Great Land – Great Impact

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Great Land Technology

Developed by Australian scientists

Great Land is a patented liquid biological soil conditioner, comprised of live microbes which function to release soil-bound nutrients and facilitate greater nutrient availability. Following the application of Great Land, soil conditions are enhanced to improve plant growth and plant defences against environmental stress, pests and pathogens. Further, Great Land can enable reduction of fertiliser and chemical use, which benefits the environment and lowers input costs to farmers.

Great Land is based on naturally occurring bacterial species from the *Lactobacillus* and *Acetobacter* genera isolated from the environment and selected through a scientific process to develop the product formulation.

Great Land is produced under controlled, sterile fermentation conditions to build microbe populations, then blended with energy and nutrient sources required to sustain bacteria for the duration of product shelf life. Every batch is QA tested for minimum microbe population levels and viability.

Studies in the laboratory, glasshouse and the field have demonstrated that functions performed by Great Land are consistent with those reported in scientific literature (Glick, 2012) on a group of microbes loosely categorised as 'plant growth promoting bacteria' (PGPB). Understanding the precise modes of action of Great Land is subject to ongoing research and will enable improvements in the effectiveness of farm applications.

Great Land is widely used by conventional farmers. It is also used by organic farmers as it is a certified organic input in Australia and New Zealand and complies with the USDA National Organics Program (NOP).

Great Land is a Registered Trade Mark with issued patents in Australia (No. 2012321092), New Zealand (No. 614079 and 630117) and under patent examination in other markets.

Commercialisation of Great Land to date is a validation of Terragen's technology platform - targeted to have a big impact on agriculture by harnessing the power of Mother Nature. Other products in our development pipeline are aimed at addressing significant problems while reducing reliance on conventional chemicals.

21st century agriculture embraces biological solutions

Enhancing beneficial biological diversity and activity in the soil is central to the responsible management of soil nutrients. Soil biology has for too long been the forgotten component in conventional systems yet, if managed correctly, it is shown to be the most effective means of performing critical functions in feeding plants, protecting plants, correcting soil structure for better water storage/filtration and building stable soil organic matter (humus) as an essential nutrient pool and carbon sink.

Enhanced soil microbiology leads to productive, healthy systems

Multiple productivity gains conferred by beneficial microbes in agricultural systems are well documented (Compant et al, 2014; Bhardwaj et al, 2014; Glick, 2012; Huang et al, 2014; Trivedi et al, 2016). However, we have only just started to understand the potential scope of benefits and modes of action.

Key functions of beneficial soil microbes include solubilisation of 'locked up' soil nutrient pools, fixation of atmospheric nitrogen, delivery of nutrients to the plant and synthesis of antimicrobial compounds which can either kill or inhibit growth of pathogens. Additionally, reported benefits include improved nutrient cycling, better plant nutrient density, improved resilience against pathogens or environmental stress, improved soil structure and lower use of soluble fertilisers or chemicals.

Circle of Influence

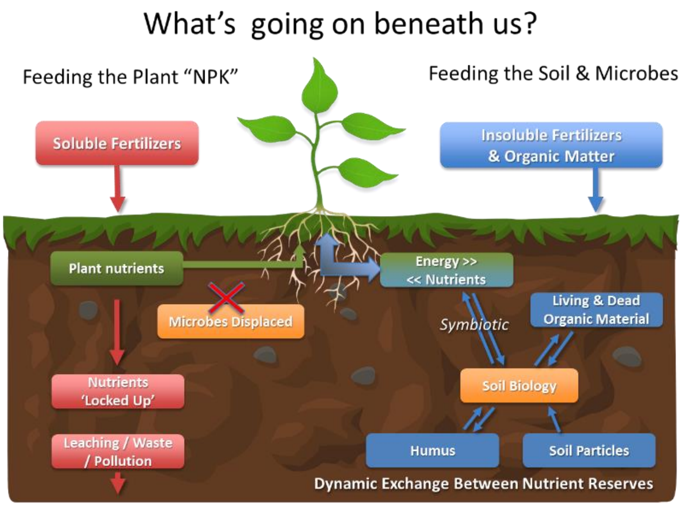
Advanced farmers reduce dependence on synthetic fertilisers and chemicals – profitably

Progressive approaches to farming are demonstrating how it is both possible and profitable to reverse the conventional trends of wasted inputs, declining produce quality and environmental damage associated with conventional farming practices. The application of synthetic fertilisers and chemicals is in decline as farmers and regulators witness far reaching detrimental effects from decades of excessive use. Advanced corrective practices are centred on ecological diversity in soils and plants plus the enhancement of natural processes related to cycling, storing and delivering nutrients to plants.

Resource management principals applied to farm nutrients

A large portion of applied synthetic nutrients, which are either 'locked up' in the soil or leave the farm, represent a significant loss to the farmer and become a waste product causing harm to soils, downstream waterways and the atmosphere. Refer to Appendix B for 'Myths and Facts' around soil and plant nutrients. Principals of responsible resource management – 'reduce, re-use and recycle' - can be translated to synthetic nutrient management on farm, mitigating the negative impacts from their excessive use.

