Impact of tillage system on sweet corn yield and some soil properties: Year 2 of LandWISE Hawke's Bay

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Abstract

The LandWISE project demonstrates minimum tillage for crop establishment on wind erosion prone soils. Conventional and no-tillage were compared for sweet corn production near Hastings. Sweet corn plant populations and yield were similar for the two treatments, but soil quality was higher and nitrate leaching losses were lower under no-tillage.

Additional key words: Zea mays, soil, quality, leaching

Introduction

Increased competition from other land uses on the Heretaunga Plains in Hawke's Bay, has forced annual cropping onto more marginal soils where productivity can be low and the environment more fragile. The aim of the LandWISE project is to demonstrate minimum tillage as an alternative management technique to conventional cultivation, especially to those farmers growing crops on wind erosion prone soils.

Soil degradation has a demonstrable effect on sweet corn yields (Reid *et al.,* 2001) and tillage methods play an important role in maintaining high quality soil. On marginal soils, effects of tillage on crop production, soil quality and other environmental consequences are generally more pronounced.

For a second consecutive season, we compared two tillage systems on a wind erosion prone soil in the Hawke's Bay. Soil and crop measurements were conducted during the 2000-2001 cropping season, and nitrate leaching was monitored during winter 2000.

Materials and Methods

The trial site was on the southern outskirts of Hastings. The predominant soil type is the Pakipaki silt loam derived from ash and alluvial deposits of Taupo pumice. The 2000-2001 cropping season was the second consecutive season a no-tillage system was implemented in the same paddock. The site history is further described in Pearson *et al.,* (2000).

Two non-replicated tillage regimes were re-established in the trial paddock in the same manner as the previous season. The tillage treatments are conventional tillage and no-tillage. Conventional tillage involved primary and secondary cultivation; soil in the no-tillage treatment was undisturbed. Further treatment details are given in Pearson *et al.,* (2000).

Both treatments were planted in sweet corn (cultivar "Dominion") on 23 November 2000 at a sowing rate of 65 000 plants/ha. Sufficient fertiliser was applied at planting and side-dressing six weeks later. Regular irrigation ensured crop yields were not limited by soil moisture.

Monitoring plots (15 m x 15 m) were established in each of the tillage strips. Eight contiguous plots in each tillage treatment were monitored for winter nitrate leaching. The first four plots in each treatment were used for soil and crop measurements. Plots in the no-tillage treatments were 11 m from plots in the conventional tillage treatment.

Yield assessments were made from each monitoring plot on 7 March 2001 just prior to commercial harvest. Plant populations were measured by counting plant numbers along two randomly selected 5 m rows. For yield measurements, all the cobs from 25 randomly selected plants within those rows were collected and the moisture content determined. Harvestable yield, cobs more than 15 cm long and 4 cm wide, was also assessed.

Soil measurements were taken from 0-15 cm in each plot at or after harvest in March 2001. Five earthworm counts were made per plot using the 'farmers spade method' (Fraser *et al.,* 1999). Samples for soil microbial biomass carbon and total organic carbon were collected using a 25 mm wide soil corer, with 20 cores collected and bulked per plot. Microbial biomass C was determined using the chloroform fumigation-extraction method (Vance *et al.,* 1987). Total organic carbon was determined by dry combustion using a LECO CNS analyzer.

Five spade-sized samples of soil (0-15 cm) were collected per plot. These samples were bulked then sub-sampled for soil aggregate size and soil aggregate stability. The average aggregate size, reported as mean weight diameter, was determined by sieving approx. 2 kg air dry soil sample through a sieve nest as described by White (1993). Aggregate stability, reported as % of stable aggregates (2-4 mm) remaining in the 2 mm sieve, was determined by wet sieving (Kemper & Rosenau, 1986). Dry soil bulk density to 15 cm was measured by collecting five 8 cm wide cores per plot that were weighed and subsample for moisture content (Blake & Hartge, 1986).

The two main influencing factors of nitrate leaching were determined, firstly the amount of water draining through the soil profile, and secondly the concentration of nitrate in that drainage water. In Hawke's Bay, most nitrate leaching is likely to occur over winter when excess rainfall drains through the soil profile.

The amount of drainage was calculated using a simple soil water balance featuring rainfall, potential evapotranspiration and an estimate of soil moisture deficit (Francis *et al.*, 1992). Samples of drainage water were collected using ceramic tipped solution samplers installed at 60 cm depth (two samplers per plot). Following significant rainfall (> 10 mm), a vacuum was applied to collect a sample of drainage water for nitrate analysis by colorimetric determination (Blakemore *et al.*, 1987). Gravimetric soil water content to 60 cm depth was measured at the start of winter along with soil mineral nitrogen in the nitrate (NO_3^-) and ammonium (NH_4^+) forms (Blakemore *et al.*, 1987).

Due to logistical constraints the tillage treatments were not replicated. However, the paddock was surveyed before applying the treatments to ensure there were no consistent differences between the monitoring sites other than the applied treatments. Variation in the topsoil depth (range 25 to 45 cm) was observed along the length of the trial area but this was consistent for tillage treatments. Pre-treatment chemical analysis of soil samples 0-15 cm depth gave the similar results for each tillage treatment. The means of the four monitoring plots in each tillage treatment are reported.

