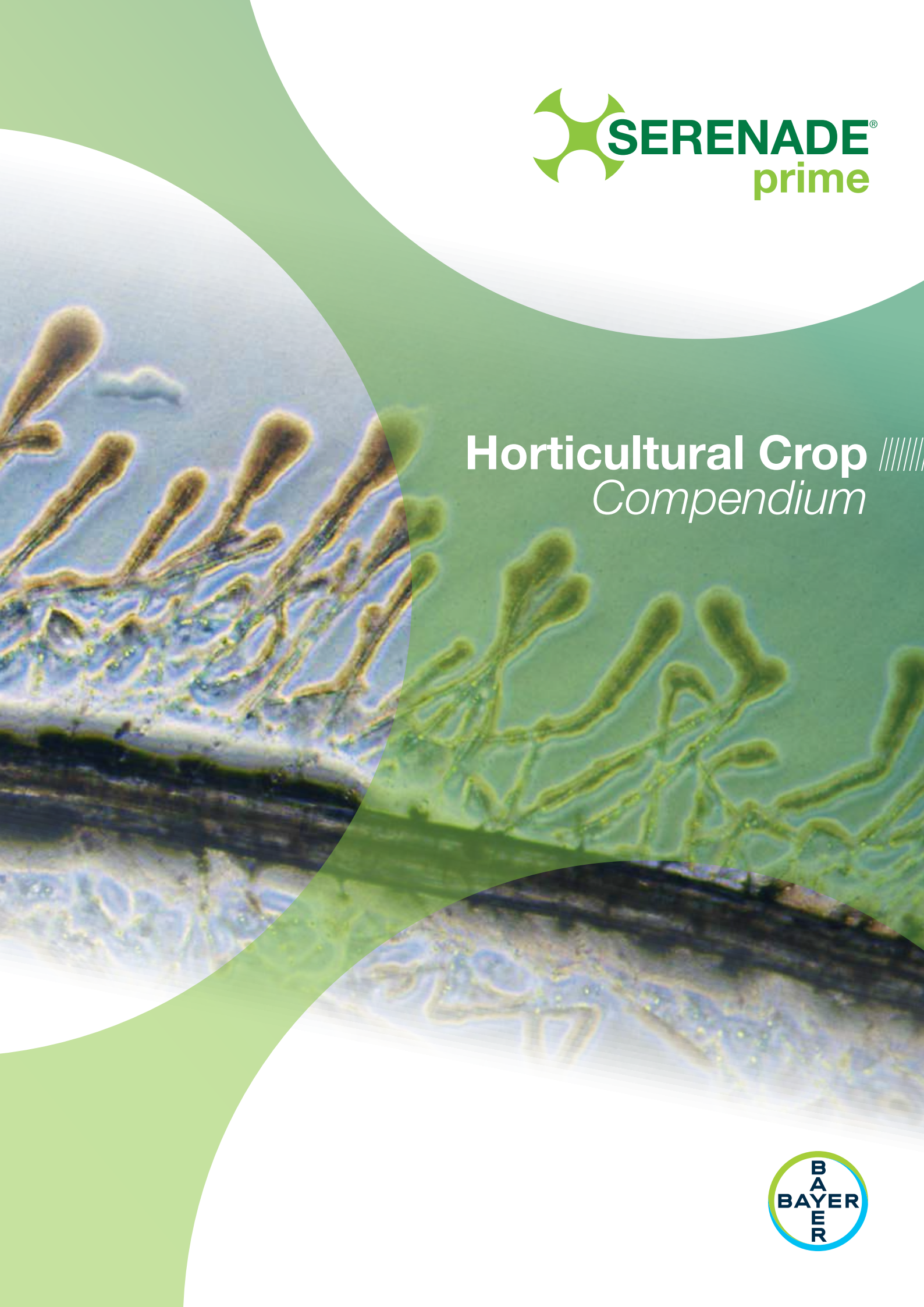




# Horticultural Crop *Compendium* //







*This compendium details the increased plant-accessible nutrient availability and uptake where Serenade® Prime has been used as a soil ameliorant across a range of horticultural crops. Nutrient uptake, root architecture and colonisation (qPCR) studies were performed under replicated glasshouse conditions by Bayer Biologics Division, West Sacramento, California.*

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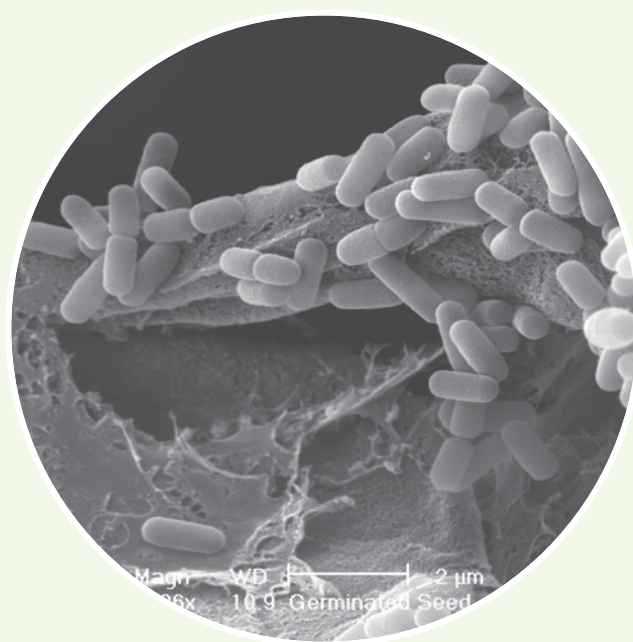


# Serenade Prime

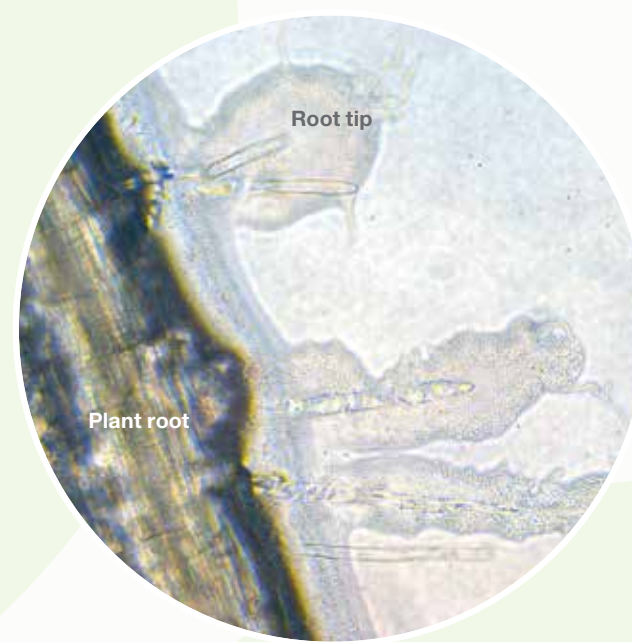
Serenade<sup>®</sup> Prime contains spores of *Bacillus amyloliquefaciens* (strain QST 713). This beneficial bacteria was selected amongst thousands of strains for its excellent root colonisation ability. The bacteria was formulated into a stable liquid suspension to allow convenient on-farm application. It's proven to frequently improve size and quality at harvest in a wide range of horticultural crops in diverse soils and climates around the world.

## Root colonisation

Serenade Prime starts to colonise the plant root surfaces within hours of application. This process is triggered by the release of exudates, sugars, from the roots. The QST 713 bacterium utilises these exudates as food to grow and multiply, building a dense film around the roots, which symbiotically acts to modify soil nutrients, to make them more available to the plant. Serenade Prime acts as a bridge between the roots and the soil to both improve nutrient availability (form) and uptake, allowing a supply of plant-available nutrients ahead of critical periods of crop demand.



Serenade Prime spores rapidly colonise roots



Serenade Prime builds a dense film around root tips



Serenade Prime builds a supply of plant-available nutrients



## Nutrient Uptake

Serenade Prime has the ability to increase soil nutrient availability, boosting plant nutrient uptake and growth. For instance, when iron is limited in the soil, the QST 713 bacteria secrete siderophores, which chelate iron into plant usable forms.

When phosphorus is ‘fixed’ as either calcium, iron or aluminium phosphate, or other compounds, it can release organic acids which mobilise the phosphorous into a plant-available form. It has been shown to significantly increase (+28%) phosphorus uptake compared to other beneficial *Bacillus amyloliquefaciens* strains under typical phosphorous programs used in intensive cropping (Figure 1).

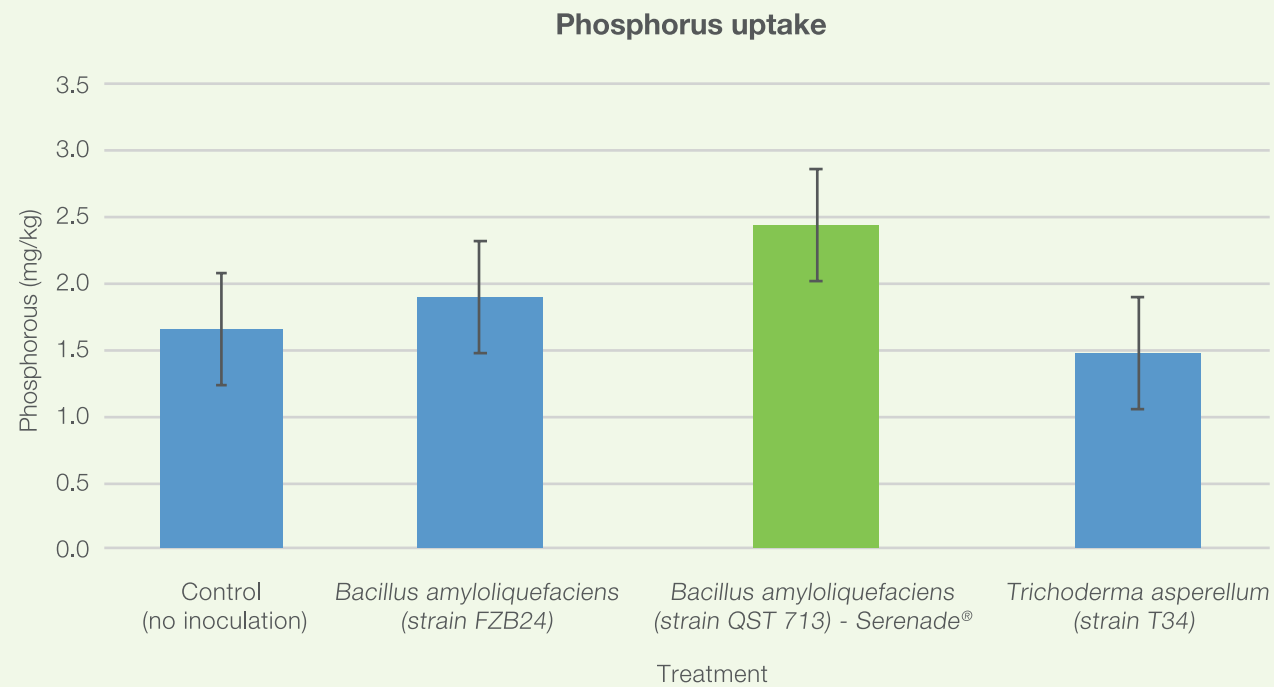


Figure 1. Effect of different microorganisms on phosphorous uptake in cucumber (Garcia-lopez, A., et al. 2016).

