PFR SPTS No. 21288

Sustainable Vegetable Systems — Quarterly report April to June 2021

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1 Summary

This report summarises activity carried out by The New Zealand Institute for Plant and Food Research Limited (PFR) from 1 April to 30 June 2021 (Quarter 4) across the different workstreams of the Sustainable Vegetable Systems (SVS) project. Within Workstream 1, broccoli and oat crops are nearing harvest in the Canterbury rotations, and pak choy is nearing harvest in the Hawke's Bay rotation. Plant biomass samples from the regional field trials of Workstream 2 in Canterbury, Manawatu, Hawke's Bay, Waikato and Pukekohe have been collected, and samples are being analysed for nitrogen content. Useful discussions around nitrogen (N) budgeting have been initiated with the Workstream 2 technical working group. Soil samples from regional sites are also being processed to estimate soil bulk density. In Workstream 3, an initial model calibration of Simple Crop Resource Uptake model operating within the Agricultural Production Systems sIMulator (SCRUM–APSIM) identified areas of further work, particularly around water drainage predictions in the model. A series of focus groups and interviews have been designed for implementation in Workstream 4 that will provide information on how best to proceed with extension of project findings and tool development.

2 Workstream activity

2.1 Workstream 1: Field experiments

Activity this quarter focused on establishing crops and collecting data for the different rotations of each of the experiments being grown at PFR research farms in Canterbury and Hawke's Bay.

Experimental details are outlined with more detail in the Year 1 annual report (Searle et al. 2021), but briefly, the treatments are four rates of N fertiliser rates (N0, N1, N2, N3) and two irrigation rates (I1, I2). These are replicated four times in a split plot randomised block, with irrigation as the main treatment.

The N rates aim to ensure that, where possible, a growth response to N is obtained with the optimum rate being provided at N3. But the primary aim is to ensure that there are differences in soil N over time, and in leaching between the N treatments, as this is the data needed for modelling and developing a farmer-facing tool that can support nutrient management decisions. The irrigation rates aim to provide a non-limiting amount of water to the crop (I1) and to irrigate to field capacity (I2) so that there is increased likelihood of drainage and this leaching during growth of a crop.

The exact rates of N and irrigation for each treatment will vary depending on the crop that is being grown.

Some initial results for the work in these experiments are presented in the Year 1 Annual report (Searle et al. 2021)

2.1.1 Canterbury Potato — Onion rotation

- During this quarter the crop in this rotation was broccoli (Figure 1). Broccoli transplants of the variety 'Nobel' with an average of four leaves were planted on 3 March 2021 (Figure 2). Harvest of the previous wheat crop in early February, and the additional ground preparation for the broccoli meant planting was delayed to early March.
- Broccoli seedlings were planted at 30 cm spacing within a row, with two rows in a 1.5 m bed (centre – to – centre) (Figure 2). Our measured plant population was 38,800/ha.

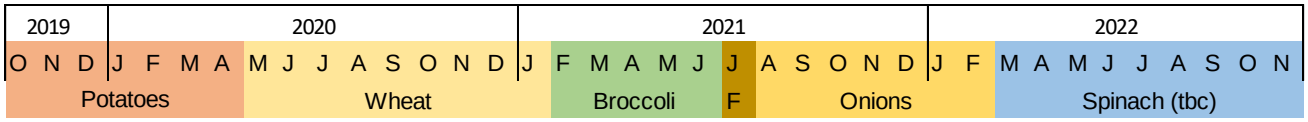

Figure 1. Canterbury potato — onion rotation crops. The final spinach crop is to be confirmed; the alternative is a ryegrass to follow the onion crop.

Figure 2. Broccoli experiment. Clockwise from top-left: 1) Transplanting broccoli crop, 2) initial plot set-up after any failed or missed transplants were replaced, and neutron probes (NP) and time-domain reflectometers (TDR) for soil water measurements were installed, 3) plot set-up; NP and TDR can be seen in the foreground, 4) aerial view of broccoli experiment. Ryegrass was sown between each block of broccoli; a block was a combination of all nitrogen treatments and an irrigation treatment.

