**IFA Hong Kong October 2024**
Presentation by
**Peter Prentice - Managing Director**
**Agripower Australia**

# Plant Available Silicon (PAS)

## *Agriculture's Differentiator*

*The most significant change to fertilisers in 100 years*

# Plant Available Silicon (PAS)

Global game-changer
Solutions for food security, the environment & emissions

Granulated Silicon Fertiliser

## *Economic impact*

- Crop Yield, by up to 120% ↑
- Crop resilience against stress ↑
- Crop Quality, Value & Shelf Life ↑
- Soil moisture, health & fertility ↑
- Heavy metal contamination ↓
- Water usage ↓
- Nutrient run-off & leaching ↓
- Crop losses ↓

**Farmer Profits, Increased by up to 40%** ↑

## *Sustainability impact*

- Carbon sequestration ↑
- Protection of ecosystems ↑
- Carbon Trading potential ↑
- Soil carbon ↑
- Uptake of NPK & other nutrients ↑
- Zero emissions in application and extremely low carbon footprint ↓
- $N_2O$ emissions ↓
- $CH_4$ emissions ↓

**Pollution & Emissions Reduced** ↓

# PLANT AVAILABLE SILICON (PAS)

**The key to unlocking the benefits of silicon to agriculture**


# WHAT IS PAS?

## Silicon in a soluble form: Monosilicic Acid - $Si(OH)_4$

1. Being ‘SOLUBLE’ it is an ‘ACCESSIBLE’ nutrient for plants: Plant Available Silica (PAS)
2. Plants and Soils can now utilise silicon’s uniquely powerful benefits.
3. Available in a 100% NATURALLY DERIVED GRANULAR FORM it can be blended with traditional fertilisers such as NPK.
4. Silicon concentration in plants ranges from 0.1% to 10% (dry weight).
5. PAS in silica fertilisers is best measured using the 0.01M Calcium Chloride method which attempts to replicate soil conditions. The alternate “5 Day $Na_2CO_3$-$NH_4NO_3$ Extraction Method is not a consistently accurate methodology across all silica fertilisers

$SiO_2$ (silica) comes in two principal forms:

- ***Structured*** or ‘*crystalline’ e.g. sand* (*which is silicon in a form unavailable to plants)*
- ***Unstructured*** or ‘*amorphous’* which is a more soluble form, and which readily converts to *‘monosilicic acid’* known as **PAS (Plant Available Silicon)** *which is… bioavailable to plants.*

PAS (Monosilicic acid) is 100% bioavailable to plants.

PAS works in 3 important ways:

1. **Mechanically** *(by strengthening plant cells)*
2. **As a Biostimulant** *(to optimise plant health)*
3. **Nutritionally** *(for plant and biomass growth)*

# Silicon Fertilisers International Recognition

## 1950

**JAPAN | KOREA**

Formally classify Si as agronomically essential

## 2004

**BRAZIL**

Ministry of Agriculture rules Si as a beneficial nutrient

## 2012


**USA**

Si officially recognised as beneficial substance by AAPFCO

## 2018

**SRI LANKA**

Si recognized as input for agriculture

## 2019

**INDIA**

Amorphous Silicon (PAS) entered into the Fertiliser Control Order

## 2021

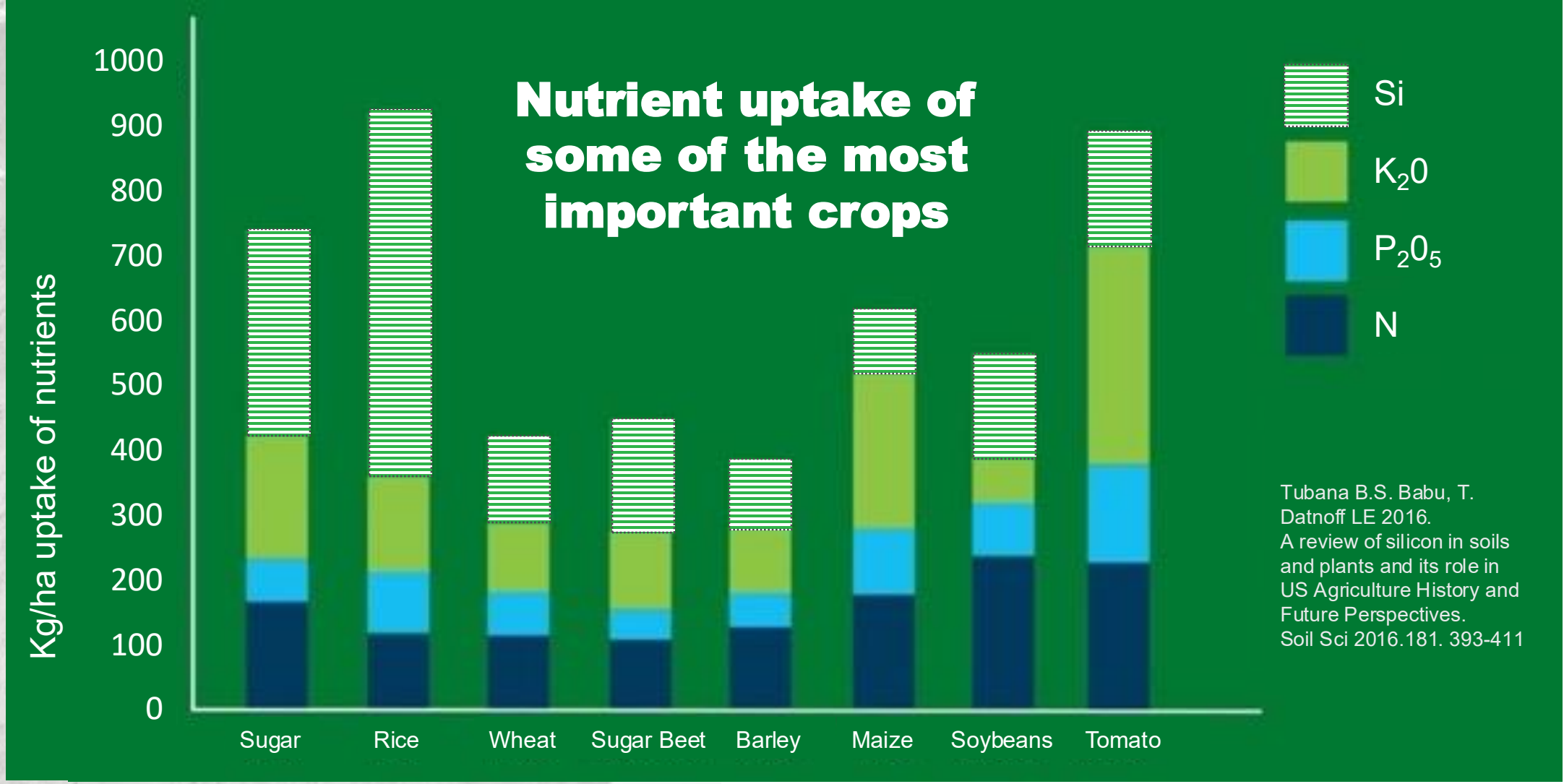
**EU**

Si recognised as an input for agriculture

## 2024


**USA**

Being considered as an ESSENTIAL ELEMENT by AAPFCO




Tubana B.S. Babu, T. Datnoff LE 2016.
A review of silicon in soils and plants and its role in US Agriculture History and Future Perspectives.
Soil Sci 2016.181. 393-411

# Why PAS is necessary

- Crops remove 210-224 Million Tonnes of Silicon (Si) from soils p/a worldwide
- Silicon (Si) is removed by crops in similar quantities to NPK
- Rice and sugarcane remove more Si than NPK combined
- Without Si fertilisers, crops can become Si-deficient



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# Movement of PAS through the Plant


**Silicon as PAS ($Si(OH)_4$)** is transported in the plant up through the xylem via water transpiration.

Accumulates as silica ($SiO_2$) gel in phytoliths in growing points, mainly leaf. New research showing in some crops e.g. tomato accumulation of $SiO_2$ in roots