## Root Architecture

Serenade Prime improves the soil root interface which has a positive effect on nutrient uptake. This increased access to nutrients results in plants developing a more comprehensive root structure with which to harvest the available nutrients. Improvements in root architecture are especially important for immobile nutrients, like phosphorous, zinc, iron and manganese, which are absorbed in very close proximity to the root surface. These nutrients are often isolated away from the roots (Figure 2).

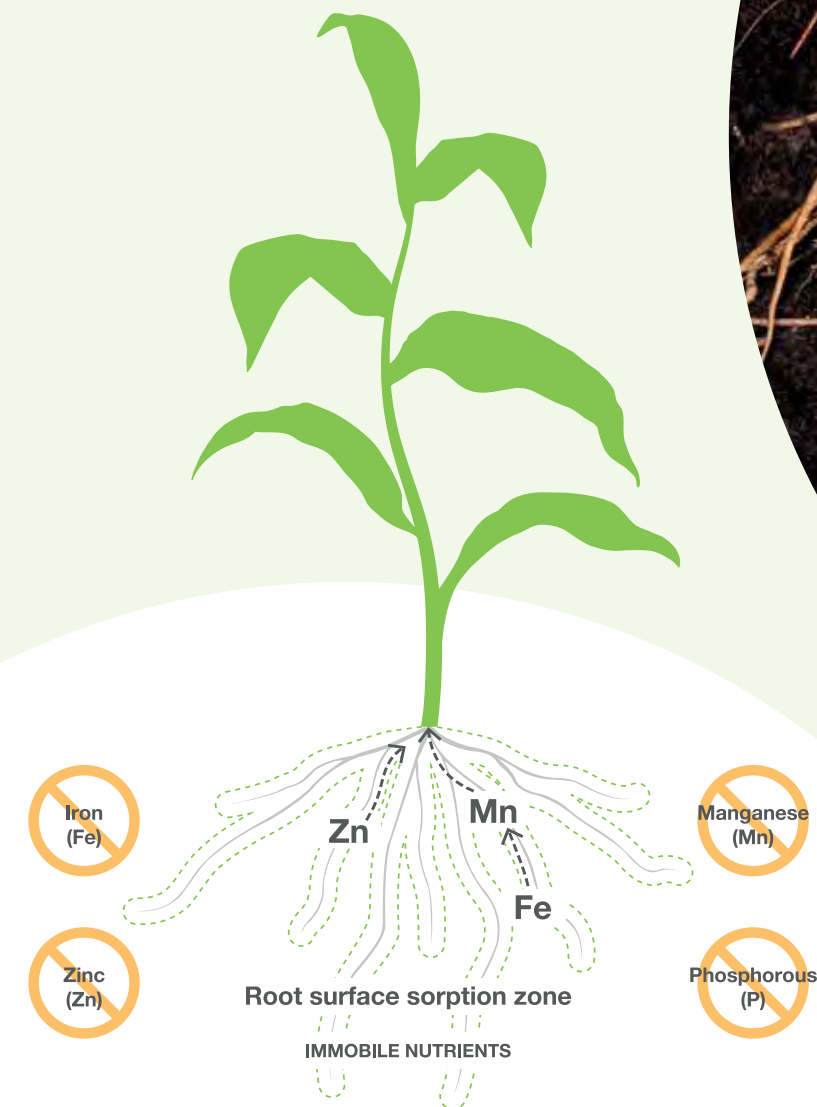


Figure 2. Root growth and pattern (fineness, depth) greatly influence uptake of immobile nutrients. Figure adapted from Brown, P. n.d.





# Almond

+80% leaf surface area

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of almond var. *Hansen*. It improved uptake of nitrogen (+107%), iron (+64%) and boron (+108%) when applied as a soil drench at 35 mL/plant at transplanting (Figure 3). DNA analysis (qPCR) confirmed successful colonisation at 3 months after application.



Nutrient uptake (mg/plant)

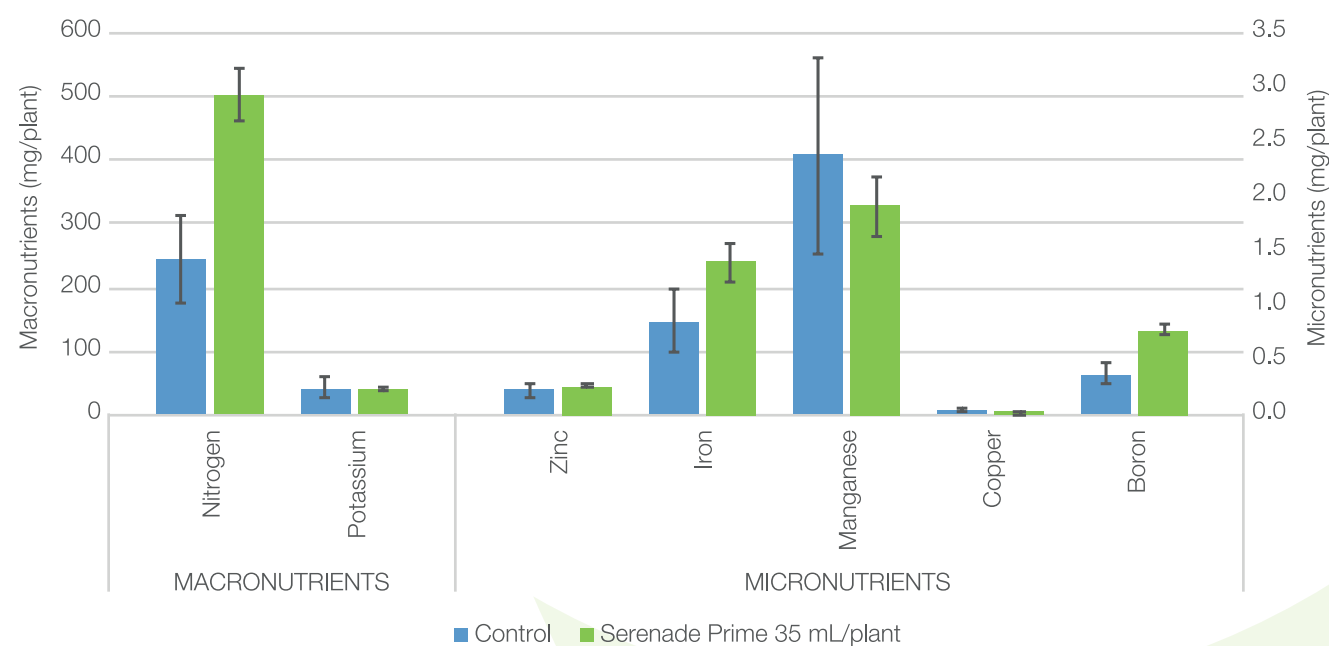


Figure 3. Nutrient uptake (mg/kg) in almonds. Nutrient uptake (mg/kg) = leaf analysis (mg) x dry plant weight (g). A total of 15 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved the nutrient uptake and increased root growth of almonds when analysed using root-scanning software, WinRHIZO, at 3 months after application. It resulted in an increased root surface area (+24%) and root length (+16%) (Figure 4).

