

Yield and Nitrogen Content of Corn under Different Tillage Practices

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ABSTRACT

The objective of the study was to determine whether tillage and residue practices have a significant effect on the yield and N content of corn (*Zea mays* L.) under nonlimiting soil N conditions. Nitrate leaching has been identified as a source of non-point-source pollution. By identifying tillage practices which maximize corn N uptake, recommendations can be based on how to minimize N loss. A 2-year field study was conducted in southwestern Quebec on a 2.4-ha site of a Typic Endoaquent (Humic Gleysol) cropped to corn. Three types of tillage practice (conventional tillage, reduced tillage, and no-till) were combined with two residue levels (with and without) in a randomized complete block design. The effect of these practices on corn yield and corn N were studied. Seedling emergence rates in spring, and corn moisture content at harvest, were also monitored. Residues hindered initial plant emergence in the no-till plots. Corn N and moisture contents in 1996 and 1997 indicated that no-till with residue had a delayed maturity relative to the other treatments. However, total corn biomass and grain yields were not affected by tillage or residue treatments. No correlation between corn yield and corn N content was found.

CORN is the second most widely crop grown in Quebec and Ontario, and has been for the past 15 years (Statistics Canada, 1991, 1994; Bureau de la statistique du Québec, 1995). Today, emphasis is placed on conservation farming technologies, such as conservation tillage practices. There is a need for studies in Quebec to see how these practices influence crop yields and crop N uptake.

Conservation tillage practices are a viable option for increasing nutrient use efficiency by crops, since these practices retain residues after the crop has been harvested. Residues play a critical role in nutrient distribution and plant growth (White, 1984) and affect the amount of soil nutrients available to the crop (Bandel et al., 1975; Blevins et al., 1984; Dalal, 1989). Residues allow N to be plant available for longer periods of time, by initially immobilizing, and then gradually mineralizing, the N (Aulakh et al., 1991; Maskina et al., 1993; McKenney et al., 1995).

Grain N content and corn yield are often higher in no-till, because no-till crops are more efficient at removing soil N than conventionally tilled crops (Angle et al., 1993). In contrast, Olson and Kurtz (1982) found more N deficiency symptoms in corn with no-till than with conventional tillage. One of the drawbacks of incorporating residues, especially those with high C:N ratios, is the immobilization of nutrients (especially N) by residues.

Furthermore, tillage practices cause soil disturbance, which may contribute to a decline in available soil N (Stevenson, 1965; McCarthy et al., 1995) due to mineralization of organic matter, which is vulnerable to oxidation.

Soil N content is affected by tillage and residue practices, which subsequently influence crop N concentrations. Changes in crop N may influence yield and plant growth. This study examines corn grain and stover N content after harvest, and corn yield, as influenced by three tillage practices (conventional tillage, reduced tillage, and no-till) in combination with two residue levels (with residue and without). Our objectives were to (i) assess the effects of tillage practices on corn N content at the end of the growing season, (ii) determine if corn yields are affected by different tillage and residue practices, and (iii) determine if higher corn N contents lead to greater corn yields.

MATERIALS AND METHODS

A field experiment was conducted on a 2.4-ha area of loamy sand or sandy loam (mean thickness of 28 cm) overlying marine clay (mean thickness 18 cm) on the Macdonald Campus Research Farm in southwestern Quebec. The soil was of the St. Amable and Courval series (Typic Endoaquent; Humic Gleysol) with a slope of <1%. The tillage practices for the study were implemented in May 1991; the site was cultivated, limed (6–8 Mg ha⁻¹), and planted to corn (*Zea mays* L.). In the year prior to the initiation of the study, the site was planted with alfalfa (*Medicago sativa* L.), which was plowed under in early May 1991. Each plot had a subsurface drain (mean depth 1.2 m) in the center, and was separated by a 2-m grass buffer strip. Data reported in this study were collected from May 1996 through November 1997.