Synthetic nitrogen is a special case. Excess application of nitrogen (in particular, urea) results in long term loss of soil organic matter and detriment to plant and animal health. In addition, the entire synthetic nitrogen life cycle is responsible for significant greenhouse gas (GHG) emissions - manufacturing is highly energy intensive and involves emission of nitrous oxide; distribution requires substantial transport miles; on-farm loss of organic matter makes soils net emitters of CO_2, and, under some conditions nitrous oxide is released to the atmosphere. Nitrous oxide is 300 times more potent than CO_2 as a GHG, with a half-life exceeding 120 years.



A matter of balance

Synthetic fertilisers and chemicals will continue to have a role in integrated farming systems striving to meet global food demand. However, decades of accumulated excesses are clearly manifested in declining farm (soil) performance, poor health outcomes and environmental harm. The status quo is not sustainable. Fortunately, conditions are now set to drive real change in mainstream practices to a more balanced, biologically driven paradigm as we see emerging consumer pressure towards responsible farming and advances in technology to enable validation of biologically enhanced systems.

Ecologically minded farmers know that better soil microbial health is the key driver in transitioning from a narrow and damaging 'NPK' model to capture the power and efficiency of biological systems. The physical and financial outcomes of farmers 'who dare' is an inspiration for change on a large scale.

Great Land - Demonstrated Performance

Great Land has been available to the market since late 2012. Commercial applications are geographically spread from Tasmania to far north Queensland across a range of enterprises and demonstrating multiple benefits. Field trials and case studies have taken a variety of forms including simple split block comparisons, temporal comparisons on whole farm use and independent replicated randomised trials with formal objective assessments.

Great Land has proven effective in a range of enterprises and farming systems from conventional to organic.

Best performance is seen when soil moisture conditions can be reliable maintained through the productive growth phase of plants, that is, high rainfall or irrigated systems.

A consistent trend of positive performance is found with specific benefits being observed or measured to varying degrees, including:

Significant increase in root mass and fibrous/feeder roots surface area during early stage growth and other active growth periods of the plant. Interrelated benefits arise from the plant gaining access to a greater volume of soil nutrients and increased biological activity over a larger rhizosphere – feeding and protecting the plant.

Increases in the level of solubilised minerals - quantified with more than 200 soil incubation tests conducted over two years.

Improved product output - total yields and/or uniformity and quality (grading, pack-out, shelf life).

Improved moisture retention in soil with improvement in plant resilience to dry conditions.

Enabling reduction in use of synthetic fertilisers.

Improved resilience to disease pressure.

A common concern about the use of microbial inoculants for soil conditioning is the inconsistency of performance. Farming is a biological endeavour, which is never linear in its results and always subject to varying responses to different soil types and variable conditions. Conventional agricultural practices are subject to the same factors and variable performances within a complex system. Reports of Great Land’s performance covered in this section reflect a wide range of outcomes in different aspects of the system but the consistency of positive trends and compounding benefits is indisputable.

Great Land – Notable Results

Pastures and Annual Crops

Pastures – Dairy

Independent Study on Milk Production, 2016 season, University of Queensland (UQ)

This extensive, controlled and blind study conducted independently by UQ for Terragen, found a positive association between cows grazing pasture treated with Great Land (GL), milk production and herd health. The study was conducted over 6 months using over 200 cows randomly split and managed as two separate herds. All cows were fully fed, supplemented with a mixed ration and grazed at the same stocking rate. Two important outcomes were reported:

- Cows grazing Great Land treated pasture achieved 7.3% higher milk production ($p<0.05$), compared to cows grazing untreated pastures.
- The overall incidence risk of mastitis was 14% lower for cows grazing on GL treated pastures. Further analysis showed that affected cows had a 33% lower ($p<0.05$) repeat incidence of mastitis.

Consistent with this formal evidence are the observations made by many dairy farmers in Australia and New Zealand. These farmers who consistently expose their entire herd's grazing areas to Great Land are reporting a wide range of observed benefits.

Victoria and NSW Pasture Harvest Trials - Commercial

Throughout the 2015/16 dairy season, over 40 dairy farmers across Victoria and southern NSW participated in conducting 118 split paddock trials to compare pasture growth and pasture harvested between treated and control paddocks. Weekly plate metering was conducted and grazing times recorded for computation of pasture consumption. Results and observations:

- Regional average gains of 12% to 37% in pasture harvested (kg dry matter per hectare). Additional dry matter production converts directly to production of milk when cows are fully fed.
- Notable observations commonly reported in comparisons between treated and control paddocks:
  - Visually noticeable increase in pasture density, higher clover content and reduction in weeds
  - Treated paddocks were more heavily grazed and evenly grazed – indicating better palatability
  - Treated paddocks remained greener for longer during dry periods
- All of these points demonstrate the positive influence of Great Land on quality and health of pastures and the benefits provided to the animals grazing on these pastures.

