Future Proofing Vegetable Production: Baseline Performance Assessment

Pip McVeagh, Dan Bloomer, Georgia O'Brien

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Future Proofing Vegetable Production

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405649-M02: Baseline performance assessment – Levin and Gisborne

(Due 31 January 2019)

1 Base Line Assessment Introduction

The Future Proofing Vegetable Production project under Milestone 2 had four objectives:

1. Growers' fertiliser equipment assessed using FertSpread
2. Growers' irrigation equipment assessed using INZ Guidelines
3. Overseer nutrient budgets prepared for each farm based on a typical year scenario
4. Group and farmers supported to build capacity and capability

A brief summary of each objective and outcomes are provided in the following sections.

2 Fertiliser calibration assessments

2.1 Introduction

One of the four key areas within the Future Proofing Vegetable Production project aims to improve the accuracy of fertiliser applied. Growers were invited to participate in having their equipment assessed. Equipment was tested with growers in both Horowhenua and Gisborne. Ten fertiliser applicators have been assessed through working with eight growers. Multiple settings or products were tested for some equipment.

Performance assessment of fertiliser application equipment provides information on actual rates applied and the evenness of application. Ensuring that fertiliser is applied evenly minimises the risk of leaching if over application occurs, or the risk of yield penalties if under application occurs where nutrient availability is limiting plant growth. Growers were confident their equipment was spreading evenly, however the assessment results show there is room for improvement.

Fertiliser application equipment measured can be split into two main categories:

1. Direct placement machines (banders, side dressers and planters)
2. Broadcast fertiliser spreaders (spinning disc, oscillating spout)

Examples are shown in Figure 1.

2.2 Methodologies

Different methodologies are appropriate for broadcast versus direct placement equipment.

- Broadcast fertiliser spreaders were tested according to the FertSpread Protocol: see www.fertspread.nz
- Power take off driven placement equipment (banders or adapted oscillating spouts) were assessed by placing buckets under the outlets and collecting fertiliser for a measured time (~30 – 60 Seconds). By determining travel speed the application rate can be calculated.
- Ground driven equipment (most side dressers and planters) were assessed by collecting fertiliser from outlets over a set distance in-field or from 20-wheel rotations in static testing.

Figure 1: Examples of fertiliser application methods commonly used in vegetable growing systems: broadcast (left), potato planter (centre), and broadcast spreader modified into 2 row bander (right).

Tests were repeated twice, however where results between tests appeared quite different, the test was repeated up to six times. For some machines multiple settings or fertiliser products were tested.

Direct placement machines were assessed using a calibration calculator that has been developed over the period of testing this equipment as there is currently no accepted assessment by industry.

Three key performance indicators are suggested:

1. Target application rate vs. actual rate applied
2. Variation between outlets/spouts
3. Variation between test runs

2.3 Results

The application variability of the direct placement equipment tested varied quite markedly; from 0.4% CV to 26.4% CV. A summary of the test results for direct application equipment is provided in Table 1. All but one of the machines tested are within the SpreadMark accepted performance for broadcast spreaders applying nitrogen-based fertilisers. The actual rates of fertiliser applied varied from the target rates. In one case the actual average rate applied was 48% of the target rate, the greatest over application was 152% of the target rate.

The draft fertiliser calibration calculator for the assessment of direct application machines is included in the supporting documentation. This spreadsheet calculates and reports a wide range of statistics to assess performance.

Table 1: Summary of fertiliser applicator results for direct application machines

ID	Equipment type	Key performance assessment		Outcome and grower responses
		Actual as % of target rate applied	Overall CV%	
1	Bander	96	26.4	Grower made repairs and retested himself. Outlets are now significantly more even.
2	Bander	79	10.5	
3	Bander	79	0.8	
4a	Bander		16	Results of first test prompted grower to want to know actual rates applied using different settings of the same equipment.
4b	Bander	66	5.9	
4c	Bander		2.0	
5	Planter	114	4.1	Grower wants to clean out machine properly and have testing repeated to assess the difference between outlets as one outlet consistently lower than others. If results still show a difference, adjust openings and re test.
6	Side dresser	148	5.3	Concerns about bulk density of same product purchased in different years and effect on rate applied.
7	Side dresser	152	2.9	
8a	Side dresser	96	6.7	Difference in actual vs. target rates have prompted the performance assessment of fertiliser application equipment to be routinely completed prior to planting each season.
8b	Side dresser	48	6.5	
9	Side dresser	117	3.7	

Fewer broadcast spreaders were assessed as direct placement machines are more commonly used in intensive vegetable production systems. Table 2 provides a summary of the two broadcast spreaders assessed. Figure 2 gives a snapshot of part of the report produced through the FertSpread website. In this example, if the grower reduced their bout width, the machine performance would be within the acceptable level for nitrogen and non-nitrogen fertilisers.

