RESEARCH SUB-PROGRAM

INVESTIGATING METHODS OF INTEGRATING LIQUID MANURE INTO A CONSERVATION TILLAGE CROPPING SYSTEM

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FORWARD

This report is one of a series of **COESA** (Canada-Ontario Environmental Sustainability Accord) reports from the Research Sub-Program of the Canada-Ontario Green Plan. The **GREEN PLAN** agreement, signed Sept. 21, 1992, is an equally-shared Canada-Ontario program totalling $64.2 M, to be delivered over a five-year period starting April 1, 1992 and ending March 31, 1997. It is designed to encourage and assist farmers with the implementation of appropriate farm management practices within the framework of environmentally sustainable agriculture. The Federal component will be delivered by Agriculture and Agrifood Canada and the Ontario component will be delivered by the Ontario Ministry of Agriculture and Food and Rural Assistance.

From the 30 recommendations crafted at the Kempenfelt Stakeholders conference (Barrie, October 1991), the Agreement Management Committee (AMC) identified nine program areas for Green Plan activities of which the three comprising research activities are (with Team Leaders):

1. **Manure/Nutrient Management and Utilization of Biodegradable Organic Wastes** through land application, with emphasis on water quality implications
   - **A.** Animal Manure Management (nutrients and bacteria)
   - **B.** Biodegradable organic urban waste application on agricultural lands (closed loop recycling) (Dr. Bruce T. Bowman, Pest Management Research Centre, London, ONT)

2. **On-Farm Research**: Tillage and crop management in a sustainable agriculture system. (Dr. Al Hamill, Harrow Research Station, Harrow, ONT)

3. **Development of an integrated monitoring capability** to track and diagnose aspects of resource quality and sustainability. (Dr. Bruce MacDonald, Centre for Land and Biological Resource Research, Guelph, ONT)

The original level of funding for the research component was $9,700,000 through Mar. 31, 1997. Projects will be carried out by Agriculture and Agri-Food Canada, universities, colleges or private sector agencies including farm groups.

This Research Sub-Program is being managed by the Pest Management Research Centre, Agriculture and Agri-Food Canada, 1391 Sandford St., London, ONT. N5V 4T3.

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Green Plan Web Address: **http://res.agr.ca/lond/gp/gphompag.html**

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Investigating Methods Of Integrating Liquid Manure Into A Conservation Tillage Cropping System

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Executive Summary

This research project was funded by the Canada-Ontario Green Plan. Green Plan research activities were designed to promote environmentally sustainable agriculture within the farming community. The objectives of this project were established by the Green Plan Agreement Management Committee and included:

- Objective A - to determine the influence of the source (cattle, swine, poultry), amount and method of manure application on the nutrient status in the soil and availability to crop growth in a conservation tillage system; and
- Objective B - to investigate techniques of retaining the nutritive value of manure within the rooting zone in a conservation cropping system.

While the objectives of the project were focused on an investigation of methods of integrating manure management in a conservation tillage system, an important secondary goal was to produce information which would be directly relevant and of immediate use to a wide range of farmers. This was the underlying purpose behind conducting on farm research. The direct and significant involvement of farmers in designing, implementing and interpreting the research was seen as key to wider application of results and significant impact on the goals of the Green Plan.

Research experiments were conducted on field length plots at six farm sites in southwestern and eastern Ontario in the growing seasons of 1994, 1995 and 1996. The farms sites included two dairy farms, three hog farms and a poultry farm, which provided a range of manure types. The conservation cropping systems in place at the six farms included three different modified no-till systems, an aeration tillage system using an Aerway™ implement, a chisel tillage system and a ridge tillage system. This broad range of tillage activities provided wide scope for testing manure application practices under a range of field conditions and timing requirements.

The experimental treatments included the application of 100% of the estimated nitrogen requirement from manure, 100% from inorganic fertilizer and a combination of approximately 75% of the nitrogen requirement from manure and 25% from inorganic fertilizer. The effect of the timing of manure application was evaluated through comparisons of treatments involving pre-plant and side-dress manure applications, and different side-dress application timings.

The effect of the treatments on the nutrient status of the soil was evaluated through soil fertility and soil N tests in spring and fall. The effect of the treatments on agronomic and crop productivity was evaluated using corn yield and weed counts at some of the sites. The effect of the treatments on farm management activities was evaluated by the farmer co-operators. Farmer impressions and comments were used extensively to evaluate the operational and economic feasibility of treatments.

As would be expected in a broad ranging field research program, results varied widely from year to year and from site to site. Difficult weather patterns, weed and pest pressures and changing farmer requirements posed challenges to the conduct of the research and the interpretation of results. However, within the statistical limits of field research, several conclusions were reached.

First, the research confirmed that liquid manure is an effective substitute for inorganic fertilizer in conservation tillage corn production. Manure application rates should be based on the nitrogen content of the manure and the nitrogen response of the field as indicated by the nitrate soil test. A wide range of manure volumes (2000 to 9000 gallons per acre) and total N applications (100 to 200 kg/ha) were evaluated. Where the total N applied was close to the maximum economic rate (MER) for the field, yields were similar for manure and mineral N sources. Calculating manure application rates was a straight forward matter based on manure analysis and soil nitrate. Delivering the required volumes of manure to the field under conservation cropping systems was not always straight forward. However, with typical farmer ingenuity, equipment was modified, practices were refined such that the manure was effectively and efficiently applied in most cases. Highly concentrated poultry manure and highly dilute dairy manure were extreme situations that tested farmer ingenuity and equipment flexibility. Yet even in these challenging situations, methods were developed to deliver the volume of manure necessary to provide the appropriate nitrogen amount to the corn.

Second, the research demonstrated that there is flexibility in the timing of the application of manure under conservation tillage. Pre-plant broadcast of manure and application of substantial volumes of manure to standing corn crops were both shown to produce similar yields as mineral N sources, with no un-surmountable operational difficulties. Once again equipment modification and farmer ingenuity played an important role in getting the manure nutrients to the crop at the right time and without crop damage.

Third, the research suggests that the groundwater implications of using manure in a conservation cropping system are similar to using mineral N sources. Residual soil nitrate levels after harvest were measured as an indicator of nitrate volumes potentially available to leach to groundwater. The results of these measurements varied widely from site to site, and some high, and potentially detrimental, levels were detected. However, the levels were similar whether the nitrogen was from manure or mineral sources. Based on the reasonable assumption that conservation tillage provides water quality benefits beyond conventional tillage, the use of manure in conservation systems is as environmentally sound as the use of mineral nitrogen, and seems to offer water quality benefits over the use of manure in conventional systems.

Fourth, the research showed conclusively that manure can be integrated in to conservation tillage in an effective and efficient manner that will be acceptable to farmers. All the farmers involved in the research were able to solve their problems and develop a manure management/conservation tillage system that worked for them. Based on their own whole farm accounting, taking into account all the costs and benefits specific to their own situation, 5 of the 6 farmers saw reasons to invest time and money in the systems. One farmer abandoned conservation tillage during the course of the experiment, but this decision seems to have been based on a wide range of issues not specifically related to difficulties with manure applications. Following three seasons of data collection, it is evident that no single system of manure application tested was the most efficient in terms of corn yield and minimizing residual N left in the soil profile in the fall. Conditions vary from farm to farm and it is essential that the manure application system be tailored to the requirements at each site. Ongoing on farm research and demonstration sites should be used to promote the concept of conservation tillage to a wider group of livestock producers.

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1. Introduction

1.1 Study Approach

This research project is part of the Canada-Ontario Green Plan Research Activities administered for Agriculture Canada by the London Research Centre. It falls under the on-farm research program area which is focused on tillage and crop management in a sustainable agricultural system. As part of the on-farm research area the major purpose of this project is the development of information directly and immediately applicable at the farm level. To ensure applicability of results the research included extensive farmer input to study design and implementation. Direct farmer involvement and field scale plot research yields many benefits in terms of direct applicability of results and a focus on current and relevant issues. However, it requires a high degree of flexibility in research design and execution and it also results in tradeoffs and compromises in data collection and analysis. This research program was designed to maximize the benefits of on-farm research and minimize the compromises.

To maximize benefits a wide range of research partners were involved including six separate farmers and three research organizations. To minimize the tradeoffs required, experimental design, data collection and analysis were kept relatively simple. This was research conducted in the context of farming operations and over the three field seasons, the context and approach of the research evolved in response to the changing requirements and preferences of the farmer cooperators. The research could not be conducted using the standard cause and effect, controlled conditions paradigm, but had to adopt more of an iterative, problem solving approach. The problem solving and technology transfer focus of the program determined the way the field research was designed, implemented, analyzed and reported.

1.2 Background

Research on manure and nutrient management has been conducted for many years on farms managed under conventional tillage systems. However, the results of research based on conventional tillage practices are not directly applicable to farms where reduced, or conservation tillage is practiced. Conservation tillage systems can help to control soil erosion and nutrient losses resulting from surface runoff and can also bring about savings in terms of energy costs associated with tillage operations. However, when manure is used as the primary nutrient source, conservation tillage farmers are faced with a number of management decisions that have not been thoroughly explored and that have major implications on the sustainability and economic viability of the farm operation. Furthermore, much of the available information on manure management was obtained through plot scale research, which does not address many of the challenges and issues faced when operating at a field scale.

Minimum, or conservation, tillage presents new challenges and new opportunities to farmers in terms of manure management. The challenges include maintaining economic levels of crop productivity, avoiding or dealing with potential increased weed pressures, accomplishing all the necessary field operations with limited time, equipment and labour resources and minimizing environmental hazards (primarily ground water contamination) associated with manure use. If these challenges can be met, liquid manure application, in combination with conservation tillage, can result in an efficient system for using on-farm nutrient sources, protecting soil resources, reducing chemical use and decreasing input costs. In essence, this research program was an opportunity for six progressive farmers to explore alternative methods of manure management inside their own conservation farming systems. Agricultural researchers assisted the farmers in documenting the productivity and environmental implications of their systems and captured general advice on manure management that would be of value to a wider audience in the farming community.

1.3 Objectives

The objectives of the Green Plan Program were presented on the basis of individual research projects. This project was awarded under Project D: On Farm Research Investigating Methods of Integrating Liquid Manures into a Cropping System and the Effect on Soil and Water Quality. The objectives of this project were established in the statement of work and included:

A. To determine the influence of the source (cattle, swine, poultry), amount and method of manure application on the nutrient status in the soil and availability to crop growth in a conservation tillage system:

    1. By establishing the amount of various liquid manures applied to the soil and/or the crop in a continuous cropping system to maintain optimum crop production, compared to mineral nitrogen sources.

B. To investigate techniques of retaining the nutritive value of manure within the rooting zone in a conservation cropping system

    1. By measuring the effect of liquid manure shallow injection and/or surface applied within a standing corn crop on subsequent corn growth and weed management.

    2. By measuring the influence of timing and application techniques (e.g. surface injected) on crop growth, soil quality, soil nutrient content and water quality.

Six separate experiments were designed to address these objectives. The experiments, and the specific objectives addressed by each, are described in the following sections of this report. In order to address these objectives outlined above the following three main characteristics of sustainable farm systems were studied:

1. environmental conditions (soil and soil water properties),
2. productivity (crop yield and weed pressures) and,
3. the overall management of individual farm operations (manure storage requirements, equipment, timing, labour needs etc.)

The research included a range of different manure types, application methods, rates, and timing. This range of management options was studied on field scale plots located on six working livestock farms managed under a range of conservation tillage systems. This research included the investigation of a number of factors relating to the application of manure, including:

- the effect of the applied N coming totally from manure, a combination of manure and inorganic fertilizer sources or totally from inorganic fertilizer;
- the effect of different manure application rates;
- the effect of the timing of manure application (pre-plant or side-dressing); and,

- the effect of manure application with incorporation or without incorporation into the soil.

The project was managed by Ecological Services for Planning and the on-farm activities were carried out by REAP-Canada in southwestern Ontario and Ag-Knowledge in eastern Ontario.

2. Literature Review

The impacts of agricultural practices on the environment are of increasing concern to the public, both urban and rural. Miller et al. (1982) estimated that the total P load to the Great Lakes from the more than 300 sub-basins of the agricultural portion of the Canadian Great Lakes Basin was 3,000 t year^{-1}. Source studies indicated that about 70% of this load was attributable to cropland runoff, 20% to livestock operations, and 10% to a combination of runoff from unimproved land and streambank erosion. Neilsen *et al.* (1982) studied the impact of agriculture on nitrogen in the water. They suggested that improved fertilizer N efficiency in corn production may provide the greatest potential for reducing stream N loading.

The proper siting of manure storage facilities and controlled application of manure are also necessary. Approximately 70% of NO_3-N and total N loading to streams occurred during the mid winter to early spring runoff season between January and April (Neilsen *et al.*, 1982). The time of application of manure has a large effect on its environmental impact. Winter application of manure at any rate on areas that contribute runoff directly to surface water is not recommended (Phillips *et al.*, 1981; OMAF, 1992). Proper sizing of manure storage facilities is recommended (OMAF, 1992) so that manure does not have to be applied during the winter. Problems may still occur in other seasons, especially on slopes and with heavy rainfall.
With an increased specialization in agriculture in the Great Lakes Basin there has been a separation of livestock production from crop production. This makes the utilization of livestock manures a challenge especially when they are regarded as wastes and there is insufficient land for their disposal. Continued applications of manure at high rates can cause rapid impairment of groundwater quality (Patni *et al.*, 1981; Phillips *et al.*, 1981).

The impact of agricultural practices on groundwater quality is evident from recent surveys of domestic farm wells. In one survey (Rudolph, 1993), the water in 13% of the wells was found to contain nitrate at concentrations greater than 10 mg/L, the maximum acceptable concentration for nitrate in drinking water. Leaching of nitrate from the root zone is influenced by many factors and processes related to climate, soil, land use and N-application (Steenvoorden, 1989). Some of these, such as crop choice, irrigation and N-application rate can be controlled to some extent. Climatic conditions and soil characteristics cannot be controlled. The influence of site-specific factors such as soil type and groundwater level leads to large variations in reported nitrate leaching losses.
Vulnerability for nitrate leaching is strongly associated with soil type. Sandy soils give much higher nitrate leaching losses than clay soils at the same level of N-fertilization. Sandy soils normally have a lower water content in the unsaturated zone than other soil types, resulting in a greater leaching depth for a given amount of precipitation. Moreover, a lower water content improves aeration, which leads to a reduced denitrification potential in the unsaturated zone. Direct leaching occurs not only in terms of nitrates, but in terms of microbial contamination and other forms of nitrogen such as NH_4 (Dean and Foran, 1991; Flemming and Bradshaw, 1992; Gangbazo et al., 1992).

An additional concern is the direct movement of liquid manure into drainage tiles (Dean and Foran, 1991). Four major factors influencing the impact of land application of liquid manure on tile drain water quality are; the presence of established continuous macropores, tile drain flow at the time of spreading, rainfall shortly following manure application, and the rate of application, (Dean and Foran, 1991). Other related factors are soil texture, cropping history and depth of water table.

Manure is a valuable source of plant nutrients and can have beneficial effects on the soil. A long term study found that soil microflora populations were greatly improved by applications of solid cattle manure and of pig slurry (Ndayegamiye and Côté, 1989). Manure application also increased the degree of macro-aggregation in soil (Weill *et al.*, 1988). Improved aggregate stability from manure application reduced the amount of runoff during a series of artificial rainfall events (Roberts and Clanton, 1992). However, not all manures have the same effects on soil properties.

Manures are highly variable in both their nutrient concentrations and plant availability of the nutrients. Factors that affect the characteristics of manure include the rations the animals receive, the amount of litter in the manure, and how it is stored. Typically, the highest concentrations of nutrients are found in poultry manure, followed by pig and cattle manures (Kirchmann and Witter, 1992). In the same study, it was found that aerobically treated manure was characterized by low concentrations of nitrate (<0.5% of total N), while anaerobically treated manure was characterized by high ammonium N concentrations (typically 50-75% of total N). The C/N ratios increased during anaerobic decomposition in all materials. Liquid manures are generally stored under anaerobic conditions.

To manage manures as sources of plant nutrients, information is required on the relative availability of these nutrients as compared to inorganic sources. This estimate of relative availability is dependent on the manure source as well as application method. Beauchamp (1983) found that injection of liquid cattle manure either before planting or as a side-dressing between the corn rows resulted in approximately 60% of the manure N being available as fertilizer N. Application of liquid cattle manure to the soil surface as a side dressing resulted in manure N being approximately one-third as available as anhydrous ammonia N. Surface application resulted in greater volatilization loss of NH_3 (Thompson *et al.*, 1987; 1990a; 1990b). However, injection of beef cattle manure can result in problems of uneven growth, yellowing, and reduced corn yields. Conditions toxic to plant roots developed in the concentrated bands of liquid manure. These conditions included: reducing conditions, NH_3 toxicity, and accumulation of high concentrations of NO_2-N (Sawyer and Hoeft, 1990a,b). Application by sweep injection rather than knife injection greatly reduced the problem (Sawyer *et al.*, 1991).

Predicting the nutrient availability of applied manure is subject to considerable uncertainty. Motavalli *et al.* (1989) found that ranges for N, P, or K availability in the first year for injected dairy manure were 12 to 63, 12 to 89, and 24 to 53%, respectively. The interactions between manure nutrients and the soil influence how much is plant available. Processes to consider are net N immobilization and N losses through denitrification (Comfort *et al.*, 1988). Beauchamp (1986) concluded that N release from the organic fraction of solid beef manure differed substantially from that of the liquid poultry manure and liquid dairy manure studied. The organic N in manure will be available later in the season and in subsequent years. Current recommendations are that no more than 75% of the N requirements should be applied as manure, with the balance provided in inorganic form, to reduce the likelihood of over application and hence the amount of potentially leachable nitrate released from the organic fraction late in the season (Bertrand, 1992; OMAF, 1992). In practice, farm managers must deal with a series of approximations as they are dealing with a dynamic system. Theoretical manure application rates may be difficult to achieve with consistency and significant variations in soil N can occur within a single field (Starr *et al.*, 1992) .

There is a limited amount of information on the effects of liquid manure applications in soil conservation systems and some researchers have reported disappointing results. Low seed germination, decreased effectiveness of herbicide treatments and increased slug problems have been associated with direct seeding into fields which have received heavy surface manure applications (Walter et al., 1987). When manure is used as a source of fertilizer, zero-till can result in poorer emergence, weed control problems and increased risks of frost damage (Weil et al., 1989).

Soil physical properties can be negatively affected by heavy traffic operations related to liquid manure spreading and injection. Soil compaction can lead to lower saturated hydraulic conductivity. Annual applications of liquid dairy manure injected at a depth of 20 cm prior to planting and ridge-tilling resulted in relatively low Ksat values in the Ap horizon of a silt loam compared to chisel tillage, possibly because of surface layer compaction produced during manure injection (Wu et al., 1992).

The surface infiltration rate of a soil can be affected by liquid manure applications through plugging of the macropores. Roberts and Clanton (1992) showed that soil columns of loamy sand exhibited short term plugging when either cattle or swine waste slurries were surface applied with no incorporation. However, surface application of dairy slurries on a silt loam soil apparently prevented formation of a surface seal and improved the infiltration capacity of the soil (Roberts and Clanton, 1992). Livestock waste application noticeably reduced the amount of runoff during a series of artificial rainfall events on both soils. It was believed that the solids fraction within the liquid manure was protecting the soil surface from the energy of the impacting raindrops (Roberts and Clanton, 1992).

The lack of annual tillage, as occurs under continuous no-till management generally encourages the development and persistence of macropores and other preferential flow paths that are potentially important for the downward movement of water and chemicals (Edwards, 1991). While conventional tillage can increase the volume of large pores, the continuity of macropores may be destroyed. Greater saturated hydraulic conductivity observed in no-till conditions has been mainly attributed to the presence of continuous macropores but also to increased soil organic matter and reduced bulk density (Wu *et al*., 1992).

A three year study was conducted to examine combination effects of tillage (no-till, conventional-till), manure, and inorganic fertilizer on leaching of nitrates from the root zone of corn (Angle *et al.*, 1993). Leaching of nitrate-N significantly increased as fertilizer N rates increased, especially when rates exceeded the crop's potential to assimilate N. Soil nitrate concentrations were consistently lower under no-tillage when compared with conventional tillage. Tillage differences where greatest when high rates of N were added to soil.

Many studies have demonstrated that no-till practices can reduce soil erosion by 95% compared to mouldboard plough. Surface run-off and soil erosion are generally lower under minimum tillage practices, but certain studies have demonstrated that loss of fertilizer nutrients, notably phosphorus, can be enhanced (Johnston *et al.*, 1979; Barisas et al., 1978).

With minimum tillage, fertilizer nutrients will have a tendency to accumulate in top soil layers, particularly phosphorus and potassium since they are less mobile (Thibodeau and Ménard, 1993). This stratification can also result in a lower soil pH in the top layer due in part to nitrification of NH_4^+ fertilizers (Ismail, 1994; Randall and Swan, 1990). A low pH at the soil surface would give an advantage to surface applications of liquid manure since significant amounts of manure NH_3 may be volatilized when exposed to the air in a high pH environment. Paul and Beauchamp (1989) showed that the soil pH increased shortly after application of dairy cattle slurry because of the oxidation of volatile fatty acids contained in the manure.

According to Beauchamp and Kachanoski (1990), conservation tillage practices should work very well with manure injection systems by conserving available N and allowing acceptably low P losses in runoff. Surface applied manures that are not incorporated into the soil could result in significant P contributions to streams through runoff. It is generally considered important that manure K and especially manure P be located close to roots for maximum availability (Beauchamp and Kachanoski, 1990).

While injection of manure may be an ideal way to minimize odour and losses of ammonia to the air, conventional systems for injecting manure may contribute to tile water degradation at least as much or even more than simply broadcasting the manure onto the soil surface. Flemming and Bradshaw (1993) and Côté (1994) recommend to break the continuity of the macropores by working the soil prior to spreading in order to minimize potential flow to tiles. This recommendation may be contradictory to no-till management practices but can be implemented following row crop cultivation or following ridge building after crop emergence.

For farm managers with mixed farming operations, the challenge is to develop an optimum system, tailored to their unique set of conditions, that will allow them to efficiently utilize manure as a resource within their cropping system while minimizing negative environmental impacts. A team approach with farmers and researchers as full partners can be an effective approach to meeting this challenge (Francis *et al.*, 1992; Gerber, 1992).

The research reported on in this document does not directly address all the issues identified in this literature review. As an applied research project, this work was primarily focused on developing systems that worked for individual farmers and reduced or at least maintained the status quo in terms of potential environmental problems. Other research projects commissioned under the Green Plan program have been specifically designed to contribute to an understanding of the processes behind nitrogen dynamics, nutrient transformation, soil properties, tile flow water quality etc. However, information on many of these issues can be indirectly derived from the productivity and soil nitrate measurements collected during this study and a basic understanding of N movement in soil is important to interpreting results of the current study.

3. Methods

3.1 Plot Establishment

Six farmers participated in the research project as farmer cooperators. Cooperators were chosen by the field research coordinators (REAP-Canada and Ag-Knowledge) with input from the overall study manager (Ecological Services for Planning) and the scientific authority. Co-operators were chosen to ensure that the study included;

- a mix of soil and climatic conditions;
- a range of conservation farming systems;
- different manure types; and
- geographic coverage of Ontario.

Four of the farms were located in southwestern Ontario (one dairy farm and three hog farms) and two in eastern Ontario (a poultry farm and a dairy farm). The locations of the research sites are shown in Figure 3.1. The management systems represented in the study included modified no-till systems, an aeration tillage system using the Aerway™ implement, chisel tillage and ridge tillage. The Aerway™ tool is a non-powered soil aeration tool which can be pulled in combination with planters, manure spreaders, other tillage implements. It has rolling teeth which penetrate the soil and open up macro-pores. The rolling action also incorporates surface residue to some degree. However, all systems tested qualified as conservation tillage systems by virtue of greatly increased residue cover on the soil surface after planting as compared to traditional plowing and disking systems.

The management systems and farm locations chosen for this study provided a diversity of soil conditions, management and equipment options for liquid manure management in no-till/minimum tillage corn. Selected characteristics of each farm site are listed in Table 3.1.

Figure 3.1 Location of Research Sites

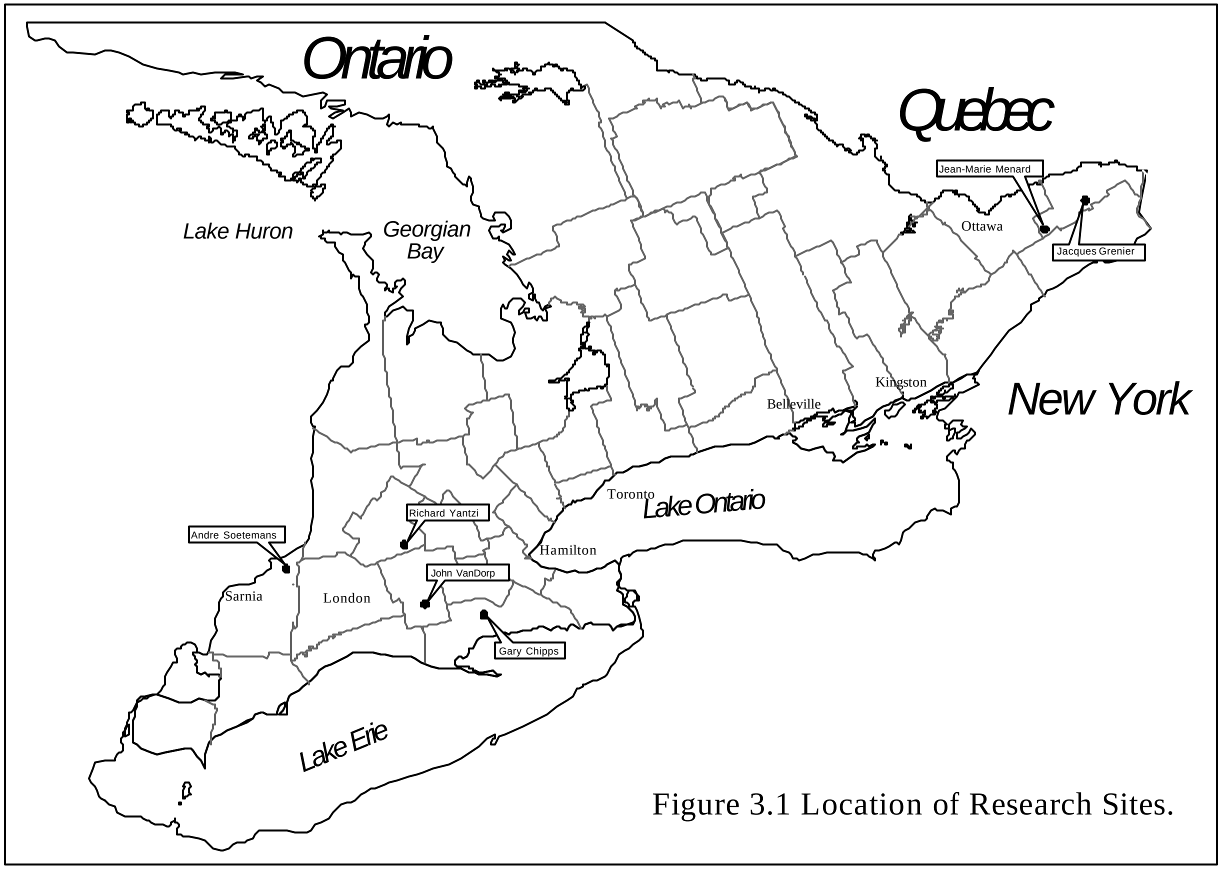

Figure 3.1 Location of Research Sites.

