

Future Proofing Vegetable Production - Milestone Report 5



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PAGEBLOOMER
ASSOCIATES LIMITED

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Report prepared for LandWISE Inc
by Page Bloomer Associates Ltd

1. Executive Summary

This report summarises progress made, and deliverables met for Milestone 5 due 30th September 2019.

1.1 Key Deliverables

- Nitrate Mitigation Pilots installed
- Preliminary agreement on group and individual actions needed to meet overall community management of common pool resources
- Nitrate mitigation trials monitoring
- Catchment group and individual farmer supported to build capacity and capability

We are behind in some areas and ahead in others.

We have not installed a bioreactor as we need to determine where a bioreactor can be effective. We have instituted a drain network monitoring programme to identify potential locations. We have preliminary indications of a potential site and are monitoring it at present. The sites for two wetlands we planned have been withdrawn while other uses of the land are prioritised.

The growers in Arawhata, all members of the Tararua Growers' Association, are working together to meet Horizons Regional Council requirements. Much of their discussion about community management is taking place outside this project, and some is considered commercially sensitive.

All growers are committed to the drainage network monitoring to identify nitrate movement and quantities through the catchment. They are further considering management of sediment and enhancing biodiversity.

We note the Gisborne District Council requirement for Farm Environment Plans is a focus for those growers. We have been discussing how these should be developed in the intensive vegetable production areas and particularly where land is leased short-term.

In Gisborne and Levin (and Hawke's Bay) we are receiving requests for help with fertiliser equipment calibration and are doing these with growers in Levin, Gisborne and Hawke's Bay.

We are working with individual growers to plan on-farm trials. A number are established and more set to go as planting takes place. These will be reported in more detail in the January milestone report.

We have completed one alternative method of fertiliser application trial (broccoli at the MicroFarm – see below) and have another planned in Levin and a supporting trial in Hastings. We have identified several alternative application technologies and are negotiating support for regional demonstrations (MS6).

2. Milestone Progress

This report describes progress towards Milestone 5 of SFF 405649 “Future Proofing Vegetable Production” (FPVP) – due 30th September 2019. We are behind in some areas and ahead in others.

We have not installed a bioreactor as we need to determine where a bioreactor can be effective. We have instituted a drain network monitoring programme to identify potential locations. The sites for two wetlands we planned have been withdrawn while other uses of the land are prioritised. Growers in Levin are working together on a whole catchment treatment option, but details are not public.

Our focus in recent months has been information sharing through workshops, fertiliser equipment calibrations and one-on-one conversations. We have been working with individual growers to plan on-farm trials. A number are established and more set to go as planting takes place.

We have completed one alternative method of fertiliser application trial (broccoli at the MicroFarm – see below) and have another planned in Levin and a supporting trial in Hastings. We showed the Y-drop liquid fertiliser application system at LandWISE Conference 2019 in May. We have identified several alternative application technologies and are negotiating support for regional demonstrations (MS6).

2.1 Nitrate Mitigation Pilots

2.1.1 Aims

The project set out to test the effectiveness of woodchip bioreactors to strip nitrate from drainage water through denitrification. We previously noted that Pip McVeagh travelled to Queensland to review their approach to nitrate management which includes bioreactors and we maintain links with the discussion group on this topic.

The bioreactors are increasingly used in the US Mid-West and Queensland and Gisborne District Council reported to us their trials for urban wastewater treatment were very successful. We are following a parallel SFF project, “Innovative Drainage Management Technologies” that has installed a bioreactor in Bulls. The LandWISE team plus Jay Clarke and Adam Jory from Woodhaven Gardens attended the “Innovative Drainage Management Technologies” field day at Waitatapia Station on 18 July to view that situation and site and take part in discussions.

As we investigated this technology, we found it is essential to understand where in the drainage system the nitrate is concentrated. There is no information about nitrate distribution in either the Arawhata Catchment in Levin/Horowhenua or the Taruheru Catchment in Gisborne.

An efficient and affordable bioreactor needs to be situated in an area that receives a high concentration of nitrate and a low flow of water.

2.1.2 Drainage Water Nitrate Monitoring

We have worked with Horizons Regional Council to understand nitrate loads and concentrations in the Arawhata drainage network to identify where a bioreactor or bioreactors might be established. The monitoring programme aims to identify sources and high concentration ‘hot spots’ of nitrate in the catchment by sampling sites throughout the catchment.

We have identified 25 sampling sites from which Horizons staff have collected samples for full State of Environment Monitoring assessment. The selected monitoring sites begin above the cropped land in the catchment and follow the four main drain sub-networks through the cropping farms to

the boundary with dairy farmland, through the dairy farm and to the Hokio Beach Council Monitoring Site (see Figure 2).

Because we need a higher temporal resolution than is possible from the Horizons SOE monitoring, we have developed a “citizen science” programme with the growers. The Horizons monitoring is supported and enhanced by more frequent nitrate testing with Quick-N test strips (Figure 1) carried out by LandWISE staff and Arawhata growers.

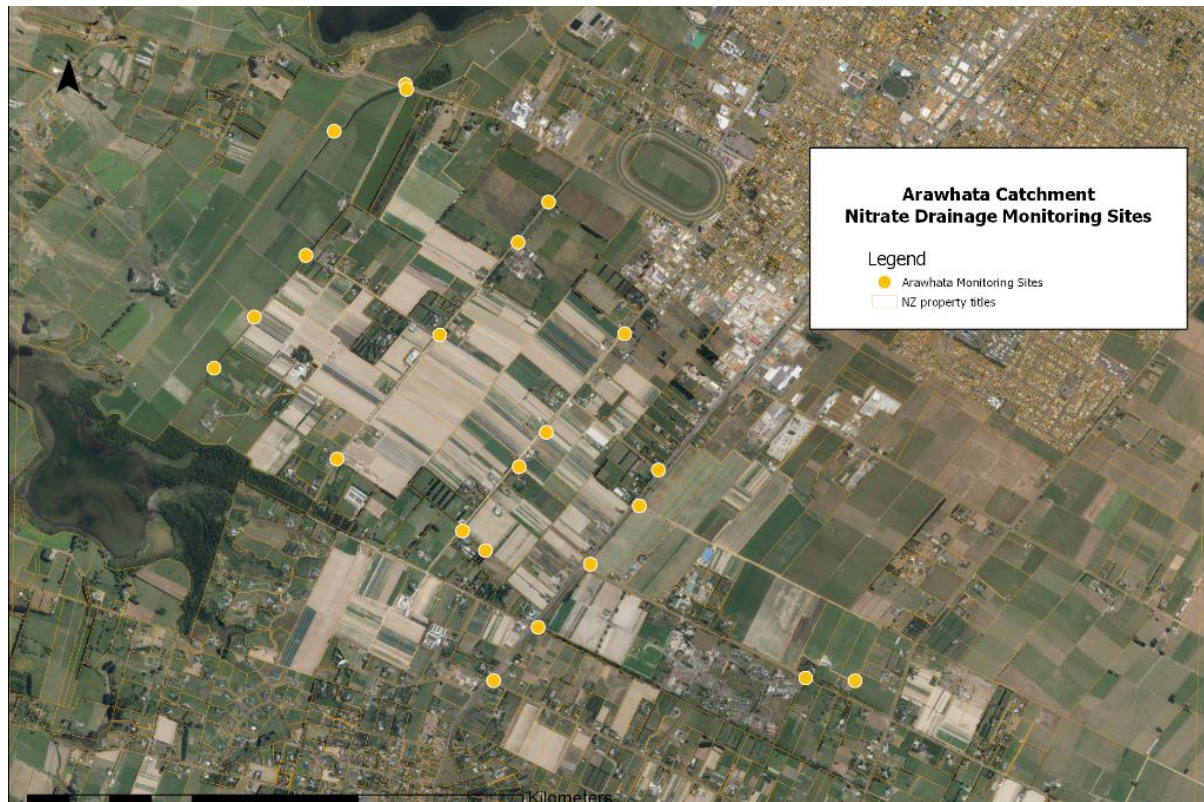


Figure 2. Arawhata Catchment Nitrate Drainage Monitoring Sites



Figure 4. Example of a monitoring site in the Arawhata Drainage Network



Figure 1. A nitrate test strip held against the calibrated colour switch to assess drainage water nitrate concentration.

Figure 3. Screen shot of the Survey 123 app for collection of data from grower drainage water monitoring

We provide Quick-Nitrate test strips that are sensitive in the 0-50 ppm range (Figure 1) and together with growers are undertaking regular monitoring when there is significant flow in the drain network. The strips are like those that growers are using for soil nitrate testing but are ten times more sensitive.

The sites (Figure 4) were labelled with numbered ear-tags ensuring growers, LandWISE and Horizons can relocate the sampling sites and record them correctly in the Survery123 App (Figure 3) and we maintain the consistency of the data points.

2.1.3 Preliminary Observations

At the Arawhata for whole network monitoring, Horizons staff have sampled the sites twice – both at relatively low flow. The first Horizons sampling event on 30th July was done at a very low flow, and only 5 of the 15 sites visited had enough water to be sampled (Figure 4). The second Horizons sampling on 13th August was done in conjunction with the LandWISE team at slightly higher flow, and almost all sites were sampled.

In addition, the growers tested the water quality on most sites twice between the 6th and 9th of September while drains flowed after rain. The main finding was that while high readings (10ppm) were coming from the Hokio Beach Rd Bridge or the main drain, only two sites along the growers' blocks measured significant (<2ppm) nitrogen levels during the drainage event.

One grower identified a tile drain outlet as a possible “hotspot”. We are monitoring the nitrate levels and trying to determine the flow rates from the drain. If this is confirmed as a valid treatment point, a bioreactor will be designed and installed.

2.2 Community Management of Common Pool Resources

The growers in Arawhata, all members of the Tararua Growers' Association, are working together as they work to meet Horizons Regional Council requirements. Much of their discussion is taking place outside this project, and some is considered commercially sensitive.

All growers are committed to the drainage network monitoring to identify nitrate movement and quantities through the catchment. They are further considering management of sediment and enhancing biodiversity. They are investigating options for a community wetland where sediment and nutrient stripping could take place. In addition, they are following the woodchip bioreactor investigations and indicate commitment to installation once a suitable site and design are confirmed.

Notably, all the growers are working with us to ensure fertiliser equipment is correctly calibrated and most have on-farm trials planned to test alternative nitrogen management options against current practice. In many cases, they have already changed practice, so trials are being reviewed regularly as we endeavour to keep up.

