LandWISE INCORPORATED

HAWKE'S BAY FUTURE FARMING
TE MATAU A MĀUI AHU WHENUA-HĪKINA TAIAO

Carbon Positive Milestone 6

Operational Report Prepared by LandWISE Inc.

Due 1st February 2024

Contents

Milestone 6 Due 1 Feb 2024

Date: 1 Feb 2024	**Milestone 6**
Milestone description	Year 2 Progress as per planned milestones
Target Outcome	Showcasing growing mixed crops under alternative management systems
Activities undertaken	PSG Meeting to review milestone reports, Year2 summer process crops established, crop monitoring, outreach Field Day Further activities as per Annual Project Plan and Annual Science Plan.
Deliverables / evidence of completion / achievement of Outcome	Trial results, copies of all extension material. Photos of events (preferred but not essential) PSG and TAG meeting minutes. Deliverables as per milestones within Annual Project Plan and Annual Science Plan.
MPI Funding amount	$83,303.55
Co-Funding contribution	$35,701.52
Total	$119,005.07

Milestone 6 Science Plan Activities

Activity	Completion Date	Details
PSG Meeting to review milestone reports	1/02/24	
Crop Monitoring	Ongoing	
Soil Monitoring		
Soil Nitrate Quick Test	Ongoing	Fortnightly 3 depth increments: 0 – 15 cm, 15 – 30 cm, 30 – 45 cm
Hot Water Extractable Carbon (Intermediate Sampling) Results	10/11/2023	0 – 15 cm, 15 – 30 cm & 30 – 60 cm, 10 x 30 cores per plot. Combine East and West ends 5 cores each) at each depth and send composite sample for lab testing (Due in MS5 reported MS6)
Soil moisture probe	Ongoing	(LandWISE – GroPoint sensors to 90 cm (15 cm intervals) calibrated against neutron probe)
Soil temperature	1/02/24	In planting line (GroPoint sensors and i-Buttons at 10 cm depth in planting line)
Soil infiltration rate	10/11/2023	Overdue
Soil moisture release curve	10/11/2023	Overdue
Plant Monitoring		
Establishment percentage	1/02/24	Population after planting
Canopy development	Ongoing	Weekly from planting to closure using Canopeo App
Agronomic observations/ crop health monitoring	Ongoing	Weekly crop walks alongside field agronomist
Observable deficiencies recorded	Ongoing	Foliage test if suspicious
Tissue testing	Ongoing	After planting, before in-row closure (side dressing), late season
Pest and disease presence	Ongoing	Sticky traps, relative slug activity
Weed survey	Deferred until cover crop planted	4 x 0.25 m^2 quadrat. Identify species in quadrat, and score amount of that weed (1 = few, 2 = some, 3 = many)
Maturity	Ongoing	*Confirm measurements with Watties
Record Keeping		
Record applied nutrients	Ongoing	All granular and foliar nutrient applications recorded
Record agrichem applications	Ongoing	All herbicides, insecticides, fungicides applications recorded in ProductionWise
Record biological product applications	Ongoing	All biological product applications recorded
Record irrigation events	Ongoing	By linear irrigator as required according to monitoring All treatments will receive the same irrigation program
Other Actions		
Water sensitive paper testing	1/02/24	Test spray coverage during season
EIQ Risk Assessment calculated	Ongoing	AgChem applications https://cals.cornell.edu/new-york-state-integrated-pest-management/risk-assessment/eiq/eiq-calculator
Outreach field day	1/02/24	Monthly crop field walks
Magazine article	10/11/2023	Part of MS 5 (report in MS 6)

Overview of Tomato Production

At the time of reporting the crop of Heinz-Watties tomatoes has been growing for 12 weeks. While there was a wet start to the season, particularly through November, the weather has turned hot in the New Year, and the tomatoes have been growing well. The linear irrigator at the LandWISE MicroFarm has been turned on for the first time in two years to counter the dry weather. Figure 1 shows mean air temperature (red line) and rainfall (blue bars) since planting.

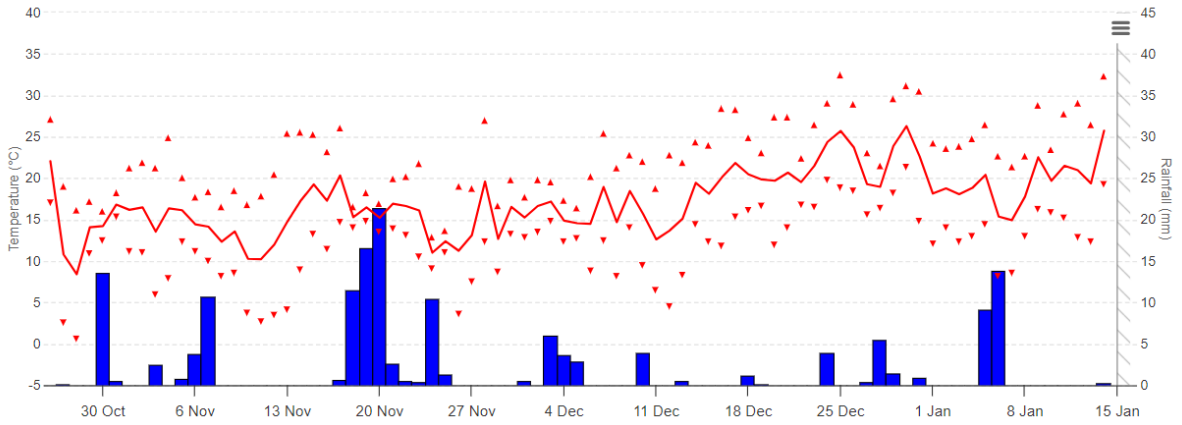


Figure 1 Soil Moisture and Rainfall data (Ruahapia Road Weather Station 26th Oct - 15th Jan retrieved from HortPlus MetWatch)

The tomatoes have been monitored closely through the season, with a particular focus on weekly crop walks which are attended by members of the Operations Advisory Group including Heinz-Wattie's staff, technical field reps, growers, and other advisors. These meetings have been held each Thursday at 9am, with up to eight people joining to discuss the week that's been and the week ahead. Key topics of discussion include irrigation, crop protection and nutrient management. Crop protection and nutrient management has been different across each treatments, and we continue to work within the three frameworks or philosophies of the different 'farm systems'. It should be emphasised how important these weekly catch ups have been to the overall success of the crop so far, as well as the excellent engagement seen from those attending the meetings.

There has been a range of weekly and fortnightly measurements completed to monitor crop development and soil conditions, and there are some interesting trends and treatment differences emerging which will be discussed in this report. Figure 2 shows visual changes in each of the three treatments, week on week.

In this Milestone Report, results from the Hot Water Extractable Carbon (cores taken as part of Milestone 5) will be reported.

Harvest date is planned for the 5th of March.

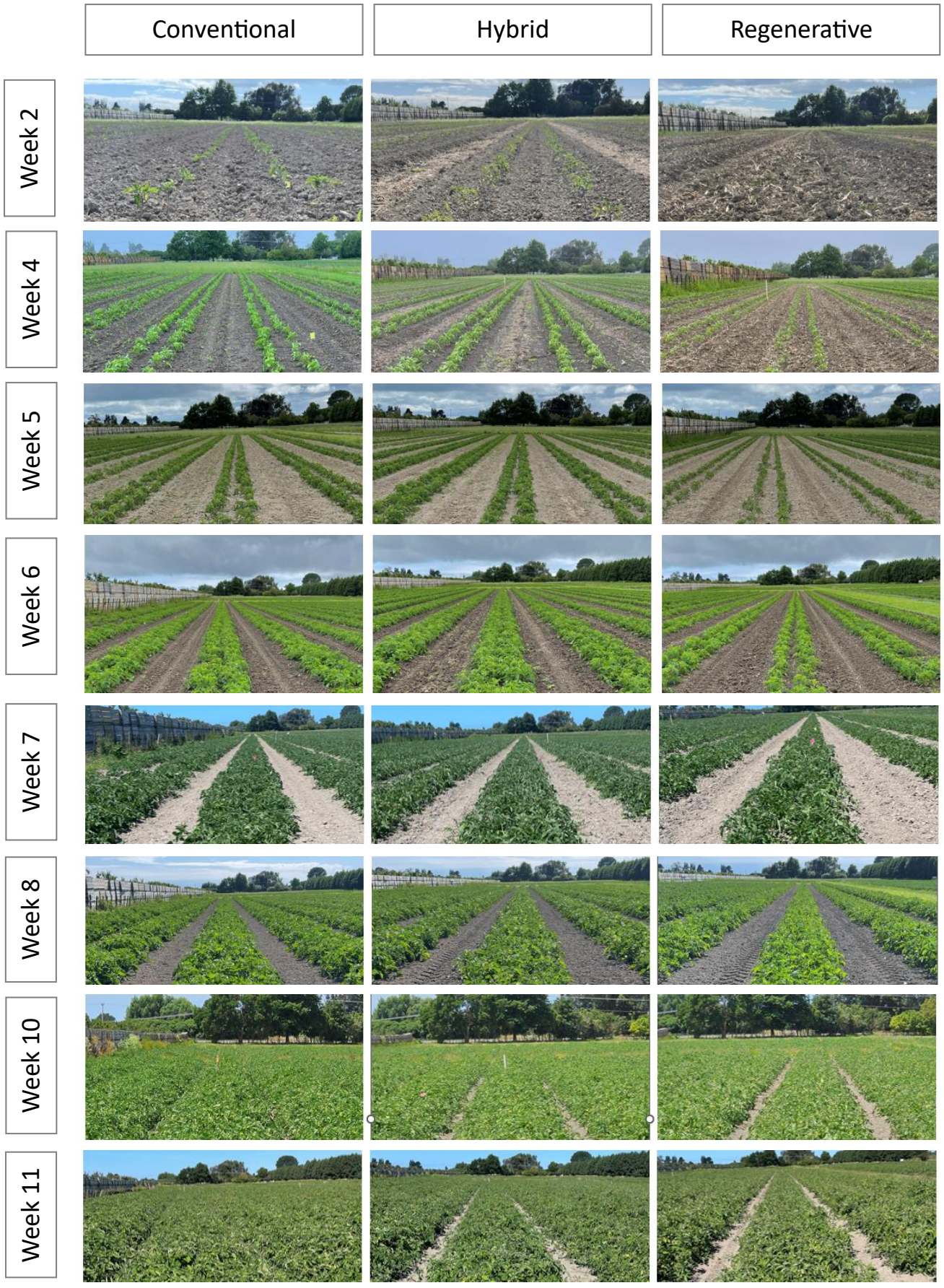


Figure 2 Week on week visual changes of three treatments

Soil Monitoring

Soil Nitrate Quick Test

Soil Nitrate-N has been measured fortnightly using the Nitrate Quick Test method. Monitoring started pre-planting (Week 0), and a test was timed two days ahead of side dressing to ensure we had up to date nitrogen data to inform fertiliser decision making. Monitoring nitrate has been especially interesting as the Regen treatment had the cover crop of oats incorporated the day before planting. It is assumed some nitrogen will be temporarily 'locked up' in the breakdown of the plant material in the soil, with nitrogen being made available slowly through the growing season. Samples were taken and tested to at least 30cm (in two 15cm increments), and to 45cm as the weather allowed it. It is predicted that most of the plant root mass will be in the top 30cm of the soil profile, based on observations that in most of the plots there is a tillage pan at about 30cm, which roots will likely struggle to growth through.

We have been experimenting with a Nitrachek-404 device (imported from Germany) which is designed to give a more accurate nitrate concentration of a nitrate test strip, rather than using a visual colormetric reading. This provides a greater level of confidence in the results of the test strips, and so far, appears to be more precise within the concentration range expected from the soil samples. Nitrate concentration is converted using the FAR Mass Balance Tool to determine kilograms of nitrate available per hectare.

Figure 3 shows the results of the nitrate tests in the top 15cm of the soil profile. Nitrogen was applied at varying rates, to all treatments at planting (26th Oct) and side dressing (15th Dec). Nitrate levels have been lower in the Regenerative plots than in the Conventional and Hybrid plots. Soil nitrate levels have been dropping since side dressing (Week 7), as the plant demand for nitrogen has increased through the early-mid stages of fruit set. The most recent test in mid-January shows the lowest nitrate levels from any of the previous tests in the Conventional and Hybrid Treatments, and levels in the Regenerative treatment have dropped towards the pre-plant levels. It appears that plant demand for nitrogen is exceeding nitrogen availability.

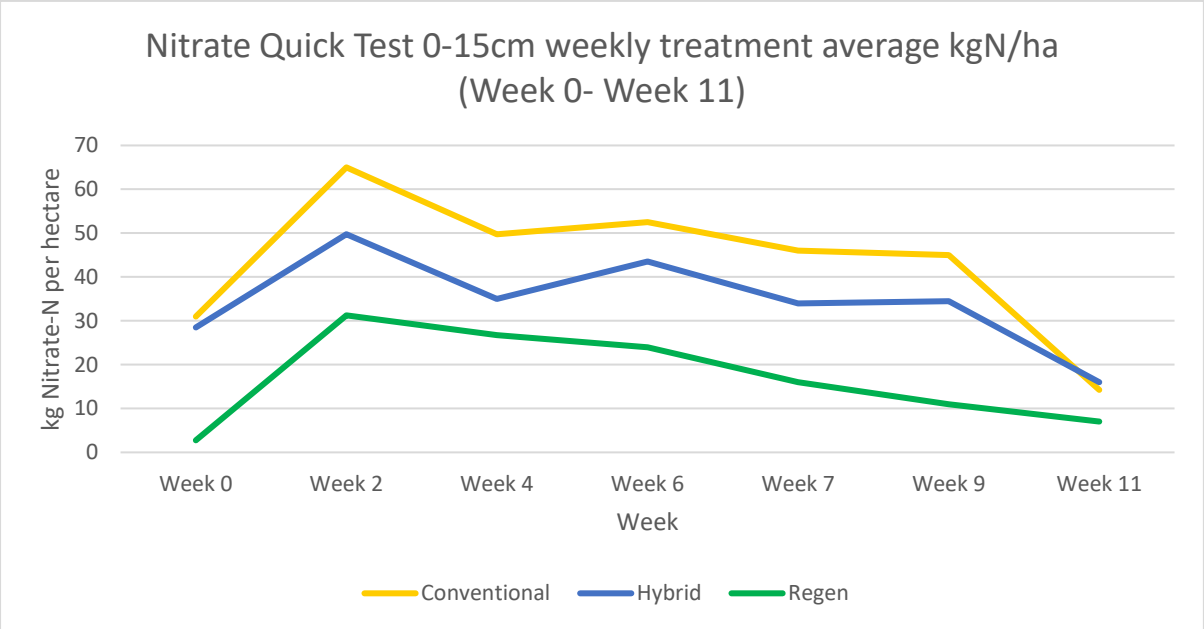


Figure 3 Nitrate Quick Test results 0-15cm, average result per treatment.

