THE EFFECTS OF TILLAGE, ZERO TILLAGE AND FERTILIZER SOURCES ON CORN GROWTH AND YIELD AND SOIL PHYSICAL PROPERTIES

by

John Kevin Kelly

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

Department of Agricultural Engineering
Macdonald College
McGill University
Montreal

January 1985

TILLAGE AND FERTILIZER EFFECTS ON SILAGE CORN PRODUCTION

REVISED APRIL 1985

UNIVERSITE McGILL

FACULTE DES ETUDES AVANCEES ET DE LA RECHERCHE

Date ______________________

NOM DE L'AUTEUR: ______________________

DÉPARTEMENT: ______________________ GRADE: ______________________

TITRE DE LA THÈSE: ______________________

____

____

1. Par la présente, l'auteur accorde à l'université McGill l'autorisation de mettre cette thèse à la disposition des lecteurs dans une bibliothèque de McGill ou une autre bibliothèque, soit sous sa forme actuelle, soit sous forme d'une réproduction. L'auteur détient cependant les autres droits de publications. Il est entendu, par ailleurs, que ni la thèse, ni les longs extraits de cette thèse ne pourront être imprimés ou reproduits par d'autres moyens sans l'autorisation écrite de l'auteur.

2. La présente autorisation entre en vigueur à la date indiquée ci-dessus à moins que le Comité exécutif du conseil n'ait voté de différer cette date. Dans ce cas, la date différée sera le ______________________

____

Signature de l'auteur

Adresse permanente:

____

____

____

____

Signature du doyen si une date figure à l'alinéa 2.

(English on reverse)

ABSTRACT

M.Sc. JOHN KELLY Agricultural Engineering

THE EFFECTS OF TILLAGE, ZERO TILLAGE AND FERTILIZER SOURCES ON CORN GROWTH AND YIELD AND SOIL PHYSICAL PROPERTIES

An experiment was initiated in 1982 to study energy conservation in silage corn production in two Quebec soils, a sandy loam and a clay. Conventional, reduced and zero tillage treatments were cross classified with inorganic and organic (dairy cattle manure) fertilizer sources in a 3 X 2 factorial experiment with three replicates. Zero tillage significantly increased density levels in the topsoil of both soils, but did not affect crop yields. The use of manure as an alternate fertilizer source was more successful in the clay soil than in the sandy soil. Plant populations were reduced through the use of zero and reduced tillage in both soils. Yields of corn silage on a per plant basis were not affected by any treatment. Reduced or zero tillage with inorganic fertilizer, as well as conventional or reduced tillage with an organic fertilizer were found to be viable alternate silage corn production system components, applicable in southern Quebec and eastern Ontario.

RESUME

M.Sc. JOHN KELLY Génie Rural

EFFETS DU LABOUR CONVENTIONNEL, MINIMAL, SEMIS-DIRECT ET DU TYPE DE FERTILISANT SUR LE RENDEMENT DU MAIS-ENSILAGE ET DES PROPRIETES PHYSIQUE DU SOL

C'est en 1982 qu'a débuté une expérience dont l'objectif était de comparer la demande énergétique de différents programmes de production du mais-ensilage. Le mais à été cultivé sur deux types de sol: i) un loam sablonneux, et ii) de l'argile. Trois méthodes de labourage: i) conventionnelle, ii) minimale et iii) semis-direct combinées à deux types de fertilisants: i) inorganique et ii) organique (fumier de vache laitière) formaient les six programmes de production étudiés. Ils ont été répartis dans chaque champ suivant un model statistique factoriel avec trois répliques. Il a été observé que la pratique du semis-direct résultait en une augmentation significative de la densité de la couche superficielle de chaque sol, mais sans affecter le rendement du mais-ensilage. L'utilisation du fumier comme substitut au fertilisant inorganique a été plus fructueux dans l'argile que dans le loam sablonneux. La population végétale a été réduite dans les parcelles dans lesquelles les techniques de labourage minimale et semis-direct étaient employées. Aucun des programmes de production étudiés n'ont affectés le rendement de mais-ensilage par plant de mais. Il découle de cette étude que l'usage du labour minimal ou semis-direct, combiné à un fertilisant inorganique, ainsi que l'usage du labour conventionnel ou minimal combiné à un fertilisant organique, sont des alternatives viables pour la production du mais-ensilage dans les regions du sud du Québec et de l'est de l'Ontario.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to the following persons who have been helpful in the completion of this work:

- Professor E. McKyes, my academic advisor and research supervisor, for his encouragement, guidance and suggestions throughout the course of this study.

