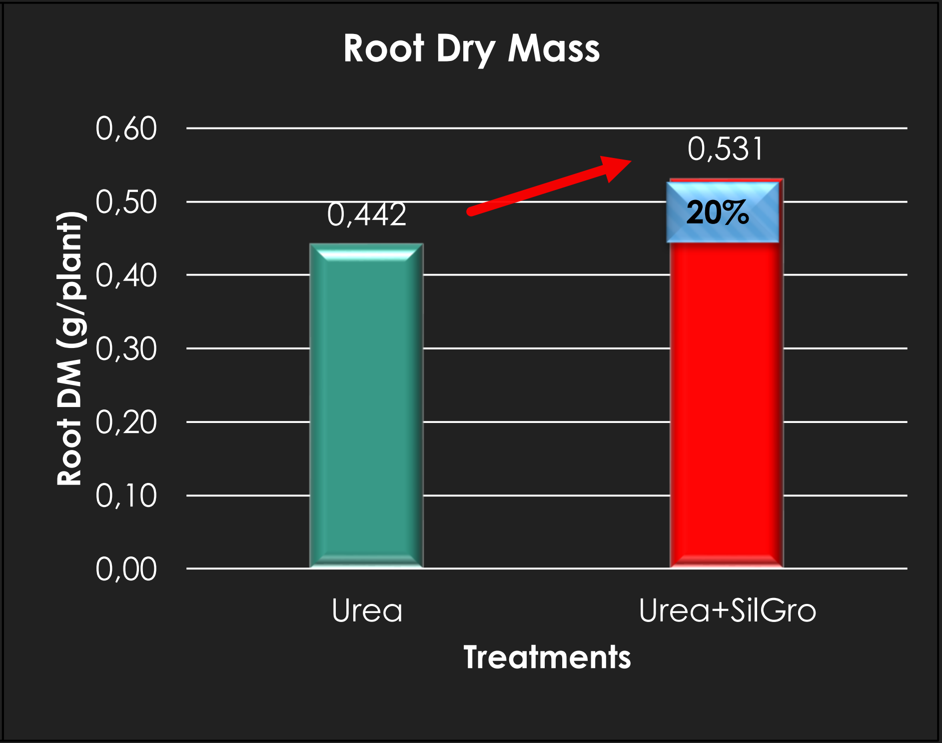
PLANT VIGOUR OF WHEAT





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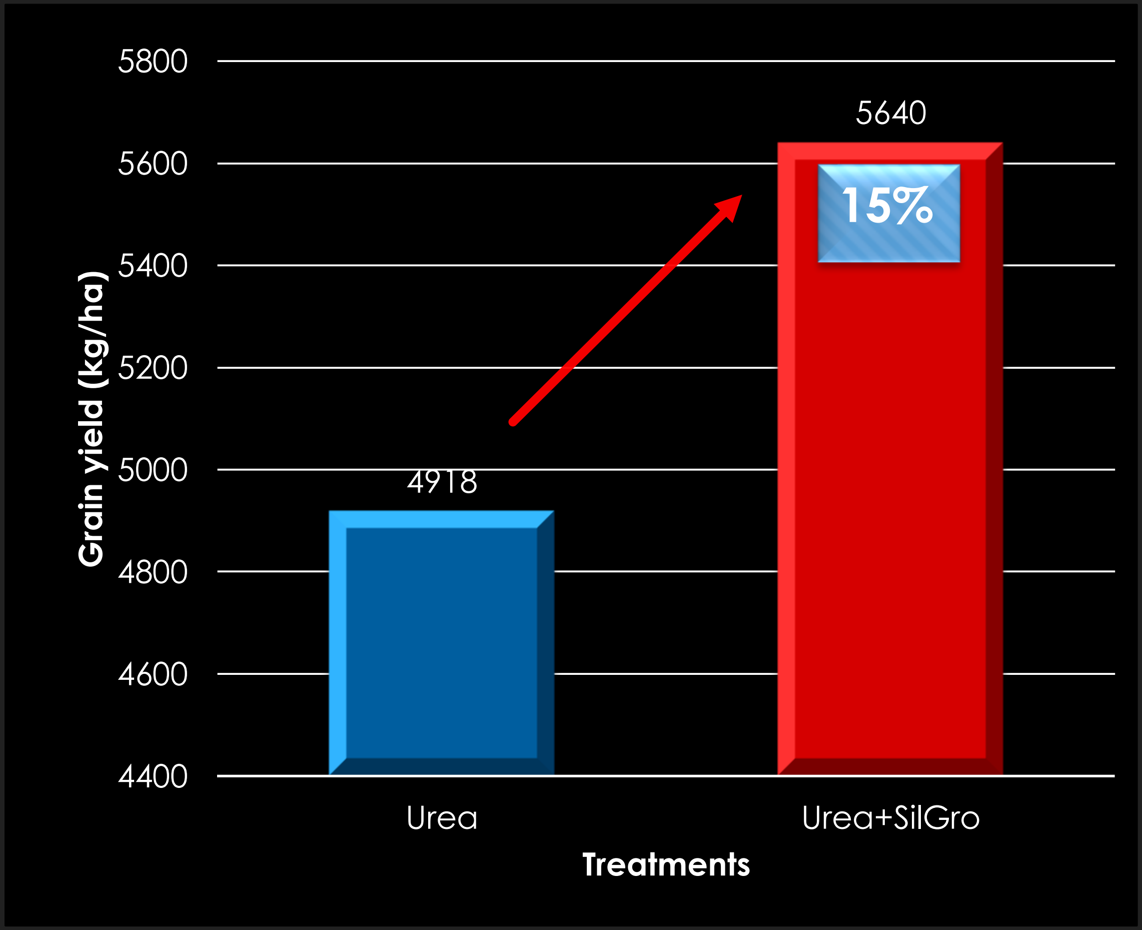
GRAIN YIELD OF MAIZE