Figure 4 shows the Nitrate Quick Test results in the middle 15 – 30cm of the soil profile. Similar to the top 15cm, it appears that the levels of soil nitrate at this depth have been trending down since early December.

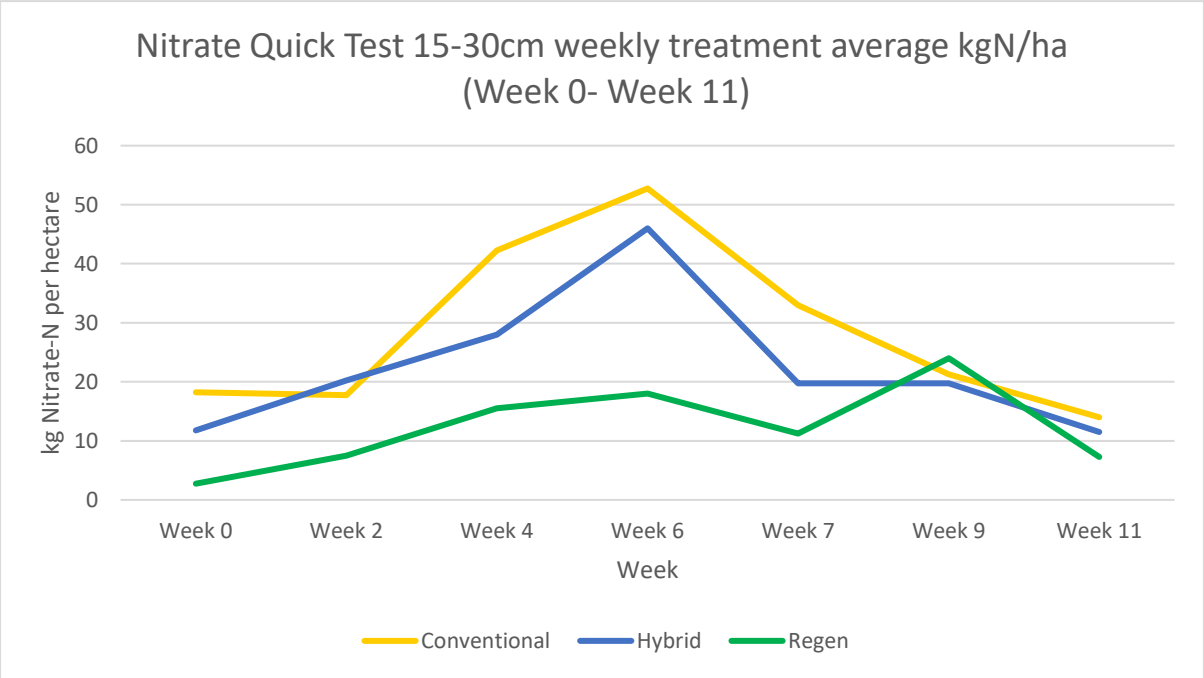


Figure 4 Nitrate Quick Test results 15-30cm, average result per treatment.

Figure 5 shows soil nitrate measured from 30 – 45cm. Measurements have only been taken at this depth when conditions have allowed (not too wet or too hot). As mentioned above it is assumed that the greatest proportion of plant roots will be in the top 30cm. In some plots, concentration of nitrate has been below the detectable limit of the Nitrachek (<5ppm) and is given as 0kgN/ha.

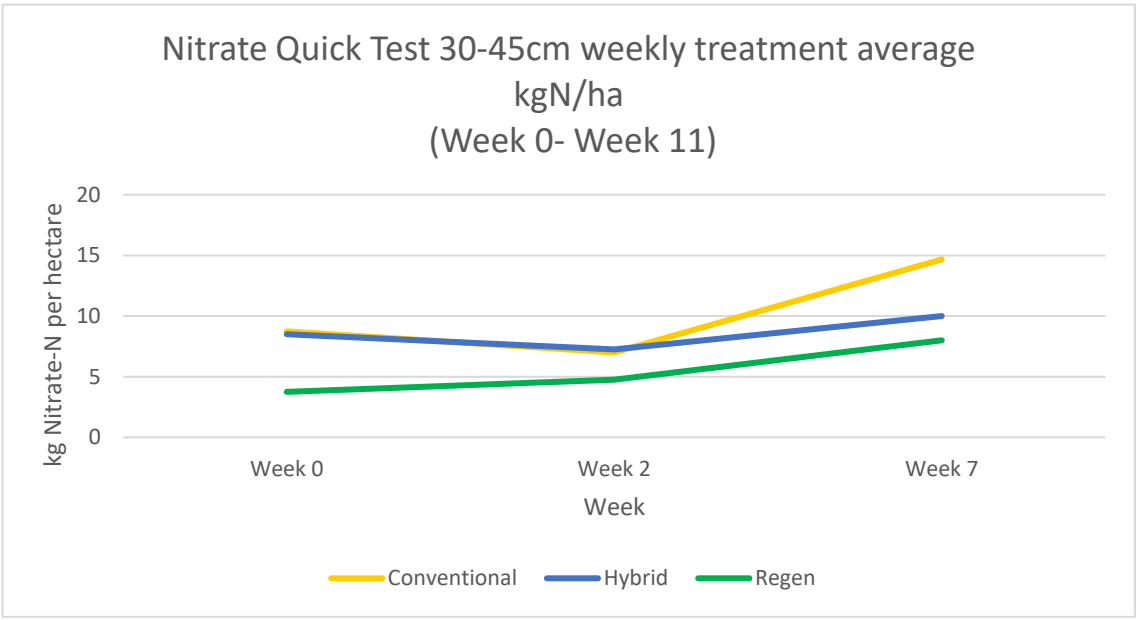


Figure 5 Nitrate Quick Test results 30-45cm, average result per treatment.

This data has been used to inform nitrogen management decisions for each treatment so far and will continue to be used to evaluate crop nutrition plans towards the end of the season. There is eight weeks to go until harvest, and nutrient management is currently focused on ensuring that there is an appropriate amount of nutrient (particularly nitrogen) available to the crop to enable plants to mature the fruit that has been set.

Further details of the Nitrate Quick Test data as histograms are presented in Appendix 1.

Hot Water Extractable Carbon (Intermediate Sampling) Results

Cores were taken for Hot Water Extractable Carbon (HWEC) on the 2nd and 3rd of November. This was the most practical time to complete sampling as the tall oat crop needed to be mulched before we could sample.

Ten cores were taken along the already established transect in each plot using a 30mm diameter corer. Plots were split into two, with five cores taken from the West End and five cores taken from the East End. Cores were split into three depths (0 – 15 cm, 15 – 30 cm and 30 – 60cm), therefore each plot had six samples sent for laboratory analysis (72 samples total).

Soil organic carbon is reported as a percentage in the soil sample of certain depth, converted to a meaningful amount per hectare. For example: i.e. 10,000 m^2 in one hectare x 0.15 m soil depth x 1.4 g/cm^3 bulk density x 1.2% = 16.8 t/ha.

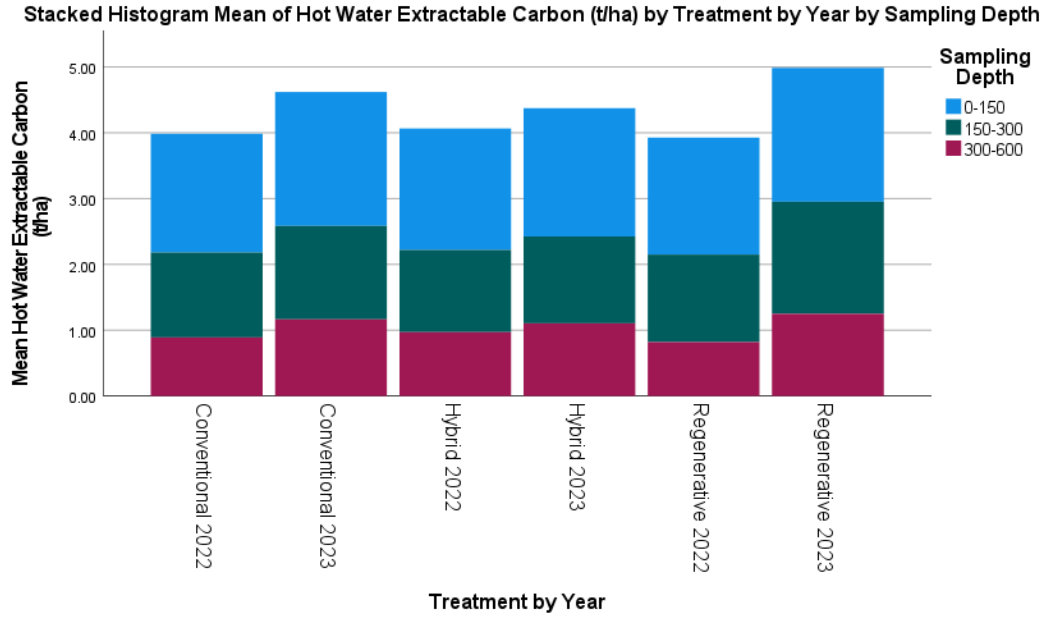


Figure 6 Stacked histogram of mean Hot Water Extractable Carbon (t/ha) by treatment by year by sampling depth.

Figure 6 shows the total HWEC from 0-60 cm depth by treatment in 2022 and 2023. In each case the HWEC has increased slightly, and more so in the regenerative treatment.

Figure 7, Figure 8 and Figure 9 are boxplots showing the range of results for HWEC in each treatment at each of three depths, 0-15 cm, 15-30 cm and 30-60 cm, in 2022 and 2023. They suggest the biggest difference in in the 15-30 cm soil depth band.

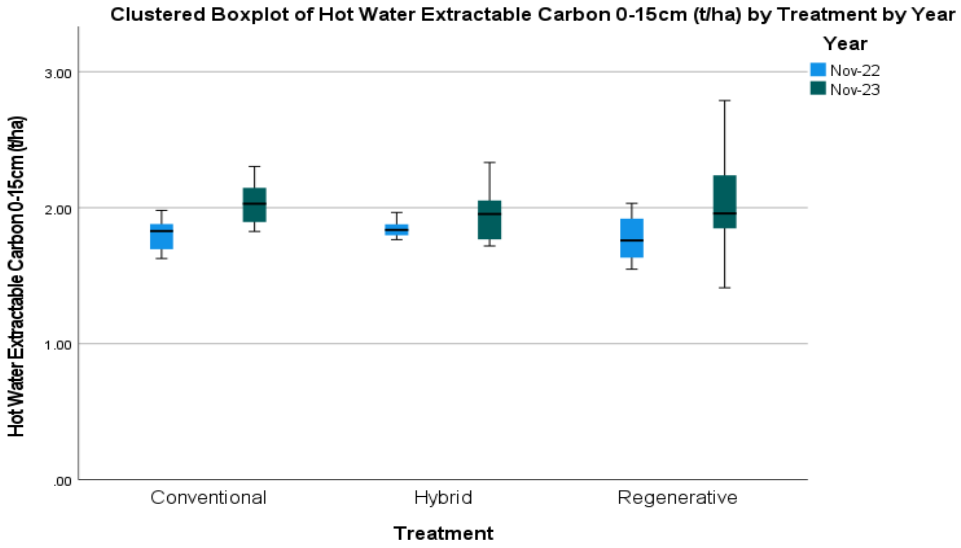


Figure 7 Boxplot of Hot Water Extractable Carbon (t/ha) at 0 - 15 cm soil depth by treatment by year

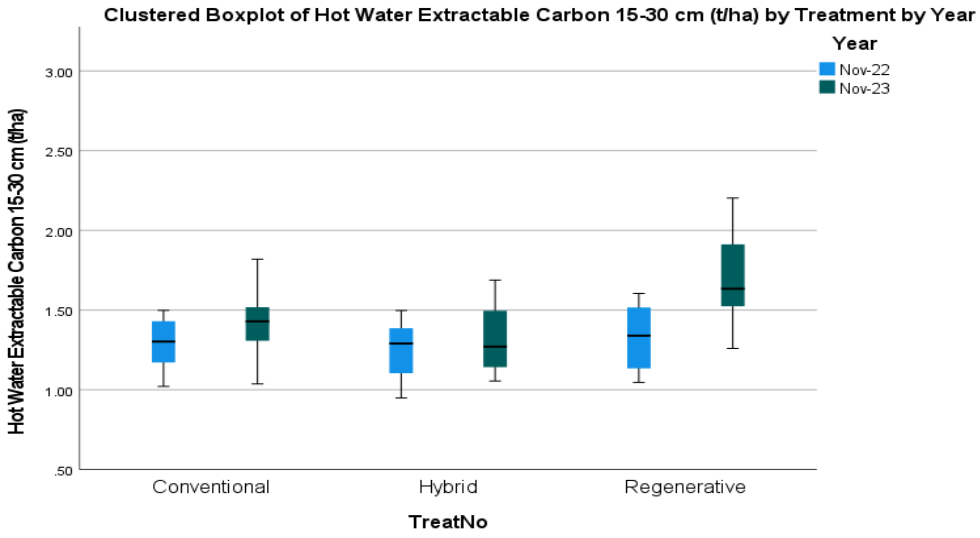


Figure 8 Boxplot of Hot Water Extractable Carbon (t/ha) at 15 - 30 cm soil depth by treatment by year