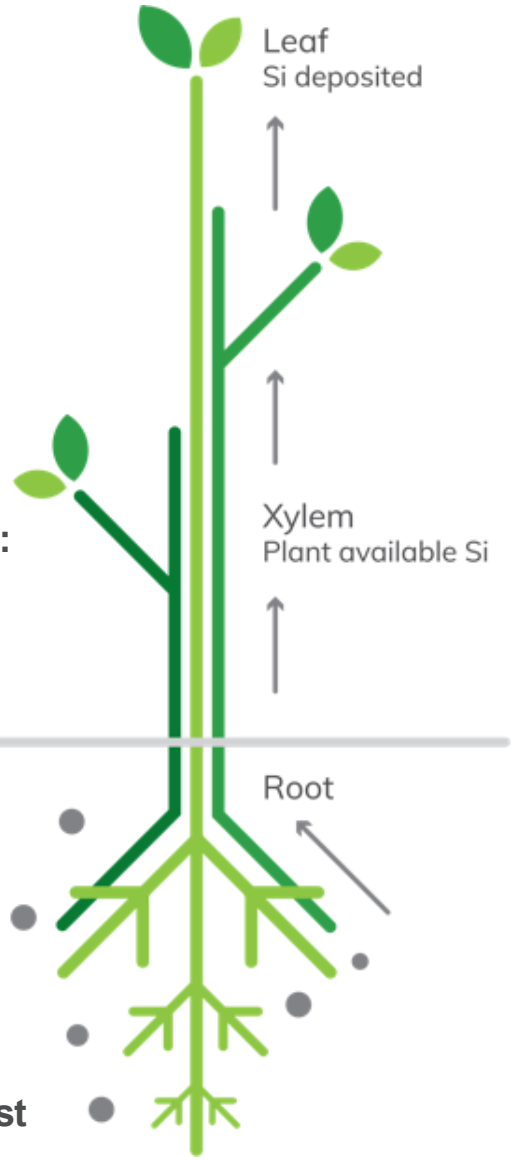
Active process mediated by specific transporter proteins in some species e.g rice :

- *influx transporter gene, Lsi 1*
- *efflux transporter gene, Lsi 2*
- *distribution of Si in the shoots gene, Lsi 6*

Passive movement in dicot species from soil solution into roots.

Silicon concentration in plants ranges from 0.1% to 10% (dry weight).

Silicon is found in all plant organs with highest concentration in leaves.




# KEY BENEFITS OF PAS

- ✓ **INCREASE** Yield, Quality & Shelf-Life — slides 8-9
- ✓ **INCREASE** Nutrient-Use Efficiency (NUE) — slides 10-12
- ✓ **INCREASE** Water-Use Efficiency (WUE) — slides 13-17
- ✓ **REDUCE** Crop Loss (Abiotic & Biotic Stress) — slides 18-20
- ✓ **SUPPORT** Sustainable Agriculture — slides 21-22



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# Examples of significant yield increases by applying PAS

| Crop | Country | Yield Increase % | Grower profit a$/ ha No Silicon Fert | Grower profit AU$/ha with Silicon Fert | Additional Profit AU$/ha with Silicon Fert | Number times Silicon Fert cost covered (ROI) |
|---|---|---|---|---|---|---|
| Apple | Morocco | 50 | 22,200 | 37,400 | 15,200 | 28.1 |
| Avocado | Australia | 27 | 74,700 | 95,570 | 20,870 | 50.7 |
| Banana (greenhouse) | Morocco | 26 | 35,400 | 44,000 | 8,600 | 16.4 |
| Barley | Australia | 92 | 364 | 735 | 371 | 4.5 |
| Blueberry | Morocco | 6 | 75,500 | 79,600 | 4,100 | 15.6 |
| Cherry | Australia | 20 | 87,500 | 104,800 | 17,300 | 99.9 |
| Chilli | Australia | 59 | 100,000 | 158,730 | 58,730 | 210.8 |
| Citrus (Mandarin) | Spain | 23 | 26,000 | 29,800 | 3,800 | 22.7 |
| Coffee | India | 34 | 2,300 | 3,100 | 800 | 6.7 |
| Cotton | India | 21 | 1,640 | 1,930 | 290 | 5.1 |
| Cucumber | Australia | 34 | 92,400 | 123,800 | 31,400 | 113.1 |
| Date Palm | Saudi Arabia | 8 | 42,300 | 47,360 | 5,060 | 25.1 |
| Grape (Wine) | Spain | 30 | 14,000 | 18,000 | 4,000 | 20.0 |
| Grape (Table) | Brazil | 27 | 28,500 | 36,500 | 8,000 | 65.0 |
| Hazelnut | Turkey | 70 | 30,000 | 64,000 | 34,000 | 82.0 |
| Macadamia | Australia | 30 | 16,740 | 22,130 | 5,390 | 26.7 |
| Maize | Zimbabwe | 21 | 2150 | 2600 | 450 | 3.2 |
| Melon | Brazil | 34 | 31,700 | 42,500 | 10,800 | 39.6 |
| Olive | Spain | 19 | 4,000 | 4,880 | 880 | 9.4 |
| Onion | Australia | 63 | 16,200 | 18,400 | 2,200 | 13.6 |
| Pear | Spain | 68 | 9,500 | 15,750 | 6,250 | 32.9 |
| Pomegranate | India | 31 | 12,500 | 16,060 | 3,560 | 18.0 |
| Potato | Zimbabwe | 17 | 24,800 | 29,100 | 4,300 | 17.5 |
| Raspberry | Morocco | 23 | 70,000 | 86,000 | 16,000 | 77.2 |
| Rice | Turkey | 26 | 6,500 | 8,000 | 1,500 | 8.1 |
| Rice | India | 28 | 1900 | 2400 | 500 | 4.8 |
| Soybean | India | 17 | 1,500 | 1,800 | 300 | 5.3 |
| Stawberry | Australia | 21 | 174,000 | 209,000 | 35,000 | 67.7 |
| Sugar Beet | Morocco | 62 | 2,800 | 5,000 | 2,200 | 11.5 |
| Sugarcane | Brazil | 85 | 3,500 | 6,500 | 3,000 | 17,1 |
| Sugar cane | Australia | 11 | 3,200 | 4,200 | 1,000 | 5.1 |
| Tea | India | 16 | 8,900 | 10,200 | 1,300 | 7.2 |
| Tomato (Field) | Spain | 29 | 19,200 | 23,400 | 4,200 | 40.0 |
| Tomato (greenhouse) | Morocco | 12 | 62,900 | 70,400 | 7,500 | 11.9 |
| Wheat | Zimbabwe | 19 | 3,400 | 4,050 | 650 | 18.6 |
| Wheat | Morocco | 49 | 1,300 | 1,700 | 400 | 4.8 |

Source: Agripower based on independent trials

| Crop | Yield Increase % | Number of times Silicon Fert cost covered (ROI) |
|---|---|---|
| Apple | 50 | 28.1 |
| Avocado | 27 | 50.7 |
| Banana (Greenhouse) | 26 | 16.4 |
| Barley | 92 | 4.5 |
| Blueberry | 6 | 15.6 |
| Cherry | 20 | 99.9 |
| Chilli | 59 | 210.8 |
| Citrus (Mandarin) | 23 | 22.7 |
| Coffee | 34 | 6.7 |
| Cotton | 21 | 5.1 |
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| Macadamia | 30 | 26.7 |
| Maize | 21 | 3.2 |
| Melon | 34 | 39.6 |
| Olive | 19 | 9.4 |
| Onion | 63 | 13.6 |
| Pear | 68 | 32.9 |
| Pomegranate | 31 | 18.0 |
| Potato | 17 | 17.5 |
| Raspberry | 23 | 77.2 |
| Rice | 26 | 8.1 |
| Rice | 28 | 4.8 |
| Soybean | 17 | 5.3 |
| Strawberry | 21 | 67.7 |
| Sugar Beet | 62 | 11.5 |
| Sugar Cane | 85 | 17.1 |
| Sugar Cane | 11 | 5.1 |
| Tea | 16 | 7.2 |
| Tomato (Field) | 29 | 40.0 |
| Tomato (Greenhouse) | 12 | 11.9 |
| Wheat | 19 | 18.6 |
| Wheat | 49 | 4.8 |

