Grower Summary

PE 017

Nutrient management for disease control in tomato: A review

Final 2014

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

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Before using all pesticides check the approval status and conditions of use.

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GROWER SUMMARY

Headline

- Modulation of nutrition (e.g. N, Ca, Si) can produce plants that are more resistant to pathogen attack.
- Increased plant resistance will potentially reduce the use of pesticides, improve efficiency of production, optimise product quality and increase the potential for effective use of biological controls.
- Yield and fruit quality must be considered in novel recipes.
- As well as increasing concentrations, active uptake by the plant must be encouraged.
- Targeted information for growers remains scant; further R&D is required to provide new insights and develop robust strategies of nutrient management for increased resistance to diseases that are consistent and effective.

Background

Plant nutrient management has been primarily targeted at achieving high crop yield and quality, with relatively little work carried out to enhance disease resistance. On a commercial basis, any improved resistance that can be achieved with targeted mineral nutrition must be balanced against optimum yields, fruit quality, taste and flavour.

Targeted and accurate nutrient management is beneficial for numerous reasons. Firstly, the cost of fertiliser is kept low and waste is minimised. Successful cropping is becoming increasingly challenged by the need for water use efficiency (Water Framework Directive, 2000/60/EC) and less reliance on harsh chemicals (Sustainable Use Directive, 2009/128/EC) at the EU level. This has hastened the need to recycle water and nutrients, with the target of emitting as little drain water as possible. Systems that allow greater accuracy may further facilitate manipulation of the crop with beneficial effects, not only on yield, but also on disease susceptibility. Currently, numerous growing systems exist within UK tomato production sites, which involve a range of substrates and fertigation techniques.

There has been little research over the last 10 years evaluating the role of nutrition in disease management in protected edible crops. This literature review and critical examination of the latest research findings was therefore undertaken to identify links between nutrient management and disease.

The commercial objective of this project was to evaluate the potential of targeted nutrient management as a cost effective and sustainable approach to enhance crop pathogen resistance. Application of this approach would enhance the reputation of the industry, and will help to meet the expectations of the retailers and consumers in the purchase and consumption of safe and nutritious food. The project aim was to clarify the role of individual nutrients for plant disease resistance, tolerance and reduced disease development in tomato. Specific objectives were:

1. To summarise current and potential future practices in nutrition of hydroponic tomato crops;
2. To review current literature on the impact of crop nutrition on the occurrence and severity of plant diseases in protected edible crops and identify knowledge gaps;
3. To identify potential nutrient management strategies for use in hydroponic tomato which have a high probability of conferring improved disease control to long season tomato crops;
4. To propose research and development areas where there appears to be significant potential to develop crop nutrition management strategies to assist sustainable disease control in tomato.

Summary and main conclusions

Objective 1 – Nutrition practices in hydroponic tomato crops

Current practices

Crop fertiliser application systems in hydroponic crops are usually based on two tanks of stock solution (to prevent precipitation of phosphates) which continually dose the irrigation solution applied to the crop. UK crops are most commonly grown in rockwool, coir or by Nutrient Film Technique (NFT), though other substrates are available. NFT is less popular compared to rockwool or coir because it has a lower buffering capacity, necessitating more active nutrient management and ensuring no leaks, blockages or pools exist in the system. Measurements of pH and EC values are regularly recorded by growers, and it is possible to make alterations to the nutrient solution based on these. However, in order to monitor the concentration of individual nutrients and the balance between them, it is necessary to take samples of the hydroponic system solution for laboratory analysis; ideally taken on a fortnightly basis.

Solution target values were collected via a questionnaire to growers. There was some variability around the ‘optimum’ concentration for each nutrient supplied. Growers take account of environmental variables and varietal differences and work to slightly different product specifications. Most recipes used in hydroponics are many years old and based on original empirical nutrient recipes for starter solutions (dependent on the different hydroponic systems and influencing conditions) and refill solutions (accounting for daily uptake conditions). Improved and more targeted recipes have, over the years, resulted in higher yields, but water and nutrient losses to the environment remain a problem. Nutrient losses occur through flushing of the system, denitrification, leaks (to groundwater), but mainly through surplus nutrients added to open systems, which is usually around 30% of the total.