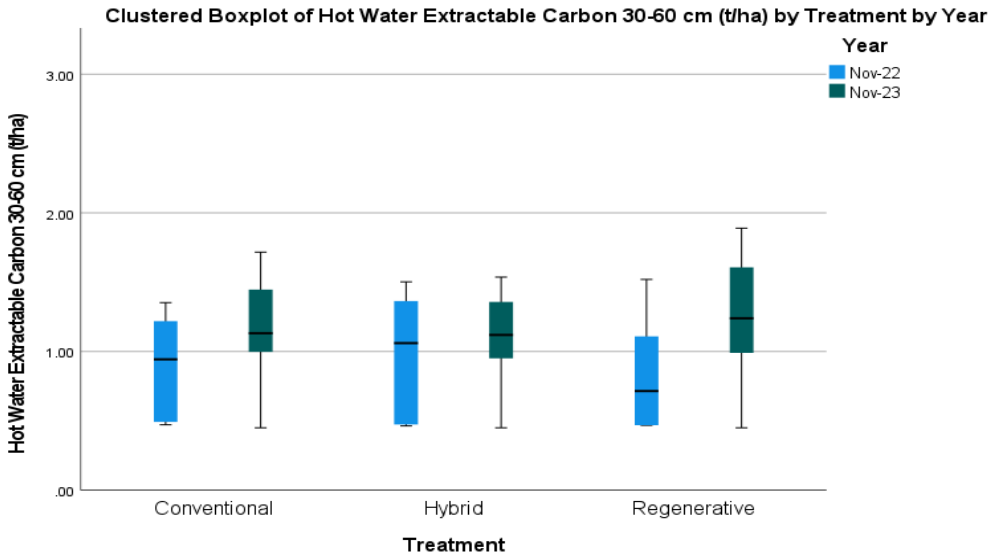
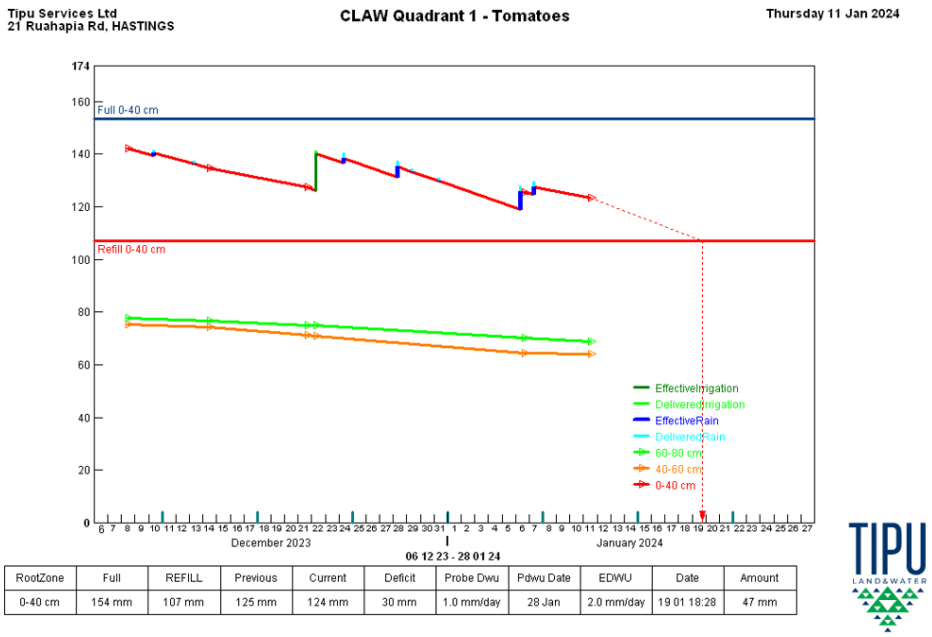


Figure 9 Boxplot of Hot Water Extractable Carbon (t/ha) at 30-60 cm soil depth by treatment by year

Soil Moisture Probe

GroPoint moisture probes have been installed in each block but we are still having trouble getting data presented in usable format. We are working with the data technology provider to fix this issue.

We have contracted a neutron probe monitoring service to cover this aspect until GroPoint probe readings are reliable (Figure 10), and we are continuing with weekly Hydrosense II TDR readings at multiple points in each block (Figure 11).



RootZone	Full	REFILL	Previous	Current	Deficit	Probe Dwu	Pdwu Date	EDWU	Date	Amount
0-40 cm	154 mm	107 mm	125 mm	124 mm	30 mm	1.0 mm/day	28 Jan	2.0 mm/day	19 01 18:28	47 mm

Figure 10 Report from neutron probe soil moisture measurements showing Full Point, Refill Point, Current Moisture and Soil Moisture Deficit by depth over time and irrigation recommendation.

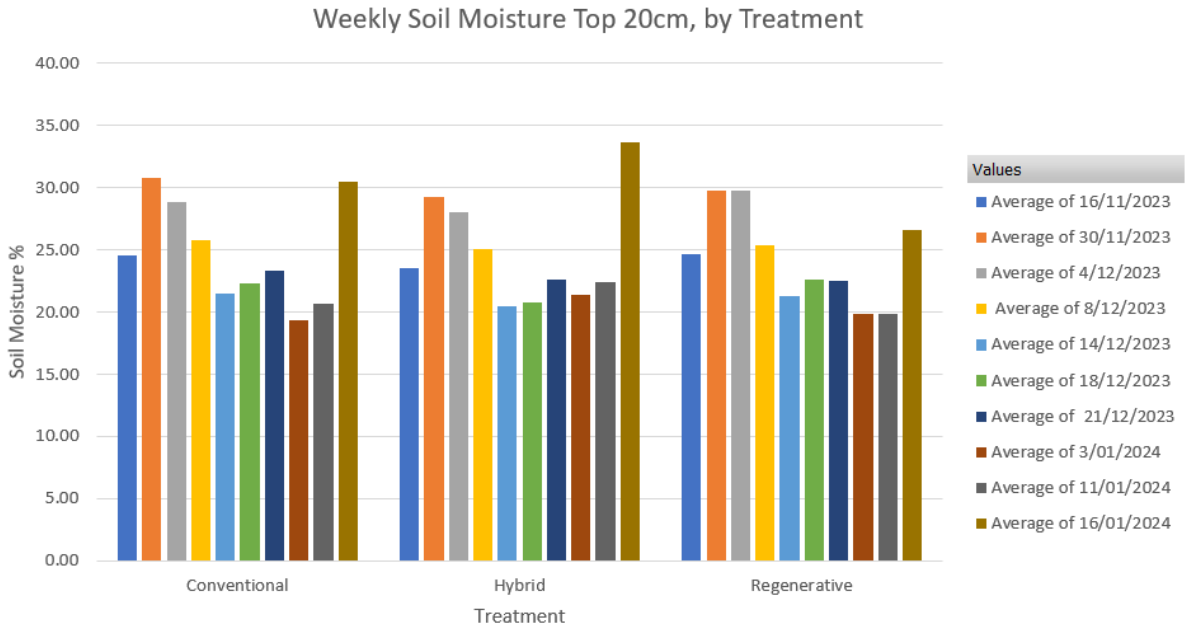


Figure 11 Soil moisture percentage in the upper 20 cm of soil by treatment over time

Soil Temperature

Soil temperature monitoring was mostly relevant when plan was to have mulch planting in regenerative treatment blocks and cultivated soil in the others. Since all treatments were cultivated, all temperatures are relatively similar. Temperature is a feature of GroPoint sensors and data to date show no significant differences at 10 cm.

Soil Sorptivity and Macroporosity

We have set up Disc Permeameters to assess sorptivity and porosity. These units enable application of water to the soil surface under a changeable tension, avoiding water loss through wormholes or soil cracks, both problems with saturated ring testing. Scientific support has been accessed through Brent Clothier at Plant & Food Research, co-developer of the technology (Clothier and White, 1981[1]).

The disc permeameter is an alternative and possibly better way to assess the effects of our treatments on water holding and related parameters than using twin ring saturated conductivity (see Soil Infiltration Rate below).

Soil Infiltration Rate

Rings requested from Plant and Food Research have yet to arrive.

Soil Moisture Release Curve

Our contracted provider has not completed this. We are collating all raw data from our GroPoint sensors and will be able to derive soil water holding, full point and stress point values once the data are processed by that data handler. We similarly can estimate these data from the neutron probe curves as we build a longer history.

[1] Clothier, Brent and Ian White. "Measurement of Sorptivity and Soil Water Diffusivity in the Field." *Soil Science Society of America Journal* 45 (1981): 241-245.

Irrigator Performance

An IRRIG8 linear irrigator performance assessment was completed using the bucket test method developed by Page Bloomer Associates[2]. This is a publicly available resource promoted by LandWISE, Irrigation New Zealand, industry sectors and others (Figure 12).

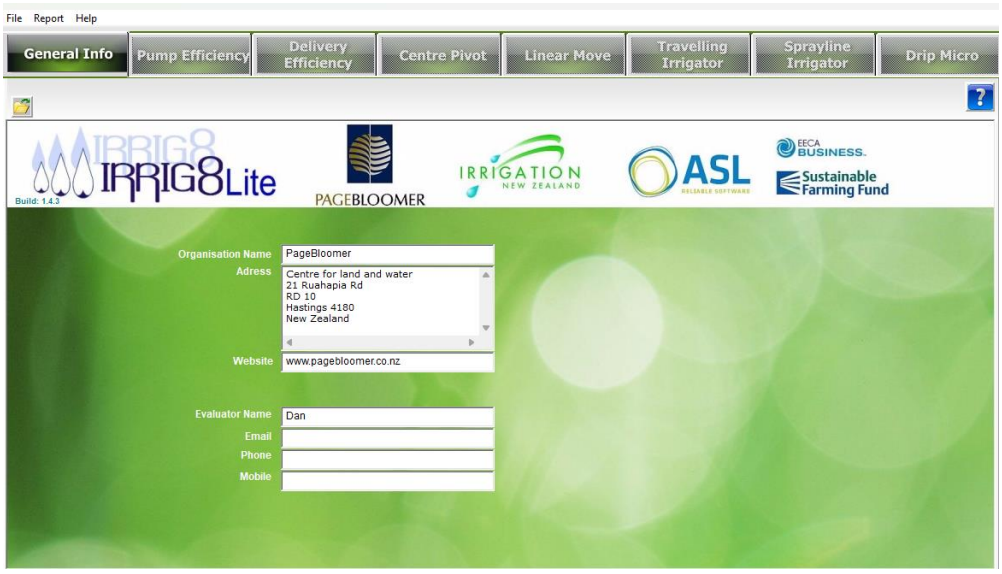


Figure 12 IRRIG8 Lite home screen showing the irrigation system types included in standard assessment protocols.

The testing was completed in December 2023 and showed the overall result is Good with the actual applied depth (15.6 mm) close to the target depth (15.0 mm) and distribution uniformity (DU) of 0.88. An issue that was identified is over application at the end, which was determined to be caused by incorrect nozzle replacement after a recent demonstration event (Figure 13). This is being corrected, and is expected to raise performance to Very Good.

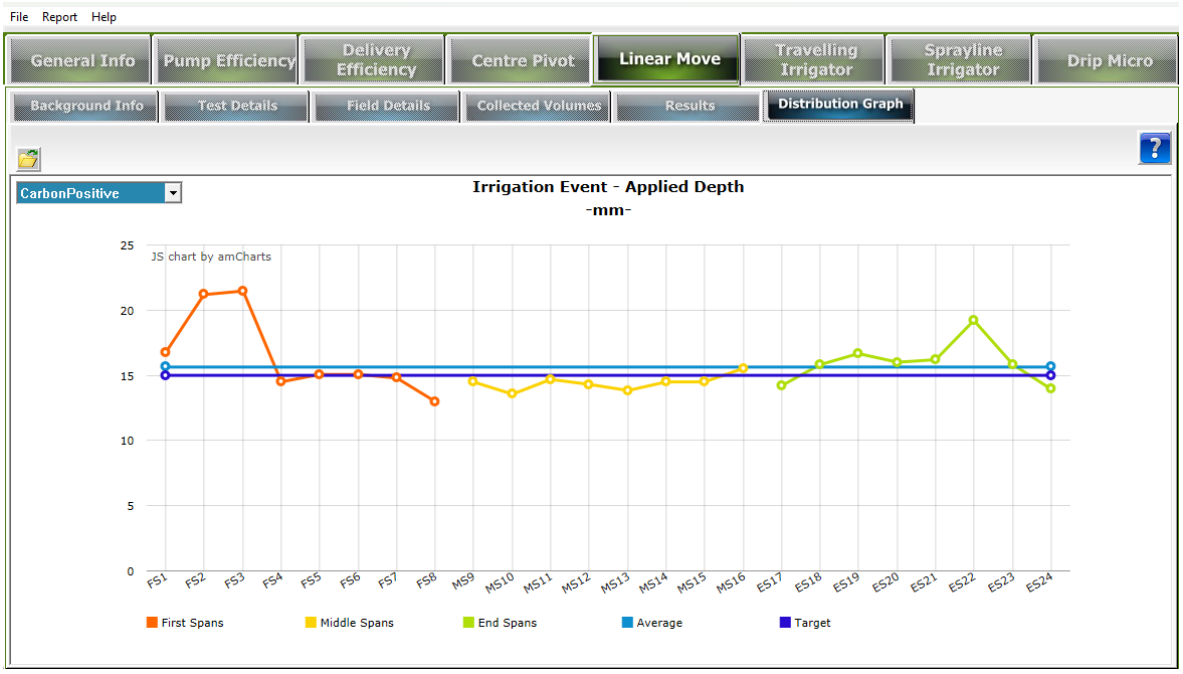


Figure 13 Final report screen showing the applied depths of the MicroFarm linear irrigator tested in December 2023.

[2] https://www.pagebloomer.co.nz/resources/irrigation-calibration/irrig8lite/

Plant Monitoring

Four sub-plots have been established in each plot, indicated by coloured flags (4m long x 2m bed width). These sub-plots are where most of the plant monitoring measures are completed.

Establishment percentage (population)

Plant population was estimated by counting the number of plants in each of the 4m sub-plots and multiplying out to a per hectare population. The target population was 25,000 plants/ha. Across the plots, population ranges from approximately 21,250 – 23,750 plants per hectare, 85-95% of target. The main reason for reduced population is plant damage by rabbits. Plots that had the greatest impact were Plot 1 (Conventional) and Plot 6 (Conventional) which are located on the edges of the trial area, neighboured by apple bins or orchards where it is assumed the rabbits are hiding out. There were not significant levels of damage within the sub-plots to warrant moving these measured areas.

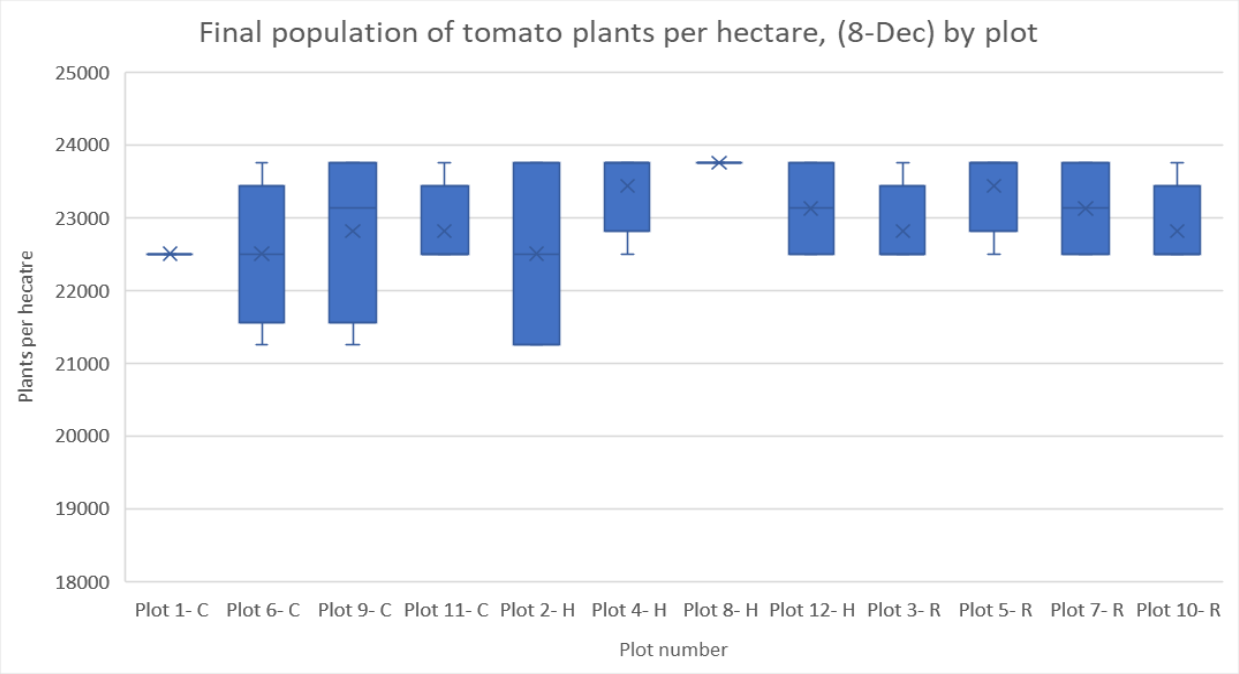


Figure 14 Final tomato population per hectare 8 December 2023

Canopy development

Canopy cover has been measured each week using the Canopeo phone app. Canopeo analyses Fractional Green Canopy Cover (FGCC), which can be used to estimate canopy development and light interception. This tool is being used to monitor how quickly canopy cover increases across the different treatments, which can be related to plant biomass and crop yield after harvest. In weeks 2-8 percentages were adjusted to account for the entire 2m bed width (image only of 1m planted area). In Weeks 10 and 11 images have been taken from a height which captures the entire bed width as tomato canopy has grown into the interrow.