The experimental design was established in May 1991 and consisted of a factorial arrangement of three tillage and two residue levels. The site layout consisted of three blocks, each containing six plots (each measuring approximately 15 by 80 m), assigned in a randomized complete block design. The treatments were conventional tillage with residue (CT+R) and no residue (CT–R); reduced tillage with residue (RT+R) and no residue (RT–R); and no-till with residue (NT+R) and no residue (NT–R). Nitrogen fertilizer was applied at a nonlimiting rate as recommended by the Association des fabricants d'engrais du Québec (1990), for a projected yield of 6.5 Mg ha⁻¹ dry matter.

Corn (Funk 4120 hybrid) was planted with a modified John Deere planter (7100 MaxEmerge integral, double-disk seed opener) at a density of 76 000 seeds ha⁻¹. At seeding, 40 kg N ha⁻¹ was applied as (NH₄)₂HPO₄ (diammonium phosphate; 18–46–0 N–P–K), banded 5 cm beside and 5 cm below the seed. Three weeks after planting, 140 kg N ha⁻¹ and 58 kg K ha⁻¹ were applied as a urea–KCl mixture (26–0–13) in 1996, and as NH₄NO₃ and KCl (26–0–13) in 1997. The timing and dates of herbicide applications are shown in Table 1. The NT

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Table 1. Timing of field operations at the McGill University Macdonald Campus Research Farm, Quebec.

Operation	1996	1997	Description†
Spring cultivating	13 May	22 May	CT and RT plots disked 10–15 cm with a 2.5-m-wide Massey Ferguson. Funk 4120 hybrid, 76 000 plants ha ⁻¹ , 0.76-m rows; modified John Deere no-till planter (7100 MaxEmerge integral).
Planting	14 May	26 May	
Spraying: preemergence	21 May	—‡	<i>No-till plots only:</i> 2.5 L ha ⁻¹ glyphosate, 0.8 L ha ⁻¹ octylphenoxy-polyethoxy ethanol. 2.75 L ha ⁻¹ metolachlor, 3 L ha ⁻¹ atrazine. <i>No-till plots only:</i> 4 L ha ⁻¹ glyphosate.
	—	27 May	
Spraying: postemergence	29 May	—	1.25 L ha ⁻¹ dicamba + 2.5 L ha ⁻¹ atrazine.
	—	17 June	<i>All plots:</i> 2.2 L ha ⁻¹ bentazon + surfactant.
	25 June	—	<i>Block 1 only:</i> 2.25 L ha ⁻¹ bentazon + surfactant.
Fertilizer application	13 May	26 May	40 kg N ha ⁻¹ as (NH ₄) ₂ HPO ₄ (18–46–0 N–P–K) applied in band with seeding, P ₂ O ₅ 100 kg ha ⁻¹ .
	3 June	—	140 kg N ha ⁻¹ as a urea–KCl mix 26–0–13 incorporated between rows 5–10 cm deep into wheel tracks with a double-disk opener.
	—	12 June	140 kg N ha ⁻¹ as NH ₄ NO ₃ and KCl mix (26–0–13 N–P–K).
	18 June	9 June	83 kg ha ⁻¹ K ₂ O as muriate of potash (0–0–60 N–P–K).
Hand harvest	7 Oct.	16 Oct.	1-row New Holland 707 silage harvester.
Harvest: grain plots	25 Oct.	20 Oct.	8-row (6-row in 1997) John Deere combine.
Harvest: silage plots	25 Oct.	5 Nov.	2-row New Holland 890 harvester.
Fall cultivating	4 Nov.	—	CT plots moldboard plowed 20 cm deep with Kongskilde 20 series. RT plots disked 10–15 cm with a 2.5-m-wide Massey Ferguson.

† Chemical names: atrazine, 6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine; bentazon, 3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide; dicamba, 3,6-dichloro-2-methoxybenzoic acid; glyphosate, *N*-(phosphonomethyl)glycine; metolachlor, 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide.

