TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM SOIL AND WATER ENVIRONMENTAL ENHANCEMENT PROGRAM

<u>FINAL REPORT</u>

CEREAL COVER CROP STUDY

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ON BEHALF OF: Agriculture Canada
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EXECUTIVE SUMMARY

The Effect of Crop Species and Method of Planting of a
Cereal Cover Crop on the Growth and Yield of Corn

During 1987-1989 four trials were conducted in Middlesex and Huron Counties, in southwestern Ontario to study the effect of cereal crop species (rye, barley, oats) and method of planting on the growth and yield of no till planted corn. The methods of planting included broadcasting the seed at soybean leaf drop, broadcasting the seed at soybean harvest, tilling the soil and drilling the seed into soybean residue and a control where no seed was planted. Excess rainfall during the fall of 1987 and l988 and drought during late spring of 1988 affected the performance of the cover crops and main (corn) crop. Results from two years of study indicate that winter rye, spring barley and spring oats seeded at soybean leaf drop or at harvest increased soil residue cover when compared to soybean stubble alone, through winter and early spring. Barley and to a lesser degree, oats, seeded at harvest followed by seeding at leaf drop achieved the best corn growth and yield. Practical considerations related to labour needs, weather and the timing of cover crop establishment for adequate fall growth do not favour the planting of cereal cover crops at or after harvest.

ACKNOWLEDGEMENTS

The following study was funded by Agriculture Canada through the Technology Evaluation and Development (TED) sub-program of the Soil and Water Environmental Enhancement Program (SWEEP).

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1. 0 INTRODUCTION AND OBJECTIVE

1.1 Purpose of the Cover Crop Research

It is our understanding that the Technology Evaluation and Development (TED) sub-program of SWEEP was established to facilitate the evaluation of existing technologies and the adaptation of such technologies for soil conservation and phosphorus (P) load reduction purposes. It is intended that TED-sponsored investigations would be undertaken mainly at field-scale and within commercial farming operations.

An important objective of this sub-program is the involvement and close cooperation of the farming community in the process of developing and refining technologies and systems. Through this involvement it is expected that the results of TED-sponsored research will be directly applicable to important problems and needs faced by farmers as they attempt to deal with soil degradation. Rapid adoption of such technologies will be necessary for SWEEP to realize its phosphorus reduction goals within the specified time frame.

Because of the high proportion of P loss that occurs during spring run-off especially in row crop fields, it is desirable to achieve a temporary vegetative cover over winter and during spring runoff to hold the soil in place. Added organic material and possibly nitrogen from cover crops may also benefit soil stability and productivity.

A number of farm operators have been experimenting on their own with a variety of cover crop species and management methods. Of note is the work of several operators in the Rondeau Bay watershed over the past half dozen or so years. For row crops grown in highly erodible, rolling landscapes, as happens in that watershed, winter cover is essential. In many cases residue from the previous crop is not acceptable or adequate to keep the soil from eroding.

Conditions such as those found in the Rondeau Bay watershed occur on many other landscapes across southwestern Ontario, with their long steep slopes and row crops which occupy a high proportion of the cultivated land. It is clear that wider scale use of cover crops could have a significant impact on SWEEP's P reduction target.

By 1987 efforts by innovative conservation farmers to develop effective cover crop management systems showed significant progress. Numerous questions regarding the best species/varieties, application and kill methods and timing, remain to be answered. It is the intent of the TED cover crop study to address these questions.

In order to make relatively rapid progress in our understanding of this area and the subsequent adoption of suitable practices, it is important to work with existing crops where the basic management techniques are widely known and practised. It is also important to work with those alternatives that provide an adequate level of erosion control and are relatively inexpensive to implement.

While the use of cover crops is most conveniently associated with a no tillage cropping system it is recognized that many Ontario producers will adopt some form of a reduced or minimum tillage system. With this in mind, the cover crop studies should be of value to users of either type of system.

1. 2 Rationale for Cereal Cover Crop Research

Our interpretation of the terms of reference indicated that the initial work was to serve as a prelude to field scale testing, i.e. to carry out investigations that would assist with the decisions about which longer-term, field-scale studies should be undertaken. Plot or field strip experiments were desired in the field season.

The initial work was expected to determine:

a) which cover crops can be grown effectively in corn-bean rotations under various soil (and climatic) conditions;

b) optimum techniques for establishing and killing cover crops prior to planting primary crops;

c) the effect of cover crops on yield response, on weed pressure, harvesting and related management operations.

Corn and beans continue to be the major cash crops grown in southwestern Ontario. The likelihood of a continued supply of relatively cheap cereal grain seed makes it an attractive alternative as a potential winter cover crop for use in corn-bean rotations. Previous research using winter cereal crops for this purpose has indicated problems, for example, with allelopathic effects on the following crop.

In addition, extra expense is incurred in order to kill the winter cereal prior to seeding of the next crop.

If a spring cereal could be established that would provide enough cover to protect the soil against erosion, then the added benefits of low cost seed and no additional herbicide expense could be realized. The potential for crop inhibiting allelopathic affects would also likely be lessened due to the expected limited vegetative growth (in comparison to winter rye for example) and poor winter survival rate of the spring cereals.

To further reduce the overall cost of planting a cover crop it is worthwhile examining potential methods of seeding the crop using the least amount of time and energy possible. To this end, it may be possible to develop a method of seeding the cover crop using the mulch effect provided by the natural senescence of leaves in white and soybean crops. Alternatively, if the seed could be broadcast during combine harvesting of the crop, the chaff could also serve as a suitable mulch to aid in the rapid establishment of the cereal cover crop.

With these concepts in mind, the purpose of the following study is to determine the effect of crop species and method of planting of a cereal cover crop on the growth and yield of corn.

1.3 Objectives of Cereal Cover Crop Research

i) to determine the effect of crop species and methods of planting of a cereal cover crop on the amount of residue and/or live plant cover remaining on the soil surface between harvest and the establishment of the next crop canopy;

ii) to quantify the amount of above ground cereal plant dry matter present in relation to study treatment at various times in the growing season;

iii) to examine the soil for the presence of phytotoxic compounds resulting from the growth and/or decomposition of a cereal cover crop;

iv) to determine the effect of crop species and method of planting on the growth and yield of grain corn;

v) to prepare preliminary recommendations on the management of a cereal cover crop with regard to species and method of planting.

1.4 Objective of Spring Cereal Species/Variety Trial

Experience with spring cereals in 1987-88 indicated that some varieties of barley may survive through the winter. Thus, this trial was added in the fall of 1988 to determine if winter survival is common among spring cereal varieties.

2.0 LITERATURE REVIEW

Cash crop producers in southwestern Ontario are presently showing an increased interest in soil conservation as the effects of soil erosion become more widely known. The vulnerability of soils to water erosion is often increased during the springtime. Estimates of the contribution of snow-melt run-off from plots maintained bare during the entire year to total annual run-off range from 10% to 88% (Kirby and Mehuys, 1987). Under normal cultural practices (presence of a crop during at least part of the season) the relative contribution of winter soil loss would be greater. These estimates are mainly affected by soil type and slope gradient (Kirby and Mehuys, 1987). Van Vliet and Hall (1981) estimated that about 10% of the annual soil erosion due to water occurs in the spring period in southern Ontario. However, Dickinson et al. (1975) suggested that 50% of the annual sediment load of rivers of the same area took place during the spring run-off period. These values demonstrate the need for good ground cover during the early spring.

The use of cover crops as a method of soil erosion abatement has long been established. Rye (Secale cereale L.) has traditionally been used as a break and cover crop on tobacco soils of southwestern Ontario. However, some current green manuring practices deserve investigation so they may be adapted to contemporary cropping systems. The use of cereals as an over winter ground cover is examined. Their benefits and shortcomings, as well as ways they may be potentially modified to better suit modern farming in southwestern Ontario, are covered in this report. The following review discusses the role of cereals as potential winter cover crops.