Figure 15 shows the change in canopy cover percentage in the first 12 weeks. In the first 5 weeks the Hybrid and Conventional treatments were similar, however after Week 6 the Conventional treatment has consistently had the largest canopy of the three treatments. From Week 10-11 canopy growth has slowed for all treatments, with the Regen canopy becoming almost flat. This could be related to nutrients applied, cultivation method (tillage pan/root depth) and soil moisture.

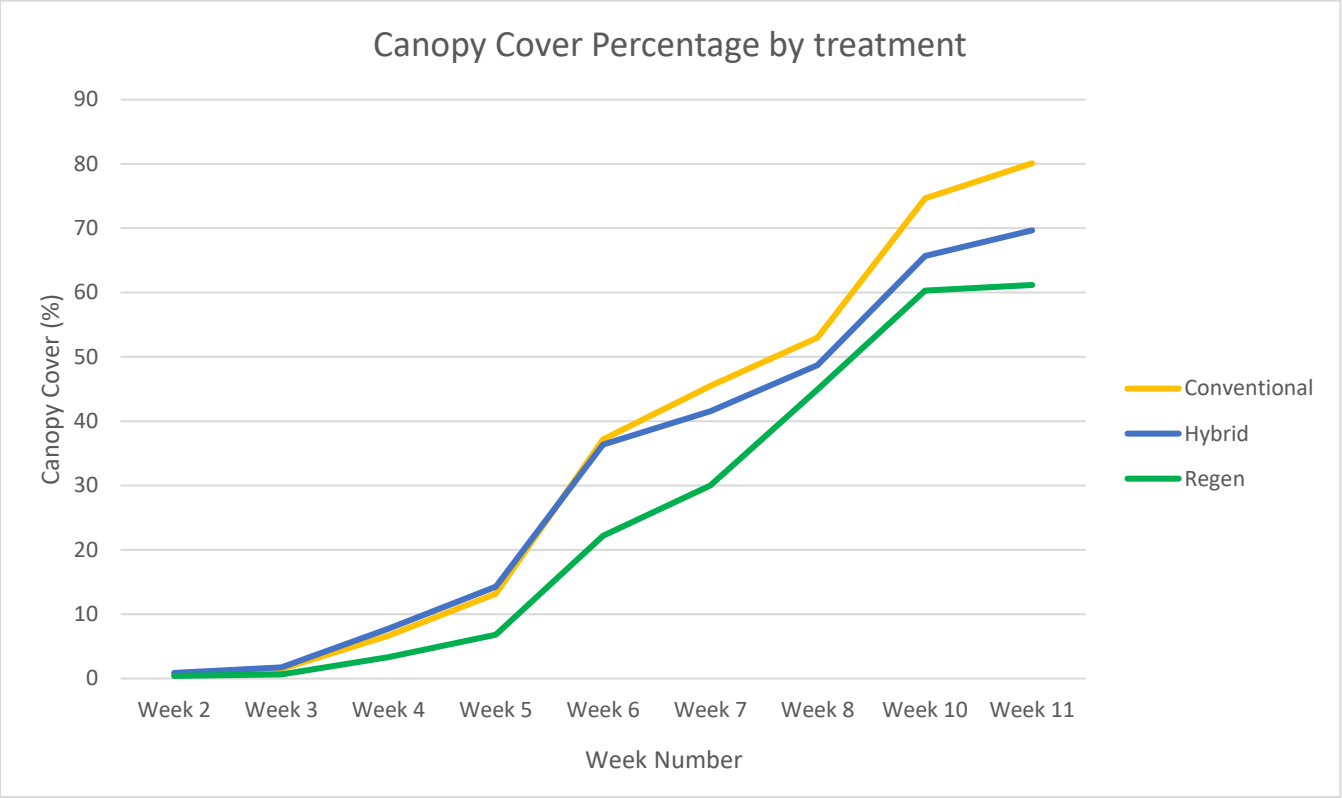


Figure 15 Weekly Canopy Cover percentage by treatment

Aerial Imagery

We have begun working with Argos Aerial Mapping, a local aerial imagery provider, to assess canopy status using a range of indices including NDVI, GNDVI, NDRE, LCI and MCARI. We have extracted data from individual plots with the soil area excluded. All data points are within our usual sampling zone avoiding the outside beds and first and last 10 m of each plot.

Example maps are shown below in Figure 16, Figure 17 and Figure 18. These show how different indices highlight different areas depending on the absorption and reflectance of different bands of light. Bands are selected to differentiate between water, soil and vegetation, and within vegetation, between plants that are evidently stressed or have differing levels of chlorophyll, which tends to be closely related to nitrogen availability.

The aerial surveying clearly identified the different blocks and the different treatments with the conventional plots showing highest canopy cover, highest chlorophyll content and by implication highest access to available nitrate. The hybrid and regenerative plots show progressively lower results.

We are compiling data to allow these maps to be compared with other measurements such as Canopeo ground cover, soil nitrate levels, moisture and leaf test data.

NDVI

NDVI = Normalized Difference Vegetation Index which is used to measure biomass (). That means it is the one most equivalent to our Canopeo ground cover measurements, but note it uses a different index so our values are not directly comparable.

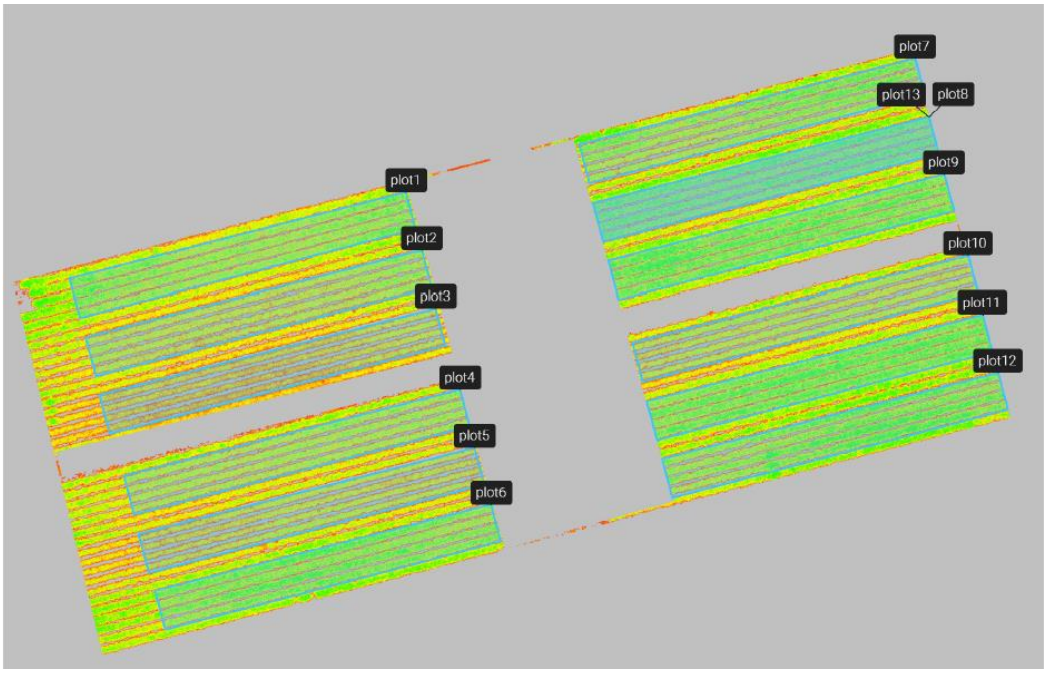


Figure 16 Normalised Difference Vegetative Index (NDVI) map of the MicroFarm tomato crop showing areas in each plot from which data are extracted.

NDRE

NDRE = Normalised Difference Red Edge is sensitive to chlorophyll content in leaves against soil background effects. NDRE can be used to analyse whether images obtained from multi-spectral image sensors contain healthy vegetation or not. It is similar to NDVI but uses the ratio of Near-Infrared and the edge of Red (the spectrum centred around 715 nm).

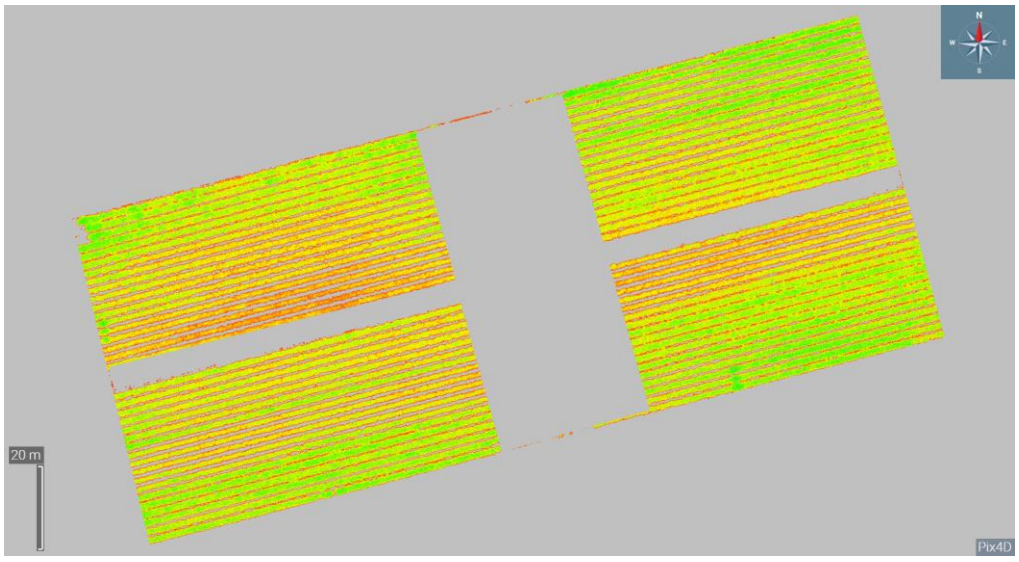


Figure 17 Normalised Difference Red Edge (NDRE) map of the MicroFarm tomato crop showing areas in each plot from which data are extracted.

GNDVI

GNDVI = Green Normalized Difference Vegetation Index (Figure 18) which is an index of the plant's "greenness" or photosynthetic activity. It is one of the most widely used vegetation indices to determine water and nitrogen uptake in the crop canopy. This index is mainly used in the intermediate and final stage of the crop cycle. The GNDVI uses near infrared and visible green (instead of visible red).

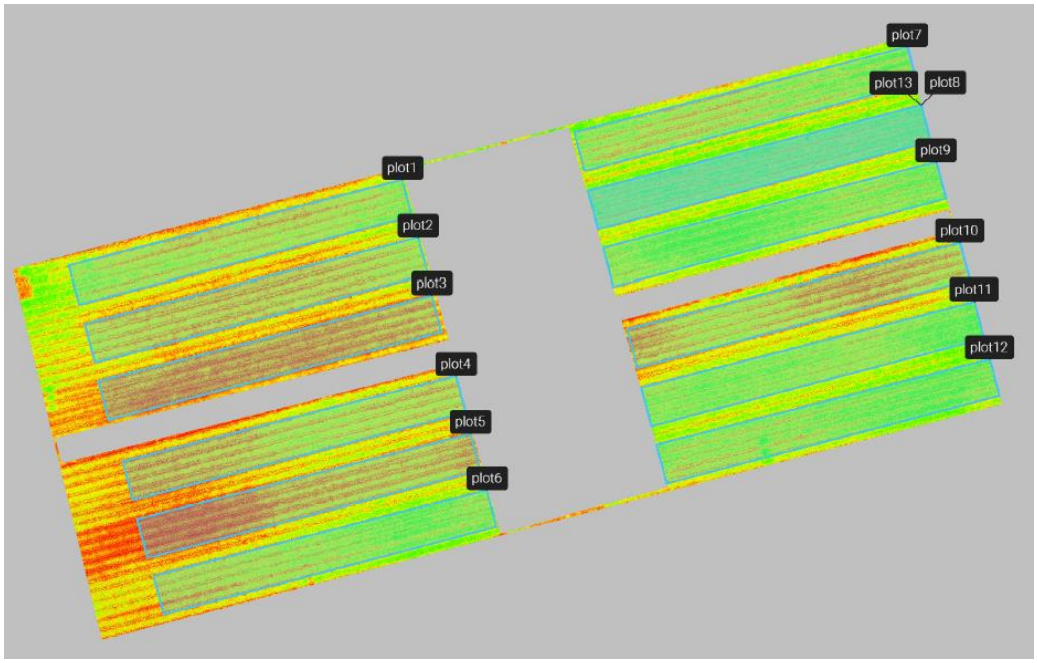


Figure 18 Green Normalised Difference Vegetative Index (GNDVI) map of the MicroFarm tomato crop showing areas in each plot from which data are extracted.

Agronomic observations/ crop health monitoring

Crop walks have been held weekly with Wattie's field staff, relevant technical field staff and consultants to assess the tomatoes and decide on actions for the following seven days for each treatment. Wattie's Agronomist Caleb Burbury has been the lead for crop monitoring. Key areas of discussion include weed pressure, insect and disease pressure, soil moisture, nutrient requirements, overall crop development, and the weather. These meetings have been attended by seven to eight people each week, with a range of different thoughts and perspectives provided to inform decisions.

There is consideration for factors like recent weather conditions, predicted weather conditions and observations from other crops in the area, particularly in relation to insect and disease pressure. A crop protection plan was developed for each treatment prior to the beginning of the season, which has been used as a guide for actual crop protection. However, there have been many modifications made to these plans due to weather conditions, irrigation scheduling, insect pressure, disease risk etc. which was expected.

Observable deficiencies recorded.