- Soil content of phosphorus (P) and potassium (K) were slightly low prior to planting (Table 1), so a base fertiliser application was recommended by the supporting agronomist, at rates of 82 kg/ha of P and 84 kg/ha of K using a mix of triple super and potassium sulphate. In addition, 10kg/ha of boron (B) was applied with the base fertiliser.
- Soil mineral-N content in the N3 plots (these are the plots for recommended optimum N rates) was 37 kg N/ha in the top 60 cm, with 239 of kg/ha of mineralizable N in the top 60 cm, of which 130 kg N/ha was available in the top 30 cm of soil (Table 2).
- Using the potentially available N in the top 30cm of the soil, based on the agronomists recommendations and those of the Nutrient Management Handbook (Reid and Morton 2018), the chosen fertiliser rates for the treatments were 0, 30, 60 and 120 kg N/ha. These were applied as calcium ammonium nitrate (CAN) in two equally split side-dressings 35 and 62 days after planting.
- A final harvest will be completed in the next quarter; soil samples and biomass samples are being analysed.

Table 1. Soil nutrient content of soil for the broccoli crop of the Canterbury potato–onion rotation.

pH	Olsen P (mg/L)	Potassium (me/100g)	Calcium (me/100g)	Magnesium (me/100g)	Sodium (me/100g)	CEC (me/100g)	Base saturation (%)
6.2	21	0.27	9.6	0.74	0.20	15	73

CEC is the cation exchange capacity of the soil, a measure of the cations (including calcium, magnesium, potassium and sodium) that can be held by the soil and are available for plant uptake. The base saturation is a measure of the proportion of the CEC that is occupied by the basic cations (calcium, magnesium, potassium, and sodium).

Table 2. Mineral nitrogen (N) and potentially available N in the top 60 cm of soil. Samples were recorded prior to planting of the broccoli crop. Potentially available N was measured using the hot water nitrogen test, as a measure of N that can potentially become available during growth of the crop.

Soil depth (cm)	Mineral N (kgN/ha)	Potentially available N (kgN/ha)
0–30	32	130
30–60	5	109
Total	37	239

2.1.2 Canterbury — Vegetable rotation

- Oats were grown during the quarter in this rotation (Figure 3). The variety ‘Milton’ was sown 3 March 2021 at a rate of 120 kg/ha and had started to emerge by 9 March 2021 (Figure 4).

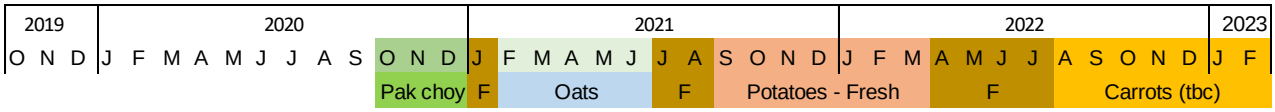

Figure 3. Canterbury vegetable rotation. The final carrot crop is to be confirmed; the alternative is a ryegrass to follow the fresh potato crop.

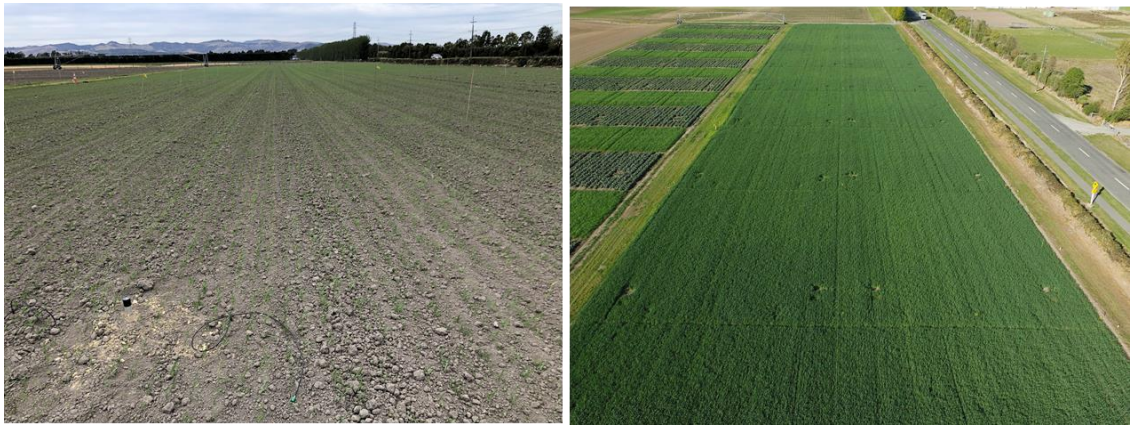

Figure 4. Oat experiment. Left image shows the crop approximately 1 week after emergence. A neutron probe and time-domain reflectometer (TDR) sampling point for soil moisture measurements can be seen in the foreground. Right image is an aerial view of the crop approximately 2 months after planting. The broccoli experiment in the potato–onion rotation can be seen to the left of the oat experiment. Biomass sampling points can be seen in the different oat plots.

