Are you a Turf Grower?

Increasing Turf Quality and Production using GrowGreen.

Under favourable growing conditions, producing and maintaining high-quality turf in Australia is labour and input intensive. The additional challenges brought on by the current drought and subsequent water shortages exacerbate management issues, causing industry professionals to investigate practices to mitigate the burden of reduced water availability. GrowGreen products provide solutions to increase efficiency and viability during drought conditions leading to an increase in turf quality and production.

Importance of Turf Industry in Australia

Following vegetable and fruit production the turf industry is an integral component of Australia's horticultural sector.

According to Turf Australia (2016):

- Turf production encompasses about 4400 hectares, producing an estimated $300 million worth of turf (farm gate value) annually.
- Turf maintenance work is associated with the care of golf courses, bowling greens, wicket and pitch preparation, racing clubs, institutional and recreational playing fields. Maintenance services are valued at over $500 million and tend to more than 10,000 prepared turf surfaces throughout the country.

Challenges Facing Turf Production/Maintenance

Managing turf, whether it be for production purposes or maintenance of sports fields and golf courses is demanding, high input operation regardless of water availability. The end goal of producing and maintaining lush, vibrantly green, weed free turf with no visible signs of nutrient deficiencies, insect infestations, or disease problems requires a management approach using the following tenants:

1. Frequent chemical applications of fertilisers, herbicides, pesticides, and fungicides.
2. High water consumption, with the water being applied at frequent intervals.
3. Increased mowing frequency of golf courses and all other playing fields to maintain an appropriate blade length for the turf purpose.

These management practices do result in high quality turf, but it simultaneously creates a scenario where the turf is increasingly susceptible to both biotic and abiotic stressors. The use of GrowGreen products provides growers with a sustainable, environmentally sound solution that strengthens plant defences again both biotic and abiotic stressors, and increases turf production and quality, even under times of drought.

Benefits of GrowGreen Products

GrowGreen products are classified as biostimulants, which help farmers to meet the increasing production demands and challenges they are facing while simultaneously increasing sustainability.

Fish-soluble nutrients **(FSN)** have long been used as a fertiliser source for a wide variety of fruits and agricultural crops *(Aung, & Flick, 1980; Emino, 1981; Aung, & Flick, 1982; Snyder, 1982; Aung, Hubbard, & Flick, 1983; Aung et al., 1984; Logendra, 1984)*. Seaweed extracts have great potential as biostimulant products; different types of seaweeds and their resulting extracts have long been utilised in agriculture due to their positive effect on plant growth and crop yield.

With a range of products offered to growers to meet varied management needs, the three fundamental biofertiliser products are AminoElite™, Microbe Plus® Kelp, and AminoKelp™.

- AminoElite™ is formulated from the breakdown of sea fish and crustaceans' proteins to create a product containing vital amino acids, macro and micronutrients, beneficial microbes, and chitin.
- Microbe Plus® Kelp contains a digested blend of high-grade seaweed extracts with plant essential nutrients, and beneficial microbes (bacteria and fungi) to create a high nutrient rich fertiliser.
- AminoKelp™ incorporates the benefits of two GrowGreen products, AminoElite™ and Microbe Plus® Kelp.

Another Product Offering Great Promise & Many Benefits Is Xtend™

Xtend™ is an organically certified spray adjuvant, sticker/spreader made from food grade canola oil. When mixed with products like fertilisers, herbicides, and insecticides it improves their spreading ability and efficacy.

Benefits of the aforementioned GrowGreen products are seen in turf production and maintenance by providing the turf with readily available nutrients, amino acids and a balanced phytohormone profile, decreasing nutrients lost to leaching for better delivery to the roots, stimulating microbial colonies in the soil, strengthening plant natural defences, and improving water use efficiency.

Readily Available, Plant Usable Amino Acids

In the plant, they are the building blocks for protein synthesis and serve essential functions in both primary and secondary plant metabolism. In the soil, they serve as an important source of nitrogen for the plant and help to chelate nutrients for improved uptake through the roots.

The requirement of amino acids in essential quantities is a well-researched phenomenon in turfgrass production. Applying them exogenously is known to increase healthy growth and the overall quality of the turf, as well as combating the spiral of decline that stems from abiotic stresses like drought, temperature, traffic, and mowing height.

A wider range of benefits is seen with the application of GrowGreen products. Different species of fish have been digested at room temperature, using microbes. With natural microbiological digestion, all the components of the fish offal (muscle, scales and bones) are fully digested to release a wide range of beneficial molecules. As amino acid content varies across species, incorporating a blend of different species in the emulsions produces a formulation containing a wider spectrum of amino acids *(Butchova, 2008; Skibniewska et al., 2013; Toppe et al., 2007)*.

- Muscle contains carbohydrates, nitrogenous compounds, various phosphates, sulphates, macro and micronutrients, and the amino acids glycine, proline, arginine, taurine, alanine, and glutamine *(Robertson, 1961)*.
- Scales consist of slender collagen fibres covered with calcium salts (16% - 59% mineral content in weight). The collagen contains glycine, proline, hydroxyproline, and arginine *(Zhu et al., 2011)*.
- Bone contains 60% - 70% inorganic substances, mainly calcium and phosphate. The remaining percentage consists of collagen which contains high levels of glycine, glutamic acid, arginine, proline, aspartic acid, and alanine *(Toppe et al., 2007)*.