Gisborne growers are more spread and operations diverse, and rather than the community, it is individual farms working with us. We are pleased to have engagement with many, including all key players. We note the Gisborne District Council requirement for Farm Environment Plans is a focus for growers. We have been discussing how these should be developed in the intensive vegetable production areas and particularly where land is leased short-term. Keeping specific paddock details up to date will be very difficult in such cases and generate considerable work for both growers and council.

2.3 Grower Support and Capability



Figure 5. Gisborne Soils Field Day.

In Gisborne and Levin (and Hawke's Bay) we are receiving requests for help with calibration and have a number of nitrogen trials planned as the season gets underway. These will be reported in more detail in the January milestone report. We have spent time with individual growers reviewing soil test results comparing them with previous years and with the Nutrient Management for Vegetable Crops guidelines.

2.4 Soil Sampling and Nutrition Workshops

Workshops covering soil sampling, soil test results and fertiliser were held in Levin (18 attendees) and Gisborne (24 attendees) on 16 and 17 July and an additional one delivered by request in Hastings on 20 August. We have been approached to offer this workshop in Canterbury but have not confirmed details or dates.

The workshop was initiated when conversations with growers and examining their soil test results had highlighted opportunities to improve nutrient use through building understanding of key principles and concepts.

Soil sampling	▪ <i>Learning outcome:</i> Growers are aware of the key steps to collecting representative soil samples (transects, no. of cores, timing, core depth, variability, areas to avoid etc.)
Sending samples away for laboratory analysis	▪ <i>Learning outcome:</i> Growers understand the key steps to ensuring their soil samples reach the laboratory in a state suitable for soil nitrogen testing
Soil testing with nitrate test kits	▪ <i>Activity:</i> collect a soil sample, prepare and analyse ▪ <i>Learning outcome:</i> Growers can confidently collect, prepare and analyse a soil test using the nitrate test kits
Interpreting soil test results, and Soil test trends over time	▪ <i>Activity:</i> Discussion around soil test values from one grower's paddock over several years – having a soil fertility strategy/plan
Correcting deficiencies and excesses	▪ <i>Learning outcome:</i> Growers have sufficient understanding of optimum fertility ranges and how they vary between crops.
The recently published Vegetable Nutrient Guidelines	▪ <i>Learning outcome:</i> Growers are aware of the newly published vegetable nutrient guidelines, the basic content that can be found within the book.
Fertiliser planning	▪ <i>Learning outcome:</i> Growers gain knowledge and are empowered to discuss and ask questions regarding recommendations provided by fertiliser representatives.

2.4.1 Gisborne Field Day

On the 22nd of August, LandWISE held a practical workshop in Gisborne (Part 2 of the Soils Workshop series) at Leaderbrand's Hexton site. Some twenty local growers and support staff attended the workshop.

2.4.2 Fertiliser equipment calibration

Leaderbrand brought all staff (12) involved in fertiliser application together to check calibration of two machines: a 6-row squash side-dresser (Figure 7) and a baby-leaf bed fertiliser spreader (Figure 6). Leaderbrand has their own methods which we reviewed. We consider their systems are appropriate and will ensure instances of over (or under) application are rare.



Figure 7. Calibrating six row side-dresser



Figure 6. Calibrating baby-leaf bed spreader

2.4.3 Visual Soil Assessment

During the Soil Sampling and Nutrition workshops, we introduced the concept that poor soil structure could prevent plants accessing nutrients, which could make it seem the soil was short of nutrients. To address this, we presented a demonstration of the Visual Soil Assessment (VSA) process (Figure 8). With Leaderbrand support we showed trafficked and un-trafficked soils and discussed soil wetness and cultivation limits. Leaderbrand had also excavated a large pit so we could view the full soil profile (Figure 9).



Figure 8. Sorting soil pieces as part of the VSA soil health demonstration



Figure 9. Soil pit excavated by Leaderbrand in Gisborne to show the soil profile.

2.4.4 Quick N-Test

While we have previously provided test kits to growers to use for the Quick-N Test, we had not demonstrated its use widely. The Gisborne demonstration took place in a recently levelled paddock where lettuce crop growth was notably variable. We combined the N-Testing with a discussion and demonstration of representative soil sampling and dug up plants from well and poorly performing areas (Figure 10).



Figure 10. Excavating a lettuce plant to view its root system



Figure 11. Roots of healthy lettuce (left) and poor growing lettuce (right)

Of note was that the plants in the good growth areas had fresh white roots and those in the poor areas had less and browner roots (Figure 11).

When we performed the Quick-N test, we found the available nitrate in the area where lettuces were growing well was very low, and in the poorly performing area the available nitrate was significantly higher. This leads to the assumption that nitrate was not limiting growth, therefore applying more would not help. We are following this field with interest. At present soil tests have been sent away, and our conjecture is that soil pH is too low, causing high aluminium availability to relatively toxic levels – leading to poor root development and poor leaf production.

2.5 Fertiliser Calibrations

We continue to support growers with fertiliser calibrations. We are seeing increased interest and increased awareness of the value of this process but note many growers have not been shown how a valid calibration can be done simply. Almost all report checking the right amount of fertiliser went on the paddock by comparing tonnes and hectares, but many do not realise that uniformity can play a major role in poor efficiency.

As noted, the calibration exercise at Leaderbrand included all staff involved with fertiliser application. We are following up tests of one specialised machine which we had not previously encountered.

We are calibrating all equipment to be used in the on-farm trials we are running with growers. Most machines benefit from some adjustment to improve uniformity, some significantly so. Ways this can be achieved are being demonstrated and explained.

2.6 Grower Trials

Following the Soils workshops in Levin and Gisborne, and building on earlier Overseer budget case studies, we have been engaging with growers to match their fertiliser usage and choices with apparent crop demands. Growers are cautious to change current farm practices when changes create an uncertainty on crop performance and profitability.

We are setting up small replicated trials on their blocks to help them assess reductions to fertiliser use. In each, four randomly selected areas will be marked out to receive the alternative treatment, generally by hand (Figure 12). This ensures basic trial design requirements are met without unduly imposing extra work on growers.

Key aspects of trials are considering splitting fertiliser timing to reduce leaching risks and modifying fertiliser types/rates. Using the *Nutrient Management for Vegetable Crops in New Zealand* guide, we have setup trials to adjust nitrogen rates from current practice (fixed rate every year) to a justified rate based on an Available Mineral N (AMN) test.

Across the soil tests from Levin, the AMN test varies between blocks significantly from below 30kg N/ha to over 100kg N/ha. Pre-season testing allows growers to estimate the total amount of additional nitrogen required to grow the planned crop. By doing a AMN test, a grower can potentially justify adjusting his nitrogen rate for a Summer lettuce crop from 120 kg/ha to 40 kg N/ha.



Figure 12. Example plot layout for grower trials shows four randomly selected areas where the alternative treatment will be applied.

One “trouble” we have faced is that as we share more “science” with the growers, they change practice and so impact the trial designs. For example, instead of doing the new, lower-rate test treatment on the small replicated areas in the paddock, the growers want to change their whole practice to the new treatment. This demonstrates that by working with the growers, we have helped them realise there are opportunities to reduce inputs and losses, and still grow good, marketable crops. We are finding growers happy to change the trial to test other good practice farming principles as they seek to reduce their environmental footprint.

One challenge faced with smaller leafy greens growers has been identifying yield/ha to estimate nutrient removal rates. When doing multiple picks from one crop on small areas they do not weigh crop but count marketable units or crates.

Considering crop demands and soil test levels, growers have also been considering their other soil fertility and nutrient removal rates. Having a high Olsen P reading (>70), increases the risk of phosphate loss to water without any yield gain.

Massey PhD student Fernando Avendaño is running two trials in parallel with us at Arawhata. His work is supported by Horizons Regional Council and growers and he is investigating nitrate leaching under fresh vegetable production. One of his trials focuses on potatoes and the other on leafy salad crops.

2.6.1 Case 1: Fertiliser Application Timing for Potatoes – Levin

This trial is comparing current practice of placing all fertiliser on up front, mounded into the potato beds. This grower practice recognises the difficulty in getting later applications to the roots as broadcast fertilisers can fall off the side of the mound into the wheel tracks. Our alternative treatment will apply split doses of nitrogen as a liquid formulation, dribbled along the centre of the bed. We believe this could be achieved by a modified sprayer so would be a practical solution.

Fernando Avendaño will lead this two-year trial and will be taking extra nitrate leaching measurements with suction cups and other sampling techniques.

2.6.2 Case 2: Alternative N Fertilisers for Leafy Green Crop Rotations – Levin

Initially we planned a trial including a summer maize component intended to capture nitrate that had leached below the shallow root zone of salad vegetables such as lettuce. However, the grower tries that, found they could grow a good maize crop with no added fertiliser, and determined further trials were not needed.

The current plan is considering a comparison using an organic nitrogen source such as chicken manure. This trial is also anticipated to be part of Fernando Avendaño's work in the Arawhata Catchment.

2.6.3 Case 3: Reduced Nitrogen Rates for Broccoli – Levin

Can we apply less fertiliser in winter/spring without losing Broccoli yield?

Current grower practice applies about 162 kg N/ha as a complex fertiliser. Based on a 20% reduction target, we plan applications of 113 kg N/ha but will apply other products to ensure other nutrient levels (P, K, S, Ca, Mg) are constant. However, the rates will depend on Mineral N soil test value plus fertiliser as recommended by Reid & Morton, 2019.

This trial is set up and being monitored (Figure 13). First fertiliser applications as side-dressing are due soon.



Figure 13. Site of a broccoli trial comparing current practice with a 20% lower rate of nitrogen.

2.6.4 Case 4: Split Nitrogen Applications for Brassicas – Levin

Does splitting up one (800kg/ha) upfront fertiliser application into three (200, 300, 300kg/ha) applications give the same Broccoli and Cauliflower yield?

Current grower practice applies all fertiliser a few weeks after planting. This theoretically increases the risk of leaching. Splitting applications would leave less free nitrate available to leach but must ensure enough is available for acceptable growth and production of marketable heads.

In this trial, we will apply the normal grower practice except in four small plots where applications by hand will be split. Prior to each application, soil Quick-N tests will be undertaken to check available nitrate. If enough is already present, the application plan will be reviewed.

2.6.5 Case 5: Reduced Starter Fertiliser for Tomatoes – Gisborne

Can we reliably maintain current tomato yields while reducing starter fertiliser application rates from 450 kg/ha to either 300 or 200 kg/ha?

Excessive Nitrogen rates in tomato crops increases the percentage of green fruit and reduces yield quality. By matching crop demands to fertiliser rates, we can improve crop quality while reducing nutrient application and cost of production.