- Soil tests results prior to sowing are shown in Table 3. Fertiliser applied was 22.5 kg/ha of K as base fertiliser prior to sowing.
- The oats were treated as a catch crop and no N fertiliser was applied; soil test results show a total of 91.3 kg N/ha of mineral N in the top 60 cm of soil (Table 4).
- Final harvest will be completed in the the following quarter; soil samples and biomass samples are being analysed.

Table 3. Soil nutrient content of soil for the oat crop in the Canterbury Vegetable rotation.

pH	Olsen P (mg/L)	Potassium (me/100g)	Calcium (me/100g)	Magnesium (me/100g)	Sodium (me/100g)	CEC (me/100g)	Base saturation (%)
6.0	26	0.27	9.2	0.66	0.18	15	67

CEC is the cation exchange capacity of the soil, a measure of the cations (including calcium, magnesium, potassium and sodium) that can be held by the soil and are available for plant uptake. The base saturation is a measure of the proportion of the CEC that is occupied by the basic cations (calcium, magnesium, potassium, and sodium).

Table 4. Mineral nitrogen (N) and potentially available N in the top 60cm of soil. Samples were recorded prior to planting of the broccoli crop. Potentially available N was measured using the hot water nitrogen test, as a measure of N that can potentially become available during growth of the crop.

Soil depth (cm)	Mineral N (kgN/ha)	Potentially available N (kgN/ha)
0–30	71.7	130
30–60	19.6	90
Total	91.3	220

2.1.3 Hawke's Bay — Onion rotation

- The land is being prepared for this rotation which will start in July/August 2021 (Figure 5).

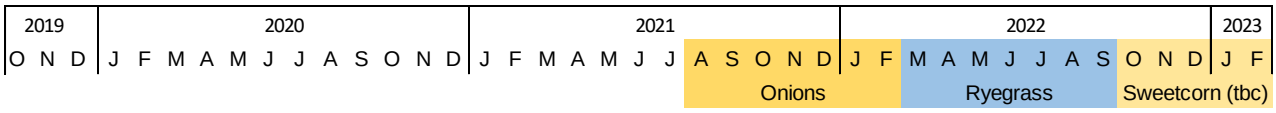

Figure 5. Hawke's Bay onion rotation. The final sweetcorn crop is to be confirmed; the alternative is that this rotation will finish with the ryegrass crop.

2.1.4 Hawke's Bay — Vegetable rotation

- The first crop in this rotation, pak choy (Figure 6), was sown on 22 April 2021. Plant spacing was 9.3 cm within a row with four double rows (Figure 7) across a 1.82 m bed, giving a plant population of 472,645 per hectare.

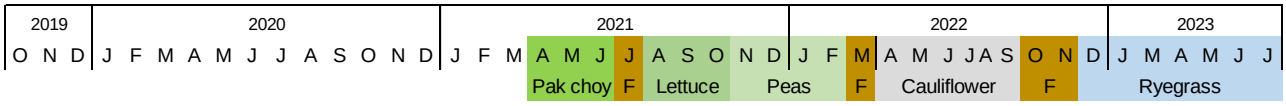

Figure 6. Hawke's Bay vegetable rotation.

- Unlike the Canterbury based rotations, which are sown in a single column of 200 m length and 50 m wide (1ha), the Hawke's Bay rotations are grown in two columns 100 m long and 50 m wide (Figure 7). This is due to the field size and arrangement in the PFR, Hawke's Bay farm allowing column lengths of 100 m. The column width of 50 m matches the width of the travelling irrigator boom.

Figure 7. Pak choy experiment in Hawke's Bay vegetable rotation. Left image shows the two columns used for planting, separated by a grass trip 5 m wide. The right image shows the plots in the first columns approximately 1 month after sowing. The arrangement of four double rows per bed can be seen.