TREATMENTS

1. Urea applied at 150 kg/ha
2. Urea @ 150 kg/ha + SilGro™ @ 10 kg/ton + CoatGro @ 2 L/ton.

- Note: Applied pre-planting to soil, 250 mm below soil surface.



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Pot trial with SilGro™ & CoatGro™ on Wheat

BRAZIL

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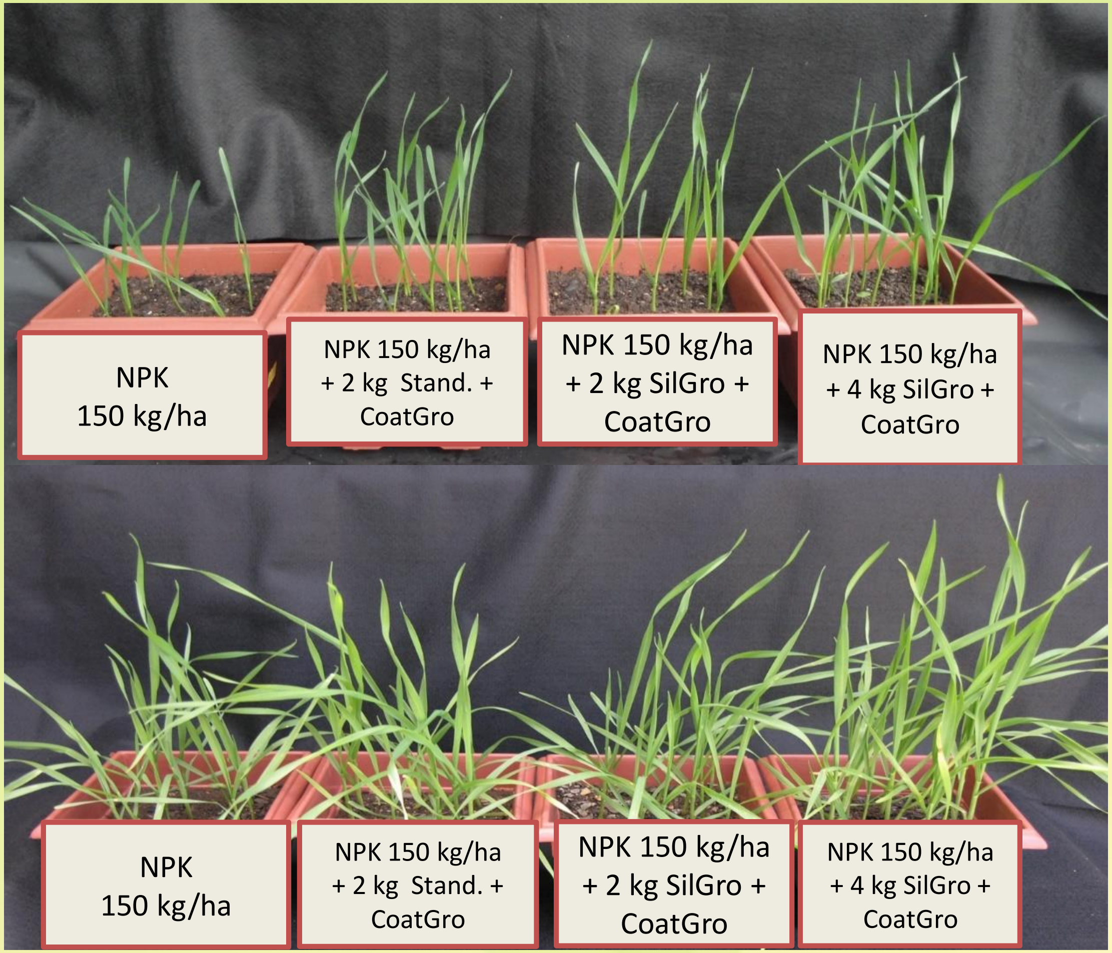