Table 2: Summary of results for broadcast applicators

ID	Equipment type	Key performance assessment		Outcome
		Actual as % of target rate applied	CV%	
1	Broadcast	23	50.8	Grower went looking for technical documents received when other fertiliser application equipment was purchased. This provides guidelines for different products, rates and recommended settings of equipment to achieve this.
2	Broadcast	87	26.8	

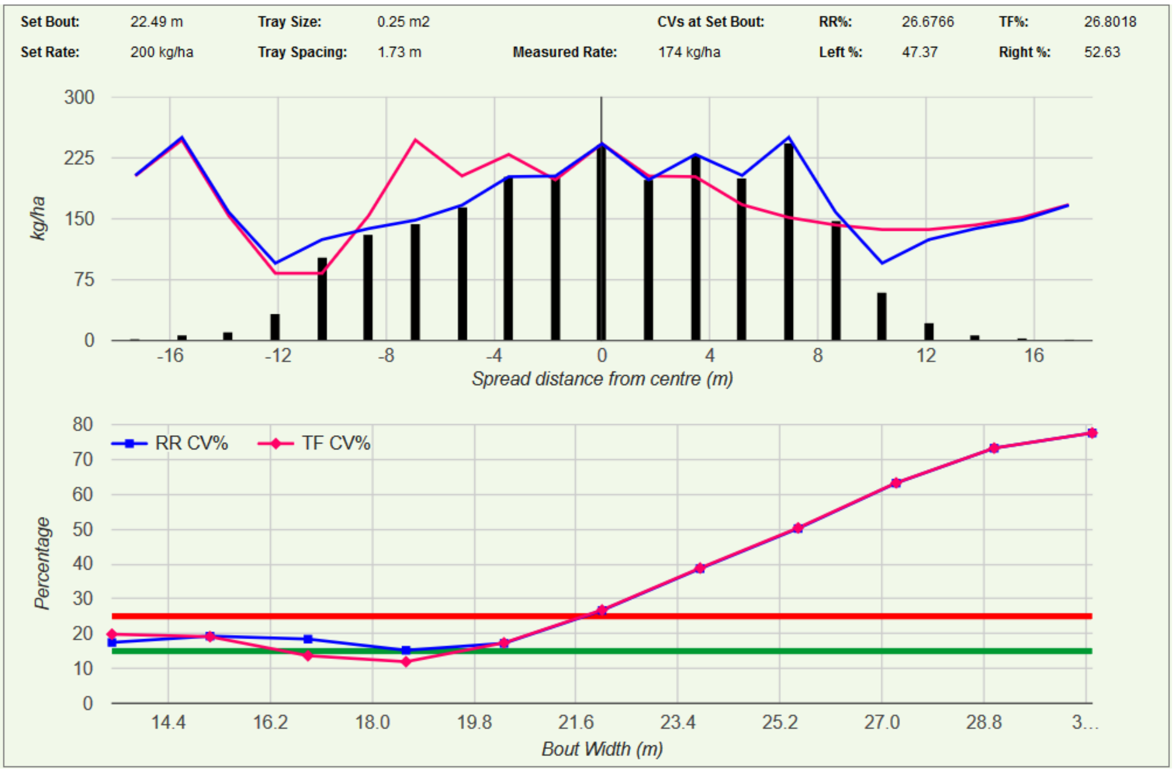

Figure 2: Example of the results of one of the broadcast fertiliser spreaders as reported in FertSpread.

The test results were entered in the spreadsheet and shown to the growers on a laptop at the time the tests were conducted. Growers will receive a formal report of their equipment performance in due course.

2.4 Discussion

Assessments have been completed on a range of fertiliser application equipment in both Levin and Gisborne. Most of the equipment tested has been direct application (banders, planters and side dressers), rather than broadcast spreaders. Fertiliser applications for vegetable production are predominantly applied as banded strips along the bed or scarified during planting or as a side dressing. There is currently no accepted protocol for the assessment of this type of equipment.