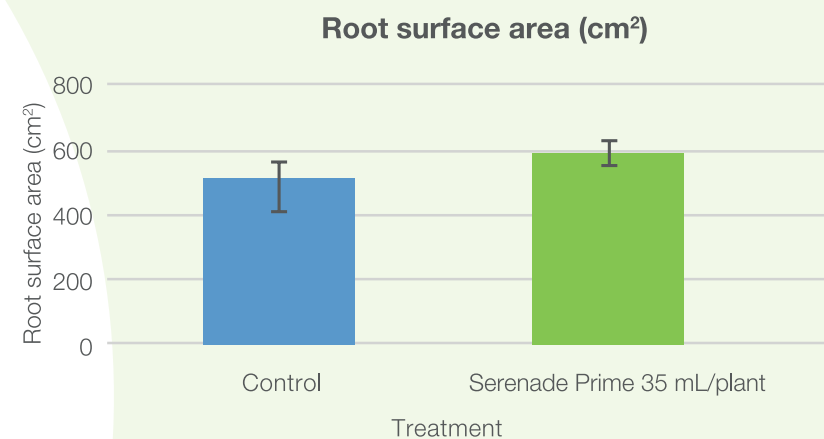
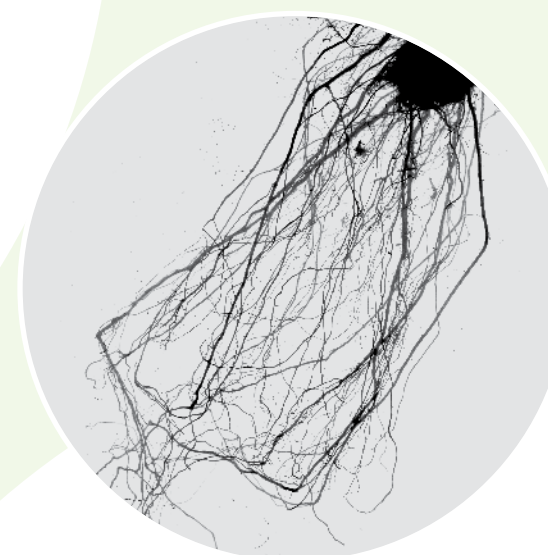
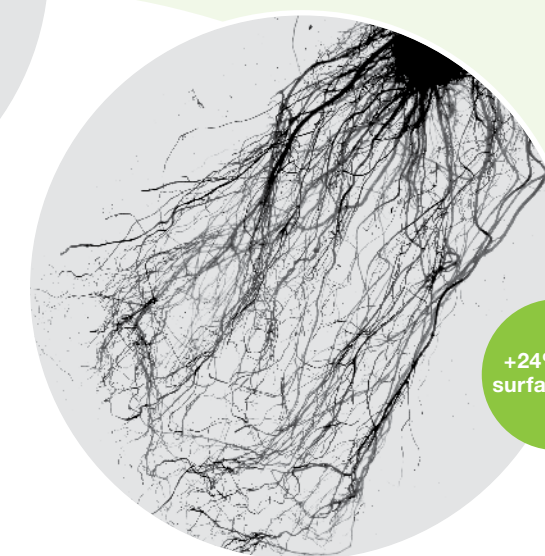


Figure 4. Root surface area (cm²) in almond at 3 months after application.



Control



+24% root surface area

Serenade Prime 35 mL/plant



# Avocado

+39% leaf surface area

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of avocado var. *Zutano*. It improved the uptake of calcium (+28%), zinc (+42%) and iron (+43%) when applied as a soil drench at 35 mL/plant at transplanting (Figure 5). DNA analysis (qPCR) confirmed successful colonisation at 3 months after application.

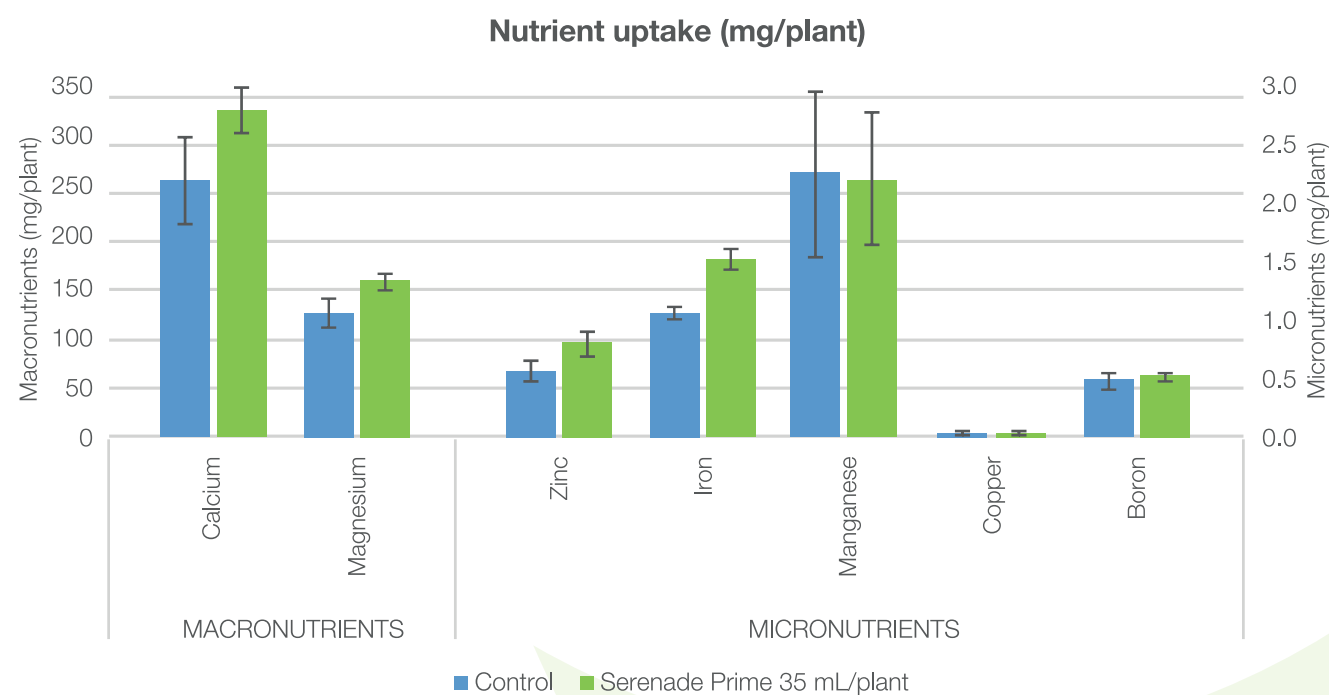


Figure 5. Nutrient uptake (mg/plant) in avocados. Nutrient uptake (mg/plant) = leaf analysis (mg) x dry plant weight (g). A total of 12 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved nutrient uptake and increased root growth of avocados when analysed using root-scanning software, WinRHIZO, at 3 months after application (Figure 6). It resulted in an increased number of new root tips (+23%). This improvement in root architecture resulted in improved calcium and immobile soil nutrient uptake.

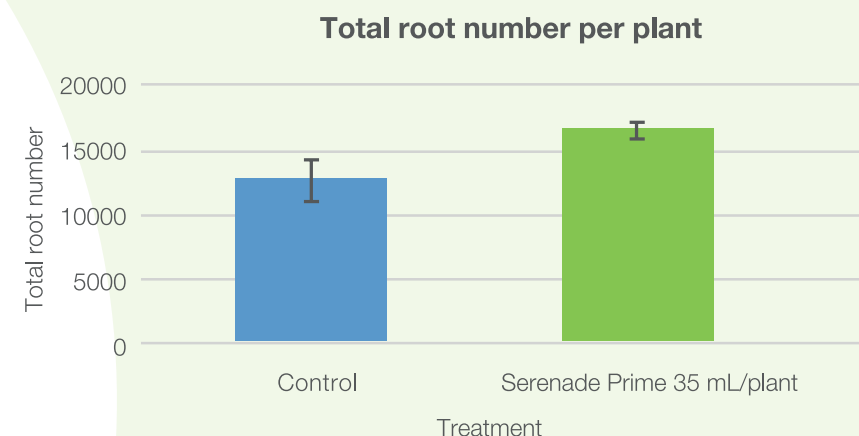
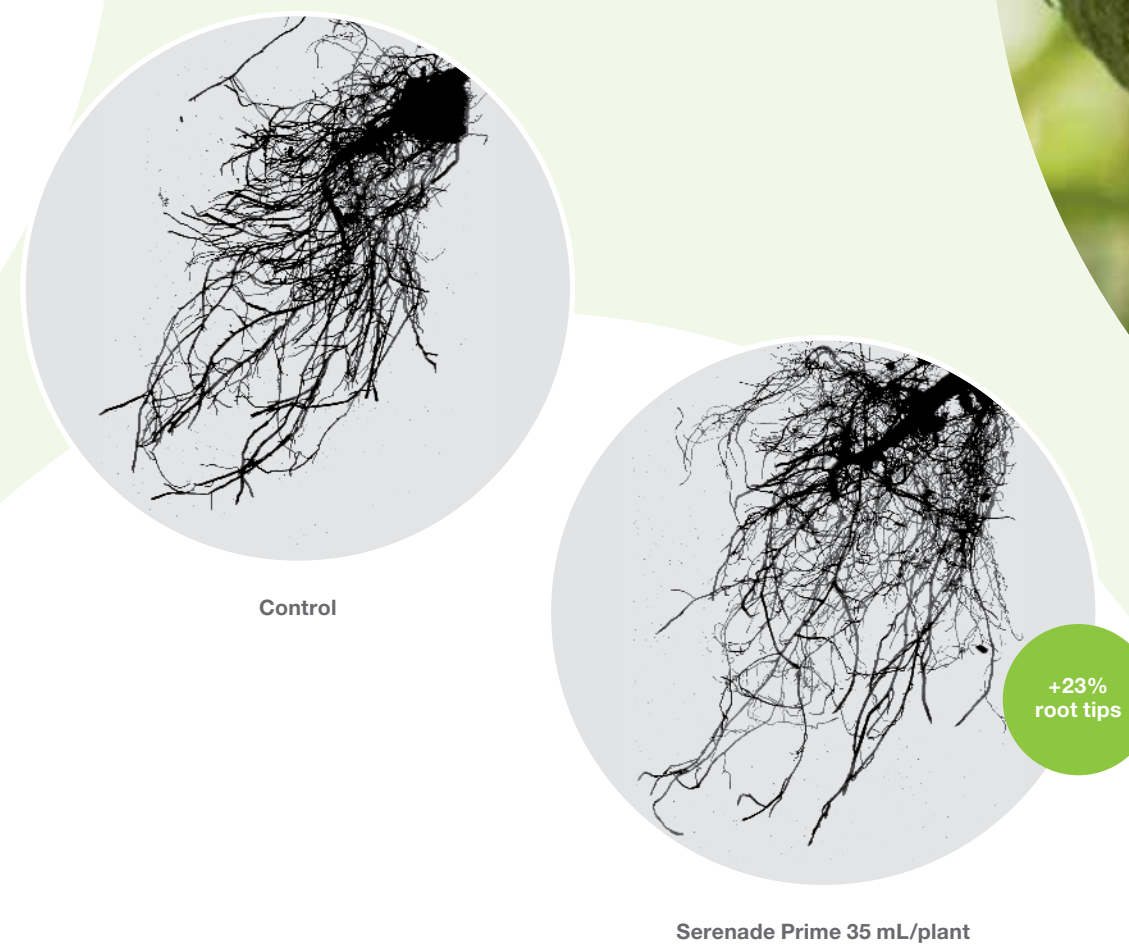


Figure 6. Total root number per plant in avocados at 3 months after application.