New Zealand – Commercial Application, Full Farm Case Summary

In this case, Great Land was applied to the whole farm, allowing a reduction in nitrogen application to 5-10 kg N/ha, compared to an industry average of 200 kg N/ha. Meanwhile, the dairy has been achieving milk production of 480 kg MS/cow (largely through home grown feed) compared to an industry average of 350 kg MS/cow. Stocking rate is approximately 2.5 cows per effective milking hectare.

Great Land applications have been an important part of this farm's program. Observed impacts are consistent with all dairy farmers who consistently expose their entire herd's grazing and calving areas to Great Land treatment:

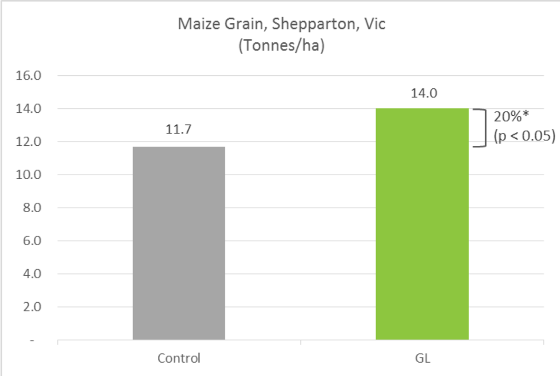
- Improved pasture production.
- Increased pasture density, clover content and palatability.
- Better resilience of pastures during environmental stress (both dry and wet conditions).
- Improved health – including lower somatic cell counts and reduced incidence of ailments such as lameness and mastitis in cows or sickness and mortality in calves.

Maize

Maize – Replicated Trial, Independent (AgLogic)

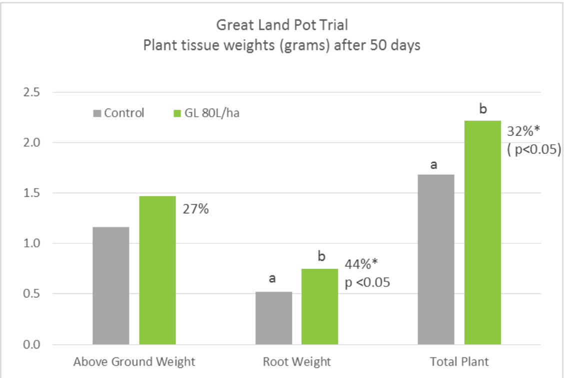
A maize grain trial conducted in Victoria, overseen and analysed independently, measured the grain weight yield differences from treatment with Great Land at 80 L/ha injected into the soil at the time of sowing.

The treated strips yielded an average of 2.3 t/ha more grain (moisture at 13%) than control strips, representing 20%* better yield performance over untreated maize strips. Superior uniformity of yield was also achieved across Great Land treated replicates which had a range of 0.6 t/ha, compared to control replicates with a range of 3.0 t/ha.



Lucerne

Pot Trial, Replicated, Independent (Aglogic)



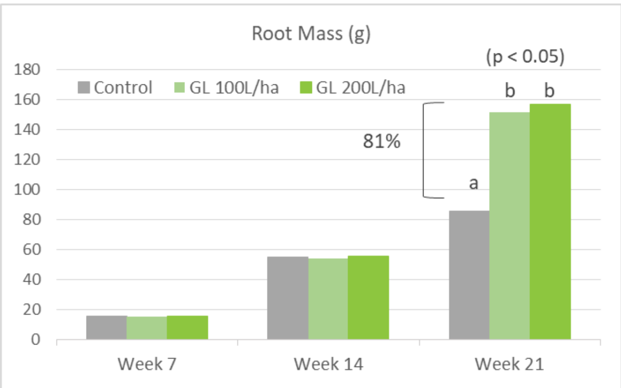
Significant positive treatment effects were recorded in root mass and total plant biomass after 50 days post sowing. These early establishment gains* of treated lucerne were 44% and 32%, respectively, over untreated plants.

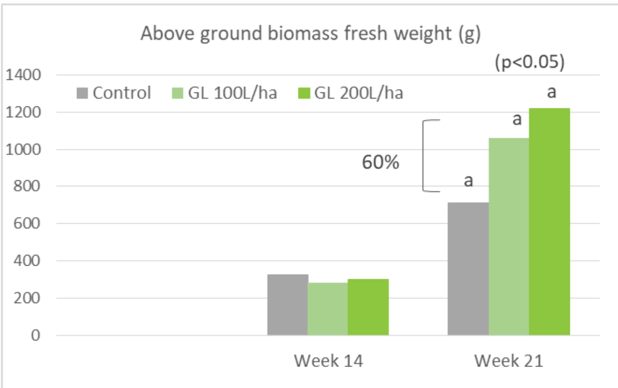
Where good growing conditions are maintained the early establishment benefits will translate to a gain in yield.

Sugarcane

Sugarcane Pot Trial, Replicated, Independent (Farmacist)

After 21 weeks from planting, replicates treated with Great Land had on average 81% more root mass and 60% more above ground biomass over those that were untreated.