# Grower Crop Yield and ROI with PAS

***Farmer return on investment (ROI) significantly justifies additional cost of Granular Silicon Fertiliser –***

**Farmers gained from 3x up to >100x outlay**

- *Silicon fertilizers increase the uptake of all nutrients including nitrogen, phosphate and potassium and better utilize all these within the plant*
- *PAS is taken up by plant root in form of silicic acid and transported throughout the plant by its vascular system*
- *Silicon strengthens plant cells resulting in more erect stems and leaves even in warm conditions*
- *Plants are able to capture more sunlight, $CO_2$ and water, essential for plant growth and photosynthesis*
- *Increased photosynthesis from silicon fertilizing results in greater biomass, improving crop size, weight and quality*

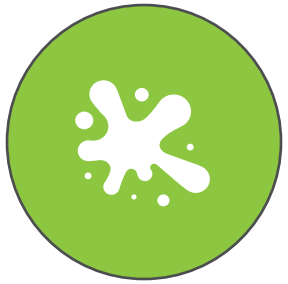
*Source: Independently managed trials by Universities and Corporate farms using granulated silicon fertiliser*

# PAS Increases NUE Nutrient-Use Efficiency

Increased nutrient UPTAKE by the crop

Increased YIELD per KG of applied nutrient

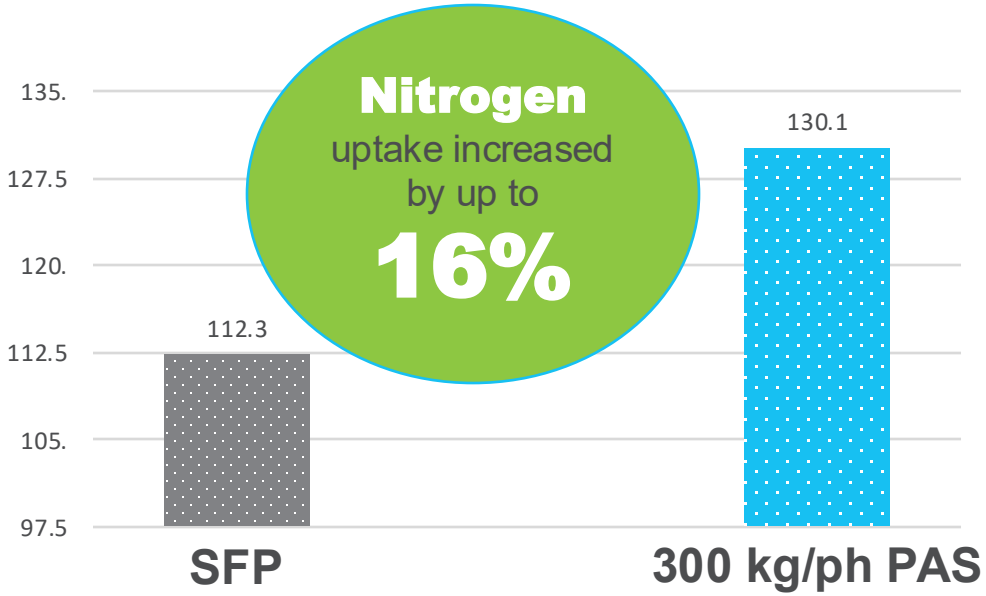
Increased farmer PROFIT

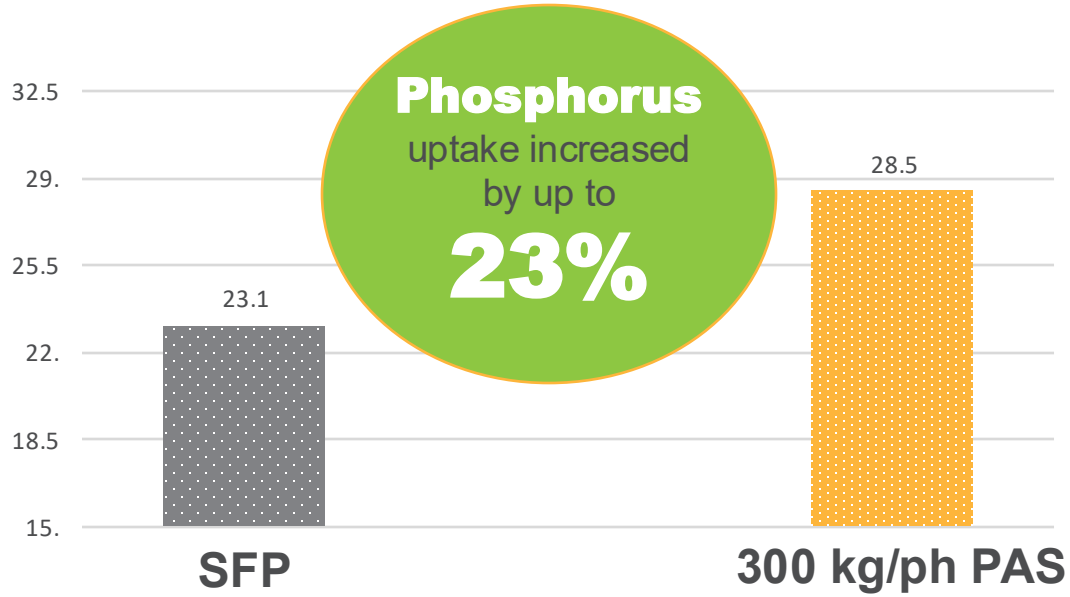


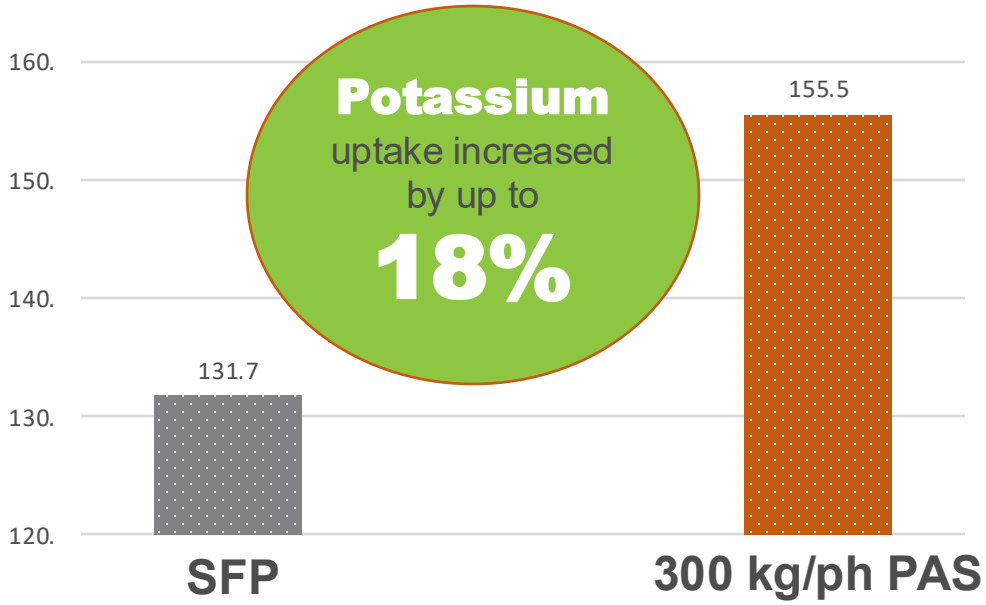
