TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFICIENCY OF RESIDUE MANAGEMENT FOR PROVIDING OPTIMAL CORN GROWING CONDITIONS IN A NON-TILLED SANDY LOAM

FINAL REPORT

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EXECUTIVE SUMMARY

No-till corn production is a soil conserving system that presents several challenges in terms of crop performance. The presence of crop residues on the soil surface results in many changes of physical, chemical and biological nature. These changes concern mainly soil temperature but also, soil water content, nutrient availability and phytotoxicity. In order to distinguish between residue effects on corn due to low soil temperatures fromother residue effects, corn development was related to soil temperature for eight different types of residue covers: grain corn, spring canola, spring barley, spring barley and red clover killed early or killed late, soybean, soybean and fall rye killed early or killed late. Analysis shows that only corn plants growing in canola residues may have been delayed by a factor other than soil temperature.

The changes in soil temperature result almost invariably in delaying development of a corn crop when residue-covered soil is compared to a bare soil. The objective of another study was to determine if clearing the residues off the row in the interrow could alleviate the problem and improve the water status of a droughty soil. This management study showed that half of the delay (5 days) due to the presence of residues on the no-till plots could be avoided by clearing the residues off the row. This practice did not have much effect on water content when the plants had attained a large size. Two hybrids previously rated well and less-well suited for no-till production in 1988 in Huron county were used in the study. The hybrid rated less-well suited for no-till production yielded more grain per plant than the other hybrid. These hybrids

were also used in another study designed to address the problem of uneven plant emergence and final establishment in no-till corn production. This problem is due to changes in surface properties of no-till compared to conventional tillage. There was a need to measure the variability of emergence and try to correlate it to some selected soil properties. The soil properties studied were soil water content, bulk density and seed depth. Bulk density was negatively correlated to emergence in conventional plots and water content was negatively correlated to emergence in no-till plots. The emergence of the hybrid rated less well-suited for no-till production in 1988 was less variable and less sensitive to seed zone environmental conditions than that of the hybrid rated well-suited for no-till production.

PART I. Effects of residue management on corn development, growth, yield and soil water content for two hybrids adapted to southwestern Ontario

ASTRACT

A major problem related to no-till corn production is the slow development of the crop in spring. By mid-summer no-till plants can be delayed by several days compared to plants having emerged on the same day, but growing on conventionally-tilled land. The objective of this study was to determine if residue management could alleviate the problem as well as improve the soil water status of a droughty, sandy soil. Two hybrids previously rated as well-suited and less well-suited for no-tillage production in Huron county were used. The residue management treatments consisted of a first-year no-till with corn residues either left untouched, removed from the row, or removed from the entire plot and, a spring-plowed treatment. Development of corn grown in the no-till plots with residues removed from the row was intermediate between that of the no-till treatment with residues untouched and that of the spring-plowed treatment. The developmental delay of corn grown in plots with residue removed from the row was half of the delay of plants grown in plots with residues left untouched. Growth (measured as height) in all no-till treatments was as good or better than in the conventional treatment. Soil water content differences among residue management treatments were limited both in the row and in the interrow. The hybrid previously rated less suited for no-till production in Huron county produced more grain per plant in the no-till treatment than the other hybrid.

INTRODUCTION

Reduced tillage systems minimize soil erosion and run-off problems, encourage build-up of organic matter and improve resistance to compaction and crusting through greater aggregate stability. However, there are problems related to the adoption of such tillage practices involving uneveness of emergence and stand establishment (Al-Darby and Lowery, 1987; Mock and Erbach, 1977), inadequate weed control (Phillips and Phillips, 1984) and slow development of the crop (Fortin and Pierce, 1990) when compared to conventional tillage.

The goals of this study were to 1) determine whether residue management such as the removal of the residues in the row could increase the rate of development of corn, 2) determine whether the presence of residues in the soil would improve the water status of a sandy soil, and 3) determine whether two hybrids rated in Huron County in 1988 as well and less well-suited for no-tillage practices (pers. comm., B. Shillinglaw) would perform similarly for a second year in a different location. The residue management treatments consisted of a conventional tillage treatment and three first-year no-till treatments with previous year's corn residues left untouched, completely removed or removed 15 cm on each side of the row.

METHODS

Field experiments were conducted in Harrow on a site cropped to conventionally-tilled corn for several years by Mr. Bernard Calhoun on a Harrow sandy loam. Four tillage treatments and two genotypes were used in a factorial experiment arranged in a randomized complete block design with four replications. Previous year's corn was left standing in fall 1989, chopped in spring 1990 and treatments were established as follows in spring 1990: 1) a first-year no-till treatment (NT); 2) a spring-plowed conventional treatment (C); 3) a first-year no-till treatment with residues cleared on each side (15 cm) of the row and pushed manually in the interrow, simulating the use of trash whippers on a planter (TW); 4) a first-year bare no-till treatment where all residues were manually removed from the plot (B).

Corn was planted using a no-till planter at 66,000 plants ha^{-1} on 10 May 1990. Two hybrids were used: Pioneer 3790 (2850 H.U.) and Pioneer 3902 (2650 H.U.). Starter fertilizer was applied through the planter at a rate of 7,25 and 25 kg ha^{-1} for N, P, K, respectively, and was followed by a broadcast N application of 168 kg ha^{-1} as ammonium nitrate.