Aside from benefits in nutrient use efficiency arising from more root mass, a crop specific benefit in sugar cane is more stable plants during harvest therefore reducing loss of plants for subsequent ratoon crops.

Further trials are in progress to establish the effect of Great Land over the entire crop life-cycle. Better root establishment will reduce the physical loss of plants through harvest.

Horticulture – Perennials

Macadamias

Commercial Application, Full Farm, Case Studies

Case studies of two macadamia growers using Great Land over their entire productive area show objective gains in production, quality grading (kernel recovery) and significant reductions in soluble fertiliser applications. Additional benefits have been observed in tree health, resilience to pest/disease and environmental stress. The complex nature of a farming system makes it difficult to attribute positive outcomes to any single factor in the absence of a controlled experiment. However, the skilled and well-respected farmers in both these cases are emphatic in their assessment that Great Land has been an important contributor to the benefits recorded.

The pictures below show common and significant differences found in early establishment and fibrous root mass of macadamia seedlings when treated with Great Land.

Germination and early establishment.

The upper middle block treated with Great Land,

Near block was untreated.

Typical influence on fibrous root growth on seedlings treated with Great Land (left). Seedling on right is untreated.

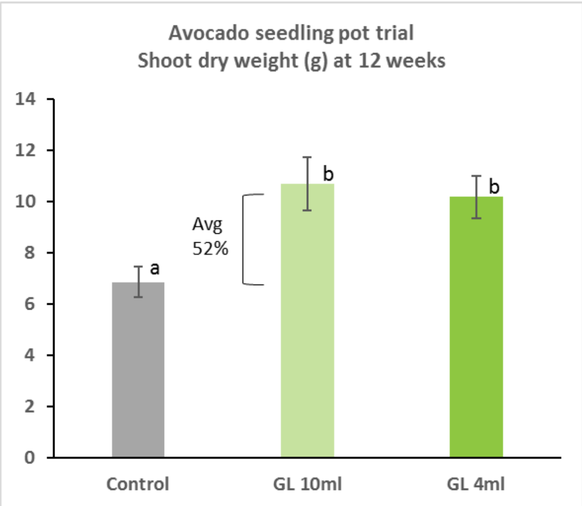
For disease conditions, all macadamia nut growers who have applied Great Land under a recommended program have reported strong suppression of phytophthora. This is consistent with laboratory studies resulting in clear antimicrobial action inhibiting of the pathogen. Husk spot in macadamia trees has also been reduced after foliar applications of Great Land.

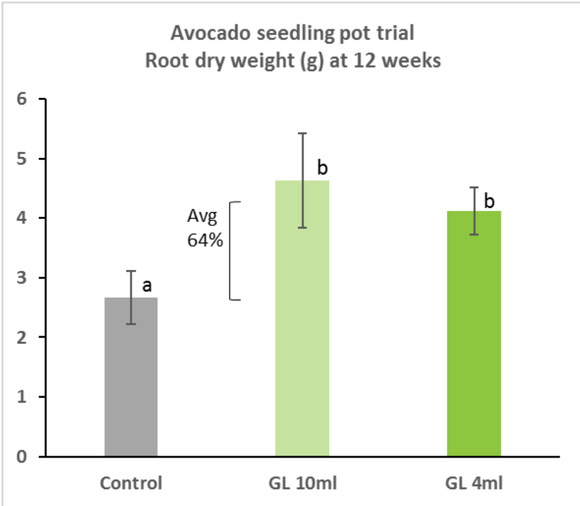
Avocados

Avocado seedling demonstration trials are currently in progress. Visual observations show a large difference in seedlings treated with Great Land and preliminary evaluation of root and shoot mass show significant treatment effects.

The trial was established by planting of 1600 avocado seeds into standard sized nursery planter bags. Four groups, each with 400 plants were given different treatments rates. 25 pots from each treatment were randomly selected before germination then grown in the same conditions, in a greenhouse. At 12 weeks from sowing, plant and root mass was measured on 6 of the tallest plants from each treatment group.

Initial results show that two of the treatment rates, 10mL and 4mL of Great Land per pot diluted in 100mL water and applied at planting, had statistically significant differences ($p<0.05$, $n=6$) of more than 50% compared to untreated pots for assessments in shoot dry weight and root dry weight. Results are illustrated below.





Further evaluation of treatment performance will be made throughout the growth phase of remaining plants.

Separate commercial application of Great Land in other nursery and orchard plantings have shown increased stem diameter, improved general plant health and resilience to tough conditions.