Reduced nutrient LEACHING & RUN-OFF

Less water POLLUTION

Less $N_2O$ EMISSIONS



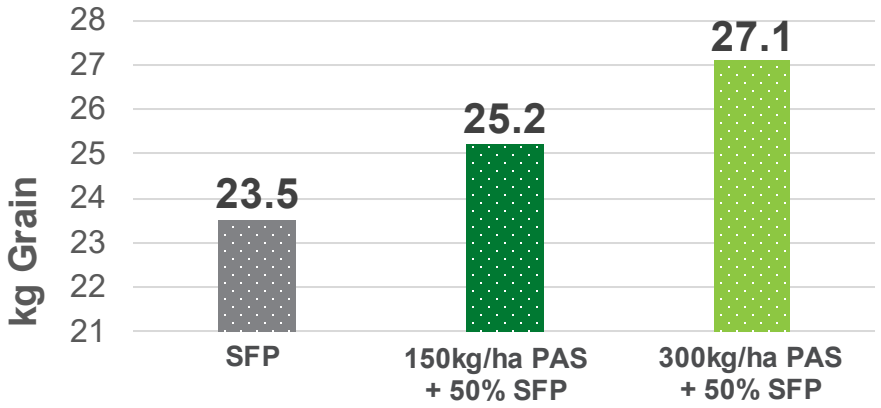




## Nutrient-Use Efficiency

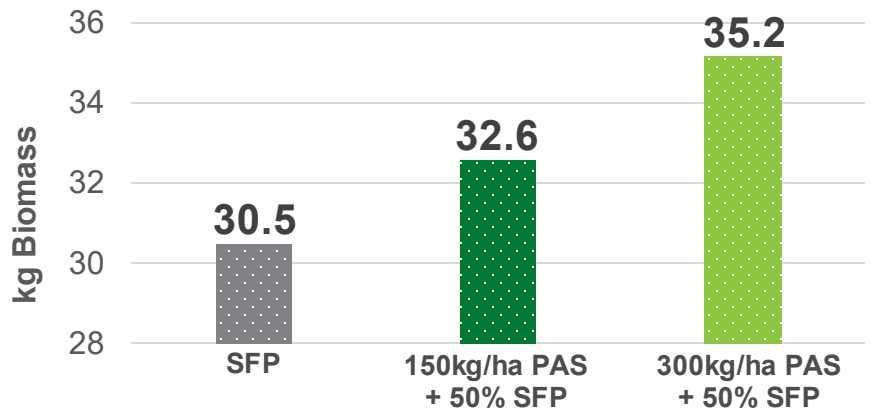
- **Average NPK uptake of 12 Rice trials conducted by universities**
- **Soil type across the 12 trial sites varied from sandy, sandy loams and clay loams.**

# NUE & YIELD increased in Rice when Applied with just 50% Standard Fertiliser Practice (SFP)

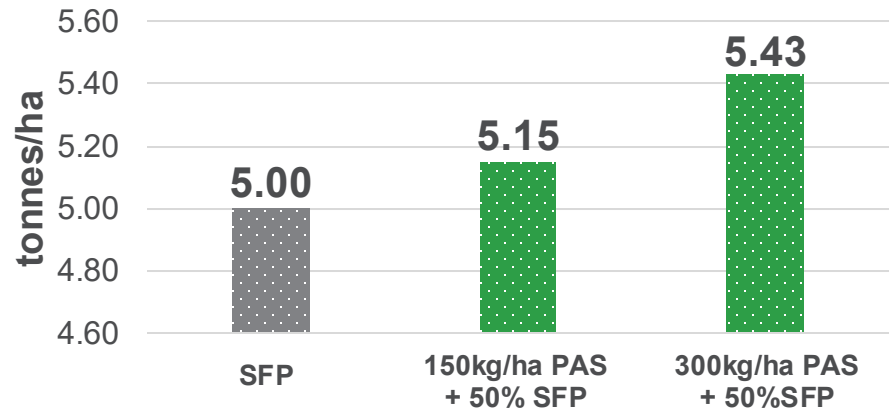
## NUE: kg **Rice Grain** / kg Applied NPK



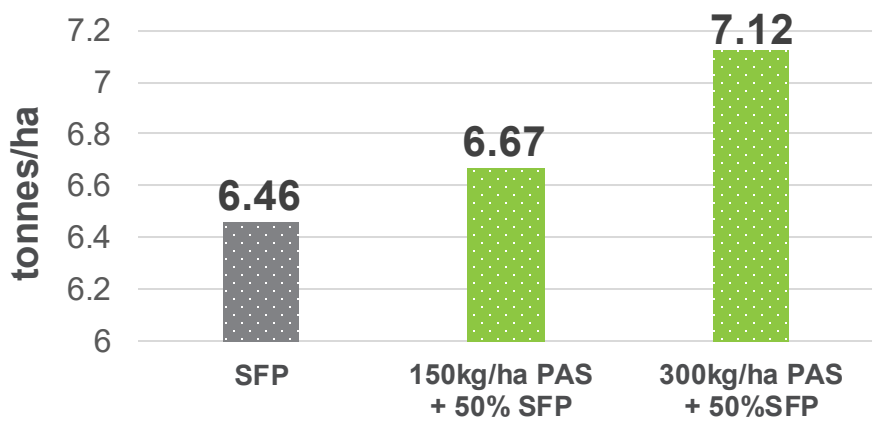

## NUE: kg **Rice Biomass** / kg Applied NPK




## **Rice Grain Yield** (t/ha)




## **Rice Straw Yield** (t/ha)




*Applications of granulated PAS (Si fertiliser).*

***Results show more grain and biomass*** *produced per kilogram of NPK applied.*

*University trials* conclusively showed significant yield* ***increases due to improved fertiliser uptake utilisation within the plant by applying PAS*** *(Si fertiliser) with 50% NPK.*

*Grain yield increased by up to* ***8.6%*** *and straw yields by up to* ***10.2%***



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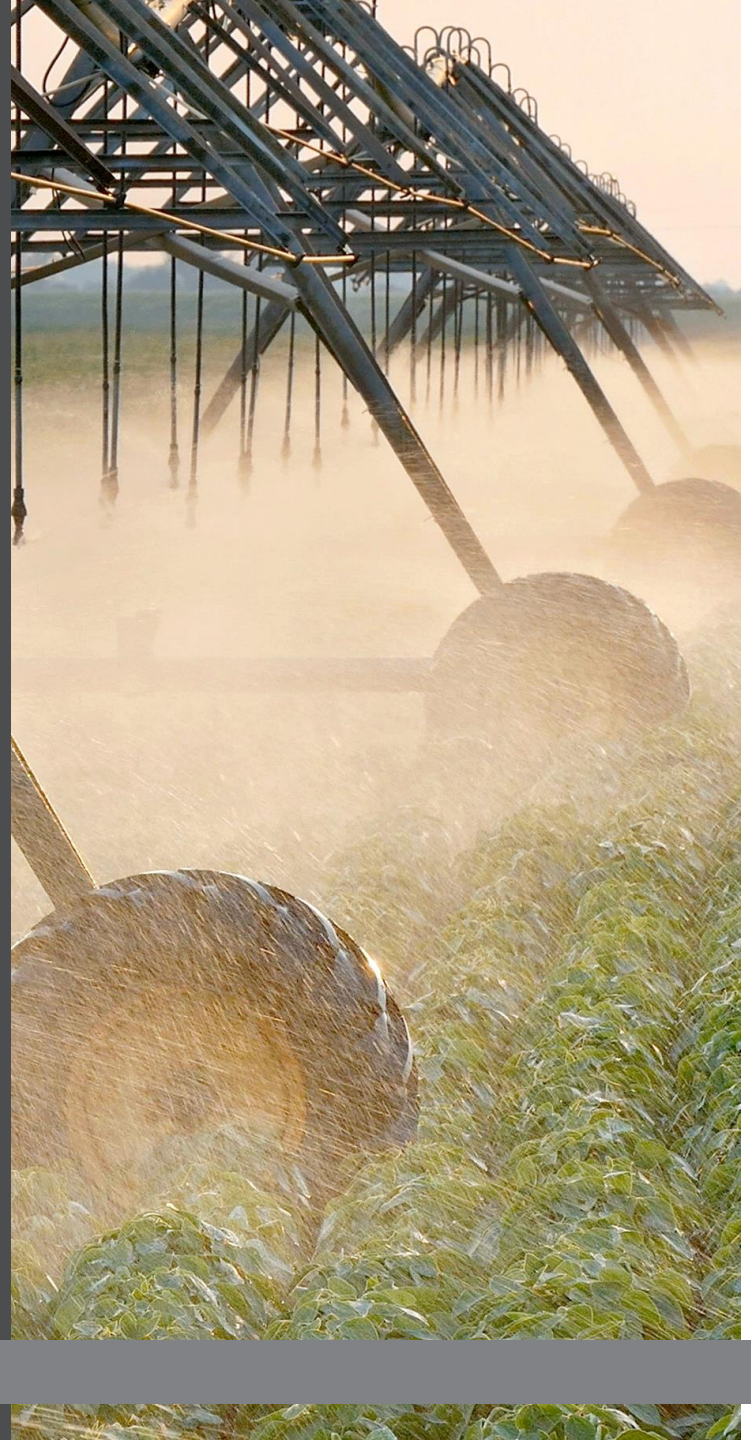
# PAS Increases WUE Water-Use Efficiency