‡ Blanks: not applicable.

plots were not tilled at any time; the RT plots were disked to a depth of 10 cm in spring (before planting) and in fall (after harvest) with an offset disk; the CT plots were disked to 10 cm with an offset disk before planting, and moldboard plowed to a depth of 20 cm after harvest. At harvest, the grain in the residue plots was removed with an eight-row John Deere combine, and the residues (cobs, leaves, and stalks) were chopped. The residues were left on the surface (NT treatment), or partially incorporated by disking (RT), or completely buried by the moldboard plow (CT). The no-residue (–R) plots had the whole plant (grain, cob, leaves, and stalk) removed at harvest with a two-row New Holland 890 harvester.

Soil Data Collection

Organic matter was measured in the spring and fall of each season, and once in August 1996, using the Walkley–Black method (Nelson and Sommers, 1982). Soil organic matter was calculated by multiplying the amount of carbon obtained from the titrations by a conversion factor of 1.724.

Soil strength was measured in 1996 on 9 May, 1 July, 10 August, and 28 October, using a static cone penetrometer (Bradford, 1986), with readings taken at 10-, 20-, and 30-cm depths.

Crop Data Collection

In both 1996 and 1997, counts of emerging seedlings were made in 2-m-long sections of 10 randomly selected rows in each plot, at 2 wk and at 3 to 4 wk after seeding.

Grain yields in 1996 and 1997 were determined from six randomly selected 2.5-m-long sections of rows in each plot, by hand-harvesting. The sampled stalks and grain were weighed, dried in a forced-draft oven at 70°C for at least 48 h, and reweighed to determine the moisture content.

During the growing seasons, corn N readings were obtained by following the same procedure as Dwyer et al. (1994); using a portable leaf chlorophyll meter (SPAD Model 502, Minolta Corp.) and taking measurements from the upper most fully extended leaf. After silking, the leaf at the base of the cob ear was measured. The SPAD readings were converted to total leaf N (g kg⁻¹) by using the following regression equations from Dwyer et al. (1994): $y = 0.708 + 0.0184x + 0.0004x^2$ before silking and $y = 0.708 + 0.00898x + 0.0004x^2$ after

silking, where y is leaf N (g kg⁻¹ dry wt. basis) and x is SPAD 502 reading.

At harvest, subsamples of the chopped stalks and the grain were tested for total Kjeldahl N content by using a standard Kjeldahl procedure (Bradstreet, 1965). Subsamples of the oven-dried (70°C) grain and stover were ground using a Wiley mill. Kjeldahl analysis was carried out on 0.5 g of grain and stover samples.

The residual crop biomass was measured before and after fall tillage in 1996. Using 1-m² quadrats and a knife, the amount of aboveground residue was measured at three locations in each plot by collecting and cutting all standing stubble at the ground level. The residue was washed, oven-dried (70°C), and weighed.

Statistical Analyses

The data were analyzed using the general linear model (GLM) procedure of the Statistical Analysis System, SAS (SAS Inst., Cary, NC) to perform analyses of variance, means separations using *t*-tests (unprotected LSD), and selected correlations. All analyses used plot means rather than subsample values. A probability level of $P \leq 0.05$ was considered significant.

RESULTS AND DISCUSSION

There were 476 mm of precipitation during the 1996 growing season, which was slightly under the long-term normal (499 mm), while the 1997 growing season received more precipitation (563 mm) than normal. There was little variation in seasonal temperatures between the two years (Table 2).

Soil Data

The effects of the treatments on soil properties over the study period are presented in the form of soil organic matter and cone penetrometer data. In fall 1997, soil organic matter differences were apparent at 0 to 15 cm; NT–R had less organic matter than all other treatments, and NT+R had significantly higher organic matter (Table 3). The no-till treatments were the only treatments to

Table 2. Meteorological conditions for 1996 and 1997 growing seasons.[†]

Period	Total precipitation			Mean monthly temperature		
	1996	1997	Norm [‡]	1996	1997	Norm [‡]
	mm			°C		
Apr.	177.8	96.9	74.8	5	4.8	5.7
May	92.0	76.0	68.3	12.3	10.7	12.9
June	65.5	104.5	82.5	18.6	20.1	18.0
July	106.0	135.0	85.6	20.2	20.6	20.8
Aug.	22.5	106.4	100.3	20.4	19.0	19.4
Sept.	115.1	91.5	86.5	16.3	14.6	14.5
Oct.	74.5	49.3	75.4	8.1	8.0	8.3
May–Oct.	475.6	562.7	498.6	16.0	15.5	15.7

[†] Montreal International Airport, located 20 km east of the field site (monthly meteorological summaries; Environment Canada, 1996, 1997).