2.4.1 Direct fertiliser application (banders, planters and side dressers)

To enable the assessments to be completed within the project, a draft protocol and fertiliser calibration calculator for direct applicators has been developed and is being refined. This is currently in an Excel spreadsheet which has been developed as we have been testing equipment. The number of tests required and the statistical analysis to report the suggested three key indicators is still to be discussed and agreed upon. This concept and draft calculator will be taken to the annual Fertiliser and Lime Research Centre conference in February 2019 for advice from leading experts. The acceptable level of equipment performance and report outputs provided to growers will be discussed.

It is currently accepted for broadcast fertiliser spreaders that the coefficient of variation, CV, should not exceed 15% for nitrogen fertilisers and 25% for non-nitrogen fertilisers. The method of calibrating fertiliser rates applied ‘through the spout’ to achieve target rates are accepted, however a different statistical analysis is required for an assessment to be completed and best practice or acceptable levels of variation need to be defined. It is suggested that a CV of 15% for nitrogen or even non-nitrogen fertilisers is well below the capability of these direct placement applicators.

Machinery in good working order should achieve a CV of much lower than this, but an acceptable CV is not currently defined.

This has opened a new discussion around how the acceptable CV is determined and if this is applicable in vegetable production systems. Our understanding is that accepted variance is based largely on pasture value and response curves, we query what values are appropriate for high value vegetable crops. Excess fertiliser increases leaching risk, insufficient fertiliser can make a crop unsaleable through quality loss. This is another area that it is felt important and worth further investigation.

The results of the tests carried out on direct placement equipment highlighted several key areas to address:

- The target rate is not often achieved, the results showed machines are both over and underapplying, which have implications for leaching risk and potential marketable yield penalties or decrease nutrient use efficiency.
- In some cases, the outlets are not applying fertiliser at equal rates. The cause of this is different for each machine. However, the growers were keen to investigate why one outlet was applying a lower rate. In one case the grower was able to fix the equipment and significantly reduce the variation between outlets.
- One machine resulted in different rates being applied in each test. This is a greater concern for older equipment that is worn and manually operated hoppers.
- The amount of the fertiliser in the hopper appeared to affect the rate of fertiliser applied. This suggests that as the hopper empties that rate applied to the beds decreases. This also appeared to change significantly with the bulk density of the fertiliser product. More testing is required to investigate this further. There may be a minimum amount of fertiliser (product/bulk density dependent) required to be in the hopper to achieve an even application.

The interest and engagement of growers through testing their equipment has built awareness. Once a protocol is developed, the spreadsheet will then be developed into a tool for growers. Prior to next season, workshops demonstrating how to calibrate equipment, use the tool and interpret the report will be run in Gisborne and Levin, with the possibility of visiting additional regions. Conversations with growers during visits have shown there is good support for an event.

2.4.2 Broadcast fertiliser spreaders

Broadcast spreaders are less commonly used, and only two-disc spreaders were assessed. The results showed that at the current bout width used neither machine was achieving an acceptable CV for nitrogen fertilisers. One of the two was on the limit of acceptable for non-nitrogen fertiliser products. This suggests that the growers need to change either settings and/or bout width to achieve an acceptable CV.

There are companies who offer an assessment service where gear is tested according to SpreadMark and Amazon dealers have technicians that assess and calibrate their equipment. Some of the growers have been using these services to have their equipment assessed but we have been unable to find anything more than a certificate as evidence that the machine ‘passed’.

Reports are generated for all equipment we tested and are being distributed to growers. Some growers have requested that we re-test their equipment after they have made adjustments or prior to next season.

3 Irrigator assessments

3.1 Introduction

Irrigation assessments are important for ensuring the correct amount of water is applied to avoid yield lose due to moisture stress. However, excessive irrigation is a cause of nitrate leaching. A key aspect of the project addresses keeping nutrient in the root zone. Through assessing irrigation uniformity and depth applied, machine and irrigation management could be improved.

3.2 Methodologies

The irrigator assessments followed the 'bucket test' protocols as described in the Traveling Irrigator Performance Quick Test (http://www.pagebloomer.co.nz/wp-content/uploads/2009/08/IRRIG8Quick-TravellerGuidelines.pdf) . In brief, buckets were place at 1m intervals across the path of the irrigator (see Figure 3). The speed of the irrigator was measured as it travelled over the buckets. Once the irrigator had passed over the buckets, the volume of water collected in each bucket was then measured. The data was entered into IRRIG8Lite software and reports generated.

Figure 3: Bucket test layout under a travelling boom irrigator that was assessed.