2.1 Small Grain Cover Crops

Fall rye is often sown following a soybean (Glycine max L.) crop, either before or after soybean harvest, since there is usually insufficient crop residue remaining to provide an adequate mulch over winter. The rye reduces the soil loss potential both in the autumn and in the spring when snow-melt run-off can be a significant cause of soil erosion.

There are two major drawbacks to the use of a fall rye cover crop: 1) it must be removed prior to planting the subsequent crop, often corn (Zea mays L.); and 2) allelopathic effects from the rye residue have been shown to interfere with corn growth (Daynard et al., 1985). Rye growth in the spring must be arrested either with the application of herbicides or with cultivation; both processes resulting in increased production costs. For those years with a particularly wet spring, corn planting may be delayed because of the postponement removal operation until the ground is sufficiently drained to allow these operations to take place. This can lead to a further reduction in corn yield. The allelopathic interference from the rye has been reported as most important when the corn is planted shortly after the rye crop is killed by chemical or tillage methods (Daynard et al., 1985). The resulting effects on corn development can include slower development, delayed silking date, lower leaf area index (LAI), shorter plants, higher percent plant moisture at harvest and reduced grain yield (Daynard et al., 1985).

It would therefore appear advantageous to plant a cover crop that would not require removal before sowing the following crop and that would permit a timely planting of the main crop without possible yield losses from allelopathic interactions. Alternatives to rye such as spring barley (Hordeum vulgare L.) and spring oats (Avena sativa L.) may provide adequate ground cover for erosion protection in the fall and the winter-killed plants could also act as a mulch in the spring. These spring crops would have the additional benefits of not requiring chemical or tillage control in the spring as well as less or no inhibition of the following crop.

Work done in Pennsylvania by Janke and co-workers (1987), indicated that spring oats and spring barley planted in late September into a soybean stand showed excellent germination, biomass production and ground cover going into the winter months. A study comparing various species for cover crops in corn production in New York (Smith et al., 1987) indicated that oats seeded after corn silage harvest provided 26% ground cover in November and 19% in May. In comparison rye and wheat values were 50% and 37%, respectively, in the fall and 76% and 37%, respectively, in the spring. Corn grain yields following the oat, rye and wheat treatments were 5195, 5006, 4874 kg/ha, respectively. Yields, however, were not significantly different at the 5% probability level.

Research conducted in the Ridgetown, Ontario area (Swanton, pers. comm.) demonstrated that spring barley and spring oats planted in raised vegetable seed beds in late August produced good fall growth (15 to 20 cm) and provided satisfactory ground cover in the autumn. However, according to Swanton (pers. comm.) the frequent freeze-thaw conditions of that area contributed to rapid decomposition of the above-ground plant matter and, in his opinion, the ground cover was inadequate to control spring soil loss from run-off. This experiment was undertaken to study the influence of spring grains on weed populations. It is worthwhile to note that the spring grains did seem to reduce the levels of winter annual weeds.

A number of conditions affect the degree of allelopathic interference. These include species, duration of plant matter decomposition (Yakle and Cruse, 1983), management of plant residue (cultivation/herbicide), soil moisture (Lynch, 1977; Harper and Lynch, 1982) and soil temperature (Wallace and Elliot, 1978; Cochran, 1977). Anaerobic wet seed bed conditions alter the soil microbial population which, in turn, affect the decomposition of plant matter (Harper and Lynch, 1982). Lynch (1977) reported that toxic concentrations of organic acids were produced only when wheat (Triticum aestivum L.) straw was decomposing under anaerobic conditions. An aerobic environment, however, stimulated barley seedling root growth. With indoor experiments decaying wheat straw produced higher levels of acetic acid at 20°C than at lower temperatures (Wallace and Elliot, 1978) and an optimal temperature for acetic acid production has been suggested at above 15^{o}C by Elliot and colleagues (1978). However, in a field experiment Cochran et al. (1977) observed a greater severity in allelopathic interferences at temperatures less than 15^{o}C.

According to Ellis and Lynch (1977) allelopathic effects of decomposing crop residues are most significant when: 1) there is a short time interval between crops, which allows little opportunity for the loss of toxins through leaching and/or microbial degradation; and 2) seeds are exposed to higher toxin concentrations which occur under conditions of shallow cultivation or direct drilling. There is evidence indicating that the duration of the decomposition period for which the allelopathy is significant is relatively short. Working with wheat straw extracts, Tang and Waiss (1978) found that the phytotoxic effects of these extracts on wheat seed germination decreased after 17 days. Also, studying wheat seedling inhibition, Kimber (1973) observed that the toxic effects from a range of decaying grasses and legumes generally disappeared within 14 to 21 days. Reports from a number of farmers having established a fall rye cover crop and who have removed it with a herbicide treatment at least 10 days prior to corn planting indicate that the negative effects of the rye residue on the corn were not evident. Daynard et al. (1985) have suggested a two week interval between rye harvest and corn planting in order to overcome the phytotoxic effects of rye on the corn.

Mulches may also affect the subsequent corn crop by postponing plant emergence due to delayed soil warming resulting from the presence of a ground cover (Gupta et al., 1983). If the mulch is non-living, soil moisture may remain at a high level because little evaporation and no transpiration is occurring, while a living cover crop will use up soil water. This situation may become detrimental when soil moisture is limiting. Killing the cover crop with tillage would aggravate moisture loss because of evaporation. However, Daynard et al. (1985) noted that during the wettest year of their study, there were fewer large (<25 mm) soil aggregates where no rye cover crop had been grown in comparison to where rye had previously been seeded. The plots with rye tended to retain more moisture than the bare plots.

There are a number of methods of treating cover crops, all of which differently affect the phytotoxicity of the residue. Research conducted at the University of Guelph (Daynard et al., 1985), compared corn planted into untilled rye stubble, corn planted into rototilled rye stubble and corn planted into rototilled bare soil. The corn grown in the untilled rye stubble produced an average of 14.6% less total dry matter yield and was wetter at harvest than corn grown in the other two treatments. The percent decrease in productivity ranged from 8.4% to 41.9% and reflected different locations, corn planting dates and years. The same study compared four different rye cultivars and found that differences between cultivars with regards to corn whole plant dry matter yield and corn whole plant moisture were either not significant or significant at the 5% probability level but not at the 1% probability level.

Lynch and co-workers (1981) contrasted the effects of burning with those of chopping and spreading oat straw on oat grain yield. The non-burned straw was either left on the soil surface, disced or rotovated; grain yield was 44%, 56% and 66%, respectively, of the burned straw treatment.

A herbicide treatment may produce conditions similar to those resulting from surface decay of winter-killed plants. Plant residue from spring grains would remain on the soil surface however, their advanced state of decay may partially or totally overcome phytotoxic activity. Fresh corn residue placed near seedling roots has been found to reduce root and shoot weight more than partially decomposed residue (Yakle and Cruse, 1983). The spring cereal above ground biomass should therefore not add to this effect. Daynard et al. (1985) showed that the removal or retention of rye top growth after cutting had no effect on corn dry matter yield, suggesting that allelopathic activity is due to soil or root related factors.

Little information on time and method of cover crop seeding is currently available. Comparing three fall rye planting dates that ranged from early September to early October, as well as broadcasting into standing corn versus direct drilling, Daynard and co-workers (1985) did not observe significant differences in spring rye dry matter yields. Direct drilling led to slightly better yields. This was suggested to be the result of a more uniform stand.