Competing products may have similar concentrations of specific amino acids and claim similar benefits to products such as AminoElite™ and AminoKelp™, but the range of amino acids available in the formulations differs based upon the species of fish used in the emulsion and the type of digestion process employed. GrowGreen natural manufacturing processes result in a higher quality product with a wider range of amino acids.

Amino Acid Analysis Of AminoElite™ And AminoKelp™

Table 1 shows the amino acid analysis of AminoElite™ and AminoKelp™ on a percent weight by volume basis (w/v) and the associated metabolic function(s).

Table 1. Amino Acid (AA) Analysis (mg/L) and Benefits of AminoElite™ and AminoKelp™

Amino Acid	*Metabolic functions of AA*	AminoElite™	AminoKelp™
Aspartic Acid	Seed germination	**5.0%**	**7.6%**
Threonine	Improved drought tolerance	**2.5%**	**4.1%**
Serine	Chlorophyll production, stomata regulation, improved pollination	**4.5%**	**5.7%**
Glutamic Acid	Chlorophyll production, stomata regulation, pollination, seed germination	**10.0%**	**11.3%**
Proline	Heat, salt, and drought tolerance	**9.0%**	**7.1%**
Glycine	Chelation, heat tolerance, chlorophyll production	**27.5%**	**21.6%**
Alanine	Chlorophyll production, seed germination	**12.5%**	**10.3%**
Valine	Drought tolerance, seed germination	**4.5%**	**4.4%**
Methionine	Ripening, stomata regulation	**0.2%**	**2.3%**
Isoleucine	Salt and drought tolerance, pollination	**3.0%**	**3.1%**
Leucine	Salt and drought tolerance, pollination	**5.5%**	**5.7%**
Phenylalanine	Humic compound, lignin formation	**0.8%**	**2.4%**
Histidine	Aids fruit ripening	**1.0%**	**1.8%**
Lysine	Chlorophyll production, seed germination	**5.0%**	**5.7%**
Arginine	Root development, induces flowering and fruiting hormones	**4.0%**	**4.8%**
Hydroxyproline	Defence against pathogen attack, water movement through plant	**5.0%**	**n/a**
Tyrosine	Drought stress tolerance, pollination, pollen germination	**n/a**	**2.2%**

How Amino Acids In GrowGreen Products Benefit Turf

Under sufficiently irrigated conditions, foliar-applied amino acids are significantly promising to plant growth *(Abdel-Mawgoud et al., 2011; Koukounaras et al., 2013; Sadak et al., 2014)* resulting in notably better-quality growth and higher yields. This is due to their ability to optimise nutrition, chelate plant essential nutrients, and enhance primary and secondary metabolic functions of the plant.

When plants experience drought conditions – similar to those being currently experienced in some regions of Australia – foliar applied amino acids have an increased ability to significantly improve plant growth.

Under drought conditions, plants experience changes in metabolic functions as they try to offset low soil water potential and protect their plant tissues from dehydration. Two significantly notable changes in metabolic functions are an accumulation of proline and glycine in leaf tissue and a reduction in photosynthetic pigments with a correlating increasing of carotenoids.

Plant response to drought is related to low water potential and the fundamental role osmotic pressure plays in water stress responses and the resulting growth *(Osakabe, 2013)*. To prevent movement of water and nutrients from inside the plant back into the root zone when low potential occurs in the soil from drought, amino acids modulate membrane permeability and ion uptake. This dehydration avoidance occurs via solute accumulation in the tissue. By accumulating proline in plant tissues *(Gzik, 1997)*, lower water potential is created within the cells without experiencing any water loss *(Verslues, 2006)*.

Applying a product such as AminoElite™ or AminoKelp™ before turf experiences water stress, or even under drought conditions protects tissues from dehydration and the resulting movement of water and nutrients back into the soil. Turf is better able to withstand low water conditions without seeing water loss with the blades of grass.

A study in maize demonstrated up to a 30% yield increase (mass/1000 grains) when plants were sprayed with exogenous amino acids under drought conditions; spraying amino acids before water stress was experienced was up to 20% more effective than spraying once plants are stressed *(Kasraie, 2012)*. Research conducted by Azimi et al. *(2013)* showed applicated of amino acids at a concentration of 1 mL/L reduced damage due to stress by 70% in wheat.

A marked decrease in chlorophyll a, b, and total chlorophyll production results in an increase in carotenoid concentration in leaf tissues, this is shown when maize cultivars experience water stress *(Mohammadkhani, Nayer & Heidari, Reza 2007)*. Lower chlorophyll concentration means a slowed photosynthesis rate. This lessened rate leads to corresponding decreases in plant biomass and a reduction in yield but mitigates any further loss of water from plant tissues. Higher carotenoid levels protect the remaining chlorophyll from photo oxidation and the production of free radicals (reactive oxygen species).

Supplementing turfgrass with plant-available amino acids keeps the production of chlorophyll a, b, and total chlorophyll at a constant level, preventing a decrease in the rate of photosynthesis.

Turf continues to grow at a steady rate even if water stressed from drought.

Amino acids also improve beneficial microflora in the soil by strengthening microbial colonies, increasing their adversity to harsh climates. They are used by microbes to stabilise cell membranes or as an organic source of nitrogen and proteins. Robust microbes aid in better, more efficient nutrient uptake by plants and facilitate a healthier, more extensive root system in turf where shallow roots are a paramount concern.