2.6.6 Case 6: Sweetcorn N Rate Following Winter Cover Crops – Gisborne

Can we maintain current sweetcorn yields with less fertiliser after winter green-manure crops and spring process peas?

Cover crops are used to soak up excess N in the soil in the Autumn and Winter following process cropping and to return organic material to the soil. Growers are interested to see if they can then reduce the fertiliser rate in the following sweetcorn crop as the green manure breaks down and mineralises N.

We are setting up a trial to test current fertiliser practice vs using a AMN soil test to predict N supply and adjust side dressing rates to match the soils ability to supply nitrogen to the current sweetcorn crop.

2.6.7 Case 7: Sweetcorn Starter Phosphate – Gisborne

Throughout most horticulture areas in NZ, fertiliser has been extensively used and soil test levels of phosphate are high. This trial is looking to answer the question “Can we remove the phosphate in starter fertiliser when we have a high Olsen P level?”

Previous trial work in NZ has shown that there is likely to be no response to phosphate fertiliser in sweetcorn crops where the Olsen P is above 20 – the trial will work with growers to challenge them to justify their nutrient use and to allow slow mining of currently high soil fertility levels. A full season sweetcorn crop is removing just 14kg P/ha in crop yield. When planting Sweetcorn with *Cropmaster 20* at a typical rate of 300kg/ha, we are applying 30 kg P/ha – which is likely to increase the soil Olsen P by between 2-3 units per crop.

30t/field yield	N (kg/ha)	P (kg/ha)	K (kg/ha)
Crop removal	93	14	51
300kg/ha Cropmaster 20	56	30	-
250kg/ha Side-dress Urea	115	-	-

Table 3. Sweetcorn nutrient demand

2.6.8 Case 8: Liquid N for Sweetcorn

Applying all nitrogen close to planting allows growers few options to manage seasonal variability and increases the risk of nitrogen loss following heavy spring or summer rainfall events. Current practice of knifing nitrogen into the soil at V4-V6 for sweetcorn is good as it reduces nitrogen volatilisation. But it does not reduce leaching risk from heavy rain events.

The trial will compare dry fertiliser knifed into the soil with liquid N surface-applied at the same rates close to the base of the plants. Identifying potential changes or gains in the sweetcorn crop will assist grower decisions when considering changes to fertiliser application.

If we can achieve the same yields with liquid N, can we then further split our side-dressing timings to mitigate climate risks on nitrogen loss?

2.7 Broccoli Trial at the MicroFarm

2.7.1 Trial Aim and Method

On the 20th of April, a small field scale trial of Broccoli was planted at the MicroFarm to investigate alternative fertiliser application methods. The aim of this trial was to test the efficacy of liquid side dressing vs dry fertiliser banded. Using liquid to apply fertiliser close to the plant is more suited to multi-row side-dressing, allowing growers a simple and easy method of split-applying nitrogen, based on crop demand.

The trial tested both Urea and CAN applied dry in one application or liquid as a split application vs no nitrogen fertiliser. Due to rainfall timing and a mild winter, the final liquid N application got missed due to the crop being ready for harvest before there was an opportunity to apply the additional N.

Treatment	Fertiliser Applied (kg/ha)			Nitrogen Applied (kg/ha)		
	Application 1 5/6/19 – 7 weeks post-transplant	Application 2 12/7/19 – 12 weeks post-transplant	TOTAL	Application 1 5/6/19 – 7 weeks post-transplant	Application 2 12/7/19 – 12 weeks post-transplant	TOTAL
Dry CAN	370	0	370	100	0	100
Liquid CAN	123	123	246	33	33	66
Dry Urea	217	0	217	100	0	100
Liquid Urea	72	72	144	33	33	66
Control	0	0	0	0	0	0

Table 1. Broccoli Fertiliser Trial Treatments.

2.7.2 Harvest Results

NOTE: These results are still to be checked and reviewed by Plant & Food Research. A separate trial summary will be posted once complete.

The trial was harvested as a single cut on 19th August. The whole plant was harvested at soil level then weighed before and after the desired head was removed (central flowerhead, without leaves).

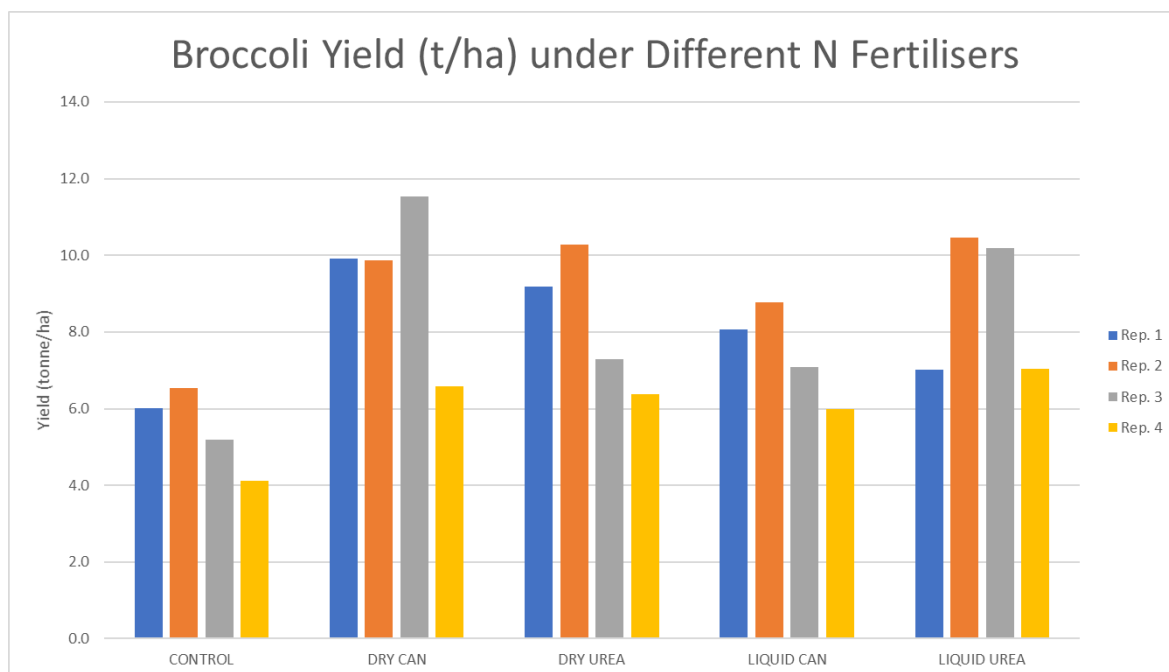


Figure 14. Harvested Yield from Broccoli Trial Treatments

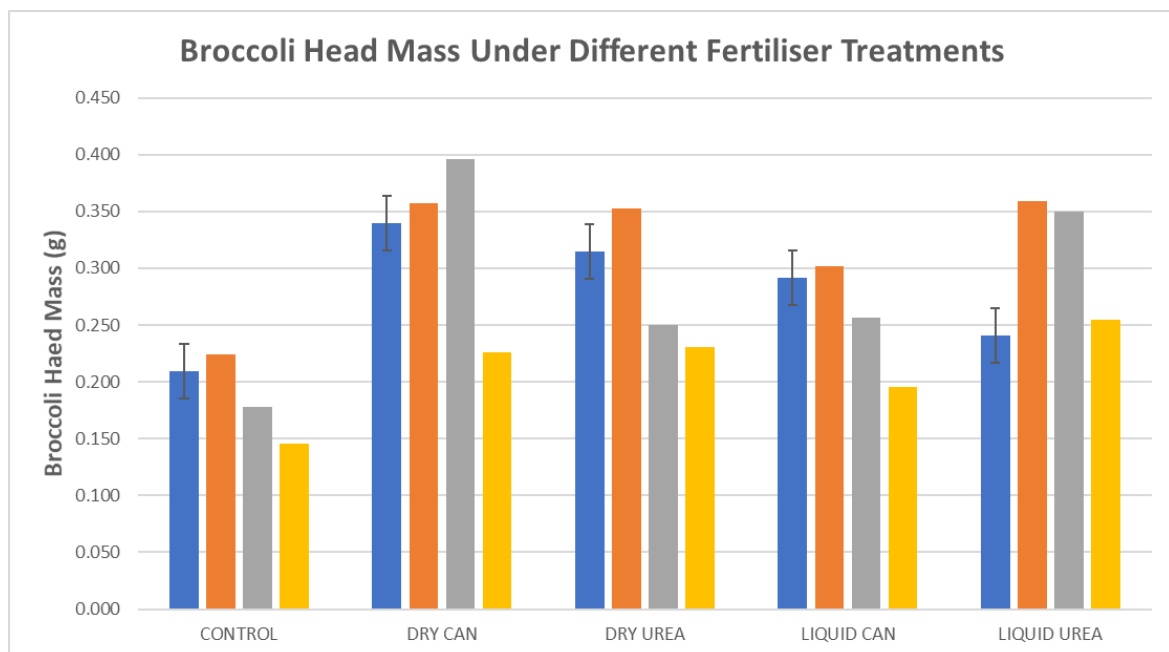


Figure 15. Broccoli head mass under different fertiliser treatments

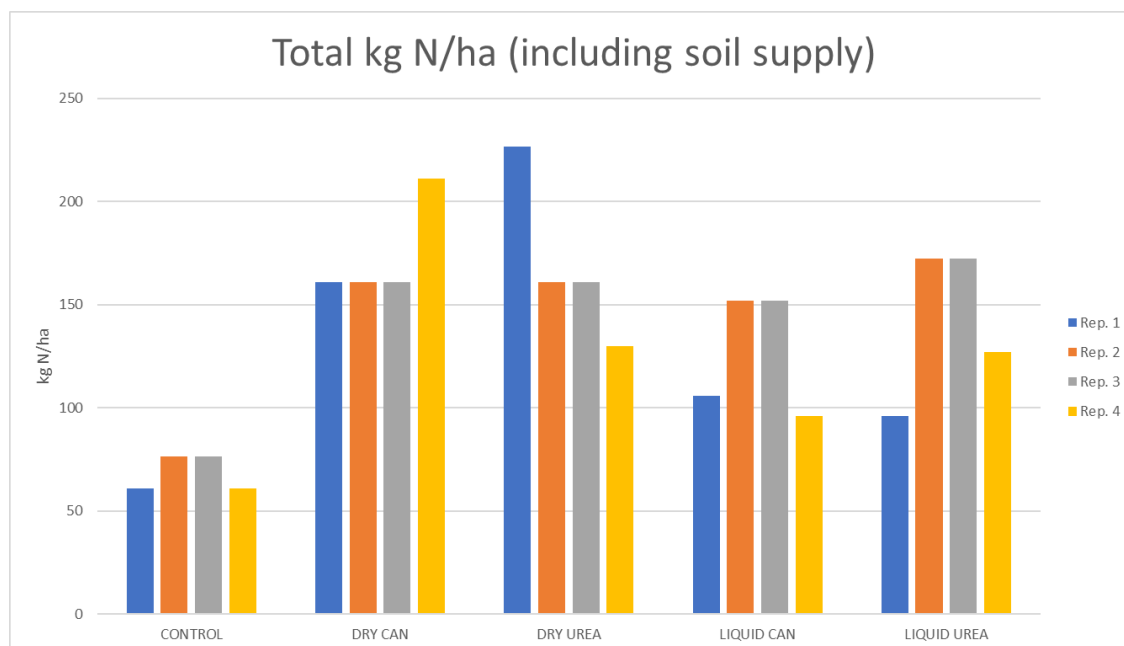


Figure 16. Total nitrogen supply by plot including soil supply and added fertilisers