Wheat Trial, Brazil

NPK is an Inorganic Fertilizer

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Pot trial conducted in China on rice, 2018

与南通大学合作室内盆栽试验（水稻）
Laboratory pot experiment with NanTong university （Rice）

SilCat™ is a powder product applied at 2 kg/ton dry granular fertilizer as a coating and contains both Plant Available Silicon as well as unique Plant Extracts.

MAIN ATTRIBUTES:

- To Enhances soil Microbial Activity
- Optimize Crop Yield.

Preferably avoid use with heavy metal containing fertilizers (most of micro-elements), magnesium and calcium.

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MEASURING SOIL MICROBIAL ACTIVITY USING THE FDA METHOD

FDA method description

Total microbial activity is measured using the fluorescein diacetate (FDA) method. FDA hydrolysis is widely accepted as an accurate and simple method for measuring total microbial activity in a wide range of soils. Colourless FDA is hydrolysed by both free and membrane-bound enzymes, releasing a coloured end-product, fluorescein which can be measured by spectrophotometry.

The advantages of the FDA method is that it is simple, rapid and sensitive (Adam and Ducan 2001; with permission from Elsevier).

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STUDY 1: SOIL MICROBIAL ACTIVITY

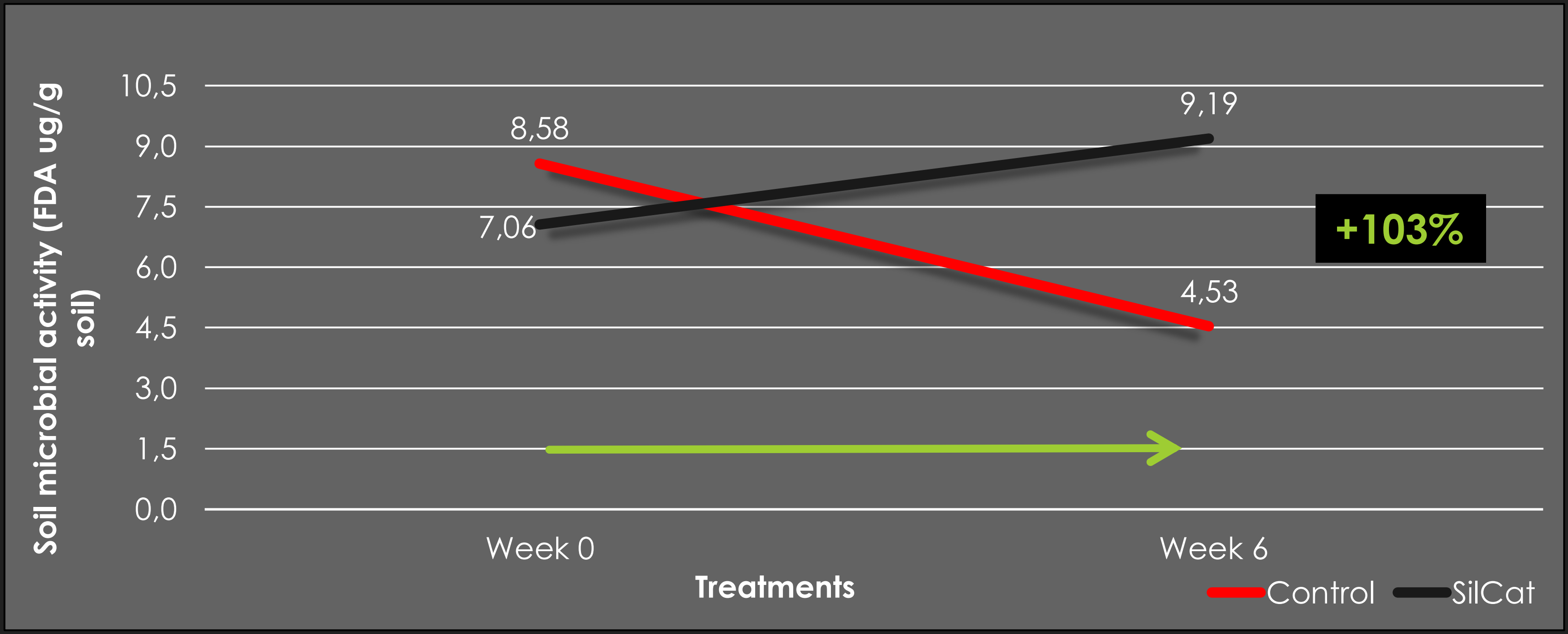


Figure: Soil microbial activity at start of trial and 6 weeks later according to the FDA method in a maize greenhouse study for dry fertilizer coated without and with **SilCat™.**