More research is needed to elucidate the effects of spring grain cover crops on the next crop. These cover crops offer several potential advantages over a fall rye cover crop, namely reducing production costs, improved timeliness of farming operations and probable decreases in the allelopathic influence on subsequent crops. The full extent of their potential contribution to southwestern Ontario cropping systems has yet to be explored.

3.0 DEVIATIONS FROM THE WORK PLAN

Due to prolonged wet weather in the fall, 1988 the harvest of soybeans at Site 4 did not actually occur until two weeks after the cereals were seeded in the `broadcast at harvest' treatment. The till and drill treatment was not applied due to the lateness in the season. As a result, data for this site are not included in the combined analysis of data over locations but are presented as an individual site.

Cereal dry matter was collected at sites 3 and 4 in late fall, early spring and after planting. Data for early spring and after planting were misplaced during processing at the University of Guelph and results are not available.

An additional study (site 5) to determine which spring cereals survive winter conditions was implemented in the fall of 1988. Wet weather conditions also inhibited the complete planting of all treatment varieties.

4.0 MATERIALS AND METHODS

4.1 Location and Characterization of Treatment Plots

The cereal cover crop trials were located on two different sites in each of two years.
Site 1 (year 1) was located on Lot 23, Concession 13, London Township, Middlesex County.
Site 2 (year 1) was located on Lot 18, Concession 15, Goderich Township, Huron County.
Site 3 (year 2) was located on Lot 76, Maitland Concession, Goderich Township, Huron County.
Site 4 (year 2) was located on Lot 7, Concession 2, Biddulph Township, Middlesex County.

The spring cereal species/variety trial was located on Lot 76, Maitland Concession, Goderich Township, Huron County (site 5, year 2).

Soil samples were taken to determine the soil texture and fertility levels. The samples were analyzed according to the standard procedures used by the Department of Land Resource Science, University of Guelph. See Appendix A for specifications.

4.2 Experimental Design and Analysis

The cereal cover crop trials for sites 1-4 were set up as a split-plot design consisting of four replications. Each replicate of 12 plots consisted of three main treatments (A-barley var. Leger; B-oats var. Ogle; and C-rye var. common fall), by four sub-treatments (a-seed broadcast at leaf drop, b-seed broadcast at harvest, c-till and drill seed after harvest; and d-unseeded soybean stubble (control)). The dimensions of each plot were adjusted to fit the cooperators' equipment.

The data were analyzed using an analysis of variance for a randomized complete block design two factor factorial with split and where appropriate, combined over locations at a 0.05 level of probability.

The spring cereal species/variety trial was set up as a randomized complete block design consisting of four replications each with twenty-four treatments. The treatments included varieties of barley (var. Albany, Birka, Bruce, Joly, Leger, Helena, Micmac, Mingo, OAC Kippen, Rodeo, Sophie), oats (var. Donald, Dumont, Marion, Ogle, Oxford, Tibor, Woodstock), triticale (var. Triwell) and wheat (var. Columbus, Glenlea, Katepwa, Laval 19, Max). Each plot consisted of four rows eighteen feet in length.

4.3 Agronomic Practices

In the fall of 1987 (year 1) and 1988 (year 2) the cereal cover crop studies were initiated in fields planted to soybeans.

During the first year of the study (fall l987), soybean leaf drop progressed rapidly. As a result of this and the timing of study initiation cereals were broadcast when leaf drop ranged between 70 and 78% at one site and between 84 and 93% at the other site. In fall, l988 cereals were sown at the target 10% leaf drop stage.

At all sites, seed sown at leaf drop (a) and at harvest (b) for sub-plot treatments \`a' and \`b' were hand broadcast using a chest seeder with a crank handle. The third seeding (c) was carried out using each cooperator's disc for tilling and drill for planting the cereal after the soybeans were harvested.

The rates of seeding were as follows:

Species	Sub-plot treatment	Rate (kg/ha)			
		Site 1	Site 2	Site 3	Site 4
barley	a, b	160	160	173	186
	c	235	233	179	-
oats	a, b	169	169	157	174
	c	176	131	165	-
rye	a, b	110	110	120	106,162
	c	152	209	179	-

The discrepancy in rates between hand broadcast seeding and drilling occurred due to the use of different drills (belonging to the cooperators) at the sites and the omission of a drill calibration exercise due to time constraints.

In the fall of 1988 the spring cereal species/variety trial was established in a soybean stubble field. The seed was sown into a disced seedbed using a hand pushed single row planter (Planet Jr.) at rates recommended in "Field Crop Recommendations" (Publication 296) published by OMAF.

In the above study, wet weather conditions delayed planting. All barley varieties, Triwell triticale and Marion, Oxford and Tibor oats were seeded on October 16, 1988. Woodstock, Ogle, Dummont and Donald oats were planted on October 20, 1988. Glenlea wheat was also planted on this date, but rainfall caused seed and soil to stick to the planter as this variety was planted. Unfortunately, after this date the weather stayed consistently wet and some varieties were not planted. Those varieties not planted included Laval 19, Columbus, Katepwa and Max wheat.

In the spring of 1988 (year 1) and l989 (year 2) the sites were planted no-till to corn. The specifications for each site were as follows:

Site 1 - Planted May 14, l988
- var. Pioneer 3790
- 28,100 seeds per acre
- Kinze 4 row crop planter
- 30" rows

Site 2 - Planted May 6, l988
- var. Pioneer 3790
- 26,000 seeds per acre
- White 5100 row crop planter
- 30" rows

Site 3 - Planted May 18, l989
- var. Pioneer 3790
- 26,000 seeds per acre
- White 5100 row crop planter
- 30" rows

Site 4 - Planted May 18, l989
- var. DeKalb 834
- 28,000 seeds per acre
- John Deere 7000 row crop planter
- 30" rows

Manual and chemical methods were used throughout the spring and summer to control weeds and volunteer grains in plots.

Maximum, minimum and mean daily temperatures and daily total precipitation are summarized for the months of May to October, 1988 and 1989 in Appendix B. Information for these tables was obtained from the Atmospheric Environment Service, Environment Canada, Ilderton and Brucefield stations.

4.4 Measurements

4.4.1 Cover Crop Establishment and Development

4.4.1.1 Cereal Cover Crop Establishment and Development

i) Soil Residue Cover

A rope with knots at 15 cm intervals was used to make four counts of residue cover per plot. Residue cover was determined by counting each knot on the rope that touched a piece of residue (previous crop and cover crop residue). The knotted rope was positioned diagonally across the plot. Two counts were taken from the top right to bottom left corners and two from the top left to the bottom right corners. These data were taken in late fall on the control plots only for Sites 1 and 2 and on all treatments at Site 3. In early spring after run-off and after planting residue levels were measured on all treatments at each site. Data were adjusted to percent residue cover.

ii) Soybean - Leaf Drop

Plants were visually assessed for the amount of leaves that had dropped prior to the implementation of sub-plot `a' treatment (seed broadcast at leaf drop). The plants were rated from 0 to 100, where 0 was equal to no leaf drop and 100 was equal to all leaves dropped.

iii) Cereals - Dry Matter

Live and/or dead cereal plants from a 0.25 m^2 area were clipped at ground level, placed in a bag and frozen. These data were taken in late fall, early spring (after run-off) and after planting on all treatments at all sites. The samples were subsequently dried to a constant weight in a forced-air dryer. The dried weight values were adjusted to kilograms per hectare.

4.4.1.2 Spring Cereal Species/Variety Establishment and Development

i) Cereals - Emergence

The number of seedlings emerged per square metre were counted for each treatment. These data were taken on November 15, 1988.

ii) Cereals - Dry Matter

All above ground live cereal seedlings from a one square metre area were clipped, placed in a bag and frozen. The samples were subsequently dried to a constant weight in a forced air dryer and weighed. The samples were taken on November 15, 1988.

iii) Cereals - Winter Survival

The number of plants that survived the winter season were counted within a one square metre area. These data were taken in May, 1989.