3.3 Results

All three irrigators tested were traveling booms. The performance assessment was carried out twice on one of the travelling booms. An example of the distribution graph is provided in Figure 4**Error! Reference source not found.**. Of the four tests completed, the distribution uniformity assessment for two were 'adequate' and two were 'poor'. The distribution uniformity for the four tests were 0.72 and 0.75 for the 'adequate' performing machines and 0.6 and 0.45 for the 'poor' performing machines.

Figure 4: Example distribution graph from one of the irrigators assessed.

3.4 Discussion

The results so far show that there is room for improvement in the performance of the irrigators tested so far. Higher than average rainfall has meant irrigation events have not been required as often so far this season. However, some growers briefly ran their irrigators to allow tests to be completed. We will continue to assess irrigators as we are able to access them over the coming months.

4 Overseer

Overseer modelling for intensive vegetable production systems has proven to be a greater challenge than anticipated. The software was initially designed to support agricultural farming systems and has since added horticultural and cropping features. Thus, it has limitations in this area, and has not been / is not set up for these farming systems and limitations have been documented. However, this work has been beneficial in instigating conversations around these issues and the complexity of nutrient budgeting for intensive vegetable production systems.

Since reading the Parliamentary Commissioner for the Environment's report on Overseer, it has become clear that the model's application to vegetable cropping is limited. A summary of the reports' findings relating to this project are:

- High uncertainties in the model's outputs exist in cropping due to a lack of experimental sites
- Nitrogen calibration has been done in one arable crop site (Lincoln, Canterbury)
    - Compared with 8 nationally for pastoral systems
- No Phosphorus calibration has been done in arable systems
- Overseer relies on soil information as a key input; sites without S-Map data are limited to using the Fundamental Soil Layer (an older and less detailed soil map of New Zealand)
- Overseer cannot operate confidently outside of its calibration range (uncertainty >50%)

Creating Overseer budgets for all farms is unrealistic which has meant that this deliverable is unachievable at this time. This will also have implications for Milestone 3 where the deliverable required nutrient budgets to be combined to catchment scale. Overseer budgets have been attempted and are provided in the report (see section 4.1). This is an important issue given growers in the Horizons region are required to complete Overseer budgets. One grower has been quoted

$30,000 for an Overseer budget to be completed by a certified nutrient management advisor, with simpler production systems given estimates of$5,000-6,000. We will continue discussions with relevant parties in this area.

As part of the project we aimed to complete Overseer budgets for the vegetable growers involved in the project so that a catchment plan can be created using the combined nutrient loads. Whilst only one grower's operation has been modelled in Overseer, we have made significant progress in understanding and engaging with the software and its developers. This evidenced by:

- Attendance of the OverseerFM workshop in Hastings (31st January)
- Enrolling in Massey University's Certified Nutrient Management Adviser Certificate Programme (commencing late February)
- Email and phone correspondence with Overseer Helpdesk Staff (content of which is summarised in section 4.2)

4.1 Grower X Overseer Nutrient Budget Report – Potatoes and Onions

Grower X grows potatoes and onions. In order to simplify the multiple and complex operations they undertake in their farm system, we chose to model two paddocks (totalling 23.2 ha) that are representative of the majority of their production. A year end Overseer analysis was chosen as this is the regulatory mechanism Horizon's Regional Council are targeting in One Plan. Overseers 2015 version of Best Practice Data Input Standards was followed, minimising the uncertainty of data input quality.

Year 1 is modelled from data relating to the 2017/18 season, the start and end of which varies with crop (e.g. July 2017 to June 2018 for Potatoes, and April 2017 to March 2018 for Onions). Reporting year is modelled from data relating to the 2018/19 season (with the same start and end dates). The leaching loss data is modelled on reporting year data; however, year 1 data informs the model of previous land use to estimate crop residue retained from last year and the starting level of soil nutrients.