Table 3.1.1 Basic Information About the Six Farm Research Sites

Farm Site	Chipps	Soetemans	VanDorp	Yantzi	Grenier Site #1 and #2	Menard
County	Haldimand-Norfolk	Lambton	Oxford	Perth	Prescott and Russell	Prescott and Russell
Location (nearest town)	Delhi	Forest	Woodstock	Tavistock	St-Isidore-de Prescott	Embrun
Soil Texture	Loamy sand	Clay loam	Silt loam	Silt loam	#1 Loam #2 Sandy loam	Silt loam
Manure Type	Dairy	Hog	Hog	Hog	Poultry	Dairy
Crop Rotation (91-92-93-94)	C-C-S-C	W-C-S-C	C-C-C-C	C-S-C-C	S-C-S-C	S-C-W-C
Spreader	Houle	Husky 2000	Mic 2700	Husky 2500	Houle	Houle
Tillage	No-till	No-till + cultivation	Aerway & Disking	Aerway & Disking	Ridge tillage Strip Crops Disking	Mulch tillage Disking

In addition to the manure application equipment owned by the farmer cooperators, rental arrangements were made with two farm machinery suppliers for additional equipment at one of the sites. Side-dressing equipment was obtained from Husky farm equipment while Holland equipment provided an Aerway™ for use on some of the southwestern Ontario farms.

The experimental treatments differed at each location in order to adapt to the unique management conditions encountered. Randomized complete block experiments were established with field length strips as plots. Due primarily to the farmer's rotation patterns, the plots at all but two of the sites (Chipps and VanDorp) had to be moved in at least one of the field seasons.

Farmer cooperators were involved in establishing the experimental designs and each design included a treatment that, within the limits of the study, reflected what the cooperator believed to be the most appropriate for their unique set of circumstances. Treatments were established and managed using farm scale equipment and farmer labour for most activities.

The following discussion of general methods applies to all sites. Site specific details are presented in Sections 4 to 8.

3.2 Data Collection

The study collected data on three main characteristics of sustainable farm systems: environmental conditions (soil and soil water properties), productivity (crop yield and weed pressures) and the overall management of individual farm operations (manure storage requirements, equipment, timing, labour needs etc.) To meet these data requirements quantitative data were collected for key environmental and productivity components. Manure, soil and crop performance data were collected in all the experiments; and data on the nitrate levels in shallow groundwater (environmental effects) were collected from open well piezometers beneath individual plots at the Experiment 4 (Yantzi) site in southwestern Ontario and the Experiment 5 (Grenier) site in eastern Ontario. Qualitative and anecdotal data were collected on the impact of different manure management practices on the farm operation. These qualitative data were collected during the course of the experiments by recording general impressions and specific comments from researchers and the farmer cooperators on issues such as equipment requirements and potential improvements and the impact of different practices on overall farm management issues such as timing of operations, challenges and opportunities for modified practices and the need for capital investment.

Statistical analyses were conducted on all quantitative data using Tukey's HSD test to compare the means between treatments. Significance was determined at P # 0.05.

3.2.1 Manure Data

At each site, manure samples were taken before and at the time of application for analysis of total N, P, K, NH_4-N, dry matter and pH. In southwestern Ontario, manure analysis was done by either the University of Guelph Analytical Services Laboratory or the Stratford Agri Analysis Inc. In eastern Ontario, the manure was analyzed by Accutest Laboratories Ltd., in Nepean. This repeated testing was critical since the nutrient content of the liquid manures varied among the farms and from year to year at individual farms.

3.2.2 Soil Data

Soil testing was carried out at a number of times during the growing season. Soil samples were based on composites of eight to fifteen soil cores, depending on the length of the plot. Soil samples were taken to 15 cm depth before the initiation of the experiment to provide baseline data on soil particle size and soil fertility, including soil P, K, Mg, Ca, pH and organic matter. Soil samples were again collected for fertility analysis after the manure applications and at harvest.

Soil nitrogen (0-30 cm depth) was tested a minimum of three times during the growing season. Sampling occurred during the spring N soil test period, one to two weeks after manure applications, and after corn harvest. The Experiment 4 (Yantzi) site was used as the main site to examine the effect of manure on soil properties in southwestern Ontario. The soils at this site were sampled more frequently (four to five times annually) and at depths of 0 to 30 cm and 30 to 60 cm. Intensive soil sampling was also undertaken at the Experiment 5 (Grenier) site in eastern Ontario.

Soils were sampled for nitrate analysis from a depth of 0 to 30 cm. Soil nitrate levels from this depth range are multiplied by 1.62 to obtain roughly equivalent soil nitrate at a 0 to 60 cm depth, then multiplied by 4 to convert to kg/ha (OMAF, 1995).

Soil samples were taken between the corn rows to avoid the influence of starter fertilizer applied in or near the row. All soil analysis from the southwestern farm sites was conducted by the Analytical Services Laboratory at the University of Guelph. Soil analysis for the eastern Ontario sites was conducted by the Agriculture Canada soils laboratory in Ottawa.

Soil nitrate readings after harvest were assumed to represent a measure of the relative amounts of soil N available to leach to groundwater over the winter, and, therefore, a measure of potential environmental impacts from the different treatments.

3.2.3 Agronomic Data

Yields were measured by various methods depending on equipment availability and plot layout. Combine yields were measured using weigh wagons at three of the four sites in southwestern Ontario. Due to the limited plot size, corn at the Experiment 3 (VanDorp) site was harvested by hand on two 5m centre rows in each of the N trial plots and on six 5-m centre rows in each of the main plots. At the two eastern Ontario sites, yields were determined using combine yield monitors. Yields for a plot were the average of all readings from the yield monitor, omitting erroneous yield readings.

Surface residue cover was counted in the spring at the southwestern Ontario sites. Qualitative measurements of the relative weed pressures between treatments were collected at all sites. Quantitative measures of weed biomass were made at the Experiment 1 (Chipps) site in 1995 and 1996.

3.2.4 Nitrogen Response Plots and Nitrogen Rates

Nitrogen response plots were established at each of the sites, with the exception of the first two years at the Experiment 6 (Menard) site. The plots consisted of a strip that was divided into three to five sections. Each section received a different inorganic nitrogen rate. Where possible, a zero nitrogen treatment was included. However, in most cases the farmers were reluctant to plant corn without at least a starter fertilizer. At two of the sites (Chipps and VanDorp) the nitrogen response plots were located on the same piece of land for the three successive years of research. It is possible that the soil retained some nitrogen from the previous year's nitrogen response trials, especially for the high N rate treatments. However, any confounding effects due to residual N are believed to be minor in comparison with the differences associated with the various N rates that were compared.

The nitrogen response plots were hand harvested at all of the southwestern Ontario sites. At the eastern Ontario sites both the N response plots and the main plots were harvested using combines with on-board yield monitors. At the southwestern Ontario sites the main plots were machine harvested using a combine and weigh wagon. Differences between the yields obtained in the N response plots and the main plots may be partially due to the method of harvest. The exception to this was at the VanDorp site, where both N response plots and main plots were hand harvested.

The yield results from the nitrogen response plots were used to evaluate the efficacy of the N rates that were used in the main plots and to determine if the field was responsive to N.

The maximum economic rate (MER) of N was calculated from the regression equation of the yield curve produced by graphing yield on the Y axis and nitrogen added on the X axis. The regression equations were generated by the graphical analysis package, Excel™, and were of the form $y = a_2 x^2 + a_1 x + a_o$, where y is yield (kg/ha), x is the amount of inorganic fertilizer applied (kg/ha) and a_o, a_1 and a_2 are regression coefficients.

Using the regression equation and the calculated nitrogen loading from the manure and/or inorganic nutrients that were applied, the yield predicted by the nitrogen response curve could be determined.

The maximum economic rate of N application was calculated using the following equation (Sheard *et al*, 1990):

$$MER = \frac{PR - a_1}{2a_2}$$

where PR is the ratio of the cost of N fertilizer to the cost of corn. In all cases, the MER was calculated using a PR value of 5.

Experimental nitrogen rates were established by balancing a number of factors, including the farmer cooperator's yield targets and the rate recommended in Publication 296 (OMAF, 1993) on the basis of the spring soil N readings. Manure N availability was assumed to be 50% for the five sites using swine and dairy manures. At the Experiment 5 site, where liquid poultry manure was used, an 80% N availability was assumed. It should be recognized that these assumptions include a significant range of true N availability and, therefore the comparison of manure N rates to inorganic N rates is not exact.

3.2.5 Groundwater Nitrate

Groundwater samples were obtained from open well piezometers installed to a depth of two to three metres beneath individual plots at the Experiment 4 (Yantzi) site in southwestern Ontario and the Experiment 5 (Grenier) site in eastern Ontario. The piezometers were constructed from ¾” diameter flexible PVC piping. Holes (¼” diameter) were drilled through the tubing in the bottom 40 cm and drainage tile filters installed over the perforated area of the pipe. An auger was used to create the holes for the wells, sand was placed at the bottom of the hole, the piezometer put in place, and sand was used to fill in around the pipe over the depth which included the filter; the sand was packed around the pipe. Soil was used to fill around the remaining length of pipe to the soil surface, where it was sealed around the opening. The piezometers were constructed so they could be capped at 30 cm below the soil surface to allow for permanent installation.

Water samples were obtained by inserting a hose into the well, purging the well using a backpack-mounted pump and withdrawing a water sample of the recharge. The exception was in drier months on the sand site, where water quantity in the well was low and the water sample was obtained from the well without purging. In 1996, the well was modified so a hose was permanently installed in the well and attached to the cap fitted with an adaptor so the well did not need to be opened in order to obtain a sample. This reduced the possibility of contamination during sampling.

The piezometer water samples were analyzed for nitrates by the Analytical Services Laboratory in Guelph and the Agriculture Canada Laboratory in Ottawa for Experiments 4 and 5, respectively

4. Experiment 1: Effect of Pre-plant Liquid Manure and Fertilizer on Corn Growth at the Chipps Farm

This study examined the effect of different nutrient sources including liquid dairy manure, inorganic fertilizer and a combination of liquid dairy manure and inorganic fertilizer on soil nutrients, groundwater quality, performance of no-till corn and overall conservation farm systems management. In conjunction with other experiments which included different manure types, this study addresses *Objective A: to determine the influence of source amount and method of manure application.* The following measurements were used to examine impacts:

- soil nutrients indicated by general soil fertility;
- potential impacts on groundwater indicated by residual soil nitrate after harvest;
- performance of no-till corn indicated by weed biomass and corn yield; and
- overall management impacts as determined by the farmer cooperator.

4.1 Site Characteristics

The experiment was conducted on loamy sand soil (77% sand, 16% silt and 7% clay by weight) at the farm of Gary Chipps (Delhi, Ont.). Gary and his brother Keith farm on 475 acres of land, of which 110 acres is in corn, 80 to 85 acres is in soybeans, 30 acres is in mixed grains, 85 acres is in hay and 60 acres is in permanent pasture. The remaining land is a woodlot. Gary first experimented with no-till between 1985 and 1987 and went entirely with no-till in 1988. His modified no-till approach includes sweeps and discs to incorporate manure and one or two inter-row cultivations.

The 100 head dairy operation at the Chipps farm includes forty to forty five milking Holsteins with the remainder kept as replacements. Manure at the Chipps farm is stored on a year round basis with all liquid manure being applied to corn ground 2-3 days before planting.

Gary uses a Houle manure tanker and has modified it to fit his system for incorporating the manure with sweeps and discs. He has reduced the PTO speed to reduce horsepower requirements while still producing an adequate and consistent spray pattern. The main reasons for his modifications were to alleviate the plugging problem experienced with his previous banded injection system and reduce horsepower requirements.

The field was planted with corn in 1992, soybeans in 1993 and corn for the 1994 to 1996 period of the experiment. Site details and field activities during the three year experiment are listed in Table 4.1.

Table 4.1 Site Details and Field Activities at the Chipps Farm, 1994 to 1996

Year	1994	1995	1996
Plot size	6m x 500m	6m x 500m	6m x 500m
Preplant Manure: Date	April 23	April 25	May 2
Rate	6140 gal/acre high rate	6090 gal/acre high rate	7900 gal/acre high rate
	4700 gal/acre low rate	5019 gal/acre low rate	6100 gal/acre low rate
Planting Date	May 6	May 5	May 13-14
Row Spacing	76 cm	76 cm	76 cm
Population (plants/ha)	65,000	68,700	68,700
Fertilizer Side-dress	June 20	June 13	June 26
Harvest Date: N Test Plots	Oct. 25	Oct. 19	Nov. 1 and 6
Harvest Date: Main Plots	Nov. 16	Nov. 6	Nov. 6

The dairy cattle manure used in this experiment contained relatively high proportions of straw compared to the swine manure used at the other three sites in southwestern Ontario. It also contained a greater concentration of potassium (K). The manure analysis at the time of application to the experimental plots is shown in Table 4.2.

Table 4.2 Manure Analysis at the Chipps Site at the Time of Application

Sampling Date	N %	P %	K %	NH_4-N mg/kg	DM %
28-Apr-94	0.36	0.07	0.34	2025	6.97
2-May-95	0.32	0.07	0.34	1590	7.17
2-May-96	0.32	0.07	0.27	1810	6.93

4.2 Experimental Design

The three treatments compared in this experiment were: 100% manure (M), 100% inorganic fertilizer (I) and a combination of the two nutrient sources (M+I). The liquid manure was surface-applied and incorporated with sweeps mounted behind the manure spreader. The application of the inorganic fertilizer was split as starter (19-19-19) and a side-dress of 28%N. Side-dressing was carried out at the 7-8th leaf stage of corn growth. Each of the three treatments was replicated five times, forming a total of 15 plots.

The N rate for the inorganic side-dress was adjusted to provide approximately the same N loading as the M and M+I treatments.

4.3 Field Conditions

In 1994 the site had approximately 40% residue cover from the previous soybean crop before manure spreading and planting. At the start of the experiment, prior to the first manure application, this loamy sand site had the lowest soil nutrient levels among all the sites in the study. The nitrogen response plots (see Appendix 1) indicated that this site was responsive to N during all years of the study. Based on these plots the following MERs were calculated: 1994- 91 kg/ha, 1995- 126 kg/ha, 1996 142 kg/ha.

Climatic data were collected at this site and compared to 30 year averages. Based on this comparison the site experienced average precipitation over the spring and summer of 1994, lower than average precipitation during the summer of 1995 and a much wetter than average spring in 1996. This site is particularly sensitive to drought because of the low silt and clay content of the soil.

4.4 Results and Discussion

4.4.1 Soil Properties

4.4.1.1 Nutrients Added

The nutrients (N,P,K) provided by the manure and inorganic fertilizer applications are presented in Table 4.3. Although the manure application rate could be field calibrated, in practice, a compromise had to be reached between applying the intended amount of nutrients and having a workable routine of filling the manure tanker and making complete passes down the length of the field. Thus there was some minor variability in the total amount of N applied to each treatment. This variability is not considered significant and is certainly much smaller than the variability inherent in the assumption of 50% availability for manure N.

Table 4.3 Experiment 1: Rates (kg/ha) of available nutrients⁋ (N, P_20_5, K_20) applied in manure and inorganic fertilizer at the Chipps Farm

Year	Treatment	Premanure	Starter	Side-dress	Total
1994	M	(124/44/253)	-	-	(124/44/253)
	M+I	(95/34/194)	(43/43/43)	-	(138/77/237)
	I	-	(43/43/43)	(89/0/0)	(132/43/43)
1995	M	(109/44/251)	-	-	(109/44/251
	M+I	(90/36/207)	(40/40/40)	-	(130/76/247)
	I	-	(40/40/40)	(90/0/0)	(130/40/40)
1996	M	(142/57/259)		-	(142/57/259)
	M+I	(110/44/200)	(43/43/43)	-	(153/87/243)
	I	-	(43/43/43)	(110/0/0)	(153/43/43)

⁋ Manure nitrogen applications assumed to be 50% available in the year of application.

Manure P_20_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

The addition of the starter fertilizer resulted in similar P loading rates for the M and the I treatments, while the M+I treatment had a higher P loading. The high K content of the dairy manure at this site resulted in much greater loadings of K for the treatments that included manure.

4.4.1.2 Nitrate Levels

The results of soil nitrate tests, converted to kg/ha in the upper 60 cm, are presented in Table 4.4.

The first soil nitrate measurement in 1994 was made on June 15, after the pre-plant manure and starter fertilizer, but before the inorganic side-dress. The soil nitrate analysis reflected the fact that the M and M+ I treatments had received more N, and N in different forms, than the I treatment. Significantly greater soil N was found in the plots which had received manure. There was more nitrate-N in the soil receiving manure than that receiving only inorganic N, measured in the fall as well.

Table 4.4 Experiment 1: $N0_3$ - N (kg/ha) in 60 cm depth at the Chipps Site

Sampling Date	Timing of Sample	M Pre-plant Manure	M+I Pre-plant Manure + Starter Inorganic	I Starter + Side-dress Inorganic
34499	After Manure	207.9 a	174.7 a	134.1 b
34657	Fall	63.4 a	56.9 a	45.7 b
34831	After Manure	101.7 a	97.2 a	95.9 a
34855	Before Inorg. Side-dress	208 a	204.1 a	72.6 b
35008	Fall	69.3 a	78.4 a	84.2 a
35186	Before Manure	22.7 a	21.4 a	20.7 a
35201	After Manure	137.4 a	116.6 a	57 b
35229	Before Inorg. Side-dress	74.5 a	69.3 a	70.6 a
35381	Fall	65.4 a	65.4 a	60.3 a

Means within a row followed by the same letter are not significantly different (P # 0.05)

In 1995 the Chipps site was sampled in May, shortly after the pre-plant manure and starter fertilizer applications, and then again in June, shortly before the side-dress inorganic fertilizer applications. The May soil N results were not significantly different between treatments, but the June sampling once again showed significantly greater soil N in the two treatments which had received manure. By the time of the fall sampling, the soil N levels had decreased to 70 to 84 kg/ha, and no significant differences between treatments were noted.

Wet conditions in the spring of 1996 resulted in delays to the application of pre-plant manure and planting. Prior to the manure applications the soil was considered warm enough to provide a valid spring soil N test. Results of the test showed greatly reduced soil N values compared to the previous fall. No significant differences were noted among treatments at this time. The soil N levels were all in the low 20 kg/ha range prior to nutrient additions. The recommended addition of nitrogen for soils with this N level would be close to 185 kg/ha (OMAF, 1995), or from 30 to 40 kg/ha more than that which was applied that year (Table 4.4).

The May 17, 1996 soil N test showed significantly greater N levels in the two treatments which had received manure (Table 4.4). A month later (June 14), after a period of significant crop growth and N uptake, the N content of the soils in the manure treatments had dropped and there was no difference in the soil N levels among treatments, even though side-dressing of inorganic fertilizer had not yet taken place. The manure plots yielded higher than the inorganic treatment in 1996 indicating a possible benefit due to the readily available N during this period. It is also possible that some of the rapid decline in soil N levels under the manure treatments may have been due to leaching caused by heavy precipitation during the period between samples and the highly permeable soils at the Chipps site. The early availability of N under the manure treatments appears to have had some yield benefit in 1996 (Figure 4.1).

Over the three years of field studies, the fall soil N levels at the Chipps site ranged from 45 to 85 kg/ha. The May 2, 1996 was the only spring soil test conducted before the application of nutrients (1996). The decline in soil N levels from the previous fall (1995) was approximately 45 to 60 kg/ha of nitrate N.

4.4.1.3 Phosphorus and Potassium Levels

The results of soil fertility analysis for available P and K are presented in Table 4.5 and Table 4.6, respectively. The higher rate of P application to the soils in the M+I plots (Table 4.5) was not reflected in significantly higher soil P levels than the soils of the M treatment. In the fall of 1995, the two treatments that included manure had significantly more P in the soil than the inorganic fertilizer treatment. However, overall P test levels did not increase over the 3 years of the research. For corn production and P-test levels of 13 to 30 mg/L, 20 kg P_20_5/ha is recommended.

Table 4.5 Experiment 1: Soil test P (mg/L) in 0 to 15 cm depth at the Chipps Site

Sampling Date	Timing of Sample	M Pre-plant Manure	M+I Pre-plant Manure + Starter Inorganic	I Starter + Side-dress Inorganic
34480	After manure, before inorg. Side-dress	18.8 b	22.2 a	19.0 ab
34657	Fall	17.4 a	14.8 b	16.2 ab
34812	Before manure	19.6 a	18.2 a	16.4 a
34831	After manure, before inorg. side-dress	25.2 a	22.6 a	0.41666666667
35008	Fall	25.8 a	23.6 a	17.6 b
35186	Before manure	20.4 a	20.2 a	16.8 a
35205	After manure, before inorg. side-dress	26.4 a	28.6 a	21.6 a
35381	Fall	20.6 a	19 a	0.0833333333

Means within a row followed by the same letter are not significantly different (P # 0.05)

Table 4.6 Experiment 1: Soil test K (mg/L) in 0 to 15 cm depth at the Chipps Site

Sampling Date	Timing of Sample	M Pre-plant Manure	M+I Pre-plant Manure + Starter Inorganic	I Starter + Side-dress Inorganic
34480	After manure, before inorg. side-dress	179 a	183 a	106 b
34657	Fall	104 a	80.9 a	77.3 a
34812	Before manure	200 a	173.8 b	106.7 c
34831	After manure, before inorg. side-dress	257.2 a	239.5 a	133.6 b
35008	Fall	170.0 a	162.0 a	81.8 b
35186	Before manure	206 a	181 a	117 b
35205	After manure, before inorg. side-dress	225 a	201 a	87 b
35381	Fall	182 a	158 a	73 b

Means within a row followed by the same letter are not significantly different (P # 0.05)

The higher rate of K loading in the manure treatments was reflected in soil K concentrations that were significantly higher than the soils of the inorganic treatment. After the first year of the experiment, the soil K of the two manure treatments remained in the very high (151 to 250 mg/L) range (OMAF, 1996).

High soil K levels can lead to magnesium deficiency in soils low in magnesium (OMAF, 1966), but this was not the case at the Chipps site. The soil test magnesium levels at the Chipps site (available in the complete data set) were consistently greater than 100 mg/L. Magnesium applications are recommended only if the magnesium test is below 20 (OMAF, 1996).

4.4.2 Agronomic Properties

4.4.2.1 Corn Yields

The yields in each year of the experiment are shown in Figure 4.1. There were no significant differences between corn yields at the site in any of the years. These are encouraging results for the farmer cooperator at this site who prefers to use little or no inorganic fertilizer and feels he can do so with no significant loss of yield.

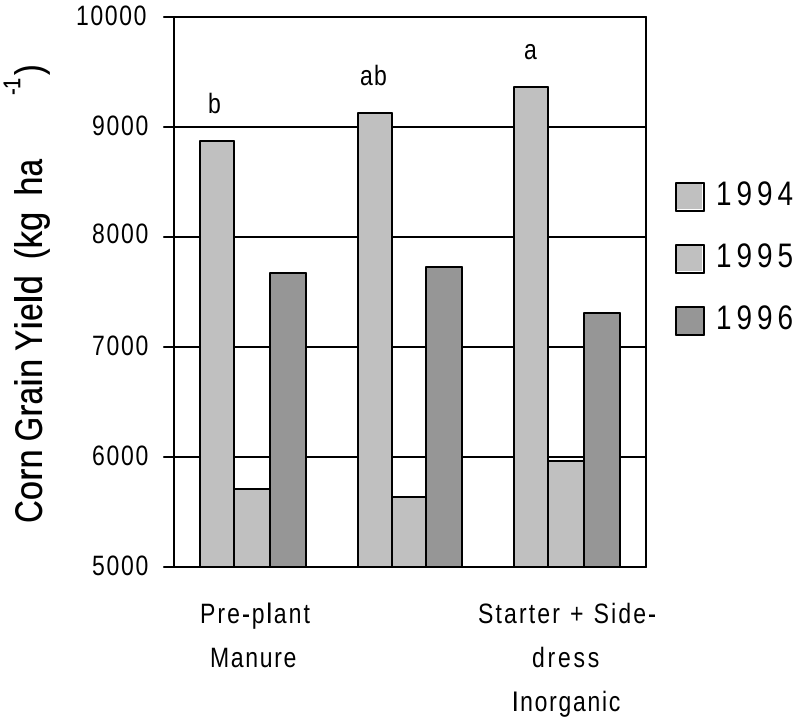

Figure 4.1 Experiment 1: Grain corn yield at the Chipps farm. All yields are at 15.5% moisture. Within 1994, bars having the same letter above them are not significantly different (P#0.05). Within 1995 and 1996 no significant differences were observed among treatments.

As discussed below, the manure treatments in 1995 were subject to heavy weed pressure relative to the inorganic treatments. This higher weed pressure was not reflected in statistically significant lower yields. However, yields from all treatments were greatly reduced in 1995. The yield reduction was due to a mid-summer drought and corn borer damage, that caused serious lodging problems and reduced combine yields. The yields measured in the hand harvested N response plots in 1995 were about 1000 kg/ha greater than the yields of the combine harvested main plots. This discrepancy is attributed to lodged corn that could not be picked up by the combine but which may have been included in the hand harvest.

4.4.2.2 Weed Observations

In 1994 the liquid manure treatments had a serious weed biomass problem by the time of corn harvest. Weed biomass measurements were included in the data collected at the Chipps site in 1995 and 1996 in order to assess treatment effects on weeds (Figure 4.2).