Grape Vines

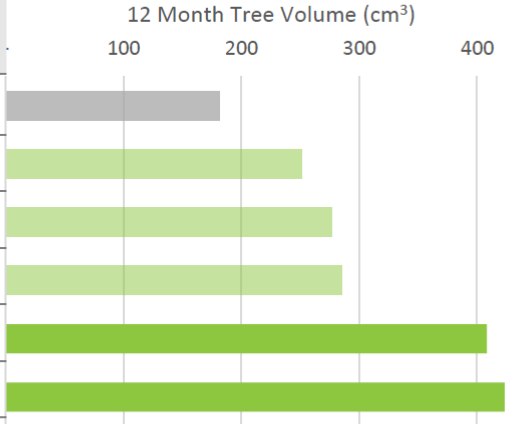
Angove Wines, Australia's largest organic winemaker, initially applied Great Land during the early stages of conversion from a conventional to organic vineyards. Having seen benefits in vine health and yield recovery following reduction in fertiliser use, especially urea, Angove Wines have expanded the application to their entire vineyards. 'Great Land XP', is NOP compliant which enables Angove Wines to export certified organic wines to the USA.

Forestry

Replicated Trial (2015-16), Eucalyptus, Hamilton Region, Vic. (Independent - Weedensol)

Planted in mid-2015, different rates of Great Land, from seedling stage to 2 months after planting, were applied and tree volumes measured when trees were 12 months old. The seasonal conditions were particularly challenging, however, treatments at 80 L/ha at the time of planting resulted in a significant difference in tree volumes against controls and other combinations of treatment. A summary of treatment regimes and results are graphed below.

Seedling Drench	Preplant Soil (L/ha)	Postplant Soil (L/ha)	Tree Volume (cm^3)	Ranking ($p < 0.05$)	
-	-	-	181.75	a	T6
Yes	40	40	251.49	a	T4
Yes	40	-	276.62	a	T1
Yes	40	-	285.39	a b	T2
Yes	80	-	408.20	b c	T3
Yes	40	80	423.18	c	T5



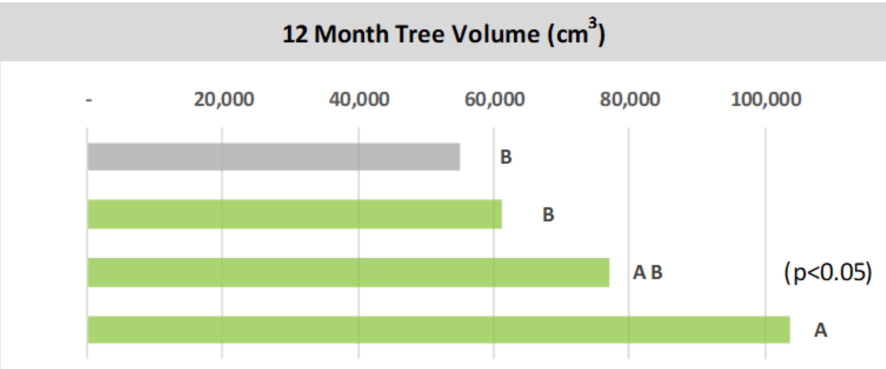
Replicated Trial (2016-17), Eucalyptus, Mumbannar Region, Vic. (Independent - Weedensol)

Great Land was applied in three different regimes from planting in mid-2016. Tree health/vigour was assessed at three monthly intervals and tree volumes measured at 12 months from planting. Growing conditions were considerably better than the above trial at Hamilton in the previous year, however, excessive spring rain caused some waterlogging issues.

By 9 months, the treatment with 80L/ha post planting showed superior leaf area, health and uniformity compared to all other treatments. The control trees in particular lacked uniformity and vigour.

A summary of treatment regimes and tree volume data is presented below.

Great Land Treatments		
ID	At planting (L/ha)	2 mth Post (L/ha)
UTC	-	-
T1	40	-
T2	80	-
T4	-	80



