TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

FIELD SCALE TESTS OF THE MODIFIED MOLDBOARD PLOW

FINAL REPORT

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EXECUTIVE SUMMARY

The erosion of agricultural land and the associated pollution of Lake Erie with sediment and phosphorus have been identified as major agronomic and environmental problems in Ontario [1,2]. Of the several methods available to control soil erosion and phosphorus movement conservation tillage systems are rated among the best [4]. A need exists for a conservation tillage system that will maintain crop yield and provide adequate residue cover.

Fall weather conditions in Ontario can prolong harvest and fall primary tillage is often done in excessively wet soil. Under these conditions the moldboard plough has been and will likely continue to be the implement of choice for many farmers. The main problem in using the moldboard plough is that the implement tends to bury almost all residue from the previous crop. As a result the potential for controlling soil erosion is considered poor. Little work has been done to improve this performance.

This research project is a continuation on a field scale of initial work[10] carried out by Conservation Management Systems (CMS) in 1988 which looked at modifications to the shapes of three moldboard types (general purpose, high speed and European) mounted on three makes of ploughs (White®, John Deere®and Overum®) commonly used in Ontario. This project studied the residue management potential capabilities of different configurations of the modified moldboard as first used by Vyn, Daynard and Ketcheson
The field scale modified moldboard trial (1989 - 90) was carried out at four different sites within the Lake Erie Basin. Each site was located in a grain corn stubble field with one site in each of Perth and Middlesex Counties and the two remaining sites situated in Kent County.

The trials were set up as a "modified" randomized complete block design consisting of three or four replications depending on the amount of room available within the cooperator's field. The treatments consisted of three modifications (cuts) to the moldboard shape and one control (full moldboard). At one site a Norcan Minibottom® was also included as a treatment.

Soil surface residue cover data were collected at four different dates within the project time frame. They included: before ploughing (fall ' 89); after ploughing (fall '89); after spring run-off (early spring ' 90), and after planting (spring ' 90). At all sites there was an average initial (before ploughing) residue cover of 80 percent or greater with little variation among sites.

Only one of the four sites (site 1) showed a definite increase in residue levels immediately after ploughing as more cuts were made to the moldboard while at the remaining sites there was no advantage to altering the shape of the moldboard with respect to residue levels. The cooperator at site 1 used a European type plough set at 40.6 cm bottom widths. Two of the three remaining cooperators (sites 3 and 4) used 30.5 cm bottoms on their European type ploughs which resulted in residue levels between 24 and 36 percent after ploughing. The remaining site (site 2) also used a European type plough but with 35.6 cm bottoms with residue levels ranging from 12 to 14 percent. The Norcan Minibottom® was also used at this site which left average residue level of 20.1 percent after ploughing.

At site 3 all four treatments left 20 percent or greater residue levels after spring run-off. Of the remaining sites, only two treatments at site 1 (2nd and 3rd cut treatments) left residue above 20 percent. The Norcan Minibottom® at site 2 plus the full moldboard and 1st cut treatments at site 4 recorded residue levels within 2 percent of the benchmark 20 percent required for soil erosion control.

The full moldboard treatment at site 4 was the only treatment to leave at least 20 percent residue after planting followed by the 1st cut treatment at 18.2 percent residue. These two treatments had residue levels significantly greater than the 3rd cut treatment at this site. At the remaining sites there were no differences among treatments with average residue levels of 13, 9.4 and 9.4 for sites 1, 2 and 3 respectively.

In this field scale study other variables such as depth of ploughing and soil texture appeared to also influence the level of residue left on the soil surface. In general, there were no consistent significant differences among treatments in soybean plant growth, development and seed yield at the different sites.

ABSTRACT

The Effect of Moldboard Modifications on the Field Scale Residue Management Potential of the Moldboard Plough

In 1989-90 four trials were conducted in southwestern Ontario to study the effect of moldboard modifications on the field scale residue management potential of the moldboard plough. It was found that when using a European type plough set at narrower bottoms (30.5 cm) and a ploughing depth of 15.2 - 19.0 cm there was no advantage to modifying the moldboard shape on the amount of residue remaining on the surface in a loam to silty clay soil texture. When using the same type of plough at wider bottom widths (40.6 cm) and a ploughing depth of 19.0 cm, the amount of residue left on the surface in a silt loam soil tended to increase as a greater portion of the moldboard was removed.

Those sites which used the narrower bottoms left between 16 and 25 percent residue on the soil surface after spring run-off while only the 3rd cut treatments using the wider bottoms left residue amounts similar to these levels.

In general, there were no consistent significant differences in subsequent soybean plant growth and seed yield among the treatments at the different sites in the growing season following fall treatment application.

ACKNOWLEDGEMENTS

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CMS extends its appreciation for the assistance of those producers cooperating in the study.

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1.0 INTRODUCTION AND OBJECTIVES

The erosion of agricultural land and the associated pollution of Lake Erie with sediment and phosphorus have been identified as major agronomic and environmental problems in Ontario[1,2]. At the same time Ontario agricultural producers are striving to reduce the cost of production to leave as wide a profit margin as possible. They are motivated by an economic outlook that generally forecasts over-supply and low prices for agricultural commodities[3]. With these perspectives in mind it is apparent that those techniques that control soil erosion and phosphorus pollution but cost little to adopt, are of particular importance to Ontario's producers.

Of the several methods available to control soil erosion and phosphorus movement, conservation tillage systems are rated among the best[4]. In the United States where soil erosion by water is the main concern, conservation tillage is defined as "any tillage and planting system that maintains at least 30 percent of the soil surface covered by residue after planting"[5]. In Ontario the benchmark figure of 20 percent residue cover of the soil surface is often used in the definition of a conservation tillage system. This is based on the recommendations of researcher T. Vyn, at the University of Guelph[5].

Crop residue left on the soil surface intercepts and dissipates the erosive actions of water and wind. Many conservation tillage systems leave more than the required 20 to 30 percent residue after planting cover and are cost-effective in the long term. However, in the wide spectrum of situations where conservation tillage should be used, there are still some technological gaps and economic drawbacks.

A need exists in Ontario for a conservation tillage system that will maintain crop yield and provide adequate residue cover especially as the clay content of the soil increases and as the drainage capabilities of the soil decline. On a soil texture basis such a system would be of special importance to a large portion of Ontario's Class 1 to 4 land. From a crop production standpoint 25 percent of Ontario's agricultural land is used to produce grain corn. Fall weather conditions often prolong harvest (as in 1985 and 1986) and fall primary tillage is done in excessively wet soil. Under these conditions the moldboard plough has been, and will likely continue to be, the implement of choice for many farmers. Chisel ploughs and discs do not perform well in these soil texture and moisture conditions. No tillage and ridge tillage systems, while viable options, will probably only be successful with very good crop managers.