4.4.2 Main Crop Establishment and Development

i) Corn Emergence

Corn emergence was measured as the number of emerged plants per square metre. Three subsamples per plot were collected in this manner. These data were collected approximately 14 and 21 days after the planting (DAP) date.

ii) Corn Plant Height

The height of individual corn plants within one square metre were recorded at three different locations within each plot. Plant heights were taken from the ground to the top of the longest, fully extended leaf on the plant. Measurements were taken to the nearest half centimetre at the 2-3 leaf and 6-7 leaf stages of growth.

iii) Corn Silking

Ten consecutive corn plants from the four centre rows of each plot were visually assessed for the emergence of silk hair from the ear of each plant. These values are presented as the number of days to 50% silking.

iv) Corn Yield and Associated Factors

The ears from all the plants along a five metre length of the two centre rows (site 1) or within a 2.5 metre section of the four centre rows (sites 2, and 3) and rows 2,3,6 and 7 (site 4) were hand harvested and weighed (TC). Ten average ears were then selected, weighed (FC) and dried to a constant weight in a forced-air dryer, at 80°C, for about four days. The dried ears were subsequently weighed (DC) and shelled.

The shelled grain was again weighed (G). The final grain yield per sample, adjusted to kilograms per hectare basis at 15.5 percent moisture content, was calculated using the following equation:

$$\text{Yield} = \frac{TC \times G}{FC} \; \frac{kg}{7.62\ m^2} \times \frac{10^4\ m^2}{ha} \times \frac{100}{84.5}$$

From the same data the percent moisture content at harvest was calculated as follows:

$$\%\ \text{Moisture Content} = \frac{FC - DC}{FC} \times 100$$

4.4.3 Phytotoxin Parameters

The phytotoxic effects of cereals were studied by graduate student Ken Janovicek, under the direction of Dr. T. Vyn. This complementary study was part of a larger TED contract. The following were obtained:

i) soil samples to analyze for the presence of phytotoxins
ii) corn plant dry matter samples

Materials and methods for these studies do not form part of this report but may be obtained through Dr. T. Vyn, Crop Science Department, University of Guelph.

5.0 RESULTS AND DISCUSSION

5.1 Cover Crop Results

i) Soil Residue Cover

Table 1 shows that the residue levels in late fall for the control plots were relatively equal at both sites 1 and 2. At site 3 the till and drill treatments for all cereal species had a consistently lower level of residue cover than the remaining treatments. At site 4 for the treatments planted there were no differences between the type of cereal species used or method of application on late fall residue levels.

When soil surface residue levels for early spring and after planting were each combined over location/years for sites 1, 2 and 3 the interactions of location/years by crop and location/years by method were significant (Table 2) . This indicates that both crop species and method of application had a different effect on residue levels over the three locations at these dates.

For three of four locations, there was no significant difference between crop species used but there was a significant difference in the method of planting treatments employed at the early spring date for residue cover measurement (Table 3). At all sites the broadcast at leaf drop and broadcast at harvest residue levels were, in general, greater than the remaining

Table 1: Mean Late Fall Soil Surface Residue Cover for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Late Fall Soil Surface Residue Cover (%)			
Treatment	Site 1	Site 2	Site 3	Site 4
Barley broadcast at leaf drop			91	94
Barley broadcast at harvest			87	95
Barley till and drill			60	
Control	84	78	89	90
Oats broadcast at leaf drop			95	95
Oats broadcast at harvest			91	93
Oats till and drill			72	
Control	84	77	88	94
Rye broadcast at leaf drop			90	95
Rye broadcast at harvest			91	94
Rye till and drill			70	
Control	81	80	88	90
c.v.			4.0	3.6
Probability				
Crop Type			NS	NS
Method/Timing			*	NS
Crop x Method			*	NS

* Significant at the 0.05 level of probability.

NS Not significant at the 0.05 level of probability.

Table 2: Mean squares of data collected for treatments combined over locations/years (sites 1-3) for the cereal cover crop study, 1987-89.

Treatment	df	Spring Residue	After plant Residue	14 DAP Emergence	21 DAP Emergence	Plant Height 2-3 leaf	Plant Height 6-7 leaf stage	Fall Dry Matter	Yield at 15.5%	Moistur e Content
Location/year	2	8462.1 *	4032.2 *	100.3 *	23.4 *	196.82 *	6688.69 *	51417.90 *	125175921.3 *	317.2 *
Rep x loc/yr	9	87.0 *	205.7 *	1.3 NS	.38 NS	6.48 *	106.6 *	3871.25 NS	1027709.4 NS	74.3 *
Crop	2	789.8 *	1642.7 *	9.9 *	1.7 *	1.3 NS	34.62 NS	28610.51 *	463991.5NS	2.2NS
Loc/yr x crop	4	7.6 *	276.3 *	2.6 NS	.24 NS	3.02 NS	13.76 NS	4093.40 NS	1315801.5 NS	7.0NS
Error	18	35.4	46.4	.96	.31	1.42	17.94	3462.64	1032465.3	23.9
Method	3	88.6 *	2154.5 *	.37 NS	.16 NS	1.03 NS	14.13 NS	1103626.92 *	1457377.6 *	6.9 NS
Loc/yr x method	6	15.1 *	128.8 *	.37 NS	.47 NS	.67 NS	4.29 NS	21056.35 *	594511.O NS	8.7 NS
Crop x method	6	3.5 *	542.0 *	.69 NS	.86 NS	.95 NS	12.96 *	12516.28 *	823324.5 NS	15.8 NS
Loc/yr x crop x method	12	1.4 NS	129.0 *	.53 NS	.24 NS	.73 NS	10.63 *	2218.28 NS	452349.6 NS	14.8 NS
Error	81	27.9	27.3	.57	.43	.74	5.26	3354.70	472827.6	13.0

* = Significant at the 0.05 Level of probability.
NS = Not significant at the 0.05 level of probability.

Table 3: Mean Early Spring Soil Surface Residue Cover for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Early Spring Soil Surface Residue Cover (%)			
Treatment	Site 1	Site 2	Site 3	Site 4
Barley broadcast at leaf drop	83	73	93	94
Barley broadcast at harvest	80	63	88	94
Barley till and drill	48	51	88	
Control	70	61	90	89
Oats broadcast at leaf drop	80	67	92	95
Oats broadcast at harvest	78	63	92	93
Oats till and drill	54	43	88	
Control	73	57	89	93
Rye broadcast at leaf drop	92	89	95	95
Rye broadcast at harvest	82	77	91	93
Rye till and drill	62	67	89	
Control	70	62	91	89
c.v.	10.7	6.4	2.6	3.1
Probability				
Crop Type	NS	*	NS	NS
Method/Timing	*	*	*	*
Crop x Method	NS	*	NS	NS

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability.

treatments for all crop species. The residue levels after planting (Table 4) decreased on average about 30 - 65% from the early spring residue levels depending on the site. The method used at all sites to seed the cover crops had a significant effect on residue cover. At three of the four sites the crop species used was also significant. Overall, the broadcast at leaf drop and harvest treatments had levels of residue equal to or better than the control with the rye treatments generally measuring the highest levels of residue of the three crop species.