Future practices – A move towards nutrient recirculation systems

Initially hydroponic systems were all ‘run-to-waste’, whereby fertiliser stock solutions were used to dose the irrigation water, which was sent through the crop only once before being disposed of, usually by release into the environment. Whilst open run to waste systems are simple, cheap and relatively easy to manage, compared with closed systems such practices are in the long term unsustainable. Currently, a number of growers are using at least partially ‘closed’ or recirculating systems, whereby nutrient solution is collected, stored, re-dosed to appropriate levels and sent around the crop multiple times. In a fully recirculating system, a small amount of solution may still have to be discharged, for example if chloride or sodium levels climb too high and the system requires flushing. Ultimately, this system provides the perfect opportunity to optimise nutrient and water efficiency, and results in release of fewer nutrients to the environment. This is becoming increasingly regulated because of the harmful effects high nutrient levels can have on natural ecosystems, and a growing system that has minimal environmental impacts is more attractive to retailers and consumers. Importantly, recirculating systems also save on fertiliser and water costs, and as they require more active management, they also facilitate a more controlled and targeted nutrient regime that could result in higher fruit quality or yields. Savings made could encourage the move away from cheaper chloride based fertiliser products that can result in chloride build up in solution, and towards higher quality nitrate based products that also contribute nitrates to the solution and may render solution nitrogen levels to be manipulated more easily.

A fully recirculating system may also render growing with NFT a more attractive option, as greater care and attention will need to be paid to consistently achieving target nutrient levels. Due to the EU legislation noted above, it is becoming increasingly likely that all UK growers will have to make the shift to recirculating systems, as has occurred in The Netherlands. Furthermore, it is likely that restrictive legislation will be implemented regarding water abstraction, adding further incentive to use water efficiently. Installing a more cost-effective and technologically advanced system now, will better prepare nurseries for these future challenges. A hydroponic system that is easily manipulated will mean that future research and development can quickly be implemented at a commercial scale, including the implementation of models based upon growth and transpiration, and which involve feedback based on climatic changes and rootzone environment. There is also the potential to introduce the management of diseases and to incorporate fruit quality. The introduction of ion selective electrodes (ISEs), represents a way to continually monitor and dose a nutrient solution in line with these ideals. In future hydroponic growing, nutrient demand and nutrient supply could be synchronized, and nutrient and water losses would be minimised by the move from open to closed recirculating systems.

Objective 2 – Review of current literature

Over 190 scientific papers were identified and reviewed. Plant mineral nutrient impacts on pathogen function were classified in relation to pathogen identity and lifestyle, for example whether vascular, foliar, or root infecting; fungal, bacterial or viral; biotroph, nectrotroph or hemibiotroph. The degree of control reported and the potential to apply to commercial crops for disease control were evaluated and synthesised. Whilst this work focused on hydroponic crops, soil grown crop data were also used to provide insights on the potential for disease-suppressing nutrient management. The likely extent to which selected nutrient management could control disease was evaluated and factors influencing how widely applicable techniques would be in a commercial production environment are discussed. The main conclusions are listed below.

- The effect of over 15 nutrients on a variety of diseases on various crops have been researched and are discussed in the Science Section (Tables 8 & 9);
- Many studies have used tomato as a model crop, but methods are not standardised;
- Effects observed in one crop cannot be easily transferred to another;
- Results include successful applications of silicon and manganese when the crops are deficient, use of silicon in glasshouse crops, use of metals to improve biocontrol efficacy and the promising use of calcium and nitrogen in tomato;
- The nutrient elements known to have the largest potential effect on disease resistance/tolerance outside the deficiency range are nitrogen, calcium, silicon, boron and phosphorus as phosphite;
- A number of interesting interactions of nutrients with biocontrols were noted;

- There has been a considerable amount of research on hydroponic nutrition overseas in recent years and it appears to be a topical research area currently;
- Nutrition in soilless tomato production presents a number of conflicts between crop yields, produce quality, microorganisms, consumer and retailer demands and environmental concerns and ideally, an optimal strategy will incorporate as much of the production process as possible.