The main problem with using the moldboard plough is that the implement tends to bury almost all residue from the previous crop. As a result the potential for controlling soil erosion is considered poor. Little work has been done to improve on this performance. If the residue management capabilities of the moldboard plough could be increased to an acceptable level with little or no interference of the lifting and shattering action, then a very large gap in conservation tillage technology would be filled.

In addition a relatively simple modification to a familiar practice could open the door to further adoption of more effective conservation practices by producers previously unwilling to risk a change in crop management.

With regard to economics, surveys have shown that most farmers own a moldboard plough[6,7]. As a result a major portion of the extra capital cost often required for the purchase of additional machinery or for planter modifications as a new tillage system is phased in and an old system is phased out, could be eliminated.

Research by Vyn, Daynard and Ketcheson[8,9]has shown the potential for using the moldboard plough as a conservation tillage tool. In order to understand the merits of the above study, it is important to consider the work of these researchers on this topic and its ramifications for the Ontario farmer.

Since 1980, tillage research conducted by Vyn, Daynard and Ketcheson at the University of Guelph has studied the effect of various primary tillage tools on grain corn yields and soil surface residue cover. Corn was grown continuously on a silt loam and clay loam soil. The results of these studies are found in Tables 1 and 2. Of particular interest are the results obtained using the modified moldboard plough treatment.

The modified moldboard treatment involved the use of a moldboard plough where 70 percent of the actual moldboard part of each plough bottom was removed. No adjustments were made to the share, shin or landside leaving the integral parts of the plough bottom intact. With regard to the effect of the modified moldboard plough treatment on grain corn yield, the data indicate that this treatment was the only one out of five tillage treatments to produce grain corn yields similar to those produced after normal moldboard ploughing on both soil types. The same tillage treatment left three times as much residue cover on the soil surface as the conventional moldboard plough. The results approached the benchmark requirement of 20 percent soil residue cover left after planting

Table 1: **Effect of Various Primary Tillage Tools on Surface Residue Cover in Spring for Continuous Corn Production on Two Soil Types (Average of 1981-84).**

Primary Tillage	Surface Residue Cover (%)			
		Silt Loam	Clay Loam	
	Pre-Plant	Post Plant	Pre-Plant	Post Plant
Moldboard plough	7	4	7	5
Modified moldboard	21	14	20	14
Wide-sweep plough	39	20	37	18
Disk-chisel plough	30	20	25	14
Modified disk-chisel	26	19	19	12
Zero tillage	62	47	56	49
S.E. (difference)	1.8	1.6	1.7	1.6

Adapted from Vyn, T.J., and T.B. Daynard. 1985. Feasibility of Various Primary Tillage Implements for Maize Production in Ontario. University of Guelph, Guelph, Ontario.

Table 2: **Effect of Various Primary Tillage Tools on Grain Yields of Corn Grown on Two Soil Types (Average of 1981-84).**

Primary Tillage	Grain Yield (t/ha)	
	Silt Loam	Clay Loam
Moldboard plough	6.86	7.05
Modified moldboard	6.58	6.93
Wide-sweep plough	6.37	6.72
Disk-chisel plough	6.45	6.53
Modified disk-chisel	6.49	6.87
Zero tillage	6.12	6.36
S.E. (difference)	0.198	0.253

Adapted from Vyn, T.J., and T.B. Daynard. 1985. Feasibility of Various Primary Tillage Implements for Maize Production in Ontario. University of Guelph, Guelph, Ontario.

for soil erosion control. Visual assessments under field conditions in Huron County using a similarly modified plough indicate that residue covers of greater than 20 percent are attainable.

Using the moldboard plough system, a farmer can increase the residue management potential while still maintaining crop yield. The expected cost of changing over to this system from a conventional moldboard plough system would be minimal. Currently, used plough bottoms and moldboards are sold for scrap metal value at best. Some are simply discarded or left lying around the farm buildings. These used parts could be recycled into a modified plough system. Most farmers have their own cutting torch or access to a local welding shop. As a result, they could remove the major portion of the moldboard and use the plough bottoms in a modified moldboard plough system.

This research project is a continuation of initial work carried out by CMS in 1988 under the TED program. The previous work [10] looked at modifications to the shapes of three moldboard types (general purpose, high speed and European) mounted on three makes of ploughs (White®, John Deere®and Overum®) commonly used in Ontario. The full moldboard on each of these plough makes was used as a control and progressive cuts were made with approximately 78, 64 and 36 percent of the moldboard remaining after each cut, respectively.

Results indicated that soil residue cover tended to increase as a greater portion of the moldboard was removed but tended to be slightly less than 20 percent after planting. Maintenance of a six inch plough depth became more difficult as the greater portion of the moldboard was removed. Also, specific draft tended to decline for the Overum® and John Deere® plough makes as a greater portion of the moldboard was removed.

The modifications made to the moldboard in the 1989-90 project were somewhat different than those made in the previous project. This research was carried out using the cooperator's actual equipment under normal field conditions and attempted to determine the effects of modifying the moldboard on soil residue cover, machine mechanical performance and subsequent crop growth.

The information gathered from the above studies could help in allowing the moldboard to fill an important gap in current conservation tillage technology. If the moldboard plough can be used successfully in a conservation tillage system, many more farmers will seriously consider the conservation option. Once a producer makes the first step toward residue management the chances of continued commitment to the idea increase substantially.

Objectives

1. To demonstrate to farm cooperators and extension personnel the effect of moldboard modifications on the amount of grain corn residue cover left on the soil surface.

2. To demonstrate where possible, these effects relative to:
    - different models of moldboard ploughs;
    - different bottom widths;
    - different ploughing depths;
    - different soils and field conditions.

3. To monitor the effects of moldboard modification treatments on soil residue cover, crop growth and yield.

4. To use this information to prepare preliminary, general guidelines on the settings and adjustments of certain moldboard ploughs with the goal of optimizing residue management potential.

2.0 DEVIATIONS FROM THE WORK PLAN

In general the work plan proceeded as indicated in the original proposal. As requested by the client, four sites instead of six were implemented.