STUDY 2: SOIL MICROBIAL ACTIVITY

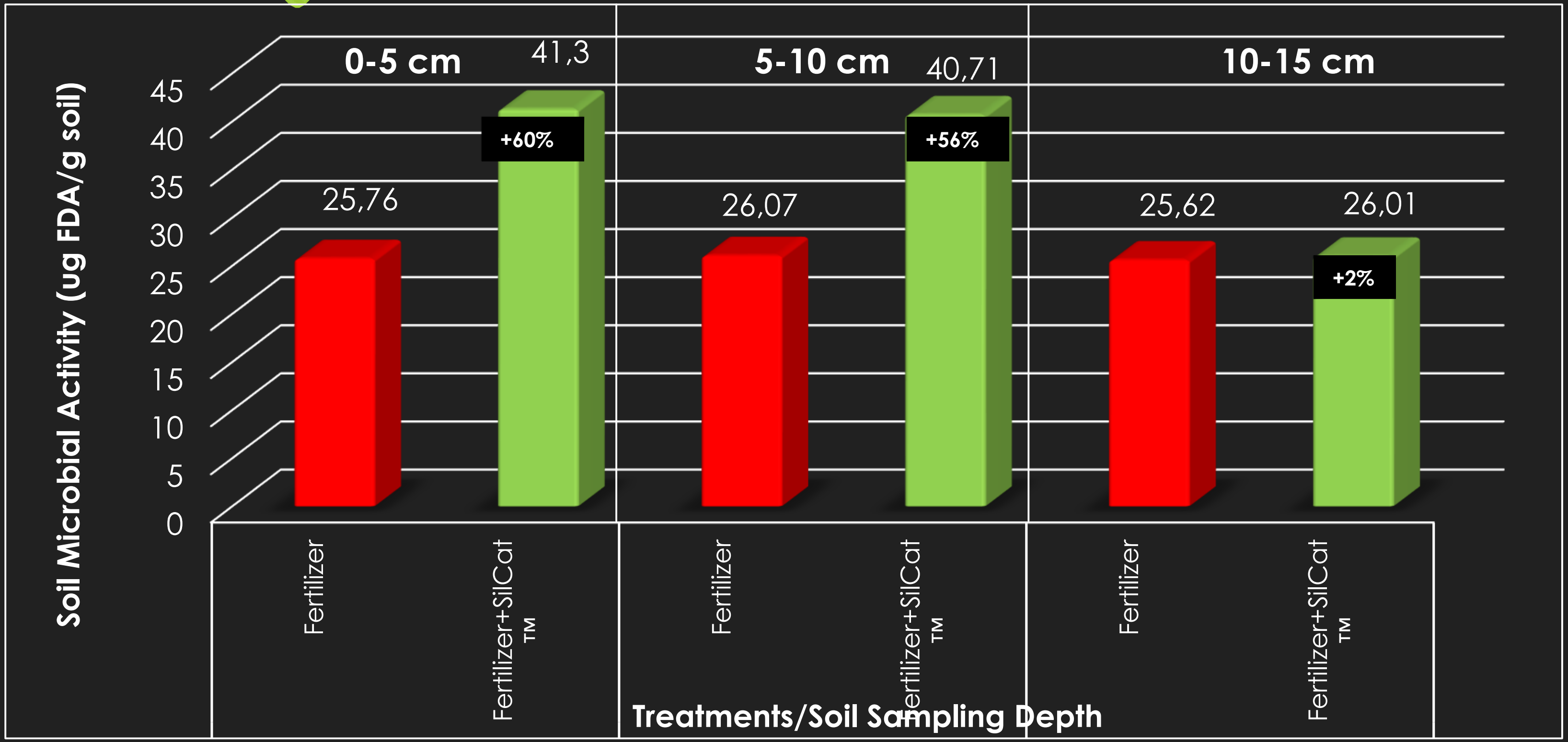


Figure: Soil microbial activity 9 weeks after treatment according to the FDA method in a maize field trial for dry fertilizer coated with and without SilCat™.