High rates of amino acid applications do not necessarily trigger gene expression of the aforementioned drought stress mechanisms. Low applications of amino acids are proven to reduce the impact of drought stress *(Mohamed, 2006)* and improve the uptake of plant essential nitrogen, phosphorus, and potassium to combat yield reductions.

AA biosynthesis in plants occurs through complex pathways and is a very energy-intensive process with essential amino acids requiring more energy for biosynthesis than non-essential ones. By providing high-quality amino acids through foliar or soil applications of GrowGreen products, the amount of energy expended on amino acid synthesis by turf decreases. Not only does the turf garner the benefits of the applied amino acids, it allows turfgrass to take the energy it would sequester for AA production and utilise it elsewhere, further improving plant growth.

L-Shaped Versus D-Shaped Amino Acids

Not only is a range of amino acids found in GrowGreen products, but they are also found in plant available forms for easier utilisation. Amino acids, except for glycine, can occur in two different isomeric forms based upon their configuration: L-shaped and D-shaped.

Amino acid production within plant cells results in the L-shaped configuration, the shape the plants need to incorporate these building blocks into necessary proteins. In biostimulant products, amino acid configuration is a direct result of the type of digestion process implemented.

The use of high temperature digestions results in the conversion of L-amino acids to the “D” form, a chemical change known as racemisation. D-amino acids are typically not taken into by plant roots due to their negative effects in overdose concentrations; in particular D-amino acids demonstrate toxic effects when seen in high levels within plants *(Erickson, 2004)*.

When D-amino acids are found in the soil, bacterial populations in the rhizosphere utilise them as carbon and nitrogen sources and through reverse racemisation, they are converted back into L-amino acids *(Zhang, & Sun, 2014; Vranova et al., 2012)*. While the result is plant usable forms, it takes time and energy for the bacteria to complete the process.

GrownGreen products are digested at room temperature to generate L-shaped amino acids, eliminating energy expenditure from the turf plant to convert them into usable forms. Once applied they are immediately available for plant uptake facilitating faster utilisation.

Balanced, Consistent Phytohormone Profile.

There are five primary phytohormones that work to regulate cellular development and gene expression controlling plant growth and plant responses to stressors: auxins, cytokinins, gibberellins, abscisic acid, and ethylene. Through complex metabolic processes, they may function independently, symbiotically, and sometimes counterintuitively depending upon the concentration of the hormone, its sites of action, and the developmental stage the plant is in.

Due to the complex nature of the phytohormone interactions, it is the ratio at which all five phytohormones are present that signal certain processes within the plant to occur.

Table 2 describes the functions and benefits of the five classical plant hormone types available in GrowGreen's Microbe Plus™ Kelp and AminoKelp™ products.

Table 2. Phytohormone Types, Functions, and Benefits.

Phytohormone	***Functions within Plants***	***Benefits***
Auxin	Shoot and cell elongation; apical dominance and various tropisms; stimulates release of ethylene.	Increase in shoot and root biomass; initiation of secondary roots.
Cytokinins	Stimulates cell division, cell growth and differentiation; promotes growth of lateral buds; delay senescence.	Stimulates bud initiation; aids in root growth.
Gibberellins	Breaking bud and seed dormancy; mobilisation of storage materials in seed during germination; elongation and bolting of stems; stimulates flowering.	Increased fruit numbers; stalk elongation.
Abscisic Acid (ABA)	Maintains seed and bud dormancy; stimulates closing of stomata; acts as a growth inhibitor.	Improved resiliency to water stress.
Ethylene	Fruit ripening; leaf abscission; sex expression in flowers.	Induces uniform ripening of fruit.

How Phytohormones in GrowGreen Products benefit Turf

Phytohormones in GrowGreen products work to encourage efficient uptake of amino acids, nutrients, and water from the soil to stimulate faster turf growth and recovery after mowing and improved responses to stress.

The inclusion of all five of the phytohormones in GrowGreen products means the following when applied to turf:

- ***Auxins*** promote growth and development such as cell division, elongation, and differentiation *(Asgher et al, 2015)*. In turf this means quicker blade growth and recovery after mowing. They also help to promote heavy metal tolerance *(Hu et al, 2013)* with the potential to enhance phytoextraction.
- ***Cytokinins*** are involved in cellular proliferation and differentiation as well as the prevention of senescence, especially in the case of premature leaf senescence *(Schmulling, 2002)*. Applications of cytokinin to the root zone of turfgrasses inhibits the decline of growth and turf quality under heat stress and alleviates heat stress injury by maintaining active antioxidants.
- ***Gibberellic acid*** demonstrates enhanced plant water uptake and reduced stomatal resistance under saline conditions *(Maggio et al, 2010)*, efficient uptake and partitioning of ions within the plant *(Iqbal & Ashraf, 2013)*, and enhanced antioxidant enzyme activity by lowering the levels of reactive oxygen species *(Manjili et al, 2012)*. They also promote uniform growth in turf.
- ***Abscisic acid*** improves stress responses and adaptation through signalling pathways in the plant *(Wilkinson et al, 2012; Sah et al, 2016).* ABA also controls root growth and water content under drought stress *(Cutler et al, 2010)* ensuring adequate root growth and water uptake in turf when water is minimal.
- ***Ethylene*** signalling significantly regulates growth and stress responses through its receptors, whose specific roles are unclear *(Fahad et al, 2014)*.