With regard to treatments involving a change in the depth of ploughing, pre-trial testing showed that different depths of ploughing were very difficult to achieve in the fall of 1989. As a result, and after discussing the problem with the scientific authority, the depth treatments were excluded from this study.

Soil moisture content and density were monitored on two of the four sites. At the third site, a breakdown in the equipment (a Campbell Pacific Nuclear Portaprobe) midway through the trial precluded the gathering of a complete set of data. At the fourth site the probe was unavailable for use due to a short lead time available prior to implementing the treatments.

Soybean seed yields were taken by the cooperator without the assistance of CMS staff at site 3. Due to extremely wet conditions at harvest only one replication was sampled. For this reason no statistical analysis was carried out on the data.

Due to computer related problems, data on final plant population and lodging at harvest are not available from sites 2 - 4 and site 3 respectively.

3.0 MATERIALS AND METHODS

3.1 Location and Site Specifications

Staff from the Ontario Ministry of Agriculture and Food (OMAF) assisted CMS in the selection of potential sites for the study. Preference was given to sites that were predominantly clay and had been planted to field corn in 1989. A total of four sites were selected for the field scale modified moldboard trials within the Lake Erie Basin. Site location and soil information for each of the sites are summarized in Table 3.

Table 3: A Summary of the Site Location and Soil Information for Each of the Sites Included in Field Scale Modified Moldboard Study, 1989-1990.

	Site 1	Site 2	Site 3	Site 4
Location				
Lot	9	19	5	178
Concession	6	Range 3 South	8	Talbot Road
Township	Downie	Caradoc	Raleigh	Romney
County	Perth	Middlesex	Kent	Kent
Soil Information				
Rep 1 Texture	Silt Loam	Silt Loam	Clay Loam	Silty Clay
% Sand	19.8	21.8	30.4	14.5
%(kg) Silt	57.1	52.0	39.7	42.3
% Clay	23.0	26.2	30.0	45.2
Rep 2 Texture	Silt Loam	Silt Clay Loam	Loam	Silty Clay
% Sand	22.4	18.8	44.0	16.2
% Silt	52.9	51.6	34.1	42.3
% Clay	24.7	29.6	21.9	41.5
Rep 3 Texture	Silt Loam	Loam	Loam	Silty Clay
% Sand	21.7	32.0	45.0	16.4
% Silt	52.2	44.0	34.2	42.2
% Clay	26.1	23.7	20.9	41.4
Rep 4 Texture			Loam	
% Sand			38.9	
% Silt			35.7	
% Clay			25.3	
Conditions at Ploughing	Excellent	Surface moisture caused slippage	Excellent	Surface moisture caused slippage

3.2 Experimental Design and Analysis

When incorporating research work into a cooperator ' s logical field scale management patterns, the standard research plot designs sometimes must be compromised. This was especially true for these trials. Farmers normally start ploughing at a "strikeout" and work across the field using the previous furrow as a guide. Creating a new "strikeout" for every plot or treatment leaves one or two open or "dead" furrows per treatment. Farmers do not want the unevenness this creates especially when soybeans follow as the next crop. In addition, when a cut or modification is made on the moldboards, all plots in all replicates associated with that treatment must be completed since the "cuts" are irreversible. As a result, the design of the trial and the implementation of the treatments is compromised somewhat from a statistical perspective. The design used for these trials is best described as a "modified" randomized complete block design. The standard design used in the 1989 trials is shown in Figure 1. The number of replications varied between locations and was dependant upon the amount of land available for the trial.

The data were analyzed, where applicable, using an analysis of variance for a randomized complete block design at 0.05 level of significance. In this report locations were analyzed individually.

The treatments consisted of three modifications (cuts) to the moldboard shape and one control (full size moldboard). In addition, at site 2, a Norcan Minibottom® mounted on a separate plough with its own tractor was also included as a treatment. Figure 2 illustrates the various cuts made to the moldboard.

3.3 Agronomic Practices

In November of 1989, CMS implemented the field scale modified moldboard trial at four locations within the Lake Erie Basin in southern Ontario. Detailed information regarding the tillage equipment used by each cooperator at each site as well as previous and subsequent cropping practices for the field are given in Table 4. It is important to note that the secondary tillage performed at site 2 was influenced by the resulting soil surface conditions which may be related to the applied treatments as well as the moisture content of soil at ploughing. Each field was previously cropped to field grain corn in 1989 followed by soybeans in 1990.