Twenty consecutive plants in each plot were marked at the beginning of the growing season and observed during vegetative growth as a representative sample for the date at which 50% of the plot would reach the following stages: emergence of first leaf, 4th, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 14th, 16th leaf, tasselling and finally silking. Height measurements were taken at selected times. Plants were harvested at maturity for vegetative and grain yield.

Soil temperature were measured hourly at the seeding depth in each treatment of one of the replicates. Air temperature was also recorded. Soil water content was monitored regularly using time domain reflectrometry at the 15 cm depth until June 7 and, at the 30 cm depth from June 7 to June 27 on each tillage treatment of the four replicates.

RESULTS AND DISCUSSION

The emergence of corn was affected by residue management treatments but not by the type of hybrids used. 50% emergence was achieved on 24 May for the bare (B) and on 25 May for the other treatments. The removal of residues along the row (TW treatment) did not result in an earlier date of emergence as compared to the no-till (NT) treatment but the complete removal of residues in the B treatment did accelerate 50% emergence by one day. The number of plants emerged was significantly different among treatments on two days only during the period of time when emergence and establishment were monitored i.e. May 10 to June 13. On 24 May, the B treatment had significantly more plants than the NT and TW treatments. On 25 May, the B treatment had significantly more plants than the NT treatment only (Fig. 1).

Subsequent developmental stages were monitored from emergence of leaf 4 to silking. Developmental stages were attained on different dates. Differences among tillage treatments were significant at all stages while differences between hybrids were significant ($p<.10$) from leaf 10 to silking (Table 1). There was no interaction between tillage and hybrid treatments. In general, the bare treatment reached specific stages first, followed by the conventional, the trash whipper and finally, the no-till treatment (Table 1). The maximum delays between the no-till and the other treatments were observed at leaf 11 stage: 5.2 days delay compared to the B treatment; 4.7 days delay compared to the conventional (C) treatment, and 2.5 days delay compared to the TW treatment.

Since the C, TW and NT treatments reached 50% emergence on the same day, direct comparisons can be made among these treatments for subsequent emergence of leaves. From the leaf 11 stage data mentioned above, it appears that the removal of residues along the row (TW) reduced the delay due to no-till by half compared to the conventional treatment: 2.5 instead of 4.7 days delay. The soil and air temperature data allow us to calculate the number of degree-days ([0.5(min+max)]-10) required for the plants to reach specific stages. There was no significant difference among tillage treatments (Table 2). This implies that the different rates of development of the residue management treatments were due to soil temperature differences among treatments. Soil temperature differences among tillage treatments for a typical 24-hour period are shown in Fig. 2. The removal of residues along the row increased seed zone temperature relative to the no-till treatment but not enough to equal seed zone temperature in the conventional treatment.

As mentioned above, developmental differences were consistently observed between hybrids from leaf 10 to silking in all residue management treatments (Table 1). The absence of interaction with residue management treatments indicates that this is purely a genotypic effect. Pioneer 3902 developed faster than Pioneer 3790. This is expected since Pioneer 3902 is an earlier maturity hybrid than Pioneer 3790. The maximum difference between the two hybrids was noted when Pioneer 3902 reached tasselling 3.6 days earlier than Pioneer 3790.

These differences in development among residue management treatments (maximum difference at leaf 11) and hybrids (maximum difference at tasselling) did not result in many differences in height of the plants measured at specific stages during the period of leaf 11 to the end of the vegetative period. Growth of the plants in the no-till treatments was similar or better than the conventional treatment in all cases (Table 3).

There were significant differences between hybrids and tillage treatments in vegetative and grain yields at the end of the season (Table 4). The later maturity hybrid, Pioneer 3790, produced 46 and 28% more vegetative biomass than the early hybrid Pioneer 3902 when grown in the treatments without residue B and C, respectively. However, the early maturity hybrid, Pioneer 3902 produced significantly more grain than the late maturing hybrid, Pioneer 3790 in the NT treatment. Therefore, under the conditions of 1990 at Harrow, the early maturity hybrid was better suited for no-till conditions.

The higher vegetative biomass of Pioneer 3790 as compared to Pioneer 3902 in the treatments without residues (B and C) may imply that slower plant development allowed this hybrid to take advantage of a longer growing season. The higher grain yield of Pioneer 3902 as compared to Pioneer 3790 in the NT treatment may be due to availability of soil water although the differences that were measured were slight. Soil water was not monitored during grain filling because of technical difficulties but was monitored regularly during a month and a half of vegetative growth. There was little difference in water content in the row, especially at the end of June when soil water content becomes crucial to a fully developed plant (Fig. 3).The interrow water content was significantly lower in the C treatment than in the NT and TW treatments until emergence and toward the end of June. Early in the season, the TW, B and NT treatments were significantly higher in interrow water content than the C treatment, indicating that in a sandy soil, the higher water content among treatments might be due as much to the absence of tillage in fall and spring than to the presence of residues on the surface.