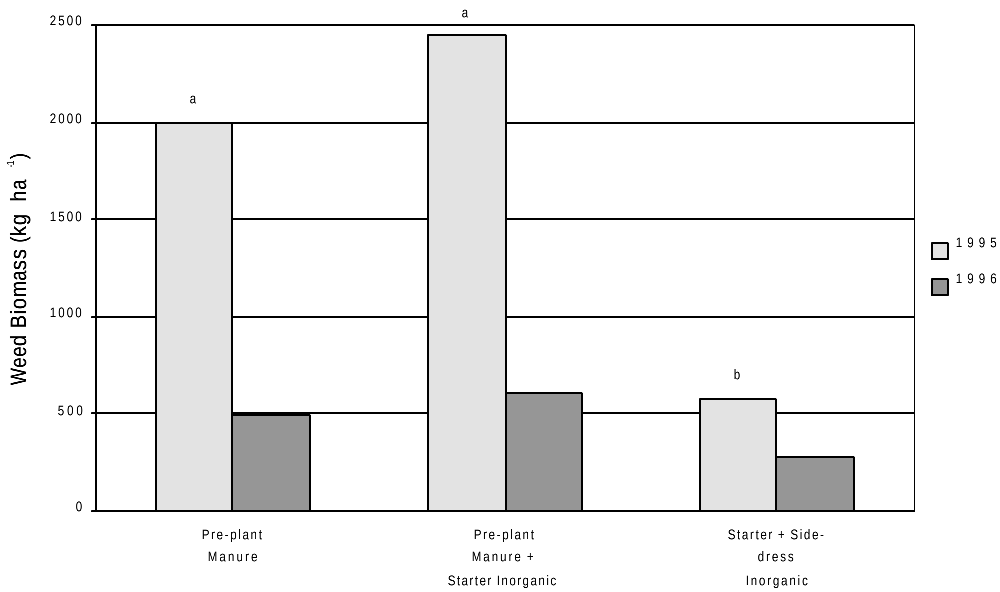

Figure 4.2

Experiment 1: Results of mid-September weed biomass measurements taken at the Chipps farm. Within 1995, bars having the same letter above them are not significantly different (p # 0.05). Within 1996, no significant difference was observed during the treatments.

Weed biomass was significantly greater for the two treatments that involved manure in 1995. While the two manured treatments continued to have greater weed biomass than the inorganic treatment in 1996, the difference was not significant.

The most commonly occurring weeds at the Chipps site were volunteer corn, pigweed and lambsquarter. A pre-plant herbicide was used in 1994 and 1995 and did not provide adequate control. In 1996 better weed control was achieved using a post-emergent application of Marksman (4.0 L/ha) and Ultim (0.10 kg/ha).

A number of theories have been suggested as to why there was increased weed pressure in the manured plots, including the presence of weed seeds in the manure, and large quantities of available nutrients loaded into the surface of the soil where weed seeds germinate. Whatever the cause, the research at the Chipps site indicated that farmers who apply liquid manure to their fields should be prepared for the possibility of additional weed pressure.

4.4.3 Farmer Impressions

Gary Chipps is confident that he can meet all his modified no-till corn fertilizer requirements on most fields with a pre-plant application of approximately 5500 gallons per acre of manure with no starter fertilizer. That rate is about mid way between the rate that was used in this experiment for the manure only treatment and the manure plus inorganic treatment. On very productive fields he would consider adding an additional 20-30 kg N/ha.

Gary has modified his Houle manure tanker and developed his own system for incorporating the manure. The modifications were necessary to alleviate plugging problems experienced with his previous banded injection system. He also feels he is getting better distribution and has lower horsepower requirements. The easier pulling enables him to travel at speeds of 5 1/2 mph. His present system is giving him greater than 95% manure incorporation.

Gary is familiar with the Aerway ™ system and prefers his system to the Aerway ™ since he gets better manure incorporation and has lower horsepower requirements. The only disadvantage he could see with his system is that it results in lower soil surface residue levels than the Aerway ™. He believes his system could be adjusted quite easily to be used for in-row applications. He would put in narrower sweeps and install cultivation cover shields to protect the corn from splashing.

Gary believes that the manure applications are making weed control requirements more challenging than inorganically fertilized fields. To reduce herbicide costs he is planning to band herbicides and use two cultivations for weed control in most fields in the future. Recently he has been broadcasting herbicides and performing one inter-row cultivation.

Since he has 365 days of manure storage, fall manure applications are not necessary. The modifications he has made to his tanker allow him to cover more ground in the spring and help him to manage a single pre-plant manure application.

4.5 Conclusions

The research conducted at this site investigated the necessary rates and cumulative effects of using liquid dairy manure in a modified no till system to supply 100% of nitrogen requirements for a corn crop.

Three years of data indicate that rates of liquid manure application ranging from 4700 gal/ac to 7900 gal/ac had no significant effects on the environmental, productivity and farm management indicators studied. The farmer cooperator determined that a rate of 5500 gal/ac would meet his N requirements in most seasons. In addition to this conclusion the following important observations were made.

- Residual soil nitrate levels after harvest were measured as an indicator of potential impacts on groundwater. At this site no significant differences in residual nitrate levels were detected between manure and inorganic treatments. Nitrate levels varied over the growing season reflecting differences in nitrogen dynamics due to manure or inorganic sources, but by the end of the growing season, when potential for groundwater contamination is highest, levels were not significantly different.
- In the three years of this experiment corn yields within a year from manure and inorganic treatments were not significantly different. Weed pressure as measured by total weed biomass was significantly higher in the manure treated plots in 1995. This increased weed pressure did not result in significantly lower corn yields.
- The farmer cooperator in this experiment has developed a system of incorporating manure into his conservation farm management system which meets his requirements and which he finds economically and operationally sustainable. Significant components of his system which ensure it works for him include 365 days of manure storage, a modified manure spreading system, and a flexible weed control program including herbicide and cultivation.

5. Experiment 2: Effect of Side-dressing Liquid Manure and Fertilizer on Corn Growth at the Soetemans Farm

This experiment examined the effect of different nutrient sources including liquid hog manure, inorganic fertilizer and a combination of manure and inorganic fertilizer on soil nutrients, groundwater quality, performance of no-till corn and overall conservation farm systems management. This experiment varied from experiment 1 in the following ways: liquid hog manure as opposed to dairy manure, clay loam soil as opposed to sandy loam soil; and post-emergent manure applications as opposed to pre-emergent. This study addresses *Objective A: to determine the influence of source amount and method of manure application*. This study also addresses *Objective B: to measure the effect of liquid manure application in a standing corn crop.*

The following measurements were used to examine these effects:

- soil nutrients indicated by general soil fertility;
- potential impacts on groundwater indicated by residual soil nitrate after harvest;
- performance of no-till corn indicated by weed density and corn yield; and
- overall management impacts as determined by the farmer cooperator.

5.1 Site Characteristics

The experiment was conducted on a clay loam soil (21% sand, 44% silt and 35% clay by weight) at the farm of Andre Soetemans (Forest, Ont.). The experiment was moved to an adjacent field in 1995 in keeping with the corn-soy rotation practiced at the Soetemans' farm. The soil at the 1995 research field was a silt loam texture (33% sand, 52% silt and 15% clay by weight). Andre farms on 180 acres and typically has 30 acres in corn, 70 acres in soybeans and 80 acres in winter wheat. Andre first experimented with no-till in 1991 and has been all no-till since 1993. He describes his tillage system as "no-till plus one" because he prefers to do a mechanical cultivation for weed control.

Andre has a 140 sow, farrow to finish livestock operation. His manure lagoon has a 200 day storage capacity. Half of his manure is applied to his own land, with the remainder going to a rented farm. Prior to being involved in the experiment his practice was to apply manure by irrigation. For this experiment a Husky Tanker was converted to apply liquid manure between 4 rows of corn after the corn had emerged.

Site details and field activities during the three year experiment are listed in Table 5.1.

Table 5.1 Site Details and Field Activities at the Soetemans Farm, 1994 to 1996

Year	1994	1995	1996
Plot size	7.3 m x 270 m	7.3 m x 270 m	7.3 m x 270 m
Spreader	Husky 2000	Husky 2000	Husky 2000
Planting Date	May 20	May 8	May 20
Row Spacing	91 cm	91 cm	91 cm
Population (plants/ha)	55,100	68,400	68,400
Side-dress Manure: Date	June 23	June 15-16	June 28
Rates	3800 gal/acre high rate	3540 gal/acre	3900 gal/acre
	2500 gal/acre low rate		
Fertilizer Side-dress	July 7	June 12	July 5
Harvest Date: N Test Plots	Oct. 27	Oct. 9	Oct 26
Harvest Date: Main Plots	Oct. 27	Oct. 11	Nov. 15

The manure analysis at the time of application to the experimental plots is shown in Table 5.2.

Table 5.2 Manure Analysis at the Soetemans Site at the Time of Application

Sampling Date	N %	P %	K %	NH_4-N mg/kg	DM %
23-Jun-94	0.68	0.32	0.3	5075	9.9
16-Jun-95	0.51	0.15	0.2	2490	4.7
35243	0.45	0.13	0.17	3100	4.3

5.2 Experimental Design

The experiment began in 1994 with the following three treatments: 100% manure (M), 100% inorganic fertilizer (I) and their combination (M+I). In 1995 the 100% manure (M) treatment was dropped as it was apparent to the farmer cooperator that a starter fertilizer was a necessary component for corn crops in his area. An additional M+I treatment was introduced to which a mechanical cultivation was added. This treatment (M+I+C) had the same nutrient additions as the M+I treatment and was added in hopes of reducing the weed control problems that had occurred on the manured plots in 1994. The M+I+C treatment was repeated in 1996. The treatments were replicated five times, forming a total of 15 plots each year.

Liquid manure was surface-applied without incorporation at the time of side-dressing. The application of the inorganic fertilizer was split as 34-0-0 starter and 28%N side-dress in 1994. In 1995 and 1996 a 40-24-24 starter fertilizer was used. Side-dressing with 28%N was carried out at the 7-8th leaf stage of corn growth in all three years of the experiment.

5.3 Field Conditions

At the start of the experiment (spring 1994) the field had a relatively low residue cover (26%) for corn following soybeans.

The spring of 1994 was drier than average at this site. At the time of soil N sampling in June 1994, the corn was stunted and exhibited drought stress as a result of the dry weather, high temperatures and strong spring winds. Later in the season significant weed pressure was experienced at this site on the liquid manured treatments.

Mid-summer dry periods occured in 1995 and 1996, and the spring of 1996 was wetter than average.

Nitrogen response curves were drawn based on a small plot nitrogen study in each year (Appendix 1) These studies revealed that the soils were responsive to N in all years. The Maximum Economic Rate (MER) for inorganic fertilizer application was determined to be 112 kg/ha in 1994, 199 kg/ha in 1995 and 133 kg/ha in 1996.

5.4 Results and Discussion

5.4.1 Soil Properties

5.4.1.1 Nutrients Added

The nutrients released by manure and inorganic fertilizer applications are presented in Table 5.3. Due to variations in the manure nutrient content, the inorganic fertilizer treatment received slightly less N than the manure treatments in 1994 and slightly more N in 1995 and 1996.This variation is unavoidable when working with manure and is relatively minor considering the possible variation in actual manure N availability included in the assumption of 50% availability.

No additions of P or K were included with the inorganic treatment in 1994 and 1996, while 27 kg/ha of P and K were added to the 1995 inorganic treatment. In comparison, over the three years of the experiment, the manure treatments received from 52 to 126 kg P_20_5/ha and from 80 to 138 kg K_20/ha.

Table 5.3 Experiment 2: Rate (kg/ha) of available nutrients[P] applied in manure and inorganic fertilizer at the Soetemans farm

Year	Treatment	Premanure	Starter	Side-dress	Total
1994	M	-	-	(145/126/138)	(145/126/138)
	M+I	-	(38/0/0)	(95/83/91)	(133/83/91)
	I	-	(38/0/0)	(84/0/0)	(122/0/0)
1995	M+I	-	(45/27/27)	(101/55/86)	(146/82/113)
	M+I+C	-	(45/27/27)	(101/55/86)	(146/82/113)
	I	-	(45/27/27)	(118/0/0)	(163/27/27)
1996	M+I	-	(40/0/0)	(99/52/80)	(139/52/80)
	M+I+C	-	(40/0/0)	(99/52/80)	(139/52/80)
	I	-	(40/0/0)	(110/0/0)	(150/0/0)

P Manure nitrogen applications assumed to be 50% available in the year of application.

Manure P_20_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

5.4.1.2 Nitrate Levels

Soil nitrate present in the 0 to 60 cm soil layer is presented in Table 5.4. Soil nitrate content measured on June 15, 1994 was not significantly different between treatments although the plots with inorganic fertilizer (I and M+I) had received a starter fertilizer of 38 kg N/ha by that time. At the time of the fall 1994 measurement, the inorganic fertilizer treatment had a significantly lower nitrogen soil content than either of the manure treatments (Table 5.4). This treatment also had a significantly higher corn yield (Figure 5.1). The lower nitrate content may have been a result of the higher corn yield and higher N uptake as well as the lower rate of N applied to the inorganic treatment in 1994 (122 kg/ha vs. 145 and 133 for the manure treatments). However, since both manure plots had significantly higher weed pressure than the inorganic plot in 1994 the nitrogen uptake/yield relationship is confounded.

Table 5.4 Experiment 2: Soil $N0_3$ (kg/ha) in 60 cm depth at the Soetemans Site

Sampling Date	Timing of Sample	M Side-dress Manure	M+I Starter + Side-dress Manure	M+I+C Starter + Side-dress Manure + Cultivation	I Starter + Side-dress Inorganic
34499	After Planting, Before Manure	87.5 a	107.6 a		96.6 a
34658	Fall	74.5 ab	79.7 a		60.9 b
34864	After Planting		62.9 a	65.4 a	65.4 a
34882	After Manure and Inorg. Side-dress		151.6 a	141.9 a	80.4 b
34991	Fall		49.9 b	38.9 b	91.4 a
35232	After Planting		137.4 a	129.6 a	105.6 a
35255	After Manure and Inorg. Side-dress		129.6 a	108.2 a	68 b
35389	Fall		50.5 a	44.7 a	47.3 a

Means within a row followed by the same letter are not significantly different (P # 0.05)

Soil samples obtained on June 15, 1995 showed no differences in N levels between treatments, as could be expected since all treatments had received the same amount of starter fertilizer (45 kg/ha). The soil N results from samples obtained on July 3, after the manure and inorganic side-dress applications, showed significantly more N in manure treated soils. By the time of the fall 1995 sampling, the treatments that had received manure had significantly less soil nitrate remaining than the inorganic side-dress treatment. The greater soil N in the inorganic treatment soils could be attributed to the combined effects of the greater amount that was applied that year (in comparison with the manure N) and a slower conversion and uptake of the inorganic N. There were no significant yield differences observed in 1995.

The 1996 data also reflect different rates of nitrification between manure and inorganic N. In 1996, there were no significant differences in soil N between treatments after planting, but after the side-dress applications of manure and inorganic fertilizer, the manure treatment soils had significantly more N. However, after crop growth the fall 1996 sampling showed no significant differences in soil N for any of the treatments..

5.4.1.3 Phosphorus and Potassium Levels

The results of soil fertility analysis to determine available P and K are presented in Table 5.5 and Table 5.6, respectively. Samples were taken less frequently at this site, particularly in the first two years of the experiment. The soil P levels at the field used for the experiments in 1994 and 1996 were almost all in the 31 to 60 mg/L range which is considered "very high" (OMAF, 1996). No P additions would be recommended for this soil, but that is not an option if manure is to be applied. The high background soil P levels were likely the result of manure applications in previous years.

The field used for the 1995 experiments had a background soil P level of 16 mg/L, for which the suggested P addition would be 20 kg/ha (OMAF, 1996). In 1996, the soils that received the manure treatments had significantly more soil P than the inorganic treatment.

Table 5.5 Experiment 2: Soil test P (mg/L) in 0 to 15 cm depth at the Soetemans Site

Sampling Date	Timing of Sample	M Side-dress Manure	M+I Starter + Side-dress Manure	M+I+C Starter + Side-dress Manure + Cultivation	I Starter + Side-dress Inorganic
34464	Background: Pre-plant		Average =	32	
34841	Background: Post-plant		Average =	16	
35212	Background: Post-plant		Average =	35	
35232	Before Side-dress		43.8 a	42.6 a	36.8 a
35255	After Manure and Inorg. Side-dress		63.4 a	56.8 a	41.2 b
35389	Fall		40.6 a	39.8 a	27.8 b

Means with a row followed by the same letter are not significantly different (P # 0.05)

Table 5.6 Experiment 2: Soil test K (mg/L) in 0 to 15 cm depth at the Soetemans Site

Sampling Date	Timing of Sample	M Side-dress Manure	M+I Starter + Side-dress Manure	M+I+C Starter + Side-dress Manure + Cultivation	I Starter + Side-dress Inorganic
34464	Background: Pre-plant		Plot Average = 156		
34841	Background: Post-plant		Plot Average = 112		
35212	Background: Post-plant		Plot Average = 171		
35232	Before Side-dress		172.2	166.7	168.7
35255	After Manure and Inorg. Sidedress		254.6	241.2	229.2
35389	Fall		153	157	152

Within a row, means were not significantly different according to Tukey's HSD (P#0.05)

The field used for the 1994 and 1996 experiments had soil K concentrations considered "very high" (OMAF, 1996), while the 1995 field had a "medium" background soil K (OMAF, 1996). The addition of K from the manure treatments but not the inorganic treatment did not result in greater soil K levels in the manure treatment soils in 1996 (Table 5.6).

5.4.2 Agronomic Properties

5.4.2.1 Corn Yields

The yields in each year of the experiment are shown in Figure 5.1. The inorganic (I) treatment had a significantly greater yield than the manure (M) treatment in 1994. There were no significant yield differences between treatments in 1995 or 1996.

Mid summer droughts occurred in all three years and wet spring conditions were a problem in 1996. In 1995 the crop suffered major damage from corn borer.

In 1994, the inorganic treatment had a significantly greater yield than the manure treatment. The inorganic treatment received 122 kg/ha of N in 1994, compared to 133 kg N/ha on the manure + inorganic treatment and 145 kg N/ha on the manure treatment. According to the nitrogen response trials in 1994, the MER at the Soetemans site was 112 kg/ha. The yield differences in the main plots were consistent with the nitrogen response curve.

Dry mid summer conditions contributed to the low corn yields at the Soetemans site in 1994. Greater weed pressure was noted on the manure treatments, which may also have affected the yields. The farmer cooperator believed that it was unrealistic to expect a full crop of corn on his clay loam soil using only post emergent liquid manure without a starter fertilizer.

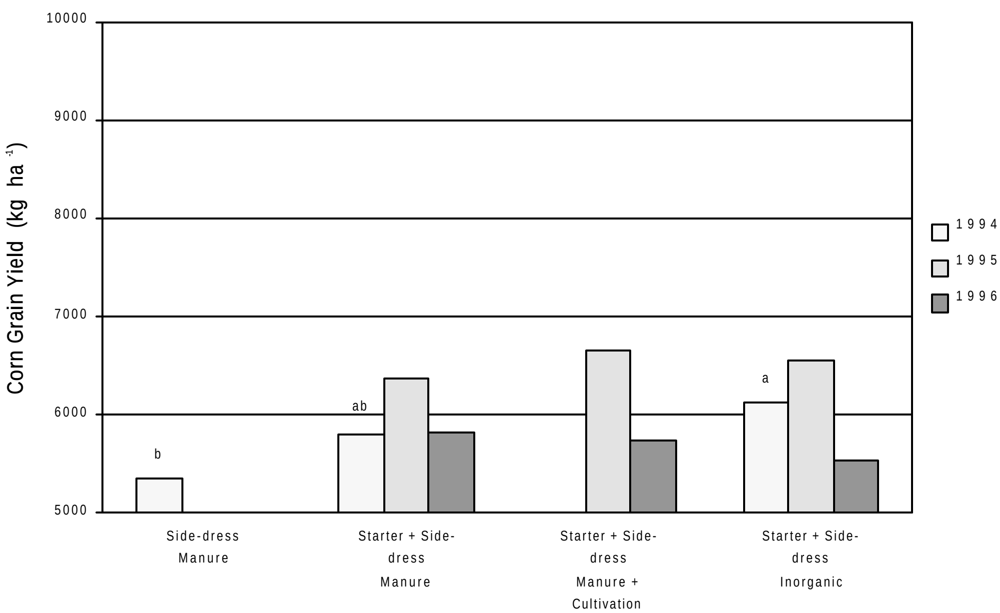

Figure 5.1 Experiment 2: Grain corn yield at the Soetemans site. All yields are at 15.5% moisture. Within 1994, yield bars having the same letter above them are not significantly different (p # 0.05). Within 1995 and 1996, no significant difference was observed among the treatments.

There were no significant yield differences among treatments in 1995 or 1996. There was also very little weed pressure. As a result, the beneficial effects of the late June cultivation on weed control could not be assessed.

In both 1995 and 1996 the starter inorganic + side-dress manure treatments produced yields comparable with the inorganic treatment.

5.4.2.2 Weed Observations

In 1994 weeds per square meter counts were significantly higher on the M plots than on the I plots, the combination treatment (M+I) was intermediate. At the time of fall combining, extensive weed growth was observed on the liquid manure side-dressed plots. In 1995 weed biomass measurements were made in addition to a weed count to assess treatment effects on weeds. However, weed pressure in 1995 was uniformly low and biomass measurements did not show any difference in weed pressure. Weed pressure was negligible in 1996.

5.4.3 Farmer Impressions

Andre believed that manure side-dressing was his best option to minimize compaction and enable earlier spring planting on his clay loam soil. He preferred to leave the manure on the surface rather than trying to incorporate it in his soil. He believed that the corn plants provided some shelter from the wind and reduced the amount of N losses due to volatilization. He also felt that the drier soil conditions at side-dressing time would result in reduced manure losses through tile drains, compared to earlier applications. He reported no problems with the side dressing attachment for the manure tanker.

Andre felt he had more weeds on the manure plots than where he had applied inorganic fertilizer, particularly in 1994. He felt the weed pressures resulted in poorer yields and felt that weed problems were worsened when rain immediately followed the manure application. As a response he instituted a no-till cultivation in subsequent years. This cultivation seemed to work reasonably well for weed control after manure application. However, weed pressures in general were reduced in 1995 and 1996 and it was difficult to assess the value of the practice and possible impact on yields. He felt unless the weed problem was severe, it is questionable if there would be enough crop response to cultivation to justify the operation.

5.5 Conclusions

The research conducted at this site investigated the feasibility and implications of using liquid hog manure as a post emergent nutrient source in a modified no till system to supply 100% of nitrogen requirements for a corn crop. Three years of data indicate mixed results for the environmental, productivity and farm management indicators studied. Rates ranging from 2500 gal/ac to 3900 gal/ac of liquid hog manure applied within a standing corn crop were generally effective in maintaining optimum crop production when compared to mineral nitrogen sources, provided the manure was supplemented with a mineral starter fertilizer. The following observations provide additional detail on the findings relative to the objectives of the study.

- Manure applications without a starter fertilizer resulted in substantially reduced corn yields the first year and the treatment was abandoned.
- Residual soil nitrate levels after harvest were measured as an indicator of potential impacts on groundwater. At this site significant differences in nitrate levels were detected between manure and inorganic treatments in two years. In 1994 manure treatments had significantly higher residual N levels while in 1995 the trend was reversed. No conclusions on the implications of side dressing manure for groundwater quality can be drawn from this experiment. As in the first experiment, nitrate levels varied over the growing season reflecting differences in nitrogen dynamics due to source of N, but by the end of the growing season, when potential for groundwater contamination is highest, the measurements were inconclusive.
- In the three years of this experiment corn yields from manure and inorganic treatments were not significantly different for two seasons, and in one season the corn with manure as a nitrogen source yielded significantly lower than corn with an inorganic nitrogen source. Weed pressure, as measured by

weeds per square metre, was significantly higher in the manure treated plots for 1994 and may have contributed to the yield advantage for the inorganic plots. This was not evident in 1995 or 1996 where weed biomass was low to negligible.

Ë The farmer cooperator in this experiment adopted a new form of manure management in his conservation farm system which he was able to integrate with ongoing operations. He identified concerns after the first year and modified the system to his satisfaction in the subsequent two years.

6. Experiment 3: Evaluation of Pre-plant Manure Application with Aerway™ tillage at the VanDorp Farm

The objective of the experiment was to determine which of two different application rates for liquid manure incorporated with an Aerway ™ tillage tool could be most effective for achieving crop production equivalent to crops fertilized with inorganic nitrogen. The experiment included different rates of liquid hog manure, inorganic fertilizer and a combination of manure and inorganic fertilizer. This study addresses *Objective A: to determine the influence of source, amount and method of manure application*. The effects on soil nutrients, groundwater quality, performance of no-till corn and overall conservation farm systems management were measured by the following indicators:

- soil nutrients indicated by general soil fertility;
- potential impacts on groundwater indicated by residual soil nitrate after harvest;
- performance of no-till corn indicated by corn yield; and
- overall management impacts as determined by the farmer cooperator.

6.1 Site Characteristics

The experiment was carried out on a silt loam (35% sand, 54% silt and 11% clay by weight) texture field at the farm of John VanDorp. John farms on 168 acres near Woodstock, Ontario. He has 111 acres in corn, 25 acres in soybeans and 32 acres in alfalfa. He stopped plowing his fields in 1988 and switched to the Aerway™ tillage tool in the belief that it would promote better infiltration.

John has an 84 sow, farrow to finish livestock operation and finishes 1200 to 1400 pigs per year. His manure tank provides him with 200 days of storage. His current manure management routine is to apply 3500 gallons per acre in the fall and 3500 gallons per acre in the spring.

The field where the experiments were conducted was in corn for two years prior to the experiments. Site details and field activities during the three year experiment are listed in Table 6.1

Table 6.1 Site Details and Field Activities at the VanDorp Farm, 1994 to 1996

Year	1994	1995	1996
Plot size	7.3 m x 150m	7.3 m x 150 m	7.3 m x 150 m
Spreader	Mic 2700	Mic 2700	Mic 2700
Preplant Manure: date	May 3	May 8	May 17
rate	5230 gal/acre high rate	5230 gal/acre high rate	5230 gal/acre high rate
	3590 gal/acre low rate	3590 gal/acre low rate	3590 gal/acre low rate
Planting Date	May 11	May 13	May 20
Row Spacing	50.8 cm	50.8 cm	50.8 cm
Population (plants/ha)	76,100	76,100	76,100
Fertilizer Side-dress	June 20	June 21	June 29
Harvest Date: N Test Plots	Oct. 28	Oct. 10-11	Oct. 25
Harvest Date: Main Plots	Nov. 7	Oct. 12-13	Nov. 8

The manure analysis at the time of application to the experimental plots is shown in Table 6.2.

Table 6.2 Manure Analysis at the VanDorp Site at the Time of Application

Sampling Date	N %	P %	K %	NH_4-N mg/kg	DM %
3-May-94	0.36	0.12	0.15	1990	7.53
17-May-95	0.45	0.23	0.16	2460	11.81
17-May-96	0.43	0.2	0.15	2250	7.98

6.2 Experimental Design

The four treatments in this experiment included: 100% preplant manure at either a high rate (MH) or a low rate (ML), the combination of low rate preplant manure with inorganic fertilizer (M+I) and 100% inorganic fertilizer (I). Each treatment was replicated four times, for a total of 16 plots.

The inorganic fertilizer (28% N) was applied by side-dressing at the 7-8th leaf stage of corn growth. Manure spreading and Aerway ™ treatment were combined as one operation, to reduce soil compaction and fuel consumption compared to multiple passes. The Aerway™ implement was mounted behind the manure spreader and the spreading manure flow dropped after the Aerway ™ implement. The Aerway ™ operation created holes in the ground and loosening the soil to encourage manure infiltration into the top 20 cm of soil, while maintaining residue cover on the soil surface.