4.1.1 Modelled Paddocks Overseer Results

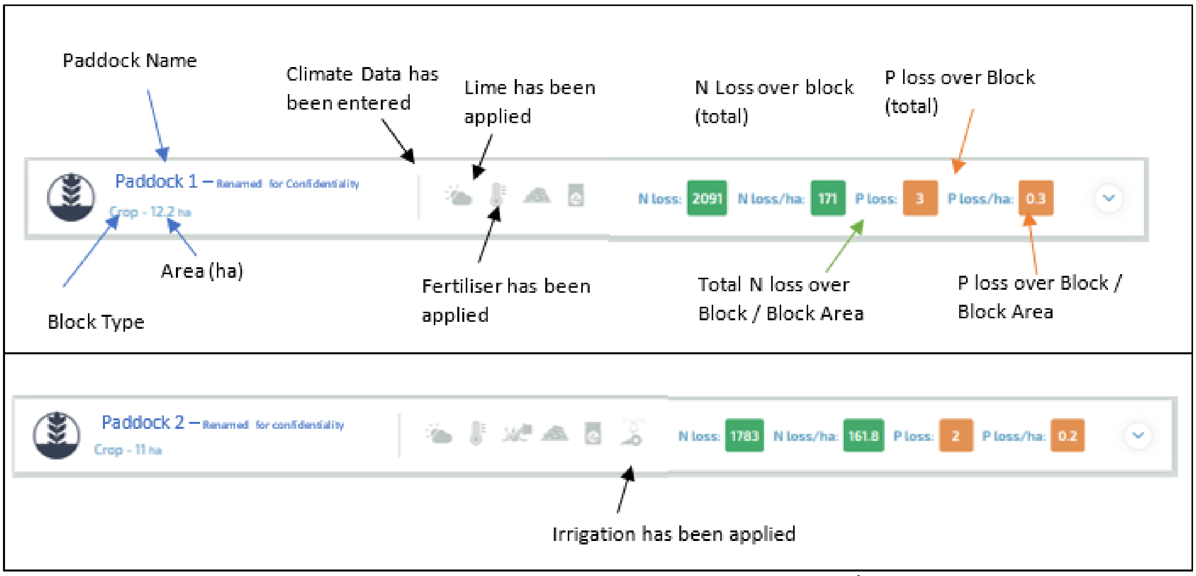

Figure 5. Overseer Results Bar Explained (raw data for table 3).

Leaching losses for the 2018/19 reporting year are as follows for the modelled areas (paddocks 1 and 2 on X's property).

Table 3. Table of Leaching Losses from Paddock 1 & 2.

Paddock	Area (ha)	Year Modelled	Leaching Losses	
			N (kg)	P (kg)
1	12.2	2018/19	1783	2
2	11		2091	3
TOTAL	23.2		3874	5
AVERAGE (per ha)			**167**	**0.22**

The average leaching loss across the two paddocks modelled is 167kg/ha of N, this is 557% of the One Plan allocated maximum leaching loss.

The nutrient budget created for grower X, reported leaching losses of N much greater than the allocated loss limit from One Plan (overall leaching averaged across area = 167kg N/ha). There were several difficulties with data inputs, and as a result the model does not include all the information, detail, and resolution that the grower provided. Furthermore, some information required by Overseer was not able to be obtained such as recent soil tests and soil information.

4.2 Areas for improvement

A case study of two representative fields of an onion and potato growing operation shows the software is not developed for intensive vegetable growing operations. Some of the key issues for creating a nutrient budget for a cropping system are outlined below.

- Two operations cannot be added in the same month e.g. cultivation and planting
    - For growers, land is often cultivated twice in a month before sowing the crop in the same month – often on the same day as the second cultivation so it is difficult to capture this information in the monthly schedule of Overseer
    - Many vegetable crops are grown in very short periods e.g. Summer lettuce is only in the ground for 6 – 8 weeks, so there are many operations going on in a single month (cultivation x 2, planting, harvest)

- Cultivation method inputs are limited
    - For example, spring tine, deep ripping (both non-conventional), and rotary hoe (conventional) have different levels of soil disturbance – and thus, amount of N mineralisation
    - Cultivation options include "minimal" and "no till" but it is unclear how similar these are to the non-conventional ones mentioned above

- Blocking land is difficult with the complexity of crop rotations and sequential operations
    - Many vegetable growers lease land and this is not easily included in a farm nutrient budget
    - Small paddocks e.g. 2 ha area are planted and harvested over an extended period so the cultivation may be identical for the area, but planting and harvesting dates are sequential based on market demand e.g. 2 ha lettuces = 400,000 lettuces total,

50,000 planted every week (over 8 weeks), then sequentially harvested as they mature, (50,000 harvested per week for 8 weeks or longer)
        - This is a very small area out of a much larger operation to split up into the many blocks that would be necessary to include for Overseer Best Practice Input Standards
    - Crop rotations mean that some blocks are split up some years and combined in others, previous land history for a piece of land over several years can be lost in this way. This means interannual averaging is not available to vegetable growers which is recommended by Overseer to achieve more accurate results.

