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CARBON POSITIVE – TRIALLING REGENERATIVE AGRICULTURE FOR INTENSIVE PROCESS CROP PRODUCTION

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Introduction

Carbon Positive is a six-year study investigating the effects of applying regenerative agriculture principles to intensive process crop production. Regenerative agriculture has re-emerged as a trend supported by governments and industry (Kraft Heinz Company, 2021; Thomas, 2022; McCain Foods, 2023). It places emphasis on sequestering carbon and reducing the use of chemicals (Grelet & Lang, 2021; Schlesinger, 2022; Danley, 2023). It is seen as a production system focused on reducing the impacts of food production on the environment, a way to shift to low-emissions and a sustainable economy and is part of the Government and primary sectors' "Fit for a Better World" roadmap (Ministry for Primary Industries, 2022). Our trial is evaluating soil, crop and profitability differences within New Zealand cropping systems that are applying management which is 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 seeks to integrate the use of biological stimulants and foliar nutrition and minimise the use of artificial fertilisers and synthetic 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. Our Carbon Positive trial is a three-systems comparison, evaluating differences between a conventional high-input, high-output cropping system typical of successful conventional crop producers, a system producing the same crops managed according to regenerative practice principles, and a "hybrid" treatment that may adopt practices from either system (Figure 1). The hybrid system evaluates the effects of amending some practices or might reflect a transitional conversion from conventional practice to a regenerative one. Key parameters measured include carbon stocks, labile carbon, VSA, aggregate stability, and earthworm abundance. Crop development, yield and quality are monitored, and gross margins using standard input costs and contractor rates calculated. We are learning, crop-by-crop, how we might apply regenerative principles to intensive process vegetable production. We have no guidebook, and much of it is new to both the process cropping and regenerative farming communities.

In year one a sweetcorn crop was grown for McCain Foods, and in year two a tomato crop was grown for Heinz-Watties. A double crop of peas then beans for McCain Foods is planned for year three. Other crops being considered in subsequent years are beetroot, broccoli and cauliflower.

Figure 1 Aerial view of the LandWISE MicroFarm and the Carbon Positive project trial site, overlaid with twelve "paddocks" which form the trial plots, with conventional treatment plots shown in yellow, regenerative treatment plots shown in green, and the hybrid treatments shown in blue.

Progress to date

First summer crop – process sweetcorn

Our 2022-2023 summer cash crop was process sweetcorn for McCain Foods, an industry partner and co-funder of the project. 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 (Figure 2).

