ESTABLISHMENT OF MAIZE INTO CULTIVATED AND ZERO-CULTIVATED MAIZE STUBBLE IN THE MANAWATU

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ABSTRACT

Maize was sown into farmers' paddocks at three sites in the Manawatu in 1980 and 1981. Similar planting dates and inputs of fertiliser and herbicides as used by the farmers were added to cultivated and zero-cultivated maize stubble seedbeds. Seed was sown with a White-Oliver 5400 planter with a large wavy disc preceding each double-disc sowing coulter.

Yields in cultivated plots ranged from 6.0 - 10.0 t/ha grain, and in zero-cultivated plots 1.0 - 9.6 t/ha grain. Attempts were made to identify causes of the more variable yields in the zero-cultivated seedbeds.

The primary cause was lower plant establishment, especially in a wet over-cultivated soil and a very dry soil. Secondary causes, not related to plant establishment, were possibly related to supplies of nutrients and water to zero-cultivated plants which was likely to be in turn caused by slower rates of root extension.

Further research is required into the interactions of root development, water and nutrient supply to plants and final crop yields. Research is also needed into ways of managing problems, e.g. methods of adding fertilisers, avoidance of unsuitable soils and irrigation.

Additional Key words: *zero-cultivation, maize, maize stubble, crop growth, grain yield.*

INTRODUCTION

Maize farmers in the Manawatu generally mould-board plough the previous crop stubble and cultivate before planting. Some farmers, aware of the damage continuous cropping can do to soil structure, carry out a reduced or minimum tillage programme using disc or tyne cultivating implements only before sowing. Very few, if any, use zero-cultivation techniques.

The advantages of zero-cultivation, or conservation tillage are becoming well-known in New Zealand, especially in the areas of time-saving and long term maintenance of desirable soil properties. If mono-culture crops are to be grown on a large scale in the future (e.g., for energy farming) zero-cultivation may become desirable. Much interest is presently being shown in the use of zero-cultivation for pasture renovation (Campbell, 1981; Charlton and Brock, 1980) and also for establishing small grain cereals, and other cash and fodder crops (Janson, 1979; Yortt, 1981).

When maize is harvested, large amounts of thick stalks, cobs and piles of trash are left in the paddock by the harvester, especially in the headlands. Generally this material must be buried by cultivation to enable maize planters to operate. Some past attempts in New Zealand to direct-drill maize for grain into maize stubble have been limited by inadequate drilling machinery (e.g. McCormick and Mackay, 1973). Yortt (1981) however obtained good yields of grain using the method. USA experimenters sometimes mention difficulty in matching planting machinery to zero-cultivated or compacted soils (e.g. Mock and Erbach, 1977; Henry and Johnson, 1969). Many report yields equal to cultivated crops (e.g. Jones *et al.*, 1968; Shear and Moschler, 1969; Triplett *et al.*, 1968).

Cannell (1981) listed some factors limiting the adoption of zero or reduced cultivation methods in the UK. Some of these factors e.g. need for specialised drills, efficiency of herbicides, lack of management skills, cannot be regarded as long-term constraints. Other factors such as suitability of soil-type may be at least equally important, especially with regard to the ability of the crop plants to proliferate roots and obtain adequate water and nutrients. Different water withdrawal patterns under tilled and non-tilled corn were reported by Blevins *et al.* (1971).

The trials reported here are an initial survey to identify the possibilities and problems of growing zero-cultivated grain maize in the Manawatu. They were carried out on farmers' properties where conditions were similar to those experienced by commercial maize growers, using a maize planter designed to sow into stubble and crop residues. An attempt was made to identify some possible areas of further research.

METHODS AND MATERIALS

Maize was sown into cultivated and zero-cultivated maize stubble with a White-Oliver 5400, 4-row planter, with 450 mm diameter wavy disc preceding both the fertiliser and seed-drilling double disc coulters. Row width was 810 mm.

The trials were in maize growers' paddocks in the Manawatu and had the same inputs of basal fertiliser and herbicide as the remainder of each farmers' crop. The zero-cultivated areas were not cultivated in any way but remained as the harvester had left them. Cultivated areas were mould-board ploughed and harrowed to form a seedbed.

TABLE 1: Details of trial sites in 1982.