[‡] Long-term average: 1961–1990.

have no residue incorporated (Fig. 1); the aboveground residue in the NT–R plots stems from the stubble (approximately 15 cm high) that was left after the fall harvest. Residues decompose much more rapidly when incorporated than when left on the soil surface and, since organic matter takes several years to accumulate, it may be only after 6 years, under these soil conditions, that the treatment differences become apparent.

On 9 May 1996 (before planting), cone penetrometer readings showed NT treatments (both with and without residue) to have significantly greater soil strength than other treatments at 0 to 10 cm (Table 4), most likely due to the lack of tillage which breaks up and loosens the soil. Vyn and Raimbault (1993) obtained similar results in their study.

Corn Emergence Rate

The presence of a residue cover hindered the emergence of corn seedlings in all treatments with residue, especially at 2 wk after planting (Table 5). The emerging corn shoots were not strong enough to push through the surface residues. Treatments without a residue cover were the fastest to emerge with the greatest number of plants emerging 2 and 3 wk of seeding in 1996 (NT–R and RT–R), and 2 wk after seeding in 1997 (RT–R). The treatments with the greatest amount of residue cover was NT+R (Fig. 1), which consequently had the greatest delay in seedlings emerging 2 or 3 wk after seeding in 1996, and 2 wk after seeding in 1997 (Table 5). The greater soil compaction measured with the cone penetrometer in the no-till treatments may have contributed to the delayed seedling emergence in NT+R.

Despite lower seedling emergence 2 wk after planting in 1997, NT treatments had significantly higher amounts of seedling emergence at 4 wk after the planting date, showing that, despite initial slower growth rates, corn in NT+R had the ability to compensate for lower emergence rates. This may have been related to climatic factors, as rainfall was less (yet still above the normal) in May 1997 than in May 1996. No-till yields have been observed to be greater than in traditionally plowed soils when precipitation is limiting; however, in southwestern Quebec precipitation is not a limiting factor.

Table 3. Soil organic matter (g kg⁻¹) at the 0- to 50-cm depth and significant treatment effects.

Treatment [†]	Organic matter, 0–15 cm						Organic matter, 15–25 cm						Organic matter, 25–50 cm					
	Spring 1996	August 1996 [‡]	Fall 1996	Spring 1997	Fall 1997		Spring 1996	August 1996 [‡]	Fall 1996	Spring 1997	Fall 1997		Spring 1996	August 1996 [‡]	Fall 1996	Spring 1997	Fall 1997	
	g kg ⁻¹						g kg ⁻¹						g kg ⁻¹					
NT+R	7.0a§	40.7a	34.6a	45.2a	44.3a		14.5a	42.9a	34.3a	36.6a	37.5a		23.1a	25.7a	13.4a	11.3a	34.4a	
RT+R	5.1a	35.7a	30.8a	41.5a	36.0ab		4.5a	39.4a	20.9a	31.5a	30.2a		25.2a	27.1a	5.7a	15.6a	9.7a	
CT+R	6.8a	37.2a	37.4a	40.0a	37.8ab		9.2a	34.8a	19.4a	41.9a	33.0a		25.4a	24.9a	5.77a	14.5a	16.9a	
NT–R	7.3a	36.8a	33.2a	42.1a	32.1b		4.7a	39.1a	26.9a	23.5a	29.2a		25.2a	26.0a	11.3a	18.8a	12.7a	
RT–R	4.2a	35.5a	41.6a	42.7a	37.5ab		4.4a	33.8a	21.9a	36.1a	32.7a		23.3a	25.0a	18.9a	13.5a	18.1a	
CT–R	13.5a	36.5a	35.9a	39.0a	35.7ab		12.3a	38.1a	40.7a	36.3a	3.61a		22.2a	20.5a	12.8a	14.1a	28.3a	
Effect						<i>P</i> > <i>F</i>												
Block	0.136	0.113	0.295	0.591	0.055¶		0.531	0.007*	0.058¶	0.530	0.262		0.245	0.088¶	0.196	0.520	0.562	
Tillage	0.0945¶	0.6558	0.8152	0.5126	0.7426		0.3179	0.2712	0.1866	0.3330	0.5346		0.9944	0.8824	0.7411	0.9620	0.7135	
Residue	0.2828	0.5689	0.5441	0.7501	0.0341*		0.5252	0.4192	0.4761	0.3582	0.9366		0.7952	0.7424	0.1454	0.8361	0.5056	
Till × Res	0.2326	0.8337	0.4249	0.8282	0.0248*		0.3172	0.3329	0.0724¶	0.3401	0.1893		0.8392	0.9520	0.2992	0.5861	0.1590	
CV, %	52.98	15.80	21.17	14.60	9.97		87.32	13.62	35.83	29.07	15.25		33.19	52.57	65.36	69.17	79.92	
Mean	0.73	3.71	3.52	4.18	3.72		0.83	3.80	2.77	3.43	3.29		2.41	2.48	1.08	1.46	2.00	