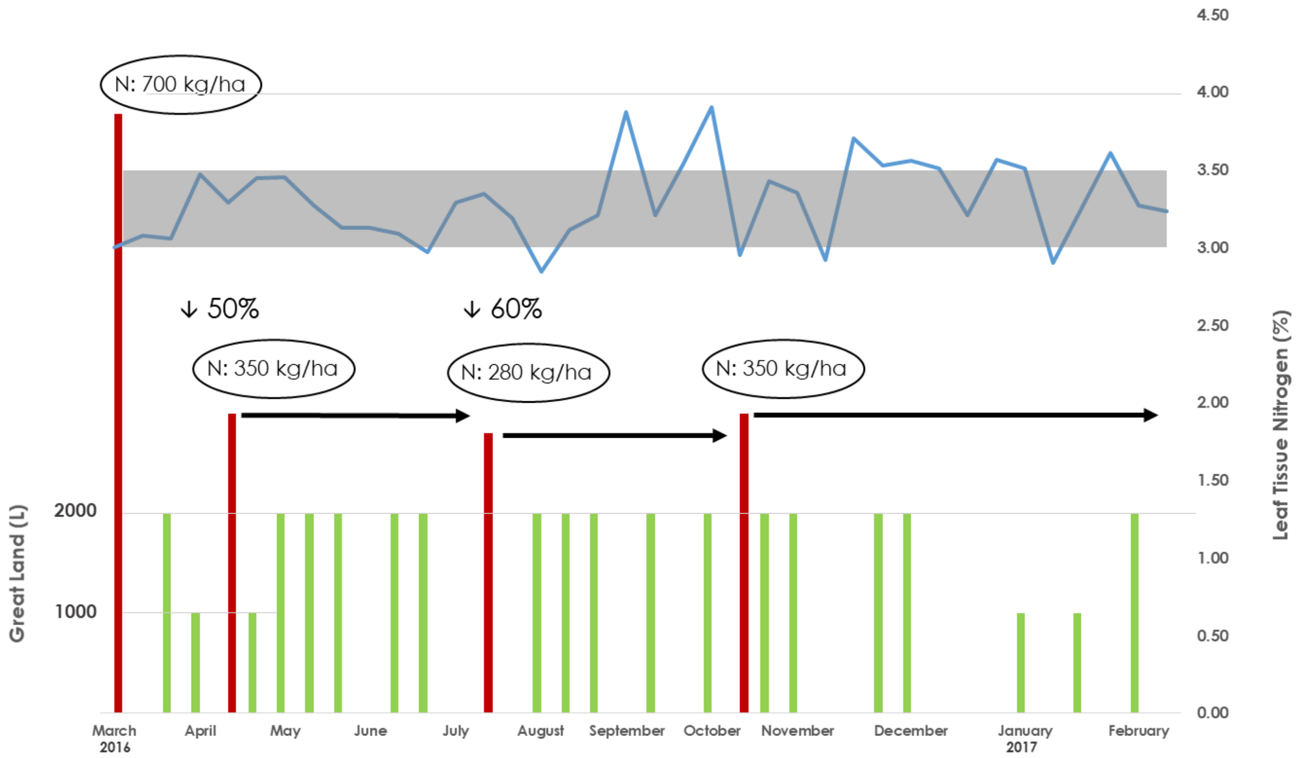
Applying GL at 80 L/ha two months after planting resulted in a significant difference in tree volumes against the untreated control.

Horticulture – Annuals

Bananas

Commercial Application Full Farm, Case Update

On a large banana plantation near Innisfail, Qld, soluble urea application rate was reduced by approximately 50% after applying Great Land through the fertigation system. Close monitoring of leaf tissue tests show nitrate-N has been maintained for the duration of the new regime. Fruit yields are similar, fruit quality (size and bruising) has been improved and on the basis of crop turnoff and ratoon tree development, the timing of crop cycles is shortened to a point that is commercially very advantageous.



Strawberries

Gowinta Farms, conducted commercial trials with Great Land on their strawberry operation during a difficult growing season. Results:

- 34% increase (203 g/plant) in yields per plant, over the untreated yield, averaging 593 g/plant.
- Earlier harvesting of treated blocks enabled improved prices in the market.
- Observed better quality fruit from treated blocks (size, colour, firmness), although not quantified.
- Leaf tissue testing showed higher levels of most macro and micro-nutrients in treated plants.
- Plants in treated blocks showed increased size, root growth, general vigour and minimal mortality compared to those in the untreated blocks.

The outcome motivated continued use of Great Land on a full commercial scale.

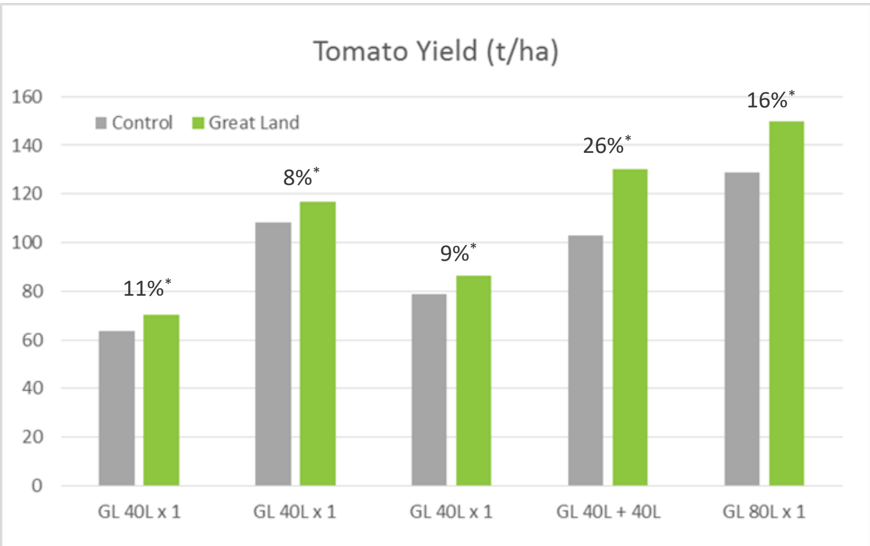
Tomatoes

Multiple trials have been conducted with tomatoes, all showing positive trends in root mass growth, plant health and production yields. Two examples are summarised below.

Seedling Trial – Visual Assessment: Early stage plant and root growth show consistently better establishment in Great Land treated pots, as illustrated by the photo below of representative samples.

Left: Nil treatment
Middle: Flowphos (fertiliser)
Right: Great Land treated

Field Trials – Yield Assessments: the chart below summarises consistent trends of increased tomato yields arising from Great Land application at flowering as a surface spray, across varying soil types.