All suspected deficiencies, leaf abnormalities, etc. have been photographed for later identification, or inspected as part of weekly crop walks. Two examples of possible deficiencies identified are shown below.

Figure 20 shows a tomato leaf with strong interveinal yellowing, which is similar to a magnesium deficiency, however, is present on random plants in the different plots so could be a deficiency caused by a virus. This is not occurring on a scale that warrants action at this stage.

Figure 20 shows a tomato leaf with purpling along the leaf margin and curling of the leaves. This is more obvious in the Regenerative treatment, on the youngest leaves, however, is present in the other two treatments as well. This is thought to be a phosphorus deficiency (which can appear after irrigation) or a potassium deficiency.

Figure 20 Image of interveinal yellowing on tomato plant

Figure 20 Image of leaf purpling and leaf curling on tomato plant

Tissue testing

The initial plan was to complete a post-transplant tissue test, a pre-side dressing tissue test, and a final test before harvest. The post-transplant test was deemed unnecessary given the plants were so small, and it would be five to six weeks until fertiliser would be applied. Instead, it was decided to do monthly tissue tests would be completed (Dec, Jan, Feb). The December test was completed ahead of side dressing, to inform nutrient management decisions. January tissue tests have been submitted to the lab (awaiting results).

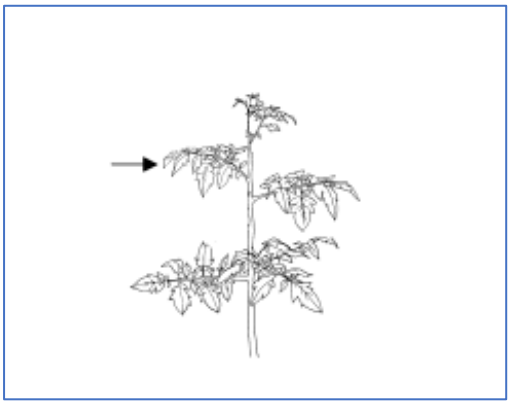


Figure 21 Diagram of which leaf to sample for tissue test

Youngest mature leaves were collected from plants, as the nutrients in these leaves will be more stable than very young or older leaves. Tissue was tested for basic nutrients and molybdenum, as recommended by Hill Laboratories. Results were reviewed by Mark Redshaw (Yara Crop Nutrition), Wattie's staff and other OAG members.

Tissue tests showed that the Regenerative treatment had lower potassium, manganese, copper, and zinc concentration compared to the other two treatments, but comparatively higher phosphorus, sulphur, calcium, molybdenum, and iron.

Yara nutrient specialist, Mark Redshaw, commented that *"Despite early difference in growth, leaf nutrient levels appear adequate, although across majority of plots phosphorus leaf levels are not deficient but could be higher".*

Table 1 Average of nutrient levels in each treatment- December tissue test.

Treatment	N_%	P_%	K_%	S_%	Ca_%	Mg_%	Na_%
Conventional	5.65	0.49	4.575	0.6875	4.17	0.655	0.05325
Hybrid	5.4	0.455	4.65	0.82	3.6475	0.625	0.0435
Regen	5.6	0.545	4.225	1.1225	4.64	0.67	0.059

Treatment	Cu_mg/kg	B_mg/kg	Mo_mg/kg	Mn_mg/kg	Fe_mg/kg
Conventional	52	42.75	0.5875	75.75	202
Hybrid	56.5	43.25	0.5625	73.75	199
Regen	29	44	0.945	41.75	262.75

The January tissue test results will be used to inform nutrient management decisions in the coming weeks and will be particularly important for establishing both solid and liquid (foliar) fertiliser requirements.

Pest and disease presence

Insect and disease monitoring has been challenging to standardise as the standard Wattie's crop protection programmes have a strong 'protectant' focus, and for many of the pests and diseases, no 'threshold' has been developed for deciding when to spray. In a typical growing scenario, the crop would be assessed for requirements ahead of a spray application, however many of the products included in the programme are used to prevent the development of fungal or bacterial infections starting (e.g., copper).

Method

Using resources from the Integrated pest management for process tomatoes (1995) guidelines, PennState Extension Scouting and Identifying Tomato Disease video guide, and other crop scouting guides a simple method has been developed for pest and disease monitoring. Within the established sub-plots, one plant is selected and five leaves on the plant are assessed from presence of insects and diseases, or any other abnormalities. This method has been reviewed by Plant and Food Research and given this is not a main focus of the project, the number of plants assessed was determined to provide sufficient data for statistical analysis but not be too onerous to complete. Any unidentified issues are photographed from identification later.

Insects

The main insect pest for tomatoes is Tomato Potato Psyllid (TPP). TPP was first found in New Zealand in 2006 and has since spread throughout the country. The small flying insects impact solanaceous crops (e.g., tomatoes, potatoes, capsicum, and eggplants), and vectors a disease called Candidatus Liberibacter solanacerum (CLso) or Zebra Chip virus (BioForce Ltd, 2023). In tomatoes the virus causes leaf curling and yellowing, and softening of fruit, causing the fruit to be unfit for processing (Anderson & Davidson, 2020).

Yellow sticky traps have been placed in the paddock (North/South/East/West and Centre) to trap for Tomato Potato Psyllid (details below). This trapping has been set up in line with the Heinz-Wattie's Tomato Psyllid Sampling Guide 2017. Wattie's agronomists are not formally monitoring for psyllid at a commercial level this year, as it is believed that populations have been supressed.

While it is assumed that psyllid will be present in the trial site, none have been seen yet.

Other insects that can cause problems are aphids and thrips, however the insecticides used to control psyllid also control thrips and aphids so these are less of a concern and are unlikely to increase to numbers where there would be an economic impact to the crop.

Diseases

The early part of the season was wet and cool, and the main diseases of concern were Late Blight (fungal infection) and bacterial speck (bacterial infection). To date, there have been minimal disease issues, likely due to the warmer, drier conditions experienced late December and early January. There are some lesions on plant leaves, however a lot of this is not the result of disease pressure, but from fertiliser burn or mechanical damage.

Slugs

Slug monitoring through Relative Slug Activity, as was done for the cover crops, was dropped as it is no longer relevant: the Regenerative treatment did not have a mulch layer left on the surface. Slugs could have been a concern if there was a mulch layer, as there would have been a good habitat created for them. All treatments had some cultivation (either strip tilled or rotary hoed), which will have killed some of the slugs, and buried much of the plant residue where they reside. This measure will be revisited once winter cover crops are planted.

Weed survey.

Weed control has included herbicides, mechanical weeding, and hand weeding. While a conventional grower would not typically hand weed, some time has been spent hand weeding plots, with the aim of preventing the weed seed bank increasing further. While it would have been interesting to complete a weed survey, it has been hard to time this activity to get sensible data during tomato production i.e., without interference from weed control methods.

The main weeds present are nightshades, wire weed, red root (Amaranthus), fat hen, thorn apple and nettle. The aim is to defer the weed survey until the cover crop has been planted in the autumn.

Maturity

Through the season we have established that crop maturity is not formally measured for tomatoes within the standard Heinz-Watties programme. While flowering is normally a good measure for maturity in some crops, the variety of tomato planted has been bred to flower vigorously, and in some cases the plants have flowers not long after transplanting. Additionally, fruit ripeness is also not necessarily a good measure of maturity in the variety of tomatoes grown, as fruit ripening is artificially brought on through the use of ethrel (chlorethephon) just before harvest. At this stage in the season red fruit is developing, however fruit that is mature now will likely be rotten by harvest time.

There have been visual differences in flowering times and vigour through the season, with the Regenerative treatments appearing to have entered the main part of flowering later in comparison to the other two treatments, however this has not been quantified. Rather than focus on crop maturity, the focus will be on other factory quality assessments, mostly measured at harvest.

Record Keeping

Record applied nutrients.

Nutrient applications are recorded after each application, keeping a running total of total nutrients applied to each treatment. Nutrients are recorded in ProductionWise, as well as in a production summary document.

A summary of nutrients applied is given below. A breakdown of nutrients applied can be found in Appendix 2.

Table 2 Summary of nutrients applied to each treatment at time of reporting.

Treatment	Applied N kg/ha	Applied P kg/ha	Applied K kg/ha	Applied Mg kg/ha	Applied S kg/ha	Applied Ca kg/ha
Conventional	80.207	62	140	42.4	6.835	10.126
Hybrid	74.447	30.165	91.224	48.15	10.035	15.282
Regenerative	69.637	15.627	47.51	54.271	5.235	114.532

There is a considerable difference in nutrients applied, particularly in the amount of phosphorus and potassium applied across the treatments. Additionally, the Regenerative, and to a lesser extent the Hybrid have had a portion of their nutrients applied as foliar applications.

Record agrichem applications

All agrichemical applications (herbicides, insecticides, and fungicides) have been recorded in ProductionWise and in a production summary document.

A detailed list of agrichemicals used for each treatment to date can be found in Appendix 3.

Record biological product applications.

Biological products have been used mostly in the Regenerative treatment, with some products added to the Hybrid as well. These products include foliar fertilisers, biostimulants, bio-bactericides and fungicides. These products have been recorded in ProductionWise and in a production summary document. Products used as part of the foliar nutrition programme have been included in the crop nutrition summary in Appendix 2. Products used as part of the crop protection (spray) programme in place of conventional agrichemicals have been included in the agrichemical record in Appendix 3.

Record irrigation events

Every irrigation event and cross-checks of applied depth, travel speed and metered water volumes recorded. A summary of this season's irrigation is presented in Table 3. Irrigation is guided by soil moisture monitoring and to date has been at the lower end of recommended amounts, especially at the start of the season.

Table 3 Record of irrigation events and depth of irrigation applied on the tomato crop by field quadrant.

Date	Crop	Paddock	Actual Application Depth (mm)
16-Dec-23	Tomatoes	Q1	17
16-Dec-23	Tomatoes	Q3	17
17-Dec-23	Tomatoes	Q4	17
17-Dec-23	Tomatoes	Q2	17
18-Dec-23	Tomatoes	Q2	18
19-Dec-23	Tomatoes	Q4	18
20-Dec-23	Tomatoes	Q3	17
20-Dec-23	Tomatoes	Q1	16
22-Dec-23	Tomatoes	Q1	17
22-Dec-23	Tomatoes	Q3	17
23-Dec-23	Tomatoes	Q4	17
23-Dec-23	Tomatoes	Q2	17
27-Dec-23	Tomatoes	Q2	18
28-Dec-23	Tomatoes	Q4	18
29-Dec-23	Tomatoes	Q3	16
30-Dec-23	Tomatoes	Q1	16
14-Jan-24	Tomatoes	Q1	17
14-Jan-24	Tomatoes	Q3	16
15-Jan-24	Tomatoes	Q4	16
15-Jan-24	Tomatoes	Q2	16

Q1 Plots 1-3, Q2 Plots 7-9, Q3 Plots 4-6, Q4 Plots 10-12

Other Actions

Water sensitive paper testing

Water Sensitive Paper is a tool that can be used to monitor spray distribution, droplet density, and droplet sizing for agrichemical spray applications. Spray cards yellow and have a special coating which turns blue when an aqueous solution drop onto it. Spray cards are laid out in the field, within the crop canopy before spraying, and the yellow cards will stain following exposure to sprays (or any liquid). Cards are folded in half and stapled onto a leaf, to see spray distribution on both the top and underside of leaves.

The size, number and density of the droplets can be evaluated to determine the efficacy of the spray application. This is particularly important in the tomato crop, as there are a number of contact fungicides used, which require good coverage to provide adequate crop protection. Additionally, as the tomatoes grow, the canopy becomes more dense and inside the canopy it can be warm and damp, with less airflow, increasing the risk of disease. Larger canopies become harder to penetrate sprays into, so most tomato growers have 'air assistance' on their sprayers, which blasts air into the canopy to provide better coverage. The sprayer used for this trial does not have air assistance.

Figure 23a and Figure 23b show two examples of water sensitive paper used in the field. Figure 23a was the standard sprayer set up, and shows large spray droplets, which have uneven distribution. Figure 23b shows water sensitive paper after the sprayer set up was modified to have a higher spray pressure, to achieve more, finer droplets. While the pressure is more appropriate, the underside of the leaves is not being well-covered by any spray, which means the underside of the leaf could be a disease entry point.

This coverage has been discussed with Heinz-Wattie's agronomists and there are still commercial growers spraying tomatoes without air assistance, with reasonable efficacy, so this is thought unlikely significantly affect the trial.

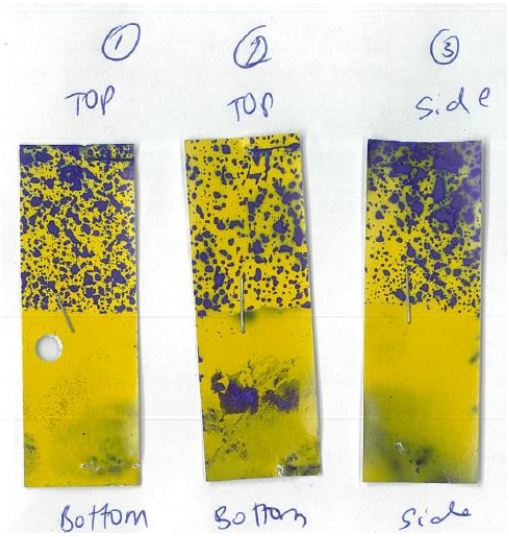


Figure 23 First Water Sensitive Paper Test (spray application 2)

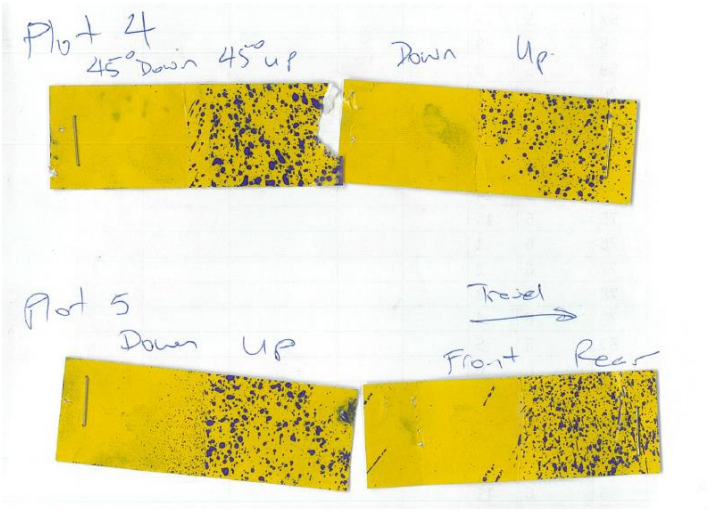


Figure 23 Second Water Sensitive Paper Test (spray application 3)

EIQ Risk Assessment calculated.