6.3 Field conditions

In 1994 the field, which had previously been in corn, had 52% residue cover before planting. As desired by the farmer cooperator, all plots were disked immediately after manure application to increase soil temperature as the spring was cool and wet. The disk operation incorporated residue into the soil and resulted in a decrease in residue cover to 15%.

Weather conditions at this site generally conformed to long term averages.

The nitrogen response trials (Appendix 1) revealed that the soils at this experimental site were not consistently responsive to N. The field had a history of manure applications and was not the first choice for the experiments. It was selected when a land tenancy problem developed at the intended field shortly before the 1994 experiments were to begin. The experiment was continued for the information it could provide on variables other than crop yield response to N.

6.4 Results and Discussion

6.4.1Soil Properties

6.4.1.1Nutrients Added

The plant available nutrient application rates were calculated for each year of the experiment and are presented in Table 6.3. Nitrogen additions were similar for all treatments in a given year, except for the manure low (ML) treatment, which received less. The inorganic treatment did not receive any P or K additions during the three years of the experiment.

Table 6.3 Experiment 3: Rates (kg/ha) of available nutrients[P] (N, P_2O_5 and K_2O) applied in manure and inorganic fertilizer at the VanDorp farm

Year	Treatment	Pre-plant manure	Starter	Side-dress	Total
1994	MH	(106/65/95)	-	-	(106/65/95)
	ML	(73/45/65)	-	-	(73/45/65)
	ML+I	(73/45/65)	-	(34/0/0)	(107/45/65)
	I	-	-	(106/0/0)	(106/0/0)
1995	MH	(132/124/102)	-	-	(132/124/102)
	ML	(91/85/70)	-	-	(91/85/70)
	ML+I	(91/85/70)	-	(41/0/0)	(132/85/70)
	I	-	-	(132/0/0)	(132/0/0)
1996	MH	(126/108/95)	-	-	(126/108/95)
	ML	(87/74/65)	-	-	(87/74/65)
	ML+I	(87/74/65)	-	(40/0/0)	(127/74/65)
	I	-	-	(120/0/0)	(120/0/0)

[P] Manure nitrogen applications assumed to be 50% available in the year of application.
Manure P_2O_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

Despite the lack of nitrogen response at this site, the timing of applications may have favoured the manure treatments by providing a readily available N source or by changing N dynamics. No inorganic starter fertilizer was applied to any of the treatments. As a result, the inorganic treatment received no nutrient additions until the 28%N side-dress applications, which were delayed due to wet weather in both 1994 and 1996.

6.4.1.2 Nitrate Levels

Soil nitrate test results taken at various times during the growing season in each year of the experiment are shown in Table 6.4. In general these readings show the relatively high residual levels of N at this non-responsive site. In 1994 the fall nitrate levels were the highest of any encountered during this experiment and represented a significant potential for nitrate leaching to groundwater. Several anomalous readings were encountered, for example, the May 16, 1995 results show that the MH treatment, which had received 132 kg/ha of N, had similar soil N levels to the I treatment, which had received no N additions since the side dress of 1994.

In 1994, the inorganic treatment had significantly more soil N in the fall than the other treatments which was attributed to a lack of rainfall following N side-dress application, resulting in reduced grain yield (Section 6.4.2.1) and higher residual N in the soil at harvest, than manure treatments. In the fall of 1995, the MH had significantly more soil N than the other treatments, while in the fall of 1996 there were no significant differences in soil N levels between treatments.

Soil N levels usually decrease between the time of the fall and spring sampling. Between the fall of 1994 and spring of 1995, a decline between 62 to 111 kg N/ha occurred, with the greatest decline occurring in the inorganic treatment soils. It is this soil N that is at the greatest risk of leaching into the groundwater. Between the fall of 1995 and spring of 1996 the soil N levels increased. This anomaly is probably due to the cold temperatures in early December of 1995, which resulted in decreased microbial activity and soil test N results, compared to the conditions at the time of the May 16, 1996 sampling.

Table 6.4 Experiment 3: Soil $N0_3$ - N in 60 cm depth (kg/ha) at the VanDorp site

Sample Date	Timing of Sample	MH Pre-plant Manure (high rate)	ML Pre-plant Manure (low rate)	ML+I Pre-plant Manure (low) + Side-dress Inorg/	I Side-dress Inorganic
34481	After manure	177.9 a	159.7 ab	146 b	123.8 c
34501	Before inorg. side-dress	272.4 a	221 ab	238.2 a	172.6 b
34648	Fall	107 b	96.4 b	101.5 b	144.5 a
34823	Before manure	33.7 a	34.3 a	35 a	33.7 a
34834	After manure	97.2 a	112.8 a	135.4 a	96.6 a
34861	Before inorg. side-dress	152.9 a	127 b	98.5 c	57.7 d
35036	Fall	38.1 a	32.6 b	33 b	30.1 b
35200	Before manure	77.8 a	51.2 a	49.2 a	53.1 a
35213	After manure	114.7 a	66.1 ab	63.5 ab	47.3 b
35235	Before inorg .side-dress	105.6 a	68 b	71.3 b	54.4 b
35388	Fall	55.1 a	47.3 a	48 a	44.1 a

Means within a row followed by the same letter are not significantly different (P # 0.05)

6.4.1.3 Phosphorus and Potassium Levels

The results of soil fertility analysis to determine available P and K are presented in Table 6.5 and Table 6.6, respectively. The soils at this site had received manure in the past and were well supplied with P and K from the start of the experiment.

On many of the sampling occasions, the high rate manure treatment had significantly more soil P than the inorganic fertilizer treatments. This is to be expected, since P was supplied in the manure, but not in the inorganic treatments. Soil P in the range of 31 to 60 mg/L is considered "Very High" (OMAF, 1996) and no additions of P would be recommended. Despite no additions of P, the soils of the inorganic treatment had spring P values in the 21 to 30 mg/L "High" range, for which the recommended P addition is 20 kg/ha (OMAF, 1996). The high manure rate could cause concern for long term P build up in the soil if the farm management did not include rotation to crops such as soybeans and alfalfa to which manure is not applied.

Table 6.5 Experiment 3: Soil test P (mg/L) in 0 to 15 cm depth at the VanDorp Site

Sampling Date	Timing of Sample	MH Pre-plant Manure (high rate)	ML Pre-plant Manure (low rate)	ML+I Pre-plant Manure (low) + Side-dress Inorg.	I Side-dress Inorganic
3-May-94	Before manure		Average = 26.1		
25-May-94	After Manure	50.8 a	39.8 b	39.8 b	41.5 b
11-Nov-94	Fall	28.3 a	19.8 a	19 a	18.5 a
4-May-95	Before manure	37.8 a	29.3 a	30 a	29.3 a
16-May-95	After Manure	42.3 a	37.8 a	35.5 a	30.5 a
5-Dec-95	Fall	46.3 a	33.5 b	33.3 b	28.0 b
16-May-96	Before manure	55.5 a	36.5 b	41.8 b	31.8 b
29-May-96	After Manure	46.5 a	39.5 a	38 a	25 b
20-Nov-96	Fall	53.0 a	38.0 ab	36.5 ab	24.0 b

Means with a row followed by the same letter are not significantly different (P # 0.05)

Table 6.6 Experiment 3: Soil test K (mg/L) in 0 to 15 cm depth at the VanDorp Site

Sampling Date	Timing of Sample	MH Pre-plant Manure (high rate)	ML Pre-plant Manure (low rate)	ML+I Pre-plant Manure (low) + Side-dress Inorg.	I Side-dress Inorganic
3-May-94	Before manure		Average = 99.4		
25-May-94	After Manure	169.4 a	120.7 a	120.7 a	125.5 a
11-Nov-94	Fall	70.4 a	50.4 a	48.7 a	46.4 a
5-May-95	Before manure	118.9 a	94.1 a	99 a	90.9 a
16-May-95	After Manure	120.1 a	89.0 b	98.1 b	83.9 b
4-Dec-95	Fall	96.8 a	69.8 a	70.5 a	65.5 a
16-May-96	Before manure	116.2 a	89.7 a	89.5 a	67.7 a
29-May-96	After Manure	106 a	87.7 a	76.6 a	69.3 a
20-Nov-96	Fall	91 a	73 a	65.3 a	61.5 a

Means with a row followed by the same letter are not significantly different (P # 0.05)

Soil K in the high manure treatment was significantly greater than the other treatments on one sampling occasion (May 16, 1995). Despite annual loadings of 95 to 102 kg K_20/ha, the soil test K reached the "very high" (151 to 250 mg/L) range only once, following the manure application in 1994.

In the fall of 1996, with no added K for three growing seasons, the soil test K of the inorganic fertilizer treatment was in the "medium" range (OMAF, 1996). The recommended addition of K_2O for soils in this range would be 80 kg/ha (OMAF, 1996).

6.4.2 Agronomic Properties

6.4.2.1 Corn Yield

The yields in each year of the experiment are shown in Figure 6.1. This was the only site where the yields of the main plots were hand harvested.

In the first two years of the study all of the treatments that included manure had significantly greater yields than the inorganic treatment. In 1996, the ML treatment had a significantly lower yield than the other treatments.

As previously observed, the timing of nutrient applications may have favoured the manure treatments by serving as an early source of readily available nutrients or by changing N dynamics. It is also possible that the Aerway™ tillage associated with manure application had a beneficial effect.

In 1994 the season was exceptionally favorable for corn growth and the higher nutrient levels present on this site resulted in substantial yields for all treatments. Yields ranged from 10746 kg/ha for the M+I treatment to 9953 kg/ha for the I treatment. The late side-dressing of inorganic fertilizer appeared to be more effective as a supplement than as the entire nutrient addition, as it was for the I treatment.

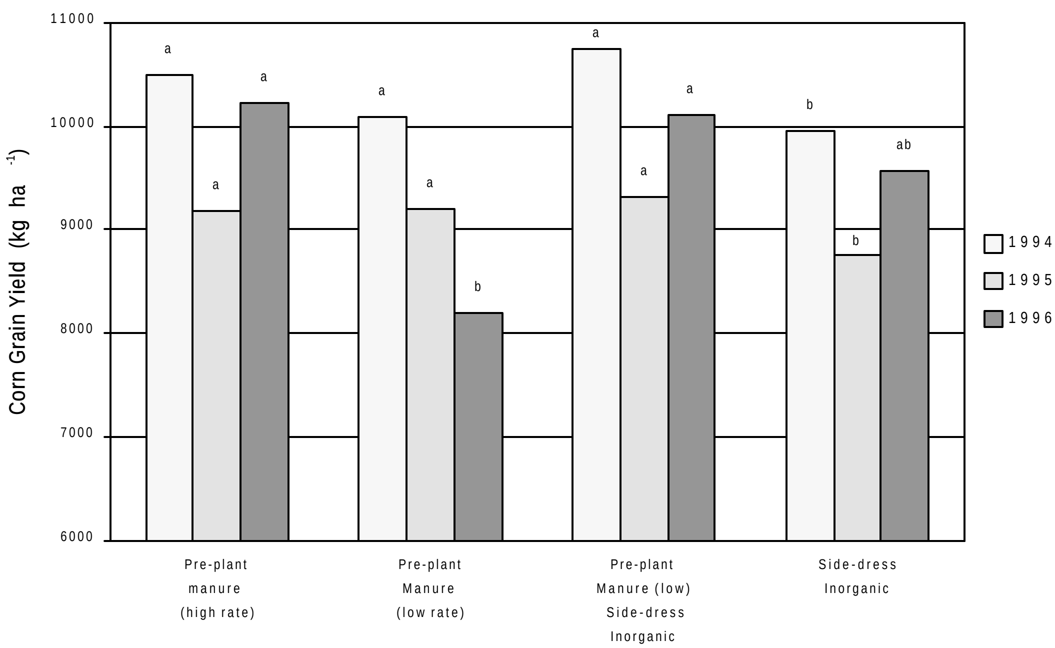

Figure 6.1
Experiment 3: Grain corn yield at the VanDorp farm. All yields are at 15.5% moisture. Within a given year, yield bars having the same letter above them are not significantly different (p # 0.05).

In 1995, the yields ranged from 9320 kg/ha for the M+I treatment to 8760 kg/ha for the I treatment. In 1996, the MH treatment had the greatest yield, at 10220 kg/ha, while the ML treatment had the lowest yield (8200 kg/ha).

6.4.3 Farmer Impressions

John has been applying pre-plant manure to his corn fields for many years and has been using the Aerway™ tillage tool since 1988. In this experiment he had the opportunity to compare two different rates of manure application with an entirely inorganic fertilizer treatment and one that was part inorganic/part manure.

John felt that the high rate of manure application was the most effective of the two rates of manure application that were compared. It provided top yields and had low input costs. He didn't see the need for a starter fertilizer on his light soil type (11% clay) and preferred to work with manure alone. He liked to use the Aerway™ on his fields after the manure application because it removed the tanker tracks that would otherwise have created difficulty during planting because of compacted soil conditions. On his silt loam soil he felt that if he used the Aerway ™ on the soil before running the manure tanker over it then the soil would become too soft to support the heavy manure tanker.

6.5 Conclusions

Conclusions based on the data from this site are difficult to make given its relatively non-responsive characteristics, uniformly high yields and several anomalous nutrient measurements. However, the work does suggest that relatively high rates of manure (from 3590 gal/ac to 5230 gal/ac) can be used successfully in a conservation tillage system without significantly greater danger of nitrate leaching when compared to lower rates of manure and inorganic nitrogen sources. It also provided the farmer cooperator an opportunity to fine tune the use of aeration tillage in conjunction with manure management.

7. Experiment 4: Effect of Incorporation of Pre-plant Manure and Post Emergent Liquid Manure at the Yantzi Farm

The objective of this experiment was to gain further understanding about the effects of pre-plant and side-dress liquid manure applications in no-till corn. Factors being examined were how the timing or method of the liquid manure application affected crop productivity and soil nutrients. The agronomic and environmental effects of using liquid manure versus inorganic fertilizer as the nitrogen source were compared. This study addressed *Objective A: to determine the influence of source, amount and method of manure application, specifically the value of aeration tillage in manure incorporation*. This study also addressed *Objective B: to measure the effects of liquid manure application to a standing corn crop*. This site received the most intensive soil nitrate sampling of the four southwestern Ontario farm sites in addition to the following measurements:

- soil nutrients as indicated by general soil fertility;
- potential impacts on groundwater indicated by residual soil nitrate after harvest ;
- performance of no-till corn indicated by corn yield; and
- overall management impacts as determined by the farmer cooperator.

7.1 Site Characteristics

The experiment was established on a silt loam soil (23% sand, 59% silt and 18% clay by weight) at the farm of Richard Yantzi (Tavistock). Richard farms on approximately 780 acres of land. In a typical year he has 250 acres in corn, 250 acres in soybeans, 200 acres in winter wheat, 50 acres in white beans and 30 acres in alfalfa. Richard first experimented with no-till between 1985 and 1986. Since 1988 he has gone completely with no-till. In his livestock operation he has 400 sows and finishes about 4000 pigs per year. He has approximately 300 days of manure storage capacity in his lagoon.

A Husky 2500 manure tanker was leased to the project for the pre-plant and side-dress manure application experiments at the Yantzi site. An Aerway ™ tillage tool was attached immediately in front of the manure outlet spreader plate for the pre-plant manure applications. When lowered, the Aerway ™ conditions the soil by breaking up deep macropores and creating new shallow macropores. A different toolbar with disk incorporators was used for side-dress manure applications.

For the 1995 field season, the experiment was moved to an adjacent field, also a silt loam soil (20% sand, 62% silt and 18% clay by weight). The change in field was required in order to conform to the corn-soy rotation practiced at the Yantzi farm. The site and field activities are summarized in Table 7.1.

Table 7.1 Site details and field activities at the Yantzi farm, 1994 to 1996

Year	1994	1995	1996
Plot size	4.6 m x 310m	4.6 m x 233 m	4.6 m x 310 m
Spreader	Husky 2500	Husky 2500	Husky 2500
Preplant Manure: date	May 21	May 15	May 30
rate	3800 gal/acre	4775 gal/acre	4850 gal/acre
Planting Date	May 23	May 19	June 4
Row Spacing	76 cm	76 cm	76 cm
Population (plants/ha)	66,700	75,335	75,335
Side-dress Manure date	June 23	June 16	June 28
rate	3800 gal/acre	4775 gal/acre	6800 gal/acre
Fertilizer Side-dress	July 6	June 16	July 3
Harvest Date: N Test Plots	Oct. 25	Oct. 18	Oct. 25
Harvest Date: Main Plots	Oct. 26	Nov. 30	Oct. 31

The manure analysis of samples taken at the time of the treatments is shown in Table 7.2. The first sample shown for each year was used for the pre-plant applications and the second sample of the year represents manure used in the side-dressing applications. In the final year of the experiment the manure, which was stored in a lagoon, was diluted by heavy spring rainfall, resulting in a much lower nutrient content for 1996.

Table 7.2 Manure Analysis at the Yantzi Site at the Time of Application

Sampling Date	N %	P %	K %	NH_4-N mg/kg	DM %
23-May-94	0.34	0.23	0.13	1585	3.68
23-Jun-94	0.28	0.39	0.33	1661	1.34
17-May-95	0.28	0.18	0.14	1720	3.63
6-Jul-95	0.36	0.23	0.18	2148	4.53
30-May-96	0.12	0.01	0.03	1000	0.6
35251	0.12	0.03	0.1	989	1.19

7.2 Experimental Design

All plots received a starter fertilizer, with the balance of the nutrients supplied by either 100% manure or 100% inorganic fertilizer. The treatments used in the experiment were:

A Preplant manure with Aerway soil conditioning

NA Preplant manure without Aerway soil conditioning

D Side-dress manure with disk incorporation

ND Side-dress manure without disk incorporation

I Inorganic Side-dress 28% N fertilizer application

A sixth treatment was introduced in 1995 in response to suggestions by the farmer that the Aerway™ alone may be improving crop growth. This treatment (IA) was the same as the inorganic fertilizer treatment (I) except that the soil was treated with the Aerway prior to planting. The treatment did not result in any improvements over the inorganic fertilizer treatment in 1995. Conditions were not ideal for its use in the spring of 1995 because wet field conditions were present. It was not repeated in 1996 because of space limitations.

The manure plus starter fertilizer plots were treated with either preplant manure or side-dress manure. The side-dress manure and the 28% N inorganic fertilizer applications were made at the 7-8th leaf stage of corn growth. The five treatments were replicated four times, forming a total of 20 plots.

7.3 Field Conditions

In 1994 a high residue cover (about 60% on average) was observed at the Yantzi site due to a significant volume of residue remaining in the field from the previous year's corn crop.

The soil nitrate concentration before the initiation of the experiment was 9.48 mg/kg on average over the site.

The nitrogen response curves (Appendix 1) revealed that the soils were not consistently responsive to N. In 1994, the response curve had a positive quadratic coefficient (Figure 10) and the regression equation for the curve can not be used to calculate the MER for inorganic fertilizer application. In 1995 and 1996 there appeared to be a small response to fertilizer - N. The overall lack of N responsiveness at the Yantzi sites can probably be attributed to a history of manure applications to the fields. Both the field used in 1994/1996 and the field used in 1995 were located fairly close to the manure lagoon. The results of the N response tests would indicate that differences in yield cannot be attributed to N, particularly in the first year.

7.4 Results and Discussion

7.4.1 Soil Properties

7.4.1.1 Nutrients Added

The soil nutrients added by manure and inorganic fertilizer applications are displayed in Table 7.3.

Table 7.3 Experiment 4: Rates (kg/ha) of available nutrientsP (N, P_2O_5 and K_2O) applied in manure and inorganic fertilizer at the Yantzi farm

	Treatment	Premanure	Starter	Side-dress	Total
1994	A	(73/90/60)	(45/13/3)	-	(118/103/63)
	NA	(73/90/60)	(45/13/3)	-	(118/103/63)
	D	-	(45/13/3)	(60/153/152)	(105/166/155)
	ND	-	(45/13/3)	(60/153/152)	(105/166/155)
	I	-	(45/13/3)	(84/0/0)	(129/13/3)
1995	A	(75/89/81)	(30/8/2)	-	(105/97/83)
	NA	(75/89/81)	(30/8/2)	-	(105/97/83)
	D	-	(30/8/2)	(97/114/104)	(127/122/106)
	ND	-	(30/8/2)	(97/114/104)	(127/122/106)
	I	-	(30/8/2)	(89/0/0)	(119/8/2)
	IA	-	(30/8/2)	(89/0/0)	(119/8/2)
1996	A	(33/5/18)	(43/10/2)	-	(76/15/20)
	NA	(33/5/18)	(43/10/2)	-	(76/15/20)
	D	-	(43/10/2)	(46/21/82)	(89/31/84)
	ND	-	(43/10/2)	(46/21/82)	(89/31/84)
	I	-	(43/10/2)	(89/0/0)	(132/10/2)

P Manure nitrogen applications assumed to be 50% available in the year of application.

Manure P_20_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

7.4.1.2 Nitrate Levels

Soil nitrate measurements are presented in Table 7.4.

Significantly higher nitrate concentrations were measured under the pre-plant manure plots in the May and June 1994 measurements. By July 4, 12 days after side dress manure applications, nitrate readings indicated that the side dress treatments had significantly higher levels than the pre-plant manure treatments. The inorganic fertilizer treatment had significantly lower nitrate levels since the inorganic side dress had not yet been applied due to wet soil conditions. After the harvest, the inorganic treatment had a significantly higher nitrate level than any other treatment. Similar general trends were observed in 1995 and 1996.

Table 7.4 Experiment 4: Soil NO_3-N (kg/ha) in 0 to 60 cm depth at the Yantzi Site

Sampling Date	Timing of Sample	NA Pre-plant Manure	A Aerway + Pre-plant Manure	ND Side-dress Manure	D Side-dress Manure (Disked)	I Side-dress Inorganic	I+A Aerway + Side-dress Inorganic
31-May- 94	After pre-plant manure	115.4 a	128.3 a	81 b	82.2 b	91.5 b	
16-Jun-94	Before side-dress manure	198.2 a	208.2 a	130.2 b	136.2 b	148 b	
4-Jul-94	After side-dress manure	132.6 bc	147.6 b	213.2 a	219 a	108.1 c	
3-Nov-94	Fall	66.4 b	80.5 b	77.5 b	81.6 b	120.3 a	
23-May-95	After pre-plant manure	53.5 a	54.1 a	75.2 a	66.8 a	74.2 a	79.8 a
14-Jun-95	Before side-dress manure	104.5 a	105.3 a	60.4 b	55.0 b	67.9 b	62.0 b
4-Jul-95	After side-dress manure & inorg.	114.2 a	114.7 a	112.5 a	166.1 a	116.0 a	112.9 a
14-Aug-95	Mid summer	19.7 b	25.8 b	27.7 ab	60.5 a	43.9 ab	38.0 ab
5-Dec-95	Fall	27.3 a	31.5 a	31.7 a	38.1 a	36.5 a	34.7 a
27-May-96	Before pre-plant manure	62.5 a	60.5 a	59.0 a	58.3 a	55.9 a	
20-Jun-96	Before side-dress manure	102.4 a	108.0 a	87.9 a	83.0 a	80.6 a	
2-Jul-96	After side-dress manure	104.9 a	75.9 a	99.4 a	140.0 a	81.8 a	
17-Jul-96	After side-dress inorganic	14.0 b	11.8 b	27.7 b	74.9 a	21.0 b	
20-Nov-96	Fall	61.0 b	70.0 ab	70.6 ab	88.0 a	71.3 ab	

Means within a row followed by the same letter are not significantly different (P # 0.05)

7.4.1.3 Phosphorus and Potassium Levels

The results of soil fertility analysis to determine available P and K are presented in Table 7.5 and Table 7.6, respectively.

The soil fertility measurements showed that the pre-plant manure application on both the Aerway™ and no-Aerway ™ plots increased soil P compared to the untreated plots. No significant differences in K were found among the treatments at most sampling dates. The fall 1995 sampling indicated that manured treatments had higher soil K levels at the end of the season than non-manured treatments.

Table 7.5 Experiment 4: Soil test P (mg/L) in 0 to 15 cm depth at the Yantzi Site

Sampling Date	Timing of Sample	NA Pre-plant Manure	A Aerway + Pre-plant Manure	ND Side-dress Manure	D Side-dress Manure (Disked)	I Side-dress Inorganic	I+A Aerway + Side-dress Inorganic
18-May-94	Before pre-plant manure		Background:		24.8		
31-May-94	Before side-dress manure	16 a	16.7 a	13 a	9 a	12.3 a	
9-May-95	Before pre-plant manure		Background		8.8		
23-May-95	Before side-dress manure	12.8 a	9.5 a	22.0 a	13.8 a	11.0 a	13.5 a
5-Dec-95	Fall	19.5 ab	23.0 ab	20.6 ab	29.0 a	12.2 b	11.0 b
27-May-96	Before pre-plant manure		Background:		26.2		
10-Jun-96	Before side-dress manure	15.0 a	15.8 a	14.3 a	13.3 a	9.8 a	
17-Jul-96	After side-dress	17.5 a	16.3 a	17.5 a	19.3 a	11.3 a	
20-Nov-96	Fall	14.3 a	14.3 a	12.8 a	13.3 a	7.8 a	

Means within a row followed by the same letter are not significantly different (P # 0.05)

Table 7.6 Experiment 4: Soil test K (mg/L) in 0 to 15 cm depth at the Yantzi Site

Sampling Date	Timing of Sample	NA Pre-plant Manure	A Aerway + Pre-plant Manure	ND Side-dress Manure	D Side-dress Manure (Disked)	I Side-dress Inorganic	I+A Aerway + Side-dress Inorganic
18-May-94	Before pre-plant manure		Background:		184.8		
31-May-94	Before side-dress manure	287 a	266.8 a	238 a	257 a	256 a	
9-May-95	Before pre-plant manure		Background		129.2		
23-May-95	Before side-dress manure	159.4 a	107.9 a	79.1 a	134.5 a	121.9 a	146.9 a
5-Dec-95	Fall	119.8 abc	131.0 a	126.7 a	123.3 ab	101.8 c	105.5 bc
27-May-96	Before pre-plant manure		Background		190.2		
10-Jun-96	Before side-dress manure	141.1 a	138.4 a	145.6 a	174.3 a	126.3 a	
17-Jul-96	After side-dress	156.8 a	149.8 a	171.8 a	159.8 a	143.9 a	
20-Nov-96	Fall	146.5 a	128.8 a	120.3 a	116.8 a	129.8 a	

Means within a row followed by the same letter are not significantly different (P # 0.05).

7.4.2 Nitrate In Shallow Groundwater

Data on nitrate levels in shallow groundwater as sampled from piezometers are presented in Table 7.7. Data are only available for 1994 and 1996, as piezometers were not installed in the field used for the 1995 experiments.