In conclusion, the droughty sandy soil benefited to a limited degree of the absence of tillage as far as soil water content is concerned. The absence of residue in the row caused slight differences in water content when compared to no-till, but did increase seed zone temperature to the point where developmental delays were only half of those observed in no-tillage but still 2.5 days behind the conventional treatment. Differences between hybrids were noted in developmental rates and in vegetative and grain yield. The early-maturing hybrid Pioneer 3902, yielded more grain than the late maturing hybrid Pioneer 3790 in the no-till treatment. In 1988 Pioneer 3902 was shown to be less well suited for no-tillage than Pioneer 3790 in Huron county. The opposite was true in 1990 in Harrow, Essex county. Pioneer 3902 also yielded more grain per plant under no-till conditions than under the three other types of residue management treatments.

Table 1. Julian day for completion of developmental stages.

Stages	NT	C	TW	B	Lsd(.05)	P3790	P3205	Lsd(.05)
Emergence of:								
Leaf 4	151.5	150.3	151.0	149.7	0.9**	-	-	NS
Leaf 5	156.8	153.7	155.2	153.5	1.5**	-	-	NS
Leaf 6	159.8	157.8	158.7	157.2	1.3**	-	-	NS
Leaf 7	163.3	160.7	161.3	159.8	1.2**	-	-	NS
Leaf 8	166.7	163.7	164.7	162.5	1.4**	-	-	NS
Leaf 9	169.2	165.8	167.5	165.3	1.4**	-	-	NS
Leaf 10	172.7	168.7	170.2	168.5	1.9**	170.6	169.4	.05<p<.10
Leaf 11	176.3	171.6	173.8	171.0	2.1**	174.0	172.5	1.4*
Leaf 12	179.2	175.3	177.2	174.6	1.9**	177.3	175.8	1.4*
Leaf 14	184.5	180.5	182.0	180.5	0.9**	183.2	180.6	1.3**
Leaf 16	193.7	190.0	190.3	189.3	2.1**	191.8	189.8	1.4*
Tasseling	203.3	200.5	201.7	200.2	1.5**	203.2	199.6	1.1**
Silking	204.2	200.8	202.3	200.8	1.4**	203.7	200.4	1.0**

*, **: significant at the 0.05, 0.01 levels, respectively.

NS: probability > 0.10

Table 2. Degree-days required for completion of developmental stages.

Intervals	NT	C	TW	B	Lsd(.05)
Emergence of:					
Leaf 4-6	86.5	93.0	93.7	92.7	NS
Leaf 6-8	86.1	83.7	84.5	75.5	NS
Leaf 8-10	92.0	82.3	92.3	94.5	NS
Leaf 10-12	80.6	93.1	97.3	91.4	NS
Leaf 12-16	194.7	193.5	177.5	187.0	NS
Leaf 16-S	142.5	144.8	159.6	157.3	NS

NS: probability > 0.05:

++: silking

Table 3. Height (leaves extended) of corn at selected stages.

Treatments	Height (cm)		
	Leaf 11	Leaf 14	Silking
No-till	70.8	104.3	171.6
Conventional	71.1	101.4	160.2
Trash Whipper	70.0	104.1	171.3
Bare	71.0	100.4	163.9
Lsd(0.05)	4.9	3.6	8.7

Table 4. Vegetative and grain yields at 15% moisture (g plant^{-1}).

	Grain Yield			Vegetative Yield		
Hybrids / Residue Management	P3790	Pa3902	Lsd(0.05)	P3790	P3902	Lsd(0.05)
No-till	110.8	141.3	18.2	76.5	79.4	ns
Conventional	118.1	121.8	ns	92.5	72.3	18.6
Trash Whipper	119.11	123.6	ns	79.9	82.5	ns
Bare	123.3	103.3	ns	89.9	61.3	18.6
Lsd(0.05)	ns	18.2		ns	18.6	