GrowGreen products not only contain a broader spectrum of the classical phytohormones than leading competitors, but analytical results from independent testing laboratories demonstrate consistency in the hormone levels.

Inclusion of all five classical phytohormones in GrowGreen products extends the benefits seen from either soil or foliar application. The symbiotic and sometimes counterintuitive relationships between the plant hormone types are adversely affected when any of the types of hormones are lacking; this effect isn't seen when all five are present.

As a natural product, the plant hormone concentrations gained from the seaweed extract have the ability to vary, as natural products do. Consistent lab results validate the consistency and quality of GrowGreen's products regardless of their natural makeup.

Just like amino acids, biosynthesis of phytohormones within root and plant tissues is a highly energy intensive process. Supplementing exogenous phytohormones through biostimulant application allows turf to direct the energy it would use for hormone manufacturing towards other metabolic processes and growth. This results in better growth and other health attributes.

Leaching Loss Reduction and Increased Nutrient Delivery

Turf often has a shallow root zone, making nutrient delivery to plants a challenge. Frequent mowing decreases the blade length of turf reducing the surface area on which photosynthesis can occur, resulting in shorter, less expansive root systems.

Nutrient loss to leaching, especially on sandy soils found under golf course greens and other recreational turf fields is a common problem in turf maintenance, exacerbated by the short root systems.
The implementation of GrowGreen products help to ameliorate this problem, keeping nutrients in the root zone, encouraging prolific root growth, and increasing delivery through plant uptake.

Beneficial microorganisms in biostimulant emit different substances - organic acids, vitamins, growth hormones (auxins) - in the form of "sticky" substances that bind nutrients to particles in the soil stratum. Nutrients are easily attached to soil particles in the root zone and are difficult to wash off into deeper soil layers where they become unavailable for uptake, ensuring improved absorption by turf while protecting groundwaters from contamination.

GrowGreen products also contribute to the organic matter content in the soil, increasing the cation exchange capacity and water holding capacity significantly. Increasing the CEC holds more nitrate-N in the soil, reducing leaching, a benefit especially important in the sandy soils *(De Pascale, Rouphale, & Colla, 2017)* under golf course greens. Better nutrient retention reduces fertiliser needs. As water retention increases in soils, less water movement occurs through the soil profile and less fertiliser leaches into groundwater.

Enhanced Colonies Of Beneficial Soil Microbes

Plant growth promoting rhizobacteria (PGPR) are found in the rhizosphere of plants or on the root surface and are known to promote plant growth and strengthen plant defences against abiotic and biotic stresses.

GrowGreen's natural microbial digestion process using a proprietary blend of plant beneficial microbes produces products (such as AminoElite™, Microbe Plus™ Kelp, and AminoKelp™) containing a comprehensive suite of bacteria and fungi that provide beneficial microbes to turf soils.

- Root-associated microbes have a mutualistic interaction with symbiotic microbes and the host turf plant to improve growth under stress through the induction of cellular osmoregulation, phytohormonal balance, and changes in metabolic processes *(Nadeem, 2014; Park, 2017)*.
- Plant defences against pathogens are strengthened through pathogen antagonism: PGPR outcompetes other pathogens for needed resources, in turn producing compounds such as antibiotics and anti-fungal metabolites.
- This special class of bacteria converts nitrogen, phosphorus, and iron found in the soil to plant usable forms, facilitating uptake through enhanced solubility *(Canbolat, 2006; Liao, 2008)*.

A vigorous root system strengthens turf response to disease and disadvantageous environmental conditions.

PGPR also synthesise phytohormones in the rhizosphere or root tissues *(Etesami et al, 2015)* to stimulate changing root morphology when exposed to abiotic stresses *(Spaepen et al, 2008; Khan et al, 2011)*. A vigorous root system strengthens turf response to disease and disadvantageous environmental conditions.

- Cytokinin-producing species stimulate the root development of plants *(Naz et al, 2009)* and can protect turf against root rotting diseases caused by ectotrophic root-infecting (ERI) fungi;
- Root-associated IAA-producing bacteria have been found to improve drought stress and plant growth/development under nutrient-poor soil conditions.

Beneficial fungi found in the soil or introduced through biostimulants creates a symbiotic relationship with the roots of turfgrasses. Known as a mycorrhizal association, the fungus colonises the host plant's root tissues, either intracellularly as in arbuscular mycorrhizal fungi (AMF or AM), or extracellularly as in ectomycorrhizal fungi. Stimulating the mycorrhizal associations through the application of AminoElite™, Microbe Plus™ Kelp, and AminoKelp™ in turf systems improves water and nutrient uptake, pest and disease resistance, and overall soil health.

Strengthened Plant Defences

When turf undergoes water stress, the overall health of the plant is affected, impairing its defences against other abiotic stressors making it more susceptible to infestation of fungal infections, diseases, insects, and other pathogens. Applying GrowGreen products to turf under drought conditions helps to boost plant defence responses against other abiotic stresses through various product components, strengthening the overall health of the turf and preventing other management problems.

Chitin in AminoElite™ and AminoKelp™

Most commonly found in the exoskeletons of arthropods such as the shells of crustaceans (a component found in both AminoElite™ and AminoKelp™) and the outer coverings of insects, chitin is a monosaccharide derivative of glucose. It has been recognized for many years as playing an important role in the activation of plant defence responses *(Boller, 1995)* even though it isn't naturally occurring in plants.