Table 7.7. Experiment 4: NO_3 - N (mg/L) in shallow groundwater at the Yantzi Site

Sampling Date	Timing of Sample	NA Pre-plant Manure	A Aerway + Pre-plant Manure	ND Side-dress Manure	D Side-dress Manure (Disked)	I Side-dress Inorganic
15-Jun-94	After pre-plant manure			24.1		
4-Jul-94	After side-dress manure	29.0 a	42.4 a	25.5 a	29.9 a	37.8 a
11-Aug-94	Mid summer	19.9 a	24.2 a	23.0 a	20.3 a	23.6 a
2-Nov-94	Fall	1.3 a	2.4 a	1.4 a	2.3 a	1.2 a
9-May-96	Before pre-plant manure			12.0		10.6
28-Jun-96	Before side-dress manure	13.2 a	19.1 a	12.0 a	14.9 a	10.3 a
17-Jul-96	After side-dress inorganic	12.4 ab	18.2 a	12.4 ab	10.5 ab	6.7 b
24-Oct-96	Fall	8.7 a	12.0 a	12.3 a	10.7 a	11.0 a

Means within a row followed by the same letter are not significantly different (P # 0.05).

These data show that, despite minor temporal variations between treatments, there were only small differences in nitrate loadings to groundwater under the various treatments. However, data do indicate that for most of the sampled times the nitrate levels in shallow groundwater exceeded the Ontario provincial water quality objective of 10 mg/L. This may be attributed to excessive additions of N in a non-responsive site, and it highlights the importance of careful nitrogen management whether the source is organic or inorganic.

7.4.3 Agronomic Properties

7.4.3.1 Corn yields

The corn yields for each year of the experiment are shown in Figure 7.1. There were significant differences in the yields between treatments in 1994 (P#0.05) and 1996 (P#.10) and no significant differences in 1995. Since the site was shown to be relatively non-responsive to nitrogen additions, yield differences must be attributable to the timing of nutrient availability, and changes in physical and biological soil properties such as soil aeration, macropore structure, soil moisture and temperature and microbial activity.

The yields in 1994 were similar for the various manure treatments although there was a slight trend for increased yield with either Aerway™ or disk incorporation. The inorganic side dress treatment had a significantly lower yield than the other treatments which may have been due to the relatively late date of application. The early manure treatments in 1996 were lower yielding than later manure applications which may have been a result of the wet spring weather resulting in loss of N, and the slightly lower manure-N loading rate that was applied in the early treatments (Table 7.3). The manure was more dilute in 1996 because of the heavy spring rains, resulting in lower manure-N application rates than in previous years.

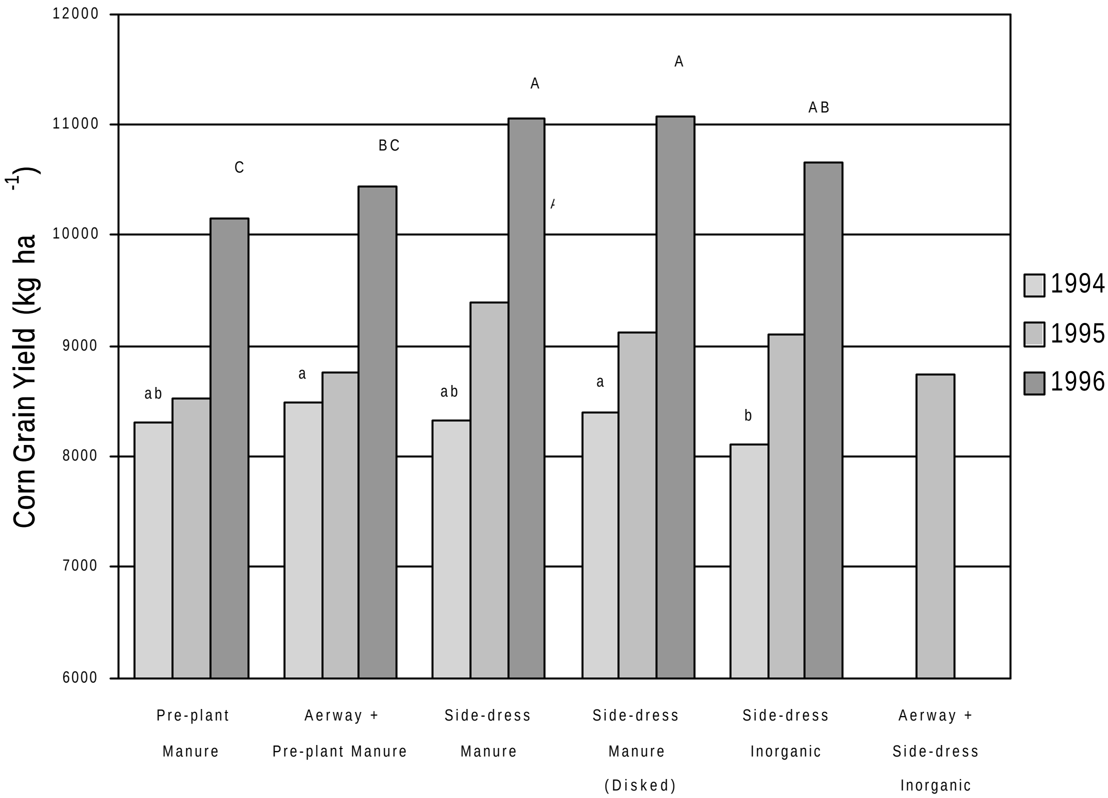

Figure 7.1 Experiment 4: Grain corn yield at the Yantzi farm. All yields are at 15.5% moisture. Within 1994 and 1996, yield bars having the same letter above them are not significantly different at P#0.05 and P#.10, respectively. Within 1995 no significant differences were observed among the treatments.

7.4.4 Farmer Impressions

Richard felt the use of the Aerway ™ immediately in front of the manure distribution system had merit for pre-plant applications. It would be his system of choice if he could count on early warming and dry spring weather. However the three springs of the experiment were late and wet. With an early spring he felt the Aerway™ would work well but with a late, wet spring it was not very effective.

Side-dress manure applications were incorporated with disks, located immediately after the manure distribution hoses. Richard felt the side-dress manure application unit provided too narrow a window of opportunity for manure applications on his farm. The potential for trampling corn was high if the operation was not completed early. Heavy rains during the window of opportunity could create a risky situation where the manure couldn't get applied due to advanced corn growth. Other problems he cited with side-dressing were the trampling of corn on the headlands and the need to manage the length of field so that the tanker either went the full length of the field or that side-dress pathways would have to be set up in the field so that the operator could turn around at certain distance.

Richard's experiments with pre-plant and between-row side-dress manure applications did not change his overall preference for applying manure by an irrigation system. The main reasons for his preference are that it is faster and there is less of a problem with timeliness. Irrigation would work on corn that was too tall for in-row applications. To reduce the risk of leaf burn he would irrigate in the late afternoon.

Overall, Richard believed the Aerway ™ was a good tool to improve infiltration, improve soil drying and to prepare the soil for planting. He currently has access to an irrigation system. In a dry spring he would use the Aerway™ then irrigate so that soil macropores are fractured prior to manure application. He has also used the Aerway™ mounted on a manure tanker for manure applications on wheat stubble in the past. He would consider using oilseed radish as a fall nitrogen scavenging crop on those fields where no weed problems exist in the wheat stubble.

7.5 Conclusions

Since this site was relatively non-responsive to nitrogen no conclusions on the productivity effects of manure N or appropriate rates can be reached from this experiment. However, the yield data indicate that the use of manure did not lead to significant yield losses due to secondary effects of manure use such as increases in weed pressure, soil compaction or leaf burn from post emergent application.

The data suggest that on this site there were no significant differences in environmental indicators between manure and inorganic fertilizer. However, the data clearly indicate that excessive nitrogen use, regardless of the source, can be a potential groundwater concern.

The farmer cooperator was able to incorporate a range of post emergent manure application methods into his conservation farming system without major operational difficulties. However, the benefits of incorporating these application methods did not convince him to abandon his current manure management system of irrigation.

8. Experiments 5 and 6 Effect of Timing, Incorporation and Rate of Application of Post Emergent Liquid Manure at Three Sites in Eastern Ontario: the Grenier and Menard Farms

The experiments conducted in eastern Ontario differed slightly in approach and methods from the experiments in southwestern Ontario. The eastern Ontario experiments are presented and discussed together since they shared some similarities and posed some unique challenges in the conduct of the research and the interpretation of results.

The most obvious challenge presented by these experiments is interpretation of soil nitrate readings. The soil nitrate readings at both Grenier sites and the Menard site were extremely low, for all treatments and at all sampling times, relative to the readings at the southwestern Ontario sites. No ready explanation for these extremely low readings was available from the lab, farmer cooperator or field researchers. While the implications of the actual nitrate levels are unclear it has been assumed that the relative differences between treatments are valid and interpretation and discussion has focused on these relative differences between treatments.

Like two of the southwestern Ontario sites, two of the three eastern sites were not consistently responsive to nitrogen. This presents a problem when trying to interpret yield differences between treatments, but it appears to be a difficult situation to avoid on a livestock farm where high levels of manure nitrogen have been historically applied to most fields.

Both these sites highlight some of the significant challenges inherent in field and on-farm research. Wet weather conditions prevented any experimental treatments from being completed at the Menard site in 1994. In 1995 the weather was so dry that the farmer cooperator felt inorganic fertilizer would be of no value and did not apply any. Changing farmer cooperator requirements and decisions led to abandonment of conservation tillage practices at the Grenier sites so that in 1996 the experiments included practices that were no longer part of the overall farm practices. In 1995 two different sources of manure had to be used on experimental plots introducing another uncontrolled variable which further confounds interpretation. However, these sites also highlight the opportunities inherent in on-farm research. Despite the shortage of reliable quantitative data and statistically significant findings, these experiments provided important qualitative and anecdotal information on farmer experiences with incorporating alternative manure management practices into their farm systems. This anecdotal information can be used for the benefit of other farmers considering changing manure management practices and as an extension tool.

8.1 Experiment 5: Effect of Timing, Incorporation and Rate of Application of Post Emergent Liquid Manure at the Grenier Farm

In this experiment, the effects of post emergent liquid manure applications to a standing corn crop in a ridge-till, strip crop system were examined so that Objectives A and B could be addressed. Factors being examined were *how the timing or method of the liquid manure application affected crop productivity, soil nutrient levels, and the nitrate content of the shallow groundwater in comparison with plots that received inorganic fertilizer*. This site was paired with the Yantzi site (Experiment 4) as a location of more detailed soil and groundwater nitrate sampling. The following indicators were measured:

- soil nutrients as indicated by general soil fertility and soil nitrate testing;
- potential impacts on groundwater indicated by residual soil nitrate after harvest and shallow groundwater nitrate levels;

- performance of no-till corn indicated by corn yield; and
- overall management impacts as determined by the farmer cooperator.

8.1.1 Site Characteristics

The experiment was established on two separate fields at the farm of the Greniers. The Grenier farm is owned and operated by Jacques & Gabriel Grenier. Jacques manages the cash crop operation and Gabriel the layer hens & broilers. Corn, soybeans and wheat are grown on 1100 acres of land in the St. Isidore de Prescott region. Soil types across the 1100 acres range from clay to sandy loam.

In 1988 Jacques started experimenting with ridge tillage. In 1990 he started strip cropping with alternating strips of corn and soybeans. In 1992 Jacques started experimenting with summer applications of manure to standing corn.

With strip cropping, corn and soybeans are planted in 15 foot alternating strips. The two crops are usually alternated yearly to avoid mono-cropping. Wheat has also been used but, in the opinion of Jacques, incorporating wheat tends to add too many complications in relation to the benefits. The rationale for strip cropping is that two outside rows of corn receive more sunlight and consequently yield 25% more than the four inside rows. The drawback is that the 15 foot swath of soybeans gets shaded by the taller corn crop and tends to suffer a slight yield reduction.

Ridge tillage was abandoned at the Grenier farm in the fall of 1995 and in the spring of 1996 all crops were planted using conventional cropping practices except for the manure research plots.

Field #1 at Grenier's has a loam textured soil (32% sand, 43% silt and 25% clay by weight). The soil at Field #2 is a sandy loam (54% sand, 42% silt and 4% clay by weight). Both fields have a dense subsurface clay layer at depths of one and a half to two metres that can cause a perched water table to occur. The site details and field activities in each year of the experiment are summarized for the loam site in Table 8.1 and for the sandy loam site in Table 8.2.

Table 8.1 Site Details and field activities at the loam site at the Grenier farm, 1994 to 1996

Year	1994	1995	1996
Plot size	4.5 m x 274 m	4.5 m x 274 m	4.5 m x 274 m
Spreader	Houle	Houle	Houle
Planting Date	May 11	May 10	May 16, reseeded May 29
Row Spacing	76 cm	76 cm	76 cm
Population (plants/ha)			
Outside Rows	111,000	111,000	111,000
Inside Rows	86,500	86,500	86,500
Side-dress Manure:Early	June 21 2000 to 2500 gal/acre	June 7 2000 to 2400 gal/acre	July 2 2000 to 2500 gal/acre
Late	July 4 2000 gal/acre	June 26 2900 gal/acre	July 22 2000 gal/acre
Fertilizer Side-dress	July 9	June 20	July 8
Harvest Date:	Nov. 8	Nov. 5	Nov. 4

Table 8.2 Site details and field activities at the sandy loam site at the Grenier farm, 1994 to 1996

Year	1994	1995	1996
Plot size	4.5 m x 274 m	4.5 m x 274 m	4.5 m x 274 m
Spreader	Houle	Houle	Houle
Planting Date	May 16	May 13	May 29
Row Spacing	76 cm	76 cm	76 cm
Population (plants/ha)			
Outside Rows	111,000	111,000	111,000
Inside Rows	86,500	86,500	86,500
Side-dress Manure:Early	June 22	June 20	July 2
	2000 to 2500 gal/acre	2000 to 2400 gal/acre	2000 to 2400 gal/acre
Late	July 7	June 26	July 22
	2000 gal/acre	2900 gal/acre	2000 gal/acre
Fertilizer Side-dress	June 22	June 20	July 8
Harvest Date:	Nov. 8	Nov. 6	Nov. 4

The analytical results of manure samples obtained at the time of application are shown in Table 8.3. The poultry manure at this site was very concentrated with high nutrients and high dry matter content compared to the dairy and swine manure used at the other farm sites. In 1995, there was not enough liquid manure in the main holding pond to meet the application needs of both sites. A different manure pond had to be used for the late season manure side-dress (T8) treatment.

Table 8.3 Poultry manure analysis at the Grenier site at the time of application

Sampling Date	Applied To	N %	P %	K %	DM %
22-Jun-94	T5,T6,T7,T8	0.99	0.21	0.19	8.35
7-Jun-95	Loam site: T5,T6,T7	0.62	0.15	0.16	5.6
20-Jun-95	Sand loam site: T5,T6,T7	0.72	0.26	0.27	6.2
26-Jun-95	Both sites: T8	0.91	0.56	0.33	22.1
3-Jul-96	T5,T6,T7,T8	0.87	0.41	0.18	12.2

8.1.2 Experimental Design

The experiment consisted of eight experimental treatments (T1 to T8) in a randomized complete block (RCBD) design. The sites had four blocks in 1994 and two blocks in 1995 and 1996. Treatments T1, T2, T3 and T4 were inorganic fertilizer treatments used to determine the nitrogen responsiveness of the field. T3 was also used as a comparison with the manure treatments. T1, T2 and T4 were established within a single field length strip in each block, while T3 occupied an entire strip. Treatments T5, T6, T7 and T8 were used to compare side-dressed liquid manure applications at different timings, with and without disk incorporation. All but one of the manure treatments (T6) had an inorganic fertilizer component. The eight treatments were as follows:

T1: 0 Nitrogen except liquid starter

T2: 75% of fertilizer requirement from inorganic fertilizer, applied as a starter and a side-dress.

T3: 100% of fertilizer requirement from inorganic fertilizer, applied as a starter and a side-dress

T4: 125% of fertilizer requirement from inorganic fertilizer, applied as a starter and a side-dress

T5: 25% of fertilizer requirement from inorganic fertilizer, applied as a starter, with remaining 75% of nutrients supplied by an early side-dress manure application, incorporated with a disk.

T6: 100% of fertilizer requirement from an early side-dress manure application, incorporated with a disk

T7: 25% of fertilizer requirement from inorganic fertilizer, applied as a starter, with remaining 75% of nutrients supplied by an early side-dress manure application, surface applied, without incorporation.

T8: 25% of fertilizer requirement from inorganic fertilizer, applied as a starter, with remaining 75% of nutrients supplied by a late side-dress manure application, incorporated with a disk.

The side dress operation was similar to that at the Yantzi site. The disc incorporator was mounted behind the manure spreader to cover the manure with loose soil immediately after side-dressing.

8.1.3 Field conditions

The response curves (Appendix 1, Figure 13-18) based on the split plot nitrogen study at this site in each year of the study revealed that the soils were consistently responsive to N at the loam site (Figures 13-15), but not at the sandy loam site (Figures 16-18). The Maximum Economic Rate (MER) for inorganic fertilizer application at the loam site was determined to be 140 kg/ha in 1994, 74 kg/ha in 1995 and 116 kg/ha in 1996.

The nitrogen response curve for the sandy loam site in 1994 (Figure 16) indicates that the MER for inorganic fertilizer application was 80 kg/ha. In 1995, the nitrogen response was linear within the range of fertilizer rates that were applied (Figure 17) and the MER-N was 393 kg/ha. The treatments that received the most N in 1995 had the highest yields. In 1996, the sandy loam site was N responsive (Figure 18). The MER for inorganic fertilizer application to the field in 1996 was 144 kg/ha.

8.1.4 Results and Discussion

8.1.4.1 Nutrients Added

The calculated nutrient application rates are shown in Table 8.4 and Table 8.5 for the loam and sandy loam sites, respectively.

Table 8.4 Experiment 5: Rates (kg/ha) of available nutrients[P] applied in manure and inorganic fertilizer at the Grenier farm, loam site

	Treatment	Pop-Up	Starter	Side-dress	Total
1994	T1	(3/13/3)	-	-	(3/13/3)
	T2	(3/13/3)	(33/0/0)	(86/0/0)	(122/13/3)
	T3	(3/13/3)	(33/0/0)	(127/0/0)	(163/13/3)
	T4	(3/13/3)	(33/0/0)	(167/0/0)	(203/13/3)
	T5	(3/13/3)	(33/0/0)	(178/43/46)	(214/56/49)
	T6	(3/13/3)	-	(222/54/58)	(225/67/61)
	T7	(3/13/3)	(33/0/0)	(178/43/46)	(214/56/49)
	T8	(3/13/3)	(33/0/0)	(178/43/46)	(214/56/49)
1995	T1	(3/13/3)	-	-	(3/13/3)
	T2	(3/13/3)	(33/0/0)	(86/0/0)	(122/13/3)
	T3	(3/13/3)	(33/0/0)	(127/0/0)	(163/13/3)
	T4	(3/13/3)	(33/0/0)	(167/0/0)	(203/13/3)
	T5	(3/13/3)	(33/0/0)	(111/31/39)	(147/44/42)
	T6	(3/13/3)	-	(134/37/47)	(137/50/50)
	T7	(3/13/3)	(33/0/0)	(111/31/39)	(147/44/42)
	T8	(3/13/3)	(33/0/0)	(237/168/116)	(273/181/119)
1996	T1	(3/13/3)	-	-	(3/13/3)
	T2	(3/13/3)	(33/0/0)	(86/0/0)	(122/13/3)
	T3	(3/13/3)	(33/0/0)	(127/0/0)	(163/13/3)
	T4	(3/13/3)	(33/0/0)	(167/0/0)	(203/13/3)
	T5	(3/13/3)	(33/0/0)	(156/85/44)	(192/98/47)
	T6	(3/13/3)	-	(195/106/55)	(198/119/58)
	T7	(3/13/3)	(33/0/0)	(156/85/44)	(192/98/47)
	T8	(3/13/3)	(33/0/0)	(156/85/44)	(192/98/47)

P Poultry manure nitrogen applications assumed to be 80% available in the year of application at both sites

Manure P_20_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

Table 8.5 Experiment 5: Rates (kg/ha) of available nutrients[P] applied in manure and inorganic fertilizer at the Grenier farm, sandy loam site

	Treatment	Pop-Up	Starter	Side-dress	Total
1994	T1	(3/13/3)	-	-	(3/13/3)
	T2	(3/13/3)	(33/0/0)	(86/0/0)	(122/13/3)
	T3	(3/13/3)	(33/0/0)	(127/0/0)	(163/13/3)
	T4	(3/13/3)	(33/0/0)	(167/0/0)	(203/13/3)
	T5	(3/13/3)	(33/0/0)	(178/43/46)	(214/56/49)
	T6	(3/13/3)	-	(222/54/58)	(225/67/61)
	T7	(3/13/3)	(33/0/0)	(178/43/46)	(214/56/49)
	T8	(3/13/3)	(33/0/0)	(178/43/46)	(214/56/49)
1995	T1	(3/13/3)	(33/0/0) **	-	(36/13/3)
	T2	(3/13/3)	(33/0/0)	(86/0/0)	(122/13/3)
	T3	(3/13/3)	(33/0/0)	(127/0/0)	(163/13/3)
	T4	(3/13/3)	(33/0/0)	(167/0/0)	(203/13/3)
	T5	(3/13/3)	(33/0/0)	(129/54/65)	(165/67/68)
	T6	(3/13/3)	(33/0/0) **	(188/78/95)	(224/91/98)
	T7	(3/13/3)	(33/0/0)	(129/54/65)	(165/67/68)
	T8	(3/13/3)	(33/0/0)	(227/123/63)	(263/136/66)
1996	T1	(3/13/3)	-	-	(3/13/3)
	T2	(3/13/3)	(33/0/0)	(86/0/0)	(122/13/3)
	T3	(3/13/3)	(33/0/0)	(127/0/0)	(163/13/3)
	T4	(3/13/3)	(33/0/0)	(167/0/0)	(203/13/3)
	T5	(3/13/3)	(33/0/0)	(156/85/44)	(192/98/47)
	T6	(3/13/3)	-	(195/106/55)	(198/119/58)
	T7	(3/13/3)	(33/0/0)	(156/85/44)	(192/98/47)
	T8	(3/13/3)	(33/0/0)	(156/85/44)	(192/98/47)

P Poultry manure nitrogen applications assumed to be 80% available in the year of application at both sites

Manure P_20_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

** Starter inadvertently applied to this treatment

8.1.4.2 Nitrate Levels

Soil nitrate data are presented in Table 8.6 and 8.7.

Table 8.6 Experiment 5: Soil $N0_3$-N (kg/ha) in 60 cm depth at the loam site of the Grenier farm

Sampling Date		T1 No Nitrogen Except Liquid Starter	T3 Inorganic At Planting and Side-dress	T5 Inorg. + Early Side-dress Manure (disked)	T6 Early Side-dress Manure (disked)	T7 Inorg. + Early Side-dress Manure	T8 Inorg. + Late Side-dress Manure (disked)
9-Jun-94	After planting	6.7 a	11.1 a	9.3 a	5.8 a	7.6 a	6.1 a
4-Jul-94	Before early manure	2.8 a	2.4 a	1.4 a	1.7 a	1.5 a	1.8 a
15-Nov-94	Fall	1.8 a	2.8 a	2.2 a	1.7 a	2.6 a	1.6 a
3-May-95	Before planting	15.0 a	12.3 a	11.7 a	14.2 a	12.3 a	16.4 a
6-Jun-95	Before early manure	27.3 ab	23.1 ab	34.1 a	17.4 b	32.6 ab	29.9 ab
31-Jul-95	After late manure	15.1 a	14.0 a	27.3 a	11.6 a	12.5 a	37.1 a
13-Sep-95	Fall	8.0 a	3.0 a	6.5 a	1.7 a	2.7 a	2.6 a
9-May-96	Before planting	5.6 a	6.4 a	5.9 a	6.2 a	5.8 a	6.6 a
2-Jul-96	Before early manure	19.1 c	27.3 bc	23.4 bc	20 c	29.2 ab	27.3 bc
13-Aug-96	After late manure	1.7 c	4.1 bc	6.5 ab	5.4 bc	8 ab	5.9 bc
20-Sep-96	Fall	3.1 b	9.3 a	10.1 a	8.6 a	12.2 a	9.5 a

Means within a row followed by the same letter are not significantly different (P # 0.05)

Table 8.7 Experiment 5: Soil NO_3 - N (kg/ha) in 60 cm depth at the sandy loam site of the Grenier Farm

Sampling Date		T1 No Nitrogen Except Liquid Starter	T3 Inorganic At Planting and Side-dress	T5 Inorg. + Early Side-dress Manure (disked)	T6 Early Side-dress Manure (disked)	T7 Inorg. + Early Side-dress Manure	T8 Inorg. + Late Side-dress Manure (disked)
16-Jun-94	After planting	48.8 a	84.7 a	54.1 a	47.8 a	78.2 a	63.7 a
7-Jul-94	Before early manure	6.2 a	13.3 a	12.1 a	5.3 a	8.2 a	14.4 a
15-Nov-94	Fall	15.3 a	18.3 a	12.9 a	17.3 a	20.0 a	21.9 a
5-May-95	Before planting	9.4 a	8.2 a	6.4 a	8.3 a	7.7 a	7.0 a
6-Jun-95	Before early manure	57.6 a	50.5 a	56.7 a	79.1 a	61.4 a	61.0 a
31-Jul-95	After late manure	1.3 a	8.2 a	19.0 a	22.5 a	6.2 a	24.9 a
13-Sep-95	Fall	9.2 a	0.4 b	2.2 b	0.8 b	0.9 b	0.8 b
14-May-96	Before planting	2.8 a	2.7 a	2.2 a	2.6 a	2.9 a	2.6 a
2-Jul-96	Before early manure	14.2 bc	37.7 a	28.8 ab	7.7 c	37.8 a	30.8 a
13-Aug-96	After late manure	0.8 c	11.4 a	8.1 ab	1.7 c	4.7 bc	4.1 bc
20-Sep-96	Fall	1.2 c	12.4 ab	7.1 bc	2.2 c	5.6 bc	4.6 bc

Means with a row followed by the same letter are not significantly different (P # 0.05)

Given the low nitrate levels, lack of statistical significance and confounding factors as discussed above these data should be interpreted with caution. However, on a relative basis these data suggest that the range of practices examined in this experiment will have similar implications for nitrogen availability and potential nitrate leaching. The data also suggest that the rates, timing and methods in this experiment may pose low risks of leaching to groundwater relative to most of the manure practices examined on the southwestern Ontario sites.

8.1.4.4 Nitrate in Shallow Groundwater

Shallow groundwater nitrate levels are presented in Tables 8.8 and 8.9.