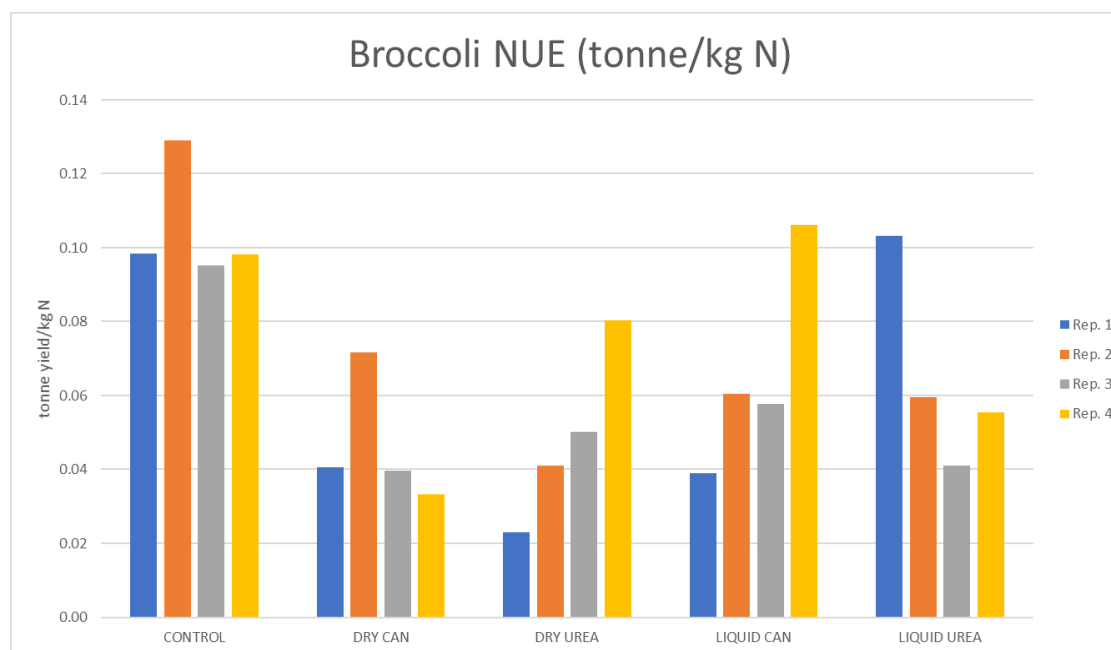


Figure 17. Broccoli Nitrogen Use Efficiency by plot and treatment

The control (0kg N fertiliser/ha) treatment had a significantly lower yield and broccoli head mass compared to any other fertiliser treatments.

Applying urea as a dry product or liquid did not affect yield even though the liquid received only 66% of the dry N-rate. This suggests the dry rate may have exceeded crop need.

Applying CAN as a liquid did significantly reduce both the head size and plant mass as compared to using either dry CAN or Urea. Note that the liquid CAN was applied at a 33% lower rate than the dry fertiliser. A possible reason for the reduced yield could be increased losses from the nitrate portion of the CAN with 30mm of rain the same day as the second fertiliser treatment.

Date	Activity	Description
8/4/19	Seedlings Treated	Plants treated with Confidor or Derevo
9/04/2019		Transplants collected from Woodhaven
16/04/2019	Soil testing	Whole block - wet chem
19/04/2019	Cultivation	Plough
19/04/2019	Cultivation	Rotary Hoe
19/04/2019	Cultivation	Beds formed - rotary hoe bed former
26/04/2019	Drench seedlings	Taipan encaps 6L/ha in 500L water for Insects/Thrips
20/04/2019	Planting	Transplanter
22/04/2019	Cover cloth	Cosio against pukekos
26/04/2019	Slugs	Metarex 4 kg /ha hand thrown
26/04/2019	Irrigation	5mm to activate pre-em herbicide - some seedlings already emerging, est barley but also flat weeds
19/05/2019	weeding	Hand pull barley plants
27/05/2019	Soil testing	Each replicate 0-300 and 300-600 quick N test (40 samples) AND treatment/depths bulked for wet chem (10 samples)
4/06/2019	Leachate monitor	Installed 2 wetting front detectors as trial
5/06/2019	Fert application	All dry fert up front (100kgN/ha of CAN or urea) and 1/3 fert applied to liquid treatments (33.3kgN/ha of CAN 240g/1.2L or Urea 140g/1.2L)
		Rain straight after application (forecast 6mL overnight but had 35.6ml)
12/07/2019	Fert Application	Applied 2nd lot of fert to liquid treatments
25/07/2019	Quick N Test	Full stops tested for nitrates, No water in FS1, approx. 40mL in FS2 - nitrite present
		5 drops of 10% Amidosulphuric acid added to 5mL samples - shaken then tested using N strips
		FS1 (June) = 175ppm Nitrate, FS2 (June) = 50ppm Nitrate
		FS2 (25/7/19 - today) = 50ppm Nitrate
19/08/2019	Harvest	See trial results sheet

2.7.3 Liquid N summary

Common reasons for yield gains achieved with liquid N application is the increased application evenness and the ability to split applications, reducing risk of loss to leaching, and apply N late, enabling addition of extra nutrient if required. While the nitrogen rate (kg N/ha) was reduced 33% on the Liquid Urea vs Dry Urea, the yields were similar suggesting that nitrogen should not have been limiting yield.

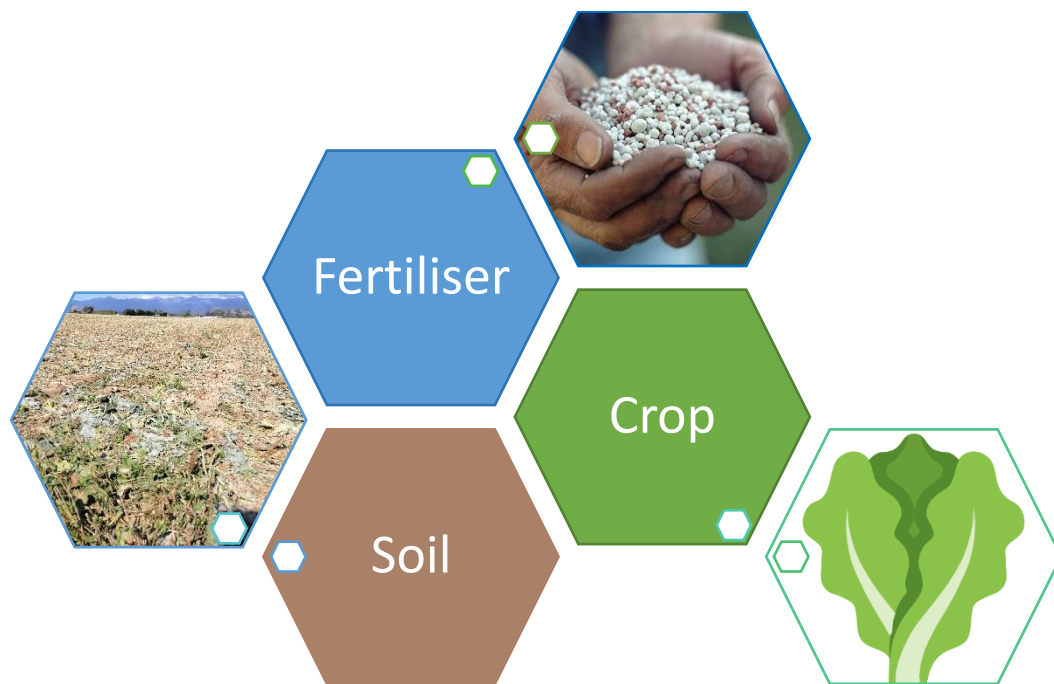
At harvest, the soil Nitrate-N levels were low (approx. 5kg N/ha) under all treatments when tested with the Quick-test N strips. This shows that the applied N was either used in the crop or lost from the soil zone through leaching.

Further work will be required to understand why the liquid CAN treatment achieved significantly lower yields than the dry CAN. From the Urea treatment, we have identified that we can use either liquid or dry will achieve similar results. The trial showed that we can change to a liquid form of N and still potentially achieve similar yields. Having this as another tool for fertiliser placement, we now need to consider how we can change our farm systems to further reduce N loss through either improved N use efficiency or more precise timing of N application.

Appendix

*Booklet supplied to attendees at Soil Sampling and Nutrient management
Workshops*

Soil Sampling and Nutrient Management for Vegetable Production



A Guide To:

- Soil Sampling
- Fertiliser Recommendations
- Fertiliser Plans

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1 What's limiting crop yield?

There are many factors that can limit crop yield. For example, soil structure, fertility status, and texture will all impact crop yield. In Figure 19, the mean zones yield is 75 tonnes/ha in the red zones and 112 t/ha in the green zones. Overall the yield ranged from 0 – 145 t/ha.

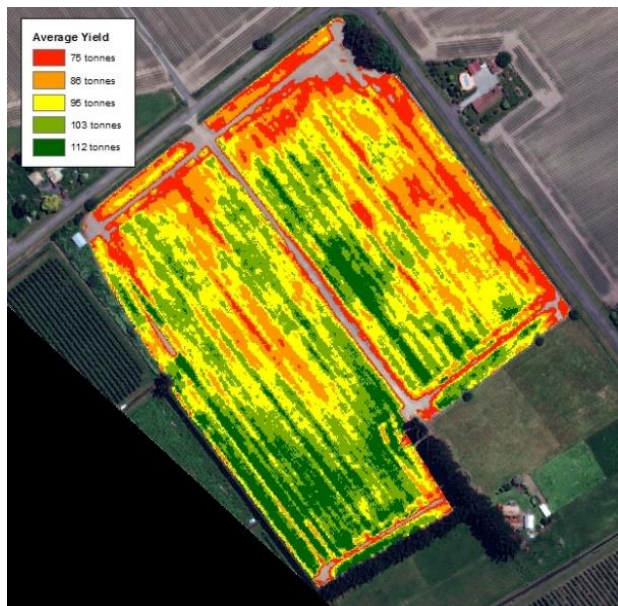


Figure 19. A Yield Map from a Paddock of Onions in Hawke's Bay.