- Soil Olsen P tests results varied between the two columns (Table 5). Consequently, fertiliser recommendations from supporting agronomists suggested basal fertiliser P rates of 44 kg P/ha in Column 1 and 22 kg P/ha in Column 2, applied as triple superphosphate prior to sowing.
- Soil N did not differ markedly between the columns. There was an estimated 91.3 kg mineral N per hectare in the top 60 cm of soil, and 99 kg N/ha potentially available through mineralisation (Table 6).
- We relied on agronomist input for N fertiliser rates, as there are no published recommendations for pak choy. The rates chosen were 0, 30, 60 and 120 kg N/ha (Table 7), with half the fertiliser rate applied at sowing with the base fertiliser, and the other half split into two side-dressings. Side-dressings occurred 28 and 56 days after planting.
- A final harvest was completed in following quarter of this year; soil samples and biomass samples are being analysed.

Table 5. Soil nutrient content of soil for the oat crop in the Canterbury vegetable rotation.

Column	pH	Olsen P (mg/L)	Potassium (me/100g)	Calcium (me/100g)	Magnesium (me/100g)	Sodium (me/100g)	Sulphate-S (mg/kg))	CEC (me/100g)	Base saturation (%)
1	6.2	12	1.00	14.5	2.25	0.15	14	21	83
2	6.5	25	1.10	14.5	1.93	0.11		20	89

CEC is the cation exchange capacity of the soil, a measure of the cations (including calcium, magnesium, potassium and sodium) that can be held by the soil and are available for plant uptake. The base saturation is a measure of the proportion of the CEC that is occupied by the basic cations (calcium, magnesium, potassium, and sodium).

Table 6. Mineral nitrogen (N) and potentially available N in the top 60 cm of soil. Samples were recorded prior to planting of the sowing of pak choy crop. Potentially available N was measured using the hot water nitrogen test, as a measure of N that can potentially become available during growth of the crop.

Soil depth (cm)	Mineral N (kgN/ha)	Potentially available N (kgN/ha)
0–30	71.7	57
30–60	19.6	42
Total	91.3	99

Table 7. Nitrogen (N) fertiliser treatment rates applied to the pak choy crop in the Hawke's Bay vegetable rotation. Side-dressing 1 occurred 28 days after sowing and Side-dressing 2 occurred 56 days after sowing.

Treatment		Base fertiliser	Side-dressing 1	Side-dressing 2	Total kg N/ha
Control	No N	0	0	0	0
Low	Half standard	15	7.5	7.5	30
Medium	Standard	30	15	15	60
High	Double standard	60	30	30	120

Data from Workstream 1 collected this quarter is being collated prior to analysis and sharing with Workstream 3 for model development. A final harvest has not yet been completed to have a complete data set, final soil samples are still to be collected and nitrogen analysis of plant and soil samples is underway. This final data set will be collated for further analysis and sharing with Workstream 3.

2.2 Workstream 2: Regional monitoring

Details of site activities:

Site	Region	Crop	Activities
1	Pukekawa	Ryegrass cover crop	*Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing. *Soil bulk density* samples received, analysis ongoing.
2	Pukekohe	Barley cover crop	*Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing. *Soil bulk density* samples received, analysis ongoing.
3	Tuakau	Mustard cover crop	*Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing. *Soil bulk density* samples received, analysis ongoing.
4	Matamata	Potato	*Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing Visit has not been able to be organised. *Soil bulk density* samples received, analysis ongoing.
5	Manawatu	Potato	*Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing. *Soil bulk density* samples received, analysis ongoing.
6	Manawatu	Summer maize	*Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing. *Soil bulk density* samples received, analysis ongoing.
7	Hawke's Bay	Squash	*Discussions* reviewing sampling methodologies and protocols as crop matured. *Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing. *Soil bulk density* samples received, analysis ongoing.
8	Canterbury	Potatoes	*Discussions* reviewing sampling methodologies and protocols as crop matured. *Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing and mostly completed. *Soil bulk density* samples received, analysis ongoing.
9	Canterbury	Pumpkin	*Discussions* reviewing sampling methodologies and protocols as crop matured. *Plant biomass* samples received, processed and submitted to lab for analysis. Plant N content analysis ongoing and mostly completed. *Soil bulk density* samples received, analysis ongoing.

2.3 Workstream 3: Modelling

Modelling design and development

- To help identify the best approach to develop a farmer facing tool, a Community of Practice has been established. This group has met to discuss the modelling priorities and identify an approach to the modelling and the tool development.
- An initial focus is on testing Overseer. One aspect of this is improving the crop coefficients used in Overseer, which will be based on expert guidance. These can then be used for better prediction within Overseer. A second aspect is to run Overseer with outputs of the rotation data obtained in workstreams 1 and 2. This is being set up, and will proceed with more crops within the rotations to evaluate options for updating Overseer.
- As data are collected and modelling carried out using these data, the needs and best approaches for modelling will be further refined. This is a necessary step to improve predictions, and especially to develop the farmer facing tool.