Table 8.8 Experiment 5: No_3-N (mg/L) in shallow groundwater at the loam site at the Grenier Farm

Sampling Date		T1 No Nitrogen Except Liquid Starter	T3 Inorganic At Planting and Side-dress	T5 Inorg. + Early Side-dress Manure (disked)	T6 Early Side-dress Manure (disked)	T7 Inorg. + Early Side-dress Manure	T8 Inorg. + Late Side-dress Manure (disked)
1-Jul-94	After early side-dress				9.9		
27-Jul-94	After late side-dress				14.6		
9-Aug-94	Mid summer	12.8 a	12.4 a	13.1 a	13.5 a		
4-May-95	Before planting	1.6 a		8.8 a	11.3 a		
7-Jun-95	Before early side-dress				21.1		
23-Jun-95	Before late side-dress	26.5 a	32.0 a	36.4 a	30.0 a		
27-Jul-95	After late side-dress	25.3 a	33.8 a	36.3 a	33.3 a		
12-Sep-95	Late summer	18.5 a	27.2 a	28 a	26.3 a		
8-May-96	Before planting	8.6 a	9.7 a	11.0 a	9.1 a	9.3 a	11.6 a
22-Jul-96	Before late side-dress	7.4 b	16.8 ab	22.5 a	10.5 b	19.6 ab	16.8 ab
15-Aug-96	Mid summer	8.5 b	12.8 ab	25.6 a	12.8 ab	16.2 ab	15.6 ab

Means within a row followed by the same letter are not significantly different (P # 0.05)

Table 8.9 Experiment 5: NO_3 -N (mg/L) in shallow groundwater at the sandy loam site at the Grenier Farm

Sampling Date		T1 No Nitrogen Except Liquid Starter	T3 Inorganic At Planting and Side-dress	T5 Inorg. + Early Side-dress Manure (disked)	T6 Early Side-dress Manure (disked)	T7 Inorg. + Early Side-dress Manure	T8 Inorg. + Late Side-dress Manure (disked)
5-Aug-94	Mid summer	5.4 a	5.3 a	4.7 a	6.2 a		
4-May-95	Before planting	12.6 a	11 a	2.6 a	6.1 a		
23-Jun-95	After early side-dress	0.1 a	1.5 a	3.2 a	0 a		
27-Jul-95	After late side-dress	6.6 a	2.9 a	4.3 a	3.7 a		
12-Sep-95	Late summer	0 a	0 a	0 a	1.8 a		
23-May-96	Before planting	4.9 a	2.6 a	0.8 a	1.30 a	4.7 a	5.3 a

Means within a row followed by the same letter are not significantly different (P # 0.05)

Where data are missing there was no water in the piezometers for sampling. Readings of "0" were below the detection limit for nitrate. While some signficant differences were observed in 1996 at the loam site, the differences do not exhibit any consistent pattern in relation to the timing, method or rates of N. The main observations derived from these data are:

- levels are consistently higher under the loam site despite similar rates methods and timing of N applications; and
- the readings regularly exceed 10 mg/l at the loam site and indicate a serious groundwater contamination problem at this site.

Since subsurface flow was not controlled at this site it is impossible to determine if lateral groundwater movement may be complicating the results. The very high readings suggest that a localized source of nitrate such as a manure lagoon or septic system may be contributing to these nitrate levels.

8.1.4.5 Corn Yields

The yields in each year of the experiment are shown in Figure 8.1 and Figure 8.2.

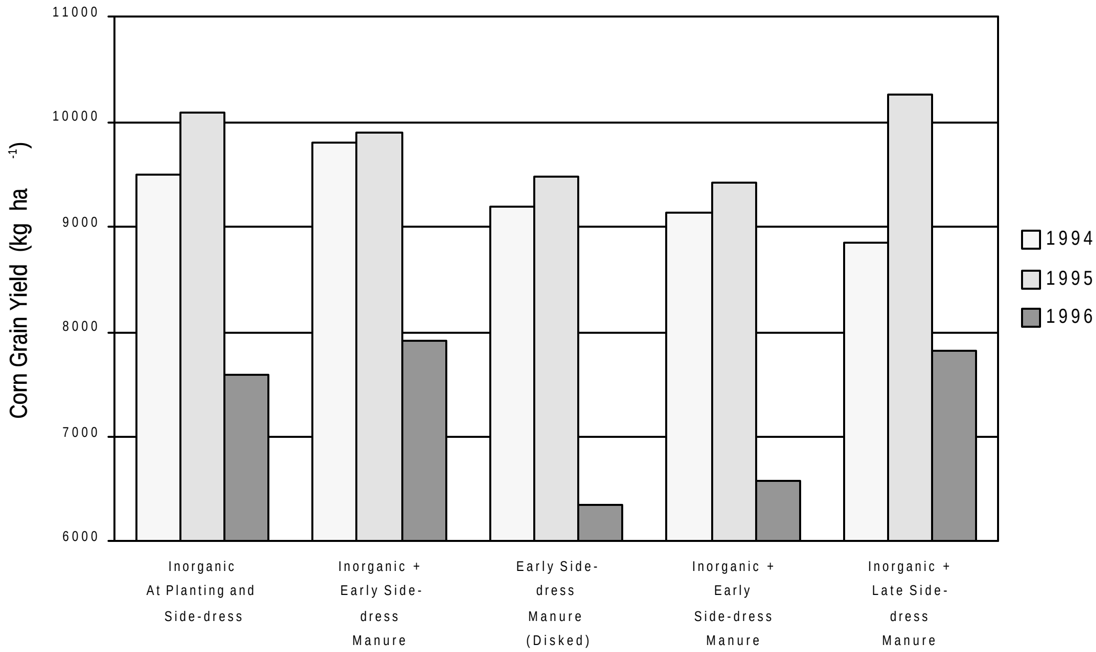

Figure 8.1

Experiment 5: Grain corn yield at the loam site at the Grenier farm. All yields are at 15.5% moisture. Within a year, no significant differences were observed among the treatments (p # 0.05).

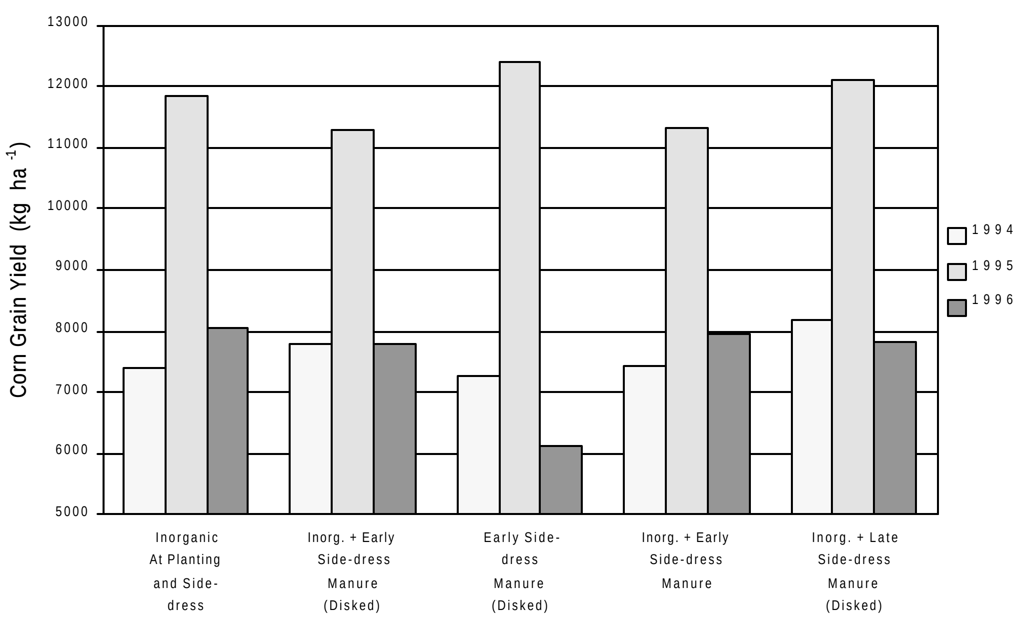

Figure 8.2

Experiment 5: Grain corn yield at the sandy loam site at the Grenier farm. All yields are at 15.5% moisture. Within a year, no significant differences were observed among the treatments (p # 0.05).

Yield differences were not statistically significant but several trends are noticeable. The early sidedress manure treatment (disked, without inorganic starter) generally had lower yields at both sites. The 1996 yields were very low relative to the other years at both sites. Yield differences between treatments were relatively small in 1994 and 1995 and much larger in 1996.

8.1.4.6 Farmer Impressions

The on-farm research at the Jacques Grenier site was conducted on ridge tilled plots in an alternating corn-soybean strip crop system. Jacques had been experimenting with summer applications of manure to standing corn since 1992.

Manure Management

Manure management at the Grenier farm has evolved to a point where operations are now more efficient and environmentally sound. Traditional spreading operations at the Grenier farm consisted of aerial spreading from a tanker pulled behind a tractor, or from a truck mounted with a manure tank. Spreading operations occurred in the spring prior to planting, in the summer after a cereal crop or in the fall after soybeans and corn. Odour complaints from the people living in the neighboring community, St. Isidore de Prescott, were common.

Jacques began experimenting with manure applications to standing corn in 1992. Initial results were discouraging. The combination of a corn crop which was too far advanced, and inadequate ground clearance of the equipment resulted in severe crop damage in the form of broken stalks.

Experimentation resumed in 1994 with the same tanker but a different injection system. Again results were unsatisfactory. The manure distribution device and the hoses exiting from it to the individual crop row middles were subject to plugging from chicken feathers or manure solids. The disk incorporation tool bar did not perform adequately as well.

In 1995 Jacques purchased a new 3550 gallon Houle tanker. He was apprehensive about purchasing equipment which had not been field tested for his particular situation, but the equipment has functioned as intended. Other than splash guards which were fitted to the outside applicator units to reduce leaf burn on soybean plants in adjacent strips, no major changes were needed to the equipment. Concave disks located behind the tanker efficiently cover the manure with soil at a shallow depth and the resulting surface composting releases nutrients to the corn plants in a timely manner.

The present manure application system is not without its challenges. High solids concentrations in the manure also increase the total nutrient concentration. This changes the required dosages and can cause problems if the application equipment is not easily adjustable. A substantial amount of trial and error is involved in determining the ideal combination of gate opening and forward speed for a particular field length and desired nutrient application rate.

Manure operations in 30 inch row corn is a delicate operation, leaving very little room for error. Maneuverability is limited and a slight twist to the steering wheel has a magnified effect at the rear of the tanker due to the geometry of the equipment. Corn stalk breakage was a problem Jacques refused to put up with. Even the best operator couldn't avoid some damage. In 1996, Jacques removed the automatic guidance system from his row crop cultivator and installed it between his tanker and the disk toolbar. It allows the operator more freedom of movement when steering the tractor without the negative consequences of cultivator blight. The system has worked very well.

With his present manure management system, Jacques Grenier is able to apply his manure to standing corn in a field 1000 feet away from residential housing without receiving odour complaints.

Lagoon operations

Emptying manure pits requires proper agitation and mixing. Poultry slurry presents an added challenge because of the high calcium content. This tends to form deposits of solids in the bottom of the tank which are difficult to bring into suspension. This causes problems with spreading equipment, particularly irrigation systems which tend to clog very easily. Jacques commented on the fact that custom manure applicators were hesitant to take work on when it was poultry slurry. He quickly discovered why when transferring manure between two tanks using irrigation hoses. This ruled out the possibility of investing in an expensive irrigation system for manuring operations. A three foot propeller type agitator solved 95% of the manure agitation problems. It reduced agitation time for an 80 x 14 foot pit from 2 days to 4 hours.

Ridge-tillage

Ridge-tillage is similar to no-till except for the fact that mechanical weed control is used and wheel traffic is limited to a confined area. Ridge tillage at the Grenier farm was not successful for several reasons, some of which are interrelated;

- The row crop cultivator did not withstand the clay soil conditions existing on other fields and was too frequently in the repair shop.
- Slabbing is a major problem in clay soil. This damages the crop and reduces the effectiveness of the weed control. A 3rd cultivator pass instead of the usual two may have helped alleviate the problem but was not considered because of time and labour constraints.
- Weed control was not satisfactory in soybeans. Jacques obtained better results when he tilled the ground, used incorporated herbicides and seeded in 7 inch rows instead of 30 inch.
- Availability of labour was also a problem. Row crop cultivation and manure spreading operations occur at the same time of the year. Ideally a second tractor and row crop cultivator would be available to efficiently cover all the acreage.
- Seedbed preparation and soil structure were not satisfactory. The Buffalo ridge-till planter does not track uneven terrain as efficiently as a conventional double disk opener and this can lead to uneven germination and sub-standard population. Soil structure in the clay soil remained poor at 5 to 30 cm depths as compared to conventionally tilled ground.
- Manuring operations using a 3500 gallon tanker on clay soils in June and July causes substantial surface and sub-surface compaction. Controlled traffic limits the extent of this but the resulting area is very difficult to cultivate with a row crop cultivator. Jacques also noticed that his infiltration rate in clay soils was not optimum.

After experimenting with a ripping tool Jacques noticed substantial improvements in infiltration. He now uses this instrument on all his fields in the fall, sometimes as the only fall tillage operation. Ridge tillage was abandoned in the fall of 1995 and in the spring of 1996 all crops were planted using conventional cropping practices except for the manure research plots.

Strip Crops

Jacques had been experimenting with summer applications of manure to standing corn since 1992. Manuring operations added complications to his ridge till-strip crop system. Manure irrigation to the standing corn was not possible because 1/2 to 2/3 of the field had a different crop. The neighboring soybean crop is not as fully developed as the corn. As a result it can suffer from leaf burn from splashing poultry manure which is high in ammonia N, leading to yield reductions. Furthermore, since half the field does not receive manure, a greater distance must be driven each year to spread the same amount of manure. The positive aspect of this is reduced potential leaching of nutrients because only 50% of the field is manured in any given year.

8.2 Experiment 6. Effect of Rate of Application of Post Emergent Liquid Manure at the Menard Farm

The objective of this experiment was to examine the effects of post-emergent liquid dairy manure applications to a standing corn crop (Objective B) in reduced tillage (mulch tillage and disking) corn. Crop productivity and soil nutrient levels were used to compare the effect of the liquid manure applications versus inorganic fertilizer applications.

8.2.1 Site Characteristics

The experiment was established on a silt loam soil at the farm of Jean-Marie Menard, (Embrun, Ont.). The Ménard farm is owned and operated by Jean-Marie & Michel Ménard. It is a 100 milking head dairy operation which uses a liquid manure handling system. Corn, soybeans, cereals and forages are grown on approximately 2000 acres of land. Soil type varies between silt loam and sandy loam. Approximately 60% of the land is tile drained. Minimum tillage (chisel plowing) has been used for the past eight years.

Jean-Marie usually applied his manure with an irrigation gun and reel. The lagoon would be emptied out in the spring prior to planting, in the summer after first cut hay and in the fall after corn and soybean harvest. The two big manure handling issues at the Ménard farm are labour shortages and the long distances to some of the fields. Under the current system fields close to the barns receive most of the manure while fields 2 km or more away receive none.

The Ménard farm is situated on the southern fringe of the Embrun municipality and conflicts due to odours have been an ongoing concern with town residents. This concern led Jean-Marie to experiment with alternative manuring practices, such as side-dressing with incorporation, to reduce odours.

The soil and field conditions at the Menard site are summarized in Table 8.10. From the start, this was a challenging site on which to conduct research. In 1994 very wet spring and early summer conditions left the field chosen for the experiment too wet for the manure tanker. By the time the soil was dry enough for machinery traffic, it was mid July and the corn was too high to drive the tanker over without knocking it down. With sparse populations and no nutrient additions possible, the plot was abandoned in 1994.

Table 8.10 Site details and field activities at the Menard farm, 1994 to 1996

Year	1994	1995	1996
Plot Size	6.1 m x 180 m	6.1 m x 150 m	6.1 m x 250 m
Spreader	Houle	Houle	Houle
Planting Date	May 24, May 29	May 20	May 28
Row Spacing	76 cm	76 cm	76 cm
Population (plants/ha)		74,100	74,100
Sidedress Manure: Date	Fields too wet. Couldn't side-dress, plots abandoned	July 3	July 11
Rate		High Rate: 9000 gal/acre Low Rate: 6000 gal/acre	9000 gal/acre
Fertilizer Sidedress			July 12
Harvest Date: Main Plots		Nov. 24	Nov. 23 and Nov. 27

In 1995 the farmer cooperator considered the soil conditions at side-dress time to be too dry for a dry fertilizer. The experiment was modified to be a comparison of two different rates of liquid manure application. In 1996, the experiment involved the comparison of a starter inorganic plus side-dress manure with a starter inorganic plus side-dress inorganic.

The manure analysis in the two years that experiments were conducted is shown in Table 8.11.

Table 8.11 Manure analysis at the Menard site at the time of application

Sampling Date	N %	P %	K %	DM %
4-Jul-95	0.22	0.04	0.19	4.2
12-Jul-96	0.22	0.04	0.21	7.7

8.2.2 Experimental Design

In 1995 the manure plots were treated with side-dress manure at a low rate (ML) and a high rate (MH) in a completely randomized design (CRD) replicated eight times across the field. Additional plots (3 plots per treatment) were left with only a starter fertilizer as a rough check on the responsiveness of the site. The manure was applied by a Houle tanker and was incorporated by disk implement that was attached to the rear of the manure tanker.

Following results in 1995 that indicated that the field was not responsive, a different field, further away from the manure tank was selected for the 1996 experiments. In 1996 there was a high rate manure treatment (MH) and an inorganic treatment (I) (CRD with 6 reps), along with the starter only treatment (3 plots per treatment). Additional nitrogen response plots were included in the experiment in 1996.

8.2.3 Results and Discussion

8.2.3.1 Nutrients Added

The nutrient loadings for 1995 and 1996 are presented in Table 8.12.

Table 8.12 Experiment 6: Rates (kg/ha) of available nutrientsÞ **(N, P_2O_5 and K_2O) applied in manure and inorganic fertilizer at the Menard farm**

Year	Treatment	Premanure	Starter	Side-dress	Total
1995	ML	-	(25/54/17)	(74/25/138)	(99/79/155)
	MH	-	(25/54/17)	(111/37/207)	(136/91/224)
	Starter Only	-	(25/54/17)	-	(25/54/17)
1996	MH	-	(13/51/26)	(111/37/229)	(124/88/255)
	I	-	(13/51/26)	(112/0/0)	(125/51/26)
	Starter Only	-	(13/51/26)	-	(13/51/26)

Þ Manure nitrogen applications assumed to be 50% available in the year of application at both sites Manure P_20_5 and K_2O applications assumed to be 40% and 90% available, respectively, in the year of application.

8.2.3.2 Nitrate Levels

Table 8.13 Experiment 6: Soil NO_3 - N (kg/ha) in 60 cm depth at the Menard site

Sampling Date	Timing of Sample	High Rate Manure	Medium Rate Manure	Inorganic N	Starter N
3-Jul-95	Before manure	9.5 a	12.5 a	na	na
13-Sep-95	Fall	1.8 a	3.9 a	na	0.5 a
5-Jul-96	Before manure	7.0 a	na	5.9 a	5.9 a
14-Aug-96	After manure	3.2 b	na	4.7 a	3.2 b
20-Sep-96	Fall	2.6 b	na	6.2 b	2.9 b

Means within a row followed by the same letter are not significantly different ($P < 0.05$)

na data not available

The results show relatively weak trends for higher nitrate levels after harvest under the inorganic treatments. However, the amounts are too low to be of any concern from an environmental perspective.

8.2.3.4 Corn yields

The yields in each year of the experiment are shown in Figure 8.3. While the difference is not statistically significant, the inorganic treatment (which was not applied in 1995) yielded 933 kg/ha more than the manure treatments. In addition, while the yield of corn receiving 125 kg fertilizer-N/ha (8288 kg/ha) was similar to that which was predicted by the response curve at that N rate (8267 kg/ha), the yield of the corn receiving manure (7355 kg/ha) was lower than that predicted by the response curve and suggested that the rate of N supplied in the manure was 38 kg N/ha. Yield of corn receiving only starter fertilizer, at 13 kg N/ha (6827 kg/ha) was similar to the yield predicted at that rate from the response curve (6823 kg/ha).

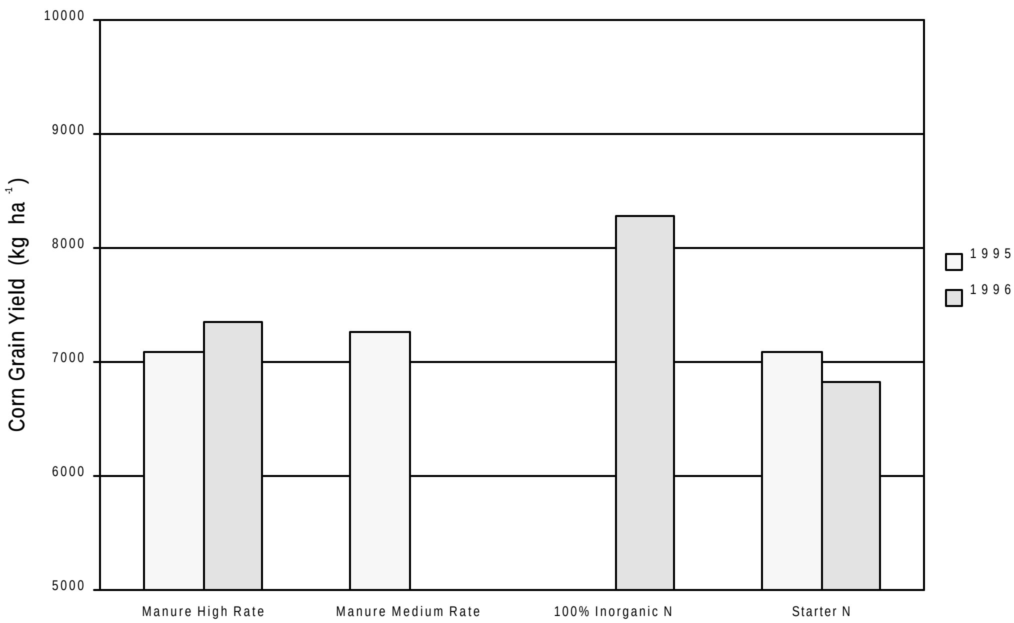

Figure 8.3

Grain corn yield at the Experiment 6 (Menard) farm. All yields are at 15.5% moisture. Within a given year, yield bars having the same (or no) letter above them are not significantly different (p # 0.05).

8.2.3.5 Farmer Impressions

Summer manure applications to standing corn with a tanker has proved to be a very appealing option to Jean-Marie. The equipment was used in tall corn without substantial stalk breakage. Dairy manure is much less nutrient rich than poultry slurry and approximately four times greater volume is needed to achieve the same N application rate. The surface incorporation with the disk toolbar is not as thorough as a result of the higher application volume. However, odour drift is significantly reduced, especially compared to an irrigation type system. The standing corn acts as a wind screen and may reduce N losses due to surface volatilization. Tanker performance was further enhanced in 1996 by a tool bar guidance system.

Jean-Marie is considering the purchase of a tanker similar to Jacques Grenier's. It would allow for manuring operations close to residential housing with fewer complaints. It would also give him a certain autonomy as compared to waiting for the custom operator. The next step in switching his current manuring system will be the construction of a lagoon at fields further away from the barn. Once in place, manure will be transferred from the farmstead lagoon with a large highway tanker. This operation could be done during the winter months when labour is readily available. The new lagoon would allow manuring to some fields for the first time, increasing manure N use efficiency. The only foreseeable drawback will be labour and tractor availability, since summer manuring operations will conflict with hay making.

8.3 Conclusions

These two research programs demonstrate both the substantial challenges and benefits which are unique to field research. An unfortunate combination of inclement weather, farm cooperator decisions, anomalous laboratory results and non-responsive field conditions, resulted in these experiments providing relatively few quantitative data with which to increase the understanding of manure management in relation to the study objectives. However, at the same time these projects clearly demonstrate how farmers can adapt technologies and overcome problems through equipment modification and creative responses specific to their farm conditions. The greatest value of these two research projects lies in the information collected and discussed in the farmer impression sections above.

These two research projects demonstrate one of the extremely important benefits of field scale research. One farmer, through a series of trial and error and equipment modification practices, developed a system of manure application which solved any significant issues for his farm. However, for a number of reasons not necessarily directly related to manure management, this farmer decided to abandon conservation tillage and return to the more conventional tillage system. Regardless, the experience of this farmer was of direct benefit to a neighbouring farmer who intends to purchase and modify manure spreading equipment in order to continue with conservation tillage practices in a manure management system.

The Grenier sites demonstrated that applications of 2,000 to 2,900 gallons per acre of nutrient rich poultry manure can be applied as a post-emergent fertilizer without signficant impacts on crop production when compared to mineral nitrogen. The Menard experiment indicated that as much as 9,000 gallons per acre of dairy manure can be used in a conservation tillage system and contribute towards achieving acceptable corn grain yields. Due to difficulties in the experimental design, no conclusion can be reached as to the relative merit of this application rate versus a mineral end source, however, it is valuable to know that fairly signficant volumes of liquid manure can be dealt with inside a conservation tillage system.

Both these experiments show that liquid manure can be applied to standing corn crop with acceptable crop production results. Equipment modification and refinements were necessary to achieve a manure delivery system that the farmers were comfortable with. However, these equipment modifications were manageable and did not discourage the farmers from pursuing the use of conservation tillage in conjunction with their manure management.

9. Discussion and General Conclusions based on the 6 Experiments

The study was designed to investigate the effect of different manure application methods on three main characteristics of sustainable farm systems: environmental conditions (soil and soil water properties), productivity (crop yield and weed pressures) and the overall management of individual farm operations (manure storage requirements, equipment, timing, labour needs, etc.) To meet this general objective the research included a range of different manure types, application methods, rates and timing studied on field scale plots located on six working livestock farms managed under a range of conservation tillage systems. This research included the investigation of a number of factors relating to the application of manure, including:

- the effect of the applied N coming totally from manure, a combination of manure and inorganic fertilizer sources or totally from inorganic fertilizer;
- the effect of different manure application rates;
- the effect of the timing of manure application (pre-plant or side-dressing); and,
- the effect of manure application with incorporation or without incorporation into the soil.

As field level research, the six experiments in the study were controlled to some extent by farmer cooperator needs and decisions which pose challenges to interpretation of some of the data collected. Recognizing the limitations to statistical analysis presented by some of the field research, there are some important trends and observations which can be based on the three years of data available. Often the most valuable observations of field research are the non-quantifiable lessons learned by the farmer cooperator and issues identified by the researchers which might profitably be the subject of future research in a more controlled experimental structure. In the following discussion and presentation of conclusions, these non-quantitative results are given equal importance to the statistically significant quantitative observations.

The following discussion is organized on the basis of the two main study objectives and the three main effects measured in pursuit of the objectives: environmental, productivity, and farm management. Within these general results areas the impacts of different aspects of manure management such as type of manure, timing and method of application, etc. are discussed.

9.1 Contributions to Green Plan Objectives

As discussed below this research directly addressed to the two specific objectives established for this project by the Green Plan Committee in the original statement of work. In addition this study contributed to other important goals of the Green Plan on farm research project by involving a broad range of farmers in research which was relevant and directly applicable to their farm situations.

Based on the research conducted during this study it is possible to use liquid manure in a conservation tillage system and maintain optimum crop production compared to mineral nitrogen sources. Experiments showed that rates of liquid manure application ranging from 2500 gal/ac to 7900 gal/ac can achieve this objective with no significant effect on environmental or farm management factors compared to fertilizer-N use. Additional comments on this objective are presented below.