Typical Plant/Root Growth

Left: GL Treated Right: Untreated

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Appendix A: Glick - An Overview

Appendix B: Myths & Facts – Summary Page

An Overview of Plant Growth Promoting Bacteria (PGPB)

A summary of the review article: *Plant Growth-Promoting Bacteria: Mechanisms and Applications*
(Bernard R. Glick, Scientifica, Volume 2012)

1. Introduction

The current global population is expected to reach 8 billion around 2020. To meet the demands of this population growth the world will need to increase agricultural productivity but in a sustainable and environmentally friendly way.

This means re-examining the use of current chemical fertilisers, fungicides and herbicides, and making greater use of new technologies, including plant growth promoting bacteria (PGPB).

2. Plant Growth Promoting Bacteria (PGPB)

Bacteria make up about 95% of all microscopic life found in soil (with up to 10^9 bacterial cells / g soil), but are often found in lower quantities in environmentally stressed soils. The number and type of bacteria are also influenced by conditions, including: temperature, moisture, salt & other chemicals, and type of plant. Bacteria are found in the greatest concentration around the roots of plants (the rhizosphere), taking advantage of nutrients secreted by the root tips.

Bacteria in general may be (a) beneficial to the plant (b) harmful to the plant or (c) neutral to the plant. However, this may change under different conditions and even beneficial bacteria may affect different plants in different ways.

Specifically, PGPB may be free living; living in a symbiotic relationship with plants; or live within the plant tissue itself (endophytic) – but they all utilise the same mechanisms. They either: (a) promote plant growth *directly*, by facilitating resource acquisition or modifying plant hormone levels, or (b) by acting *indirectly* as a bio control and decreasing the impact of pathogens on plants.

3. Direct Mechanisms

A. Facilitating Resource Acquisition

- Nitrogen Fixation: Free living and *Rhizobia* spp. bacteria are able to fix nitrogen and provide it to plants. Research on maximising the efficiency of this process is ongoing.

- Phosphate solubilisation: Despite many soils having high levels of phosphorus, most of it is insoluble, therefore unavailable to plants. Moreover, soluble inorganic phosphate fertiliser often becomes immobilised soon after application, meaning much of it is wasted. Because of this, a lack of phosphorus often limits plant growth. PGPB and plant growth promoting fungi typically solubilise and mineralise phosphorus as a side effect of synthesising various organic acids, and of other biological processes.

- Sequestering Iron: While iron is a common element, the predominant form (ferric iron, or Fe^{+3}) is not highly soluble, meaning only marginal amounts are easily available to plants. In the soil, microorganisms synthesise molecules called siderophores which attract, bind and transport ferric iron - which is then easily able to be taken up by plants and increase plant iron levels.

B. Modulating plant hormone levels

Plant growth is regulated by a number of hormones (phytohormones), including cytokinins (which promote growth in plants shoots and roots), gibberellins (which stimulate stem growth, germination and flowering), ethylene (which has many effects including the promotion of plant ripening), and auxins (including Indoleacetic Acid or IAA – which affects plant growth in a wide range of ways). PGPB have the ability to produce or modulate these phytohormones, affecting plant growth, the ability of a plant to take up nutrients, and its stress response.

4. Indirect Mechanisms

Biocontrol is a method of controlling pests and pathogens using other organisms (in this instance, using PGPB). Biocontrol can be a viable commercial alternative to the use of chemical pesticides or fungicides. There are several main ways in which PGPB may act as a biocontrol, outlined below.

- The Production of Antibiotics: Many PGPB can synthesise antibiotics which kill pathogenic cells (especially pathogenic fungi) and prevent their proliferation. However, pathogens may develop a resistance to the antibiotics that the bacteria produce; therefore this method is most useful as a biocontrol when the bacterial strain also produces hydrogen cyanide to work in conjunction with the antibiotic.

- Siderophores: These are molecules produced by bacteria which attract, bind and transport ferric iron. PGPB siderophores tend to be more efficient at attracting iron than plant pathogens, and can prevent them from proliferating due to an iron deficiency. This generally does not affect plant growth, as most plants require a much lower iron concentration than most microorganisms, and they can also utilise the iron bound by the PGPB.

- Competition: Indirect evidence shows PGPB limiting disease incidence by outcompeting plant pathogens, rapidly colonising plant surfaces and using all available nutrients.

- Modulating Stress Hormones: (notably ethylene) When affected by pathogens, plants produce excess ethylene, which exacerbates the plant's stress. PGPB can lower the hormone response, reducing the impact of stress on the plant.

- Induced Systemic Resistance (ISR): This is similar to Systemic Acquired Resistance (SAR), which is the term given to plants activating their defence mechanisms against pathogens. PGPB have the ability to trigger ISR before a plant has been attacked - essentially priming a plant to defend against a pathogen attack.