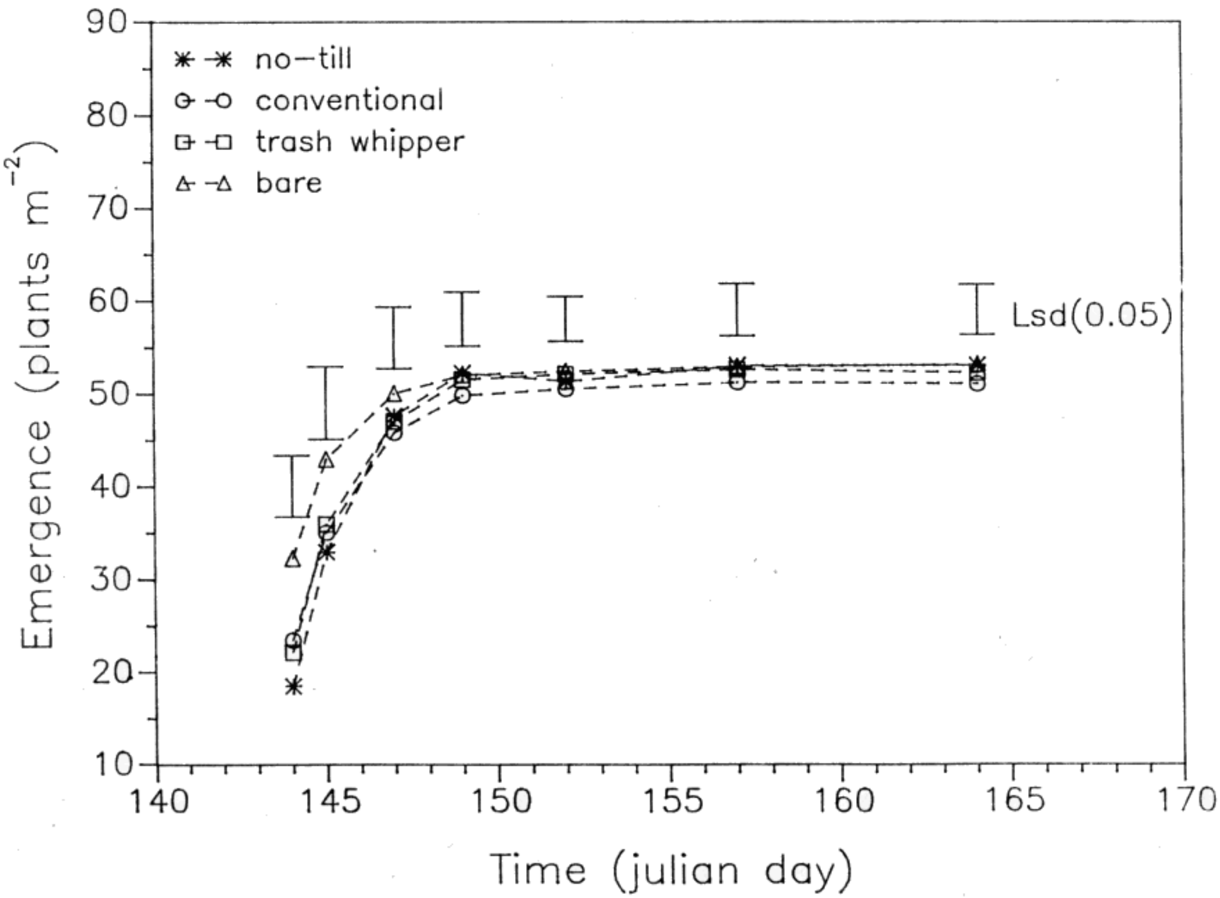

Figure 1. Emergence of corn in four residue management treatments.

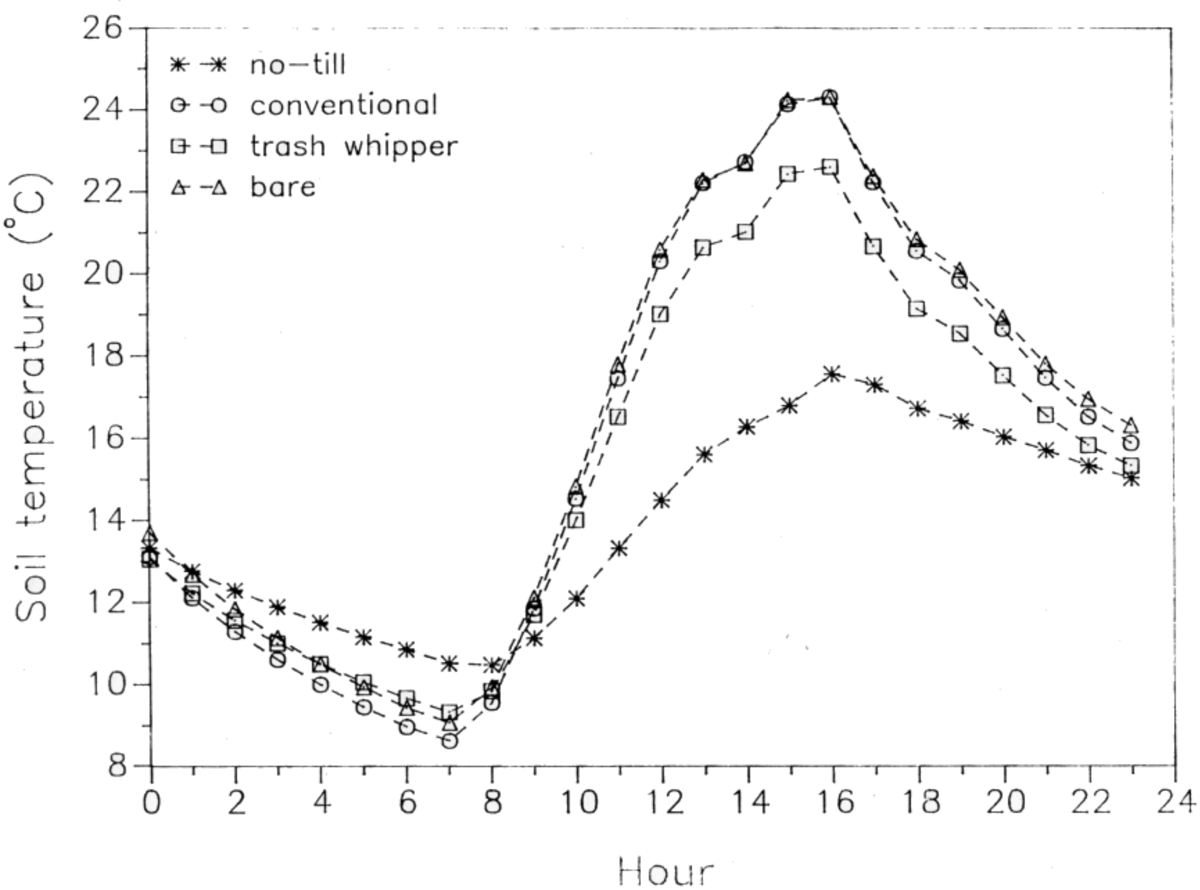

Figure 2. **Soil temperatures at the seed zone during a typical 24-hour day in May 1990 for four residue management treatments.**