Objective 3 – Identifying potential strategies

Problem diseases identified by UK tomato growers include Botrytis, powdery mildew and a variety of viruses, especially *Pepino mosaic virus*. Maintaining nutrient levels at the 'optimum' for plant growth still appears to be the best general strategy, though the nutrient levels considered 'optimum' in hydroponics vary and there are no universally agreed values. One example in current use is illustrated in Table 1. Recirculating systems are becoming more widely used, and as more growers may move to recirculation it is important that newly developed strategies consider this. If a specific disease threat is identified, or an epidemic occurs, there may be more targeted strategies that could have beneficial effects, on top of this general guide. However, although supplementation with additional nutrition has been found to reduce some diseases, the presence of excessive fertiliser, especially nitrogenous fertilisers, may also make the severity of other diseases worse. This may be linked to the different nutrition requirements of different pathogens, or to the type of plant growth produced. Currently, this approach may not be cost effective and further research and development is required.

Table 1. Optimum nutrient concentrations for hydroponic tomato plants (as supplied by May Barn Consultancy Ltd and used as part of nutrient solution lab analysis)

Slab Sample	Minimum	Optimum	High	Comments
RAG Chart: Tomato	Amber: Likely to result in nutrient deficiency	Green: at or near the optimum concentration	Red: Likely to result in plant damage	
pH	< 5.5	6.0	> 6.5	Target range: 5.8-6.2
EC (µS / cm nutrients)	< 2,500	4,000	> 6,000*	*Early season growth control
Major (mg / litre)				
NH_4-N	0	2	> 10	As low as possible
NO_3-N	150	250	> 300	
P	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
K	< 400	500	1,000	Toxicity: rare
Ca	150	250	> 300	
Mg	< 65	80	> 100	High K inhibits Mg absorption
Na	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Cl	< 100	200	> 400*	*Early season growth control
SO4-S	< 50	100	> 200	
Trace (mg / litre)				
Fe	< 2.0	3.0-4.0	> 5.0	
Mn	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
B	< 0.3	0.4-0.6	> 1.0	
Zn	< 0.5	1.0	> 1.5	Link with P and Mn
Cu	< 0.05	0.1	> 0.2	
Mo	< 0.03	0.05	> 0.1	
Ratios				
K:N	> 3.0	2.0	< 1.6	
K:Ca	> 3.0	2.0	< 1.6	
K:Mg	> 8.0	6.0	< 5.0	
K:Na	> 5.0	2.5	< 1.25	Important in recirc.
K:Cl	> 5.0	2.5	< 1.25	Important in recirc.

Information gathered in the review shows that altering the basic nutrient recipe could have advantages at certain points in the season, at certain environmental conditions, or under certain disease pressures. A nutrient regime that is frequently adjusted for variables such as crop health and fruit quality may not always be consistent with the highest yield. As the crops in the UK are largely specialist, high quality varieties, it makes sense that a forward thinking nutrient regime should account for consequences on fruit appearance, structure, taste and nutritional content.

The ratios contained in the above optimum regime are the most important aspect, and must be maintained whatever absolute values may change. An important ratio in terms of pathogen attack is the ammonium to nitrate ratio. This is generally always kept low due to numerous other factors. Too much ammonium can cause issues of pH falling too low and of calcium deficiency, whereas nitrates tend to be more beneficial in terms of yield as they are mobile, non-volatile and their assimilation is a more energy efficient process. This ratio's impact on the ability of different types of pathogen to cause damage is notable with effects in both directions. However the potential to manipulate it may be limited, as it is advised (with good reason) that ammonium is not supplied at above 15 % of total nitrogen supply. These recommended nutrient ratios attempt to account for the abiotic effects of pH and EC, synergistic relationships between nutrients, climate, and biotic variables such as pathogens, beneficial microorganisms and plant growth and transpiration.

Using the example recipe as a base, alterations could be made in light of our findings to increase the resistance/decrease the susceptibility of the crop to certain diseases, or to make the nutrient solution less hospitable to specific pathogens (Table 2). Regardless of impacts on disease, nutrient elements must not be allowed to climb to concentrations likely to result in phytotoxicity. Focus is on those diseases that are commonly a problem in UK growing. Many of the diseases where control with nutrition appears most promising are not problems in the UK at present (see Science Section). It is unlikely that these suggested changes to nutrient regimes would remain in place throughout the growing season, but may be useful at times of heightened risk or when infection occurs. It is clear that nutrition is not an equally applicable solution to all disease problems, but may be a useful part of IPM against some.