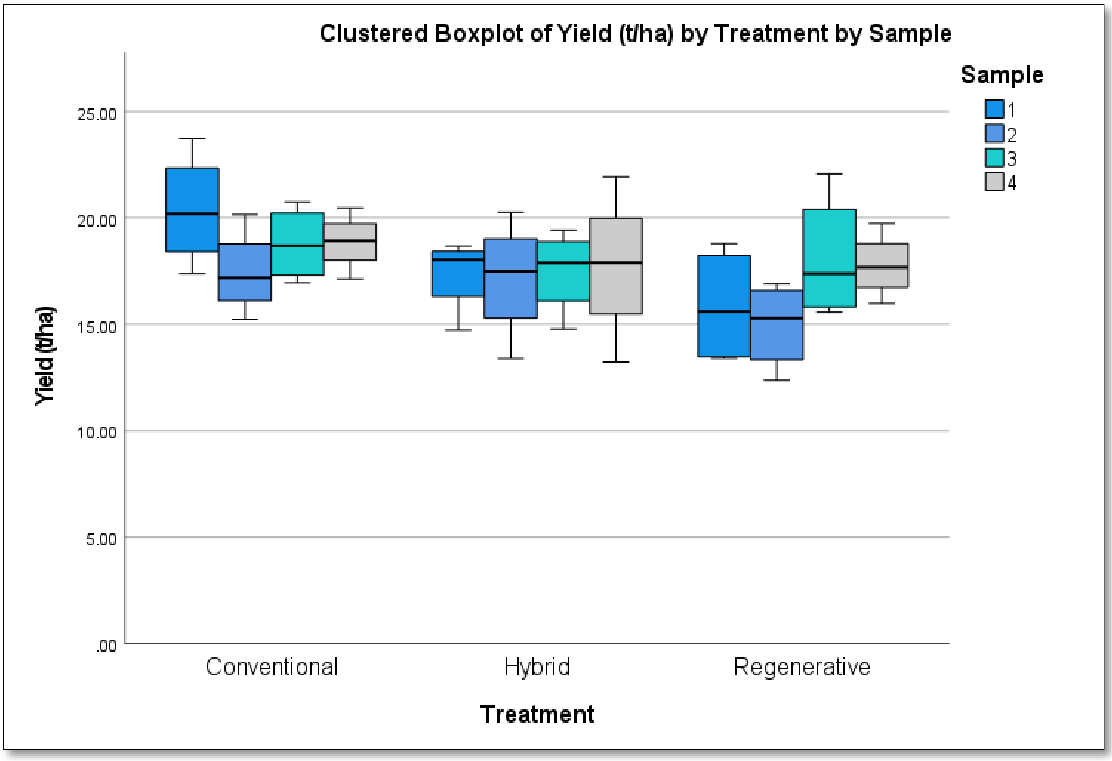

Figure 2 Clustered boxplot of 202-2023 sweetcorn yields by treatment showing individual plot yields.

Winter cropping

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, typical of current management on the Heretaunga Plains. The hybrid grass was not grazed, with the aim of minimising soil compaction by grazing animals over the winter. By termination, the regenerative cover-crop had amassed 13.65 t ha^{-1} of dry matter (Figure 3). The vetch did not grow well and was barely noticeable. The cover crop was not grazed but retained to "feed the soil" directly rather than via an animal. The termination plan was to avoid the use of herbicides, preferring to crush and/or mulch the crop to leave residue to leave a soil cover for direct mulch-planting. A trial area was mulched, mowed and mulched and crushed, but while the lupins died and the vetch was not an issue, the oats were not adequately controlled. This caused a last minute plan-change by the Operations Advisory Group immediately before the following crop was established.

Figure 3 Winter cover-crop of oats, blue lupins and vetch shortly before termination prior to tomato planting.

Second summer crop - process tomatoes

The 2023-2024 crop was process tomatoes for our industry partner and co-funder, Heinz-Watties. In spring, ryegrass was sprayed out and the hybrid system aerated and strip-tilled with a rotary cultivator. The conventional system was deep ripped and rotary hoed. While the regenerative system plan was to retain the mulched cover crop residue and plant through it using a modified transplanter, immediately prior to planting we realised that the soil was very dry and very hard. The Operations Advisory Group determined that cultivation was needed for successful establishment of the cell transplants. Continuing as planned would have risked a crop failure. The regenerative treatment plots were deep ripped and fully cultivated with multiple passes to create tilth and incorporate residues. The extremely dry soil severely impacted early growth of tomato transplants in the regenerative treatment, and the canopy differences with the other treatments were obvious throughout the season (Figure 4).