GRAIN YIELD

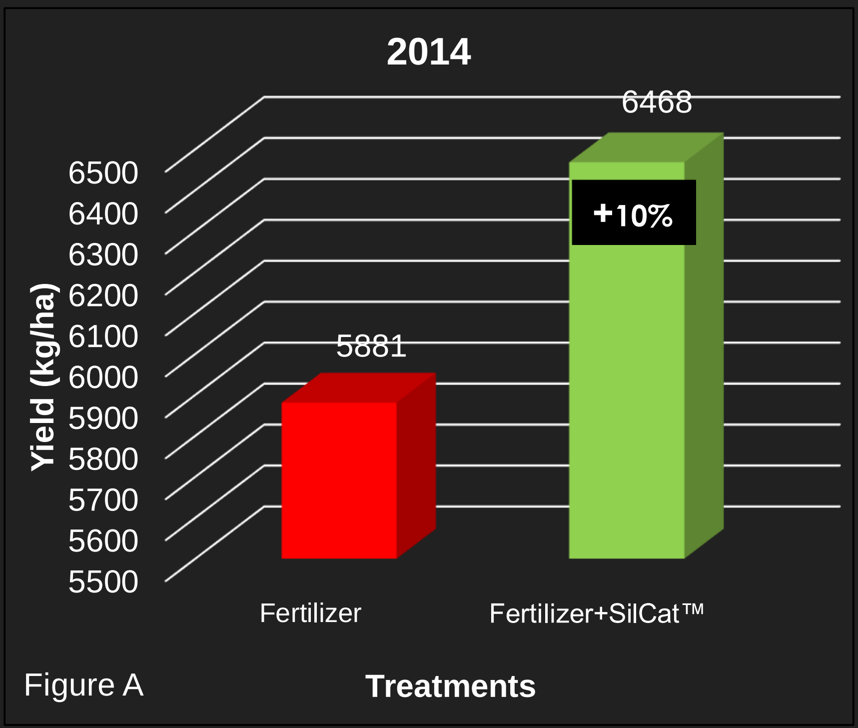


Figure A

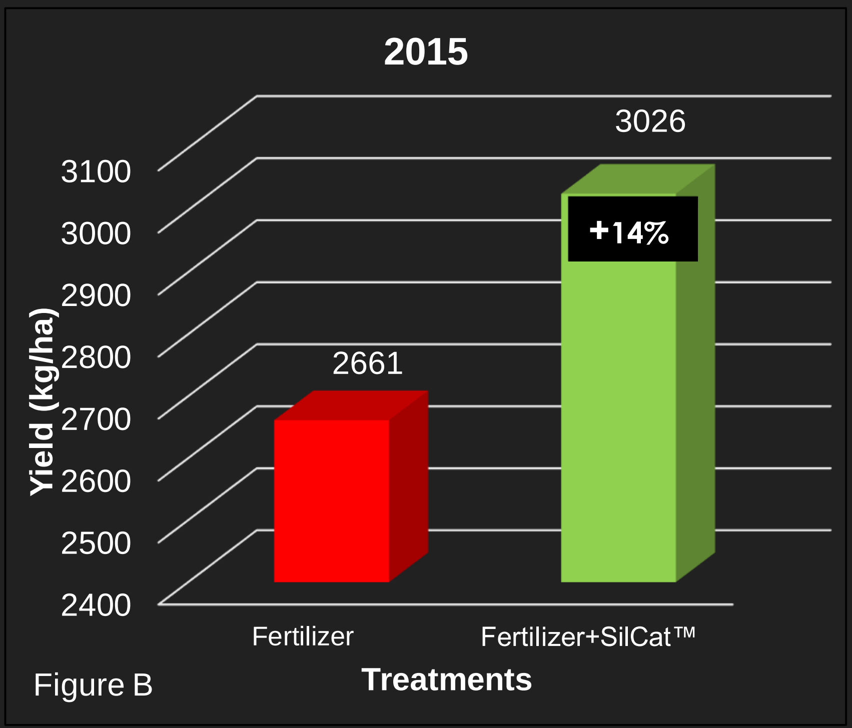
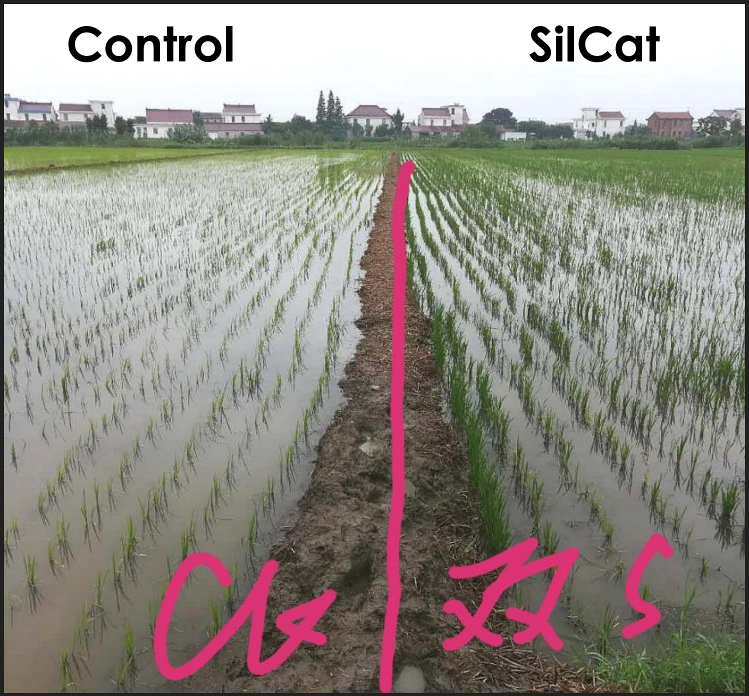