Table 2. Hydroponic tomato nutrition 'toolkit' for managing disease

Disease	First usual occurrence	Suggested change to optimum	Risks	Benefits
Botrytis cinerea	April onwards	Consider increasing N to strengthen plant against attack. Additional Ca has also been found to reduce *Botrytis* severity. In sweet basil, a regime using half the N but double the Ca to maintain appropriate nutrient balance was utilised successfully against *Botrytis.* Control of humidity is important in encouraging uptake and movement of Ca into the plant.	May encourage infection by obligate diseases. May also result in vigorous plants that require more pruning.	Significant reductions in disease have been demonstrated experimentally. Additional Ca may protect against BER and increase shelf life. Humidity control benefits both nutrition and disease control.
Oidium neolycopersici	March - September	Reduce N, especially in nitrate form as this obligate pathogen is favoured by factors that encourage plant growth. Si has also been shown to reduce powdery mildew experimentally. Disease levels were lowest at moderate EC (approx. 4 mS).	Reducing N may encourage more opportunistic pathogens. Adding Si to the nutrient solution may cause problems by precipitating out of solution and blocking the irrigation system. It may also necessitate an additional fertiliser dosing tank.	Significant reductions in disease have been demonstrated experimentally, and some fertiliser costs are saved.
Viruses E.g. PepMV, ToMV	February onwards	A study involving Ca sprays may be promising. It is beneficial to provide the plant with supraoptimal nitrate N to allow the plants to grow through the initially strong symptoms of viral infection. Using a vigorous rootstock may promote a similar growth effect as higher N. Elevated CO_2 may also help reduce severity of viruses such as TYLVC. Additional B may also have potential to prevent spread of some viruses.	Nutrient management of infected plants is already practiced in UK growing successfully. CO_2 supply may be limited.	Ca nutrition will avoid BER and may also have other disease targets.
Verticillium wilt	May onwards	Promising effects of sulphur nutrition in limiting the spread of *Verticillium dahliae* by 'sulphur enhanced defence'. It may be worth exploring if Verticillium wilt becomes problematic on grafted crops, and allowing sulphate to accumulate in solution to supraoptimal concentrations.	Sulphate is traditionally seen as an unwanted ion. Though there is a relatively large range of acceptable sulphate values in solution, allowing sulphate concentrations to climb too high will have deleterious effects.	The threshold of acceptable sulphur may be higher than previously thought, and it may offer some defence against vascular disease, though this is unlikely if disease is severe.

Pythium and Phytophthora root rots	April-June	If a threat of Oomycete root rot is present, extra care should be taken to avoid salinity stress and high EC values, which predispose crops to infection. A degree of tolerance may be initiated with elevated (700 ppm) glasshouse CO_2. Copper ion water treatment has also shown efficacy in the ornamental sector.	None, it is generally beneficial to limit salinity and EC regardless of pathogens.	Somewhat limited information.
Clavibacter michiganensis pv. *michiganensis*	July onwards	Resistance of some cultivars is dependent on adequate Ca, and higher Ca supplies reduced disease severity in both a resistant and susceptible cultivar. Survival and spread in hydroponics is encouraged by higher pH. Potential to reduce pH of drain water overnight. Higher leaf concentrations of Mg correlated with lower disease level.	Further tweaks required to nutrient solution if changes to calcium are made (N, K etc.). pH changes may alter uptake of other nutrients.	Potential to reduce disease severity in commercial cropping. Suggested lowering of pH at night. Likely a promising area of research due to aggressiveness of disease and lack of PPPs.
Agrobacterium spp. (crown gall and root mat)	April onwards	Disease requires nutrition as plant does, and excluding N, P and Ca limited tumour size. However, this would be impossible in a commercial crop.	Loss of crop, loss of productivity.	Disorders such as crown gall and root matt are not generally widespread enough in the crop to warrant a large scale change to nutrition.
Passalora fulva	May/June onwards	*In vitro* tomato cells produced a calcium dependent defence protein, so it may be prudent to ensure Ca is supplied at sufficient concentrations. Many of the pathogens effector genes are triggered by N starvation.	Maintaining sufficient Ca should be part of any successful nutrient regime, and avoiding supra-optimal N.	Though *in planta* links between nutrition and leaf mould severity are untested, supplying adequate calcium will benefit overall plant health and limiting N is cost effective.