* Significant at the 0.05 probability level.

† CT, conventional till; NT, no-till; RT, reduced till; +R, with residue; –R, no residue; Till, tillage; Res = residue.

‡ August 1996 depths correspond to 0–10, 10–20, and 20–30 cm, respectively.

§ Within columns, means followed by the same letter are not statistically different (unprotected LSD, *P* ≤ 0.05).

¶ Significant at the 0.10 probability level.

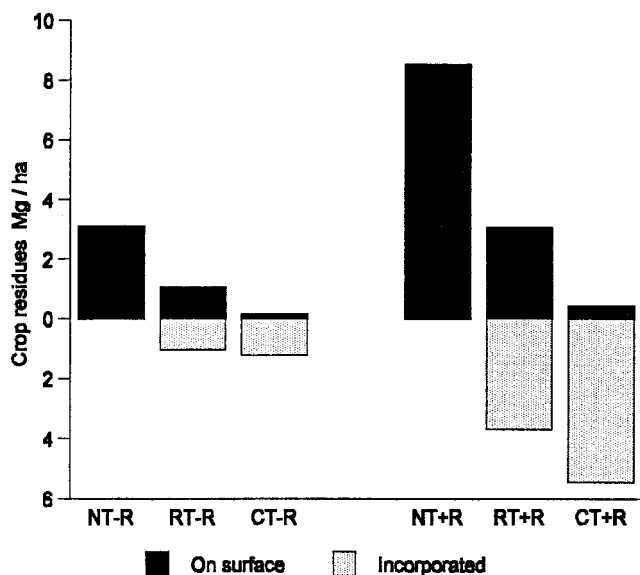


Fig. 1. Corn residue (stalks and leaves) incorporation after 1996 harvest for different treatments through cultivation (biomass incorporated does not include corn roots).

Corn Moisture at Harvest

The moisture of the corn at the time of harvest is an indicator of the corn maturity and grain quality. Corn water content was measured to note differences between treatments, and the effects of tillage practices on the properties of the corn plant. The highest grain and stover water contents at harvest were consistently found in NT+R (Table 6), perhaps due to the delayed maturity as the seedling emergence data seems to indicate. No-till soils are more compact, have fewer finer pores, and are less prone to water loss through evaporation (Dalal, 1989; House et al., 1984). In addition, the presence of residue significantly increases the soil water content (White, 1984; Aase and Tanaka, 1987). In 1997, there were significantly higher stover water contents in the residue plots than the no-residue plots. In 1996 and 1997, grain water contents were higher in the residue plots than the no-residue plots (Table 6).