Chitin comprising about 10% of fungal cell wall structures *(Ohno, 2007)*. When chitin is present within turfgrass and a fungal infection develops such as ectotrophic root-infecting (ERI) fungi, the expression of a chitin-degrading enzyme, chitinase is triggered. Chitinase accumulates at the infection site degrading the fungal cell wall to inhibit the fungal invasion. In addition, the breakdown of chitin into fragments (chitooligosaccharides or chitin oligomers) function as elicitors for numerous other defence genes found within the plant *(Eckardt, 2008).*

Crustaceans are an excellent source of chitin. When chitooligosaccharides are applied via a biostimulant such as AminoElite™ or AminoKelp™, the resulting expression of the enzyme chitinase enhances the overall immune system of turf and its resistance against various pathogens *(Wan, 2008; Tanabe, 2006)*.

Increased root growth would allow for better nutrient uptake.

Polysaccharides in Microbe Plus® Kelp and AminoKelp™

The red and brown algae types of seaweed -- found in Microbe Plus™ Kelp, and AminoKelp™ -- are a source of complex polysaccharides not found in land plants *(Siegel & Siegel, 1973; Painter, 1983; Blunden & Gordon, 1986; Craigie, 1990; Chizhov et al., 1998; Duarte et al., 2001)*. Beneficial carbohydrates in the form of alginate, laminarin, and fucoidan present in brown seaweeds have been shown to have many benefits for plant growth *(Painter, 1983; Lane et al., 2006)*.

Alginic acid is a structural component of cell walls, lending flexibility to seaweed, allowing it to withstand tidal forces. When applied to the soil, salts from alginic acid combine with metallic ions in the soil to form high-molecular-weight complexes; these complexes absorb moisture, swell in size, retain soil moisture, and in turn improve crumb structure of the soil.

Better soil aeration and capillary activity of soil pores results, stimulating the growth of the root system and boosting soil microbial activity *(Eyras et al., 1998; Gandhiyappan & Perumal, 2001; Moore, 2004).* In turf systems where the root systems are notoriously shallow, increased root growth would allow for better nutrient uptake and access to water deeper in the soil profile promoting better plant growth even in times of drought.

Laminarin, a storage β-glucan is present in brown seaweed species *(Kadam, 2015).* It is created through photosynthesis and acts as an energy reserve compound *(Garcia, 2018).* Laminarin has been shown to stimulate natural defence responses in plants and is involved in the induction of genes encoding various pathogenesis-related (PR) proteins with antimicrobial properties *(Fritig et al., 1998; van Loon & van Strien, 1999).*

Nutrient Inclusion

Potassium provided via AminoElite™, Microbe Plus® Kelp, and AminoKelp™ applications and silica from AminoElite™ and AminoKelp™ also strengthen plant defences against both abiotic and biotic stressors in turfgrass.

Potassium

Regarding abiotic stresses, potassium helps to increase a plant's overall hardiness to withstand drought, cold temperatures, and salinity.

- Potassium helps to sync stomatal opening/closing under drought stress through the regulation of cell water potential and turgor pressure *(Jordan et al., 2008; Peiter 2011)* to direct respiration and transpiration rates.
- Potassium activates the plant's antioxidant system under cold stress to prevent cellular damage or rupture.
- Under saline conditions potassium replaces sodium ions absorbed from salt-affected irrigation waters minimising sodium-induced problems in turf such as mild chlorosis of the grass blades, necrosis of leaf margins, stunted root development, compromised water uptake.

Supplementation of potassium thickens cell walls to guard against diseases and pathogens.

In terms of disease and pathogen resistance, potassium aids by strengthening cell walls within the plant and improving the stomatal functioning. Potassium deficiency affects various aspects of plant metabolism resulting in decreased leaf area, thinning of tissues, and wilting of leaves *(Severtson et al., 2016)*. Supplementation of potassium thickens cell walls to guard against diseases and pathogens. This encourages preventative protection against common problems in turfgrasses such as *Verticillium fusarium*, *Gaeumannomyces* (ERI), and damping off.

Silica

Newer research demonstrates silica's ability to increase resistance against both biotic and abiotic stressors through a variety of mechanisms. With turf systems being subject to a barrage of stresses, this increased resistance helps to minimise the occurrence of stress-induced reductions in growth and quality.

- To protect against insects and fungal infections, silica strengthens cell walls by increasing the production of cellulose and hemicellulose *(Van Bockhaven et al, 2013)*. In turf the strengthening of cell walls due to silica can act as a preventative against African black beetle, reducing fungicide treatments.
- When under drought stress, silica decreases leaf transpiration *(Yoshida, 1965; Wong et al, 1972; Matoh et al, 1991)*, increases stomatal conductance *(Chen et al, 2011)*, and maintains chlorophyll concentration *(Lobato et al, 2009)*. Some studies have shown it even enhances root growth and in turn nutrient uptake through more root surface area *(Barber, 1984)*.
- In saline conditions – which are increasingly occurring due to salt-laden irrigation waters in turf production and maintenance - silica reduces the translocation of sodium to protect photosynthetic apparatus *(Liang, 1998)* and slows lipid peroxidation, the most damaging process in living organisms *(Gill & Tuteja, 2010; Liang et al, 2003; Moussa, 2006; Soylemezoglu et al, 2009)*.
- If plants are exposed to heavy metals silica helps to limit the translocation of ions from the roots to the shoots or participates in coprecipitation of metals such as aluminium, arsenic, and cadmium *(Emamverdian, 2018)*.