	1980/81		
Location	Aokautere	Rangiotu	Karere
Soil-type	Manawatu fine sandy-loam	Parewanui silt loam	Kairanga silt loam
Years in maize:	3	5	10
Fertiliser (NPK kg/ha)			
presowing	225:56:112	22:25:0	—
at sowing	14:12: 12	31:26:26	36:30:30
sidedress	—	70: 0: 0	—
Herbicides	2,4-D Atrazine/ Metalachlor	Atrazine	Glyphosate Atrazine/ Alachlor
Sowing date	14/11/80	4/11/80	24/11/80
Sowing rate (seeds/ha x 10^3)	111	97	111
Hybrid	PX 442	PX 442	PX 442
	1981/82		
Fertiliser (NPK kg/ha)			
pre-sowing	135:0:0	0:16:32	
at sowing	—	36:30:30	
sidedress	—	68: 0: 0	
Herbicides	Atrazine/ Metalachlor	Atrazine/ Metalachlor	
Sowing date	22/10/81	13/11/81	
Sowing rate (seeds/ha x 10^3)	77.4	77.4	
Hybrid	Pioneer 3709	Pioneer 3709	

Details of the sites, sowing rates, fertiliser and herbicide inputs are shown in Table 1. Details of soil-types are given by Cowie (1978). Herbicides were applied at manufacturers recommended rates. A very high seeding rate was used in the first year because of the uncertainty of sowing success but was reduced to more usual rates in the second year. The trial at Karere was not repeated because of the deteriorated soil structure (Table 2).

TABLE 2: Some properties of soil samples taken from Karere and Rangiotu zero-cultivated plots, 1980/81 season (from Ross, 1981). Data are not available for cultivated soils, but soil-types at both sites are closely related.

	Rangiotu	Karere
Bulk density (T/m^3)	1.32	1.33
Total porosity (%)	49.1	48.8
Macroporosity (%)	7.9	negligible
Avail. water storage (mm) to 10 cm)	23.5	19.9
Penetrometer resistance (kPa)	14-20	514

MAF 'quick tests' were done on soil sampled 0-7.5 cm at each site. Weather data, shown in Table 3, was obtained from Grassland's Station, DSIR, Palmerston North (EO 5363) and from Kairanga Station, Aorangi (EO 5343). On site records were kept of seedling emergence, plant wet weights and in 1981/82 leaf mineral content was measured by argon spectrometer and Kjeldahl digestion were estimated at various times during crop growth. Final grain yields were estimated by harvesting by hand 8 x 10 m rows from each treatment.

TABLE 3: Total rainfall (mm) and total heat units above 10°C for the 7 and 14 day periods immediately after sowing. Aokautere data from Grasslands Division Station (EO 5363), Rangiotu and Karere data from Kairanga Station (EO 5343).

	7 days		14 days	
	rainfall	H.U.s	rainfall	H.U.s
Aok 1980/81	12.6	37.5	69.2	56.9
Ran 1980/81	28.3	21.5	35.0	45.6
Kar 1980/81	57.6	16.5	64.2	41.9
Aok 1981/82	12.1	21.9	15.2	37.5
Ran 1981/82	2.2	40.0	2.6	55.9

Limitations were imposed on trial design and layout at Rangiotu and Karere by the need to fit in with the farmers' cultivation programme. However, all sites were in maize paddocks well away from the headlands and an estimate of variability within treatments was obtained by random subsampling from the plots whenever a measurement was made. The Aokautere trials consisted of eight plots (four cultivated and four zero-cultivated) of size 20 m x 8 rows, the Rangiotu trials, one plot (100 m x 16 rows) of each treatment, and the Karere trial, two plots (40 m x 10 rows) of each treatment.

RESULTS AND DISCUSSION

Grain yields obtained from the zero-cultivated areas ranged from less than 1.0 t/ha to 9.6 t/ha, and from 6.0 t/ha to 10.0 t/ha on the cultivated areas (Table 4). The trials were done over two years on three sites with differing soil-types and cropping histories (Table 1) and provide a range of situations on which to base speculation on the causes of the generally lower and more variable yields obtained on the zero-cultivated plots. This can be broadly discussed with regard to the two components of crop yield i.e. plant density and yield/plant.

TABLE 4: Yield of grain at 14% m.c. (tonnes/ha). S.E.'s (in brackets) are calculated from 8 subsamples taken from each treatment, regardless of the number of plots.

	Cult.	Zero Cult.
Aok 1980/81	7.6 (0.15)	7.4 (0.22)
Ran 1980/81	7.8 (0.46)	6.7 (0.66)
Kar 1980/81	6.0 (0.30)	1.0 (—)
Aok 1981/82	10.0 (0.32)	9.6 (0.38)
Ran 1981/82	9.2 (0.27)	6.2 (0.72)
Mean S.E.	(0.30)	(0.50)

TABLE 5: Plant establishment at each site. Number of plants/hectare x 10^{-3}. S.E.'s (in brackets) are calculated from 8 subsamples taken from each treatment, regardless of the number of plots.