Figure B

Figure A & B: Grain yield of maize under rain fed conditions over two seasons for dry granular fertilizer coated with **SilCat™.**

Field trial on rice with SilCat coated on NPK-fertilizer

Nantong City, Jiangsu Province 2018, China



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Maize trial conducted by Jiangsu Nantong University, China, 2019

Seed treated with ComCat

NPK fertilizer

NPK fertilizer+ SilCat +SilGro

NPK fertilizer+ SilCat+SilGro+ seed treated with ComCat

Reduction of Cadmium content in rice grain via SilCat+SilGro coating on NPK granular fertilizer, China, 2019

SilCat+SilGro：0.13 mg/kg, Control: 0.16 mg/kg 23 % reduction in Cd.


No. WTH180551

CMA
2015190844Z

检 验 报 告

广东省清远市质量计量监督检测所
GuangDong QingYuan Supervision Testing Institute
of Quality and Metrology


No. WTH180551

广东省清远市质量计量监督检测所

检 验 报 告

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序号	检 测 项 目	单位符号	技术指标	检测结果	单项评价
1	镉	mg/kg	≤0.2	0.16	合格

No. WTH180550

广东省清远市质量计量监督检测所

检 验 报 告

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序号	检 测 项 目	单位符号	技术指标	检测结果	单项评价
1	镉	mg/kg	≤0.2	0.13	合格

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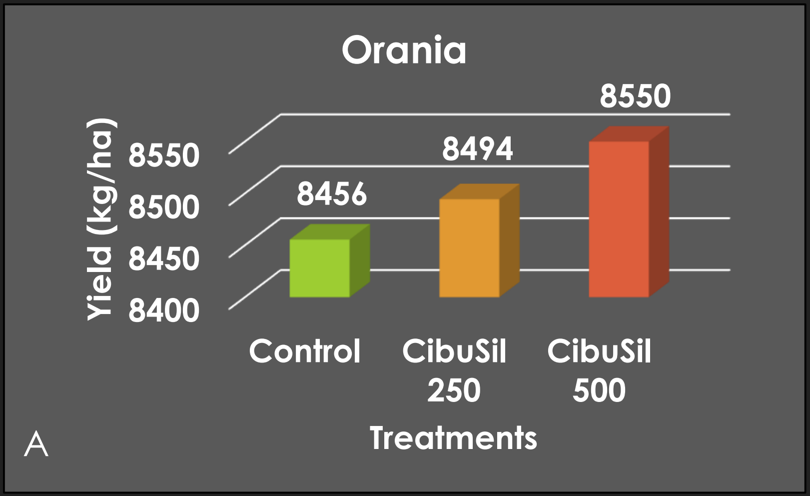
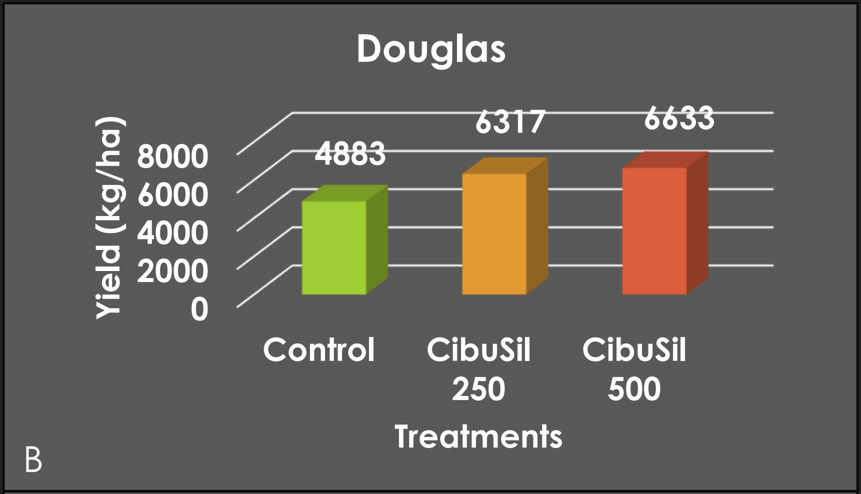
GRAIN YIELD RESULTS WITH CIBUSIL™ ON WHEAT AS FOLIAR SPRAY