+23% root tips



# Banana

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of bananas var. *Dwarf Cavendish*. It improved the uptake of calcium (+12%) and boron (+20%) when applied as a soil drench at 10 L/ha at transplanting (Figure 7). DNA analysis (qPCR) confirmed successful colonisation at 22 days after application.



Nutrient uptake (mg/plant)

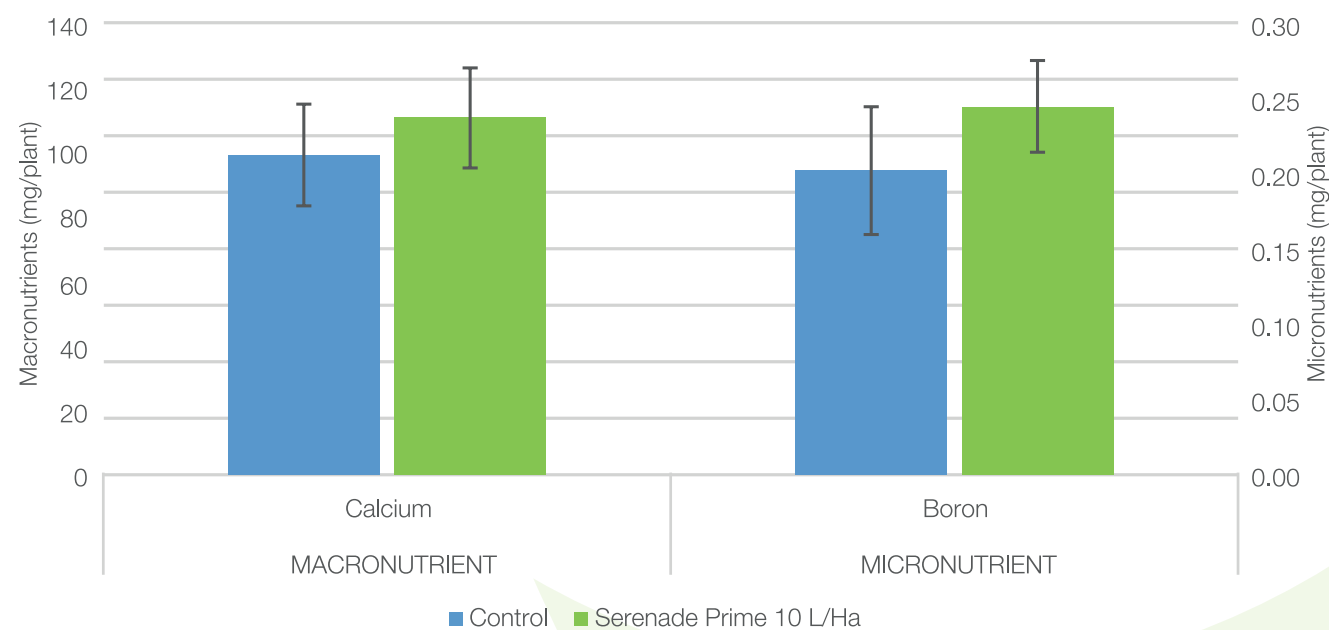


Figure 7. Nutrient uptake (mg/plant) in bananas. Nutrient uptake (mg/plant) = leaf analysis (mg) x dry plant weight (g). A total of 12 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved the root growth of bananas when analysed using root-scanning software, WinRHIZO, at 22 days after application. Applied at 10 L/ha, it increased the root surface area (+34%) (Figure 8).

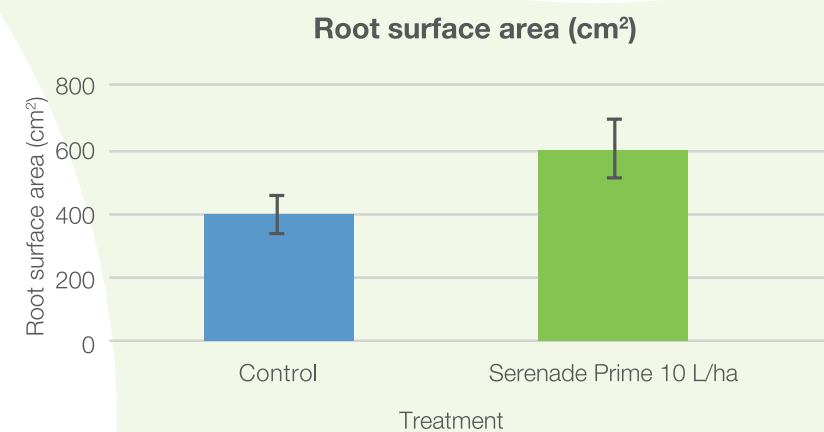


Figure 8. Root surface area in banana at 22 days after application.



Control



Serenade Prime 10 L/ha

+34% root surface area





# Blueberry

## Nutrient Uptake

Serenade Prime improved the growth of blueberry var. *Summer Sunset*. It was applied as a soil drench at either 2 or 5 mL/plant and measured at 3 months after application. The greatest increase resulted from application at 5 mL/plant, which increased the leaf surface area (+47%) compared to the control plants (Figure 9).



Figure 9. Leaf canopy area in blueberries\*

\* Tissue analysis was not performed in this trial. Visual observations suggest the control plants were showing symptoms of phosphorous deficiency.

## Root Architecture

Serenade Prime application resulted in improved root growth of blueberries when analysed using root-scanning software, WinRHIZO, at 3 months after application. Applied at 5 mL/plant, it increased the root surface area (+126%) (Figure 10).

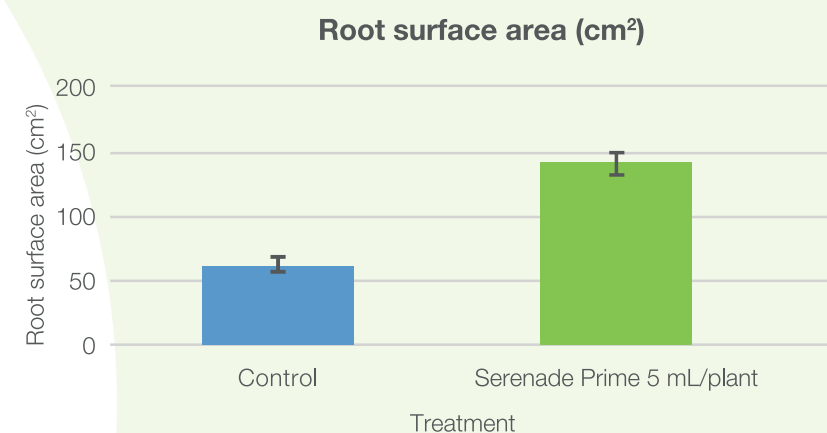


Figure 10. Root surface area (cm<sup>2</sup>) in blueberries at 3 months after application.



+126% root surface area



# Citrus

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of citrus var. *Clementine*. It improved uptake of calcium (+73%), manganese (+46%), iron (+30%) and boron (+54%) when applied as a soil drench at 10 L/ha at transplanting (Figure 11). DNA analysis (qPCR) confirmed successful colonisation at 3 months after application.



Nutrient uptake (mg/plant)

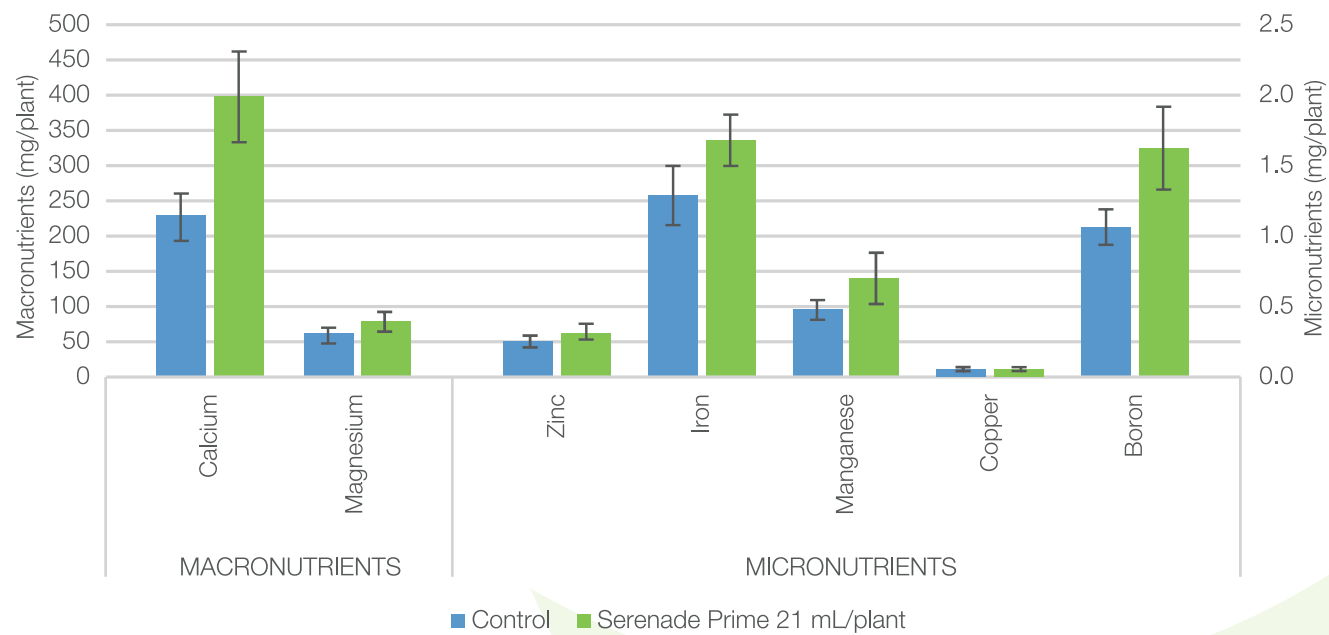


Figure 11. Nutrient uptake (mg/plant) in citrus. Nutrient uptake (mg/kg) = leaf analysis (mg) x dry plant weight (g). A total of 8 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved nutrient uptake, resulting in increased root growth of citrus when analysed using root-scanning software, WinRHIZO, at 3 months after application. It resulted in an increased root surface area (+42%) (Figure 12). This improvement in root architecture assisted in an increase in calcium and immobile soil nutrient uptake.