Rainfall simulation work was conducted by Ecological Services for Planning (ESP) as part of another TED research contract. This work was carried out between May 9-12, 1989 at site 3 (prior to corn planting) on both the rye and barley broadcast at leaf drop and till and drill treatments plus a control plot. Soil surface residue levels were between 50% (control) and 73% (rye broadcast leaf drop treatment) with all other treatments between these levels. No significant differences (p#0.10) between treatments in the amounts of soil lost from a uniform 3.4% slope were recorded. The average sediment loss from the plots was 4.9 g/m^2.

ii) Cereal Dry Matter

In late fall, there were no significant differences in dry matter weight between crop species used for the cover crop study, however the method of application did have a significant effect (Table 5). The broadcast at leaf drop treatment produced the most dry matter for all sites. At site 1 there was a crop by method interaction indicating that a specific crop type combined with one treatment produced higher dry matter than other treatment combinations. This in fact, was the rye broadcast at leaf drop treatment.

As indicated in Table 6, there were significant differences between crop species and method of application at site 2 for early spring dry matter and at sites 1 and 2 for after planting dry matter. In addition, there was an interaction between the crop species and method of application over the two dates. The broadcast at leaf drop treatments yielded the greatest amount of residue at the early spring date, with the rye species producing the greatest amount when compared to the other species. The amount of cereal dry matter collected after planting was greatly reduced (0 kg/ha) for the barley and oat species treatments. For rye, the amount of dry matter increased slightly over the amount produced at the early spring date for the broadcast at leaf drop treatment at site 2.

Table 4: Mean After Planting Soil Surface Residue Cover for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	After Planting Soil Surface Residue Cover (%)			
Treatment	Site 1	Site 2	Site 3	Site 4
Barley broadcast at leaf drop	29	49	33	36
Barley broadcast at harvest	28	43	30	40
Barley till and drill	16	36	22	
Control	28	50	31	37
Oats broadcast at leaf drop	28	42	31	40
Oats broadcast at harvest	30	42	29	32
Oats till and drill	19	28	19	
Control	25	40	29	33
Rye broadcast at leaf drop	67	81	35	41
Rye broadcast at harvest	43	53	35	32
Rye till and drill	25	41	20	
Control	25	40	32	31
c.v.	16.3	14.4	13.8	12.2
Probability				
Crop Type	*	*	*	NS
Method/Timing	*	*	*	*
Crop x Method	*	*	NS	0

* Significant at the 0.05 level of probability.

NS Not significant at the 0.05 level of probability.

Table 5: Late Fall Mean Dry Matter for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Mean Late Fall Dry Matter (kg/ha)			
Treatment	Site 1	Site 2	Site 3	Site 4
Barley broadcast at leaf drop	469	453	263	168
Barley broadcast at harvest	122	12	8	35
Barley till and drill	74	40	67	
Control	0	0	0	0
Oats broadcast at leaf drop	291	356	245	196
Oats broadcast at harvest	57	10	15	34
Oats till and drill	39	23	4	
Control	0	0	0	0
Rye broadcast at leaf drop	509	463	333	209
Rye broadcast at harvest	113	17	6	25
Rye till and drill	74	41	23	
Control	0	0	0	0
c.v.	44.3	38.2	77.6	58.6
Probability				
Crop Type	NS	NS	NS	NS
Method/Timing	*	*	*	*
Crop x Method	*	NS	NS	NS

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability.

Table 6: Early Spring and After Planting Mean Dry Matter for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Mean Early Spring Dry Matter (kg/ha)	Mean After Planting Dry Matter (kg/ha)	
Treatment	Site 2	Site 1	Site 2
Barley broadcast at leaf drop	521	0	0
Barley broadcast at harvest	41	0	0
Barley till and drill	18	0	0
Control	0	0	0
Oats broadcast at leaf drop	1031	0	0
Oats broadcast at harvest	42	0	0
Oats till and drill	38	0	0
Control	0	0	0
Rye broadcast at leaf drop	1880	1351	1957
Rye broadcast at harvest	485	241	0
Rye till and drill	556	0	0
Control	0	0	0
c.v.	73.8	72.2	43.8
Probability			
Crop Type	*	*	*
Method/Timing	*	*	*
Crop x Method	*	*	*

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability.

5.2 Main Crop Results

i) Corn Plant Emergence

When sites 1, 2 and 3 were combined over location/years for plant emergence at 14 and 21 DAP, the interactions between location/years and crop and location/years and method were nonsignificant indicating that crop species used and/or method of application had the same effect on plant emergence at all three sites (Table 2).

In general, at 14 DAP the rye treatment plots had a greater number of corn plants emerged than the oat or barley treatment plots for the combined data of sites 1 to 3 (Table 7). At site 4, no treatment recorded an increased plant emergence over another treatment. By 21 DAP, generally more corn plants had emerged on the barley treatment plots at all sites.

ii) Corn Plant Height

There was no significant difference between the interactions of location/years with either crop or method in the mean plant height of the corn plants at the 2-3 or 6-7 leaf stage when sites 1, 2 and 3 were combined (Table 2). This signifies that the crop species used or method of application employed had the same effect on plant height over the three sites.

In general for both the combined dates and for site 4 over the two dates, the average plant height was less for the rye treatment plots than for either the oat or barley treatment plots (Table 8). At the 2-3 leaf stage for site 4, the oat treatment plots had slightly taller plants followed by the barley and then rye treatments. This sequence was also observed at the 6-7 leaf stage. For the combined site data, the barley species treatments had slightly taller plants followed by the oat and then rye species treatments. Again, this order was observed at the 6-7 leaf stage.

Table 7: Mean Corn Plant Emergence at 14 and 21 DAP for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Mean Corn Plant Emergence 14 DAP (plants/m^2)		Mean Corn Plant Emergence 21 DAP (plants/m^2)	
Treatment	Sites 1-3	Site 4	Sites 1-3	Site 4
Barley broadcast at leaf drop	4.4	7.9	6.0	9.7
Barley broadcast at harvest	4.5	8.2	6.7	9.1
Barley till and drill	4.2		5.8	
Control	4.5	7.6	5.7	7.7
Oats broadcast at leaf drop	4.0	7.9	5.2	8.2
Oats broadcast at harvest	4.5	7.9	5.8	7.7
Oats till and drill	4.2		5.6	
Control	4.6	7.5	5.5	8.0
Rye broadcast at leaf drop	5.3	7.8	5.8	8.8
Rye broadcast at harvest	5.3	8.0	5.9	8.0
Rye till and drill	5.3		6.0	
Control	4.8	7.4	5.9	7.3
c.v.	16.3	8.9	11.5	10.6
Probability				
Crop Type	*	NS	*	NS
Method/Timing	NS	NS	NS	*
Crop x Method	NS	NS	NS	NS
Location	*		*	
Location x Crop	NS		NS	
Location x Method	NS		NS	
Location x Crop x Method	NS		NS	

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability.

Table 8: Mean Corn Plant Height at the 2 to 3 Leaf and 6 to 7 Leaf Stage for the Cereal Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Mean Corn Plant Height at the 2-3 Leaf Stage (cm)		Mean Corn Plant Height at the 6-7 Leaf Stage (cm)	
Treatment	Sites 1-3	Site 4	Site 1-3	Site 4
Barley broadcast at leaf drop	11.2	9.3	37.7	37.5
Barley broadcast at harvest	11.1	9.3	38.9	40.6
Barley till and drill	11.8		39.2	
Control	11.5	9.4	39.5	40.5
Oats broadcast at leaf drop	10.8	9.7	37.4	42.7
Oats broadcast at harvest	11.4	10.0	38.2	43.2
Oats till and drill	11.3		36.8	
Control	11.5	10.5	37.2	43.3
Rye broadcast at leaf drop	11.8	8.8	36.1	36.8
Rye broadcast at harvest	11.3	8.8	35.9	38.2
Rye till and drill	11.7		38.7	
Control	11.5	9.1	38.6	39.7
c.v.	7.6	6.0	6.1	6.9
Probability				
Crop Type	NS	*	NS	NS
Method/Timing	NS	NS	NS	NS
Crop x Method	NS	NS	*	NS
Location	*		*	
Location x Crop	NS		NS	
Location x Method	NS		NS	
Location x Crop x Method	NS		*	

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability.

iii) Corn Plant Silking

The type of crop species used in the treatments did not influence the days to 50% silking of corn plants at either sites 2, 3 or 4. At sites 2 and 3 however, silking was influenced by the method of cover crop application (Table 9). In general, the days to 50% silking of the corn plants in the broadcast at leaf drop and to a lesser extent the broadcast at harvest treatments for all species at sites 2, 3 and 4 were the same or slightly longer than those recorded for the control.

iv) Corn Grain Yield and Moisture Content

When corn yields were combined over location/years for sites 1, 2 and 3, the interactions of location/years by crop and location/years by method were nonsignificant, indicating that cover crop species and method of application of the cover crop had the same effect on yield over the three locations (Table 2).