- Professors A.F. MacKenzie and A.K. Watson, co-investigators on the research project, for their helpful discussions and suggestions during the preparation and execution of the experiment as well as parts of this manuscript.

- Messers Sam Gameda and Don Marshall for their continual support in all aspects of the study as well as invaluable and enduring sources of discussion.

- John Mwangi, Sultana Nantho-Jina, Rosa-Lisa Pe, Gord Owen and Paul Brenton who, over two summers, helped with the collection and processing of field data. I would also like to thank Kevin Boushel, L.J. Clogg, Lisa Brazeau, Kevin Sibley, Peter Kirby and Prof. McKyes for their help in the field when more manpower was needed and Sylvain Berard for drafting some of the figures in this report.

- The staffs of the Emil A. Lods Research Station, Renewable Resources Dept. and the Macdonald College Farm for the loan of equipment necessary to complete this experiment.

- NSERC, for providing a stategic grant No GO792 without which this project would not have been possible.

- Last, but definately not least, my parents, for their encouragement, guidance and above all understanding throughout the course of this work.

FORMAT OF THESIS

The format of this thesis conforms to the McGill University guidelines concerning thesis preparation. In particular, the option specified in section seven has been utilized. The text of this section is presented here for clarity:

> "The candidate has the option subject to the approval of the department, of including as part of the thesis the text of an original paper, or papers, suitable for submission to learned journals for publication. In this case the thesis must still conform to all other requirements explained in this document, and additional material (e.g. experimental data, details of equipment and experimental design) may need to be provided. In any case, abstract, full introduction and conclusion must be included, and where more than one manuscript appears, connecting texts and common abstract, introduction and conclusions are required. A mere collection of manuscripts is not acceptable; nor can reprints of published papers be accepted.
>
> While the inclusion of manuscripts co-authored by the candidate and others is not prohibited for a test period, the candidate is warned to make an explicit statement on who contributed to such work and to what extent. Copyright clearance from the co-author or co-authors must be included when the thesis is submitted. Supervisors and others will have to bear witness to the accuracy of such claims before the oral committee. It should also be noted that the task of the external examiner is much more difficult in such cases."

Prof. E. McKyes is listed as second author for both of the manuscripts presented in Chapters 4 and 5. His contribution to the papers was as a supervisor and advisor. Prof. McKyes was also my graduate student advisor and thesis supervisor.

Chapters 1, 2 and 6 provide the reader with a full introduction and literature review as well as an all encompassing conclusion. Chapter 8 contains a list of all authors referred to in this thesis. Additional experimental data and analyses are presented in the appendices.

TABLE OF CONTENTS

Chapter		Page

LIST OF TABLES

Table		Page

Table		Page

LIST OF FIGURES

Figure | Page

Chapter 1

Introduction

Conventional tillage practices in agriculture are being questioned today because of the high costs of labour, fuel and machinery; the need for energy conservation; the need to conserve moisture; and the loss of soil from wind and water erosion of bare soil. Zero tillage, which is the introduction of the seed directly into the previous year's stubble or crop residue without any primary or secondary cultivation is receiving increased attention from farmers and scientists. The technological advances in both the manufacture and use of pesticides over the past two decades, allows today's farmer the option of controlling weeds, insects and diseases without the use of the moldboard plow. Conjointly with this advancement, the farm machinery manufacturers are developing the specialized planting equipment necessary to provide adequate seed-soil contact, sufficient seed depth and proper coverage to ensure full germination and emergence of the seed.