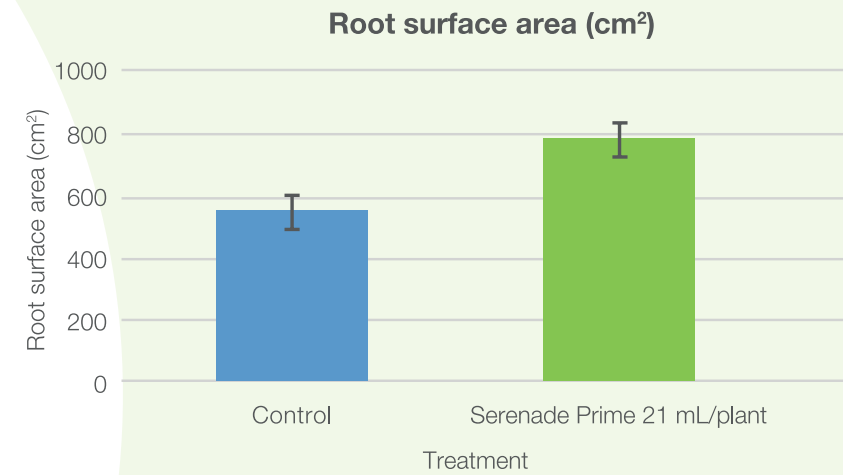
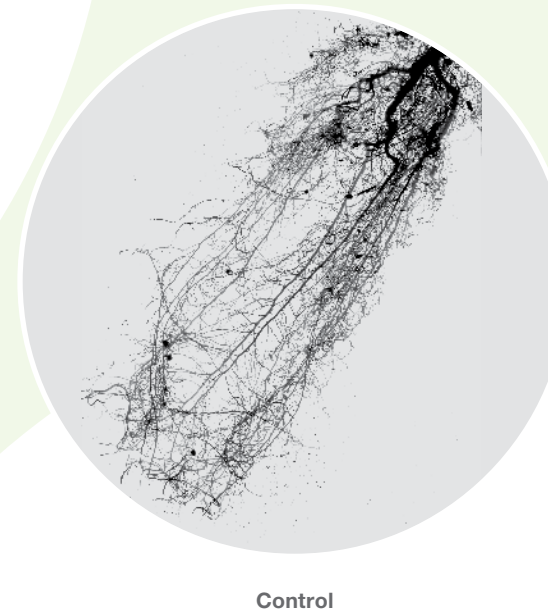
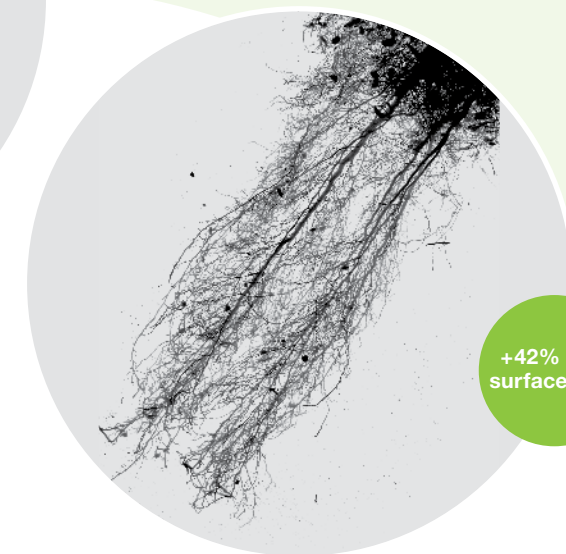


Figure 12. Root surface area (cm²) and root length (cm) architecture in citrus 3 months after application.



Control



Serenade Prime 21 mL/plant

+42% root surface area



# Grape

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of grapes var. *Cabernet Sauvignon*. It improved the uptake of calcium (+13%), magnesium (+15%), iron (+30%) and boron (+9%) when applied as a soil drench at 5 mL/plant at transplanting (Figure 13). DNA analysis (qPCR) confirmed successful colonisation at 3 months after application.

+13% leaf surface area

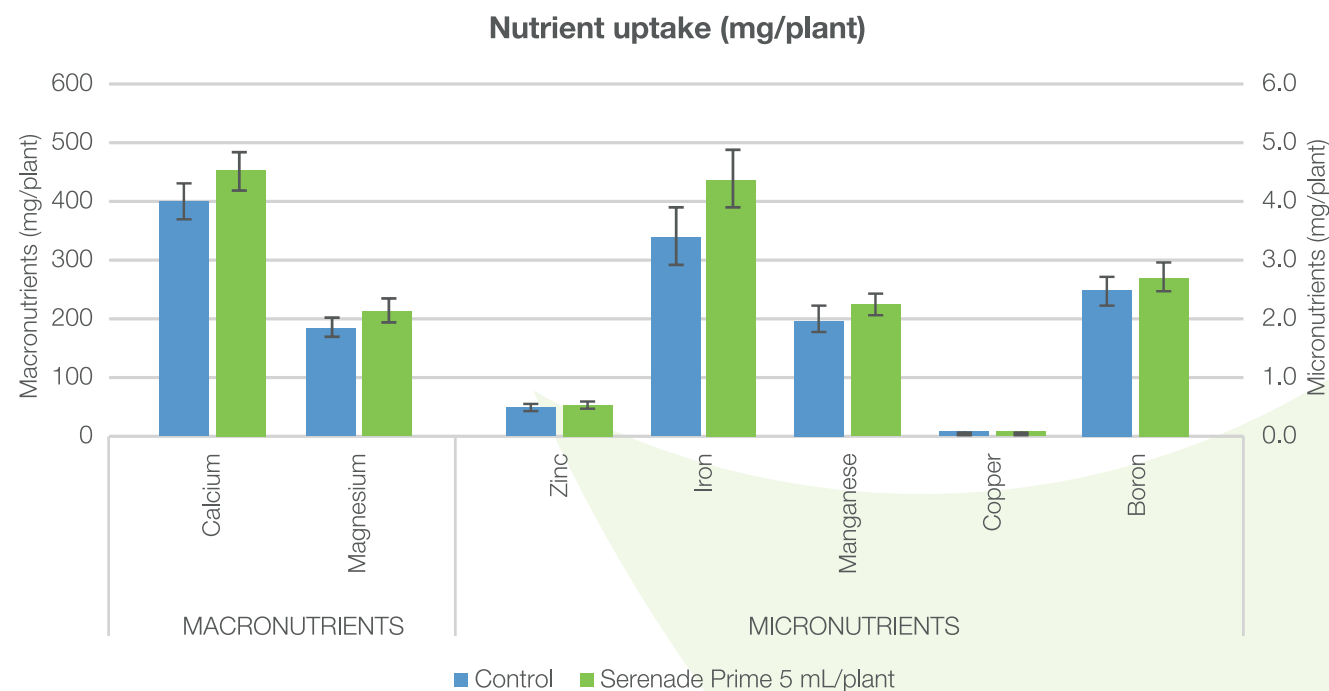
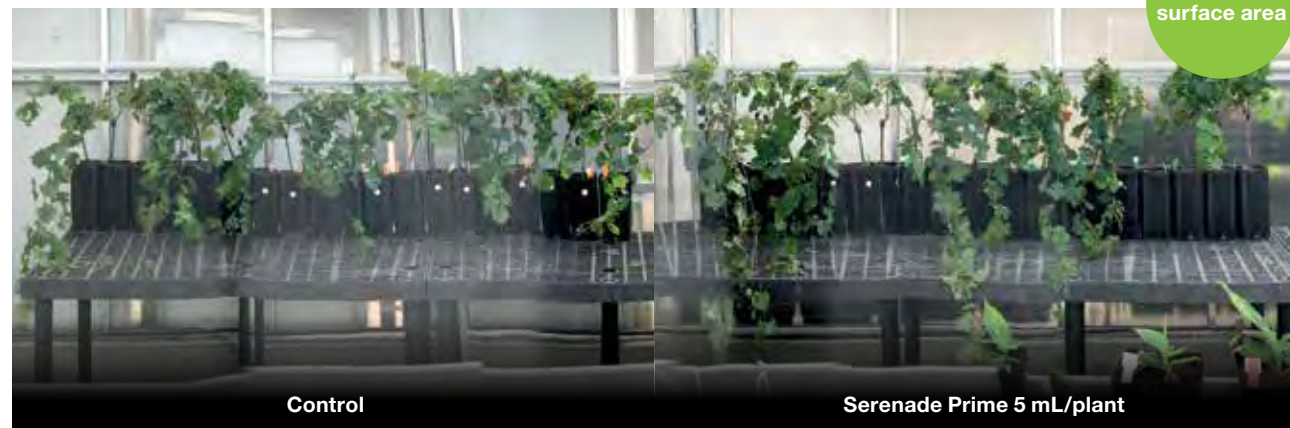


Figure 13. Nutrient uptake (mg/plant) in grapes. Nutrient uptake (mg/plant) = leaf analysis (mg) x dry plant weight (g). A total of 20 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved nutrient uptake and increased root growth of grapes when analysed using root-scanning software, WinRHIZO, at 3 months after application. It resulted in an increased root surface area (+30%) (Figure 14). This improvement in root architecture assisted in increasing calcium and immobile soil nutrient uptake.