	Cult.	Zero Cult.
Aok 1980/81	95.5 (2.5)	87.4 (2.4)
Ran 1980/81	105.8 (3.1)	106.2 (5.4)
Kar 1980/81	80.0 (3.0)	10.0 (—)
Aok 1981/82	68.9 (1.6)	66.6 (4.0)
Ran 1981/82	71.3 (3.7)	37.6 (6.5)
Mean S.E.	(2.8)	(4.6)

The primary cause of the greater variability in zero-cultivated crop yields appeared to be related to the effect zero-cultivation had on plant density. Differences in yield between treatments (Table 4) were especially great at Karere 1980/81 and Rangiotu 1981/82 and were associated mainly with lower numbers of plants established (Table 5) on the zero-cultivated areas compared to the cultivated areas. Despite the somewhat similar soil-types at Rangiotu and Karere (Cowie, 1978), seedlings established well at Rangiotu 1980/81 and very poorly at Karere 1980/81 (Table 5). The numbers of plants established at Karere were so low that a precise yield measurement was not possible and a visual estimate only was made. The Karere site, however, had been in continuous maize for ten years while that at Rangiotu had been cultivated for five years. A few of the unemerged seeds at Karere had imbibed and had sent out a radicle which failed to reach the soil surface while other seeds appeared to have rotted without any appreciable development of a radicle. Ross (1981) measured various properties on the zero-cultivated soils at Karere and Rangiotu with the results shown in Table 2. Cool wet weather after sowing (Table 3) combined with the low macroporosity and high penetrometer resistance of the Karere soil is probably correlated with seedlings dying either from 'lack of aeration' or 'physiological exhaustion' after failing to penetrate the soil to the surface. Baker and Mai (1982) have found that using a triple-disc coulter in high density soil (1.32 g/cm) resulted in inhibited root development in lupins.

In contrast to Karere, seeds at Rangiotu 1981/82 did not emerge because of the extremely dry conditions immediately after sowing (Table 3). Seeds probably were not buried deep enough nor adequately covered to avoid dessication. It was interesting to note that the crop sown by the farmer with hoe coulters into cultivated soil at Rangiotu had to be resown because of very poor plant establishment (Table 6). The data in Table 6 suggest that a deeper sowing depth or a better designed coulter may help avoid dessication by zero-cultivated seedlings. Research has shown that coulter type can cause a marked difference in seedling establishment in dry soil (Choudhary and Baker, 1980). Operator experience in adverse conditions (e.g. with regard to setting drill depths of sowing) is also likely to be important.

TABLE 6: Plant establishment (percentage of seeds sown in the farmer's paddock and on the trial areas, Rangiotu 1981/82.

Soil treatment	coulter	sowing depth	% establishment
Cultivated	hoe	25-50	30
Zero-Cultivated	double-disc	40-60	38
Cultivated	double-disc	50-100	92

In addition to the effect zero-cultivation had on plant establishment, small but consistent differences in crop yield occurred (Table 4) which can only have been caused by other factors affecting yield/plant or plant growth. Farmers cannot risk even small decreases in grain yield because of the relatively large effect if can have on crop profitability, so these secondary factors need to be identified. Inferences about what caused the yield decreases can be made from field observations, data on plant weights (Fig. 1), spectrometer analyses of leaves (Table 7), leaf water content, site histories (Table 1) and weather (Table 3). Broadly speaking, there are only five factors which influence plant growth i.e. supply of nutrients, supply of water, temperature, light, and presence or absence of inhibiting chemicals. These factors can be kept in mind when considering reasons for the poorer growth on zero-cultivated crops.

Figure 1: Percentage difference in wet weight of zero-cultivated maize plants from cultivated plants at Rangiotu and Aokautere, 1980/81 and 1981/82. Vertical lines represent SE's for each data point. Zero-cultivated plants at Karere were too sparse to obtain harvests.