Figure 1. EXAMPLE DESIGN of FIELD TRIAL

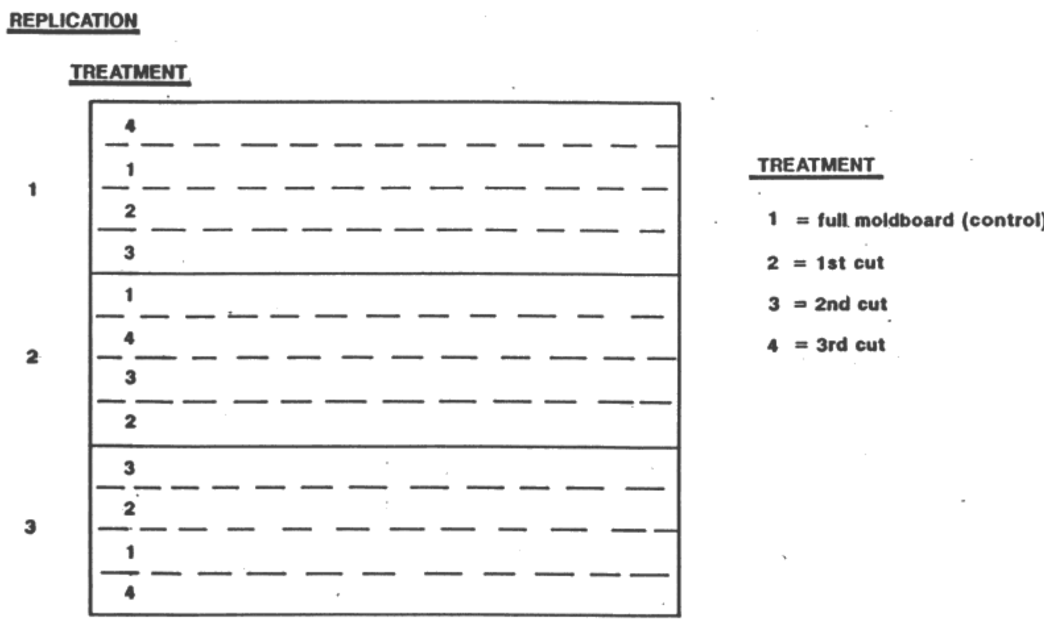
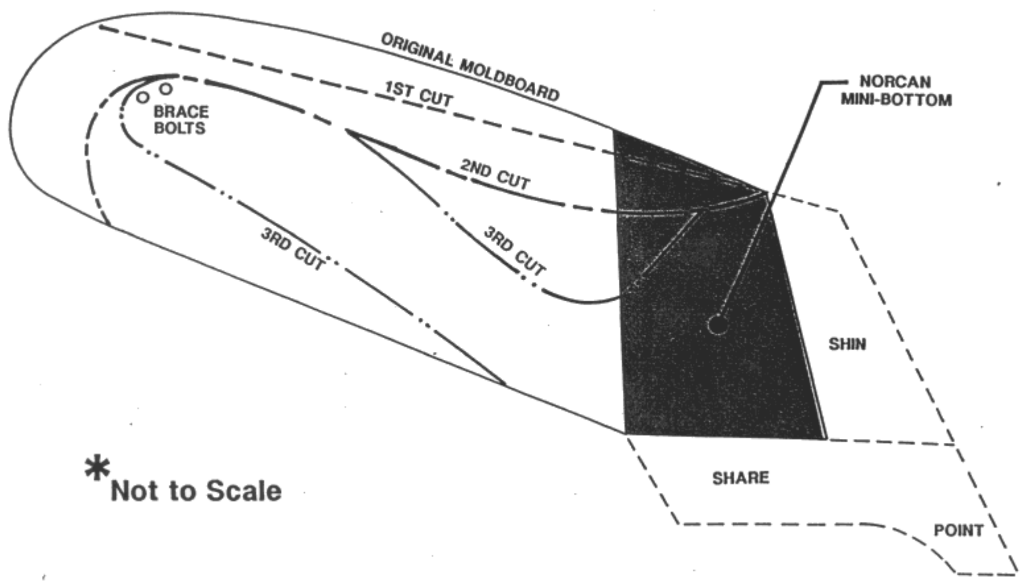


Figure 2. BASIC DESIGN of MOLDBOARD MODIFICATIONS used in 1989 TRIALS



3.4 Observations and Measurements

3.4.1 Moldboard Plough Mechanical Performance

The researchers visually monitored the changes, if any, to the performance of the plough that were a result of the modification being made to the moldboard. In addition, comments were solicited from the cooperators regarding any changes in draft for the different moldboard designs.

3.4.2 Soil Moisture Content and Bulk Density

A Campbell Pacific Nuclear Portaprobe was used to collect the soil moisture content and bulk density at two of the four sites on the day of ploughing.

3.4.3 Soil Surface Residue Cover

A rope with 50 knots at 15 cm intervals was used to make four counts of soil residue cover per plot. Residue cover was determined by counting each knot on the rope that touched a piece of residue. The knotted rope was positioned diagonally across the rows. Data were adjusted to percent residue cover using the following equation:

$$R\ (\%) = \left[\frac{\sum_{j=1}^{4} C_j}{4} \right] \times 100$$

where R = mean soil residue cover per plot (%);
C = number of knots touching a piece of residue per 50 knots;
j = individual values of C.

Soil surface residue cover data were collected at four different times within the project time frame. These included after harvest (fall 1989); after ploughing (fall 1989); after spring run-off (early spring 1990); and after planting (spring 1990).

Table 4: **Tillage and Cropping Information for the Sites Included in the Field Scale Modified Moldboard Study, 1989-1990.**

	Site 1	Site 2		Site 3	Site 4
Primary Tillage Equipment and Operating Information (1989)					
Plough type	Overum® 616 Semi-mount	Overum®	Kvernland® using Norcan® Minibottoms	Kongskilde® Trail type	Kongskilde® Trail type
Bottom width	40.6 cm	35.6 cm	35.6 cm	30.5 cm	30.5 cm
# of furrows	6	4	5	8	7
Operating speed	8.9 km/hr	8.9 km/hr	8.0 km/hr	8 km/hr	8.4 km/hr
Operating depth	19.0 cm	15.2 cm	20.3 cm	15.2 cm	19.0 cm
Date of ploughing	08/11/89	15/11/89		14/11/89	25/11/89
Comments: Combine direction of harvest relative to direction of ploughing affected the amount of residue left on soil surface after ploughing.					
Spring Tillage Information (1990)					
Secondary tillage	cultivate 2x	disc 3x		cultivate lx disc lx	cultivate 3x
Previous Crop Production (1989)					
Crop	corn	corn		corn	corn
Seeding rate	69187 s/ha	65728 s/ha		69187 s/ha	68446 s/ha
Row spacing	76.2 cm	96.5 cm		91.4 cm	76.2 cm
Yield	7526 kg/ha	6272 kg/ha		8404 kg/ha	8154 kg/ha
Current Crop Production (1990)					
Crop	soybeans	soybeans		soybeans	soybeans
Seeding date	20/05/90	31/05/90		18/05/90	13/06/90
Seeding rate	89.6 kg/ha	100.8 kg/ha		123.2 kg/ha	76.2 kg/ha
Row spacing	38.1 cm	17.8 cm		16.8 cm	38.1 cm
Planting equipment	Great Plains Drill®	I.H. 510 Drill®		Coulter Caddy®	Great Plains Drill®

3.4.4 Soybean Plant Stand

The number of soybean plants emerged per square metre were counted at four locations within each plot. These data were collected approximately two, four and six weeks after planting for site(s) 4, 1 and 2, and 3, respectively.

3.4.5 Soybean Plant Height

The height of the soybean plants within one square metre were recorded at four locations within each plot. Heights were taken from the ground to the tip of the longest extended soybean leaf to the nearest half centimetre. Plant heights were taken at approximately seven to eight weeks after planting for sites 1, 2 and 4. Data at site 3 were collected at approximately 11 weeks after planting.

3.4.6 Soybean Final Plant Population

The number of soybean plants located within a one square metre area were counted at four locations within each plot. These data were collected prior to harvesting the plots.

3.4.7 Soybean Plant Lodging

The soybean plants were visually assessed for the amount of lodging that had occurred in each plot prior to harvest. The ratings were between 0 and 100 where 0 was equivalent to no plants lodged and 100 equalled all plants lodged. The data are presented as percent lodging.