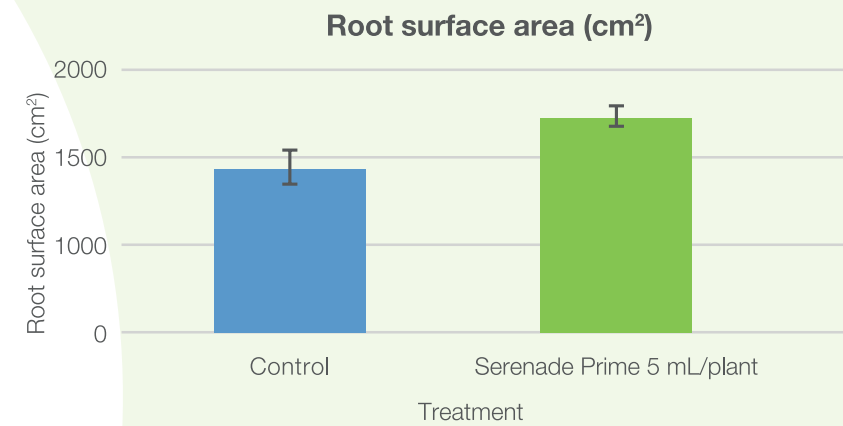


Figure 14. Root surface area (cm²) in grapes at 3 months after application.



Control



+30% root surface area

Serenade Prime 5 mL/plant





# Carrot

## Nutrient Uptake

Serenade Prime improved the growth of carrots var. Yaya. It improved uptake of calcium (+72%), iron (+58%), manganese (+42%) and boron (+64%) when applied at 10 L/ha at planting (Figure 15).

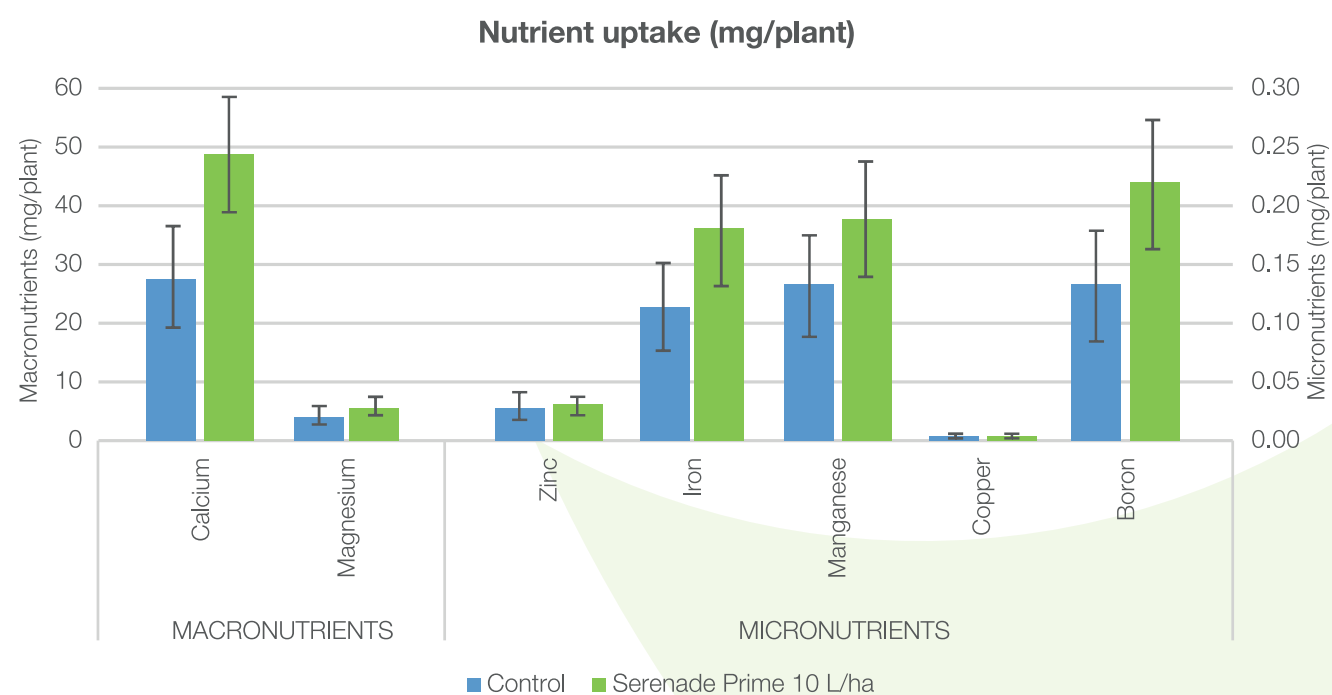


Figure 15. Nutrient uptake (mg/plant) in carrots. Nutrient uptake (mg/plant) = leaf analysis (mg) x dry plant weight (g). A total of 14 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved nutrient uptake, resulting in increased root growth of carrots when analysed using root-scanning software, WinRHIZO, at 3 months after application. It resulted in an increased root surface area (+126%) (Figure 16).

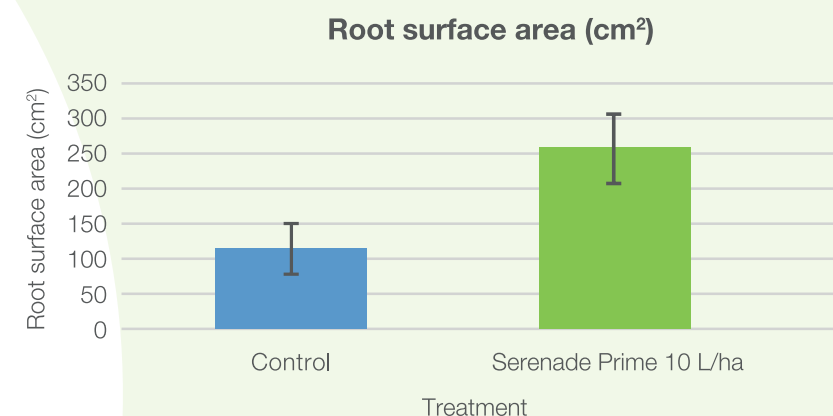
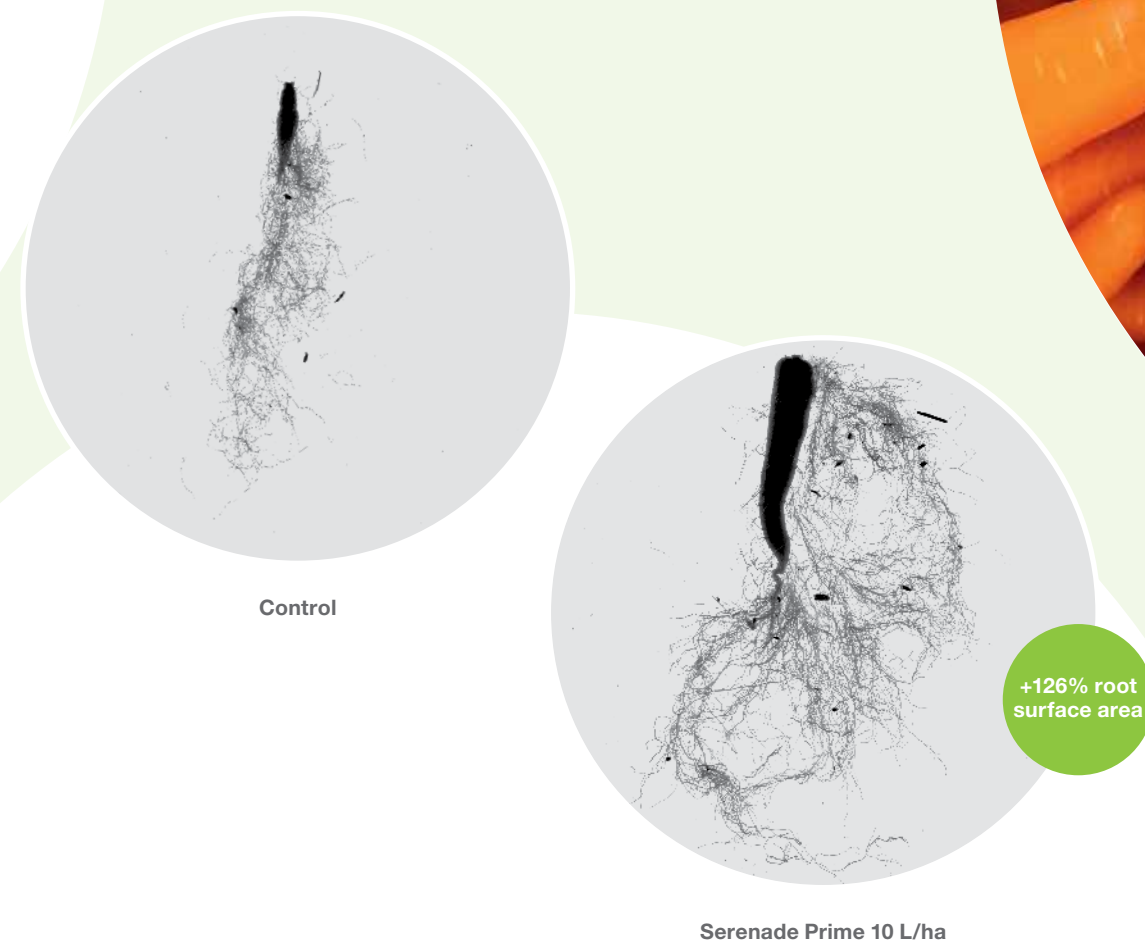


Figure 16. Root surface area (cm<sup>2</sup>) in carrot at 3 months after application.





# Lettuce

+54% head biomass

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of iceberg lettuce var. *Crispino*. Under high salt (1.5 dS/m) drip irrigation, it improved uptake of calcium (+83%), zinc (+119%), iron (+100%) and manganese (+291%) when applied as a soil drench at 7 L/ha at transplanting (Figure 17). DNA analysis (qPCR) confirmed successful colonisation at 36 days after application.