5. Modulating the Effects of Environmental Stress

In ideal circumstances, a plant's growth would be relatively linear over time. However, plants are affected by a variety of stressors in the field which impact upon growth, resulting in periods of maximal growth, interspersed with periods of inhibited growth. These stressors include temperature extremes, flooding or drought, toxins, wounding, insect predation and infection by various pathogens (bacteria, viruses and fungi). PGPB may work to overcome stress triggered growth inhibition in a number of ways:

- By modulating stress ethylene (as discussed above). PGPB which act to modulate ethylene production have been found to be effective against temperature extremes, flooding, drought, metals, salt, and organic contaminants.

- By providing the plant hormones Indoleacetic Acid (which directly stimulates growth even in the presence of inhibitory compounds) and cytokinins (which promote cell division and therefore growth).

- In some studies, PGPB have been engineered to over produce trehalose, a useful molecule which is able to decrease damage from drought, salt and temperature extremes. When these transgenic PGPB are applied to plants the result is more nodulation, higher nitrogen fixation and greater recovery from drought stress. Although plants themselves can also be engineered to produce more trehalose, it is simpler to manipulate PGPB, with the added advantage that one modified strain can be used on a range of different crop plants.

- Some cold tolerant (psychrotropic) PGPB are able to secrete antifreeze proteins into the soil to protect themselves from damage by ice crystals. This enables them to survive and be effective in low soil temperatures, which is often when fungal plant pathogens are most destructive.

6. Conclusions

The time has come for PGPB to be an integral part of agricultural practice. These bacteria are currently being used successfully in a number of countries in the developing world and this practice is expected to grow. In the developed world, where agricultural chemicals are relatively inexpensive, the use of PGPB occupies a small but growing niche in the development of organic agriculture.

However, there are a number of issues that will need to be addressed before the use of PGPB can become more widespread, and areas which need further study. These include:

- The requirement for new practical and effective approaches for the growth, storage, shipping, formulation and application of PGPB.

- The need to educate the public about the usefulness of PGPB in agriculture, and addressing the misconception that bacteria are merely agents of disease.

- The need to prove to regulators and the public that transgenic PGPB do not present new hazards or risks.

- Determination of whether further research is most advantageous into rhizospheric or endophytic bacteria, and a greater understanding of the relationship between bacteria and mychorrhizae (root fungi).

Despite these issues, it is likely that there will be a shift in focus to the effective use of PGPB in agriculture, and the future of this technology is bright.

Appendix B

Soil Health - Myth Vs Fact

BUSTING THE MYTHS

Throughout history there are many cases of widely held beliefs, often driven by commercial and political interests, that turn out to be wrong. For example, smoking was considered healthy until the mid-1900s.

In agriculture, the industrial approach to food production is on an unsustainable path - failing to feed our growing demand and having an unacceptable contribution to environmental pollution, chemical toxicity, antibiotic resistance and poor nutrition. Fortunately, technological advances and experiences can dispel some notable doctrines in conventional agriculture and proven alternatives are available as exemplified below.

They Say…	The Facts
'NPK' are the primary three limiting nutrients of significance.	• At least 16 mineral elements are required for a healthy farm system. • Reliance on soluble 'NPK' fertilisers supresses natural nutrient cycling, microbial activity and the building of soil carbon. • The 'NPK' paradigm's inherent waste of nutrients represents a significant cost - borne by farmers. • Good nutrition practices feed the soil, not the plant.
Lime/calcium is primarily used as a tool for correction of soil acidity.	• Calcium is a core foundation mineral - a base fertiliser - not a tool for correcting acidity. • The importance of calcium for nutrition and soil structure cannot be overstated. • pH is not an indication of calcium availability. • In biologically healthy soils with nutrients at appropriate levels, pH will be corrected by natural biological processes.
You can't avoid a large portion of applied phosphorous (P) being 'locked up', remaining unavailable to the plant.	• More phosphorus is made available to plants when microorganisms are active in the soil. • In healthy soils, a dynamic exchange of phosphorus occurs between significant reserves (humus, undegraded organic matter, soil particles and in solution) and plants – all of which is facilitated by active soil biology converting phosphorus to plant available form.
High rates of soluble nitrogen (N) are needed to maximize crop and pasture growth.	• High soluble nitrate levels impede the normal processes by which plants most effectively assimilate nitrogen. • Soluble nitrogen provides a short term 'sugar hit' but pastures accumulate excessive nitrate which can cause metabolic disorders in cows and affect milk quality. • Only 10-40% of applied soluble nitrogen is used by the plant. The balance is either lost to the atmosphere as gaseous nitrous oxide (N_2O), formed by undesirable bacteria, or leached into waterways. Such waste is a direct cost to the farmer.
Potassium (K) is easily leached or 'locked up', therefore, plenty of soluble K is needed to feed the plant.	• Similar situation as phosphorous. In healthy soils, significant quantities of potassium are held in dynamic balance between humus, un-degraded organic matter, soil particles and in solution. • Active soil biology releases potassium from these reserves in plant available form. • Replenishment should aim for recommended levels of potassium as a % of base saturation.