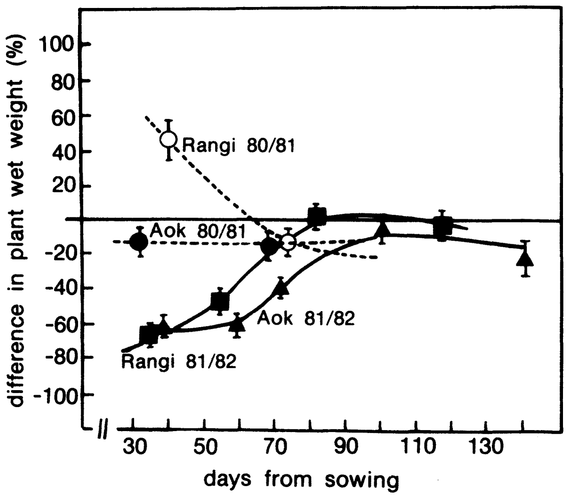

TABLE 7: Concentration of Ca, P and K in youngest maize leaf tissue from Aokautere 1981/82. S.E.s in brackets.

Treatment	Days from Sowing	Concentration (mg/g DM)		
		Ca	P	K
Cult.	59	4.8 (0.4)	3.6 (0.4)	28.7 (1.3)
Zero-cult.	59	4.2 (0.2)	3.3 (0.2)	29.8 (1.1)
Cult.	74	1.9 (0.3)	2.7 (0.2)	18.1 (0.3)
Zero-cult.	74	2.0 (0.4)	2.8 (0.4)	21.2 (0.8)

Weeds were not present to any great extent on either cultivated or zero-cultivated plots. Also MAF 'quick tests' on soil samples from each site and analysis of leaves at silking did not show any deficiencies in major elements in zero-cultivated treatments. Insect pests were also not observed to be a problem.

Zero-cultivated seedlings at Rangiotu 1980/81 were markedly larger in size (Fig. 1) than cultivated seedlings early in the season. However, the cultivated plants later caught up in size while the zero-cultivated plants became lighter green as though they were nitrogen deficient. It was possible that the urea side-dressed in December was left on the surface of the harder zero-cultivated soil and did not become available to the plants. If so, adding extra nitrogen before sowing or injecting urea solution between the rows in December may improve availability of the N. Baker and Afzal (1981) have observed that fertiliser placement has improved plant growth in their trials. It is difficult to explain why zero-cultivated plants were so much larger early in the season. Zero-cultivated seedlings at Rangiotu 1981/82 and Aokautere 1981/82 were markedly smaller than cultivated seedlings but had almost caught up in size by day 70 after sowing (Fig. 1). The crop at Aokautere 1981/82 was not side-dressed at sowing and seedlings were red-pigmented as though phosphate or nitrogen deficient. Table 7 suggests that a lower P concentration may have been present in zero-cultivated plants at day 59. Unfortunately samples taken earlier in the season and N samples were lost before being analysed. At day 74, when zero-cultivated plants were growing at a faster rate than cultivated plants (Fig. 1), a higher concentration of K in the zero cultivated plants is indicated by Table 7. The results suggest that a more detailed study integrating plant growth, root development and nutrient uptake may be useful. The lack of rainfall (Table 3) at Rangiotu 1981/82 may have caused a limiting water supply to zero-cultivated seedlings but measurements of leaf water content were inconclusive.

Many of the field observations can be explained if there is a tendency for zero-cultivated plant roots to extend more slowly than cultivated plant root systems and explore a smaller volume of soil. This advantage would decrease when the zero-cultivated plant roots developed enough to obtain nutrients and water from a sufficiently large volume of soil. The large differences in relative size (e.g. 70% at day 40, Fig. 1) when the plants were small, faded into relatively minor differences in size by the time the plants were 70-80 days old, the difference between treatments being equivalent to only a few days growth. Some of the differences in final grain yield may have been caused at a later stage in crop growth (e.g. at silking and at grain filling in January and February) when differing root distributions between cultivation systems may have interacted with supplies of water to the plants. However, nothing is presently known about what sort of root system is required to supply sufficient water to plants, i.e. in terms of rooting depth, root density or types of roots at a particular soil depth.

Further, more detailed experiments are required to evaluate relationships between root proliferation, nutrient and water supply to zero-cultivated seedlings and plants during silking and grain filling. Non-cultivated soil tends to be of higher strength which has been found to be the major cause of inhibited root growth in soils (Taylor 1971). Ascertaining how this affects final crop yields would appear to be one of the important questions facing users of zero-cultivation in New Zealand.