Tillage practices also significantly affected grain water content every year. Higher grain water contents were noticed in NT than in RT, and RT had higher grain water contents than CT. In soil under CT, pores are less continuous, and there are fewer larger-diameter pores (Blevins et al., 1984; Logsdon et al., 1990; Granov-

Table 4. Soil strength before planting, as measured by cone penetrometer readings on 9 May 1996.

Treatment†	Cone penetrometer reading		
	0–10 cm	10–20 cm	20–30 cm
	kPa		
NT+R	709b‡	999ab	1543a
RT+R	428c	1153ab	1450a
CT+R	201c	644c	1268a
NT–R	939a	1245a	2240a
RT–R	317c	902b	1626a
CT–R	220c	516c	2048a

† CT, conventional tillage; NT, no-till; RT, reduced tillage; –R, no crop residue; +R, with crop residue.

‡ Within columns, means followed by the same letter are not significantly different (SNK test).

Table 5. Corn seedling emergence in two years as influenced by tillage and residue treatments.

Treatment†	Emergence (1996)		Emergence (1997)	
	2 wk post-plant	3 wk post-plant	2 wk post-plant	4 wk post-plant
	%			
NT+R	46d‡	55c	55b	62a
RT+R	58bc	57bc	60a	59abc
CT+R	56c	61ab	60ab	58bc
NT–R	66a	61ab	63a	61ab
RT–R	63ab	61a	64a	60abc
CT–R	58bc	60ab	61a	57c
Effect	<i>P</i> > <i>F</i>			
Block	0.3992	0.1674	0.4452	0.2292
Tillage	0.0655	0.3166	0.1802	0.0290*
Residue	0.0010**	0.0180*	0.0117*	0.8554
Till × Res	0.0006**	0.0916*	0.2573	0.6630
CV, %	4.9	3.9	5.2	4.2
Mean	58	59	61	59

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

† CT, conventional tillage; NT, no-till; RT, reduced tillage; –R, no crop residue; +R, with crop residue.

‡ Within columns, means followed by the same letter are not significantly different (unprotected LSD, *P* ≤ 0.05).

sky et al., 1993; Drees et al., 1994). Capillary rise and surface evaporation were, therefore, more likely to take place in CT, leaving the soil drier than in NT or RT treatments.

Stover water contents in 1997 were also affected by the different tillage treatments. Reduced tillage plots had the least stover water content at harvest, followed by conventional tillage, and finally no-till treatments. Reasons for reduced tillage treatments having lower stalk water content than conventional tillage are not clear.

Corn Yields

In general, grain yields were found to decrease from 1996 to 1997 (Table 7), which was probably associated with the higher grain moisture contents in 1997 (Table 6), in that corn with a higher water content is more difficult for the harvesting machinery to remove from

Table 6. Moisture content of grain and stover (dry basis) at harvest in fall 1996 and fall 1997.

Treatment†	Water content (1996)		Water content (1997)	
	Grain	Stover	Grain	Stover
	g g ⁻¹			
NT+R	0.42a‡	1.25a	0.71a	1.46a
RT+R	0.30b	1.10ab	0.57b	1.40a
CT+R	0.25c	0.96b	0.56b	1.42a
NT–R	0.27bc	1.06ab	0.53b	1.43a
RT–R	0.30b	1.00ab	0.52b	1.22b
CT–R	0.27bc	0.96b	0.55b	1.37a
Effect	<i>P</i> > <i>F</i>			
Block	0.1280	0.1573	0.1437	0.0103*
Tillage	0.0003**	0.1075	0.0284*	0.0056**
Residue	0.0027**	0.1881	0.0210*	0.0072**
Till × Res	0.0001**	0.5323	0.0228*	0.0630*
CV, %	7.6	13.5	9.1	3.9
Mean	29.8	105.3	56.6	138.5

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

† CT, conventional tillage; RT, reduced tillage; NT, no-till; –R, no crop residue; +R, with crop residue.

‡ Within columns, means followed by the same letter are not significantly different (unprotected LSD, *P* ≤ 0.05).

Table 7. Dry matter yield (zero moisture) for grain and stover in fall 1996 and fall 1997.