3.4.8 Soybean Seed Yield and Moisture Content

The centre of each treatment strip was mechanically harvested using the cooperator ' s combine. The soybean seed was then weighed in a weigh wagon supplied by Agriculture Canada. Moisture content of the seed for each treatment strip was also recorded at this time. The seed yield was adjusted to kilograms per hectare at 14 percent moisture content.

4.0 RESULTS AND DISCUSSION

Within the context of field scale evaluations of promising treatments it is important to note that inherent variations in treatment implementations between sites (see Tables 3,4) precludes the comparison of the results for any parameter between sites.

4.1 Moldboard Plough Mechanical Performance

The first cut to the moldboard was designed to remove the top of the moldboard to eliminate some of the inverting action. The cut appeared to make no difference to the operation of the ploughs at any of the four sites.

The second cut was more severe and removed the wing of the moldboard. The ploughs functioned properly at all sites with no noticeable change in draft.

The third cut was designed to remove everything but the moldboard support or brace. When ploughing was complete soil surface conditions at site 1 were acceptable while the other three sites were generally determined to be too rough to be acceptable. The roughness of the soil surface after the third cut treatment may inhibit adoption of this treatment in the clay plains of Essex. A smooth soil surface is considered essential by producers for proper field drainage and drying in spring. In other counties in Ontario where the slope of the land assists in drainage, roughness of ploughing will not likely inhibit adoption. The ploughs functioned properly however and no difference was noticed in draft on the four sites.

The Norcan Minibottom®, used only at site 2, also left unacceptably rough soil surface conditions at completion. In order to make the plough pull straight with the Norcan Minibottom® attachment the plough was set to a narrower width i.e. from 40.6 to 35.6 cm.

4.2 Soil Moisture Content and Bulk Density

The volumetric soil moisture content prior to treatment implementation was similar across all treatment plots within each of sites 1 and 2. Higher volumetric moisture contents were recorded at site 2 on November 15, 1989 with values ranging from 44.9 to 49.0 percent. At site 1 the volumetric moisture content recorded on November 8, 1991 was somewhat lower than the other site with values ranging from 35.9 to 38.8 percent (Table 5). The potential effect of soil moisture content on other parameters measured is considered equal across all treatments since the soil moisture contents were relatively consistent among treatment plots within the two sites although the higher moisture content at site 2 may have influenced the roughness of the soil surface left after ploughing.

Although no physical volumetric soil moisture content measurements were taken at sites 3 and 4, it was observed by the researchers that the moisture content did not appear to change dramatically over the area of the trial .

As indicated in Table 5, the bulk densities of the soils from the two sites were found to be very similar within each site with values ranging between 1.60 g/cm^3 to 1.67 g/cm^3 and 1.59 g/cm^3 to 1.64 g/cm^3 for sites 1 and 2, respectively. Since the particle size distribution of these soils was found to be similar within each site, it may be expected that the soil bulk densities would also fall within a similar range.

Table 5: Mean Volumetric Soil Moisture Content and Mean Soil Bulk Density on the Day of Ploughing for Two Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Volumetric Soil Moisture Content (%)		Bulk Density (g/cm^3)	
	Site 1	Site 2	Site 1	Site 2
Full moldboard	36.1 a+	44.9 a	1.60 a	1.59 a
1st cut	37.3 a	48.5 a	1.64 a	1.61 a
2nd cut	38.8 a	49.0 a	1.67 a	1.60 a
3rd cut	35.9 a	45.6 a	1.67 a	1.64 a
Norcan Minibottom		45.2 a		1.64 a
c.v.	7.4	8.5	5.2	4.6

\+ Values in the same column that are followed by the same letter are not significantly different (p 0.05) according to the Least Significant Difference test.

4.3 Soil Surface Residue Cover

Soil surface residue cover results are presented in Tables 6 through 9 and Figures 3 through 6.

Prior to treatment implementation soil residue cover was measured with all sites having initial residue coverages of 80 percent or greater (Table 6). At site 1, the full moldboard treatment plots had significantly less initial residue than the 3rd cut treatment plots. The mean residue levels ranged from 85.9 percent (full moldboard) to 91.5 percent (3rd cut) with the remaining treatments having residue levels between these values. Although not significant, the full moldboard and 1st cut treatment plots at site 2 had higher initial residue levels than the 2nd cut, 3rd cut and Norcan Minibottom® treatment plots. The mean residue levels recorded for this site ranged from 89.5 percent (Norcan Minibottom®) to 92.5 percent (1st cut). There were no significant differences among treatment plots at sites 3 and 4 with average initial residue levels of 84.4 and 90.9 percent, respectively.

Even though the moldboard cuts were similar in all four trials the residue levels after ploughing were quite different. It is important to note that variations in treatment implementations between sites precludes the comparison of soil residue cover and other parameters between sites. As indicated in Table 7, site 1 showed a definite increase in soil cover residue as more cuts were made to the moldboards while sites 2, 3 and 4 showed little change in residue level. Residue level increased by 14 percentage points (13.9 to 28.2%) between the full moldboard treatment and the 3rd cut treatment at site 1. At site 2, the Norcan Minibottom® left significantly more residue than the other treatments with residue levels of 20 percent whereas the remaining treatments averaged 13 percent residue. It is important to note that the field conditions left after using the Norcan Minibottom® were unacceptably rough.

Although the initial residue level before ploughing was the lowest at site 3, it had the greatest amount of residue left on the soil surface after ploughing. The residue levels ranged from 33.6 to 37.0 percent with no significant differences between treatments. There were also no significant differences between treatments at site 4. The amount of residue remaining on the soil surface after ploughing was between 23.9 and 28.1 percent for this site.

Cooperators at both sites 3 and 4 indicated they had previously attempted to increase residue levels and found that the European models, Overum® and Kongskilde® ploughs set at 30.5 cm bottom widths, left much more soil residue cover than North American style ploughs. The erosion control potential due to residue cover did not appear to improve on these plots as moldboard modifications were made but the field conditions became prohibitively rough on all plots except at site 1.

As shown in Table 8, there were no significant differences among treatments for residue levels measured after spring run-off for sites 1, 3 and 4. Residue levels ranged from 6.2 percent (full moldboard) to 23.5 percent (3rd cut) at site 1. The average after spring run-off residue levels were 22.1 and 17.6 percent for site 3 and site 4, respectively. At site 2 the Norcan Minibottom® treatment left significantly more residue than the full moldboard and 1st cut treatments but was not significantly different from the remaining treatments. The after spring run-off residue level ranged from 12.5 percent to 19.3 percent at this site.