As discussed in MS5, the Environmental Impact Quotient (EIQ) tool has been used to quantify the impact of each of the spray programmes, in order to compare and contrast the different treatments. The EIQ tool provides four measures of impact; Field Use EIQ, Consumer EIQ, Worker EIQ, and Ecological EIQ, all of which are expressed as units per acre.

Table 4 displays a summary of each of the EIQ measures for each treatment. A detailed breakdown can be found in Appendix 4.

Table 4 EIQ values for each treatment to date (units/ac converted to units/ha)

Treatment	Field Use EIQ (converted to hectare)	Consumer EIQ (converted to hectare)	Worker EIQ (converted to hectare)	Ecological EIQ (converted to hectare)
Conventional	677.1	161.9	404.3	1456.7
Hybrid	570.8	139.6	347.9	1216.5
Regenerative	318.5	96.4	196.7	657.8

Outreach Activities

A number of outreach activities have taken place in the reporting period including both putting information out and drawing information in to guide the project. We have valued and enjoyed the considerable amount of two-way/multi-way dialogue and consider the project is progressing as a result.

Weekly agronomy walks

We have met with the Operations Advisory Group every week to report and discuss progress, and to review, update and confirm plans for the coming week or weeks. These meetings typical take about an hour but are supported by other visits and conversations throughout the week. The agenda varies according to the planned activities and to observations of crop performance. The membership varies depending on decisions to be made, with the Heinz-Watties agronomists and regenerative farming consultants fully involved and other specialist advisors attending as relevant.

Monthly field walks

Regular public events have been well supported and have drawn in a new population of interested people. These are announced in advance via the LandWISE e-newsletter with a reminder sent shortly before the walk day. We have requested free online registration which has been moderately well accepted.

Field walks cover project progress and issues that are observable at the time. They typically include and indoor update session (Figure 24) and an outdoor walk in the crop to experience changes in the different treatments (Figure 25). Through this we are reaching a new audience and receiving input from a wider range of perspectives which has informed our activities and methodologies. An example is our adoption of the Environmental Impact Quotient (EIQ) to score our crop protection programmes in an objective way.

Figure 24 Delegates at a monthly Carbon Positive Update session during a progress feedback and discussion session.

Figure 25 Discussion huddles at the January monthly field walk

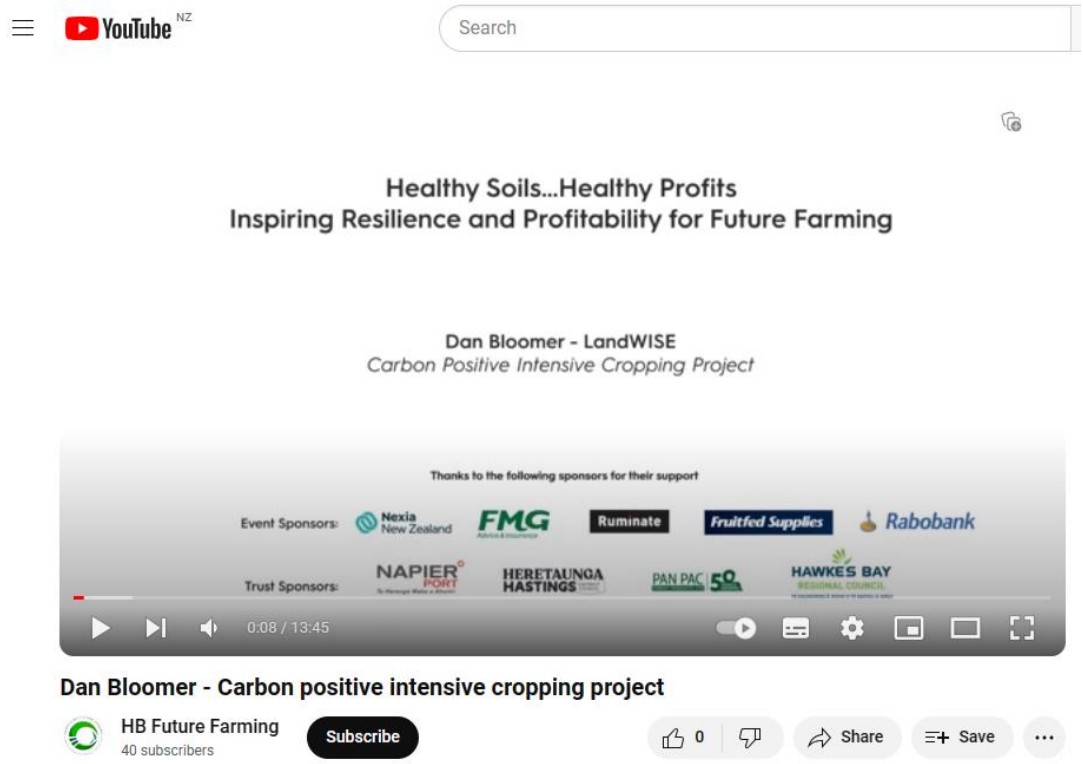
Magazines

An article on project progress was published in the Horticulture New Zealand "Grower" magazine in December 2023. A copy is presented in Appendix 5

Conference Presentations

HBFFT Afternoon Conference " Healthy Soils…Healthy Profits"

A video of our presentation is available at https://www.youtube.com/watch?v=864Bhv96miY



FLRC

A paper has been accepted for presentation at the 2024 FLRC Conference in February. The abstract is presented in Appendix 6

Websites and e-Newsletters

Both organisations have regular, approximately monthly, membership newsletters sent by email that carry updates on project progress and invitations to attend events.

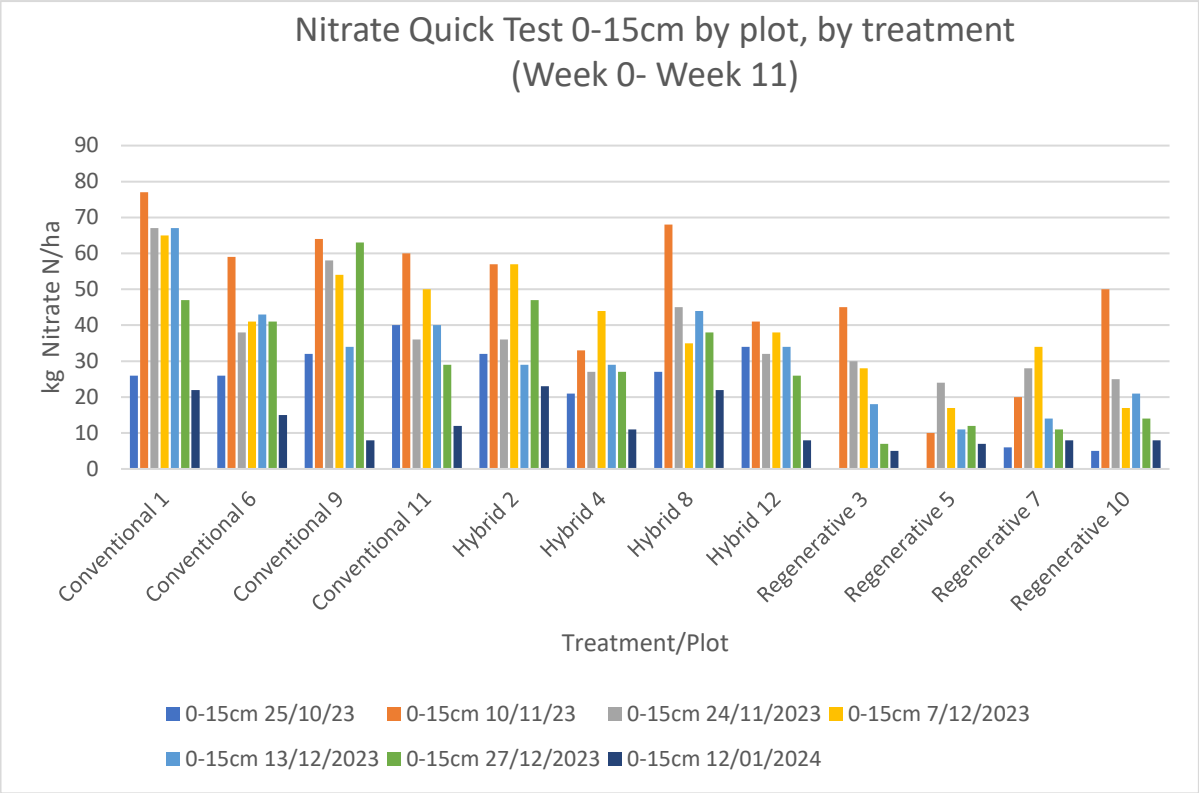
The Carbon Positive page on the LandWISE website is updated with reports after they have been accepted by MPI SFFF. See https://www.landwise.org.nz/projects/carbon-positive/ and https://www.landwise.org.nz/projects/carbon-positive/carbon-positive-reports/ .

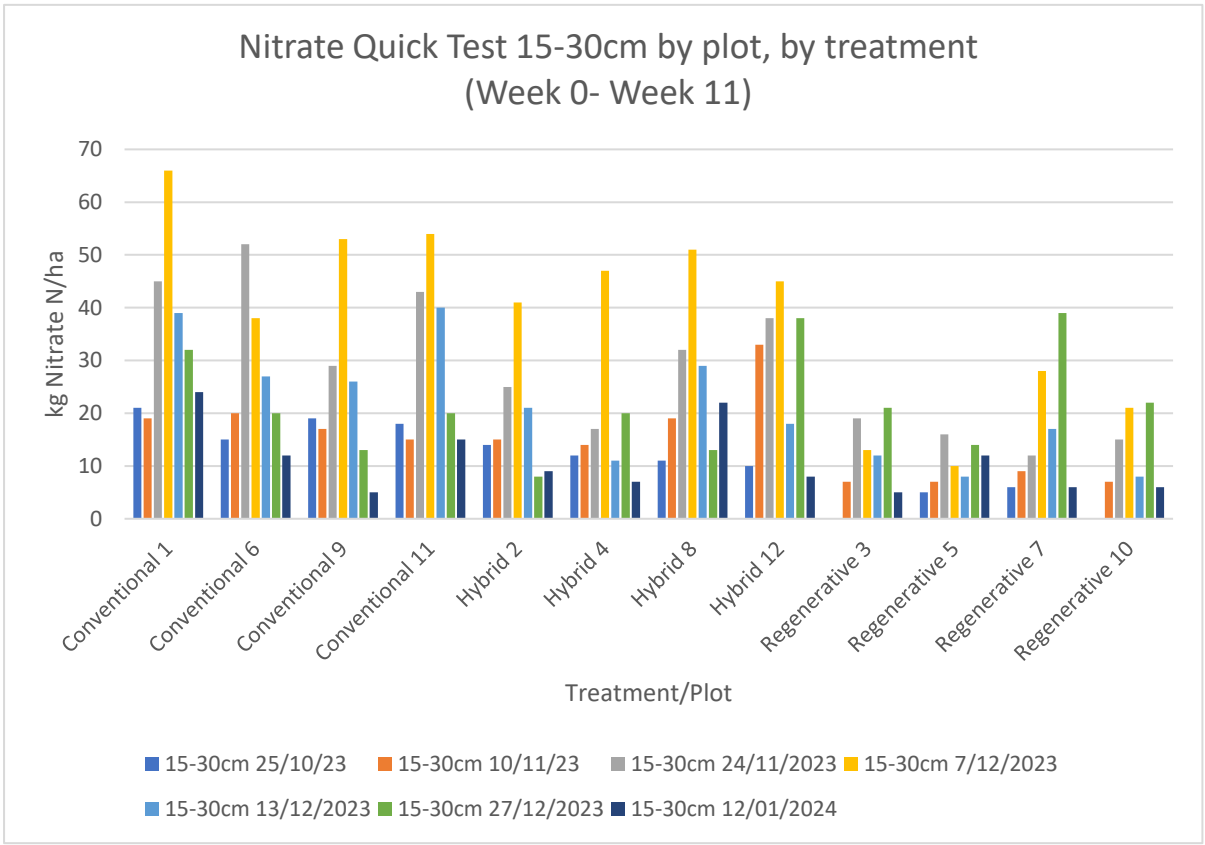
Looking Ahead

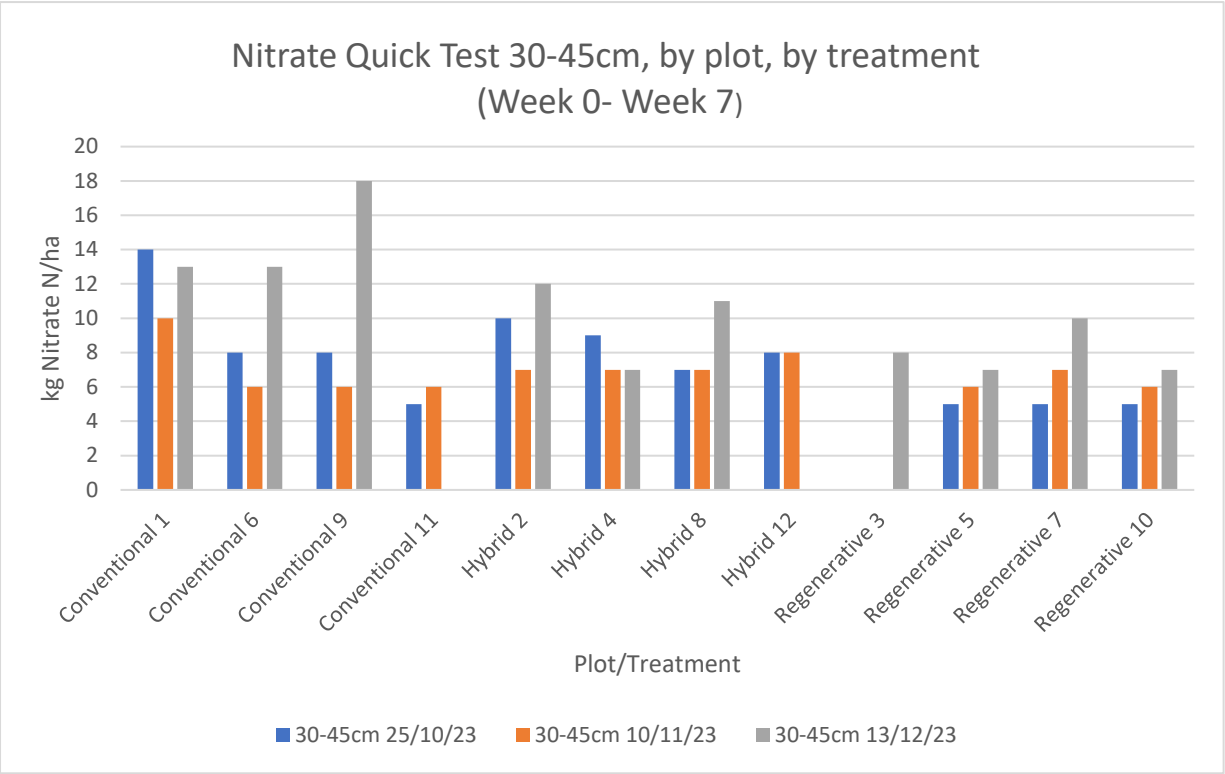
Date:1 Jun 2024	**Milestone 7**
Milestone description	Year 2 Completed
Target Outcome	Increased understanding of regenerative cropping and effects of transition
Activities undertaken	OAG team meeting, harvest, crop and soil analyses completed, winter crops established, magazine article, Outreach presentations at 1 conference. Further activities as per Annual Project Plan and Annual Science Plan.
Deliverables / evidence of completion / achievement of Outcome	Trial results, copies of all extension material and reports. Photos of events (preferred but not essential) PSG and TAG meeting minutes. Deliverables as per milestones within Annual Project Plan and Annual Science Plan.
MPI Funding amount	$83,303.55
Co-Funding contribution	$35,701.52
Total	$119,005.07