Treatment†	Grain		Stover		Total yield	
	1996	1997	1996	1997	1996	1997
	Mg ha ⁻¹					
NT+R	10.0a‡	7.6a	6.6a	5.8ab	16.6a	13.4a
RT+R	8.5b	8.1a	5.9a	5.3b	14.4a	13.4a
CT+R	9.1ab	8.3a	6.3a	5.9ab	15.4a	14.2a
NT-R	8.9ab	8.4a	6.3a	6.5a	15.2a	14.9a
RT-R	9.1ab	8.0a	6.7a	5.6b	15.7a	13.6a
CT-R	9.6ab	7.3a	6.7a	5.9ab	16.3a	13.2a
Effect	<i>P</i> > <i>F</i>					
Block	0.0647	0.0252*	0.3532	0.0022**	0.1336	0.0036**
Tillage	0.3054	0.9248	0.8387	0.0669	0.3495	0.1491
Residue	0.9657	0.8394	0.4103	0.1785	0.1655	0.1975
Till × Res	0.1091	0.3996	0.5463	0.4262	0.1823	0.1324
CV, %	7.8	13.2	11.6	7.9	8.7	9.5
Mean	9.2	7.9	6.4	5.8	15.6	13.8

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

† CT, conventional tillage; RT, reduced tillage; NT, no-till; -R, no crop residue; +R, with crop residue.

‡ Within columns, means followed by the same letter are not significantly different (unprotected LSD, *P* ≤ 0.05).

the cob. Due to the demand for harvesting equipment, the window for harvesting corn at the site in 1997 was very narrow; as a result, the corn was probably harvested too early (20 Oct.) for the region—and yet the N content indicated all treatments to have reached maturity (see next section). Nevertheless, no treatment differences were found in grain yields for any year, as a result of sufficient precipitation in both years. In a moderate to average rainfall year, NT can produce much higher yields (Taylor et al., 1984).

Although no treatment differences were observed for total yields either, the yields in NT-R, RT-R, CT-R, and CT+R declined from 1996 to 1997 (Table 7). Other researchers have observed yield differences with tillage practices (Angle et al., 1993; Beri et al., 1995; Mataruka et al., 1993; Taylor et al., 1984; Vyn and Raimbault, 1993). Yield differences are usually attributed to differences in soil properties that affect crop growth. In temperate climate, soils do not require modifications such as irrigation or drainage to enhance yields during the growing season. Therefore, tillage and residue practices that modify soil properties in favor of crop growth do not necessarily produce higher yields in southern Quebec during seasons of sufficient precipitation and fertilization.

Grain and Stover Nitrogen

From 1996 SPAD readings (Fig. 2), it was observed that NT+R had significantly lower leaf N concentrations on 11 July and on 17 July, indicating a delayed maturity. On 11 July, the NT+R corn contained 23 g N kg⁻¹, compared with 27 g N kg⁻¹ in all other treatments. On 17 July, the NT+R corn had 25 g N kg⁻¹, compared with 28 g N kg⁻¹ in CT-R, and 27 g N kg⁻¹ in the other treatments. Furthermore, on 22 July, it was observed that none of the corn plants in the NT+R treatments had silked, whereas all the other treatments had at least 46% of the corn population at the silking stage (data not shown). These findings are comparable to those of Jones and Eck (1973), who found the critical N content of the ear leaf at silking to be 27 to 35 g kg⁻¹.