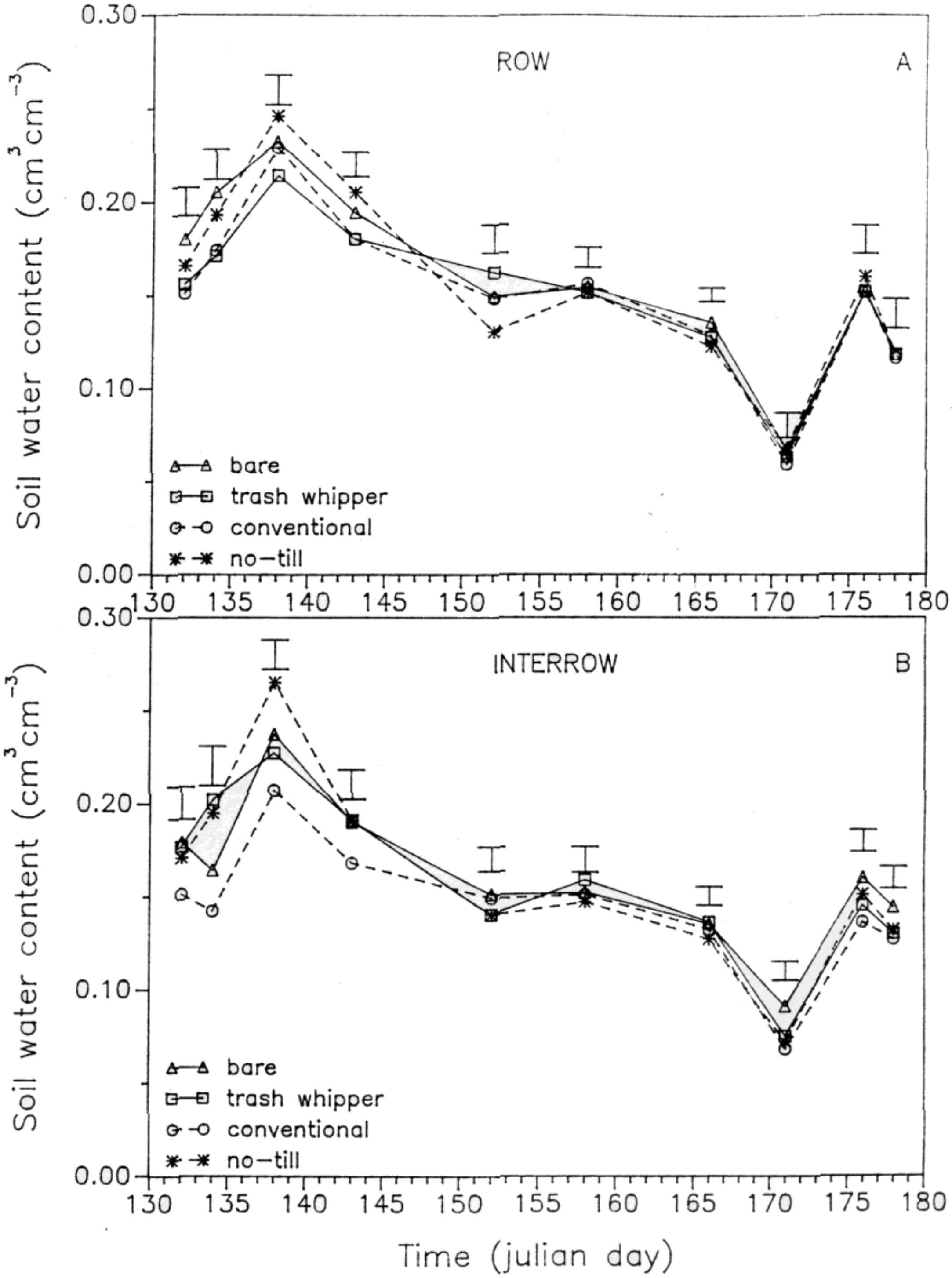

Figure 3. **Volumetric water content during vegetative growth in A) the row and B) the interrow for four residue management treatments.**

PART II. VARIABILITY OF EMERGENCE AND CORRELATIONS WITH BULK DENSITY AND SOIL WATER CONTENT IN NO-TILL AND CONVENTIONAL TILLAGE

ABSTRACT

Variability of emergence or plant establishment in conservation tillage systems often limits economic yield. Although uneveness of emergence is often acknowledged, the nature of thisvariability is not well characterized. The goals of this study were to quantify the variability of final plant establishment and emergence patterns, to identify spatial and random components of this variability, and to try to relate variability to soil physicalfactors. The study used no-till and conventional tillage treatments for two hybrids, Pioneer 3790 and Pioneer 3902, previously rated as well-suited and less well-suited for no-tillageproduction in Huron county, Ontario. The largest variability in number of plants per length of row was observed on the first day of emergence. Final establishment ranged between 80 and 90% for alltreatments. First-day emergence variability was highest in no-tillage treatments and was spatially dependent in the no-till but not in the conventional treatments. First day-emergence was negatively correlated to water content in no-till for both hybrids; variability of first day-emergence was higher for Pioneer 3790 than for Pioneer 3902. In conventionally-tilled soil, first-day emergence was negatively correlated to bulk density for Pioneer 3790 but not for Pioneer 3902. It is concluded that Pioneer 3790is not better suited for emergence in no-till conditions than Pioneer 3902 and, in fact appears to be more sensitive to seed zoneenvironmental conditions in both conventional and no-till conditions.