It has been shown that various types of secondary tillage have the potential to increase residue levels by bringing to the surface some of the buried residue (Lobb, 1991, personal communication [(11)]). Whether or not residue levels increase as a result of secondary tillage depends on residue type, soil type, soil moisture conditions, tillage equipment used, and speed of tillage, etc. The increase in after planting residue levels for the full moldboard treatments at sites 1 and 4 may have been a result of any combination of the above factors.

The full moldboard treatment at site 4 was the only treatment to leave at least 20 percent residue after planting (Table 9). The residue level remaining after the spring tillage (cultivated three times) and planting was 20.2 percent for the full moldboard treatment followed by the 1st cut treatment at 18.2 percent residue both of which were significantly greater than the 3rd cut treatment. There were no significant differences among treatments for the three remaining sites. Residue levels ranged from 10.5 to 15.2 at site 1 and 8.5 to 10.3 at site 3. The Norcan Minibottom® recorded a residue level after planting of 14.5 percent which was approximately 5 percentage points greater than the remaining treatments at site 2.

Table 6: Mean Soil Surface Residue Cover Before Ploughing for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Soil Surface Residue Cover (%)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	85.9 b+	92.2 a	86.2 a	92.4 a
1st cut	87.3 ab	92.5 a	84.2 a	88.6 a
2nd cut	88.4 ab	91.3 ab	85.7 a	91.2 a
3rd cut	91.5 a	89.9 ab	81.4 a	91.3 a
Norcan Minibottom		89.5 ab		
c.v.	2.6	1.6	4.7	3.9

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

Table 7: Mean Soil Surface Residue Cover After Ploughing for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Soil Surface Residue Cover (%)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	13.9 b+	13.2 b	33.6 a	23.9 a
1st cut	16.4 b	12.2 b	36.8 a	24.5 a
2nd cut	21.2 ab	14.1 b	37.0 a	24.5 a
3rd cut	28.2 a	12.9 b	33.9 a	28.1 a
Norcan Minibottom		20.1 a		
c.v.	22.1	18.9	20.3	12.0

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

Table 8: **Mean Soil Surface Residue Cover After Spring Run-off for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.**

Treatment	Soil Surface Residue Cover (%)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	6.2 a+	12.5 b	20.0 a	19.2 a
1st cut	15.3 a	10.2 b	21.8 a	18.7 a
2nd cut	22.0 a	13.2 ab	22.3 a	16.7 a
3rd cut	23.5 a	14.5 ab	24.1 a	15.7 a
Norcan Minibottom		19.3 a		
c.v.	23.2	24.7	17.6	25.1

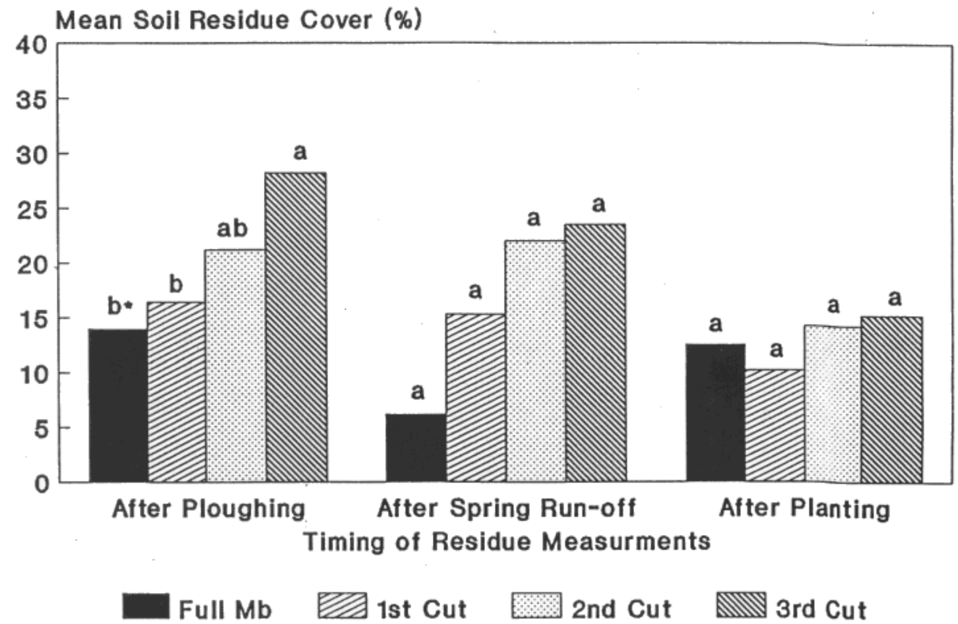
\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

Table 9: **Mean Soil Surface Residue Cover After Planting for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.**

Treatment	Soil Surface Residue Cover (%)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	12.5 a+	9.7 a	8.5 a	20.2 a
1st cut	10.2 a	6.2 a	8.8 a	18.2 a
2nd cut	14.2 a	8.5 a	10.3 a	13.8 ab
3rd cut	15.2 a	8.0 a	9.9 a	9.2 b
Norcan Minibottom		14.5 a		
c.v.	22.7	52.6	30.5	29.4

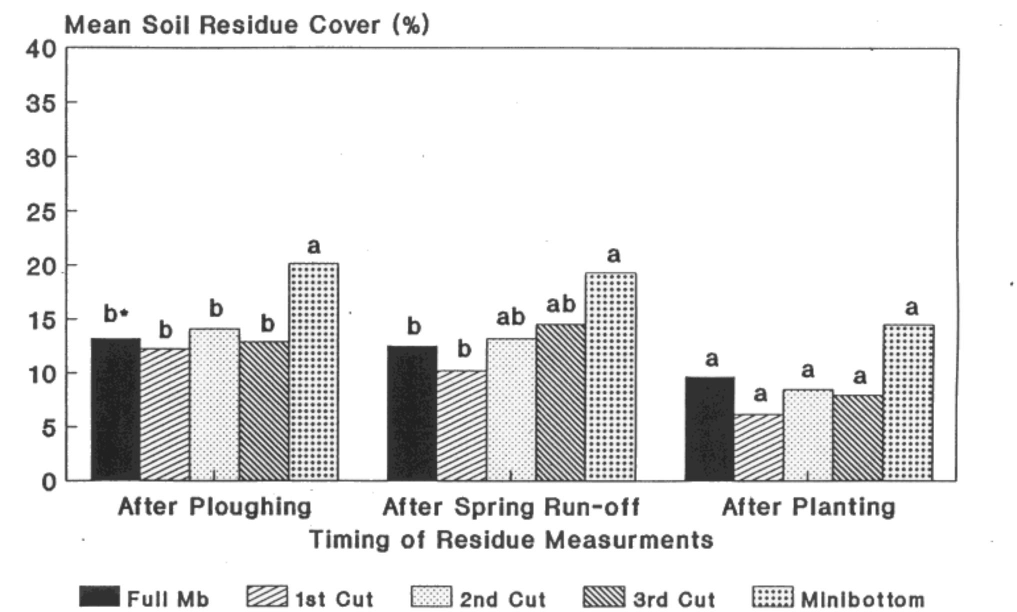
\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

Figure 3: Mean Soil Surface Residue Cover Over Time at Site 1. Field Scale Modified Moldboard Study, 1989-90.