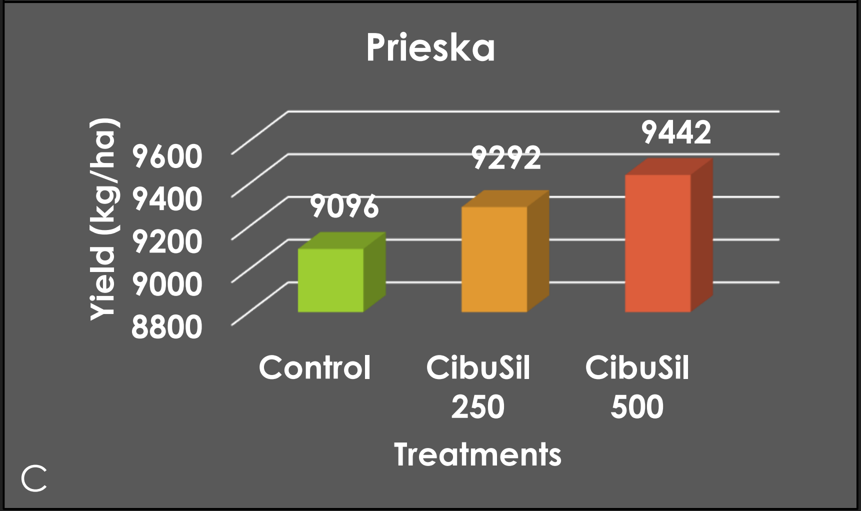


Figure A-C: **Grain yield** of wheat in statistical trials over different areas in South Africa, 2015.

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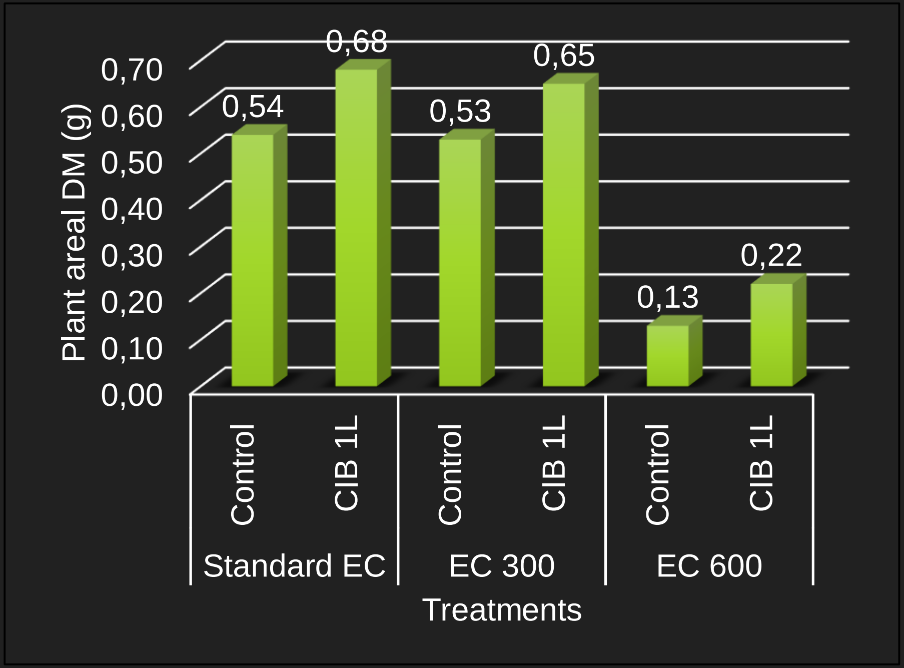
SALT STRESS TRIAL WITH CIBUSIL™ APPLIED ON WHEAT (UFS)