- Reduced crop water loss in drought conditions
- Increased yield per mm of rainfall
- Lowers irrigation usage and costs
- Potential to reduce Methane ($CH_4$) emissions by using less water e.g. growing rice aerobically

# PAS Increases Water-Use Efficiency (WUE)

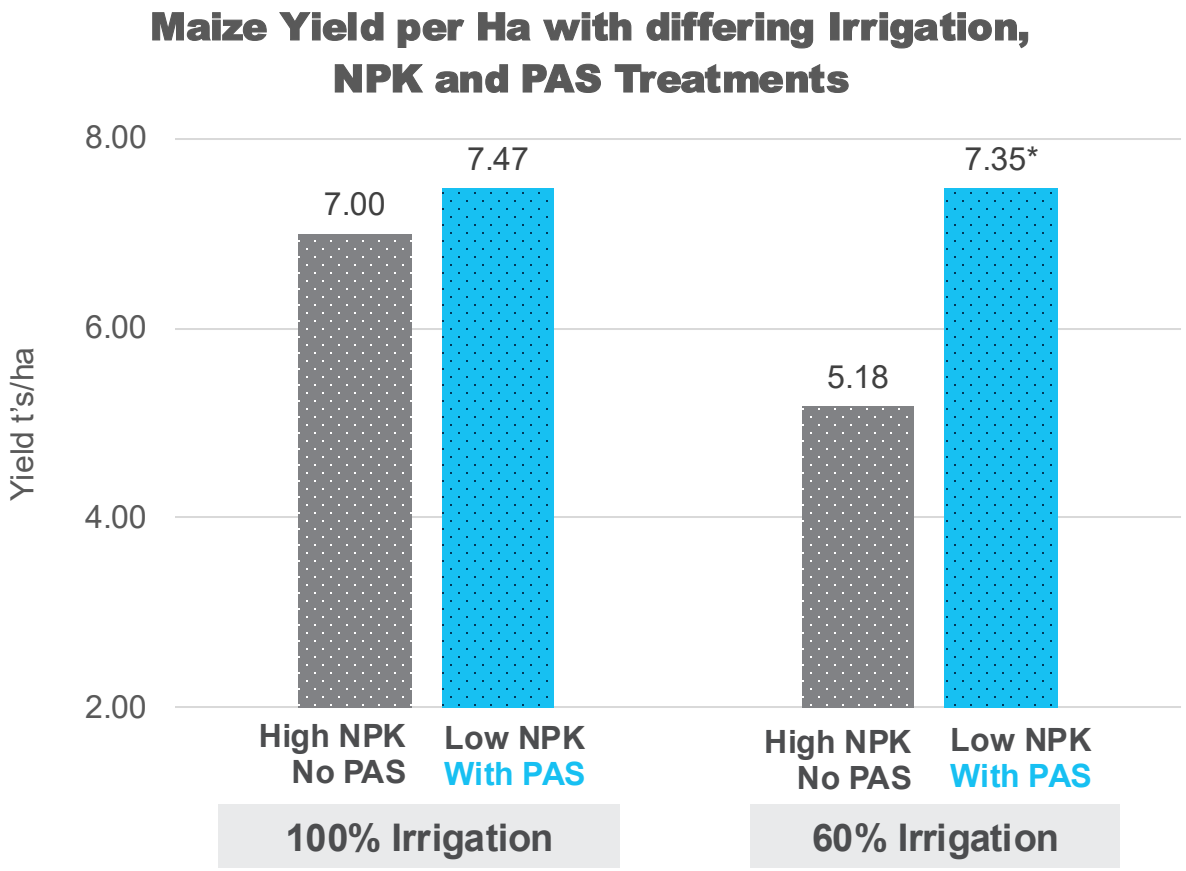
The importance of Plant Available Silicon (**PAS**)

**PAS has been demonstrated to improve crop tolerance to drought and improve WUE (over 60 published reports in the past 10 years).**

## Known Modes of Action Include

- ✓ Silicon fertilisation maintains/increases photosynthesis of plants under drought stress[1]. The result is that the crop is able to produce a higher root:shoot ratio with a proliferation of fine laterals, allowing the exploration of deeper soil strata for water and nutrients.
- ✓ Silicon is deposited in leaf epidermis (apoplast), where it forms a physical barrier reducing water loss through plant stomata and leaf[2]. During drought stress, Si increases the root hydraulic conductance and stomatal conductance but reduces cuticular transpiration, allowing more water into the cell, reducing reactive oxygen species.[3,4]
- ✓ Reduced oxidative damage (by increasing antioxidant enzyme activity) and reduced electrolyte leakage.[5]
- ✓ Altering gene expression[6]


1 Rastogi et al (2021)
2 Thorne et al. (2020)
3 Luyckx et al., (2017)
4 Coskun et al., (2019)
5 Sattar et al., (2019)
6 Shi et al. (2016)




*Significant difference P < 0.05

| | N kg/ha | $P_2O_5$ kg/ha | $K_2O$ kg/ha | PAS kg/ha |
|---|---|---|---|---|
| HIGH NPK / NO PAS | 171 | 68 | 68 | 0 |
| LOW NPK / WITH PAS | 144 | 40 | 56 | 66 |

# PAS Increases WUE Water-Use Efficiency

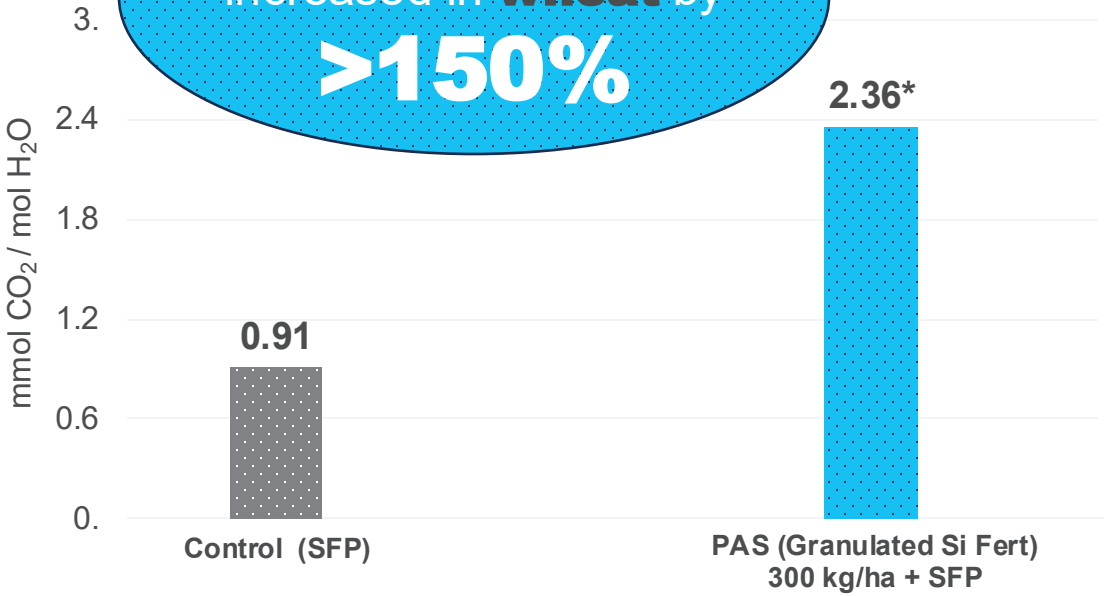
**Application of PAS fertilizer significantly increased yields using less NPK and less water.**

*Field trials have proven:*

- *Improved crop yield with 60% of recommended irrigation rate*
- *Increased yield per litre of applied irrigation*
- *Lower irrigation usage and costs*

At Left: Replicated trial conducted on maize by Universidad De la Rioja, Spain.

**WUE** increased in **wheat** by **>150%**




* Statistically significant difference between PAS treatments and nil PAS treatment P<0.05

Jeer et al 2021. Silicon 13 901-920

Field trial carried out by ICAR National Institute of Stress Management India.