Improved Water Use And Chemical Application Efficiency Through Adjuvant Use

GrowGreen's biostimulants such as AminoElite™, Microbe Plus® Kelp, and AminoKelp™ provide many proven benefits to plants, with enhanced response to stresses helping to facilitate plant growth even under subpar conditions. While different in its formulation and benefits, the use of GrowGreen's Xtend™ as an adjuvant can improve the efficiency of not only the aforementioned biostimulants, but also other chemical applications in turf production and maintenance.

This improved efficiency correlates to a reduced amount of plant protection applied. When combined in a spray application, Xtend™ improves the efficiency of other products by more than 20% due to its adjuvant characteristics, resulting in a significant yield increase. Turf grass boasts a labour-intensive management strategy that requires frequent application of chemicals. A reduction in spraying not only reduces input costs but also the labour cost associated.

Using Xtend™ as an adjuvant reduces the treatment cost, while also significantly reducing the amount of water needed for treatment application.

When oil adjuvants and nitrogen fertilisers are added to herbicide sprays in maize, nicosulfuron applications can be reduced from 60 g ha^{-1} to 30 g ha^{-1} with comparable grain yield *(Idziak, & Woznica, 2013)*. With high levels of nitrogen fertilisers applied to turf to maintain a lush, green appearance, a reduction of that degree in fertiliser application rates due to using Xtend™ would result in a significant decrease in chemical input costs.

When using foliar sprays for fertiliser application, a plant's ability to uptake nutrients through the leaves is directly related to the ability of the spray to stick to plant parts. Research shows adjuvant use in the foliar application of phosphorus (P) demonstrates advancing contact angle for adjuvant treatments, with no adverse impact on P uptake by the plants *(Peirce, Priest, Facelli, McBeath, & McLaughlin, 2014)*. Thus, leading to better nutrient uptake and improved turf growth.

Water conservation is critical in areas such as southern Australia where increasing salinity and pressure on water resources is presenting dire challenges for turf production and maintenance. GrowGreen Xtend™ offers a plausible alternative method of water conservation.

Conclusion

The inclusion of GrowGreen products such as AminoElite™, Microbe Plus® Kelp, AminoKelp™, and Xtend™ can be extremely advantageous in increasing turf quality and production, especially under drought conditions. The use of biostimulants and adjuvants in high-input systems like turf production and maintenance provide amino acids, phytohormones, reduce leaching losses, enhance beneficial soil microorganisms, strengthen plant defences and improve water and chemical use efficiency.

References

Abdel-Mawgoud, A. M. R., El-Bassiouny, A. M., Ghoname, A., & Abou-Hussein, S. D. (2011). Foliar application of amino acids and micronutrients enhance performance of green bean crop under newly reclaimed land conditions. Australian Journal of Basic and Applied Sciences, 5, 51-55.

Aung, L. H., & Flick, G. J. (1980). The influence of fish solubles on growth and fruiting of tomato. Hort Science, 15, 32-33.

Aung, L. H., & Flick, G. J. (1982). Fish solubles as fertiliser for growing plants. VPI-SG-82-06, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Aung, L. H., Hubbard, J. B., & Flick, G. J. (1983). Mineral composition of vegetable crops fertilised with fish soluble nutrients. Journal of Agricultural and Food Chemistry, 31, 1259-1262.

Aung, L. H., Flick, G. J., Bluss, G. R., Aycock, H. S., Keefer, R. F., Singh, R., Brandon, D. M., Griffin, J. L., Hovermale, C. H., & Stutte, C. A. (1984). Growth responses of crop plants to fish soluble nutrients fertilisation. VPI-SG-84-07, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Barber SA (1984) Soil nutrient bioavailability: a mechanistic approach. Wiley-Interscience, New York

Blunden, G., & Gordon, S.M. (1986). Betaines and their sulphono analogues in marine algae. In: F. E. Round & D. J. Chapman DJ (Eds.) Progress in phycological research, vol 4 (pp 39-80). Bristol: Bristol Ltd.

Boller, T. (1995). Chemoperception of microbial signals in plant cells. Annual Review of Plant Physiology & Plant Molecular Biology, 46, 189–214.

Butchova, H., Svobodova, Z., & Velisek, J. (2008). Presence of amino acids in specific tissues of the two hybrids of common carp (Cyprinus carpio L.). Folia Veterinaria, 52(3-4), 189-193.

Canbolat, M. Y., Bilen, S., Cakmakci, R., Sahin, F., & Aydin, A. (2006). Effect of plant growth-promoting bacteria and soil compaction on barley seedling growth, nutrient uptake, soil properties and rhizosphere microflora. Biology and Fertility of Soils, 42, 350-357.

Chen W, Yao XQ, Cai KZ, Chen J (2011) Silicon alleviates drought stress of rice plants by improving plant water status, photosynthesis and mineral nutrient absorption. Biol Trace Elem Res 142:67–76. doi: 10.1007/s12011-010-8742-x

Chizhov, A. O., Dell, A., Morris, H.R., Reason, A. J., Haslam, S. M., & McDowell, R. A. (1998). Structural analysis of laminarin by MALDI and FAB mass spectrometry. Carbohydrate Research, 310, 203–210.