Research has been conducted worldwide to assess the feasibility of zero tillage crop production in terms of energy; economics; maintenance of acceptable crop growth and yields and soil physical, nutrient and moisture status. Unfortunately the results are as widespread as the number of research projects undertaken. Yield changes vary from a 30% reduction to a

40% increase, depending on the soil type and climate of the region. The effects on soil structure and conservation range from detrimental to highly beneficial. Most authors agree on the conservation aspects associated with zero tillage. Wind and water erosion of the soil are minimized and moisture conservation is usually maximized.

Considerable success has been achieved in areas such as the midwest corn belt of the United States and in the United Kingdom. Over 50% of the corn produced in the state of Maryland is grown on zero tilled land. The problem is that the results and recommendations from both the places where sucess has been realized, and where failures have occurred, cannot readily be transferred to another geographic location with different soils and a different climate.

In particular, very little testing has been executed to date in the region of southwestern Quebec and eastern Ontario to determine whether or not zero tillage or reduced tillage could improve the economics of feed production and conserve the quality of arable soils there. Furthermore, among the most expensive inputs to a corn production system, in terms of energy and dollars, is nitrogen. Commercial fertilizers amount to 40% of the variable costs of production, and up to 50% of the expenditures on energy based farm inputs (Agriculture Canada, 1983). Very little work has been done investigating alternate sources of nitrogen to produce direct drilled corn. If cattle manure were a viable alternative to manufactured inorganic fertilizers under zero tillage, then a true energy conserving corn production system might be possible.

Therefore, this study was designed to assess the feasibility of using reduced and zero tillage in combination with two sources of fertilizer to grow silage corn on two soils in southwestern Quebec.

Chapter 2

Literature Review

During the 1980's in the United States alone, the large primary and secondary tillage implements move each year the equivalent amount of soil that would be required to build a superhighway from New York to California (Phillips and Phillips, 1984). This vast expenditure of energy and dollars, coupled with the need to prevent soil erosion by wind and water from bare soil has led to the introduction of reduced and zero tillage practices in many parts of the world. In the states of Kentucky, Maryland and Virginia in the early 1960's, zero tillage corn production occupied less than 2% of the land under cultivation for corn. By the early 1970's, this figure had risen to 25, 50 and 24% in each of these three states respectively (Hill and Blevins 1973, Bandel et al. 1975 and Moschler and Martens 1975).

2.1 Conventional Tillage

Conventional tillage usually consists of first plowing with a moldboard plow, then working the plowed soil with secondary tillage implements, such as the disk and harrow, until the entire soil surface is smooth and uniform (Olson and Schoeberl 1970) In many cases, post-emergent inter-row cultivations are used to control weeds (Fenster 1977).

The responses to the question as to why farmers plow usually center around controlling weeds more than any other reason. Aeration of the soil is also considered important after the compaction created by heavy cultivation and harvesting equipment making several passes over the field (Phillips and Phillips, 1984). Other valid advantages include: pest control through incorporation of crop residues; incorporation of fertilizers to improve their effectiveness; increase soil temperature; stimulate root growth and of course there is always the pressure of tradition and aesthetic value of emerging seedlings in a totally clean soil surface environment (Cannell and Ellis 1979, O'Sullivan 1983, Southwell and Ketcheson 1978, Triplett and van Doren 1977, Phillips and Phillips 1984, Voorhees 1976 and Vyn et al. 1979).

As is the case with any management practice apparently abundant with advantages, conventional tillage is burdened with disadvantages. Greacen, 1983 points out that continuous tillage will eventually work against the buildup of organic matter by increasing the rate of decomposition. The same author also reports that tillage requires traction, and with the type of agriculture we have in the 1980's, this means heavy compactive traction. The two main effects of tillage, loosening and compacting are heavily dependent on the soil water content at the time of plowing. Plowing in wet conditions can cause smearing of the plow sole which may cause both restricted infiltration of water and restricted root elongation (Cannell et al. 1978, Robertson and Erickson 1978). Excessive soil tillage can lead to the destruction of soil structure including continuous pores, earthworm holes and old root channels. Infiltration is the first soil property to suffer, which leads to increased erosion caused by the water runoff (Greacen 1983, Davies et al. 1979, Southwell and Ketcheson 1978). This continuous cultivation leads eventually to a build up of a dense layer, just below the depth of plowing, which has a greater bulk density and higher penetration resistance than any layer of an untilled soil. During dry periods, the effects of this layer are more pronounced since only a small portion of the roots are able to penetrate it and reach the deeper water (Ehlers et al. 1983, Ellis and Barnes 1980, Vyn et al. 1979). Another major disadvantage of conventional tillage is that the soil surface is left bare and exposed to wind and water erosion. Soil losses of between 10 and 30 t/ha/yr are not uncommon on sloping plowed soils (Fenster and Wicks 1976, Harrold and Edwards 1974 and Webber 1964). The greatest disadvantage, however is the demands that conventional tillage makes upon the farmer in terms of energy, labour, and machinery costs (Wittmuss et al. 1975, Pidgeon 1979).