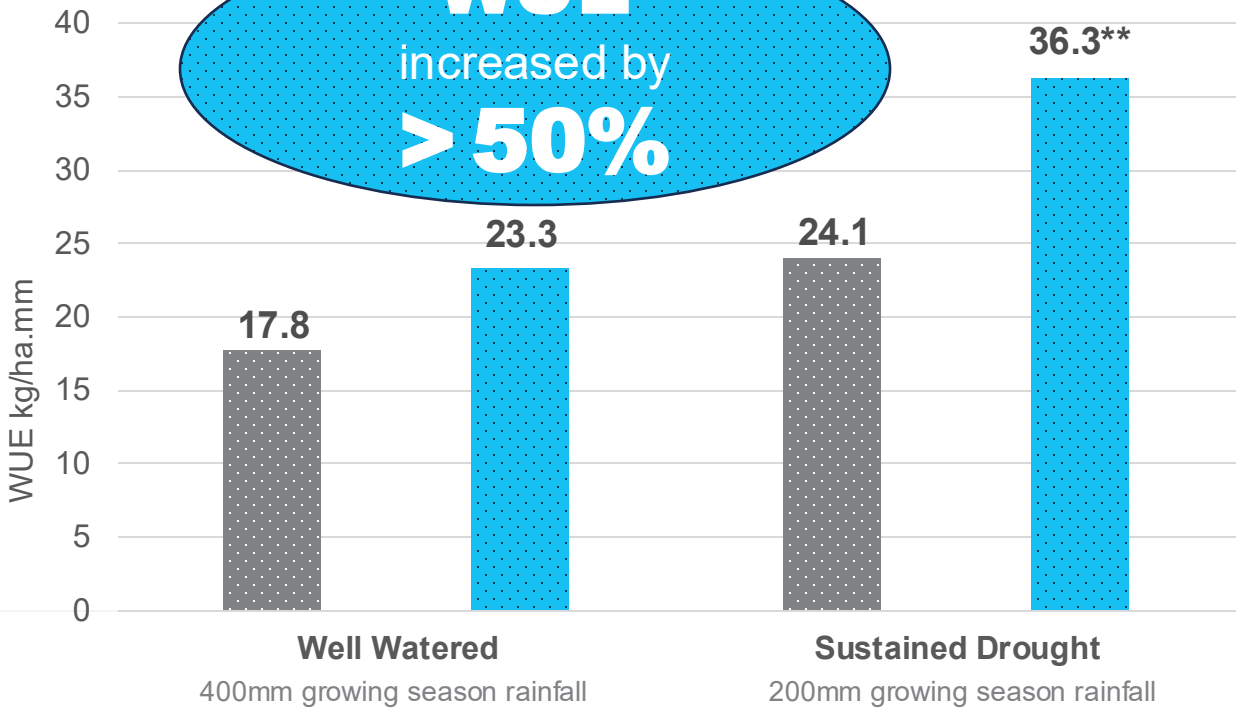
***Improved WUE was due to significantly****

1. ***increased photosynthesis*** ***(+98%)***
2. ***reduced transpiration rate*** ***(-7%)***
3. ***reduced white ear damage*** ***(-45%)***
4. ***and increased yield*** ***(+61%)***

*And…*

***Silicon content in plant stem tissue at harvest significantly**** ***increased*** ***(>160%)***

**WUE** increased by **>50%**




Johnson S.N. et.al. 2022. Western Sydney University Australia

Statistically significant difference between PAS treatments and nil PAS treatment * P<0.05, ** P<0.01

SFP = Standard Fertiliser Practice 80kgN/ha, 50kg$P_2O_5$/ha

Field trials conducted by University of Western Sydney Australia Under Sustained Drought Conditions, using PAS (Si fertiliser).

1. ***WUE significantly increased by up to*** ***51%*** ***(kg grain produced per mm irrigated)***
2. ***Shoot Mass significantly increased by up to*** ***72%***
3. ***Yield significantly increased by up to*** ***49%***



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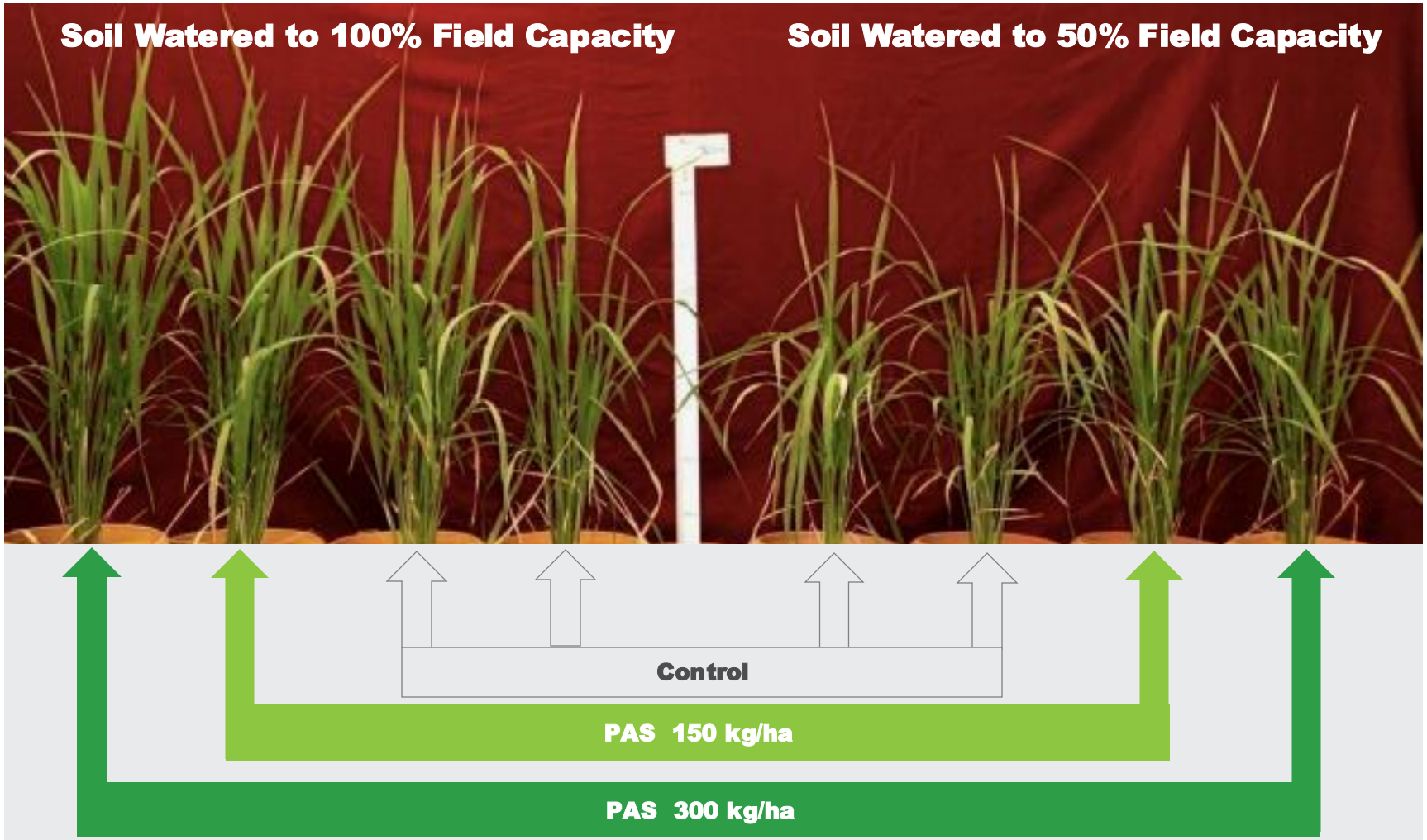
# PAS Increases WUE Water-Use Efficiency

**Replicated Pot Trial on Rice conducted by University of Benagluru, India**




In both 100% and 50% Field Capacity PAS

- increased Leaf Relative Water Content
- Increased Plant height
- Reduced electrolyte leakage
- Reduced Proline (plant stress marker) levels
- Improved WUE