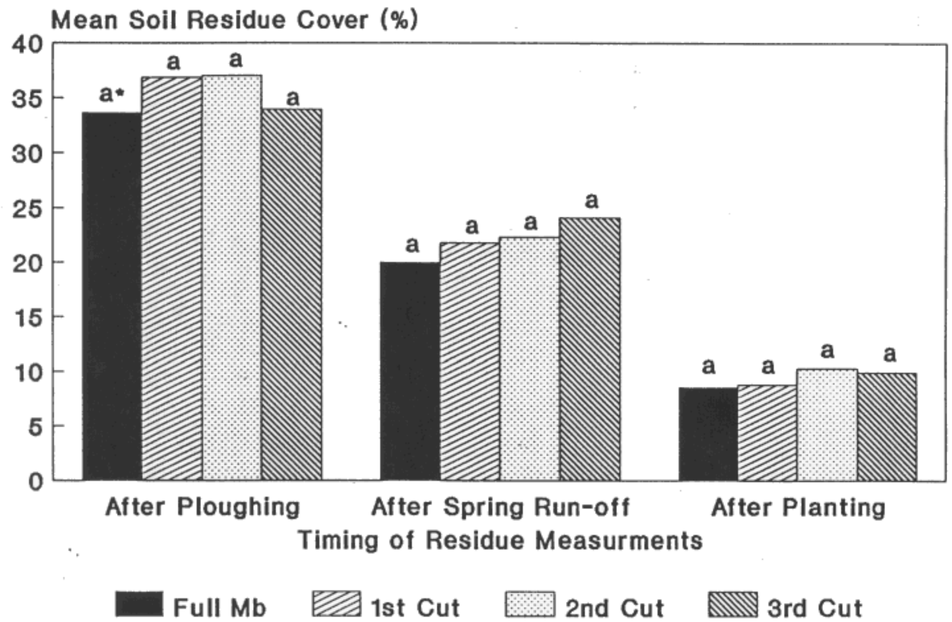
* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD).

Figure 4: Mean Soil Surface Residue Cover Over Time at Site 2. Field Scale Modified Moldboard Study, 1989-90.



* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD).

Figure 5: Mean Soil Surface Residue Cover Over Time at Site 3. Field Scale Modified Moldboard Study, 1989-90.



* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD).

Figure 6: Mean Soil Surface Residue Cover Over Time at Site 4 Field Scale Modified Moldboard Study, 1989-90

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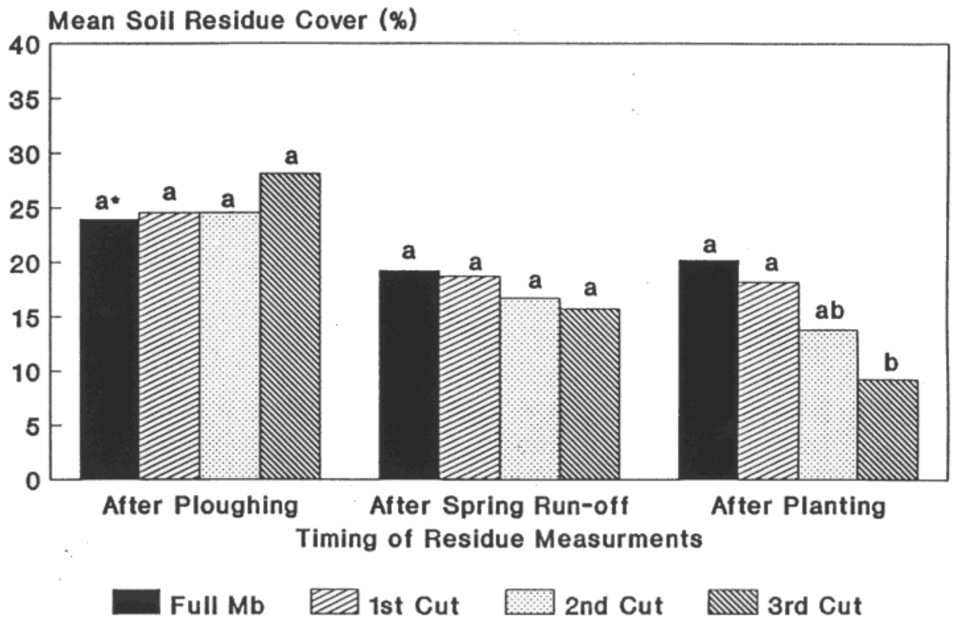

* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD).

4.4 Soybean Plant Stand

As shown in Table 10, significantly fewer plants per square metre were counted on the 2nd cut treatment (28.8) than the 1st cut treatment (35.3) at site 1 with no significant differences among the remaining treatments. There were relatively small differences between the number of plants per square metre at the other sites. The average population was 38.4, 38.6 and 30.4 plants per square metre for sites 2, 3 and 4, respectively.

Table 10: Mean Soybean Plant Stand for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Mean Soybean Plant Stand (Plants/m^2)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	31.9 ab+	38.3 a	39.6 a	31.1 a
1st cut	28.8 b	38.0 a	40.1 a	27.3 a
2nd cut	35.3 a	41.8 a	36.5 a	31.7 a
3rd cut	30.3 ab	37.0 a	38.3 a	31.5 a
Norcan Minibottom		37.0 a		
c.v.	10.2	10.9	4.6	12.6

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

4.5 Soybean Plant Height

The results (Table 11) indicate that soybean plant heights at sites 1 and 4 were not significantly different among treatments. At site 2 the soybean plants within the full moldboard treatment plots were significantly taller than the soybean plants within the 3rd cut treatment plots. The full moldboard treatment at site 3 also recorded the tallest plants. These soybeans were significantly taller than those in the 1st cut treatment plots but not significantly different from those in the 2nd and 3rd cut treatments.