- Yield inputs are in dry matter tonnes/ha – most growers of leafy vegetables (e.g. lettuce, cauliflower, broccoli) measure their harvest in terms of the number of full crates thus in volume rather than weight. The percentage dry matter of harvested crops is not measured.
    - Some growers weigh their harvest when weighing their transport trucks, thus a tonne value may be obtainable for fresh weight
    - Fresh weight yield for potatoes and onions was available for the farm we modelled, however, dry matter % conversion was based on industry averages that may not necessarily reflect the actual crop values.

The work completed attempting to enter the crops into Overseer has stimulated much discussion around the issues of using the tool in not only intensive vegetable systems but any cropping systems. These notes are a summary of the conversations via phone and email with Overseer Helpdesk staff. Following their feedback, it appears that the interface and input format can easily be changed, however it is unclear how the "engine" of the model could be adapted to adequately represent cropping systems. The availability of data/science to develop and calibrate for the wide range of vegetable crops has been questioned. It has been suggested that the PARJIB type modelling that informs the recent "Nutrient management for vegetable crops in NZ – recommendations and supporting information" may be helpful.

4.3 Next Steps in Overseer

Now that our preliminary modelling has been done, we have a greater understanding of the way Overseer functions, and its potential for improvement. Our next steps will be to apply it in modelling exercises with consistent methodologies to ascertain the sources of variation in its key outputs (N and P losses). This will allow our evaluation of its relevance and strength as a regulatory tool in intensive vegetable systems to be more informed, and when Overseer-determined N limits are enforced – to support growers to meet their targets.

5 Grower support

Through field visits and meetings, we have been able to provide support to growers involved with the project. The project is set up to work with and engage growers throughout the process. The conversations we have are helping us to gain an insight into the management strategies and difficulties growers are facing. This engagement in important for tailoring the project and identifying areas where our support is beneficial. Information flows in both directions!

For example, one grower explained that he only keeps his latest soil test results. However, trends in soil test results over years provides really important information and monitoring trends is recommended over one-off testing. We are endeavouring to obtain his records from labs so we can review them with him and explain their significance for his nutrient management decision making.

During discussions about nitrate-strip soil testing, several growers noted they were getting highly variable results and pointed out it depended where they took the sample. We noted that multiple cores must be combined and subsampled to get representative results. This is going to be covered in a planned workshop.

Our relationships with growers have been developing well. We have found that growers have been accommodating of us assessing their fertiliser spreaders when we arrive. Once the growers have looked over our shoulders and seen the fertiliser in the buckets and the weights, they have become very curious and involved in helping us conduct the tests. We have been pleased to be invited to stay longer for additional tests, cups of tea, or to return at a later date. We hope this reflects the benefit the growers feel they are getting from the project.

Opportunities for grower support identified:

- Development of a tool for direct fertiliser placement calibration
- Field day prior to next season to demonstrate fertiliser calibration protocols
- Understanding soil testing – collecting soil samples, interpreting results and following trends over time
- Conversations with growers regarding fertiliser rate checks have raised questions around spatial variability. Many use area (in hectares) logged via tractor GPS and known fertiliser weight in the hopper (e.g. a one tonne bag) to check the rate applied. However, we think it is important to encourage growers to consider the spatial variability within that area.

6 Additional work

Additional trial work is being established that has developed from conversations and research around the project.

A trial using Trichoderma with lettuce is currently being finalized with Lincoln University. The research group have been working with Trichoderma in pastures and are enthusiastic about a trial in vegetable crops. Research completed abroad has also shown promising results in lettuce inoculated with Trichoderma with increased yield and quality under low N conditions and a decreased incidence of disease. The aim will be to maintain yield while reducing N inputs required and therefore N leaching through inoculating lettuce with Trichoderma.

Potatoes NZ are running a field walk on one of the farms involved in the project. This event is scheduled for 27th February. They have requested we attend and explain the potential use of the Teralytic probes that were recently installed. We will investigate the use of the probes to track N movement down the soil profile.

Another trial is being developed to assess using a Y-drop system to apply liquid N fertiliser directly next to the crop. Results in corn from the University of Illinois have shown promising results in this area. The ability to apply liquid N across multiple rows would be beneficial in terms of: labour/fuel saving as more beds could be covered in one pass; reduced soil compaction from driving fewer passes; the variation in application rates of liquid fertiliser could be reduced compared to granular fertiliser. This trial is likely to be used on lettuce and broccoli at the MicroFarm in April/May.

Observations of changes in the applied rate at different hopper fill levels indicates that field application variability is likely to be greater than our static testing shows. We plan additional testing of fertiliser application equipment at different hopper fill levels, and GIS modelling will assess the likely field uniformity/variability that results from changing application rates.