# PAS Increases resilience against crop stress

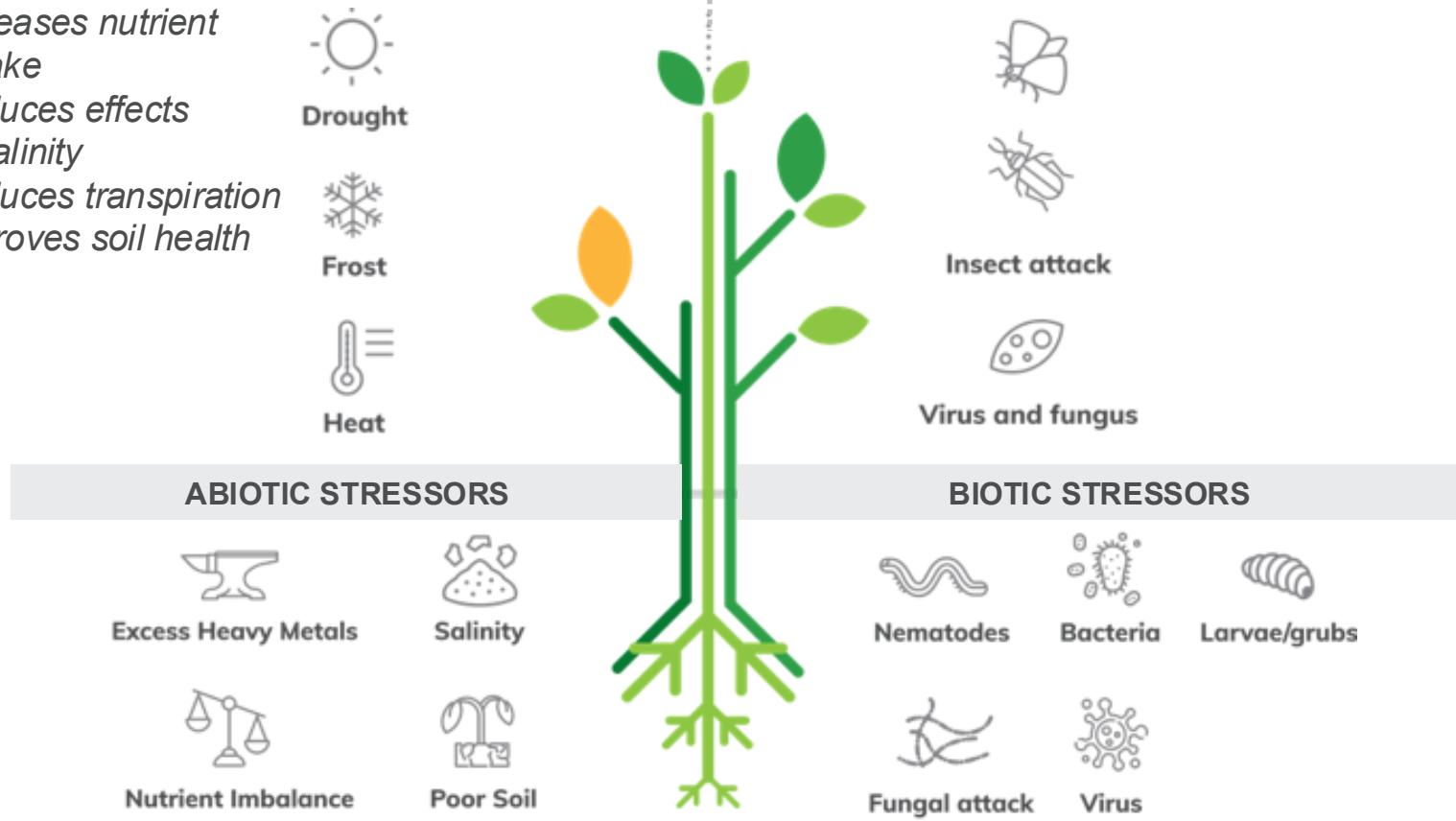
*Up to **82%** of crops are lost annually due to stress, threatening farmers and global food security*

## PAS and Abiotic Stress

- ✓ *Increases photosynthesis*
- ✓ *Increase water use efficiency*
- ✓ *Reduces heavy metal uptake & toxicity*
- ✓ *Increases nutrient assimilation*
- ✓ *Increases nutrient use efficiency*
- ✓ *Increases nutrient uptake*
- ✓ *Reduces effects of salinity*
- ✓ *Reduces transpiration*
- ✓ *Improves soil health*

## PAS and Biotic Stress

- ✓ *Primes plants defence mechanisms*
- ✓ *Increases cell wall strength*
- ✓ *Improves crop resilience to insect pests*
- ✓ *Improves crop resilience to fungal disease*



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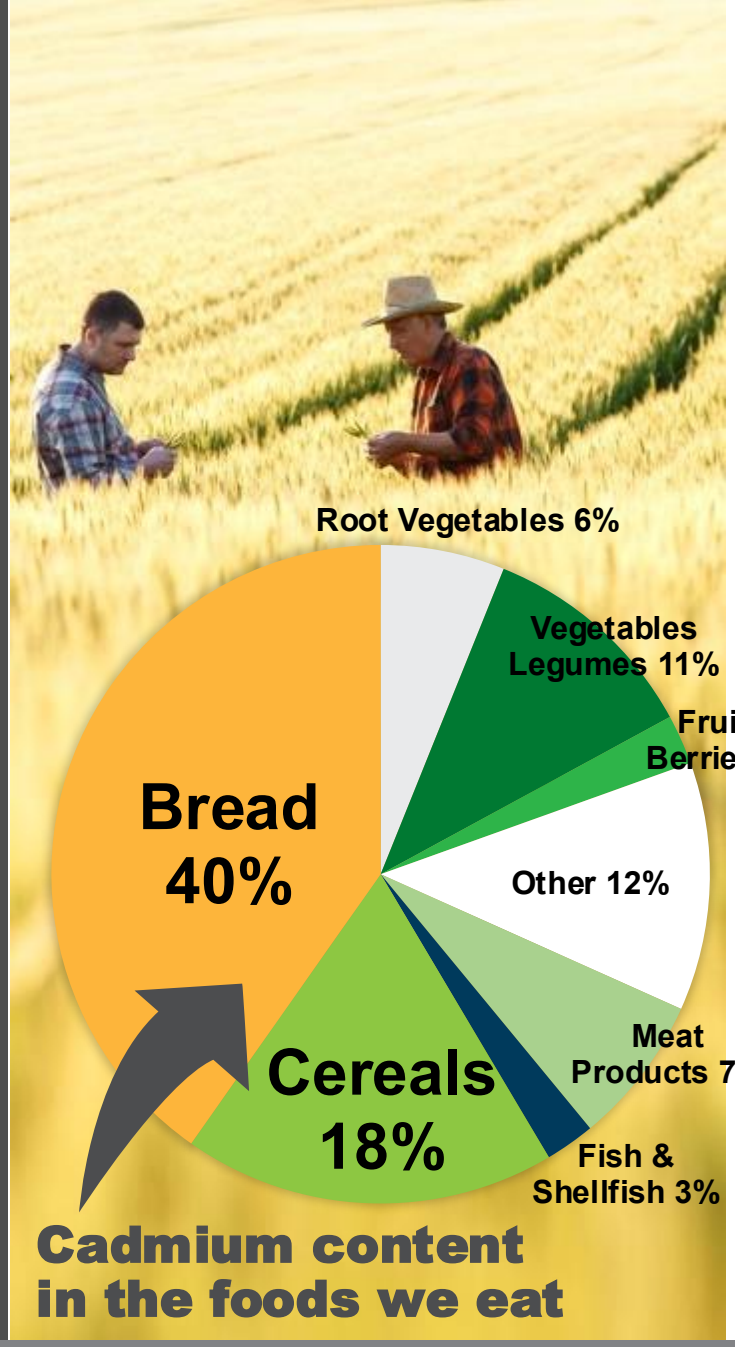
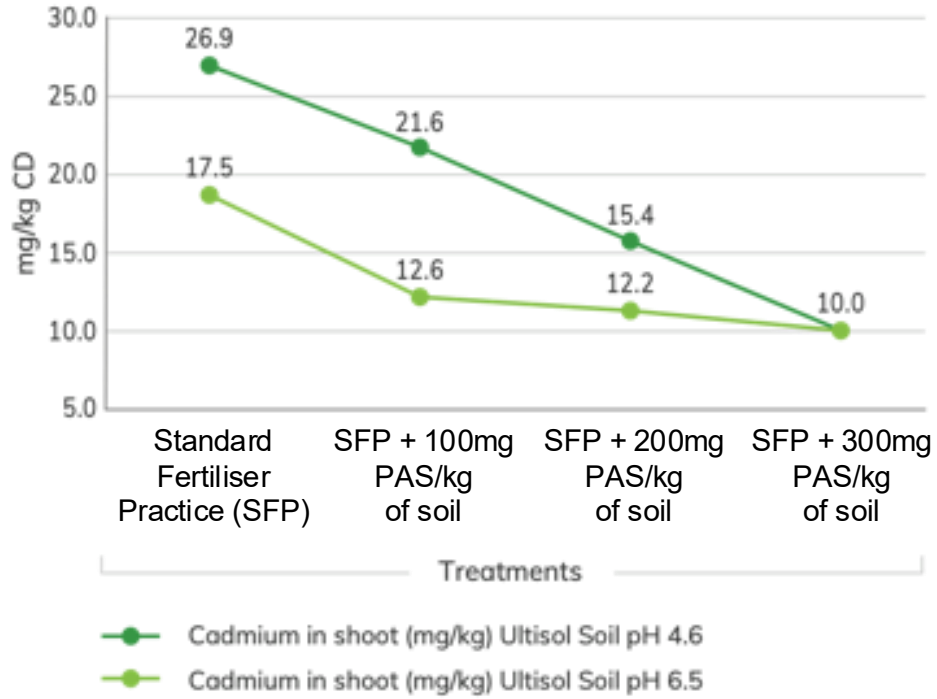
# PAS Reduces Heavy Metal Uptake by Crops