For sources of information and more detail, see the Science Section.

Costs of implementation

Reductions in the severity, sporulation and pathogenicity of *Botrytis cinerea* have been illustrated by numerous studies supplying plants with additional nitrogen. The cost of Botrytis control is estimated at £2,500 per hectare, and a reduction in these costs would represent a significant saving, compared with the cost of raising nitrate to 500 mg/L, estimated at approx. £1600 per season. However, this does not account for other required changes to the recipe, for example increased potassium, and more frequent nutrient solution analysis.

This example shows there is potential for a reduction in disease due to modified nutrient strategies, and this could confer cost benefits to growers. However, it is unlikely that these could be realised in commercial cropping without further research into plant nutrition due to the high number of variables present in UK tomato growing.

Objective 4 – Proposed research and development priorities

Nutrition delivered to the root-zone has the potential to affect almost every aspect of cropping, including disease resistance. It is in turn affected by a variety of environmental variables and is unlikely to have a constant effect in changing conditions. Even different strains of the same pathogen were found to react differently to changes in plant nutrition, and variables such as substrate, water supply and quality, climate, variety and fertilisers used may all affect nutrient uptake by the crop. Knowledge of how this can be manipulated in a commercial setting would be invaluable. From the findings of Objective 2 and analysis undertaken in Objective 3, a series of proposed research and development priorities is proposed (Table 3). This is based on the perceived benefit to the tomato growing industry and the probability of successful research as well as the likely time period for promising results. Further research specifically on commercial tomato is required as many of the effects identified are crop and disease specific.

The interactions between nutrient, crop and disease are highly complex and as yet not fully understood. Further research in a variety of areas that may be promising but not immediately beneficial to the UK industry are summarised in Table 4. Increasing the efficiency of systems, especially drain water nutrient recirculation systems to allow greater accuracy of dose application, maintenance of slab targets and monitoring of pH, EC and nutrients in the system will ensure optimum growing conditions are achieved. Further determination of what ‘optimum’ concentrations are, and how far ranges can be pushed will also contribute to this.

Table 3. Proposed R & D priorities to improve the use of nutrient management for disease management

Potential R & D priorities	Description	Impact	Cost	Likelihood of success	Time until uptake	Rank
Re-evaluate optimum nutrition concs for recirculation systems	Likely that recirculation will play a major role in future growing. Quantify the savings in nutrient & water.	Increased yields, greater disease resistance/tolerance. More cost effective, environmentally friendly fertiliser and water use.	May save money in terms of fertiliser and disease control programmes and may also increase yields.	High. Optimums have not been evaluated in the UK in years, and it is likely beneficial changes can be made to regimes.	Possible to start now.	1
Improved nutrient technology	Work ongoing in Canada and China on ISEs and modelling software.	Potential to match nutrient supply with plant demand closely, optimising nutrition.	Cost of new technology is generally high, but savings and improved profits would also be facilitated.	Medium. If can be shown to work effectively in practice they would be very attractive to growers if the price was acceptable.	In development for over 10 years, but not yet adopted. These systems do seem like the future, but time to market is uncertain.	2
Large, commercial scale nutrition experiments	Many promising interactions that warrant further exploration e.g. use of silicon (as a silicic acid spray, slow release slab, or potassium silicate + acid).	Possible reductions in pesticide use, improvements in plants tolerance to stress. Possible impacts on yield and quality should be included.	Large commercial trials are more expensive than smaller trials, but the latter have already shown promise, and commercial trials will show if a technique will be effective.	High. Will succeed in generating further data on which to base decisions on future nutrition strategies.	Potential to develop new recipes for use in specific situations is present currently, and is performed by growers to differing degrees.	3
Production of grower guide on hydroponic nutrition	No singular source of comprehensive information on growing hydroponic tomato exists. Also potential for further KT.	This would recap growers on the basic rules of crop nutrition, & inform on recent and future developments. It may also stimulate open discussions on the topic.	Bringing together information would make tomato nutrition more accessible to industry professionals, saving time & money.	High.	Could be started at any time.	4
Effect of nutrition on PepMV	Limited information was found, though it is known that growers manage crop nitrogen following infection so that the crop can outgrow symptoms.	PepMV can cause considerable reductions in yield and fruit quality, appearance and flavour. Control options are currently very limited.	If a cost effective solution can be found based on crop nutrition that is more effective than methods currently in use, savings could be made. E.g. Boron	Uncertain. Could improve control, but may not be effective or practical in a commercial setting.	This control method for PepMV is already utilised, but it would be useful to establish If this could be taken further.	5
Nutrition's use within IDM	Nutrition interactions with microorganisms in the root zone, be they natural, introduced, pathogen, beneficial or saprophytic.	Reduction in pesticide use, improved efficacy and uptake of biocontrols, interaction with elicitors, cultural controls & forecasting risk.	Laboratory and glasshouse trials could result in savings on pesticides and spray applications.	Medium. Would require extensive monitoring and for the appropriate microbes to be detected effectively (as in PC 281a).	There is grower interest, but success of biocontrols has been limited. IDM is preferred over harsh pesticides, & if efficacy is improved they may be used.	6
Water treatment technology with nutritive effects	Cu electrodes ionise and disinfect water & provide plants with copper nutrition. Electrolysed water also promising – does this affect nutrition?	An effective method of reasonable cost that also provides some crop nutrition would be beneficial.	Many different methods available, differ in cost. The AquaHort method provides copper nutrition and keeps the irrigation system clean.	This method is already used effectively by many in the bedding plant industry. Heat, UV and biofilters are generally in use within Protected Edibles.	Technology already in use in Protected Ornamentals.	7
Effects of substrate	A variety of substrates with different properties, & NFT growing are in use in the UK	Substrates are known to affect nutrient uptake. Information would be useful to growers.	Many substrates are used, would require trials and monitoring of rootzone solutions.	High.	Numerous different substrates are currently available to UK growers.	8