Appendices

Appendix 1 Nitrate Tests- Plot level (3 depths)






Nitrate Quick Test 30-45cm, by plot, by treatment
(Week 0- Week 7)
kg Nitrate N/ha
20
18
16
14
12
10
8
6
4
2
0
Conventional 1
Conventional 6
Conventional 9
Conventional 11
Hybrid 2
Hybrid 4
Hybrid 8
Hybrid 12
Regenerative 3
Regenerative 5
Regenerative 7
Regenerative 10
Plot/Treatment
30-45cm 25/10/23
30-45cm 10/11/23
30-45cm 13/12/23

Appendix 2

Conventional Treatment Nutrients Applied

Application Date	Product Type	Product	Rate/ha	Unit	Applied N kg/ha	Applied P kg/ha	Applied K kg/ha	Applied Mg kg/ha	Applied S kg/ha	Applied Ca kg/ha
Week 0	Granular fertiliser	YaraMila 8-11-20	400	kg	32	42	80	10.4	0	0
Week 5	Foliar	Yara Bud Builder	3	L	0.207	0	0	0	0.435	0.126
Week 7	Granular fertiliser	YaraMila Complex	400	kg	48	20	60	32	6.4	10
				Total	**80.207**	**62**	**140**	**42.4**	**6.835**	**10.126**

Hybrid Treatment Nutrients Applied (including Biologicals)

Application Date	Product Type	Product	Rate/ha	Unit	Applied N kg/ha	Applied P kg/ha	Applied K kg/ha	Applied Mg kg/ha	Applied S kg/ha	Applied Ca kg/ha
Week 0	Planter Water	MultiKraft MicroLife	TBC	L	0	0	0	0	0	0
Week 0	Planter Water	MultiKraft Soil NRG	TBC	L	0	0	0	0	0	0
Week 0	Granular fertiliser	YaraMila Complex	300	kg	36	15	45	24	4.8	7.5
Week 5	Foliar	Yara Bud Builder	3	L	0.207	0	0	0	0.435	0.126
Week 7	Granular fertiliser	YaraMila Complex	300	kg	36	15	45	24	4.8	7.5
Week 7	Foliar	Lono	5	L	0.75	0	0.35	0	0	0
Week 7	Foliar	Foliacin	1	L	0.04	0.06	0.05	0	0	0
Week 8	Foliar	Yara Croplift	3	kg	0.6	0.105	0.348	0.15	0	0.036
Week 8	Foliar	Yara BioMaris	2	L	0	0	0.126	0	0	0
Week 11	Foliar	Lono	5	L	0.75	0	0.35	0	0	0
Week 11	Foliar	Albina	1	L	0.1	0	0	0	0	0.12
				Total	74.447	30.165	91.224	48.15	10.035	15.282

Regenerative Treatment Nutrients Applied (including Biologicals)

Application Date	Product Type	Product	Rate/ha	Unit	Applied N kg/ha	Applied P kg/ha	Applied K kg/ha	Applied Mg kg/ha	Applied S kg/ha	Applied Ca kg/ha
Pre Plant	Granular fertiliser Lime/S/B/Humate mix	Lime/S/B/Humate mix	300	kg	0	0	0	30	0	69
Week 0	Planter Water	MultiKraft MicroLife		L	0	0	0	0	0	0
Week 0	Planter Water	MultiKraft Soil NRG		L	0	0	0	0	0	0
Week 0	Granular fertiliser	YaraMila Complex	300	kg	36	15	45	24	4.8	7.5
Week 2	Foliar	Yara Calcinit	6	kg	0.93	0	0	0	0	1.14
Week 2	Foliar	Megafol	2	L	0.06	0	0.16	0	0	0
Week 5	Fungicide	Phoscheck	3	L	0	0.33	0.48	0	0	0
Week 5	Foliar	Yara Bud Builder	3	L	0.207	0	0	0	0.435	0.126
Week 7	Granular	Nitrabor	200	kg	30.8	0	0	0	0	36.6
Week 7	Granular	Humates	3	kg	0	0	0	0	0	0
Week 7	Foliar	Lono	5	L						
Week 7	Foliar	Foliacin	1	L	0.04	0.06	0.05	0	0	0
Week 8	Foliar	Yara Croplift	3	kg	0.6	0.105	0.348	0.15	0	0.036
Week 8	Foliar	Yara BioMaris	2	L	0	0	0.126	0	0	0
Week 10	Foliar	YaraVita Actisil	0.5	L	0	0	0	0	0	0.01
Week 11	Foliar	Lono	5	L	0.75	0	0.35	0	0	0
Week 11	Foliar	Albina	1	L	0.1	0	0	0	0	0.12
Week 11	Foliar	Yara Croplift K	3	L	0.15	0.132	0.87	0.12	0.036	0
Week 11	Foliar	Yara BioMaris	2	L	0	0	0.126	0	0	0
				Total	69.637	15.627	47.51	54.27	5.271	114.532

Appendix 3

Conventional Treatment Crop Protection Programme

Application Date	Product Type	Product	Rate/ha	Unit
Pre Plant	Herbicide	Weedmaster TS470	3	L
Pre Plant	Adjuvant	Li700	0.5	L
Pre Plant	Slug bait	Iron Max	7	kg
Week 0	Pre Emerge Herbicide	BoxerGold	5	L
Week 0	Pre Emerge Herbicide	Magneto	1	L
Week 3	Directed Herbicide	Sencor480sc	0.5	kg
Week 5	Fungicide	Kocide Opti	0.8	kg
Week 5	Fungicide	Ridomil Gold MZ	2	L
Week 6	Fungicide	Kocide Opti	0.8	kg
Week 6	Fungicide	Ridomil Gold MZ	2.5	L
Week 6	Insecticide	Benevia	0.5	L
Week 7	Pre Emerge Herbicide	BoxerGold	5	L
Week 7	Pre Emerge Herbicide	Magneto	1	L
Week 8	Fungicide	Dithane	2	kg
Week 8	Fungicide	Kocide Opti	0.8	kg
Week 8	Insecticide	Movento 100 SC	0.8	L
Week 8	Sticker	Bond Xtra	0.7	L
Week 10	Fungicide	Gem	0.75	L
Week 10	Fungicide	Kocide Opti	0.8	kg
Week 10	Insecticde	Movento 100 SC	0.8	L
Week 10	Sticker	Bond Xtra	0.7	L
Week 11	Fungicide	Gem	0.75	L
Week 11	Fungicide	Kocide Opti	0.8	kg
Week 11	Insecticide	Oberon	0.6	L
Week 11	Sticker	Bond Xtra	0.7	L

Hybrid Treatment Crop Protection Programme

Application Date	Product Type	Product	Rate/ha	Unit
Pre Plant	Herbicide	Weedmaster TS470	3	L
Pre Plant	Adjuvant	Li700	0.5	L
Pre Plant	Slug bait	Iron Max	7	kg
Week 0	Pre Emerge Herbicide	BoxerGold	2.5	L
Week 0	Pre Emerge Herbicide	Magneto	0.5	L
Week 3	Directed Herbicide	Sencor480sc	0.5	L
Week 5	Fungicide	Kocide Opti	0.8	kg
Week 5	Fungicide	Ridomil Gold MZ	2	L
Week 6	Fungicide	Kocide Opti	0.8	kg
Week 6	Fungicide	Ridomil Gold MZ	2.5	L
Week 6	Insecticide	Benevia	0.5	L
Week 7	Pre Emerge Herbicide	BoxerGold	2.5	L
Week 7	Pre Emerge Herbicide	Magneto	0.5	L
Week 8	Fungicide	Dithane	2	kg
Week 8	Bio Bactericide	Aureo Gold	0.15	kg
Week 8	Insecticide	Movento 100 SC	0.8	L
Week 8	Sticker	Bond Xtra	0.7	L
Week 10	Fungicide	Gem	0.75	L
Week 10	Fungicide	Kocide Opti	0.8	kg
Week 10	Insecticde	Movento 100 SC	0.8	L
Week 10	Sticker	Bond Xtra	0.7	L
Week 11	Fungicide	Gem	0.75	L
Week 11	Fungicide	Kocide Opti	0.8	kg
Week 11	Insecticide	Oberon	0.6	L
Week 11	Sticker	Bond Xtra	0.7	L

Regenerative Treatment Crop Protection Programme

Application Date	Product Type	Product	Rate/h	Unit
Pre Plant	Slug bait	Iron Max	7	kg
Week 0	Pre Emerge Herbicide	BoxerGold	5	L
Week 0	Pre Emerge Herbicide	Magneto	1	L
Week 3	Directed Herbicide	Sencor480sc	0.5	kg
Week 5	Bio Bactericide	Aureo Gold	0.15	kg
Week 6	Bio Bactericide	AureoGold	0.15	kg
Week 6	Fungicide	Ridomil Gold MZ	2.5	L
Week 6	Insecticide	Benevia	0.5	L
Week 8	Fungicide	Dithane	2	kg
Week 8	Bio Bactericide	Aureo Gold	0.15	kg
Week 8	Insecticide	Movento 100 SC	0.8	L
Week 8	Sticker	Bond Xtra	0.7	L
Week 10	Insecticide	Movento 100 SC	0.8	L
Week 10	Plant Activator	Actigard	0.04	kg
Week 10	Bio Bactericide	Aureo Gold	0.15	kg
Week 10	Fungicide	Triplex	1.5	L
Week 11	Foliar	Lono	5	L
Week 11	Foliar	Albina	1	L
Week 11	Bio Fungicide	Triplex	1.5	L
Week 11	Bio Bactericide	Aureo Gold	0.15	kg
Week 11	Foliar	Croplift K	3	kg
Week 11	Foliar	Biomaris	2	L

Appendix 4

Conventional Treatment EIQ

Date Used	Product Type	Product	Active Ingredient	EIQ Substit	AI %	Product Ra	Product Measurement Unit	Application Area	Field Use EIQ (converted to hectare)	Consumer EIQ (converted to /hectare)	Worker EIQ (converted to hectare)	Ecological EIQ (converted to hectare)
5/10/2023	Herbicide	Weedmaster TS47	470g/L Glyphosate		47	3	L	ha	47.7	9.4	25.0	108.7
5/10/2023	Adjuvant	Li700	Lecithin, Methylacetic acid, polyoxyethylene ether			0.5	L	ha	0.0	0.0	0.0	0.0
18/10/2023	Mollusicde	Iron Max	24.2 g/kg IRON PHOSPHATE ANHYDROUS		2.42	7	kg	ha	0.0	0.0	0.0	0.0
26/10/2023	Pre-emerge Herbicide	Boxer Gold	800g/L PROSULFOCARB		80	2.5	L	ha	82.3	8.9	35.3	198.4
			120g/L S-METOLACHLOR		12	2.5	L	ha	9.9	2.7	5.9	21.3
26/10/2023	Pre-emerge Herbicide	Magneto	500g/L terbuthylazine	Atrazine (cou	50	0.5	L	ha	12.6	4.0	4.4	29.4
14/11/2023	Directed Herbicide	Sencor 480SC	480g/L metribuzin		48	0.5	L	ha	15.1	4.2	4.2	36.6
28/11/2023	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
28/11/2023	Fungicide	Ridomil Gold MZ	40g/kg metalaxyl-M		4	2	L	ha	3.5	2.2	1.5	6.4
			640g/kg mancozeb		64	2	L	ha	72.6	23.0	57.1	137.6
7/12/2023	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
7/12/2023	Fungicide	Ridomil Gold MZ	40g/kg metalaxyl-M		4	2.5	L	ha	4.2	2.7	1.7	8.2
			640g/kg mancozeb		64	2.5	L	ha	90.7	28.7	71.4	172.0
7/12/2023	Insecticide	Benevia	100 g/L CYANTRANILIPROLE in the form of an oil dispersion		10	0.5	L	ha	1.2	1.0	0.7	2.0
15/12/2023	Pre Emerge Herbicide	BoxerGold	800g/L PROSULFOCARB		80	2.5	L	ha	82.3	8.9	35.3	198.4
			120g/L S-METOLACHLOR		12	2.5	L	ha	9.9	2.7	5.9	21.3
15/12/2023	Pre Emerge Herbicide	Magneto	500g/L terbuthylazine	Atrazine (cou	50	0.5	L	ha	12.6	4.0	4.4	29.4
22/12/2023	Fungicide	Dithane	750g/kg mancozeb		75	2	kg	ha	85.0	26.9	67.0	161.4
22/12/2023	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
22/12/2023	Insecticide	Movento 100 SC	100g/L spirotetramat		10	0.8	L	ha	6.2	1.0	2.2	15.3
22/12/2023	Sticker	Bond Xtra	Latex polymer, Organosilicone			0.7	L	ha	0.0	0.0	0.0	0.0
4/01/2024	Fungicide	Gem	500g/L fluazinam		50	0.75	L	ha	19.3	3.2	6.7	47.9
4/01/2024	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
4/01/2024	Insecticde	Movento 100 SC	100g/L spirotetramat		10	0.8	L	ha	6.2	1.0	2.2	15.3
4/01/2024	Sticker	Bond Xtra	Latex polymer, Organosilicone			0.7	L	ha	0.0	0.0	0.0	0.0
13/01/2024	Fungicide	Gem	500g/L fluazinam		50	0.75	L	ha	19.3	3.2	6.7	47.9
13/01/2024	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
13/01/2024	Insecticide	Oberon	Spiromesifen 240 g/litre		24	0.6	L	ha	8.9	0.7	2.2	23.7
13/01/2024	Sticker	Bond Xtra	Latex polymer, Organosilicone			0.7	L	ha	0.0	0.0	0.0	0.0
								ha	0.0	0.0	0.0	0.0
								Total Value	677.1	161.9	404.3	1456.7