Corn yields were comparable or better than the control for all treatments sown with barley, regardless of the method used (Table 10). For the plots sown with oats only the corn in the plots where oats were broadcast at harvest yielded better than the control. In a similar pattern only one treatment, rye till and drill, recorded corn grain yields comparable to the control.

At site 4 in the barley main plot the control yielded more grain corn than any other treatment. In the oat main plot all corn grain yields related to method of application treatments were similar to the control. In the rye main plot the corn planted where rye was seeded at leaf drop yielded more than the control.

The effect of crop species and method of application on corn moisture at harvest was not significantly different over location/years (Table 2). Neither crop type nor method of application or the interaction between the two influenced moisture content (Table 2). There was not a wide variation in grain corn moisture content between the treatments. Overall the corn sown in the rye broadcast at harvest treatment had the lowest moisture content (28.8%) and the corn sown in the oats till and drill treatment the highest (31.7%), with all other treatments between these two values. Again, at site 4 there was not a wide variation between treatments. The values ranged from 44.4% to 47.2% moisture.

Table 9: Days to 50% Corn Silking for the Cereal Cover Crop Studies Located in the Huron and Middlesex Counties, 1987-89.

	Days to 50% Silking		
Treatment	Site 2	Site 3	Site 4
Barley broadcast at leaf drop	84.5	70.0	80.8
Barley broadcast at harvest	81.0	70.5	81.0
Barley till and drill	82.0	69.0	
Control	84.0	69.5	80.8
Oats broadcast at leaf drop	83.5	70.0	79.0
Oats broadcast at harvest	82.5	69.5	82.0
Oats till and drill	84.0	69.5	
Control	82.0	70.0	79.5
Rye broadcast at leaf drop	85.0	71.8	81.0
Rye broadcast at harvest	83.5	71.0	81.0
Rye till and drill	82.5	69.0	
Control	80.5	69.0	80.0
c.v.	2.3	1.2	3.2
Probability			
Crop Type	NS	NS	NS
Method/Timing	*	*	NS
Crop x Method	NS	*	NS

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability.

Table 10: Mean Corn Grain Yield and Moisture Content at Harvest for the Cover Crop Studies Located in Huron and Middlesex Counties, 1987-89.

	Mean Grain Corn Yield at 15.5% Moisture (kg/ha)		Mean Grain Corn Moisture Content at Harvest (%)	
Treatment	Sites 1-3	Site 4	Sites 1-3	Site 4
Barley broadcast at leaf drop	6191	4060	31.4	46.1
Barley broadcast at harvest	6516	3600	30.5	46.9
Barley till and drill	6210		29.8	
Control	6094	4560	29.9	47.2
Oats broadcast at leaf drop	5894	4570	29.7	46.7
Oats broadcast at harvest	6742	4490	30.8	44.4
Oats till and drill	6117		31.8	
Control	6661	4460	29.7	45.8
Rye broadcast at leaf drop	6152	3600	31.7	47.2
Rye broadcast at harvest	6397	3330	28.8	47.0
Rye till and drill	6697		29.4	
Control	6651	3380	31.3	46.6
c.v.	10.8	15.2	11.9	4.0
Probability				
Crop Type	NS	NS	NS	NS
Method/Timing	*	NS	NS	NS
Crop x Method	NS	NS	NS	NS
Location	*		*	
Location x Crop	NS		NS	
Location x Method	NS		NS	
Location x Crop x Method	NS		*	

* Significant at the 0.05 level of probability.
NS Not significant at the 0.05 level of probability

5.2.1 Spring Species Variety Trial Results

In general, the barley varieties recorded the most plants emerged and produced the most dry matter followed by triticale as measured on November 15, 1988 . The Bruce variety of barley measured the greatest number of emerged plants and produced the most dry matter. Wet weather conditions persisted in the fall of 1988 and may have affected the growth of the plants.

The following spring (May, 1989) it was found that only the Triwell triticale plants survived the winter in all four replications. The number of plants per square metre for the triticale were 121 (rep 1), 59 (rep 2), 84 (rep 3) and 87 (rep 4). It is also important to note that for both Leger and Sophie barley a few plants (unmeasurable) survived the winter.

5.3 Phytotoxin Results

Analysis of soil samples for phytotoxins, carried out by K. Janovicek (U of G graduate student) on the rye only treatment plots at sites 2 and 3, showed no detectable levels of volatile fatty acids for any treatment or site. Phenolic compounds were detected and increased up to about May 10 and then started to decrease although not statistically different for treatment, year or sampling date. When concentrations of the phenolic compounds were summed over sampling days after planting, differences amongst the rye treatments were significant (p#0.05). The highest concentration occurring on the rye broadcast at leaf drop treatment.

Yields produced by the rye treatments only show that at site 2 the control yielded more than the other treatments. At site 3 there was no difference between the grain corn yields on the rye treatments versus the control. It should be noted however, that the rye broadcast at leaf drop treatment was the lowest yielding treatment at both sites.

5.4 Discussion

Weather conditions during the 1987-1988 growing season were notable for extremes in precipitation during critical times of the year. At site 1 rainfall during October and November of 1987 was approximately 70% and 32% greater than the 30 year average. A similar pattern was recorded for site 2 where rainfall was 65% and 57% greater than the 30 year average for October and November respectively. During the spring of 1988 rainfall was lower than average at both sites. The month of June was particularly dry. Air temperature during October, 1987 was lower than normal at both sites.

During the dry period, however, air temperature was not significantly higher than the long term average.

Weather conditions during the 1988-89 growing season also were notable for extremes in precipitation. At site 3, fall rainfall ranged from 72% above normal in September to more than double the normal precipitation in October, with 25% more rain in November. During the 1989 growing season precipitation was close to average except in April when 60% of the normal precipitation occurred, in July, close to corn silking time, when only 4% of the normal precipitation occurred and in August when 47% of normal precipitation occurred. In May however 75% more rain than normal was recorded. Air temperature was cooler than normal in October 1988 and April 1989. For the remainder of the season temperatures at site 3 were average.

At site 4, l988 fall precipitation was well above normal causing problems with treatment application. During 1989 precipitation was close to the average except during May and July when above normal precipitation occurred. Throughout the 1988-89 growing season air temperature was close to the long term average for the area except for October 1988 which was somewhat cooler than normal and November 1988 which was somewhat warmer than average.

As a result of the meteorological conditions, in particular extreme moisture conditions at critical periods, the magnitude of the treatment differences in the study was probably affected.