TREATMENTS

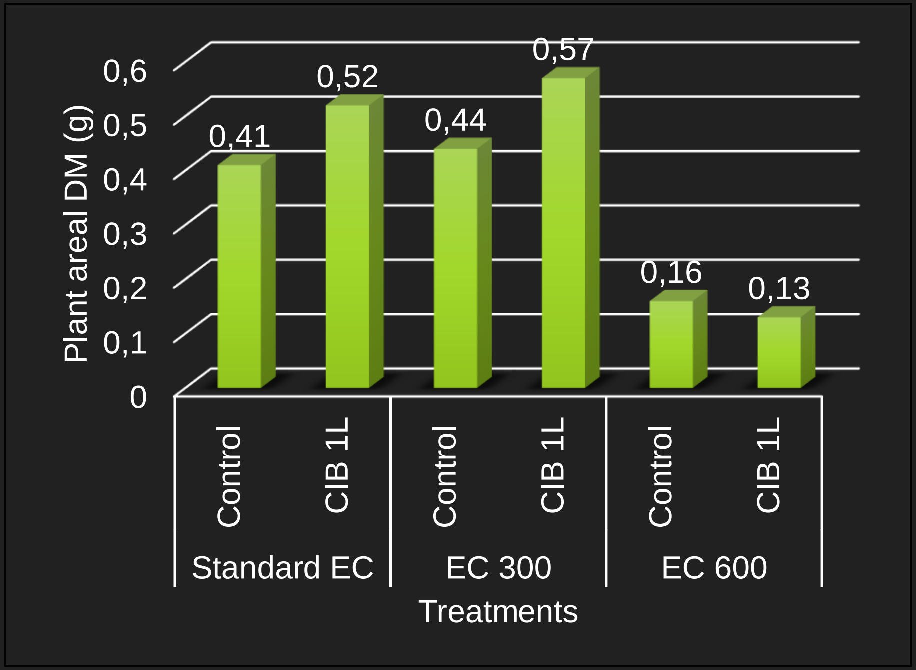
Treatments		EC_e ($mS\ m^{-1}$)
1	Control	STD (22.3)
2	CibuSil @ 1 L/ha	STD (22.3)
3	Control	300
4	CibuSil @ 1 L/ha	300
5	Control	600
6	CibuSil @ 1 L/ha	600

SALT STRESS TRIAL WITH CIBUSIL™ APPLIED ON WHEAT (UFS, 2016)

STUDY 1



STUDY 2



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Wheat trial to show the effect of CibuSil S as a drench to soil to prevent the negative effect of salt stress.
University of the Free State, South Africa, 2019

No salts apply

Salt water applied with EC = 900 mS/m

Treatments from L to R: Control, CibuSil S @ 2.5L/ha, CibuSil S @ 5 L/ha, external silicon product.

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CONCLUSION

PLANT AVAILABLE SILICON

is a **"beneficial element"** for Sustainable Crop Production

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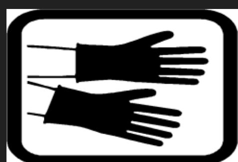
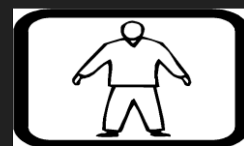
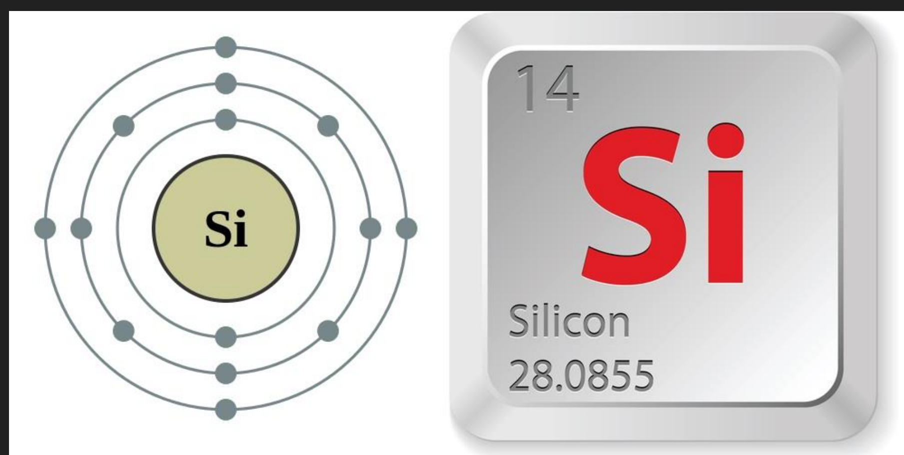
THANKS FOR YOUR ATTENTION







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