Understanding what is limiting crop growth, and therefore yield, is important. "Liebig's Law of the Minimum" states that yield is affected by the most limiting essential nutrient. This is often shown as a barrel with shorter staves as in Figure 20. The maximum allowed by the shortest stave (in this case water) sets the maximum that can be achieved. Adding more nitrogen will not increase yield.

Nutrient deficiencies in the crop can occur for a number of reasons and adding more of nutrient(s) via fertiliser application may not fix the underlying problem. **It may not always be an essential nutrient/s that are limiting crop growth and yield. There are other factors such as pH, soil compaction and drainage that must be kept in mind. For example, the graph in Figure 18 stresses that applying more and more Nitrogen will not compensate for water-stress.**



Figure 20: Liebig's Law of the Minimum states yield is determined by the most limiting factor

Potato Yield Response to N Fertiliser at Varying Levels of Water-Stress

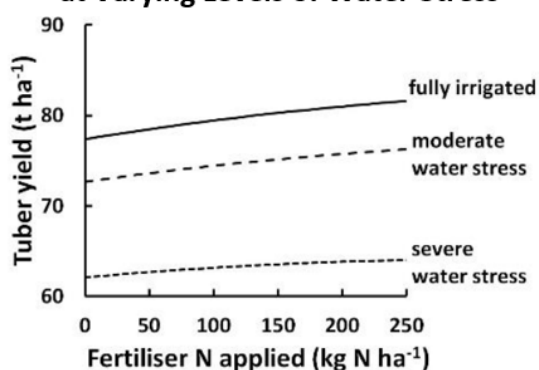


Figure 18: Potato Yield Response to N Fertiliser at Varying Levels of Water-Stress (Source: Nutrient Management for Vegetable Crops in New Zealand)

KEY POINT: The yield of a plant is limited by a deficiency of any one essential element, even though all others are present in adequate amounts.

1.1 Optimum Nutrient Levels

Adding more nutrient than needed is unwise. It will increase costs and will not increase returns. It can even reduce yield. Adding more nutrient than the plant needs does not increase yield and at high levels may even decrease yield quantity and quality. Any unused nutrients add to the risk of leaching with negative environmental effects.

Figure 21 from Incrocci and others shows the relationship between crop growth, nutrient loss risk and nutrient in the root zone for a nutrient such as nitrogen.

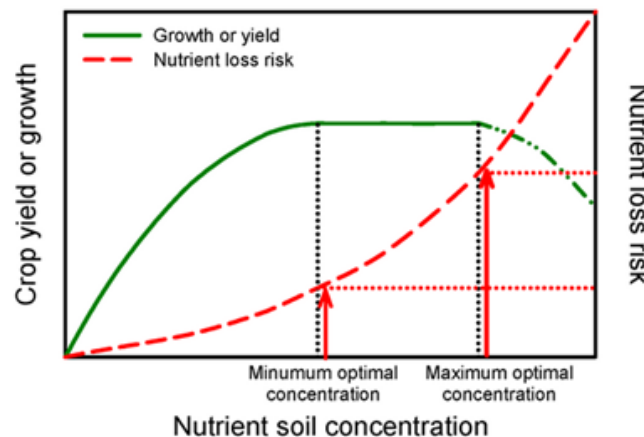


Figure 21: Relationship between crop growth (or yield) and nutrient soil concentration in the root zone. The maintaining of the minimum optimal nutrient concentration allows for reducing nutrient loss risk (e.g., NO_3^- leaching) without affecting crop produce and quality. (From Incrocci, Massa and Pardossi, *Horticulturae* 2017, 3(2), 37)

1.2 Effect of pH

The pH conditions of the soil affect nutrient availability – and at either extreme (too acidic or too basic) plant growth will suffer even if soil nutrient levels are optimum.

Optimum pH will vary for different crops however it should generally be between 5.5 and 6.5.

If the soil is too acidic (low pH) plant uptake of Magnesium (Mg), Nitrates, Potassium (K), Sulphur (S), Molybdenum (Mo), and Calcium (Ca) will be limited even if there are adequate levels in the soil.

If the soil is too alkaline or basic (high pH) plant uptake of Manganese (Mn), Zinc (Zn), Iron (Fe), and Phosphate (P) will be limited despite adequate amounts present in the soil.

Where nutrients have the same biochemical uptake pathway (Phosphate, Iron, Calcium and Aluminium), their availability curves overlap, with the notched areas indicating uptake of one nutrient will reduce uptake of the other.

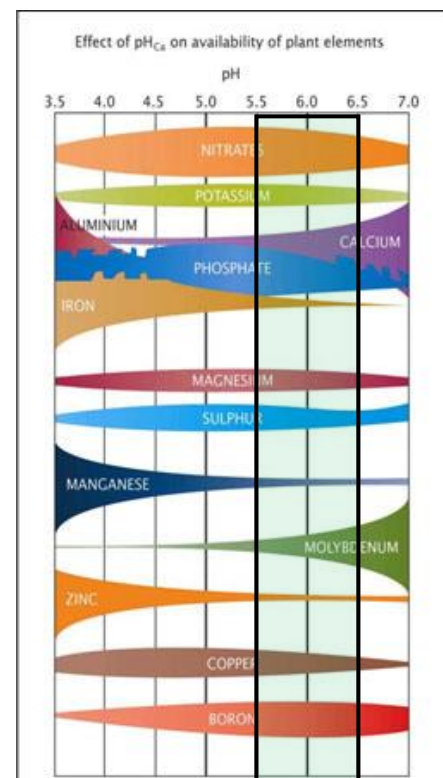
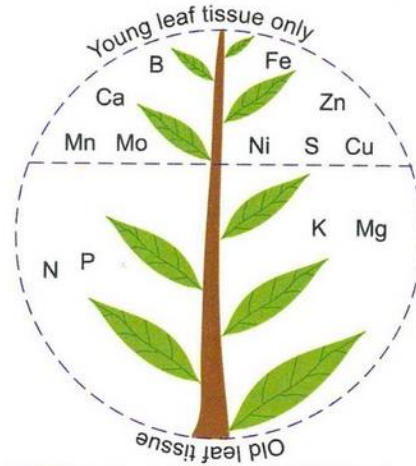
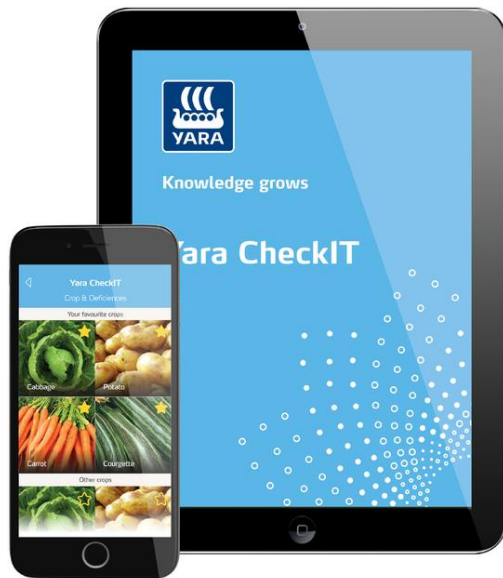


Figure 22. Effect of pH on nutrient availability, the wider the bar, the greater the nutrient availability. The greatest level of plant nutrient availability is between pH 5.5 to 6.5. (Source: Agriculture Victoria)

1.3 Nutrient deficiencies

There are a variety of online resources you can use to help identify nutrient deficiencies in your crops. Yara's "CheckIT" app allows you to scroll through a library of photos of nutrient deficiencies in a variety of vegetable crops.



Generalized diagram showing the portion of the plant where nutrient deficiency symptoms are first observed. Courtesy of the 4R Plant Nutrition Manual, IPNI 2012.

1.4 Nutrient Interactions

Nutrient uptake by plants is not an isolated process - there are interactions between the 19 essential elements (antagonistic or synergistic) that affect the ratio of nutrients taken up by plants. This is demonstrated by Mulder's Chart below (see Figure 23).

The uptake of some nutrients antagonises (blocks) the uptake of others for example, Phosphate (P) and Calcium (Ca); or Potassium (K) and Nitrogen (N). Other nutrient pairs have synergistic relationships where the uptake of one nutrient increases the availability of the other. For example, Nitrogen (N) and Molybdenum (Mo); or Boron (B) and Magnesium (Mg).

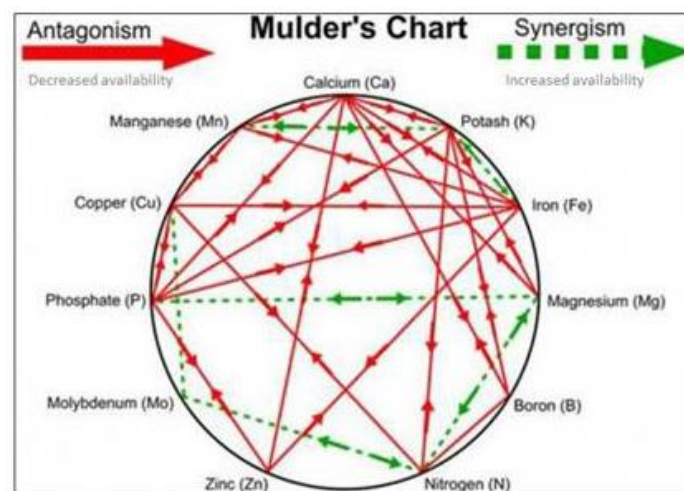
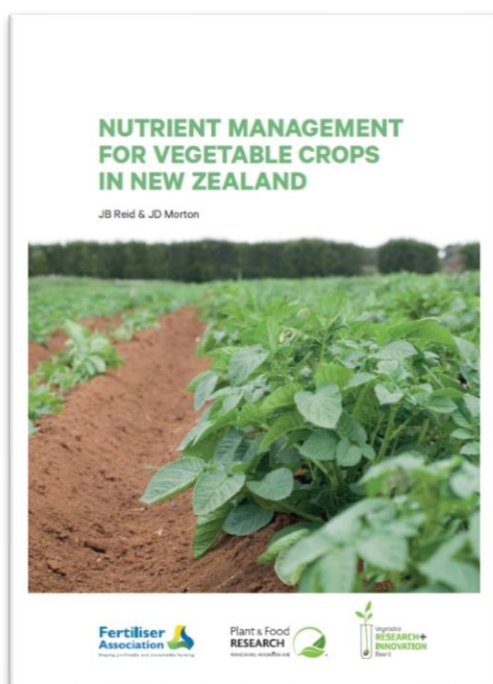


Figure 23: Mulder's Chart of Nutrient Interactions showing elements with antagonistic and synergistic relationships (From <http://www.msue.msu.edu>)

2 Vegetable Nutrition

“Nutrient Management for Vegetable Crops in New Zealand” by Jeff Reid and Jeff Morton covers the most recent research into optimum soil fertility levels, and fertiliser recommendations for Vegetable Crops grown in New Zealand conditions. Produced by Plant & Food Research for the Fertiliser Association and Vegetables Research and Innovation, it is available online at <http://www.processvegetables.co.nz/our-documents/>

Chapters 1 and 2 cover an introduction to nutrient supply from the soil, fertiliser forms, soil sampling, managing soil fertility, environmental matters, and making nutrient recommendations. The remaining chapters cover specific crops and their specific nutrient requirements based on soil type, growing region, and expected crop yield.