2.2 Reduced Tillage

Until the introduction of herbicides that could adequately control weeds, farmers were forced to totally invert the soil with a moldboard plow in order to control the weeds. Since then, various systems of reduced tillage have arisen using these herbicides to control the weeds (van Doren et al. 1977). These reduced tillage systems range from zero tillage, which will be explained later, to using a chisel plow as the primary cultivation implement. This particular method loosens the soil with a minimum of inversion of the surface and subsurface layers. Therefore, the crop residues are only partially incorporated and much remains at the surface to prevent wind and water erosion. Secondary cultivation is usually done with one pass of the disk harrow in this type of system (Erbach 1982, Meyer and Mannering 1967). A principal advantage of this reduced tillage system is a reduction in the energy required per hectare for chisel plowing as compared to moldboard plowing (Griffith and Parsons 1980). It is this form of reduced cultivation that was chosen along with conventional and no till to be the three tillage treatments in this experiment.

2.3 Zero Tillage

Zero tillage corn production may be defined as the placement of the seed into narrow slots, trenches or bands of sufficient width and depth for seed coverage and seed to soil contact in an unplowed soil (Phillips and Phillips 1984). This unplowed soil generally contains either a killed sod or the residues from the previous years crop, or both (Griffith et al. 1977 and van Doren et al. 1977).

There are several individual factors that contributed to the increased interest in zero tillage since the mid 1950's. The first and foremost was the development of herbicides to control the weeds. Population shifts from rural to urban areas began depleting farm labour pools in many parts of the world. The result was a search for less labour intensive production techniques such as zero tillage. Farm equipment manufacturers introduced zero tillage planting equipment with the capability to achieve consistent performance and reliable results. Climatic pressure, in the form of unusually heavy rainfalls occured in the late 1960's in many parts of the world, causing planting delays and ultimately reduced yields. Farmers were attracted to a practice that would save time in establishing crops as evidenced by zero tillage (Phillips and Phillips 1984). A combination of all the above social factors coupled with the many advantages to be discussed in the next section, has accelerated the acceptance of such a markedly different technique.

2.4 Advantages of Zero Tillage

There are several advantages to the zero tillage production system. Many of these advantages will be discussed in more detail in later chapters of this report. A brief synopsis of these are presented here as a summary:

1. Fuel requirements are greatly reduced with a no tillage system. The fuel savings, resulting from a lack of land preparation operations, may amount to 60% of the fuel used in a conventional tillage system (Doleski et al. 1981 and Frye et al. 1981).

2. Comparison of no tillage and conventional tillage labour requirements show that a 50% labour reduction in land preparation and planting is realized under the no tillage system (Phillips and Phillips, 1984). This great labour saving allows the farmer much better control of the timing of other field operations to prevent working on a soil that may be too wet and thus more susceptible to

compaction (Ellis and Barnes, 1980).

3. Many studies have confirmed that no tillage agriculture can reduce soil erosion (due to wind and water erosion) to almost zero (McGregor et al. 1975). McGregor and Greer (1982) found that these benefits could be obtained with no-till corn for silage as well as for grain corn, even though the amount of residue remaining on the surface after harvest is considerably less for silage corn than for grain corn.