CONCLUSIONS

Maize grain yields were generally more variable on zero-cultivated plots than on cultivated plots. The primary cause of differences in yield was poorer plant establishment which appeared to be associated with a lack of aeration and high penetrometer resistance in grossly over-cultivated soil and by dessication in very dry soil. Seed dessication may have been avoided by sowing deeper or perhaps by drill design to give better soil coverage of seed, (Choudhary and Baker, 1981). Research into problems associated with seedling establishment and machinery design is currently being carried out in New Zealand at Massey University and Lincoln.

Secondary factors affecting crop yields in zero-cultivated soil were probably influencing root proliferation and nutrient and water supply to the plants. Further research needs to be done such as experiments to monitor relative rates of root extension and distribution within the soil profile, nutrient and water supply to plants and the effects of the interactions of these during crop growth on final crop yield. Research is also needed into ways of managing the problems e.g. side-dressing at sowing, methods of adding inter-row N fertiliser, avoiding unsuitable soil-types or poorly managed soils and irrigation.

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REFERENCES

Baker, C.J., Afzal, C.M. 1981. Some thoughts on fertiliser placement in direct-drilling. Proceedings 1981 Conservation Tillage Seminar, Monsanto, Christchurch.

Baker, C.J., Mai, T.V. 1982. Physical effects of direct-drilling equipment on undisturbed soils. V. Groove compaction and seedling root development. *N.Z. Journal of Agricultural Research 25:* 51-60.

Blevins, R.L., Doyle, C., Phillips, S.H., Phillips, R.E. 1971. Influence of no-tillage on soil moisture. *Agronomy Journal 63:* 593-596.

Campbell, B.D., 1981. Observations on seedling establishment of Parewa red clover. Proceedings 1981 Conservation Tillage Seminar, Monsanto, Christchurch.

Cannell, R.Q. 1981. Potential and problems of simplified cultivation and conservation tillage. *Outlook on Agriculture 10*: 379-384.

Charlton, J.F.L., Brock, J.L. 1980. Establishment of *Lotus pedunculatus* Cav. and *Trifolium repens* L. in newly developed hill country. *N.Z. Journal of Experimental Agriculture 8:* 243-248.

Choudhary, M.A., Baker, C.J. 1980. Physical effects of direct-drilling equipment on undisturbed soils. I. Wheat seedling emergence under controlled climates. *N.Z. Journal of Agricultural Research 23:* 189-195.

Choudhary, M.A., Baker, C.J. 1981. Physical effects of direct-drilling equipment on undisturbed soils 3. Wheat seedling emergence and in-groove micro-environment in a dry soil. *N.Z. Journal of Agricultural Science 24:* 189-195.

Cowie, J.D. 1978. Soils and agriculture of Kairanga county. Soil Bureau Bulletin 33, Department of Scientific and Industrial Research, Wellington.

Henry, J.E., Johnson, W.H. 1969. Corn germination efficiencies affected by soil pressure and temperature. *Transactions of American Society of Agricultural Engineers 12:* 141-144, 149.

Janson, C.J. 1979. The establishment of a long-term direct-drilling conventional cultivation comparison. *Proceedings Agronomy Society of N.Z. 9:* 35-36.

Jones, J.N., Moody, J.E., Shear, G.M., Moschler, W.W., Lillard, J.H. 1968. The no-tillage system for corn (*Zea mays* L.). *Agronony Journal 60:* 17-20.

Mock, J.J., Erbach, D.C. 1977. Influence of conservation-tillage environments on growth and productivity of corn. *Agronomy Journal 69:* 337-340.

McCormick, S.J., Mackay, A. 1973. An evaluation of the requirements of direct seeded maize in the Waikato. *Proceedings Agronomy Society of N.Z. 3:* 39-46.

Ross, C.W. 1981. Soil physical properties of some conservation tillage trials in the southern North Island Proceedings 1981 Conservation Tillage Seminar, Monsanto, Christchurch.

Shear, G.M., Moschler, W.W. 1969. Continuous corn by the no-tillage and conventional tillage methods: A six-year comparison. *Agronomy Journal 61:* 524-526.

Taylor, H.M. 1971. Soil conditions as they affect plant establishment, root development, and yield. *In* "Compaction in Agricultural Soils", W.M. Carleton (Chairman) American Society of Agricultural Engineers, St. Joseph, Michigan.

Triplett, G.B., Van Doren, D.M., Schmidt, B.L. 1968. Effect of corn (*Zea mays* L.) stover mulch on no-tillage corn yield and water infiltration. *Agronomy Journal 60:* 236-239.

Yortt, M.L. 1981. Conservation tillage development in the southern North Island. Proceedings 1981 Conservation Tillage Seminar, Monsanto, Christchurch.