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Chapter 4: Buttercup Squash	43
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2.1 How to Interpret Recommendations

The basis of recommendations given is adding sufficient nutrient to ensure yield potential is achieved. To select the rate, you need to know what is available in the soil and how much nutrient the developing crop will require.

- Soil test the paddock before you grow the crop
 - Guideline recommendations rely on accurate and representative soil test values for N, P, K, S as well as pH
- Know your variety's potential yield in *tonnes/ha* (or *no. marketable heads/ha* for Brassicas and Lettuce)

3 Soil Sampling

3.1 A note about variability

There is always nutrient variability in any paddock, and this must be considered when taking samples for testing. Temporal variability applies to when the sample is taken. Spatial applies to where the sample is taken). There will also be a degree of variability present from the lab testing process, but this is small compared with taking the samples in the first place.

Temporal variation occurs because of seasonal nutrient cycles that change availability. Avoid confusion by sampling at the same time of year, or by only comparing soil samples from the same paddock taken at the same time of year. Many people do sampling in winter with time to plan programmes before spring fertiliser applications are started.

Spatial variation will be the largest source of variability so must be carefully considered to make sure a representative sample is collected. Variation is caused by factors such as different soil types, different crop histories and different fertiliser application patterns so where in the paddock samples are taken affects results.

Fertility also changes down the soil profile, so the depth of sampling is very important. In New Zealand, nutrient research and fertiliser recommendations for horticultural crops including vegetables are based on soil cores collected from the top 150 mm of the profile. The exception may be testing for available nitrogen which can use soil cores from the full root depth.

Electromagnetic sensors can be used to map soil patterns or variability such as the figure below. This figure shows an EM or EC map of a 3ha field at the LandWISE MicroFarm. EM maps measure electrical soil properties that are affected by wetness, salinity, density and clay content. This means EM values can be related to soil texture, highlighting the variation in sand, silt and clay content. EM maps show variation across a field and can be used for zoning areas. These maps have been used to guide soil sampling, but also other tasks such as irrigation or variable rate planting.

Figure 24 shows an NDVI image of a barley crop (in the white polygon) at the LandWISE MicroFarm. This suggests two separate soil tests, one from each of areas A and B would provide useful information.

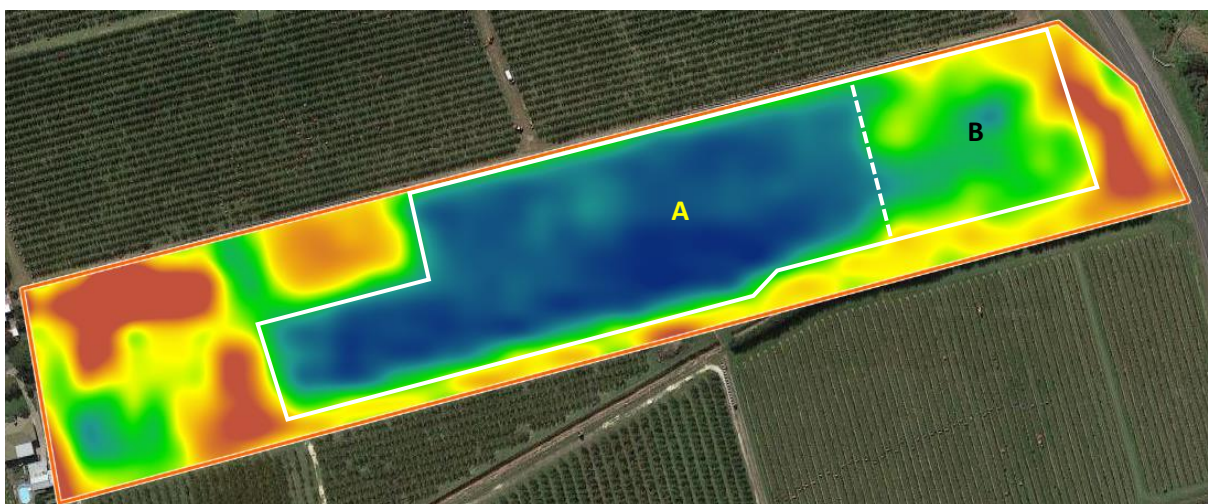
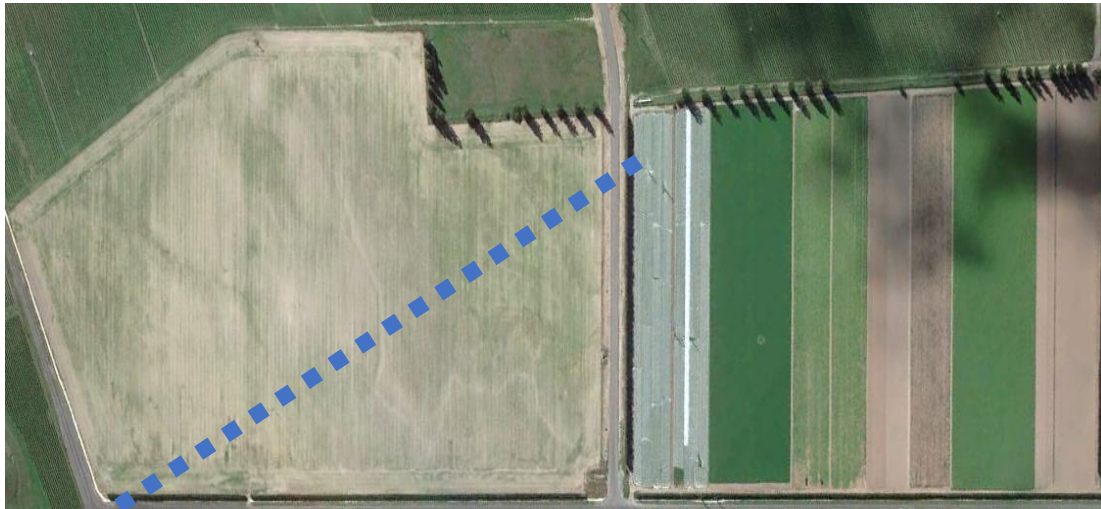


Figure 24: Free NDVI Map of LandWISE MicroFarm courtesy of Datafarming.com.au showing barley crop in white polygon

3.2 Taking a representative soil sample

To get a representative sample, avoid places that are “not representative” such as headlands, old barn sites and stream channels. To account for variability, your sample should include a minimum of 15 to 20 cores 150 mm deep per paddock or block along a “transect” (see Figure 25).

It is best to take samples from a known transect across the zone and return to the same transect when taking future samples. Ideally you will use GPS to mark these sampling points so in following years you can take cores from the same places. Smart phone apps will let you record points with $\pm 5\text{m}$ accuracy which is adequate if not perfect.



*Figure 25: Example of a Soil Sampling Transect (blue) with 20 cores sampled.
How would you sample the strip cropping on the right?*

It can be tricky to work out the best sampling strategy when paddock arrangements change. The ideal sampling pattern for the image on the left in Figure 26 is different to the ideal for the image on the right.



Figure 26: These Google Earth images show the same paddock in different years: the ideal sampling strategy differs with these different arrangements



Figure 27. Example of a transect mapped with phone GPS on Google



Figure 28: Even though root travel deep in the soil, soil testing is based on sampling the top 150 mm. For nitrate availability, a deeper depth can be sampled.

The Future Farming Centre has a more detailed explanation of soil sampling at <https://www.bhu.org.nz/future-farming-centre/information/soil-management>

3.3 Sending samples to the lab

Soil samples that are going to be analysed for N should be kept chilled and sent to the lab as soon as possible. They need to arrive at the lab at $<4^{\circ}\text{C}$ (fridge temperature) so can be frozen if they will be travelling a long way. Carry a chilly bag or bin with ice packs, particularly on hot sunny days so samples can be chilled immediately.

If soil samples are kept above 4°C , microbes will continue to mineralise nitrogen and the lab may measure more available N in the sample than is in the paddock. This could lead to a falsely low fertiliser recommendation.

If you have collected more soil than wanted for testing, you must mix the entire sample together, taking care to break up all the cores. Then take the amount you require from several places in the fully mixed sample.

4 Interpreting Soil Test Results

NOTE: New Zealand Soil Tests give the amount of the element (e.g. nitrogen or phosphate) whereas overseas tests often report the amount of the ion (e.g. NO_3^- or PO_4^{2-}) so be careful when reading overseas recommendations. You will need to convert to the same units. Also remember New Zealand soils are quite different to many soils in other countries. New Zealand recommendations are tuned to New Zealand conditions.

4.1 Common Tests – and what they actually measure

The following explanations are from Hill Laboratories Technical Notes (www.hill-laboratories.com).

4.1.1 Potentially Available Nitrogen (AN)

The Available N test [also known as Anaerobic Mineralisable Nitrogen—AMN] is a measure of N mineralised from soil organic matter under specific laboratory conditions (anaerobic incubation of soil cores at 40°C for 7 days).

This test is designed to quickly estimate the amount of N that will be available to the crop over the growing season – however the actual amount of N mineralised (available to plants over time) in the paddock will depend on soil temperature and moisture, which are highly variable. The results are reported as kg/ha assuming a 150 mm sample depth for potentially available-N (AN), or ug/g for anaerobic mineralisable-N (AMN).