4. The surface residues present in a no-tillage cropping system greatly reduce soil water evaporation and increase the amount of infiltration. These benefits translate directly into improved water availability for the plants and to reduced runoff. The mulching aspect also encourages shallow rooting, the plants are therefore better able to use the moisture from light rains and make more efficient use of the surface applied fertilizers (Estes 1972, Blevins et al. 1971, Bennett 1977). All of these advantages can lead to increases of up to 40% in grain yields with zero tillage corn production (Moschler et al. 1972, Shear and Moschler 1969 and Lal 1979).

5. A greater flexibility in planting and harvest scheduling is offered to the no till farmer. Zero tillage provides the opportunity to plant without waiting for sufficient drying time for the tillage operations (Ellis and Barnes 1980). Untilled soils also provide improved trafficability for planting, pesticide application and harvesting.

6. Increased land use resulting from an upgrade of classification due to less erosion losses is another advantage of zero tillage in agriculture. Hill and Blevins 1973 suggested that no tillage can open up rolling grasslands to cropping where they were suitable for only pasture beforehand.

7. One of the most important advantages of no tillage is the improved soil structure obtained after two to three years of continuous zero tillage (Vyn et al. 1979, Dull 1979 and Cannell et al. 1978). Increased earthworm populations, often by a factor of three or four, more continuity of vertical pores and channels, deeper and more continuous cracking in finer soils and greater stability of aggregates in the surface zone all contribute to the improved soil structure (Cannell et al. 1978, Barnes and Ellis 1979 and Soane and Pidgeon 1975). Root elongation of the seedlings may be slower but when the above mentioned changes have occured, roots can be more numerous below 50 cm, making possible greater withdrawal of water in dry conditions, sometimes with increased yields (Cannell et al. 1978).

8. Equipment requirements and therefore costs, are lower with zero tillage techniques. The use of primary and secondary tillage equipment each year is no longer necessary and therefore tractor horsepower requirements are also much lower.

2.5 Disadvantages of Zero Tillage

Unfortunately, not all the abovementioned advantages are applicable under different soil and climatic conditions. The following potential disadvantages must always be considered before a full scale adoption of the seemingly simple and successful technique of zero tillage is exercized.

1. Weed control will be a greater problem without plowing and shifts in weed populations will be more pronounced. Different timing of application, selection of herbicides and crop rotations must be adopted by the grower using zero tillage (Chase and Meggit 1971). Bennett (1977) reported that herbicide costs for no-tillage could be up to two and a half times that for conventional tillage.

2. Plant pests tend to be a more serious problem on untilled soils with a crop residue on the surface because of the more stable habitat provided (Musick and Petty 1979 and Reicosky et al. 1977).

3. Even though surface application of inorganic fertilizers has been shown to be as efficient as incorporation (Moschler and Martens 1975), nearly all nitrogen fertilizers are acid forming, and consequently, with no tillage the soil surface can very rapidly become acidic (Vitosh and Warncke 1976). This acidic soil surface can cause reduced effectiveness of herbicides (Blevins et al. 1978 and Fox 1978).

4. The soil temperature in the surface layers can be markedly cooler under the zero tillage regime. Temperatures, in some climates, can run 2-10 degrees C lower and aggravate cool soil situations for warm season crops. Work in the eastern Canadian climate, however has shown only a very small difference in the temperature profiles (Barclay et al. 1983).

5. Poorly drained heavy soils may be unsuitable for zero tillage. Increases in bulk density of 0.20 Mg/m^3 have been experienced in the surface layers of zero tilled lands and can be detrimental to crop emergence and growth on these types of soils (Gantzer and Blake 1978 and Cannell et al. 1978).

6. In most parts of the world, zero tillage corn yields are usually higher than with conventional tillage (Moschler et al. 1972, Shear and Moschler 1969 and Triplett and van Doren 1977). There are, however, certain soil and weather conditions in other parts where lower yields are experienced with zero tillage. Ketcheson (1977) in particular, reported reduced root growth due to high resistance to root penetration, causing a 20-25% reduction in corn yields.

7. The crop residues left behind with zero tillage corn production are very unique in that they cause as many disadvantages as they do advantages. While providing an excellent mulch cover to reduce erosion and evaporation, increase infiltration and available water, the residues are often blamed for otherwise unexplainable yield reductions (Papendick and Miller 1977). Difficulty in stand

establishment, reduced seedling vigor, release of phytotoxic decomoposition products, fertility imbalances, reduced soil temperatures and heavy pest infestations are some of the problems associated with these crop residues (Papendick and Miller 1977, Vyn et al. 1979 and Elliot et al. 1977).