Based on the research conducted during this study it is possible to use liquid manure as a post emergent fertilizer in a standing corn crop without significant effects on subsequent corn growth, or soil and water quality as indicated by the measurements used in this study. This study did not examine all potential soil and water quality impact mechanisms (see discussion below). The results of this study do not provide a firm basis for deciding whether application of manures to a standing corn crop is an effective technique of retaining the nutritive value of manure within the rooting zone, but they do suggest that the effects on crop growth, soil quality, soil nutrient content and water quality are similar to the potential impacts of mineral N sources.

9.2 Environmental Effects of Manure Management in Conservation Tillage

Soil nitrate measurements after harvest (residual nitrate levels) were used as a measure of the relative potential for nitrate leaching to groundwater. Most of these measurements did not show a statistically significant difference in potential leaching between plots where manure was the main nitrogen source and where inorganic N was the main nitrogen source. Where statistically significant differences were detected, there was no consistent pattern; sometimes the inorganic treatments had higher residual nitrate levels, sometimes the manure plots had higher residual nitrate levels.

The relative readings of residual nitrate showed limited statistical significance and the absolute values were highly variable. The four southwestern Ontario sites, as a group had readings which ranged from 27 to 144 kg/ha. The least variable site had readings from 45 to 80 kg/ha. As discussed earlier the two eastern Ontario sites had markedly lower absolute readings with a range of residual nitrate levels from 0.5 to 10.1 kg/ha. Two separate labs conducted the analyses for eastern (Agriculture Canada) and south-western (University of Guelph) sites. Careful review of lab methods and procedures failed to explain the reason for the large differences. Assuming these readings to be valid comparisons of potential nitrate leaching and groundwater contamination, two general possibilities exist. Either substantial leaching had already occurred at the eastern sites resulting in the lower readings, or for some reason connected with the dynamics of the nitrogen cycle, crop uptake and climate, the eastern sites had substantially lower potential for groundwater contamination. Further comparison of residual nitrate levels in eastern and southwestern Ontario landscapes in general may shed light on this issue.

To provide further information on groundwater implications, shallow groundwater nitrate was measured at one southwestern Ontario site (Yantzi Experiment 4) and at the eastern Ontario site (Grenier, Experiment 8.1) where two fields were monitored. There was a weak statistical trend at the Yantzi site to higher readings under the pre-plant manure which was aeration tilled. Aeration tillage is intended to improve water infiltration and this may be reflected in higher nitrate leaching. There were no consistent significant differences between treatments in eastern Ontario. It is interesting to note that despite the large differences between residual nitrate readings in southwestern and eastern Ontario, the shallow groundwater readings are similar. It is also important to note that many of the treatments had at least occasional high nitrate readings exceeding the provincial water quality guidelines of 10 ppm. This raises concerns about long term groundwater quality, completely independent of whether the source of N is manure or inorganic fertilizers. This concern has been, and should continue to be, dealt with through wide spread rural water quality studies and focused research on nitrogen movement through the vadose and saturated zones of the soil.

There were no indications in the data to suggest that, in order to protect groundwater, nitrogen from manure should be managed in a different manner than nitrogen from inorganic sources. If manure nitrogen is managed to enhance the efficiency of plant uptake (for example, applied as close to the period of active crop growth as possible, when intended to spur early crop growth is applied near the seed, and is applied at the maximum economic rate) data from this study suggest that the amount of excess N available to leach to groundwater will be similar to that available from mineral sources of N applied in the same manner. However, the data also suggest that in many cases both manure and mineral N use may pose a risk of contamination of groundwater due to high residual nitrate levels after harvest.

The data from this study indicate that the type of manure is not relevant to water quality issues if N loadings are controlled by manure analysis and adjusted manure rates. Manure N content was shown to be variable, making it critical to conduct analyses at the right time and with appropriate regard for the variability of the manure source.

This study did not demonstrate significant ground water quality implications, either positive or negative, related to the incorporation of manure. As discussed below, the implications of incorporation for surface water quality were not directly tested in this study.

A number of important environmental variables that are effected by manure management could not be addressed in this study. For example, surface water quality issues as impacted by runoff and associated phosphorus loads, bacteria, nitrate, ammonia loadings; direct flow to drainage tile, volatilization of N, and nutrient transformations have all been addressed in other Green Plan research projects and were not specific components of this research. However, the study provides indirect information on some of these issues.

By focusing on conservation tillage systems it is assumed that runoff and soil erosion is reduced. Residue levels measured in this study were consistently higher, often much higher, than the residue levels typically achieved under conventional tillage. Thus, while manure use generally increased phosphorus concentrations in the soil relative to inorganic fertilizer use, the use of conservation tillage reduces the negative implications of this enrichment.

There are also a number of indirect environmental impacts that can be related to manure use such as soil compaction, odour problems, increased energy use for storage, movement and spreading of manure relative to inorganic fertilizers, methane gas production, etc. These issues are largely outside the scope of this study, although some of the farmer comments touch on these briefly. These issues are important and should be addressed by innovative techniques such as full cost accounting which would compare the full environmental costs and benefits of animal agriculture to a system based on inorganic nutrient inputs.

9.3 Productivity and Agronomic Effects of Manure Management in Conservation Tillage

The consideration of yield impacts is confounded by inclusion of two out of seven fields which were not consistently responsive to nitrogen. However, even if these non-responsive sites are excluded from the analysis, there are no consistent significant yield differences in the data. The farmers involved in this study were able to substitute manure for inorganic sources of nutrients and achieve similar yields. Occasionally the manure resulted in higher yields and occasionally the inorganic treatment resulted in higher yields, but overall results were comparable. This conclusion is supported by the farmer experiences. Not one farmer complained of significant yield reductions due to the use of manure as the main N-source.

Some of the farmer cooperators expressed concern about increased weed pressure due to the use of manure in conservation tillage systems. Due to the reduced options for weed control inherent in conservation tillage systems this could be an important limitation for the wider integration of conservation tillage systems and animal systems. The general consensus among the farmer cooperators at the conclusion of the research was that, while the use of conservation tillage and manure may result in apparent increases of weed pressure at some sites, the additional weeds could be managed with modifications to the overall system and with no serious yield, management or cost concerns.

The soil fertility measurements taken during this study show that manure use often leads to significantly higher levels of phosphorus and potassium. The levels of potassium reached at some sites were high enough to cause concern about potential magnesium deficiency, but magnesium levels were also high and yields were not affected. These high levels of potassium could also be a concern under conventional tillage, however, the problem may be greater under conservation tillage due to the relative lack of soil disturbance and nutrient redistribution. This finding simply highlights the importance of regular soil testing as an important tool in long term manure management and the need for crop rotations which include non-manured crops such as soybeans and alfalfa.

Nitrate levels were measured at different times in the season as an indicator of N availability to the crop. These data produced no clear trends other than a general impression that N applied as manure resulted in higher nitrate readings more quickly than equivalent amounts of N applied in inorganic forms. Whether this was due to differences in the magnitude of denitrification, caused by changes in the physical, chemical and biological soil properties in the manure plots, or simply to differences in the physical distribution of the nitrogen sources (i.e. inorganic sources generally being applied in a more concentrated soil zone) could not be determined in this study. Some of the more complex determining factors of nitrogen dynamics are being studied under other Green Plan research and may contribute to understanding of this general trend.

Manure has often been discussed as a method of improving overall soil "health" and contributing to long term sustainable yields by positive influences on factors such as microbial activity, pH, OM changes, etc. These attributes were outside the scope of this study but were among the long term benefits that farmer cooperators expected to obtain from appropriate manure management.

Similar to the findings on nitrate levels there are no indications in the data to suggest that, from a productivity standpoint, nitrogen from manure should be managed in any substantially different ways than nitrogen from inorganic sources. In order to get maximum yield benefit from manure nitrogen it should be applied as close to the period of active crop growth as possible. Manure nitrogen intended to spur early crop growth should be applied near the seed and nitrogen should be applied at the maximum economic rate.

9.4 Farm Management Effects of Manure Management in Conservation Tillage

No economic measurements were made during this study. This was a field scale study designed, implemented and interpreted in close cooperation with farmer cooperators. The farm level economics of manure use are very complicated and specific to individual farm systems. Rather than try to make general economic measurements, which would require broad assumptions about the cost and value of manure nutrients, the individual farmer cooperators were asked to evaluate the treatments and practices as they would any change in farm management. This approach greatly simplified the economic analyses and most importantly included the farmer's own "whole farm enterprise accounting system". This type of whole enterprise accounting addresses all the farm specific, often intangible, economic parameters such as the on-farm value of manure nutrients versus the cost of disposing of the manure, marginal labour and equipment rates as affected by the timing of field operations (i.e. a field operation that must be conducted at the same time as other critical operations such as planting "costs" more in equipment and labour than an operation that can be conducted when labour and equipment are not otherwise needed), and farm specific economic relationships between animal and crop enterprises.

Specific farmer comments on these issues are presented in the conclusions of the individual experiments. The following general comments are drawn from the specific responses of the farmer cooperators.

Under the economic and farm management system analysis adopted for this study, the ultimate test of a practice is: "Would the farmer adopt it as an ongoing part of his farm management system?". Based on that test conservation tillage and manure management systems were acceptable to farmers from the economic and farm management perspectives. All six farmers successfully integrated manure management into their conservation tillage system. Various equipment and practice modifications were necessary for all cooperators but all problems were overcome through farmer ingenuity. Five of the six cooperators are continuing the practice of integrated manure management and conservation tillage, One cooperator has abandoned conservation tillage and will be managing manure with conventional tillage. This decision was due to a number of factors related to the entire farm operation and not necessarily any fundamental problem with combining manure and conservation tillage.

Manure type did not seem to pose any insurmountable problems for the farm operators. The critical attribute related to the manure seemed to be dry matter content. Manure that had too high dry matter content was difficult to apply using the liquid applicators and resulted in excessive plugging. Manure with too low dry matter content created several problems including: higher tendency to splash and burn crops when side dressing; excessive volume and weight necessary to achieve desired N rates and unacceptable impacts on field conditions such as compaction, moisture conditions etc. Manure storage and agitation had impacts on dry matter content and were important tools for management.

Timing of manure application was a significant factor in management. Timing is important to nutrient uptake and has serious implications for overall crop performance. The window of opportunity to apply manure is critical. The more flexibility the farmer has in applying the manure the better the practice will be accepted. Important variables that affect timing include stage of corn growth, precipitation patterns, available equipment, and soil type. An example of the type of quandary farmers faced was whether to apply immediately before a rain and risk high losses (surface runoff) or wait until the rain is over and risk either not getting on the field or causing compaction. When the farmer is depending on manure for all, or most of the crop nutrients, it is obviously critical that the manure get applied. Farmers, who already have enough to worry about in the spring, get understandably anxious when it appears as though they may not be able to apply crop nutrients when needed. The practices studied in this experiment presented several attractive alternatives which addressed this critical issue of timing including choices between pre-plant broadcast and pre-emergent side dress.

Some of the cooperators also mentioned other alternatives to deal with timing problems such as low traffic delivery systems including drag hose tanker and spray gun irrigation. These systems have limitations to post-emergent use since the drag hose knocks down the corn and irrigation may burn crops if not carefully controlled. Irrigation is also recognized as a wasteful and odorous practice. However, the availability of backup methods of supplying crop nutrients is critical to wider adoption of conservation tillage in animal production systems.

Manure storage was shown to be an important component of application timing and conservation tillage success. Those farmers with a full year of manure storage are obviously better equipped to move to a system with major emphasis on spring only application. Some farmers apparently grow winter wheat primarily to have land available for fall manure spreading and would be reluctant to forgo fall plowing or discing following manure application given concerns about nutrient loss and increased disease and pest potential due to wheat residue and over-wintering of high moisture and high residue conditions.

9.5 On-farm Research

This study highlighted both the shortcomings and strengths of on-farm research in developing agronomic practices. The major drawback with on-farm research is the lack of experimental control and rigour. This lack of control is due to a number of factors, some of which are completely outside the control of the investigator and some which are susceptible to some form of control.

The main management challenges encountered in this experiment were:

- a tendency of farmer cooperators to change experimental parameters. The ability for the farmer cooperator to identify and respond to limitations in the practices being studied is one of the strengths of on-farm research and should not be completely eliminated. However, with close communication between the farmer cooperator and research, such changes can be made in way which preserves the integrity of the experimental design and does not have too great an impact on the validity of results;

- a wide geographic spread of research projects with activities happening concurrently puts high demands on the researchers. Since experimental treatments are being implemented at the same time in widely separated sites, the protocol must be managed by different individuals which can lead to inconsistency in the design and measurement. This potential problem can be largely controlled through very tight, simple, experimental designs and good communication between all participants.

The benefits of on-farm research have been discussed extensively in sections above, particularly with regard to farmer impressions. Overall, the results of this experiment clearly indicate that the benefits of on-farm research outweigh the difficulties. Based on the results of this experience, on-farm research is an extremely valuable tool for developing technologies which can be quickly adapted by a wide range of farmers. It is important that on-farm research is not expected to deliver statistical results similar to laboratory or tightly controlled field studies. These type of laboratory or tightly controlled field plots should be used to answer basic process and theoretical questions such as the nutrient dynamics under different moisture and soil conditions. The results of these more detailed rigorous studies can be used to interpret the results of the on-farm field research and merge the fields of theory and practice.

10. Recommendations

Based on the results of this on-farm research program, and general consideration of the other concurrent Green Plan studies, the following recommendations are made:

1. All relevant Greenplan research into manure management and nutrient dynamics should be integrated into a comprehensive set of revised manure management recommendations built on, or complementary to, OMAF publication 296.
2. The program of field research and farm cooperator involvement in conservation tillage and manure management should continue.
3. A series of manure management conservation tillage demonstration sites should be established to show the general farm population the wide range of manure management options in conservation tillage and demonstrate the flexibility and adaptability possible within a conservation tillage approach.
4. Equipment manufacturers should be encouraged to conduct research and development in site dress applications of liquid manure to allow a broader range of farmers to use this technique without having to make their own equipment modifications.
5. The interaction between agricultural nitrogen use and rural groundwater quality should continue to be the focus of research and broad surveys, regardless of the source of nitrogen.

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Appendix 1

Nitrogen Response Curves

Experiment 1

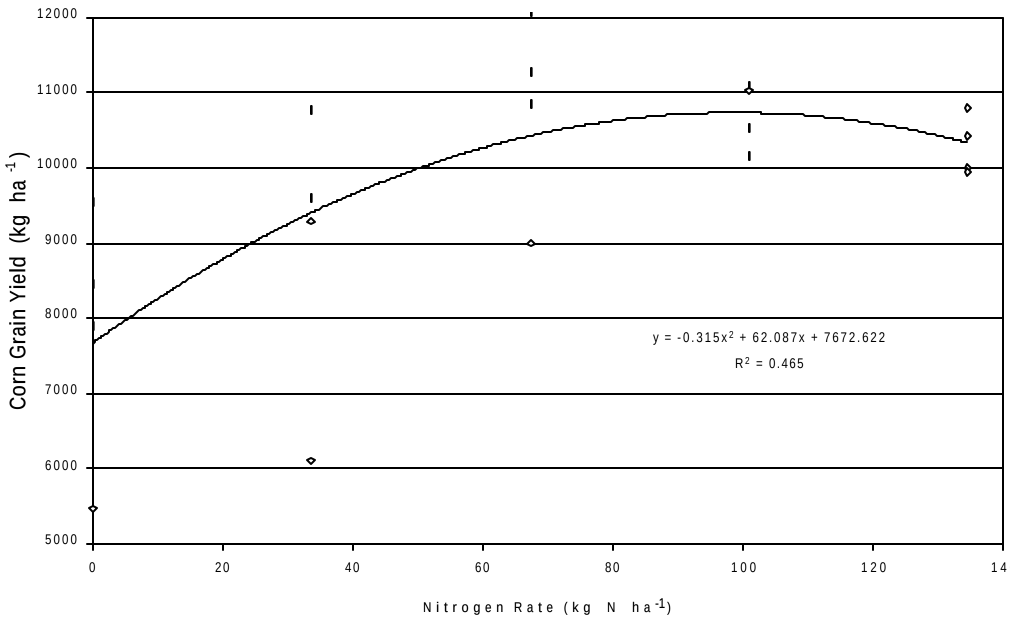

Figure 1.

Experiment 1: Nitrogen response in 1994 at the Chipps Site (MER-N=91 kg N/ha).

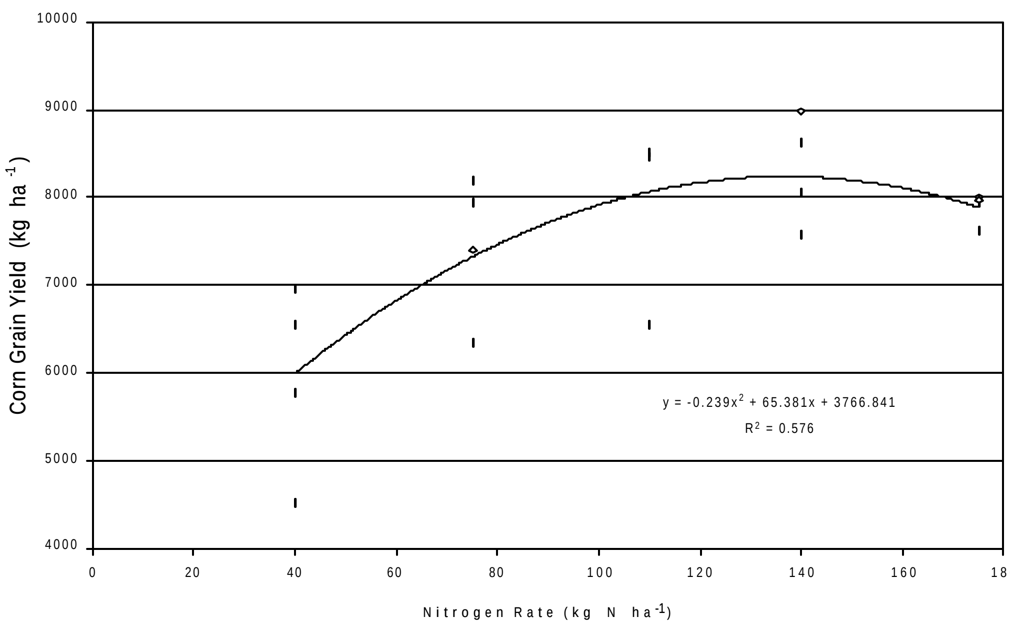

Figure 2.

Experiment 1: Nitrogen response in 1995 at the Chipps Site (MER-N=126 kg N/ha).

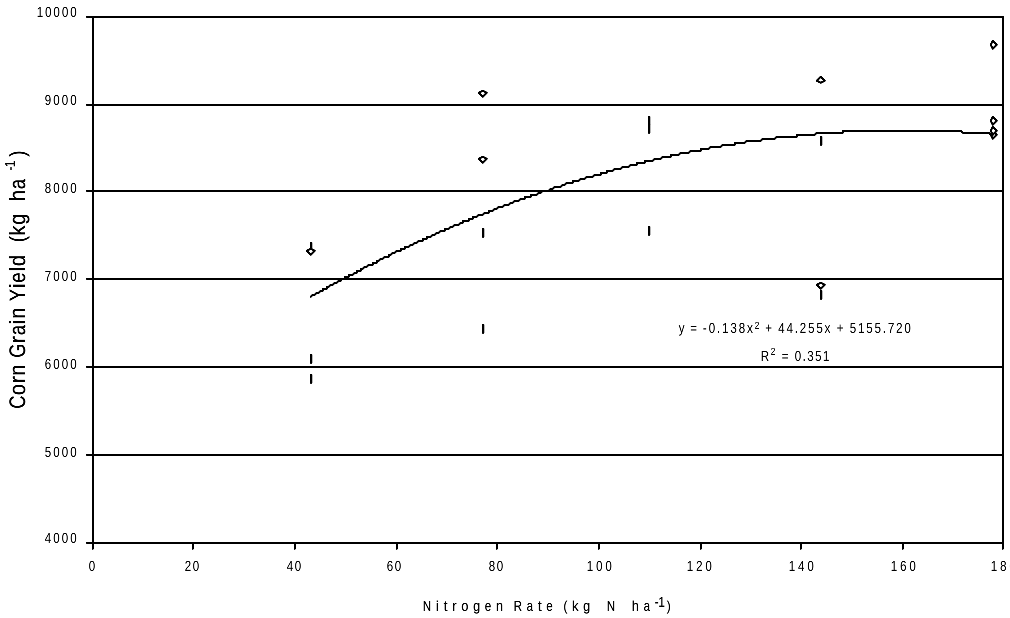

Figure 3.

Experiment 1: Nitrogen response in 1996 at the Chipps Site (MER-N=142 kg N/ha).

Experiment 2

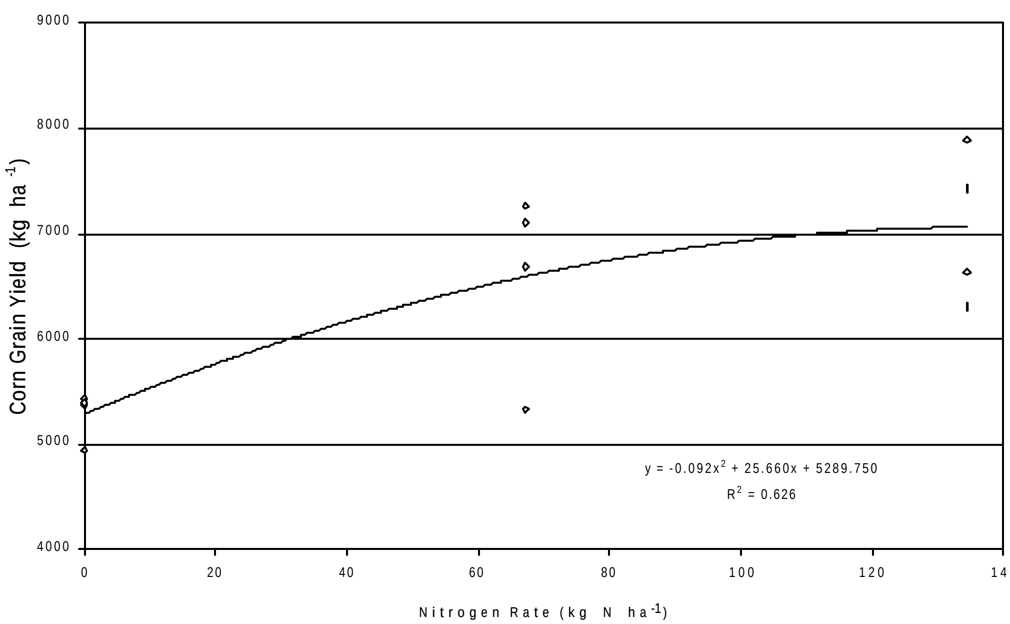

Figure 4.

Experiment 2: Nitrogen response in 1994 at the Soetemans Site (MER-N=112 kg N/ha).

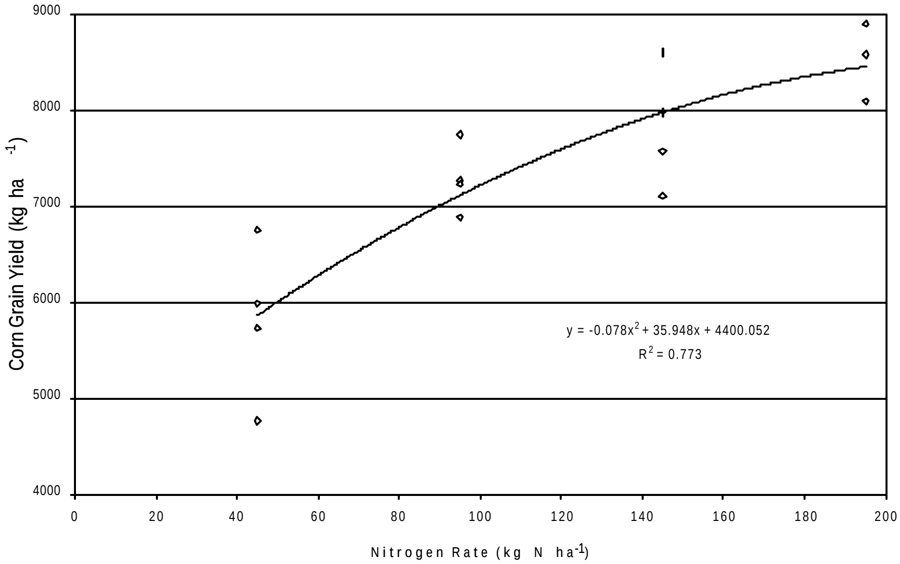

Figure 5. Experiment 2: Nitrogen response in 1995 at the Soetemans Site (MER-N=199 kg N/ha).

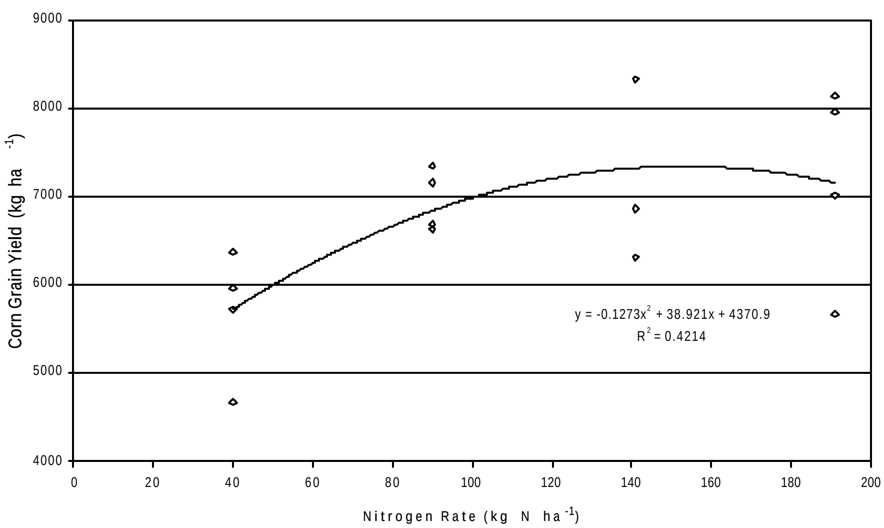

Figure 6. Experiment 2: Nitrogen response in 1996 at the Soetemans Site (MER-N=133 kg N/ha).