Modelling delivery and implementation

- Data from the potato – wheat rotation has been used to test the SCRUM–APSIM and has been reported in Searle et al. (2021). The work has identified that, on average, soil mineral N was over-predicted across treatments and indicates the need to refine the model components of N balance in the crop system. Work is underway to refine soil water prediction, which is important for reliable predictions of soil N.

2.4 Workstream 4: Technology transfer

PFR have attended online meetings held by WS4 and been actively involved in giving feedback where requested eg in the question design for the Baseline survey carried out by Folkl. The background preparation for undertaking grower interviews began to be put in place, including bring up to speed the new social researcher Waka Paul who will work alongside SVS to gather information on grower practices, views and beliefs in the area of N management. Contributions and feedback to communications developed or fostered by WS4 have also been made.

3 Key highlights and achievements

Workstream 1

- We have progressed the rotations in Canterbury and started the rotation in Hawke's Bay.
- Broccoli and oat crops nearing harvest in Canterbury rotations.
- Pak choy sown in Hawke's Bay vegetable rotation and nearing harvest.

Workstream 2

- Useful, ongoing discussions with regional crop monitoring leads on sampling protocols to ensure that appropriate samples are being collected or analysis.
- All data for first season crop collected; plant samples being processed for N analysis.
- Discussion regarding N budget approaches ongoing.

Workstream 3

- Initial calibration of SCRUM–APSIM model implemented. Identified areas where further work is needed.
- Meetings with growers to define crop coefficients for vegetables crops that at the moment do not have coefficients or use proxies in Overseer. These have also been useful in helping determine some of the issues to consider in developing a farmer-facing tool.

Workstream 4

- A design methodology and plan has been developed to engage growers in the project. Interviews and focus groups are being planned.

Governance and management

- SVS PFR programme management team held monthly meetings to align workstream activities and manage activities
- Miriam Hall, along with Programme Manager presented SVS to a group including representatives from Ngāti te Ata, Ngāto Tamaoho, Auckland and Waikato Regional Councils, Ministry for the Environment, and Ministry for Primary Industries in Pukekohe on 27 April 2021.

4 Collaboration with other programmes (optional)

- Real time N-losses — Rural Professional Fund through Our Land and Water National Science Challenge, looking at real time measurement of N losses under vegetable production in Hawke's Bay. PFR is providing data analysis support to this project. This project data provides results for onion fields that can be compared with SVS results.
- Residue incubation — PFR funded project looking to quantify the rate of decomposition of different vegetable residues and the rate of N release from the residues into the soil. Some residues will be obtained from crops grown in Workstream 1 and will inform any issues to consider in the SVS project.
- Process Vegetable Coefficients – Funded by Process Vegetables New Zealand, looking to quantify some of the coefficients needed for N uptake and use by processing crops within Overseer. This will heave direct relevance to some of the crops being considered in WS1 rotations.
- Mineralisable N to improve management — a SFF project looking to improve the measurement and prediction of the amount of biologically mineralized N in a field. This pool of N is a key component for understanding crop N requirements, together with measurements of mineral N (nitrate and ammonium).

5 Upcoming

- Broccoli and pak choy harvest will be completed in Workstream 1, and next crops will be sown.
- N budget discussions will be ongoing, and data from Worstream 1 and 2 evaluated for N budget development.
- Modelling workshop to be held and to help define design and implementation.
- Interviews with key individuals to determine issues associated with N management, and focus groups to help consider implementation will be initiated.

6 Recommendations/decision points

None for this quarter.