8. Tradition holds deep in the hearts of many farmers, and it has been hard for them to accept the ragged appearance of zero tillage fields. The uneven, unkept, untidy appearance, which continues until the crop canopy forms, has had a definite social impact on the adoption rate (Phillips and Phillips 1984).

After some 25 years of extensive research on corn production with zero tillage, one important fact stands out above all the others: The results of any individual study are not readily transferable to another geographic location due to soil and climatic differences.

The possible benefits to be gained through the use of zero tillage far outweigh the negative effects if the no-tillage technique provides adequate results in terms of yields and quality of harvested material. The potential economic, energy and environmental benefits obtainable if no-tillage and alternate fertilizer sources are successful, are adequate justification for full scale research projects to determine the feasibility in a particular region.

Research in the area of organic fertilizer sources in combination with reduced tillage is severly lacking. Using dairy cattle manure, for example, as the nitrogen source for corn production on zero tilled land would result in very large economic and energy savings.

McIntosh and Varney (1972) reported equivalent silage yields in continuous corn production between plots receiving 170 kg/ha of inorganic N with no manure and plots receiving 22 t/ha of manure with no inorganic N. In their experiment, the manure was fully incorporated into the soil.

Chapter 3

Objectives and Scope of the Study

The objectives of this study were:

1. To establish an experiment on two soil types to investigate the effects of three levels of tillage and two different fertilizer sources on silage corn production in Quebec.

2. To grow a silage corn crop on all the plots of the experiment using full scale field machinery and to quantify the effects of the treatments on corn growth parameters such as: i) leaf area index, ii) plant height, iii) dry matter accumulation, iv) moisture content, v) nutrient and chemical status of the plant tissue at harvest and vi) final plant dry matter yield.

3. To determine the treatment effects on the soil's physical, nutrient and moisture status during the growing season by measuring: i) soil dry bulk density, ii) volumetric moisture content and iii) soil fertility and organic matter content.

4. To recommend the most feasible silage corn production system, for this region, from the six treatment combinations under investigation.

5. To outline areas of concern for future researchers.

Silage corn was chosen as the crop to be grown because of its use on almost all farms in this region. A reduction in the amount of crop residues left on the field after harvest in silage corn, as compared to grain corn, facilitates the transition from conventional to zero tillage in terms of equipment requirements and pest problems, and would therefore be more readily accepted by the farmers in this region.

The tests were performed on two different soil types (a sandy loam and a clay), to further asses the adaptability of these techniques to this region. The results could be applied in any area with similar soil and climatic conditions.

Chapter 4

The Influence of Tillage, Zero Tillage and Fertilizer Sources on Corn Growth and Yield

4.1 Introduction

More then 400,000 hectares of corn are grown each year in the southwestern Quebec and eastern Ontario regions. Forty percent of that area is devoted to silage corn. Considering the potential fuel savings alone, zero tillage techniques could possibly reduce farm operating costs by up to $7 million each year.

These rising energy costs and technological advances in the production and use of herbicides over the last two decades have contributed to the orientation of crop production management towards conservation tillage systems in certain world regions (Griffith et al. 1977, Triplett and van Doren 1977 and van Doren et al. 1976). Reduced tillage practices and planting of crops by direct drilling have been widely accepted in some areas of both developed and developing countries for the purposes of water conservation and erosion control (Unger and McCalla 1980, Fenester and Wicks 1976, Ketcheson 1977a and Bennett 1977).

Studies on minimum tillage, fertilizer use and corn production have shown contradictory results depending on the location. For example, in areas such as western Ontario and parts of the American midwest, minimum tillage has resulted in reduced yields (van Doren et al. 1976, Harrold et al. 1970, Ketcheson 1980, Lindsay et al. 1983, Fink and Wesley 1974 and Kethceson 1977b), whereas other authors in Quebec, the American midwest and abroad have shown that no-tillage methods resulted in higher yields (Moschler et al 1972, Barclay et al. 1983, Estes 1972, Jones et al. 1969, Taylor et al. 1981, Shear and Moschler 1969, Brar et al. 1983, Lal 1979 and Triplett and van Doren 1969).