Table 4. Potential longer term R&D topics on crop nutrition

Point raised by review	No. studies (approx.)	Description	Pros	Cons
Impact on human health/nutrition	10+	Incorporation of beneficial compounds in produce, as well as nutrition targeted at human malnutrition problems.	Currently the area of health foods is fashionable, so there is a potential market for produce	Potentially more applicable in developing countries
Novel active ingredients	3+	Novel technology has shown new active ingredients such as lactoferrin to be effective in controlling some diseases. Potential to send elicitors through hydroponic system.	Potential for new active ingredients with novel modes of action against disease	New substances may meet specific regulatory problems, or may not be found to be cost effective
Large-scale monitoring of UK tomato crops	0	Monitoring of multiple crops nutrition and disease incidence over a growing season	May highlight key risk areas or particularly effective strategies, and the effects of recent developments in growing (e.g. dawn temperature drop's effect on calcium uptake and sinks)	So much variability may just serve to confuse matters and mask any trends present
Differing varietal/rootstock requirements	5+	Whilst some studies have focused on the response of varietal resistance to differing nutrition, further work on the requirements of different varieties may be useful	Prior knowledge of a varieties preferences or weaknesses may make for a smoother growing season and improved yields/quality	Generally, growers come to their own valid conclusions on how to differently manage varieties, and many new varieties are introduced or moved away from constantly, meaning this work may have limited use.
Changes to EC	5+	A higher EC may also reduce susceptibility to certain diseases	High EC results in smaller, more flavoursome fruits but lower yields and new, vigorous rootstocks may have the potential to tolerate higher ECs in the rootzone	Allowing EC to climb has many potential deleterious effects (e.g. BER, impaired water uptake) and has been consistently lowered by growers over the last 10 years
Effect of type of fertiliser	5+	There are numerous different fertilisers on the market, compound or single element, chemical or organic, liquid or solid form. Fertiliser choice is dependent on many different factors.	Organic fertilisers may offer some protection from soil-borne disease. Single element fertilisers, though not always available, may be more easily managed	Fertilisers differ in cost depending on the source and form, the production process and demand. Cheaper fertilisers, may be less effective, and vice versa. Organic fertilisers may also be variable in formulation.
Foliar sprays	10+	Use of foliar feed e.g. calcium, silicon to combat both disease and nutrition disorders as is done currently to some degree.	Could improve shelf life and act to top up rootzone nutrition	Application incurs higher costs to the grower, so it would have to be highly effective.