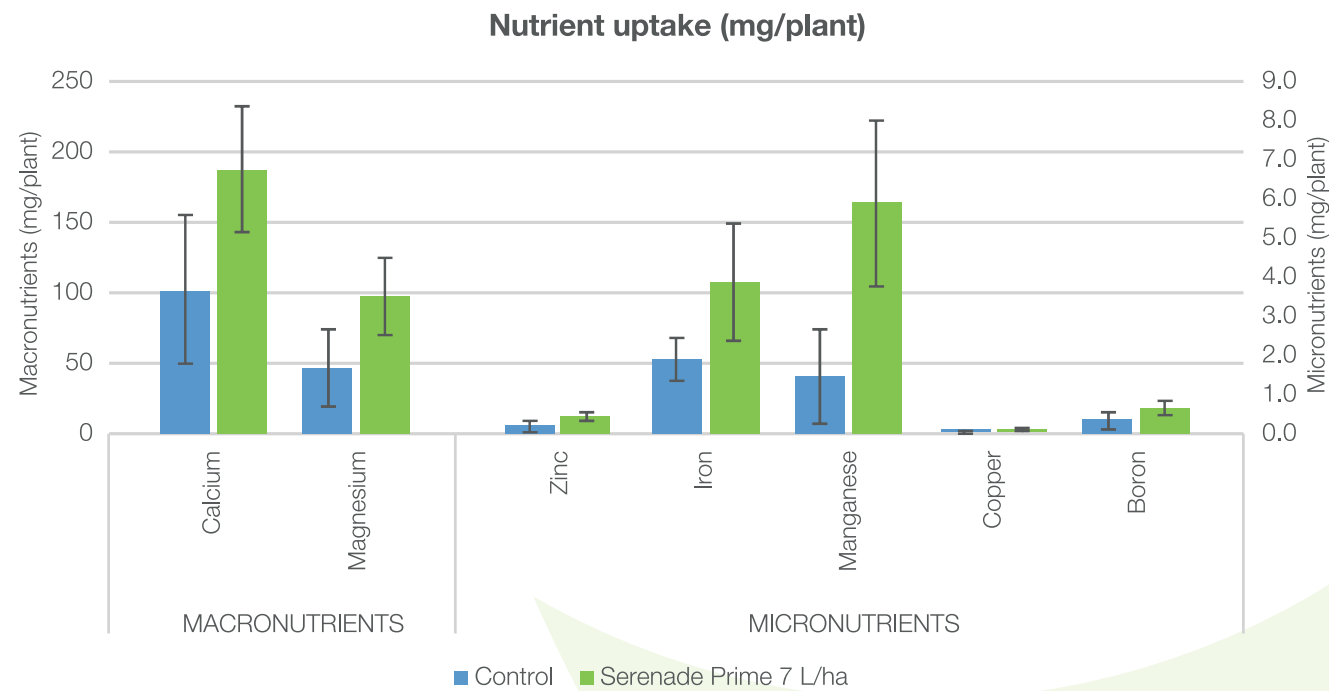


Figure 17. Nutrient uptake (mg/plant) in lettuces under high salt irrigation. Nutrient uptake (mg/plant) = leaf analysis (mg) x dry plant weight (g). A total of 12 leaf analyses were conducted per treatment to provide an average value.

## Root Architecture

Serenade Prime improved nutrient uptake, resulting in increased root growth of iceberg lettuces when analysed using root-scanning software, WinRHIZO, 36 days after application. It resulted in an increased root surface area (+21%). This improvement in root architecture results in calcium and immobile soil nutrient uptake (Figure 18).

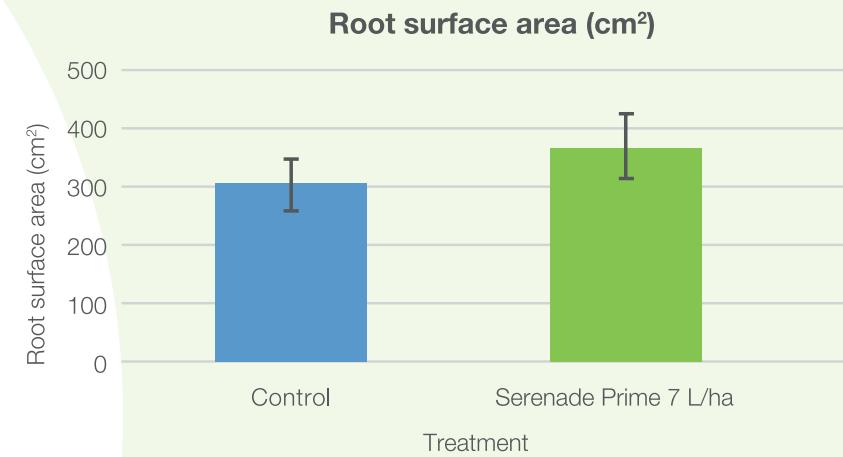
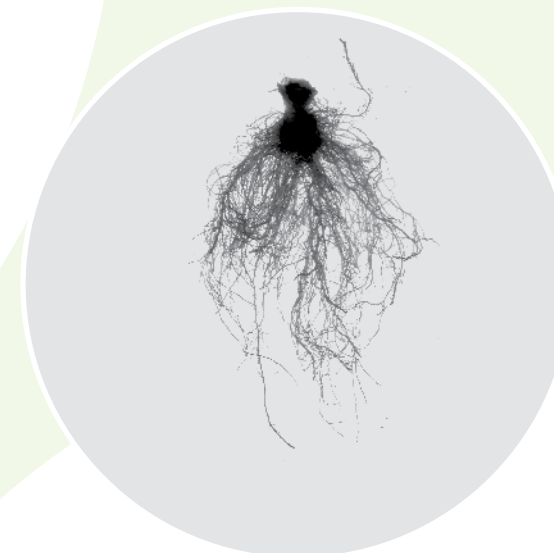
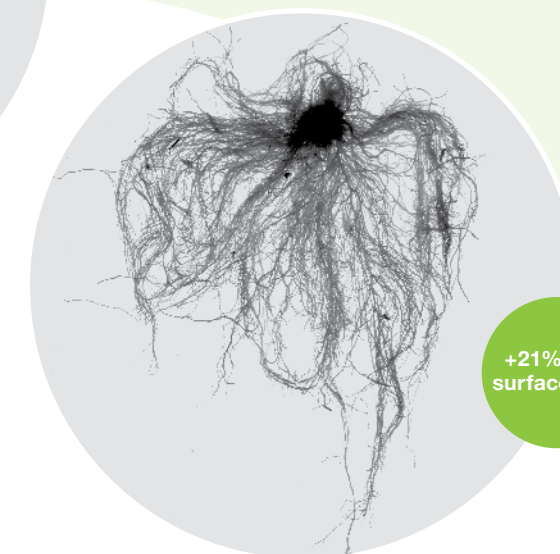


Figure 18. Root surface area (cm²) in lettuces 36 days after application.



Control



+21% root surface area

Serenade Prime 7 L/ha





# Tomato

## Nutrient Uptake

Serenade Prime improved the nutrient uptake of tomatoes var. *Coltrane* in a Soil Wealth field trial in Bowen, Queensland (VG13076). In combination with pre-plant compost application, it showed a trend to improved uptake of calcium, iron, manganese and boron compared with compost alone, when applied through drip irrigation at 6 L/ha (Figure 19).

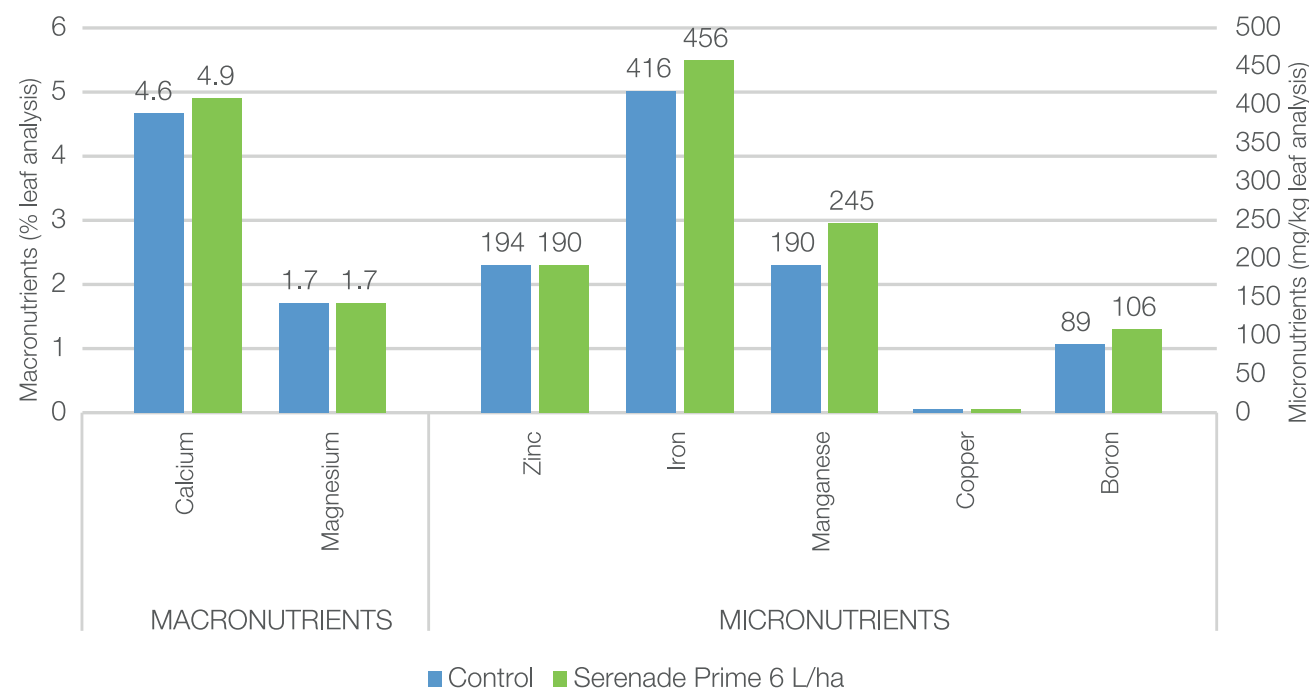


Figure 19. Nutrient content of tomato leaves at harvest.