7 Progress against work-plan

Key: Project Status

Completed	
On Track: no change to outcome(s) or milestone date; < 10% variance to budget	
Slight Variation/Delay: adverse change to expected outcome(s); > 3 month delay to milestone; 10–25% variance to budget	
Attention Required: outcome(s) not expected to be achieved; > 6 month delay to milestone; >25% variance to budget	

7.1 This Quarter

Work-stream	Financial	Timing	Outcome	Progress against Work Plan Comments
1.				1.1 – Robust data from controlled experiments
2.				2.1 – Data collection, analysis and contribution to reporting
3.				3.1 – Model design and development • Scope of farmer facing tool determined and detail required for baseline predictions, design options considered. Contribution towards annual report on progress towards model development completed. • Update IP plan. • Model calibration underway. 3.2 – Model delivery and implementation • Scoping and development of farmer facing tool • Model calibration underway
4.				4.1 – Ext Understanding the current landscape • Report on facilitating implementation 4.2 – Extension activities • Stakeholder analysis • Development of extension activity plan • Year 1 Annual extension activities and plan for Year 2 • Development of feedback loops from Workstream 4 to Workstream 2 and 3
Gov Mgmt				

7.2 Next Quarter

Workstream	Financial	Timing	Outcome	Activity in the next Quarter Comments
1.				1.1 – Robust data from controlled experiments. • Onions sown in Lincoln Potato – Onion rotation. • Potatoes for fresh market sown in Lincoln Vegetable rotation. • Onions sown in Hawke's Bay Onion rotation. • Lettuce planted in Hawke's Bay Vegetable rotation. 1.2 – Data analysis underway. • Contribution to N budget development and modelling.
2.				2.1 – Data collection, analysis and contribution to reporting. • Any changes to protocols with changing crops identified and discussed. • Data analysed and passed to Workstream 3. • N budgets developed and discussed.
3.				3.1 – Model design and development • Modelling workshop held to discuss and determine structure and requiremnts of farmer facing tool determined and detail required for baseline predictions, design options considered. Modelling workshop. • Update IP plan. 3.2 – Model delivery and implementation • Model calibration continues; provides information on system leaching and information for development of farmer facing tool.
4.				4.1 Understanding the current landscape • Focus groups initiated. • Individual grower interviews conducted. • Surveys conducted as required. 4.2 Extension activities • Data from focus groups, interviews and analysed and used to inform developing extension plan. • N budget development with WS2 participants to co-develop a useable approach. • Communication plan implemented, articles submitted for publishing. • Development of feedback loops from Workstream 4 to Workstream 2 and 3.
Governance				• Update IP plan for data and farmer facing tool development.

8 PROGRESS TOWARDS OUTCOMES

These have been taken from The Programme – Schedule 5 and KPIs in the contract.

Outcome	Target	Actual	Status	Comment
WS1 Literature review	30 Sept			
WS1 Trial sites established at PFR Hawke's Bay and Lincoln	30 Nov			
WS2 Development of a Technical Working Group	30 Sept			
WS2 Regional on farm monitoring sites established	30 Sept			
WS3 Development of a community of practice made up of current Overseer users	30 Nov			
WS4 Development of extension activity plan	30 Oct			
KPIs				
1.1 & 2.3 Methodology is developed and approved by Technical Panel	31 Oct			
2.1 Attain and maintain participation of 9 monitor paddocks for workstream 2 across 5 regions	30 Sept			
2.2 Technical Panel is established and met	30 Sept			
3.1 Agreement on monitoring data requirements and links to WS2	31 Oct			
3.2 Agreement with Overseer on model access and working relationship	30 Nov			
4.1 Development of extension activity plan	30 Oct			

Key: Outcome Status

Completed: The outcome has been delivered	
On Track: The outcome is on-track to be delivered	
Variation/Delay: There is a delay expected or a change to the outcome	
Attention Required: It is likely that the outcome won't be achieved or the benefits associated with it will be significantly reduced if changes aren't made	

9 Programme issues or risks

None for this quarter.

10 Communications and engagement

- A plan for monthly articles on the project with timely topics has been developed. The aim is to publish these articles in The Grower Magazine, or similar. This includes updates from the modelling workshop that will be held, N budget approaches, and soil testing terms.
- Within Workstream 2, individual discussion with participating growers of N budgets will help inform work in Worstream 3 and 4.
- There will be a presentation by PFR of the SVS project at the HortNZ conference (August 2021).

11 Health and safety

Health and Safety protocols have been implemented when visiting fields and conducting experimentation.

12 References

Reid JB, Searle B, Hunt A, Johnstone P, Morton JD 2019. Nutrient Management for Vegetable Crops in NZ – recommendations and supporting information. Edition 1.0. January 2019. A Plant & Food internal report. SPTS MNo. 17238. DOI 10.5281/zenodo.2401444.

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13 Acknowledgements.

We would like to give thanks to all the agronomists who have supported decision making in Workstream 1, and to Lonza Group AG for supplying agrichemicals to Workstream 1.

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