With regard to site management conditions, no problems that would significantly affect the outcome of the trials were experienced. It was noted, however, that some barley plants which overwintered did grow at all sites. No overwintering oats were observed. The survival of the barley, a non-winter hardy species, was not anticipated and a herbicide treatment to control the vegetation was required. For this reason the spring species/variety trial was implemented in year 2. Again a few barley plants did over winter, although the Triwell triticale had more consistent survival over winter than any of the barley varieties tested. This would be expected as triticale is a hybrid produced by crossing duram wheat and rye, of which both species are known to survive the winter. If spring barley varieties do over winter on a consistent basis, this could have a negative influence on the economics of this practice, since the expense of an extra control treatment may be required.

The data from two years of study indicate that soil residue cover and/or amount of surface dry matter are enhanced during the fall, early spring and after planting (rye only) by the seeding of cereal species into soybeans before or at harvest thus increasing the potential erosion control benefit during this period.

The rainfall simulation study indicates however that at site 3 on a relatively gentle slope (3.4%) under historical no till crop management the presence of a cover crop did not significantly enhance the control of soil loss due to run-off when compared to the check. In this study it is also noted that work conducted by the Ontario Institute of Pedology (OIP) recorded soil losses of 8.9 g/m^2 for no till plots and 25.6, 30.4, and 44.7 g/m^2 for chisel plough, offset disc, and moldboard plough, respectively. These results bring into question the usefulness of the cereal cover crops for erosion control in no till crop systems. Since soil surface residue cover and above ground cereal dry matter are generally greater than the control in the fall and early spring, with little benefit remaining after planting, it is apparent that for soil erosion control purposes the cereal cover crops may provide the greatest benefit when used in spring tillage cropping systems. A challenge exists in developing a conservation cropping system that will allow producers farming on poorly drained, clay-type soils to take advantage, at least in part, of the benefits obtained through the use of cover crops i.e. soil erosion and phosphorus loading control, nutrient recycling, soil structure improvement and weed control, while still minimizing the risk of poor seedbed conditions at planting. Those soils however with a high clay content and poor drainage can be delayed in drying out and warming up in the spring if residue cover is too great. Producers farming under these conditions are reluctant to plant a cover crop such as winter rye that is known for prolific spring growth, because of the risk that main crop planting will be delayed in spring due to unacceptable seedbed conditions. A cover crop system based on spring barley or oats sown at soybean leaf drop or harvest, with the main crop planted in a conventional or no till system in the spring, may be an acceptable option for these producers.

With regard to corn plant emergence and early growth, the more dry matter accumulated on the soil surface, the greater the retention of moisture under the residue. This concept may have attributed to the increase in plant emergence at 14 DAP on the rye plots, especially in the spring of 1988 when the weather conditions were extremely dry at planting. Phenolic compounds however were found in the soil samples from the rye plots in the phytoxin work carried out by K. Janovicek (University of Guelph graduate student). This may have contributed to the slower growth rate of the corn plants in the rye plots versus the rate of growth of corn in the oat and barley plots.

Producers often use crop yield as an indicator of treatment or management practice effect. When initially adopting a conservation measure main crop yields should be comparable or better than the `conventional' systems in order to encourage a more rapid adoption. In this study corn yields associated with all barley treatments and selected oat and rye treatments fell into this category. While other treatment benefits must be considered when identifying the most promising treatments, effect on main crop yield should be given substantial weight.

The results of these studies indicate that unless the cost of applying the cover crop is minimal the magnitude of the erosion control benefits may not be economical or practical in a no till system. Other benefits of cereal cover crops must be quantified and/or other crop management systems employed before the total impact of cereal cover crops is known.

6.0 CONCLUSIONS

i) Winter rye, spring barley and spring oats seeded at soybean leaf drop or at harvest increased soil residue cover when compared to soybean stubble alone, through winter and early spring.

ii) Only the presence of winter rye seeded at soybean leaf drop or harvest allowed for increased soil residue cover after no-till corn was planted relative to soybean stubble alone.

iii) The till and drill method of establishing a cereal cover crop resulted in a net decrease in soil residue cover when compared to soybean stubble alone.

iv) At the rates used in these trials, the seeding of a cereal cover crop at soybean leaf drop provided three to twelve times more above ground dry matter accumulation in the fall than any other treatment. The same treatment provided four to seventeen times more above ground dry matter accumulation in the spring. Dry matter accumulation was greatest for winter rye, followed by barley and oats.

v) Preliminary results from the thesis conducted by K. Janovicek indicate that in Ontario, the successful establishment of a rye cover crop after soybeans decreased corn yields even when the rye cover crop is desiccated two weeks prior to planting and residues are moved out of the row area using unit mounted disc-farrowers. Although not completely confirmed, inhibition of corn growth by rye residues may be due to the release of phenolic compounds.

vi) Barley and to a lesser degree, oats, seeded at harvest followed by seeding at leaf drop resulted in optimum corn growth and yield.

vii) Practical considerations related to labour needs, weather and the timing of cover crop establishment for adequate fall growth do not favour the planting of cereal cover crops at or after harvest.

viii) From the spring cereal species/variety trial it is concluded that some species of spring cereal including triticale and barley have the ability to survive the winter and thus may require tillage or herbicide treatment in the spring in order to control escapes.

7.0 RECOMMENDATIONS

After two years of study the following recommendations are suggested:

i) that the studies be continued at the field scale to further determine the effects of promising treatments on soil and crop management strategies.

ii) that the treatments used at the field scale include spring barley and oats seeded at soybean leaf drop and harvest.

iii) that a literature review be conducted to determine current estimations of the minimum cereal soil cover and dry matter accumulation required to have a significant beneficial effect on soil erosion control, phosphorus loading, nutrient recycling, soil structure amelioration and weed control.

iv) that further research studies include a determination of optimum rate of cereal seeding.

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APPENDIX A

SITE SPECIFICATIONS

CEREAL SITE CHARACTERIZATION

Site	Location	Soil Texture	pH	P	K	Mg	OM	NO_3
01	L23,C13 London Twp. Middlesex Co.	Fine	7.9	18	208	365	5.0	13.0
02	L18,C15 Goderich Twp. Huron Co.	Fine	7.9	29	163	283	5.3	15.0
03	L76,Maitland C Goderich Twp Huron Co.	Silt Loam	7.7	20	147	301	---	---
04	L7,C2 Biddulph Twp Middlesex Co.	Silt Loam	7.7	29	118	179	---	---

APPENDIX B

WEATHER SUMMARY

MAXIMUM, MINIMUM, MEAN DAILY TEMPERATURES FOR BRUCEFIELD
(near sites 2 and 3)

		1987	1988	1989	Brucefield l951-1980
January	Min (ºC)		-2.5	1.2	-2.7
	Min (ºC)		-9.9	-6.1	-10.4
	Mean (ºC)		-6.2	-2.4	-6.6
February	Max (ºC)		-2.7	-3.5	-2.0
	Min (ºC)		11.6	-10.5	-11.1
	Mean (ºC)		7.2	-7.0	-6.6
March	Max (ºC)		3.9	2.7	2.7
	Min (ºC)		-5.9	-6.1	-6.0
	Mean (ºC)		-1.0	-1.7	-1.7
April	Max (ºC)		11.1	9.4	11.5
	Min (ºC)		1.5	0.4	0.9
	Mean (ºC)		6.3	4.9	6.2
May	Max (ºC)		20.9	18.1	18.4
	Min (ºC)		7.8	6.8	6.0
	Mean (ºC)		14.4	12.4	12.2
June	Max (ºC)		25.0	23.4	23.9
	Min (ºC)		9.1	12.5	11.2
	Mean (ºC)		17.1	18.0	17.6
July	Max (ºC)		29.7	28.5*	26.2
	Min (ºC)		16.5	12.3	13.6
	Mean (ºC)		23.1	20.4	19.9
August	Max (ºC)	24.4	26.8	26.2*	25.0
	Min (ºC)	14.6	15.7	11.7	12.9
	Mean (ºC)	19.5	21.3	19.0	19.0
September	Max (ºC)	21.4	19.2	20.7	20.9
	Min (ºC)	11.0	12.3	8.8	9.7
	Mean (ºC)	16.2	15.8	14.7	15.3
October	Max (ºC)	11.1	10.4	15.0	14.5
	Min (ºC)	2.9	3.8	4.7	4.7
	Mean (ºC)	7.0	7.1	9.8	9.6
November	Max (ºC)	7.3	7.6	4.9	6.8
	Min (ºC)	0.3	1.3	-1.7	-0.3
	Mean (ºC)	3.8	4.5	1.6	3.3
December	Max (ºC)	2.3	0.7		0.1
	Min (ºC)	-2.5	-6.4		-6.8
	Mean (ºC)	-0.1	-2.9		-3.4