Craigie, J.S. (1990). Cell walls. In: K.M. Cole & R. G. Sheath RG (Eds.), Biology of the red algae (pp. 2210257). Cambridge: Cambridge University Press,

du Jardin, P. (2015). Plant biostimulants: Definition, concept, main categories, and regulation. Scientia Horticulturae, 196, 3-14.

Duarte, M. E. R., Cardoso, M. A., Noseda, M. D., & Cerezo, A.S. (2001). Structural studies on fucoidan from brown seaweed Sagassum stenophyllum. Carbohydrate Research, 333, 281–293.

Eckardt, N. (2008). Chitin Signaling in Plants: Insights into the Perception of Fungal Pathogens and Rhizobacterial Symbionts. The Plant Cell, 20, 241–243.

Abolghassem Emamverdian, Yulong Ding, Yinfeng Xie, and Sirous Sangari, “Silicon Mechanisms to Ameliorate Heavy Metal Stress in Plants,” BioMed Research International, vol. 2018, Article ID 8492898, 10 pages, 2018. https://doi.org/10.1155/2018/8492898.

Emino, E. R. (1981). Effectiveness of fish soluble nutrients as fertiliser on container grown plants. Hort Science, 16, 338.

Erikson, O., Hertzberg, M., & Nasholm, T. (2004). A conditional marker gene allowing both positive and negative selection in plants. Nature Biotechnology, 22, 455–458.

Eyras, M. C., Rostagno, C. M., & Defosse, G.E. (1998). Biological evaluation of seaweed composting. Compost Science & Utilization, 6, 74–81.

Fritig, B., Heitz, T., & Legrand, M. (1998). Antimicrobial proteins in induced plant defence. Current Opinion in Immunology, 10, 16–22.

Gandhiyappan, K., & Perumal, P. (2001). Growth promoting effect of seaweed liquid fertiliser (Enteromorpha intestinalis) on the sesame crop plant. Seaweed Research and Utilization, 23, 23–25.

Garcia-Vaquero, M, Rajauria, G., Tiwari, B., Sweeney, T., & O'Doherty, J. (2018). Extraction and Yield Optimisation of Fucose, Glucans and Associated Antioxidant Activities from Laminaria digitata by Applying Response Surface Methodology to High Intensity Ultrasound-Assisted Extraction. Marine Drugs, 16(8), 257.

Gill SS, Tuteja N (2010) Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. Plant Physiol Biochem 48:909–930. doi: 10.1016/j.plaphy.2010.08.016

Idziak, R., & Woznica, Z. (2013). Effect of Nitrogen Fertilisers and Oil Adjuvants on Nicosulfuron Efficacy. Turkish Journal of Field Crops, 18(2), 174-178.

Jordan-Meille, L., & Pellerin, S. (2008). Shoot and root growth of hydroponic maize (zea mays l.) as influenced by k deficiency. Plant & Soil, 304(1-2), 157–168.

Kadam, S. U., Tiwari, B. K. and O'Donnell, C. P. (2015). Extraction, structure and biofunctional activities of laminarin from brown algae. International Journal of Food Science Technology, 50, 24-31.

Koukounaras, A., Tsouvaltzis, P., & Siomos, A. S. (2013). Effect of root and foliar application of amino acids on the growth and yield of greenhouse tomato in different fertilisation levels. Journal of Food, Agriculture & Environment, 11, 644–648.

Lane, C. E., Mayes, C., Druehl, L. D., & Saunders, G. W. (2006). A multi-gene molecular investigation of the kelp (Laminariales, Phaeophyceae) supports substantial taxonomic re-organization. Journal of Applied Phycology, 42, 493–512.

Liang YC (1998) Effects of Si on leaf ultrastructure, chlorophyll content and photosynthetic activity in barley under salt stress. Pedosphere 8:289–296

Liang YC, Chen Q, Liu Q, Zhang WH, Ding RX (2003) Exogenous silicon (Si) increases antioxidant enzyme activity and reduces lipid peroxidation in roots of salt-stressed barley (Hordeum vulgare L.). J Plant Physiol 160:1157–1164. doi: 10.1078/0176-1617-01065

Liao, M., Hocking, P., Dong, B., Delhaize, E., Richardson, A., and Ryan, P. (2008). Variation in early phosphorus-uptake efficiency among wheat genotypes grown on two contrasting Australian soils. Australian Journal of Agricultural Research, 59, 157-166.

Lobato AKS, Coimbra GK, Neto MAM, Costa RCL, Filho BGS, Neto CFO, Luz LM, Barreto AGT, Pereira BWF, Alves GAR, Monteiro BS, Marochio CA (2009) Protective action of silicon on water relations and photosynthetic pigments in pepper plants induced to water deficit. Res J Biol Sci 4:617–623. doi: 10.3923/rjbsci.2009.617.623

Logendra, S. (1984). Fertilisation of Lycopersicon esculentum Mill. cv. Fireball with ammonium, nitrate and fish soluble nutrients. (Unpublished master's thesis). Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Matoh T, Murata S, Takahashi E (1991) Effect of silicate application on photosynthesis of rice plants. Jpn J Soil Sci Plant Nutr 62:248–251

Mohammadkhani, Nayer & Heidari, Reza. (2007). Effects of water stress on respiration, photosynthetic pigments and water content in two maize cultivars. Pakistan journal of biological sciences: PJBS. 10. 4022-8. 10.3923/pjbs.2007.4022.4028.