Since different varieties were grown at each site and the data were collected at different soybean plant growth stages for each site, the plant heights between sites were not compared.

Table 11: Mean Soybean Plant Height for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Soybean Plant Height (cm)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	37.6 a+	53.1 a	69.4 a	64.7 a
1st cut	38.0 a	50.9 ab	64.7 b	69.9 a
2nd cut	38.0 a	48.2 ab	65.8 ab	71.9 a
3rd cut	37.2 a	45.8 b	65.5 ab	73.5 a
Norcan Minibottom		51.1 ab		
c.v.	4.6	7.6	4.2	9.5

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

4.6 Soybean Final Plant Population and Lodging

The results presented in Table 12 indicate there were no significant differences in soybean plant population among treatments at site 1. The average plant population per square metre was 34.1 plants.

Since no major problems occurred over the soybean growing season it is expected that the plant population at harvest for the remaining sites would be similar to those recorded in plant stand (section 4.4).

After visually assessing the amount of lodging at site 1 it was found that the full moldboard treatment plots had, on average, less plants lodged than the 1st, 2nd and 3rd cut treatments. At site 2 approximately 50 percent of the plants were lodged across the field while at site 4 no plants were lodged.

Table 12: Mean Soybean Plant Population at Harvest for the Four Locations Included in the Field Scale Modified Moldboard Study. 1989-1990.

Treatment	Plant Population (plants/m^2)	Soybean Plant Lodging*		
	Site 1	Site 1	Site 2	Site 4
Full moldboard	32.9 a+	10.9	50.0	0.0
1st cut	35.5 a	14.2	50.0	0.0
2nd cut	32.5 a	14.6	50.0	0.0
3rd cut	35.3 a	15.9	50.0	0.0
Norcan Minibottom			50.0	
c.v.	6.7	NA	NA	NA

* Visual rating between 0 and 100 where 0 = no plants lodged and 100 = all plants lodged.

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

NA Not applicable.

4.7 Soybean Seed Yield and Moisture Content

Soybean seed yield adjusted to 14 percent moisture content and the soybean seed moisture content at harvest are presented in Tables 13 and 14, respectively.

There were no significant differences among the treatments for soybean seed yield at site 1 with the yields ranging from 2840 kg/ha (full moldboard treatment) to 2955 kg/ha (3rd cut treatment). Although not significantly different, both the full moldboard and 1st cut treatments at site 2 recorded higher yields than the 2nd, 3rd and Norcan Minibottom® treatments. At site 4, the 2nd cut treatment soybean seed yield (3389 kg/ha) was significantly higher than the 3rd cut treatment (3241 kg/ha) with the full moldboard and 1st cut treatments yielding between these treatments.

The yield results for one replication at site 3 showed little variation between treatments with a yield of 3567 kg/ha for the 1st cut treatment, 3594 kg/ha for the full moldboard treatment and 3630 kg/ha for the 2nd and 3rd cut treatments.

There were no significant differences in soybean seed moisture content at harvest among the treatments for sites 2 and 4 with an average moisture content of 16.0 and 15.75

percent, respectively. The full moldboard treatment at site 1 recorded a lower moisture content of 17.8 percent compared to 18.4 percent for the remaining treatments at this site. Variation occurred in the soybean seed moisture content recorded at site 3 with values ranging from 15.9 to 16.4 percent moisture.

Table 13: Mean Soybean Seed Yield at 14 % Moisture Content for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Soybean Seed Yield at 14% Moisture (kg/ha)			
	Site 1	Site 2	Site 3*	Site 4
Full moldboard	2840 a+	3391 a	3594	3309 ab
1st cut	2918 a	3359 a	3567	3323 ab
2nd cut	2855 a	3241 ab	3630	3389 a
3rd cut	2955 a	3143 ab	3630	3241 b
Norcan Minibottom		3280 ab		
c.v.	4.4	3.2	NA	1.8

* Soybean seed yield sampled from one replication.

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

NA Not applicable.

Table 14: Mean Soybean Seed Moisture Content at Harvest for the Four Locations Included in the Field Scale Modified Moldboard Study, 1989-1990.

Treatment	Soybean Seed Moisture Content (%)			
	Site 1	Site 2	Site 3	Site 4
Full moldboard	17.8 ab+	16.2 a	15.9	15.7 a
1st cut	18.4 a	16.1 a	16.4	15.8 a
2nd cut	18.4 a	15.9 a	16.4	15.7 a
3rd cut	18.4 a	15.8 a	16.4	15.8 a
Norcan Minibottom		15.9 a		
c.v.	1.0	1.4	NA	1.2

* Soybean seed yield sampled from one replication.

\+ Values in the same column that are followed by the same letter are not significantly different ($p \leq 0.05$) according to the Least Significant Difference test.

NA Not applicable.

5.0 CONCLUSIONS

The following conclusions may be made:

1. Moldboard plough mechanical performance was not noticeably affected as greater portions of the moldboard were removed.

2. Soil residue cover left after ploughing, spring run-off, and after planting tended to increase as a greater portion of the moldboard was removed when using a European type plough with furrow width set at 40.6 cm and depth of ploughing 19.0 cm in a silt loam soil.

3. Soil residue cover left after ploughing, spring run-off, and after planting tended to remain the same as a greater portion of the moldboard was removed when using a European type plough with furrow width set at 35.6 cm or 30.5 cm and depth of ploughing between 15.2 cm and 19.0 cm in a loam to silty clay soil texture.

4. The use of the Norcan Minibottom® increased the soil residue cover after ploughing but left the soil surface unacceptably rough.

5. In general there were no consistent significant differences in soybean plant growth and seed yield among the treatments at the different sites.

6.0 RECOMMENDATIONS

In light of the study discussed herein, it is recommended that:

1. To enhance soil residue cover when using a European type plough variables such as width of furrow and depth of ploughing should be adjusted first before modifications are made to the moldboard shape.

2. Additional studies investigate the effect of furrow width, depth of ploughing and moldboard modification in a variety of soil and crop residue conditions and in particular with respect to North American type ploughs

3. Additional studies investigate the effect of type and orientation of crop residue on soil surface cover and erosion control potential for Ontario conditions. Interactions between residue type and tillage methods that affect residue orientation, including the moldboard plough, may indicate which combination(s) provide adequate soil erosion control potential.

7.0 REFERENCES

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