The existence of differences in emergence patterns between hybrids suggest that successful no-till production might benefit from the identification of hybrids tolerant to no-till environmental conditions at planting. These correlations studies indicate that such work could possibly include screening for low oxygen/high water as well as low temperature tolerance.

INTRODUCTION

The adoption of conservation tillage systems by farmers is limited by some technical and agronomic problems. One of these agronomic problems is uneveness of emergence and plant establishment. Although yield per plant in no-till systems can be similar to that of conventional tillage, final plant establishment ultimately determines economic yield in corn. The goal of this study was to understand if the uniformity of emergence is correlated to some selected soil physical properties for two hybrids. One of these hybrids, Pioneer 3790 was rated as well-adapted while the second one, Pioneer 3902 was rated less well-adapted to no-till conditions in Huron county in 1988 (pers. comm., B. Shillinglaw) based on emergence counts and yield data. These hybrids were grown in first-year no-tillage and in spring-plowed plots. The physical characteristics selected for correlation studies were soil water content, bulk density and seed depth which are main determinants of the date of plant emergence provided that soil temperature is above 10ºC (Richards, 1965; deJong and Best, 1979; Jones and Kiniry, 1986).

METHODS

Field experiments were conducted in Harrow on a site cropped to conventionally-tilled corn for several years by Mr. Bernard Calhoun on a Harrow sandy loam. Tillage treatments and two genotypes were used. Previous year's corn residues were left standing in fall 1989. The no-till treatment consisted of a first-year no-tillage and the conventional treatment consisted of spring moldboard plowing. The hybrids used were Pioneer 3790 (2850 H.U.)and Pioneer 3902 (2650 H.U.).

Corn was planted using a no-till planter at 66,000 plants ha^{-1} on 10 May 1990. For each hybrid, emergence counts, soil water content and bulk density measurements were made on transects of four-meter long sections along one row over a total distance of 64m. Emergence counts were made on 7 days between May 24 and June 13. Soil water content measurements were made in the 0-15 cm depthon 4 different days between planting and 50% emergence. Bulk density was measured in the 0-5 cm and the 5-10 cm depths. Seed depth was measured destructively after all other measurements were terminated.

RESULTS AND DISCUSSION

Corn was planted on 10 May 1990 and emerged around 25 May 1990 after a cloudy and wet spell during the second and third weeks of May (Fig. 4). Under conventional tillage, the final establishment was 84 and 80% for hybrids Pioneer 3790 and Pioneer 3902, respectively. The coefficient of variability were 12 and 21%, respectively. 50% emergence was reached on 24 May for Pioneer 3790 and one day later for Pioneer 3902. The earliest day (first day) of emergence was 24 May for both hybrids. On that date, 53 and 42% of plants emerged with a coefficient of variability of 31 and 51% for Pioneer 3790 and Pioneer 3902, respectively. Analysis of semivariograms of variability on final emergence and first-day emergence shows that there was either no spatial variability or that the range where measurements were spatially dependent was smaller than the sampling distance, 4 m. Correlation coefficients were calculated for first-day emergence and several physical characteristics (Table 3). Pioneer 3790 first-day emergence was significantly negatively correlated to bulk density in the 0 to 5 cm layer. Bulk density values varied from 1.0 to 1.3 g cm^{-3}. Pioneer 3902 first-day emergence was not correlated with any of the parameters measured. The negative correlation with bulk density at the 0 to 5 cm depth is probably related to the crusting of the surface in the conventionally-tilled plots that followed several consecutive days of rainfall prior to emergence.

Under no-tillage, the final plant establishment was 82 and 90% for Pioneer 3790 and Pioneer 3902, respectively. 50% emergence was reached on 25 May for both hybrids. First-day emergence was only 29 and 33% with coefficient of variation of 89 and 44% for Pioneer 3790 and Pioneer 3902, respectively. First-day emergence was lower and more variable for Pioneer 3790 than for Pioneer 3902. First-day emergence was shown to be spatially variable for both hybrids with observations within 20 m of each other being autocorrelated. This suggests that both hybrids' emergence patterns are not completely random and that both hybrids are affected by a similar physical factor. Accordingly, correlation calculations for both hybrids show significant negative relationships with soil water content and none with either seed depth or bulk density (Table 3). Water content values ranged from 15 to 29%. It should be noted that a negative correlation with soil water content is also an indicator of a negative correlation with temperature since the two conditions cannot be separated.