*Cadmium & Arsenic accumulation in the edible plant parts reduced by up to*

**40%**




## Cadmium concentration in Maize shoots declined in two different soil PH's with increasing rates of PAS (Si fertilizer)




- *Introduction of the strict limit of 20mg Cd/kg $P_2O_5$ may cause serious supply disruptions to EU*
- *Bioaccumulation of cadmium (Cd) in agricultural soils constitutes a dangerous risk for the health of both the environment and humans.*
- *Reducing Cadmium uptake in crops destined for human consumption either directly or via animal products (diary, meat) means less heavy metal toxicity (abiotic stress) in crops and safer foods in the human food chain.*



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# PAS Increases Crop Resilience to Pests & Pathogens

**Stalk borer damage in Brazil sugarcane reduced by**

**57%***

**White ear damage in wheat reduced**

**45%****

**Fungal blast in rice reduced by**

**18%*****

*Olivia K.M.E. et.al. 2021. Trial Conducted on a large Brazilian Sugarcane Farm in Paraiba State

**Jeer et al 2021.

***Professor Rodrigues F.A 2018. Federal University of Vicosa, Minas, Brazil

# PAS reduces emissions $N_2O$ & $CH_4$

**ALSO…**

**PAS has ZERO emissions in its application and use and a very LOW CARBON FOOTPRINT…**

Just 0.18t $CO_2$ / tonne versus up to 30.00t CO2e / tonne of traditional fertilisers

- **In Rice:** Improved Nitrogen use by altering the primary metabolism with remobilization of amino acids to grains and hence increased crop yield[1] and reduced $N_2O$ emissions
- **In Rice:** Physiologically promotes ammonium assimilation and restrains the increase in water soluble nitrogen compounds, including amino acids and amid, decreasing losses through run off[2]
- **In Legumes:** Improves nodulation with subsequent increases in nitrogen fixation[3,4] increasing soil nitrogen levels and reducing N fertiliser applications
- **In Barley:** The application of monosilicic acid to brown soil during barley growing and flooding has a significant influence on the nitrogen emission and can change the $N_2O$:$N_2$ ratio[5]

*1.Detmann et al. 2012, 2.Takahashi 1996, 3.Mali and Aery et al. 2008; 4.Putra et al 2022; 5.Wlodarczyk et al. 685 (2019).*

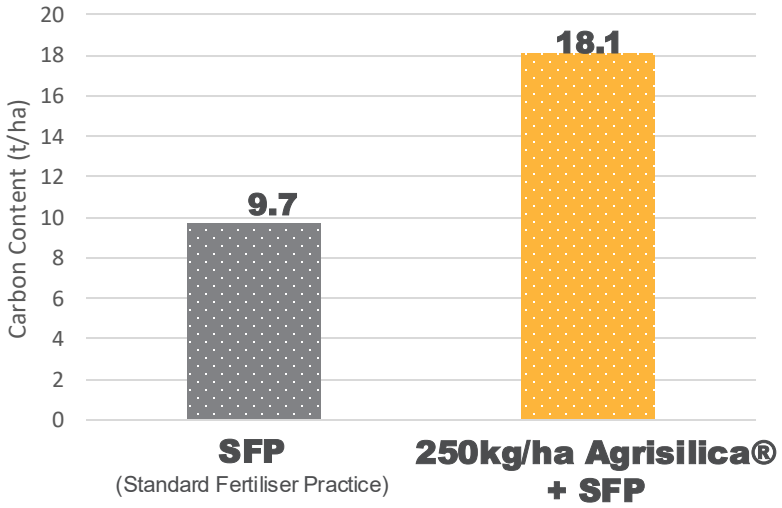
# PAS proven to increase Carbon Sequestration

**Biomass Carbon Content Increased by**

## 86% in Sugarcane in Brazil

Aug 2022 – Oct 2023 | Trial in Pernambuco State by Universidad Federal Rural de Pernambuco Brazil and Trapiche Sugar Mill Agronomists.

- **Carbon content in sugar cane increased from 9.7 tonnes to 18.1 tonnes/hectare.**
- **Total sugarcane yield increased from 72.1t/ha to 133.8 t/ha**



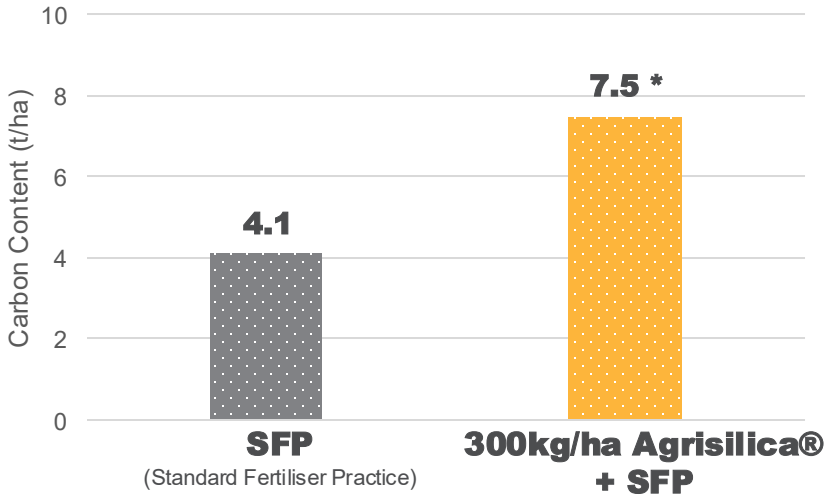

**Biomass Carbon Content In Drought Conditions Increased by**

## 83% in Wheat in Australia

Scientific trials conducted by Western Sydney University proved that **under both well-watered and droughted conditions with granulated silicon fertiliser Carbon sequestration was significantly increased.**

* Indicates significance P<0.001

See paper:
https://doi.org/10.3389/fpls.2022.1030620



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# Fertilizer Manufacturer Benefits of Co-Blending Granular Silicon Fertilisers with NPK etc

- Increased farmer satisfaction due to results
- Significant increase in profit
- Extremely low carbon footprint
- Become price setter via product differentiation
- Grow market share
- Grow environmental and climate change credentials
- Grow brand value
- Grow triple bottom line results

- Broadacre crops
- Horticulture crops
- Sugar Cane
- Tree Crops
- Nurseries
- Viticulture
- Organic
- Biodynamic
- Turf production
- Sporting fields
- Golf courses
- Parks and gardens

*To enquire further about Plant Available Silicon and its agricultural benefits, contact:*

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