* from Clinton area

DAILY TOTAL PRECIPITATION FOR BRUCEFIELD

(near sites 2 and 3)

		1987	1988	1989	Brucefield 1951-1980
January	Rainfall (mm)		29.0	28.0	23.7
	Snowfall (cm)		21.0	24.0	68.6
	Total (mm)		50.0	52.0	92.3
February	Rainfall (mm)		7.0	0.0	21.7
	Snowfall (cm)		55.6	29.0	44.1
	Total (mm)		62.6	29.0	65.8
March	Rainfall (mm)		32.3	19.0	41.3
	Snowfall (cm)		19.4	10.0	28.2
	Total (mm)		51.6	29.0	69.5
April	Rainfall (mm)		66.6	39.0	69.0
	Snowfall (cm)		3.0	6.0	5.6
	Total (mm)		69.6	45.0	74.6
May	Rainfall (mm)		61.0	118.0	68.6
	Snowfall (cm)		0.0	2.0	68.6
	Total (mm)		61.0	120.0	68.6
June	Rainfall (mm)		11.0	66.0	69.2
	Snowfall (cm)		0.0	0.0	0.0
	Total (mm)		11.0	66.0	69.2
July	Rainfall (mm)		62.2	2.8*	74.7
	Snowfall (cm)		0.0	0.0	0.0
	Total (mm)		62.2	2.8	74.7
August	Rainfall (mm)	77.3	77.0	36.7*	77.6
	Snowfall (cm)	0.0	0.0	0.0	0.0
	Total (mm)	77.3	77.0	36.7	77.6
Sept.	Rainfall (mm)	98.0	138.5	85.0	80.7
	Snowfall (cm)	0.0	0.0	0.0	0.0
	Total (mm)	98.0	138.5	85.0	80.7
October	Rainfall (mm)	133.0	193.0	86.3	77.9
	Snowfall (cm)	0.0	0.0	0.0	0.0
	Total (mm)	133.0	198.0	86.3	80.6
November	Rainfall (mm)	99.0	116.0	104.0	66.5
	Snowfall (cm)	50.0	2.0	51.0	28.2
	Total (mm)	149.0	118.0	155.0	94.7
December	Rainfall (mm)	52.0	25.0		43.0
	Snowfall (cm)	31.0	53.0		52.1
	Total (mm)	83.0	78.0		95.1

* from Clinton area

MAXIMUM, MINIMUM, MEAN DAILY TEMPERATURES FOR ILDERTON
(near sites 1 and 4)

	Ilderton	1987	1988	1989	1951-1980
January	Max (ºC)		-1.7	1.4	-2.9
	Min (ºC)		-9.3	-5.5	-10.1
	Mean (ºC)		-6.4	-2.0	-6.5
February	Max (ºC)		2.5	-3.3	-1.9
	Min (ºC)		-10.6	-9.2	-9.7
	Mean (ºC)		-6.5	-6.2	-5.9
March	Max (ºC)		4.6	3.8	3.2
	Min (ºC)		-3.5	-4.8	-4.5
	Mean (ºC)		0.6	-1.5	0.7
April	Max (ºC)		11.9	10.2	11.9
	Min (ºC)		1.8	1.2	1.9
	Mean (ºC)		6.8	5.7	6.9
May	Max (ºC)		21.2	18.7	18.6
	Min (oC)		8.4	7.9	7.0
	Mean (ºC)		14.8	13.3	12.9
June	Max (ºC)		26.1	24.2	24.4
	Min (ºC)		11.0	13.8	12.4
	Mean (ºC)		18.5	19.0	18.4
July	Max (ºC)		30.8	28.0	27.2
	Min (ºC)		16.6	15.4	14.7
	Mean (ºC)		23.3	21.7	21.0
August	Max (ºC)	25.2	27.5	25.9	26.0
	Min (ºC)	14.9	16.6	14.3	14.3
	Mean (ºC)	20.1	22.1	20.1	20.2
September	Max (ºC)	21.6	21.1	20.5	21.7
	Min (ºC)	12.1	11.1	11.0	10.9
	Mean (ºC)	16.9	16.1	15.8	16.4
October	Max (ºC)	11.7	10.1	15.5	15.0
	Min (ºC)	3.2	3.3	5.7	5.4
	Mean (ºC)	9.1	6.7	10.6	10.2
November	Max (ºC)	7.8	8.0	5.0	7.0
	Min (ºC)	1.3	2.0	-1.2	0.0
	Mean (ºC)	4.6	5.1	1.9	3.5
December	Max (ºC)	2.1	0.3		-0.2
	Min (ºC)	-2.4	-5.9		-6.6
	Mean (ºC)	-0.2	-5.6		-3.5

DAILY TOTAL PRECIPITATION FOR ILDERTON
(near sites 1 and 4)

		1987	1988	1989	Ilderton 1951-1980
January	Rainfall (mm)		23.3	27.2	25.4
	Snowfall (cm)		17.8	25.4	57.3
	Total (mm)		41.1	52.6	86.9
February	Rainfall (mm)		19.0	2.2	20.0
	Snowfall (cm)		51.4	22.0	41.0
	Total (mm)		70.4	24.2	64.4
March	Rainfall (mm)		33.6	36.8	46.9
	Snowfall (cm)		20.0	7.6	25.9
	Total (mm)		53.6	44.4	72.1
April	Rainfall (mm)		69.2	53.4	59.0
	Snowfall (cm)		0.0	10.0	7.4
	Total (mm)		69.2	63.4	76.5
May	Rainfall (mm)		65.6	101.2	80.8
	Snowfall (cm)		0.0	0.0	0.2
	Total (mm)		65.6	101.2	71.3
June	Rainfall (mm)		17.0	50.2	77.8
	Snowfall (cm)		0.0	0.0	0.0
	Total (mm)		17.0	50.2	83.4
July	Rainfall (mm)		119.2	96.0	59.0
	Snowfall (cm)		0.0	0.0	0.0
	Total (mm)		119.2	96.0	54.1
August	Rainfall (mm)	108.7	76.0	79.6	100.1
	Snowfall (cm)	0.0	0.0	0.0	0.0
	Total (mm)	108.7	76.0	79.6	88.1
September	Rainfall (mm)	67.8	92.4	52.2	73.9
	Snowfall (cm)	0.0	0.0	0.0	0.0
	Total (mm)	67.8	92.4	52.2	76.7
October	Rainfall (mm)	112.4	110.8	63.6	56.3
	Snowfall (cm)	0.0	22.2	0.0	0.9
	Total (mm)	112.4	133.0	63.6	66.1
November	Rainfall (mm)	77.4	110.0	86.6	62.3
	Snowfall (cm)	29.4	10.2	36.0	25.8
	Total (mm)	106.8	120.2	122.6	81.1
December	Rainfall (mm)	59.6	27.6		43.0
	Snowfall (cm)	44.2	53.2		56.6
	Total (mm)	103.8	80.2		102.8