Hybrid Treatment EIQ

Date Used	Product Type	Product	Active Ingredient	EIQ Substitu	AI %	Product Rate (Total/Crop	Product Measurement Unit	Application Area	Field Use EIQ (converted to kg/hectare)	Consumer EIQ (converted to kg/hectare)	Worker EIQ (converted to kg/hectare	Ecological EIQ (converted to kg/hectare)
7/09/2023	Herbicide	Weedmaster TS47	470g/L Glyphosate		47	3	L	ha	47.7	9.4	25.0	108.7
7/09/2023	Adjuvant	Li700	Lecithin, Methylacetic acid, polyoxyethylene ether			0.5	L	ha	0.0	0.0	0.0	0.0
18/10/2023	Mollusicde	Iron Max	24.2 g/kg IRON PHOSPHATE ANHYDROUS		2.42	7	kg	ha	0.0	0.0	0.0	0.0
26/10/2023	Pre-emerge Herbicide	Boxer Gold	800g/L PROSULFOCARB		80	2.5	L	ha	82.3	8.9	35.3	198.4
			120g/L S-METOLACHLOR		12	2.5	L	ha	9.9	2.7	5.9	21.3
26/10/2023	Pre-emerge Herbicide	Magneto	500g/L terbuthylazine	Atrazine (could	50	0.5	L	ha	12.6	4.0	4.4	29.4
14/11/2023	Directed Herbicide	Sencor 480SC	480g/L metribuzin		48	0.5	L	ha	15.1	4.2	4.2	36.6
28/11/2023	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
28/11/2023	Fungicide	Ridomil Gold MZ	40g/kg metalaxyl-M		4	2	L	ha	3.5	2.2	1.5	6.4
			640g/kg mancozeb		64	2	L	ha	72.6	23.0	57.1	137.6
7/12/2023	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
7/12/2023	Fungicide	Ridomil Gold MZ	40g/kg metalaxyl-M		4	2.5	L	ha	4.2	2.7	1.7	8.2
			640g/kg mancozeb		64	2.5	L	ha	90.7	28.7	71.4	172.0
7/12/2023	Insecticide	Benevia	100 g/L CYANTRANILIPROLE in the form of an oil dispersi		10	0.5	L	ha	1.2	1.0	0.7	2.0
15/12/2023	Pre Emerge Herbicide	BoxerGold	800g/L PROSULFOCARB		80	2.5	L	ha	82.3	8.9	35.3	198.4
			120g/L S-METOLACHLOR		12	2.5	L	ha	9.9	2.7	5.9	21.3
15/12/2023	Pre Emerge Herbicide	Magneto	500g/L terbuthylazine	Atrazine (could	50	0.5	L	ha	12.6	4.0	4.4	29.4
22/12/2023	Fungicide	Dithane	750g/kg mancozeb		75	2	kg	ha	85.0	26.9	67.0	161.4
22/12/2023	Insecticide	Movento 100 SC	100g/L spirotetramat		10	0.8	L	ha	6.2	1.0	2.2	15.3
22/12/2023	Sticker	Bond Xtra	Latex polymer, Organosilicone			0.7	L	ha	0.0	0.0	0.0	0.0
4/01/2024	Fungicide	Gem	500g/L fluazinam		50	0.75	L	ha	19.3	3.2	6.7	47.9
4/01/2024	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
4/01/2024	Insecticde	Movento 100 SC	100g/L spirotetramat		10	0.8	L	ha	6.2	1.0	2.2	15.3
4/01/2024	Sticker	Bond Xtra	Latex polymer, Organosilicone			0.7	L	ha	0.0	0.0	0.0	0.0
13/01/2024	Fungicide	Gem	500g/L fluazinam		50	0.75	L	ha	19.3	3.2	6.7	47.9
13/01/2024	Fungicide	Kocide Opti	300g/kg copper hydroxide		30	0.8	kg	ha	17.5	4.7	12.8	35.1
13/01/2024	Insecticide	Oberon	Spiromesifen 240 g/litre		24	0.6	L	ha	8.9	0.7	2.2	23.7
13/01/2024	Sticker	Bond Xtra	Latex polymer, Organosilicone			0.7	L	ha	0.0	0.0	0.0	0.0
									0.0	0.0	0.0	0.0
								Total Values	570.8	139.6	347.9	1216.5

Regenerative Treatment EIQ

Date Used	Product Type	Produce	Active Ingredient	EIQ Subs	AI %	Product Rate (Total/Crop	Product Measurement Unit	Application Area	Field Use EIQ (converted to kg/hectare)	Consumer EIQ (converted to kg/hectare)	Worker EIQ (converted to kg/hectare)	Ecological EIQ (converted to kg/hectare)
18/10/2023	Mollusicde	Iron Max	24.2 g/kg IRON PHOSPHATE ANHYDROUS		2.42	7	kg	ha	0.0	0.0	0.0	0.0
26/10/2023	Pre-emerge Herbicide	Boxer Gold	800g/L PROSULFOCARB		80	2.5	L	ha	82.3	8.9	35.3	198.4
			120g/L S-METOLACHLOR		12	2.5	L	ha	9.9	2.7	5.9	21.3
26/10/2023	Pre-emerge Herbicide	Magneto	500g/L terbuthylazine	Atrazine (c	50	0.5	L	ha	12.6	4.0	4.4	29.4
14/11/2023	Directed Herbicide	Sencor 480SC	480g/L metribuzin		48	0.5	L	ha	15.1	4.2	4.2	36.6
28/11/2023	Fungicide	Foscheck	400g/L phosphorous acid		40	3	L	ha	23.0	21.3	15.8	31.9
28/11/2023	Bio Bactericide	Aureo Gold	Aureobasidium pullulans		N/A	0.15	kg	ha	0.0	0.0	0.0	0.0
7/12/2023	Bio Bactericide	AureoGold	Aureobasidium pullulans		N/A	0.15	kg	ha	0.0	0.0	0.0	0.0
7/12/2023	Fungicide	Ridomil Gold MZ	40g/kg metalaxyl-M		4	2	L	ha	3.5	2.2	1.5	6.4
			640g/kg mancozeb		64	2	L	ha	72.6	23.0	57.1	137.6
7/12/2023	Insecticide	Benevia	100 g/L CYANTRANILIPROLE in the form of an oil dispersio		10	0.5	L	ha	1.2	1.0	0.7	2.0
22/12/2023	Fungicide	Dithane	750g/kg mancozeb		75	2	kg	ha	85.0	26.9	67.0	161.4
22/12/2023	Bio Bactericide	Aureo Gold	Aureobasidium pullulans		N/A	0.15	kg	ha	0.0	0.0	0.0	0.0
22/12/2023	Insecticide	Movento 100 SC	100g/L spirotetramat		10	0.8	L	ha	6.2	1.0	2.2	15.3
22/12/2023	Sticker	Bond Xtra	N/A		N/A	0.7	L	ha	0.0	0.0	0.0	0.0
4/01/2024	Insecticide	Movento 100 SC	100g/L spirotetramat		10	0.8	L	ha	6.2	1.0	2.2	15.3
4/01/2024	Plant Activator	Actigard	500g/kg ACIBENZOLAR-S-METHYL		50	0.04	kg	ha	1.0	0.2	0.2	2.2
4/01/2024	Bio Bactericide	Aureo Gold	Aureobasidium pullulans		N/A	0.15	kg	ha	0.0	0.0	0.0	0.0
4/01/2024	Fungicide	Triplex	Bacillus amyloliquefaciens BS 1b		N/A	1.5	L	ha	0.0	0.0	0.0	0.0
4/01/2024	Foliar	YaraVita Actisil	choline stabilised orthosilicic acid		N/A	0.5	L	ha	0.0	0.0	0.0	0.0
13/01/2024	Bio Fungicide	Triplex	Bacillus amyloliquefaciens BS 1b		N/A	1.5	L	ha	0.0	0.0	0.0	0.0
13/01/2024	Bio Bactericide	Aureo Gold	Aureobasidium pullulans		N/A	0.15	L	ha	0.0	0.0	0.0	0.0
								Total Valu	318.5	96.4	196.7	657.8

Appendix 5 Grower Magazine Article

YOUR INDUSTRY

CARBON POSITIVE: TOMATOES PLANTED AT THE LANDWISE MICROFARM

Dan Bloomer : LandWISE

The cover crop of oats, vetch and lupin held about 12 tonnes per hectare of dry matter

Heinz-Wattie's team planting tomato seedlings at the MicroFarm

Planting tomatoes for Heinz-Wattie's marks the start of the second year of Carbon Positive, a long-term study of regenerative practices applied to intensive process crop production, focused on increasing soil carbon, soil health and profitability. After two wet years, the soil is finally starting to dry out and seedlings were transplanted in ideal conditions. We are grateful to our contractors and the Heinz-Wattie's agriculture team for their commitment to the project and making sure everything went as smoothly as possible.

The operations programme for the 2023–2024 season was developed over the last five months in conjunction with Heinz-Wattie's, McCain Foods, regenerative consultants, advisors, interested local growers, organic vegetable producers, international process tomato growers, technical field representatives and contractors. That is a lot of people and a lot of conversations, well facilitated by Alex Dickson, the LandWISE project manager for Sustainable Systems.

We have three parallel growing systems: conventional practice, regenerative practice, and a hybrid system taking elements from each of the other two systems. So, multiply headache by three.

Planning and consultation for this process tomato crop was much more extensive than for the previous year's sweetcorn, reflecting the considerably higher need for inputs. Tomatoes are an expensive crop to grow, so there are safeguards applied to minimise risk of failure and maximise production. There is the added complication of needing to produce the required volume to feed a factory. There were several iterations of the project's operational plan, and the 'final' version is still subject to change depending on what the season brings. It has already been significantly altered.

Despite predictions of an El Niño summer, soil conditions remained wet over winter and early spring, and cultivation activities were delayed. With a factory-schedule planting date, additional passes with aerators and rotary hoes were required to achieve the mechanical tilth required to transplant tomatoes.

A notable feature in planning was to plant the regenerative plots into a mulch cover on untilled soil. A suitable transplanter was located in Palmerston North and with

support from Tobias Euerl and Robert Hall at live2give, their MulchTec machine was made available and tested. We reasoned that having a reasonably thick mulch cover would minimise the need for herbicides and help separate crop protection chemicals from the soil and microbiology below, and no-tilling would cause less disruption and carbon loss. This method is currently being trialled for processing tomatoes in Italy.

Then, just before planting, we found that the drying soil in the regenerative treatment plots was too hard for adequate root development and would impede plant growth throughout the season. Also, in an area we had mulched a week earlier, the oats were regrowing and posing a problem for weed control. A team paddock meeting determined that the cover crop should be incorporated, the ground ripped and cultivated, and the Wattie's conventional planter used to transplant seedlings.

So where to now?

We could have persisted with our no-till mulch planting in the regenerative plots but would have faced a probable large economic loss. We could have decided to drop a process crop from the regenerative system and instead focus on building the soil for a year, but again with financial implications. In the end, the operations group decided on a pragmatic approach – cultivate and plant an economically viable crop and work out how to fix it afterwards. Sounds familiar?

So, the group is now revising the regenerative crop's management plans. It means putting herbicides back into the programme. We had planned to remove some of the fungal and bacterial crop protection products, including copper, and use the 'softer' options. But we are very conscious that trying to save on early inputs could set us up for a difficult season of catch-up. The plan retains a conservative programme until fruit set, and minimising inputs thereafter where possible.

One way to compare the different crop protection programmes is using the Environmental Impact Quotient (EIQ) model developed by Cornell University. EIQ rates products according to environmental, worker and consumer safety, allowing us to compare the proposed management for each of our growing systems. Tomatoes are a 135-day crop requiring, under current practice, many spray applications each containing several products. The EIQ for tomatoes is high, especially when compared to sweetcorn, but we are endeavouring to find an effective, minimally impactful programme.

Tomatoes are considered a depletive crop, with a high nutrient demand. We are working through how we can reduce inputs of nutrients in the regenerative and hybrid treatments. We are mindful that the regen treatment has 10-12T/ha of dry matter buried the day before planting, which may have a short-term impact on the availability of nitrogen.

The MulchTec planter from live2give was tested and found suitable for planting tomato seedlings through thick residue mulch

Busy little paddocks with several operations underway as the cover crop is mulched, the ground ripped and cultivated ready for transplanting

We are investigating options to address the impact of our (industry typical) spring field-work practices, which were significant in all the plots regardless of the farming system applied. Hawke's Bay has been through a difficult couple of years, with two very wet spring planting periods, difficult if any harvest, and ongoing rain compounded by Cyclone Hale and Cyclone Gabrielle. It is only now that the soil is dry enough for rippers and aerators to be effective and lift and open it rather than smear slots.

We just smashed the soil, burned off a lot of carbon, and disrupted the microbiology. That is most definitely not what we set out to do. What is the best way to regenerate our base resource? ●

Carbon Positive is a partnership between LandWISE Inc and the Hawke's Bay Future Farming Trust, with processors McCain Foods and Heinz-Wattie's. Funding is from the Ministry for Primary Industries, Hawke's Bay Regional Council, BASF, Heinz-Wattie's and McCain Foods.

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CARBON POSITIVE – TRIALING REGENERATIVE AGRICULTURE FOR INTENSIVE PROCESS CROP PRODUCTION

Dan Bloomer[1], Alex Dickson[1], Phillip Schofield[2], David France[2]

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A six year trial is evaluating soil, crop and profitability differences within a New Zealand cropping system applying management guided by conventional or regenerative practice. Strict definition of regenerative cropping has been avoided in favour of agreed principles: minimise soil disturbance, keep the soil covered, keep living roots in the soil at all times, grow a diverse range of crops, and introduce grazing animals. The regenerative system uses biologicals and minimises the use of artificial fertilisers and sprays but there is no "ban" on any practice deemed an appropriate management response.

The Hawke's Bay trial site has moderately degraded soils after ten years' cropping. Key parameters measured include carbon stocks, labile carbon, VSA, aggregate stability, and worm counts. Crop development, yield and quality are monitored, and gross margins using standard input costs and contractor rates calculated.

Our 2023-2024 crop was process sweetcorn for McCain Foods, an industry partner. Despite being submerged for a day during Cyclone Gabrielle, the crop yield was 18.9 T/ha under conventional practice, 17.4 T/ha under the hybrid and 16.7 T/ha under regenerative practice, largely reflecting nitrogen supplies. Following harvest, the regenerative system was sown in oats, vetch and blue lupins, and the other systems in annual ryegrass. The conventional system was grazed by lambs.

The 2023-2024 crop is tomatoes for our industry partner, Heinz-Watties. In spring, ryegrass was sprayed out, and the hybrid system aerated and strip-tilled. The conventional system was deep ripped and rotary hoed. The regenerative system was to retain and plant through mulched winter cover-crop, but the soil was very hard, and cultivation was needed for cell transplants. Ultimately, it was ripped and fully cultivated prior to planting. Seasonal data will be presented.

The Ministry for Primary Industries SFFF trial at the LandWISE MicroFarm is a collaboration between LandWISE and the Hawke's Bay Future Farming Trust, McCain Foods, Heinz-Watties, BASF, and Hawke's Bay Regional Council, with considerable support from farmers, contractors and industry. The information produced will increase understanding of benefits, impacts for conversion, support the development of decision-making tools and increase confidence in regenerative farming principles through the value chain.