Results and Discussion

Crop measurements

Plant populations were lower in the conventional tillage than the no-tillage (Table 1). These results are contrary to the crop emergence measurements conducted by Slay *et al.,* (2000) in December 2000 where initial emergence on the no-tillage plots were 50 % lower than conventional tillage. This initial difference in emergence could be due to differences in aggregate sizes in the seedbed. Braunack (1995) reported earlier emergence of maize seedlings in finer seedbeds (1-5 mm) than coarser seedbeds (5-15 mm) due to various factors including seed-soil contact. The difference in plant population measured at emergence and harvest suggests something other than the tillage treatments altered plant population.

Table 1 shows total yield corrected for differences in population. Because of lower populations, the plants in the conventional tillage treatment grew larger cobs, so more of the secondary and tertiary cobs were of a harvestable size. When differences in plant population are taken into account, both total and harvestable yield are the same for both treatments. These results are similar to the previous season when there was no difference in harvestable crop yields between the no-tillage and the conventional tillage (Pearson *et al.*, 2000).

Table 1. Sweet corn population and yield.

	Plants/ha (000's)	Total Yield (t/ha)	Harvestable Yield (t/ha)
Conventional Tillage	45.4	28.4	23.8
No-tillage	53.3	28.8	20.6

Soil measurements

Total organic carbon was the same for both treatments (0-15 cm). In the previous season (1999-2000) total organic carbon was higher under no-tillage than conventional tillage as grass residues were buried below the sampling depth by ploughing while under no-tillage residues remained within the sampling zone. In this second year, the buried organic matter in the cultivated treatment was re-introduced into the 0-15 cm topsoil by ploughing and no treatment difference was found in total organic carbon levels.

As with total organic carbon there was little effect of tillage treatment on microbial biomass carbon, the more active, labile fraction of total organic carbon. Earthworm numbers were higher in the no-tillage treatment ($220/m^2$) than the conventional tillage treatment ($125/m^2$). Such differences in earthworm populations between tillage treatments are common and usually attributed to the destructive nature of cultivation and changes in soil organic matter.

Soil bulk density was the same for both treatments (data not shown). In general, no-tillage results in greater topsoil bulk density owing to the absence of annual tillage to relieve natural soil consolidation and compaction due to agricultural machinery. In no-tillage, consolidation can only be alleviated by biological activity (earthworms and root channels) and shrink/swell of the soil during wetting and drying cycles. In this study, soil bulk density was measured to 15 cm depth. Sharp increases in soil bulk density have been found below this depth under conventional tillage due to presence of plough pans (Francis *et al.,* 1987; Hao *et al.,* 2000).

Aggregate stability was higher under no-tillage than conventional tillage (Table 2). Similar results were found the previous season (Pearson, 2000). Decline in aggregate stability with cultivation has been found in many New Zealand studies (Hughes & Baker, 1977; Ross & Cox, 1981; Hart *et al.,* 1988; Sparling *et al.,* 1992; Francis *et al.,* 1987). Soils with high aggregate stability are less prone to aggregate breakdown and surface crusting.

Aggregate size is related to the degree of mechanical manipulation of the soil. Larger aggregates were found in the no-tillage treatment compared with the conventional tillage treatment (Table 2). Large soil aggregates are an important benefit on the Pakipaki soil, which is susceptible to wind erosion during the spring equinox winds.

Table 2. Soil aggregate size and stability.

	Stable soil aggregates (%)	Average aggregate size (mm)
Conventional Tillage	56	7
No-tillage	70	15

Winter nitrate leaching

Soil moisture, ground cover and rainfall were the same for both treatments so the amount of drainage calculated for both treatments was the same (125 mm from June 2000 to August 2000 inclusive). Soil mineral nitrogen at the start of winter was higher for the conventional tillage so the amount of nitrogen in the drainage water was also higher in the conventional tillage treatment (Table 3). As drainage was the same for both treatments, more nitrogen was leached from the conventional tillage treatment than from minimum tillage.

The higher soil mineral nitrogen at the start of winter under conventional tillage could be due to two factors. Firstly, in the previous season more nitrogen fertiliser was applied to the conventional tillage treatment (134 kg N/ha) than the minimum tillage treatment (88 kg N/ha). If the crop did not take up all the nitrogen applied to the conventional treatment, higher soil mineral nitrogen levels would result. Secondly, a flush of mineralised nitrogen is likely to result from the cultivation in the conventional tillage treatment prior to sowing the winter grass.

Higher soil mineral nitrogen with conventional tillage compared with no-tillage has been observed in many studies (Papini *et al.,* 1998; Grant & Lafond 1994; Catt *et al.,* 2000). Tillage is well known to enhance mineralisation of nitrogen in soil organic matter by exposing it to oxygen and microbes thus providing the microbes with new sources of energy.

In comparing drainage from different tillage treatments, Shipitalo & Edwards (1993) found 30-40 % more drainage under minimum tillage than conventional tillage. Earthworm burrows function as preferential flow paths in the soil but burrows in tilled soil are less effective flow paths than those in untilled soil due to disruption by tillage (Shipitalo *et al.,* 1994). Our nitrate leaching calculations assume the same drainage from both tillage treatments but these studies suggest drainage and hence nitrate leaching from the minimum tillage may be under estimated.

Conclusions

- Sweet corn populations and yield were similar between tillage treatments.
- Some indicators of soil quality such as earthworm activity and soil aggregate stability were higher under no-tillage compared with conventional tillage.
- Soil mineral nitrogen and nitrate leaching losses were lower under no-tillage compared with conventional tillage but the drainage in the no-tillage treatment may have been under estimated.

Table 3. Winter nitrate leaching.

	Soil mineral N 0-60 cm (kg N/ha)	Drainage water nitrate-N concentration	N Leached (kg N/ha)
Conventional Tillage	196	43	59
No-tillage	107	31	40

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