Experiment 3

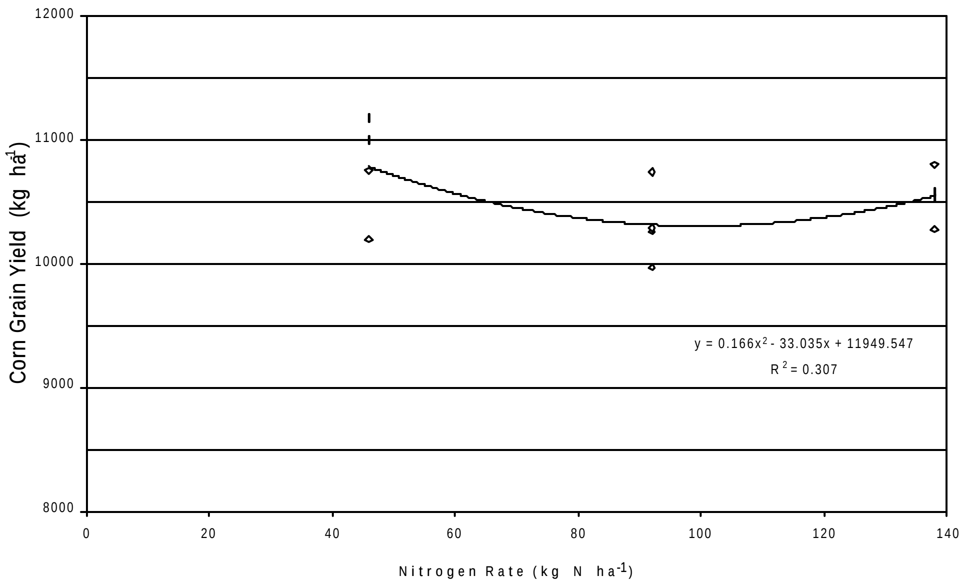

Figure 7.
Experiment 3: Nitrogen response in 1994 at the VanDorp Site (Note: in 1994 plots were not randomized due to space limitations for use of equipment).

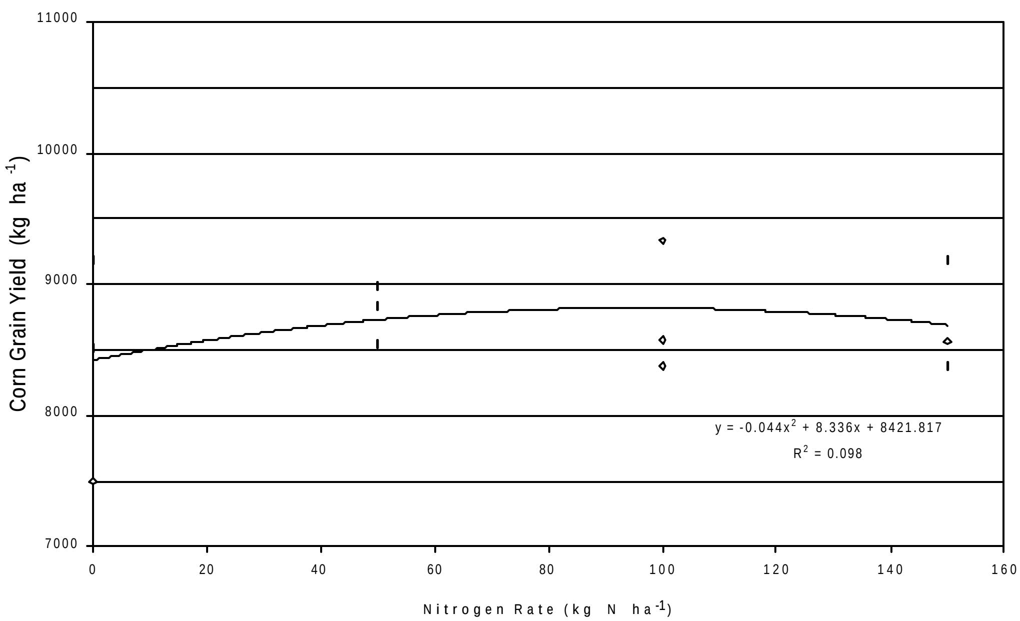

Figure 8.
Experiment 3: Nitrogen response in 1995 at the VanDorp Site (MER-N=38 kg N/ha).

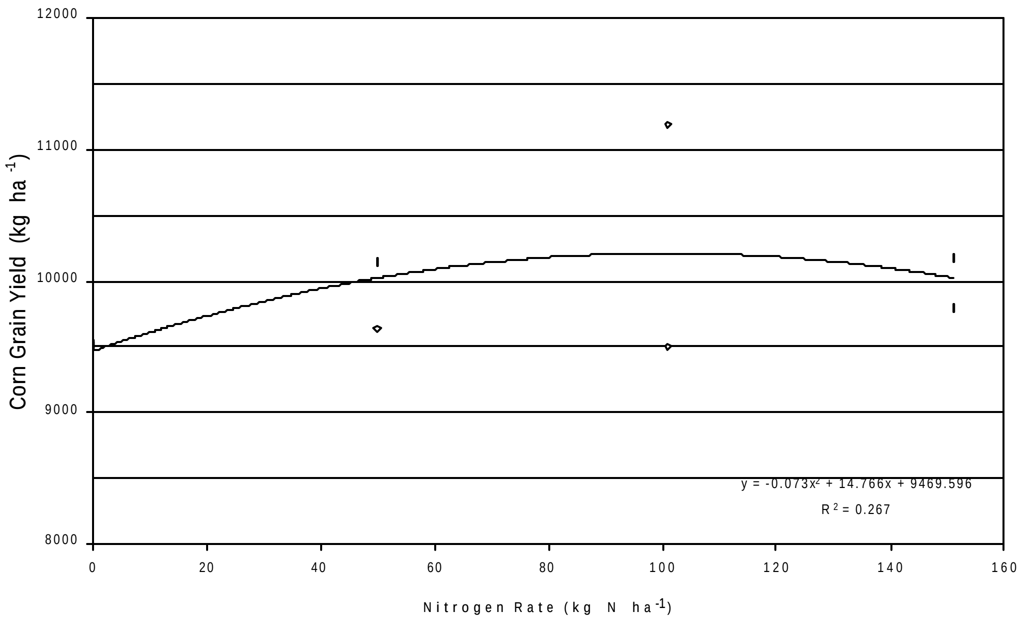

Figure 9.

Experiment 3: Nitrogen response in 1996 at the VanDorp Site (MER-N=67 kg N/ha).

Experiment 4

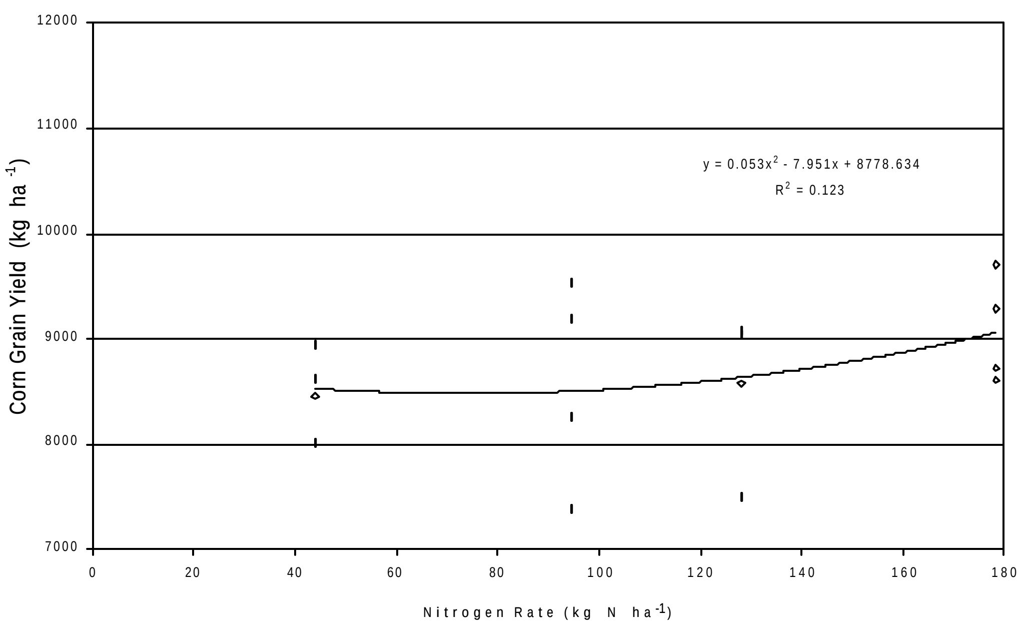

Figure 10.

Experiment 4: Nitrogen response in 1994 at the Yantzi Site.

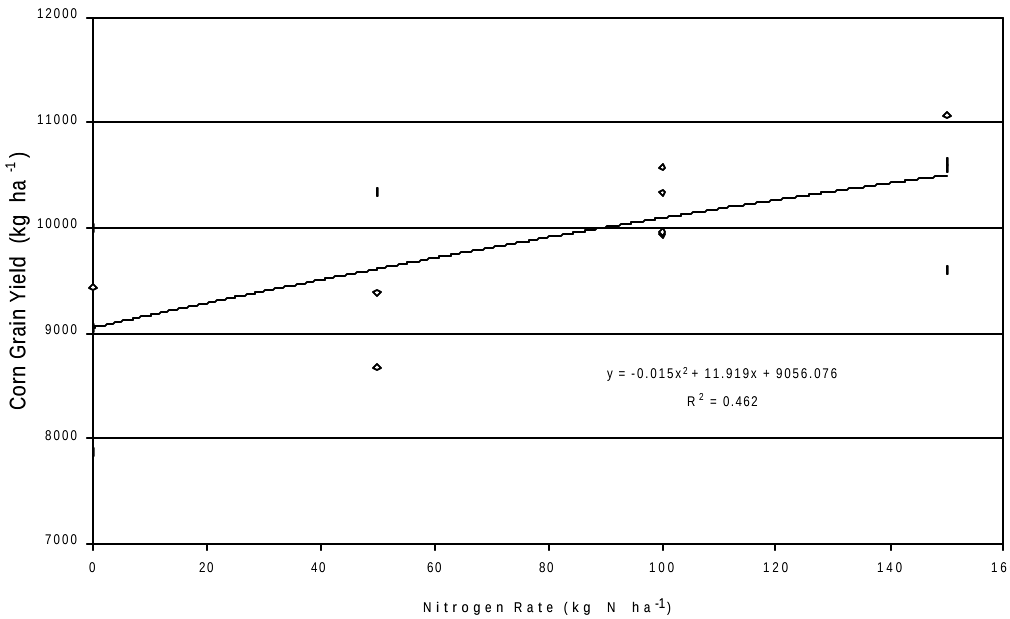

Figure 11.

Experiment 4: Nitrogen response in 1995 at the Yantzi Site (MER-N=231 kg N/ha)

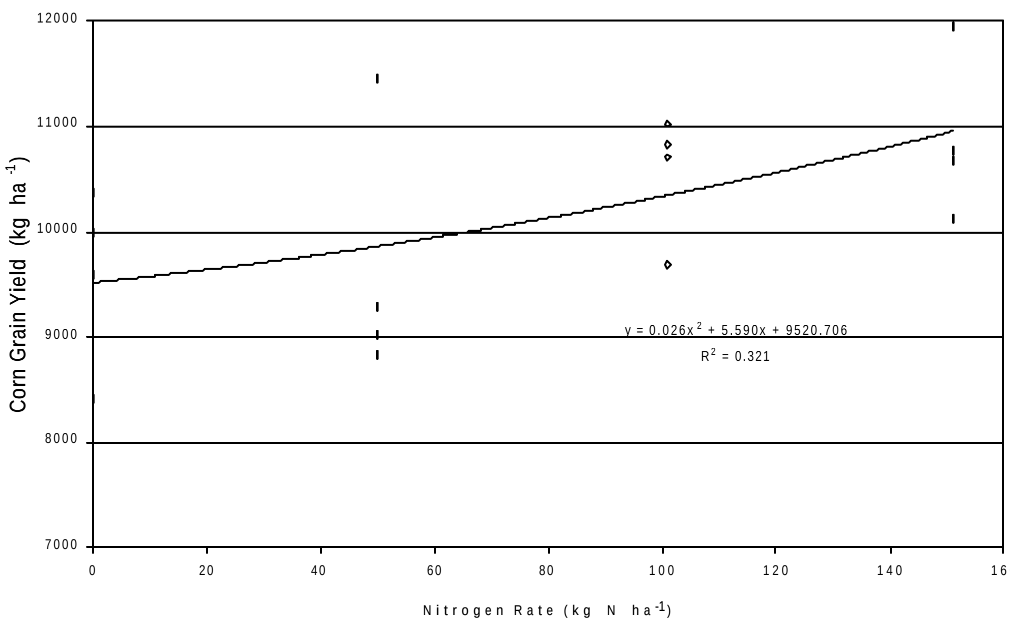

Figure 12.

Experiment 4: Nitrogen response in 1996 at the Yantzi Site.

Experiment 5

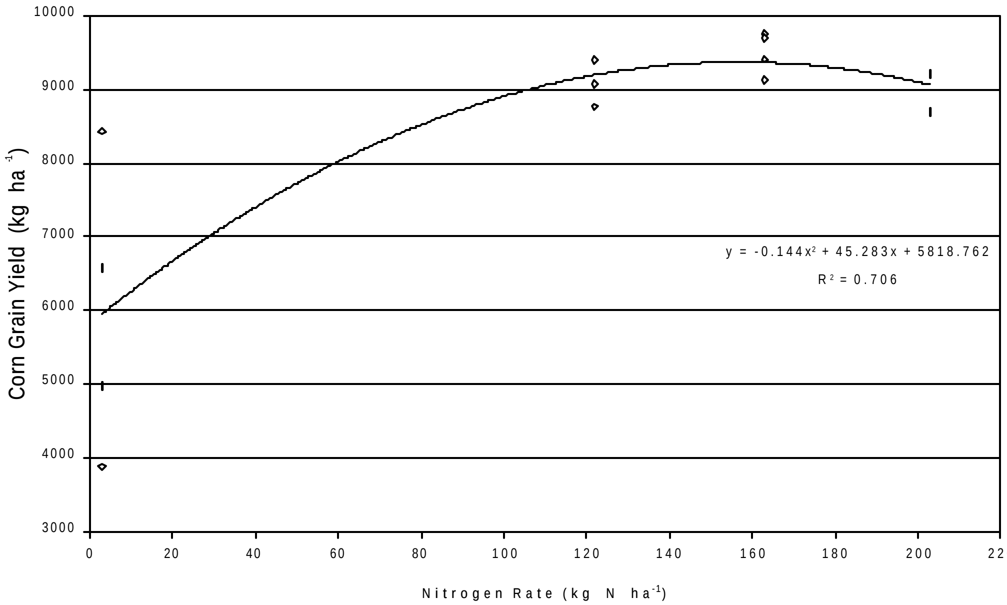

Figure 13.
Experiment 5: Nitrogen response in 1994 at the loam site at the Grenier Farm (MER-N=140 kg N/ha).

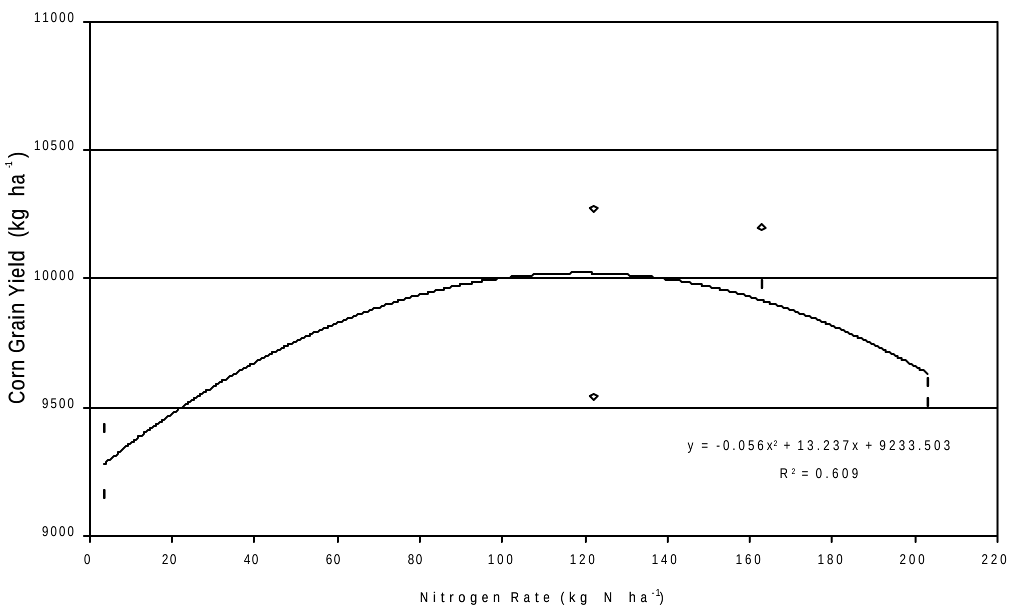

Figure 14.
Experiment 5: Nitrogen response in 1995 at the loam site at the Grenier Farm (MER-N=74 kg N/ha).

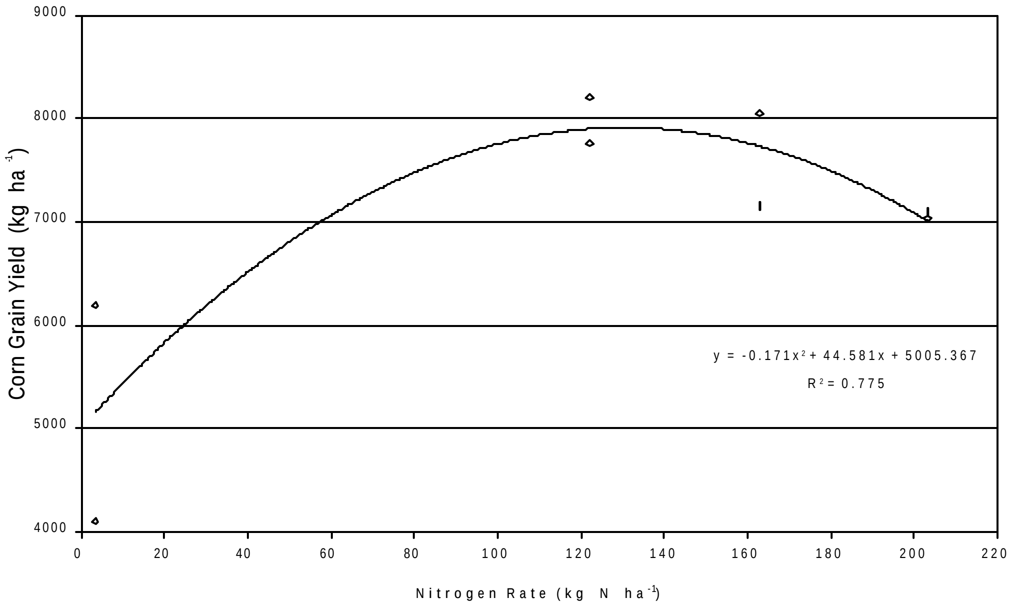

Figure 15.
Experiment 5: Nitrogen response in 1996 at the loam site at the Grenier Farm (MER-N=116 kg N/ha).

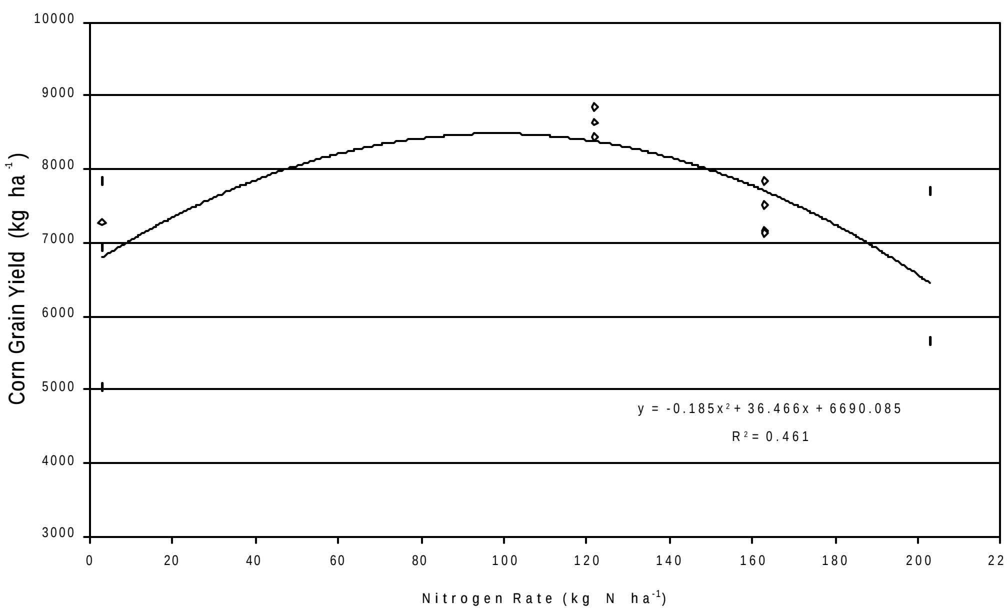

Figure 16.
Experiment 5: Nitrogen response in 1994 at the sandy loam site at the Grenier Farm (MER-N=80 kg N/ha).

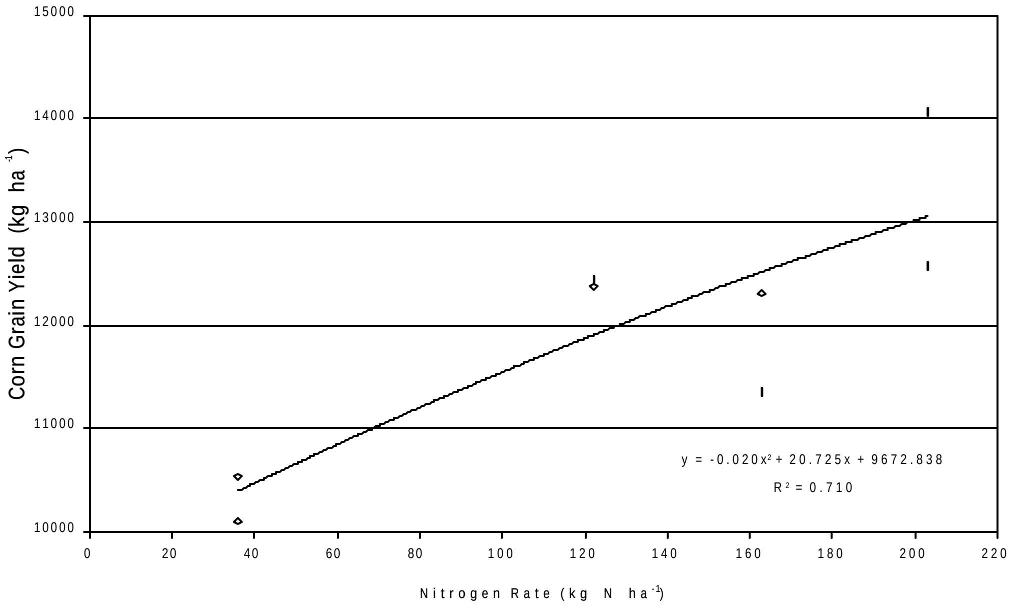

Figure 17.
Experiment 5: Nitrogen response in 1995 at the sandy loam site at the Grenier Farm (MER-N=393 kg N/ha).

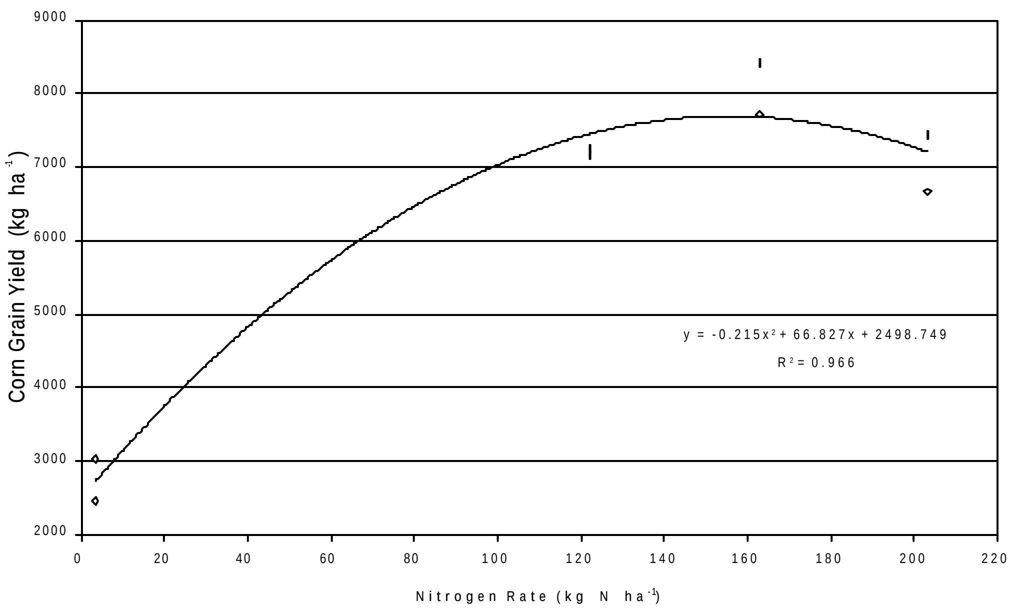

Figure 18.
Experiment 5: Nitrogen response in 1996 at the sandy loam site at the Grenier Farm (MER-N=144 kg N/ha).

Experiment 6

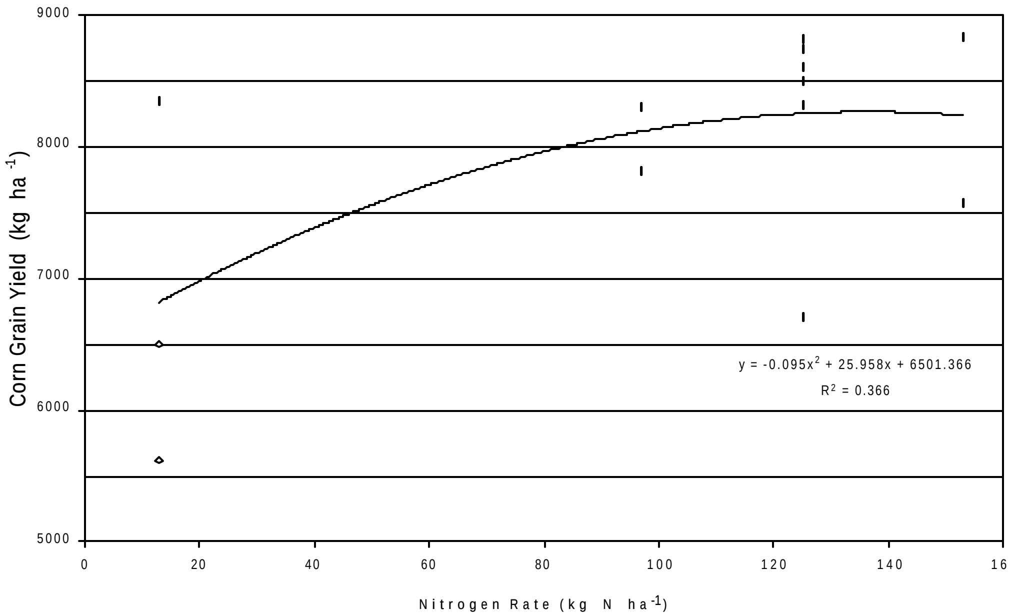

Figure 19.

Experiment 6: Nitrogen response in 1996 at the Menard Site (MER-N=110 kg N/ha).