4.1.2 Mineral Nitrogen Profile (Min N)

Also referred to as “Deep Soil Mineral N” this tests the levels of Mineral Nitrogen (Nitrate (NO_3^-) and Ammonium (NH_4^+)) in soil at the time of sampling and does not include any measure of potentially mineralisable Nitrogen. Mineral N tests are often done to 60cm in the soil profile. Mineral forms of N are immediately available to be taken up by plants. Nitrate (NO_3^-) is also available for leaching, as it is easily lost from the soil profile during drainage.

4.1.3 Total Nitrogen

This test measures the total Nitrogen in the soil and includes Nitrogen that is unavailable to the plant but is useful in determination of Carbon: Nitrogen ratios.

4.1.4 Anion Sorption Capacity (Phosphate Retention)

Anion Sorption Capacity (ASC%) also known as **Phosphate Retention** is the soil’s ability to retain and lock up available phosphate (P). Soils of volcanic origin (such as those in Horowhenua and Pukekohe) have moderate to high ASC – and thus these soils retain a lot of bound P.

4.1.5 Olsen P

Olsen P is a standardised soil test for **Available Phosphorus** levels in soil. It accounts for Phosphate Retention by measuring only the amount of P that is plant available. Phosphate is Plant P uptake is also affected by soil structure, root structure and root zone depth therefore Olsen P results should not be considered in isolation when evaluating soil P status.

4.1.6 Organic Sulphur

Organic Sulphur is a measure of how much potentially available S there is in soil reserves of organic matter.

4.2 What the numbers mean in general terms

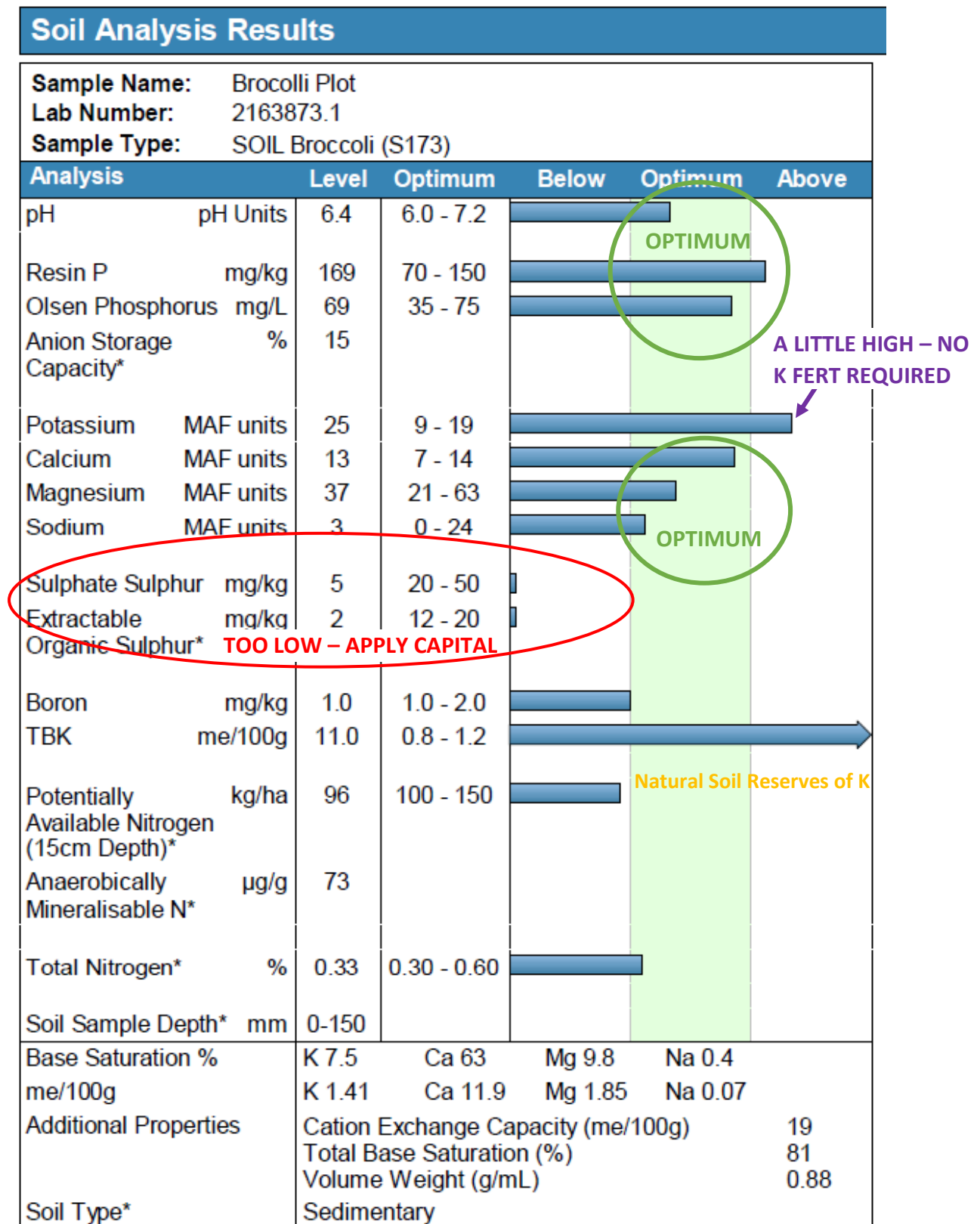


Figure 29. Annotated Soil Test Results.

4.3 Soil test trends over time

Fertiliser tests are not perfect because of sampling in variable paddocks and the testing process. Following trends over time helps determine if you are moving in a suitable direction. Keep soil test reports and look at how the results change from year to year.

The case study in Figure 30 shows sampled Olsen P from Paddock A over a 5-year period from 2014 to 2019. In 2014 Olsen P was 161mg P/kg soil which is much higher than the optimum for any crops.

The guidelines for Olsen P given in “Nutrient Management for Vegetable Crops in New Zealand” (Reid and Morton, 2019) range from Olsen P values of 35 to 70mg P/kg soil.

Since 2015, the case study grower applied less P fertiliser than the maintenance rate for their crops. Phosphate was “mined” from the soil by crops, and soil Olsen P decreased to 124mg P/kg soil by 2019.

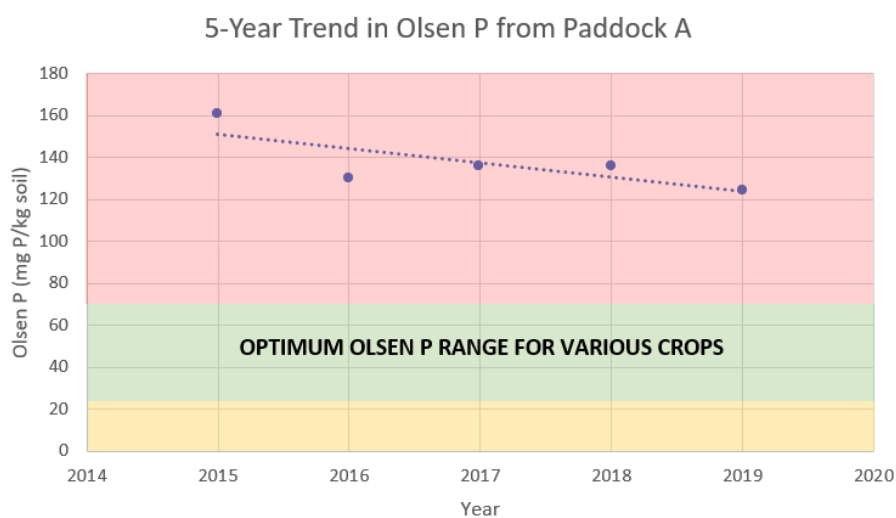


Figure 30: A graph showing how Soil Phosphate (Olsen P) is trending over time. The levels of phosphate are higher than required but are trending down towards to optimum range.

5 Fertiliser Plan

5.1 Capital and Maintenance Rates

When considering how much of a nutrient to apply to a crop, you should always consider where the soil fertility status of that nutrient is in comparison to its optimum range.

If it is below the optimum range, the crop yield may be impacted and a fertiliser application of that nutrient will be required not only to grow the crop, but also to lift the soils fertility status back up to the optimum. The amount of fertiliser required to raise the soil's fertility level back to the optimum for a specific nutrient is a capital application and will vary depending on how far below optimum the soil level of a nutrient is.

If the soil test shows the soil nutrient level is within the optimum range for the crop being planted, then a fertiliser application will only need to supply enough nutrient to grow the crop – this is known as a maintenance rate. Maintenance rates will vary depending on the crop being grown – see crop specific requirements in the Nutrient Management for Vegetable Crops in New Zealand book (Reid and Morton, 2019).

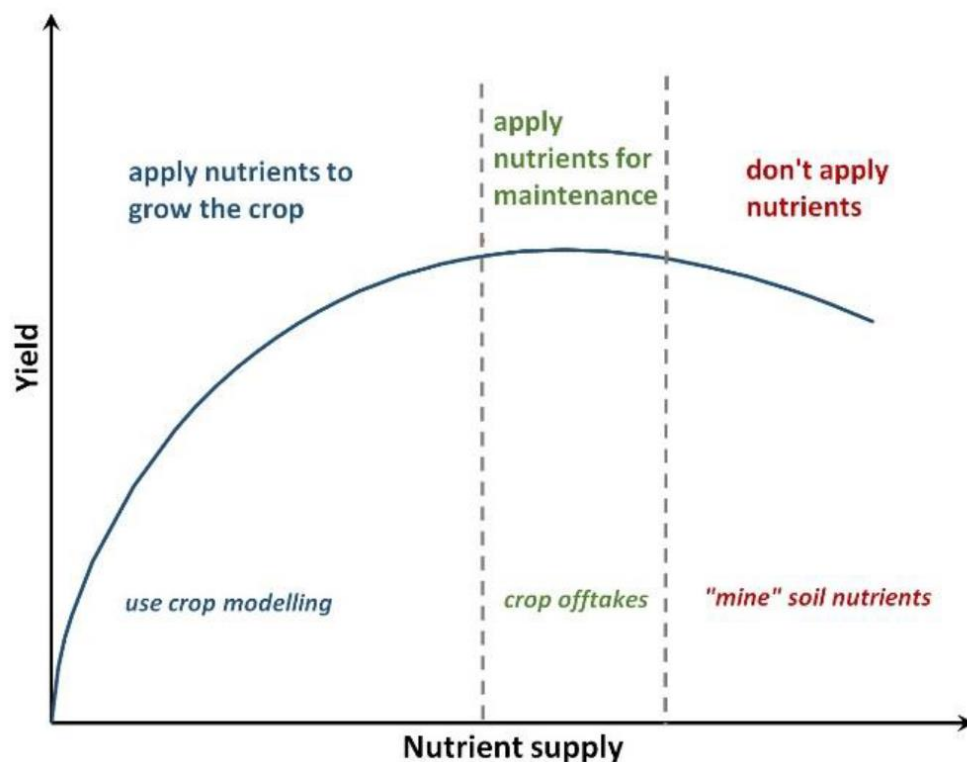


Figure 31. How Nutrient Supply Affects Crop Yield and requirement for additional nutrients. (From Reid and Morton 2019 "Nutrient Management for Vegetable Crops in New Zealand")

5.2 Fertiliser Rate

Choosing the right rate of fertiliser to apply will be determined by several factors including:

- Crop species
- Variety yield potential given the time of year and weather conditions (esp. water)
- Fertiliser nutrient analysis

Refer to the relevant crop chapter in “Nutrient Management for Vegetable Crops in New Zealand” to see specific details and recommendations.