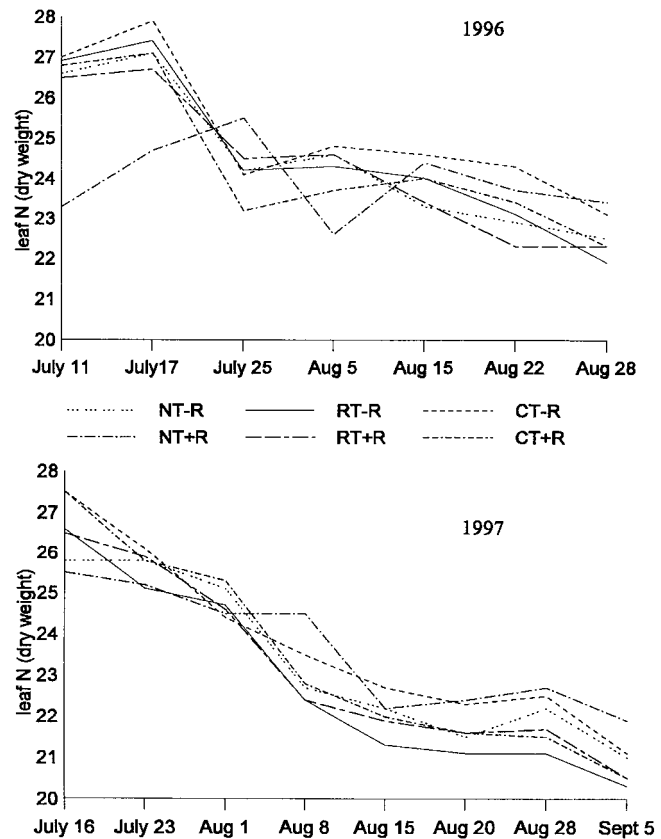


Fig. 2. Weekly corn leaf N concentrations (g kg⁻¹) for 1996 and 1997, measured with a SPAD meter, converted to N using equations by Dwyer et al. (1994).

In 1997, silking in all treatments, except in NT+R, occurred on 8 August (data not shown). However, not on any of the days when SPAD leaf N was measured was a significant treatment difference found in 1997.

The grain N content in all treatments, as measured with the Kjeldahl method, at the time of harvest was between 10 and 25 g kg⁻¹ (Table 8), which corresponds to the grain content at maturity (Jones and Eck, 1973). Despite higher water content in the grain and stover of

Table 8. Corn tissue N for grain and stover in fall 1996 and fall 1997.

Treatment†	Tissue N (1996)		Tissue N (1997)	
	Grain	Stover	Grain	Stover
	g kg ⁻¹			
NT+R	11.3a‡	6.0a	14.6a	87.7a
RT+R	11.4a	5.6a	15.2a	85.1ab
CT+R	11.6a	5.5a	15.3a	79.5ab
NT-R	11.7a	6.0a	15.8a	82.7ab
RT-R	11.3a	5.7a	15.1a	79.8ab
CT-R	11.3a	5.4a	15.1a	77.2b
Effect	<i>P</i> > <i>F</i>			
Block	0.3592	0.5153	0.4939	0.1700
Tillage	0.7287	0.1730	0.9968	0.1623
Residue	0.8837	0.8476	0.3919	0.2161
Till × Res	0.2192	0.9151	0.3030	0.8978
CV, %	2.9	7.6	5.2	6.9
Mean	1.14	0.58	1.52	0.82

† CT, conventional tillage; RT, reduced tillage; NT, no-till; -R, no crop residue; +R, with crop residue.

‡ Within columns, means followed by the same letter are not significantly different (unprotected LSD, *P* ≤ 0.05).

NT+R, as well as in the residue treatments, the corn appeared to be harvested at its biochemical maturity.

Pearson correlations were carried out to determine if the N content of the grain or the stover at the time of harvest was related to the yields obtained during the growing season. The N content of the grain or stover was not related to grain yields, or stover yields, respectively.

CONCLUSIONS

A residue cover may delay corn emergence rates up to 4 wk after seeding. Although NT+R initially had slower emergence rates, its emergence rates were higher than other treatments 4 wk after seeding. The increased emergence rate of NT+R corn seedlings 4 wk after seeding in 1997, as well as the high stover yields obtained in NT+R in 1997, showed that no-till corn has the potential to reach the same yields as conventional or reduced tillage.

The delayed emergence may, however, have caused the no-till treatments to have greater grain and stover water content at harvest. Treatments with residue also had increased water content in the grain and in the stover, which indicates that grain corn should be harvested somewhat later than silage corn.

Under conditions of nonlimiting soil N and sufficient precipitation, corn yield (grain yield as well as total yield) and corn N were not affected by tillage or residue treatments. Furthermore, yields were not related to corn N concentration.

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