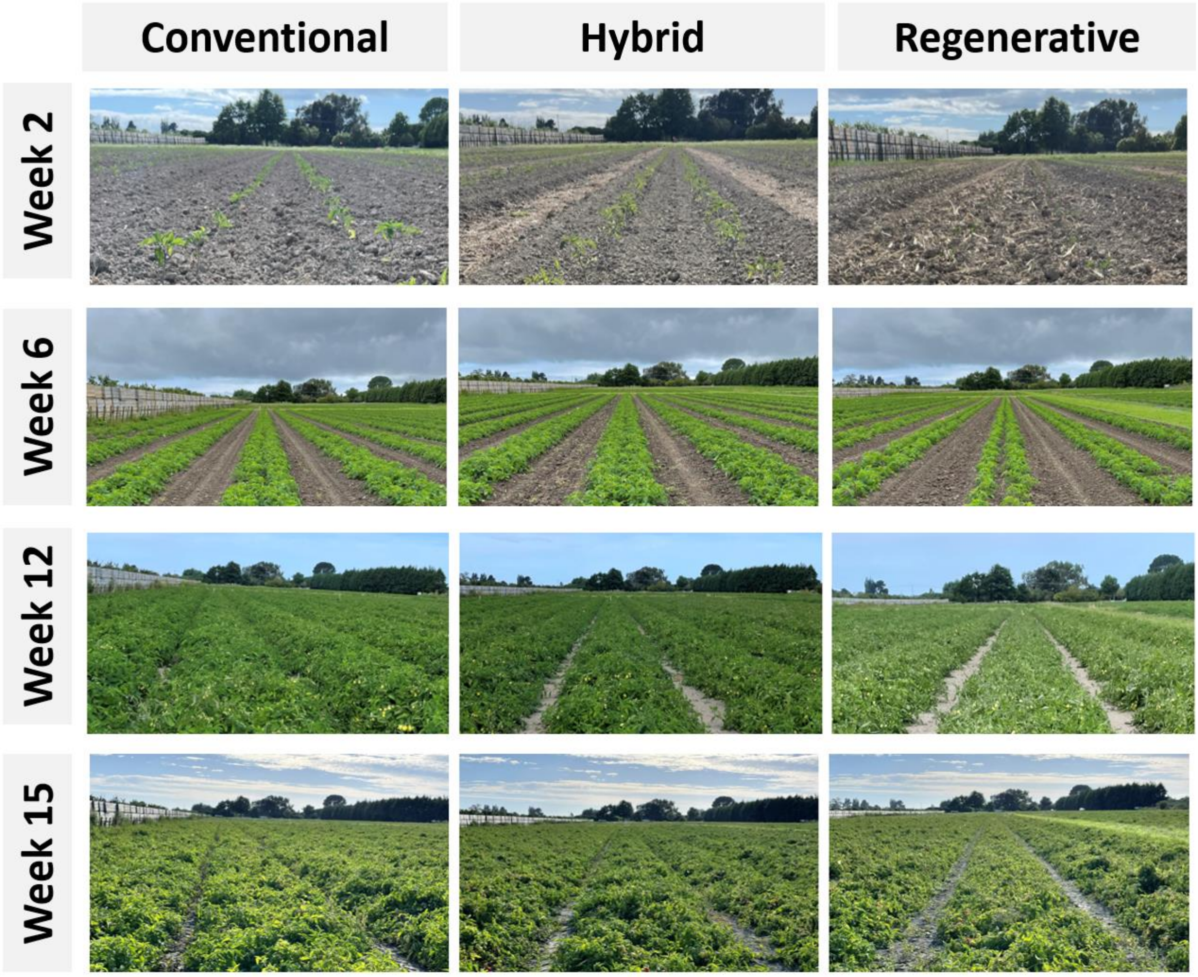

Figure 4 Comparative images of process tomatoes grown under three different management regimes: conventional, regenerative and a hybrid drawing for conventional and regenerative treatments showing canopy development over time.

Soil nitrate levels were measured at fortnightly intervals throughout the season to 30 cm using the Nitrate Quick Test procedure and a Nitrachek 404 reader, with leaf tissues sent for laboratory testing in December and January. Soil nitrate levels rose following fertiliser applications at planting and at the start of main fruiting in week seven. A late nitrate application gave a marginal and temporary increase in the regenerative treatment but did not prevent further soil nitrate decreases in the conventional and hybrid treatments (Figure 5). Additional foliar nutrition and biostimulant applications were made. Totalled over the season, there was little difference in the amount of fertiliser nitrogen added to the different treatments. Despite more than 13 t ha^{-1} DM of cover crop being incorporated in the regenerative treatment, no significant increases in soil nitrate were detected during the growing season. The mean nitrogen concentration in dry mass was 1.2%, representing 141.9 kg N ha^{-1}. The mean carbon content of cover crop in the regenerative plots was 42.6%, representing 2,391 kg C ha^{-1}. There was a high C:N ratio in the incorporated material (17:1) and despite 5 kg N ha-1 being applied at incorporation, microbial needs would absorb much released nitrate, leaving little to be taken up by the developing crop.

Leaf testing showed slightly higher than recommended leaf nitrate concentrations in late December, but late January leaf testing showed the nitrate levels had dropped below the recommended range in all treatments, with the regenerative treatment at only about half the recommended level. This may have further contributed to the reduced tomato canopy size (Figure 6).

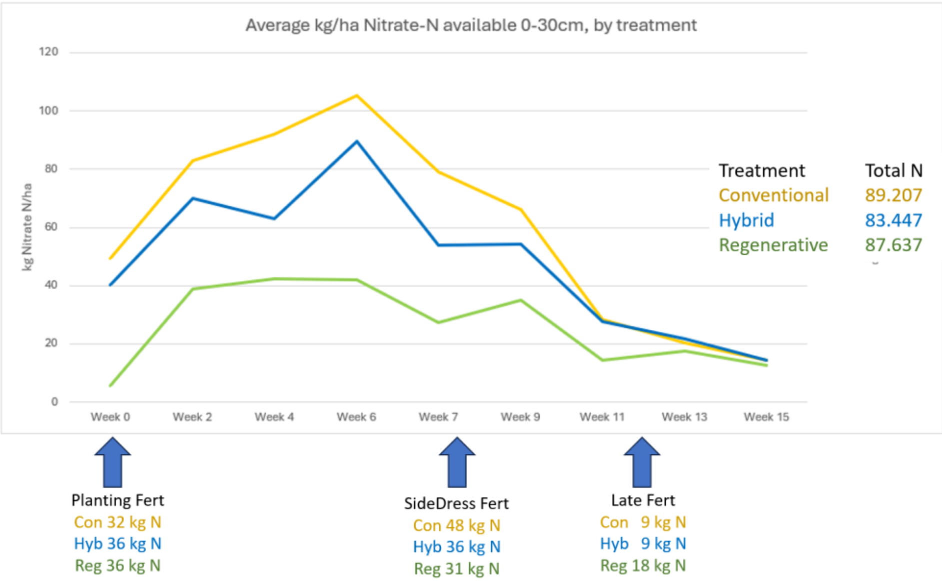

Figure 5 Line chart of soil nitrate levels over time as determined using the Nitrate Quick Test method showing that levels increased following fertiliser applications at planting, side dressing, but were only maintained by a late application 6 weeks before harvest. Regenerative treatment soil nitrate was consistently much lower than the other treatments.

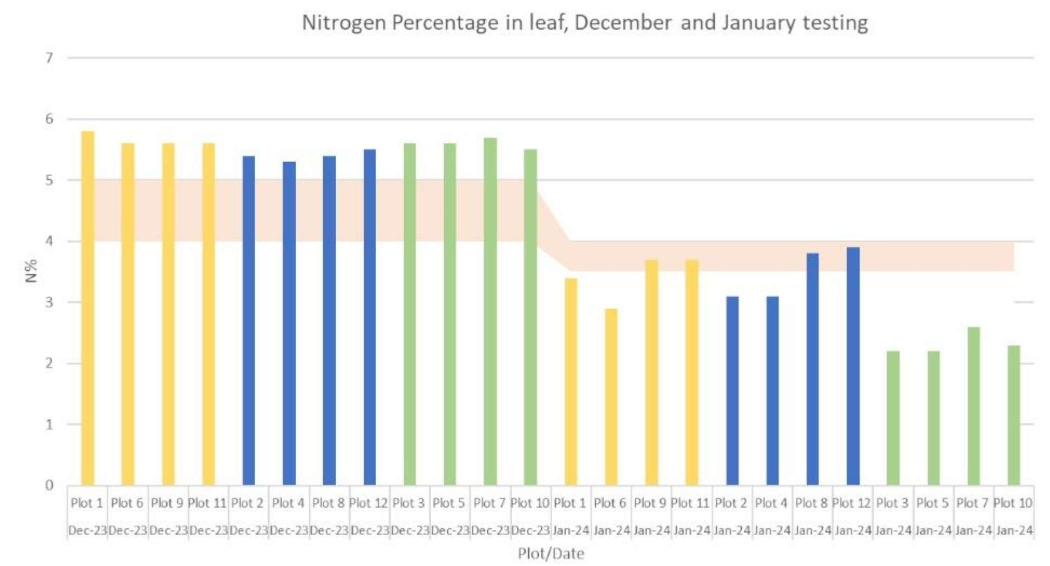

Figure 6 Histogram of tomato leaf nitrate concentration levels measured at the end of December and again in January with the histogram bars showing initially satisfactory to high levels and then lower than recommended levels a month later with the regenerative treatment plots consistently much lower concentrations than other treatments and recommendations. The pale brown stripe shows the recommended nitrate levels for tomato leaf testing before fruiting (December) and during fruiting (January) (Haifa Group, 2024).

Soil moisture

Prior to planting, the conventional and hybrid plots had moderate soil moisture, but the regenerative plots were very dry. Typical grower management of field tomatoes is to avoid irrigation for the first three or four weeks after planting, with the aim of encouraging plant roots to explore for water, developing deeper root systems. However, a simple water balance for the regenerative treatment, derived from MetWatch data for Ruahapia Road and assessments of crop groundcover, suggests the regenerative treatment plants would have been drought-stressed until rain fell at the end of October, and would have experienced some stress until mid-November. Irrigation began on 16 December with 116 mm being applied through the season.

A bucket test showed the uniformity was good and the applied depth was consistent with the operating expectations.

Crop Yields

Pre-harvest crop yield assessments were made by collecting all fruit and vine from full bed width transects 2.00 m wide by 0.50 m long (1.0 m^2) at four locations in each plot. Fruit was sorted into the four factory quality grades: reds, breakers, greens, and rots. Grower paid weight includes both red and breaker fruit. The preliminary yield assessments indicated that the regenerative treatment yields (red plus breaker tomatoes) of 93.4 t ha^{-1} were significantly lower ($p<0.001$) than the other treatments. The conventional yield estimates were 140.6 t ha^{-1} and the hybrid treatment were 148.9 t ha^{-1} and were not significantly different to one another ($p=0.29$) (Figure 7). The fresh mass of vine residue showed a different story, with the conventional mass of 22.78 t ha^{-1} being significantly higher ($p<0.001$) to both the hybrid at 17.82 t ha^{-1} and regenerative at 16.00 t ha^{-1} treatments which were not significantly different to each other ($p=0.206$) (Figure 8).

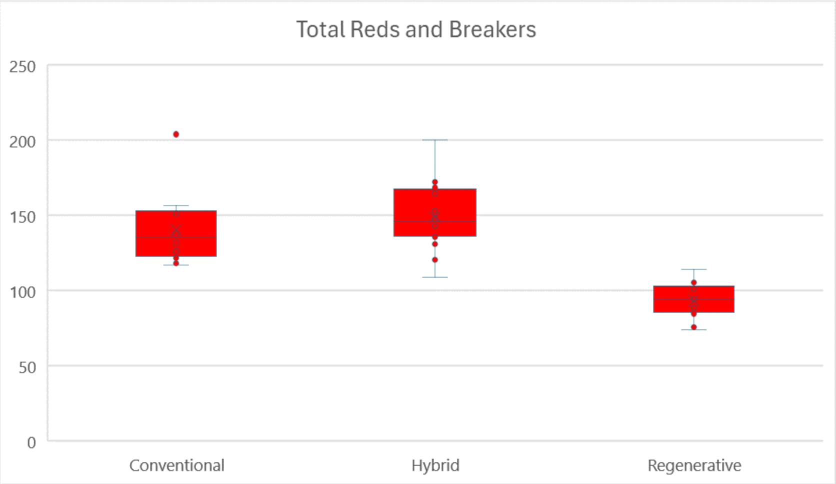

Figure 7 Boxplot of hand-harvest yield assessments showing the weight of red and breaker grade tomatoes collected, showing the conventional and hybrid treatments outyielded the regenerative treatment. Conventional and hybrid are not significantly different.

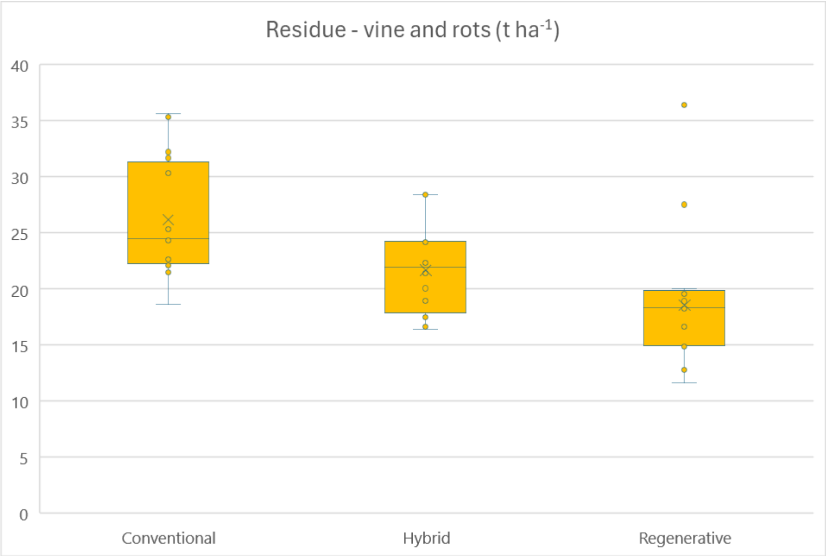

Figure 8 Boxplot of hand-harvest assessments showing the weight of residue vine and rotten fruit. Conventional is significantly different to the hybrid and regenerative treatments, which are not significantly different to one another.

Table 1 Summary of key harvest measurements by treatment

Row Labels	Total Red & Breakers t/ha	Green Fruit t/ha	Total Fruit t/ha	% Green Fruit	Average of Rots t/ha	Average of Residue t/ha	Total Biomass t/ha
Conventional	140.63	3.34	143.97	2.31	3.38	26.03	170.13
Hybrid	148.98	4.42	153.40	2.88	3.85	21.68	175.07
Regenerative	93.42	9.31	102.73	9.05	2.53	18.54	121.27
Grand Total	**127.68**	**5.69**	**133.37**	**4.75**	**3.25**	**22.08**	**155.49**

Further analyses showed that the regenerative treatment had a far higher percentage of green fruit, suggesting its maturity was delayed. While we cannot conclusively determine the causes of yield difference, it appears that the month of virtually no growth due to severe moisture stress, the low nitrate availability in the regenerative treatment plots, and possibly delayed maturity, are the main causes for the significantly lower yields. We are reconstructing our linear irrigator to have capacity to apply precision irrigation on a plot by plot basis so that in future, individualised irrigation programmes can be delivered.

Impact of crop protection

We compared the relative toxicities of the crop protection programmes applied to the different treatments using the Cornell University Environmental Impact Quotient (EIQ) model (Kniss & Coburn, 2015; Cornell University College of Agriculture and Life Sciences, 2024; Grant, 2024). The modelling shows that the impact of the regenerative crop protection programme was about half that of the other treatments Figure 9. The regenerative treatment applied biological products and plant response elicitors in preference to standard chemical options and dropped copper sprays entirely. Herbicide application was also minimised, but not eliminated. All treatments received some mechanical weeding passes. There was a higher weed pressure in the regenerative plots, but it was restricted to the interrows and thought to not affect yield.

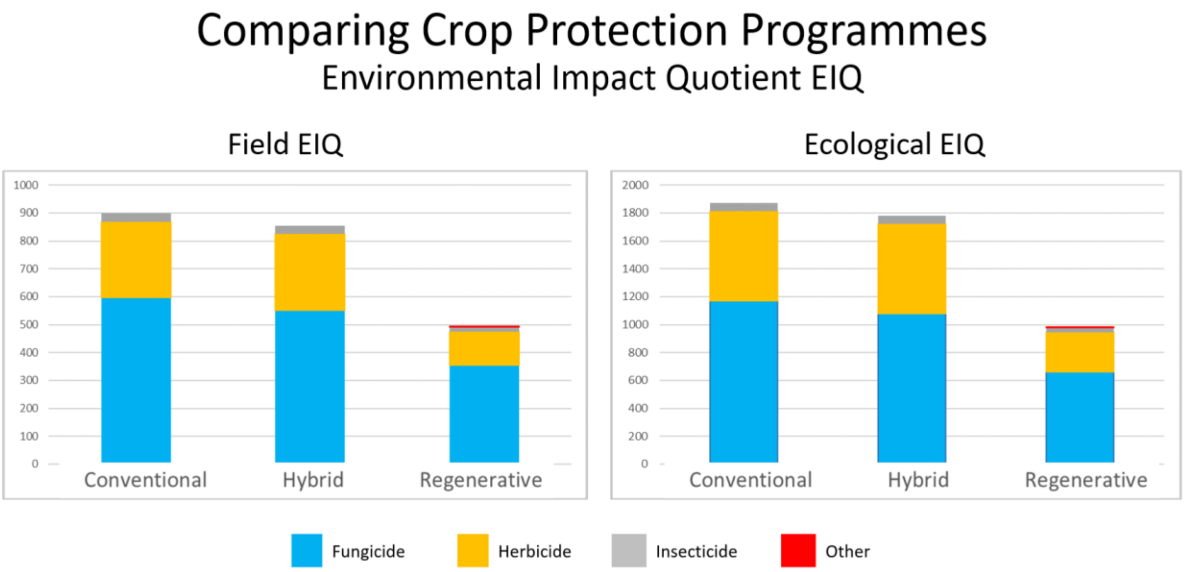

Figure 9 Histograms of the Field EIQ and Ecological EIQ of the three treatments applied to tomatoes in 2023-2024 showing the greatest contributions were fungicides followed by herbicides with insecticides and other products having minimal effect.

Funding and involvement

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

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