From this experiment we can conclude that first day-emergence variability but not final establishment variability was higher in no-till than in conventional tillage for both hybrids during an unfavorable weather period from planting to emergence (Fig. 4). First day-emergences were lower in no-till and very variable in all treatments especially Pioneer 3790 on no-tilled soil. Since both hybrids' emergence on no-till plots were negatively correlated to soil water content, this is an indication that Pioneer 3790 is more sensitive to seed zone environmental conditions than Pioneer 3902. This tendency is also observed in conventional tillage where Pioneer 3790's first day emergence was negatively correlated to bulk density of the surface layer while Pioneer 3902's first day emergence was not. Therefore, we cannot confirm that Pioneer 3790 is better suited for no-tillage than Pioneer 3902 as measured in Huron county in 1988. This study as well as the study in part I of this report both based at Harrow in 1990 suggest the opposite. This study nor study 1 did include water content measurements at the seed zone (5 cm) on a continuous basis from planting to emergence. However, it might be worth evaluating hybrids for tolerance to low oxygen conditions in addition to low temperature for short term periods in order to identify hybrids better suited for no-till planting conditions.

Table 5. Correlation coefficients for emergence on May 24 and bulk density at the 0-5 cm depth, seed depth, soil water content on four different dates.

	Emergence			
	Conventional		No-Till	
	P3790	P3902	P3790	P3902
Bulk Density (0-5 cm)	-0.78	ns	ns	ns
Bulk Density (5-10cm)	ns	ns	ns	ns
Seed depth	ns	ns	ns	ns
Soil water May 12	ns	ns	-0.66*	-0.57*
Soil water May 18	ns	ns	-0.71**	-0.60*
Soil water May22	ns	ns	-0.57*	ns
Ave. soil water	ns	ns	-0.68*	-0.62*

** , significant at 0.01 level

* , significant at 0.05 level

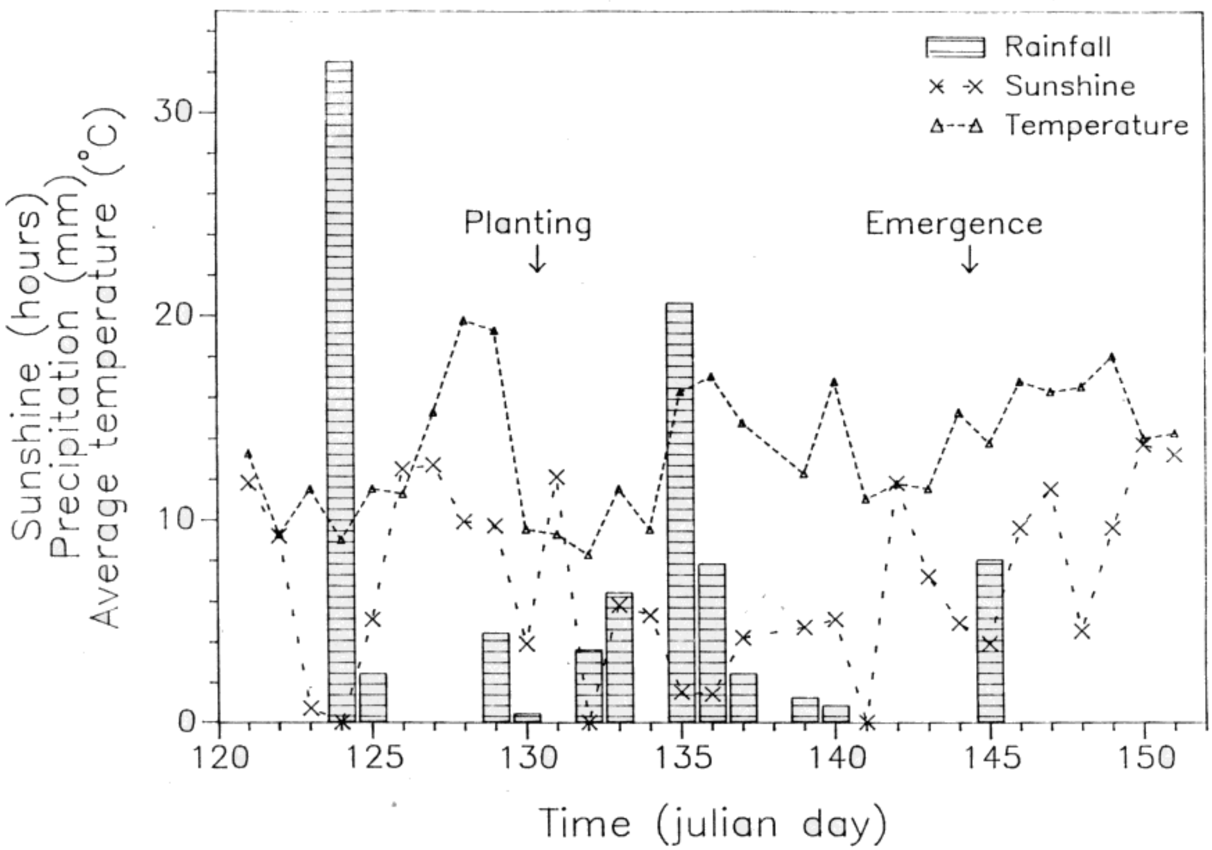

Figure 4. **Weather conditions in May 1990, Harrow, Ontario.**

PART III. Effect of soil temperature on the development of corn grown in various crop residues