5.2.1 Calculating the Application Rate

A variety of fertiliser products can apply N-P-K-S, however each product’s composition (that is, the amount of N-P-K-S etc the product will supply) differs. To calculate the amount of fertiliser product you should apply can be done with the equation below.

$$\text{Fertiliser Application Rate } \left(\frac{\text{kg}}{\text{ha}} \right) = \frac{\text{Nutrient required } \left(\frac{\text{kg}}{\text{ha}} \right) \times 100}{\text{Nutrient in Fertiliser } (\%)}$$

Worked Example from “Nutrient Management for Vegetable Crops in New Zealand” (p35)

A nutrient recommendation is for 30kg N/ha, 20kg P/ha, and 30kg K/ha,

What rate of 15-10-10 Fertiliser should be applied?

N: Rate of Fertiliser = $(30 \times 100) / 15 = 200\text{kg/ha}$

P: Rate of Fertiliser = $(20 \times 100) / 10 = 200\text{kg/ha}$

K: Rate of Fertiliser = $(30 \times 100) / 10 = 300\text{kg/ha}$

This fertiliser cannot apply the required N, P and K at the right rates.

Applying 200kg/ha of 15:10:10 meets the N and P recommendations but will only deliver 20 kg/ha of K. The remaining K (10 kg/ha) can be met by adding another fertiliser e.g. 20kg/ha Muriate of Potash (0:0:50).

6 Reducing Losses

6.1 Fertiliser type

Types of fertiliser include:

- **Solid:** Mixed dry blends of granules and powders
 - o **Granular:** Finely ground spherical fertilisers (4 – 5mm) e.g. DAP, SOA, Urea
 - o **Compound:** Combinations of chemicals formed into granules – which generally contain all the nutrients in each granule e.g. Nitrophoska, Yara Mila Complex.
 - o **Blended Fertilisers:** Dry mixes of different solid fertiliser products. There may be a risk of product separation due to uneven granule sizes when applying blends.
 - o **Controlled Release Fertilisers:** Granules are coated with a polymer that slows the release of the nutrient into the soil. Examples of compound slow release fertilisers include Osmocote and Agroblen, there are also single compound slow release fertilisers available (e.g. urea containing Smartfert)
- **Liquid Fertilisers:** made in NZ by dissolving solid fertilisers in water e.g. Urea
 - o Liquid fertilisers can be applied via fertigation, foliar spraying or through a Y-drop system (dribbled along the crop row at soil level).

For more information about Fertilisers – see Chapter 1 (pp. 13 – 20) in Nutrient Management for Vegetable Crops in New Zealand (Morton and Reid 2019).

6.2 Split Applications

Nutrients sitting in the soil awaiting uptake are at risk of leaching if there is too much rain or irrigation. Nutrient leaching occurs when nutrients in the soil are carried down the profile by drainage water. Once below the root zone the nutrients cannot be captured by plants and move with drainage to streams, lakes or the coast.

Applying just enough fertiliser in more, small doses reduces the amount that can be leached at any time. Overall this reduces leaching losses. A common approach is to apply some “starter fertiliser” at planting and wait until the plants have grown before applying the main dose as a side-dressing. Another is to fertigate through irrigation lines.

Plants need access to nutrients to grow but small plants cannot take up very much. Figure 32 shows that onions take up only 20% of their total nitrogen requirement before bulbing. In most cases, this is available from the soil without extra fertiliser needed.

Early planted crops take a very long time to reach bulbing so early fertiliser applications are at higher risk of leaching. After bulbing, nitrogen uptake increases, and fertiliser needs are met with three or four successive applications.

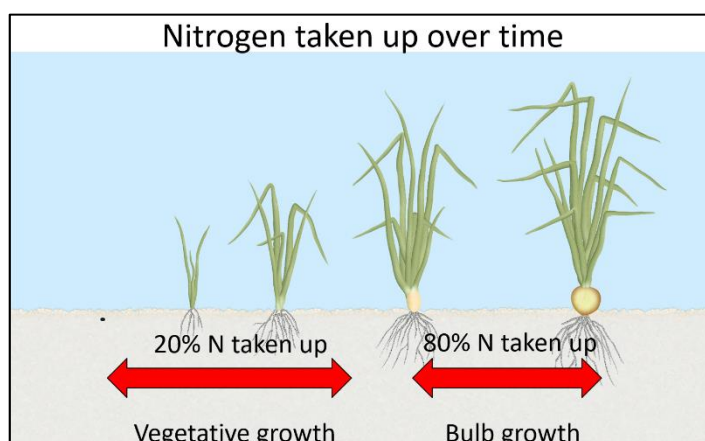


Figure 32: Timing of nitrogen uptake by onions showing 20% before bulbing and 80 % after bulbing. (Image from Plant & Food)

6.3 Application method

There are two broad categories of fertiliser application of solid fertilisers: broadcast and placement. Broadcasting covers large area more quickly with fewer passes, but placement is less accurate. Blended fertilisers that have components with different ballistic properties can separate out when broadcast, particularly over wide swaths. The risk of overthrow fertiliser reaching waterways also needs to be managed.



Figure 33: Broadcast spreading dry fertiliser on an onion crop at bulbing

Placement application includes knifing and banding of fertiliser products close the plant – both methods place fertiliser more accurately than broadcast application. By placing fertiliser close to the plant row, sparse root systems of certain crops (e.g. squash, onions) can intercept nutrients from the applied fertiliser more easily. Placing nutrients directly beside the active roots helps with nutrients such as Phosphorus that are relatively immobile in soil.

A more recent method applies liquid fertilisers directly to the roots of plants. One example is the “Y-Drop” as seen in Figure 34.



Figure 34: The “Y-Drop” liquid fertiliser application system directs nutrients to the base of crop plants and more directly to the developing root system. (Photos: Brad Bernhard, University of Illinois)

7 Nutrient Budgeting

Completing nutrient budgets enables you to estimate nutrient use efficiency, the use and losses of applied fertilisers. There are several ways to complete a budget, including Overseer and scientific models such as APSIM and SPASMO. A simple spreadsheet calculator can also give a reasonable idea of your probable efficiency.

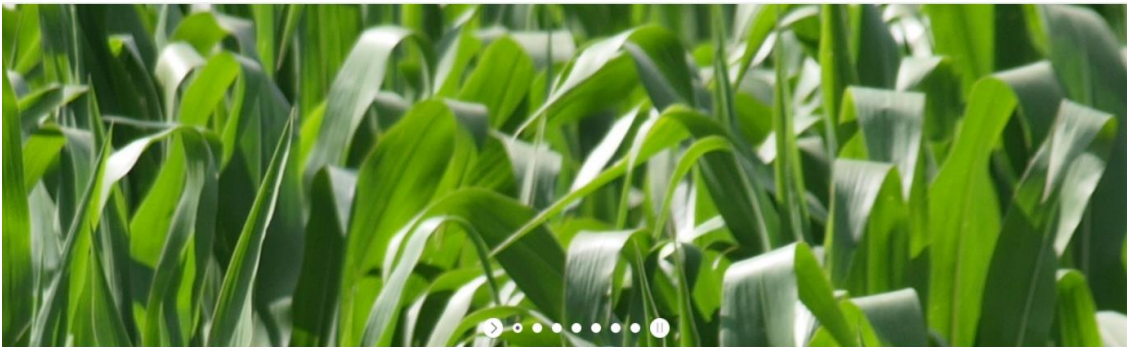
Whatever approach you take, you need to know how much nutrient was in the soil at the start and end of the crops of interest, how much nutrient was applied and how much nutrient was in the crop that was removed. These can all be measured in your paddocks, but seldom have been.

Soil nutrients are measured by soil tests. Fertiliser additions come from your application records. Crop removal comes from harvest data, but generally the weight of crop harvested needs to be measured. Typical plant nutrient can be used, or a tissue analysis could be obtained.

Overseer is a regulatory requirement in a number of regions including the Manawatu-Wanganui. Overseer has many in-built factors, but growers do need to maintain good records to ensure they can comply by correctly completing Overseer analyses. Apps such as My Ballance help keep information together.

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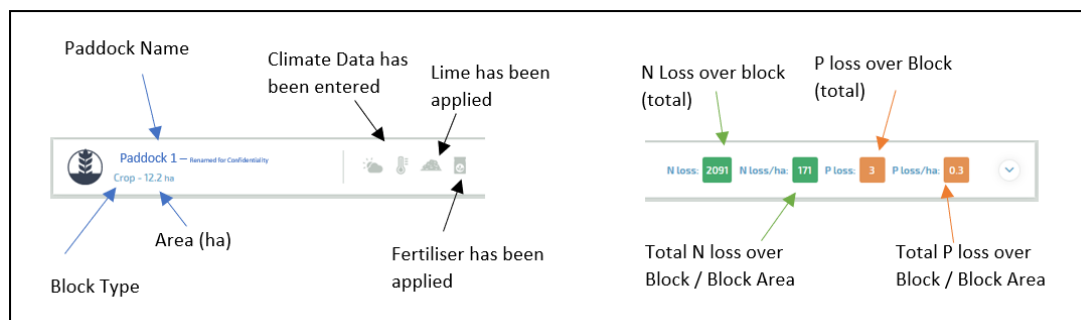
Overseer: great farming backed by science

Overseer is New Zealand software that enables farmers and growers to improve nutrient use on farms, delivering better environmental outcomes and better farm profitability.

First developed in the 1980s, Overseer is now an essential farming tool, founded on decades of scientific investment.

Some of these photos were supplied by the Fertiliser Association of New Zealand and AgResearch Limited.

[Getting Started with OverseerFM](#)



7.1 Overseer

Growers must collect and record certain information for Overseer Budgets to be completed.

Critical information includes:

