Evaluation of tillage practices for maize in a rotation system for market gardening in the Waikato region of New Zealand

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Abstract

United Nations identified seventeen Sustainable Development Goals. Goal number fifteen (Life on Land) relates to soil health as an integral part of sustainability. Furthermore, the Ministry of Primary Industries prioritised "increased sustainable resource use" as a critical success factor to ensure the wellbeing of all New Zealanders. Within the Waikato region of New Zealand, the Waikato Regional Council indicated that sediment loss would be a focus area for their Clean River Initiative. This study focused on the operations of A.S. Wilcox and Sons Limited (ASW), a vegetable grower in the Waikato region of New Zealand. Within the context of the above-mentioned policies, ASW implemented applied innovation to address core soil health improvements and to achieve financial sustainability. ASW sees the use of winter cover crops such as annual ryegrass, and the possible change in their maize growing system to use reduced-till establishment as a way to limit soil damage while maintaining crop profitability. As part of the vegetable crop rotation cycle, maize is grown primarily for grain and silage production. A field scale, strip-trial was established within the maize crop in 2018 with three treatments, being the growers' normal Full Cultivation practice (FC); Strip-till (ST); and No-till (NT) crop establishment into annual ryegrass that had been terminated using glyphosate. Four replicates of approximately 0.3-hectare strips of each treatment were established and managed to industry best practice. Yield was recorded by a yield monitor on the combine harvester, and no significant differences in grain yield or harvest moisture were found between treatments. However, due to lower costs of establishment, the NT and FC treatments had significantly higher gross margin than the ST. The findings of this trial show that the use of NT maize establishment results in the same grain yield (mean 12.1 t/ha) and gross margin ($1,853/ha) as the current practice of FC. It is therefore possible to address the requirements for soil health improvements as well as financial sustainability. This trial is being repeated in the 2019/20 season to confirm the results are repeatable.

Additional keywords: maize, minimum tillage, soil health, sustainability

Introduction

The Wilcox Group of Companies is involved with growing, packing and distributing fresh produce throughout New Zealand with facilities at Pukekohe, Ohakune, Northland and the Waikato in the North Island, and Rakaia in the South Island. Companies within this group are privately owned by the Wilcox family which has been associated with vegetable growing since the early 1930's (Wilcoxgoodness, 2018). They manage a production base of 1,500 ha with 170 permanent staff. A.S. Wilcox and Sons Ltd (ASW) have been farming in the Matamata area since 1984 and the climate and soil type found in Matamata suits the requirements for growing potatoes, onions and carrots. In rotation to these vegetable crops they grow utility crops to improve soil health and to increase the financial productivity of land.

The benefits of reduced cultivation, such as reducing the risk of soil erosion while maintaining soil organic matter, are generally well accepted (Whitehead *et al*., 2018), however there has been limited uptake of no-till and strip-till by New Zealand maize growers (Ward & Siddique, 2015). Cultivation practices can strongly influence important soil biological processes (Le Guillou *et al*., 2018), which in turn can affect the short- and long-term profitability and sustainability of arable cropping systems.

In Figure 1 the importance of soil health compromising the physical, chemical and the biological parts of soil, is highlighted.

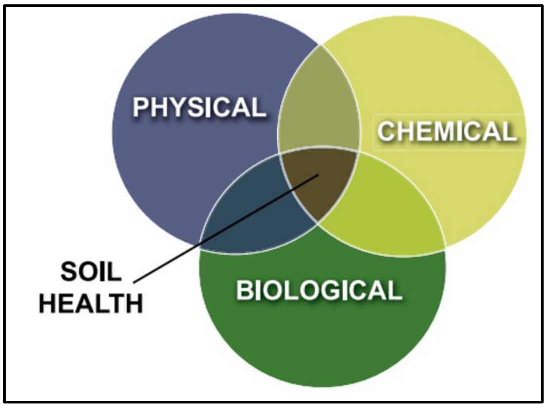

Figure 1: The concept of soil health encompasses the physical, biological and chemical components of the soil. (Adapted from Moebuis-Clune *et al*., 2017).

The sweet spot of "soil health" is where these intersect. The three circles are equal in importance and one cannot function without the other (Gugino *et al*., 2009).

Soil quality is conceptualized as the major linkage between the strategies for agricultural conservation management practices and the achievement of the major goals of sustainable agriculture (Parr *et al*., 1990).

Aim

The aim of the trial was to compare the effectiveness of full cultivation, strip-till and no-till crop establishment on the crop performance and profitability of maize. The trial will be repeated in 2019 to establish the economic feasibility of the three tillage systems and to determine their effects on the three pillars of soil health as shown in Figure 1. The practical implementation of the selected system into the current market garden production system will be evaluated.

Materials and Methods

The trial was conducted from October 2018 to May 2019 at the Dalbeth farm of A.S. Wilcox and Sons Ltd in the Matamata district of the Waikato region of New Zealand (co-ordinates 37°52'55" South and 175°43'46" East with an elevation of 80 metres above sea level). The trial site and layout are shown in Figure 2.

The trial was planted on the 25 October 2018 with three treatments each with four replicates in 16 maize rows, spaced 76 cm wide and 250 m in length.

Treatment 1 Full cultivation (FC)

The previous crop was sprayed off with a mix of 3 l of Glyphosate and 300 ml of LI 700 at 200 l/ha. After one month, the grass was chip hoed with a 5 m Celli hoe to a depth of 100 mm (Figure 3a). Ground was prepared with a Simba X-press cultivator (Figure 3b) and the maize was then planted with a John Deere 8 row planter.

Treatment 2 Strip-till (ST)

The previous crop was sprayed off with a mix of 3 l of Glyphosate and 300 ml of LI 700 at 200 l/ha. After one month, ground was prepared in planting strips with two passes of a Soil Warrior cultivator (Figure 3c) and the maize was then planted with a John Deere 8 row planter.

Treatment 3 No-till planting (NT)

The previous crop was sprayed off with a mix of 3 l of Glyphosate and 300 ml of LI 700 at 200 l/ha and the maize was then planted using a John Deere MaxEmerge 2 no-till planter.

Following grain black layer and plant dry down, the strips were harvested with a commercial John Deere combine, the moisture content and yield were recorded from the combine monitor.

Figure 2: The tillage trial layout at the Dalbeth farm in the Matamata district.

Figure 3: Preparing the trial treatments at the Dalbeth farm in the Matamata district.
a. Celli rotary hoe; **b.** Simba X-press; **c.** Soil Warrior strip-till cultivator.

Crop details

The trial site had had previous crops of Onions (*Allium cepa*) then annual ryegrass (*Lolium multiflorum*). The soil type is a Ngakura deep loam. The trial was laid out in 250m x 16 rows using a complete block design of four replicates. The maize, Pioneer hybrid P1253, was planted on 25 October 2018 at a sowing rate of 100,000 seeds/hectare. A base fertiliser of 500kg/ha Potassium Sulphate (41% K; 17% S) and 250kg/ha Urea (46% N) was applied on 24 October 2018. A side dressing of 300kg/ha SustainN (46% N) was applied on 27 November 2018. Herbicide application at planting was Acetochlor® 3 l/ha in 50 l/ha of water. A post-emergence herbicide application of Cutlass® (500 g/l dicamba SC) 0.5 l and Mesoflex® (400 g/l mesotrione) 0.2 l in 200 l/ha water was applied on 27 November 2018. Slug bait was applied during planting and as a follow up application manually. The trial was harvested 21 May 2019.

Gross margin

Gross margin was calculated based on a grain price of $415 and the same cost for each crop, except for the costs given in Table 1 relating to each establishment treatment. Partial Budgeting was undertaken for no-till and strip-till versus standard practice as per Wilcox standard procedure when considering an operational change.

Table 1: Additional establishment costs for each of the tillage treatments Dalbeth farm in

Crop establishment technique	Additional costs	$/ha
Full cultivation (FC)	Rotary hoe Simba X-press	220
Strip till (ST)	2 x strip till 2 x slug bait application	610
No-till planting (NT)	2 x slug bait application	165

Measurements

Treatments were harvested individually with a commercial grain harvester. Yield results are expressed in tonnes per hectare (t/ha) at 14% moisture. The combine yield monitor recorded yield data and moisture content. Data was analysed by extracting yield monitor results from each strip, cleaning to remove any data points more than two standard deviations from the mean, and then using the resulting mean to undertake an ANOVA test.

Climatic data was recorded using a Davis Vantage Pro 2 weather station (Davis Instruments, 2019) situated at the office of ASW, less than 800 m from the trial site. Irrigation totals and averages were not affected by missing weather data and were computed for the entire reporting period.

Financial data was collected by keeping record of machine hours and input cost and recorded in a partial budgeting work sheet to analyse effect.

Basic soil nutrient analysis was undertaken before the trial was established in 2018, and on completion of the trial in July 2019 soil testing for chemical and physical characteristics was undertaken and analysed by Eurofins Scientific. The four blocks were sampled and tested separately, with composite samples taken from each block to a depth of 150 mm.

Results and Discussion

Soil results

Figure 4 shows the results from a 2015 pass with a Veris Multi-Sensor Platform 3 unit that measures geospatial soil properties. The Veris MSP3 is pulled through the field, with one pair of coulter-electrodes injecting electrical current into the soil, while another coulter-electrodes measure the voltage drop. The voltage drop is used as a proxy of soil electrical conductivity. This figure shows the homogenous nature of the trial site. There is a strip of higher EC soil than in the centre of the paddock at each end of the paddock, which corresponds with the headlands that farm machinery turns on while working the paddock. Headlands are likely to have more compact soil than the middle of the paddock, which therefore holds more water, which will then conduct more electricity.

The soil at the trial site is a Ngakura deep loam (Table 2). There were no significant differences between the blocks in any of the measured parameters. The soil textural analysis confirmed the soil is a loam. These soil results are typical of soils used for cropping in the region, with low volume weight, pH near neutral and relatively high Olsen P.

Table 2: Soil characteristics at the trial site; measured July 2019.

Soil Characteristic		Value
pH		6.65
Olsen P		51
Cation exchange capacity		22 me/100g
Base saturation		75%
Volume weight		0.68 g/ml
Organic matter		9.9%
Total carbon		5.7%
Soil texture	Coarse sand	4.5%
	Medium sand	9.5%
	Fine sand	29.5%
	Silt	52.3%
	Clay	4.2%

Figure 4: Geospatial soil Electrical Conductivity of trial block, sampled 2015.

Weather data

The weather data recorded over the season (Table 3) was typical for the region.

Table 3: Weather results recorded at the local weather station.

Planting & report start date	25 Oct 2018
Report end date	13 Mar 2019
Report period length	140 days
Evapotranspiration	676 mm
Irrigation	Nil
Rainfall	336 mm
Solar energy (Langley Units)	59904

A unmanned aerial vehicle (UAV) flight was made over the crop in late December 2018 and no visual differences were observed, as shown in Figure 5.

Harvest results and gross margins

The crop harvest results and gross margins are given in Table 4. These show no significant difference between the grain yields and grain harvest moisture of no-till, strip-till and full cultivation established maize grain crop. The margin as presented in Table 4 is based on fixed crop costs of $2,310 per hectare, plus the additional costs as shown in Table 1. Although the yield results showed no difference between the treatments, because of the higher cost of crop establishment for the strip-till treatment, it had a significantly lower gross margin ($1,687/ha), than the full cultivation ($1,924/ha) and no-till ($1,948/ha) established crop gross margins (Table 4).

Conclusions

All three of the treatments yielded the same, however, due to lower costs of establishment, the no-till and full cultivation treatments had significantly higher gross margin than the strip-till. When analysing the yield maps (Appendix A), it is apparent that there are inherent differences in soil fertility which could be related to drainage but will have to be investigated. A possible solution would be to utilise the Veris mapping technology and to apply fertilisers with a variable fertiliser spreader for the next season.

Figure 5: Established tillage trial showing no visual differences between plots at the trial site.

Table 4: Maize grain harvest yield, grain moisture and gross margin of the different tillage treatments at the Dalbeth farm near Matamata.

Treatment	Yield (t/ha @ 14% moisture)	Grain harvest moisture (%)	Margin ($/ha)
Full cultivation (FC)	12.17	17.92	$1,924
Strip-till (ST)	12.14	18.00	$1,687
No-till (NT)	12.09	17.95	$1,948
LSD 5%[1]	0.72	0.27	$257[1]
CV%	3.7	0.9	8.7

[1] If the difference between the two treatments is equal to or greater than the Least Significant Difference (LSD), the difference is attributable to treatment differences in 95% of instances

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Appendix A: Maize Yield Map

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FARMING SMARTER

2019 Grain Harvest

Layer: Yield Mass (Dry)

AS Wilcox

AGRONOMIC DATA

Grower : AS Wilcox

Farm : Dalbeth

Field : Multiple

Year : 2019

Operation : Grain Harvest

Area : 17.82 ha

Est. Yield Mass (Dry) : 10.83 tonne/ha

Avg. Moisture : 17.97 %

Yield Mass (Dry)
(tonne/ha)

12.78 - 24.89 (2.234 ha)
12.07 - 12.78 (2.864 ha)
11.43 - 12.07 (2.899 ha)
10.69 - 11.43 (2.818 ha)
9.92 - 10.69 (2.768 ha)
8.21 - 9.92 (2.535 ha)
0.31 - 8.21 (1.693 ha)

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