ABSTRACT

The presence of crop residues on the soil surface results in many changes of physical, chemical and biological nature. These changes concern soil temperature, soil water content, nutrient availability and phytotoxicity. In order to distinguish between residue effects on corn due to low soil temperatures from other residue effects, corn development during the early part of the vegetative life cycle was related to soil temperature. The degree-day requirements for emergence of corn leaves 4 to 8 growing in eight different types of residue covers (grain corn, spring canola, spring barley, spring barley and red clover killed early, spring barley and red clover killed late, soybean, soybean and fall rye killed early, soybean and fall rye killed late) were compared to that of corn growing in a bare soil. These requirements were significantly higher (at the 0.05 level) for corn grown in canola residues than for corn growing in the bare control, indicating that only corn plants growing in canola residues may have been delayed by a factor other than temperature. When corn was planted in spring canola residues using a planter equipped with trash whippers, the degree-day requirements for leaf emergence were similar to that of the bare treatment. This suggests that if allelopathic chemicals are involved in the retardation of corn development in canola residues, these compounds are likely to have low volatility and low solubility in the soil solution. This information could serve as a basis for establishing future experimental protocols on the isolation of allelopathic compounds in spring canola residues.

INTRODUCTION

Experiments comparing the effects of crop residues to bare controls involve various potential causes for differences in crop performance. Although crop residues can affect soil water content and nutrient availability, the main effect of residue covers is to lower soil temperatures (VanDoren and Allmaras, 1978). The effect of soil temperature on corn growth and development is very important during the early plant's life cycle (Walker, 1969).During this period, any assessment of potential allelopathic effects of crop residues on corn performance should distinguish between that effect and the effect of low soil temperatures on corn performance. The objective of this study was to determine to what extent the residue-related modification of soil temperature can account for differences in development between a bare control and several types of residue cover treatments during the early vegetative growth of corn.

METHODS

Measurements were conducted at the Elora research station on the site used for Dr. Paul Voroney's research on chemical residues associated with crop residue covers. This experiment consists of four replications of a split plot design with crop residue covers as main plots and the use or absence of use of trash whippers at planting as sub-plots. Pioneer 3902 was planted on 15 May 1990 at 72,000 plants ha^{-1} using a planter equipped with or without trash whippers. Further details on the experimental layout and management can be obtained in the report of Dr. Voroney's allelopathic study (contract No.01686-0-1011/01-SE).

Crop development was monitored from leaf 4 to leaf 8 in two of the four replicates. Soil temperature at seed depth was measured every 10 minutes and averaged hourly. The temperature readings were taken in both the non-trash whipper and trash whipper subplots of the bare and eight crop residue treatments (grain corn, spring canola, spring barley, spring barley and red clover killed early, spring barley and red clover killed late, soybean, soybean and fall rye killed early and, soybean and fall rye killed late). Four copper-constantan thermocouples connected in series to a datalogger were recorded for each treatment of one of the replicates.

RESULTS and DISCUSSION:

Corn development is well understood and has been shown to be regulated by temperature in absence of severe soil water stress. Consequently, for each hybrid, a specific number of degree-days is required to accumulate before a leaf can emerge from the whorl. In the early part of the corn life cycle when the apical meristem is below ground, development is driven by soil temperature and the accumulation of degree-days at the level of the meristem. In spring, the presence of crop residues lowers soil temperature and corn development is typically slower than in a bare soil because the accumulation of soil degree-days is simply slower. On the other hand, if leaf development in a residue treatment were to be retarded by other causes in addition to low soil temperature (disease, lack of mineral nutrient, allelopathy etc...), it is expected that the number of degree-days required for leaf emergence would not only be obtained later but would also be larger than that in a bare control.

The number of degree-days required for development of corn leaves 4 to 8 in the following residue treatments (grain corn, spring barley, spring barley and red clover killed early, spring barley and red clover killed late, soybean, soybean and fall rye killed early, soybean and fall rye killed late) was similar to that of corn growing in the bare control for subplots where no trash whippers were used. There was one case where the number of degree-days required for leaves 4 to 8 to emerge was significantly higher than that of the bare treatment: spring canola required significantly more degree-days (at the 0.05 level) than the bare treatment. When this period was examined more closely, it was found that the corn plants growing in canola residue developed normally from emergence of leaves 4 to 6 but required 27.4% more degree-days than the bare control from leaf 6 to 8.

When similar types of comparisons were made for corn planted in residue treatments using a planter equipped with trash whippers, the significant difference between spring canola and the bare treatment disappeared. As with no trash whippers, spring barley, grain corn, spring barley and red clover killed early, spring barley and red clover killed late, soybean, soybean and fall rye killed early, soybean and fall rye killed late did not result in degree-days intervals significantly higher than that of the bare treatment. It must be mentioned that the two replicates of the soybean and fall rye killed late did not behave consistently. In one of two replicates, corn required more degree-days (at the 0.05 level) than the bare control for development of leaves 4 to 5. The average of the two replicates does not result in a number of degree-days for leaf emergence that is significantly different from the bare control. However, this discrepancy between plots indicates that this treatment may require further study even though its effect on corn development is less consistent than that of canola.

In conclusion, this one-year study indicates that two types of residue covers modify corn development beyond what is expected from thermal effects. This conclusion should be verified over years. However, according to this 1990 phenological analysis, spring canola is the residue type that most warrants further research on potential allelopathic chemicals. The physical removal of canola residues from the row did alleviate the problem. If this is a case of allelopathy, it might be an indication that the allelopathic compound(s) is (are) not very volatile and/or not very mobile inthe soil solution. This information should serve as a basis for the planning of further experiments on the allelopathic potential of crop residues on corn in Ontario.

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