Harvested fruit were analysed for nutrient content and shelf life during storage. Serenade Prime-treated fruit showed higher levels of calcium (+20%), magnesium (+12%) and iron (+87), and an improvement in the post-harvest condition at 14 days after harvest (Figure 20).



Figure 20. Nutrient content of tomato fruit at harvest. Nutrient content was determined by analysis of harvested fruit with 6 replicates per treatment.

## Root Architecture

Serenade Prime resulted in improved root growth of tomatoes var. *Washington Cherry* when analysed, using root-scanning software, WinRHIZO, 25 days after application. It resulted in increased root surface area (+92%) (Figure 21). This improvement in root architecture assisted in an increase in calcium and immobile soil nutrient uptake.

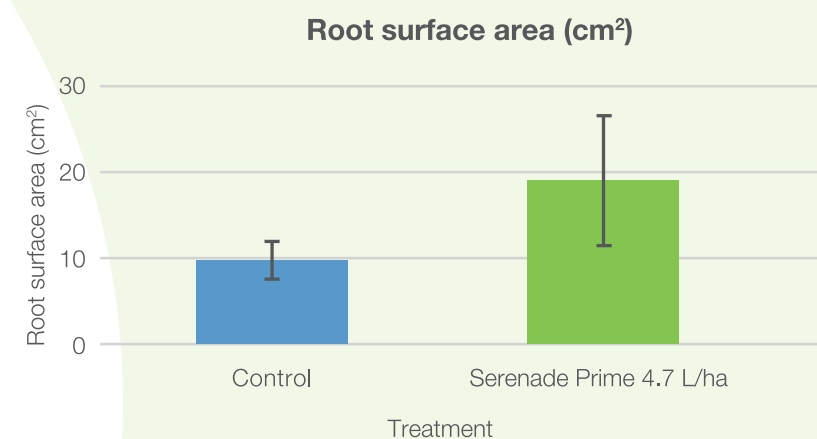
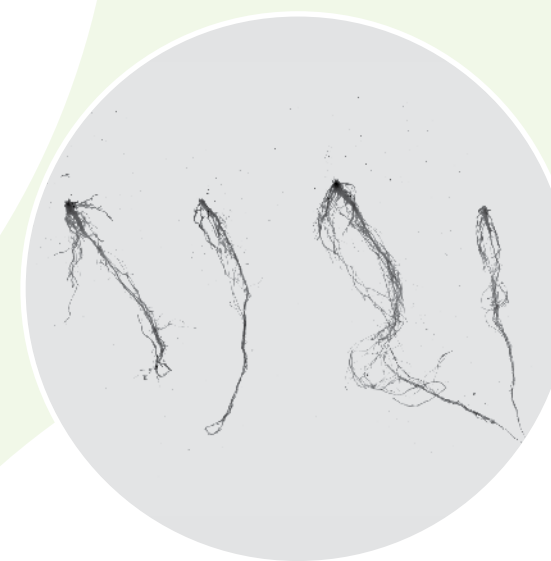
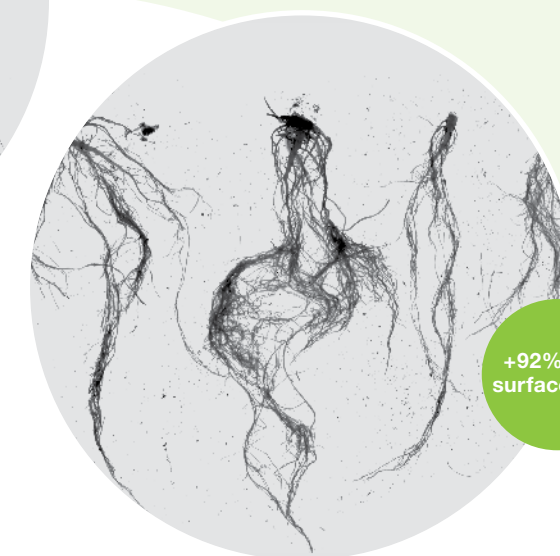


Figure 21. Root surface area (cm²) in tomatoes 25 days after application with 16 replicates per treatment.



Control



Serenade Prime 4.7 L/ha

+92% root surface area



# Potato

## Nutrient Uptake

Serenade Prime improved nutrient uptake of potatoes var. *Maris Piper*. It showed a trend to improved uptake of calcium (+20%), phosphorous (+44%), magnesium (+39%) and boron (+43%) when applied to soil at 5 L/ha at planting to potatoes grown in 1 m columns (Figure 22). DNA analysis (qPCR) confirmed colonisation at 28 days after application (Hunt, A. 2018).

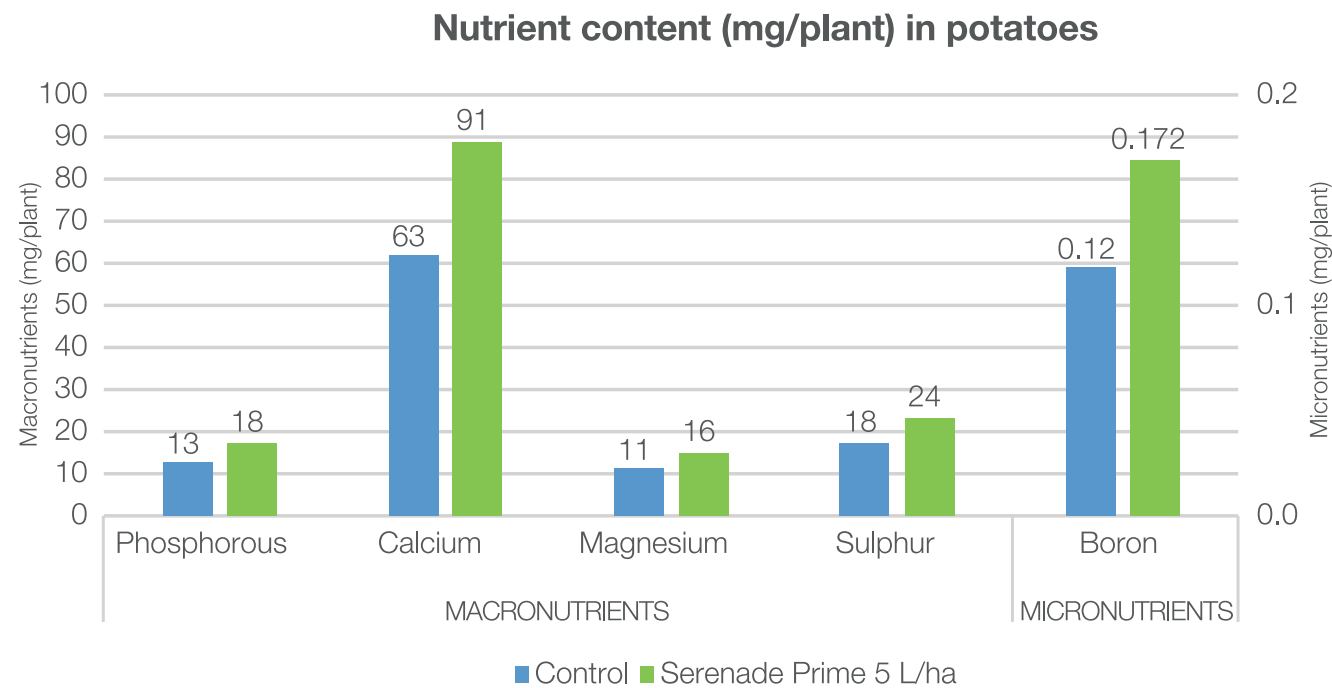


Figure 22. Nutrient uptake (mg/plant) in potatoes. Nutrient uptake (mg/plant) = leaf analysis (mg) x dry plant weight (g).



Potatoes were grown in columns prior to nutrient uptake, root architecture and qPCR analysis.

## Root Architecture

Serenade Prime improved the root growth of potatoes when analysed using root-scanning software, WinRHIZO, 36 days after application. It resulted in increased total root surface area (+49%), with the largest increase (+161%) on roots at a soil depth of between 30-60 cm (Figure 23) (Hunt, A. 2018).

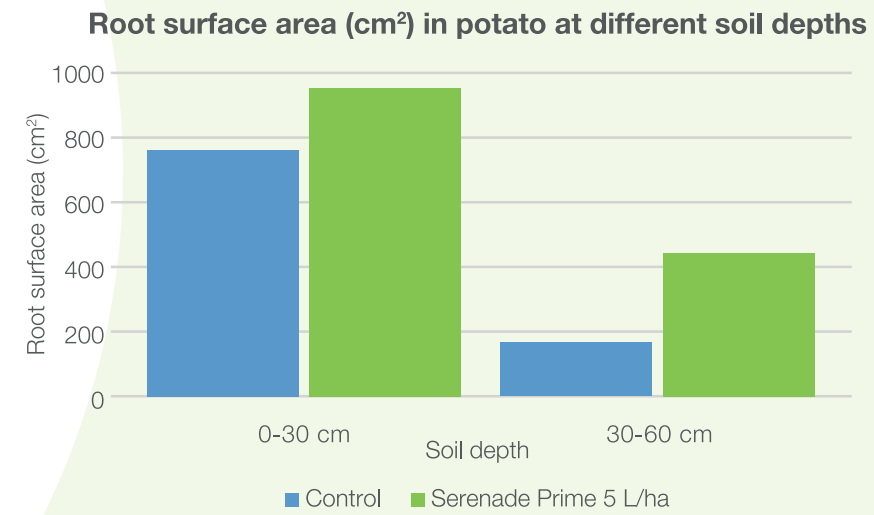


Figure 23. Root surface area (cm²) in potatoes at different soil depths 36 days after application.







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Garcia-lopez, A., Aviles, M. & Delgado, A. (2016). Effect of various microorganisms on phosphorus uptake from insoluble Ca-phosphates by cucumber plants. *J. Plant Nutr. Soil Sci.* 179, 454-465.  
Hunt, A. (2018). Evaluating the role of *Bacillus amyloliquefaciens* QST 713 as a Plant Growth Promoting Rhizobacteria. *Mres. University of Nottingham*.