Moussa HR (2006) Influence of exogenous application of silicon on physiological response of salt-stressed maize (Zea mays L.). Int J Agri Biol 8:293–297

Ohno, N. (2007). Yeast and Fungal Polysaccharides. In H. Kamerling (Eds.), Comprehensive Glycoscience From Chemistry to Systems Biology, (pp. 559-577). Amsterdam, Netherlands: Elsevier.

Painter, T. J. (1983) Algal polysaccharides. In G. O. Aspinall (Ed.), The polysaccharides (pp. 195-285). New York, NY: Academic Press.

Peiter, E. (2011). The plant vacuole: emitter and receiver of calcium signals. Cell Calcium, 50(2), 120–128.

Robertson, J. D. (1961). Studies on the Chemical Composition of Muscle Tissue. Journal of Experimental Biology, 38:707-728.

Sadak, M. S. H., Abdelhamid, M. T., & Schmidhalter, U. (2014). Effect of foliar application of amino acids on plant yield and some physiological parameters in bean plants irrigated with seawater. Acta Biológica Colombiana, 20, 141–152. doi:10.15446/abc.v20n1.42865

Severtson, D., Callow, N., Flower, K., Neuhaus, A., Olejnik, M., & Nansen, C. (2016). Unmanned aerial vehicle canopy reflectance data detects potassium deficiency and green peach aphid susceptibility in canola. Precision Agriculture, 17(6), 1–19.

Siegel, B Z., & Siegel, S. M. (1973). The chemical composition of algal cell walls. In A. I. Laskin & H. Lechevalier (Eds.), Critical reviews in microbiology (pp. 1-26). Cleveland, OH: CRC Press.

Skibniewska, K. A., Zakrzewski, J., Klobukowski, J., Bialowias, H., Mickowska, B., Guziur, J., Walczak, Z., & Szarek, J. (2013). Nutritional value of the protein of consumer carp Cyprinus carpio L. Czech Journal of Food Sciences, 31(4), 313–317.

Snyder, G. W. (1982). Responses of barley and wheat cultivars to applications of fish solubles and ammonium nitrate. (Unpublished master's thesis). Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Soylemezoglu G, Demir K, Inal A, Gunes A (2009) Effect of silicon on antioxidant and stomatal response of two grapevine (Vitis vinifera L.) rootstocks grown in boron toxic, saline and boron toxic-saline soil. Sci Hortic Amst 123:240–246.

Tanabe, S., Okada, M., Jikumaru, Y., Yamane, H., Kaku, H., Shibuya, N., & Minami, E. (2006). Induction of resistance against rice blast fungus in rice plants treated with a potent elicitor, N-acetylchitooligosaccharide. Bioscience, Biotechnology, and Biochemistry, 70(7), 1599-605.

***Turf** Australia*. (2016). Retrieved October 1, 2019, from https://www.turfaustralia.com.au/aboutus/facts-figures

Toppe, J., Albrektsen, S., Hope, B., & Aksnes, A. (2007). Chemical composition, mineral content and amino acid and lipid profiles in bones from various fish species. Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology, 146(3), 395-401. doi:10.1016/j.cbpb.2006.11.020.

Van Bockhaven J, De Vleesschauwer D, Höfte M (2013) Towards establishing broad-spectrum disease resistance in plants: silicon leads the way. J Exp Bot 64:1281–1293. doi: 10.1093/jxb/ers329

Van Loon, L. C., & van Strien, E. A. (1999). The families of pathogenesis-related proteins, their activities, and comparative analysis of PR-1 type proteins. Physiological and Molecular Plant Pathology, 55, 85–97.

Verslues, P. E., Agarwal, M., Katiyar-Agarwal, S., Zhu, J. and Zhu, J. (2006), Methods and concepts in quantifying resistance to drought, salt and freezing, abiotic stresses that affect plant water status. The Plant Journal, 45: 523-539. doi:10.1111/j.1365-313X.2005.02593.x

Vranova, V., Zahradnickova, H., Janous, D., Skene, K. R., Matharu, A. S., Rejsek, K., & Formanek, P. (2012). The significance of D-amino acids in soil, fate and utilization by microbes and plants: review and identification of knowledge gaps. Plant and Soil, 354, 21-39. doi:10.1007/s11104-011-1059-5

Wan, J., Zhang, X. C., Neece, D., Ramonell, K. M., Clough, S., Kim, S.Y., Stacey, M.G., & Stacey, G. (2008). A LysM receptor-like kinase plays a critical role in chitin signalling and fungal resistance in Arabidopsis. The Plant Cell, 20(2), 471-81.

Wong YC, Heits A, Ville DJ (1972) Foliar symptoms of silicon deficiency in the sugarcane plant. Proc Cong Int Soc Sugarcane Technol 14:766–776

Yoshida S (1965) Chemical aspect of silicon in physiology of the rice plant. Bull Natl Agric Sci B 15:1–58

Zhang, G., & Sun, H. J. (2014). Racemization in reverse: evidence that D-amino acid toxicity on Earth is controlled by bacteria with racemases. PLOS One, 9(3), e92101. doi:10.1371/journal.pone.0092101

Zhu, D., Ortega, C. F., Motamedi, R., Szewciw, L., Vernere, F., & Barthela, F., (2011). Structure and mechanical performance of a ''modern'' fish scale. Advanced Engineering Materials, 13, B1-B10