Van Doren et al.(1976), have shown that no-tillage treatments have resulted in reduced yields on poorly drained soils but have resulted in increased yields on sloping sandy soils in Ohio. Griffith et al. (1982) reported that no-tillage continuous corn will only outyield the conventional methods of tillage on light well drained soils. On poorly drained heavier soils, they have shown a yield reduction of up to 10%. On the other hand, Raghavan et al 1981, Barclay et al 1983 and McKyes et al. 1979 have all demonstrated that indeed zero tillage can be feasible in the heavy clay soils of northeast North America.

A considerable amount of research work has been done over the last 20 years in an effort to identify some of the factors responsible for either the increase or decrease in crop yields associated with zero tillage when compared to the conventional methods of moldboard plowing and disk harrowing. Work in the state of Ohio has shown that at least a 50% mulch cover is necessary for no-tillage to equal conventional yields (Harrold et al. 1970). Triplett et al. (1964) reported a positive correlation between the amount of mulch cover and no-till grain yields on silt loam soils.

Jones et al. (1969) found that a surface mulch increases yields to a greater degree than does tillage. They also found no difference in corn yields under no-tillage and conventional tillage without a mulch. Plant growth and yield response to tillage depend primarily on mulch and the structural conditions of the soil surface regulating infiltration. Not only does the mulch cover reduce evaporation from the soil surface and prevent the degrading effects of wind and water erosion, but it also increases the amount of infiltration and therefore the amount of water available to the plants. Several authors, working in semi-arid areas, have reported higher yields when corn is planted directly into a killed- sod (Moschler and Martens 1975, Estes 1972 and Blevins et al 1971). Whereas other authors have shown an increase in yields with zero tillage when a mulch, consisting of the previous years crop residues, is present (Harrold et al. 1970 and Negi et al. 1980). Increased yields of up to 23% in zero tilled silage corn are due mainly to the increased moisture conservation associated with the mulching aspects of the killed sod (Estes 1972).

The fertilizer requirements of corn grown under no-till conditions can be adequately met through surface application of the fertilizer, given proper conditions (Vitosh and Warncke 1976, Fink and Wesley 1974, Moschler and Martens 1975 and Kang and Yanusa 1977). Vitosh and Warncke (1976) suggest that on cold soils and those low in phosphorus, band applications of the phosphorus with a conservation type planter is necessary since, on these soils the phosphorus is very immobile. Field experiments on three soil types in Virginia have shown that fertilizer efficiency for no-tillage corn with surface application was higher than for conventionally tilled corn with an equal disked in application rate (Moschler et al. 1972). This was caused by higher moisture contents in the upper layers leading to increased solubility and greater uptake of nutrients (Lal 1979 and Lal 1976).

Potassium and phosphorus fertilizers have been found to be concentrated in the upper 5 cm after six consecutive years of no-till corn (Triplett and van Doren 1969, Shear and Moschler 1969) causing a higher P and K content in the leaves at the tasselling stage. Moschler and Martens (1975) reported a 14-19% increase in corn yields with no tillage over conventional tillage, caused by increased fertilizer efficiency during three years of above average rainfall in a silt loam soil.

Ammonium nitrate may be the best source of nitrogen for surface application to prevent the ammonia volatilization which might be experienced if urea were to be applied (Vitosh and Warncke 1976, Fox and Hoffman 1981, Mengel et al. 1982 and Bandel et al. 1980). Urea can be used only if at least 10 mm of rain falls within 48 hours of application. Substantial nitrogen losses are incurred to the atmosphere if no rain falls within 6 days (Fox and Hoffman 1981).

When dairy cattle manure is spread on the surface of zero tilled land, an appreciable amount of NH_3 is easily lost by ammonia volatilization (Klausner and Guest 1981). Lauer et al. (1976) demonstrated that NH_3 losses after spreading were represented by mean half lives ranging from 1.9 to 3.4

days. Rapid loss was primarily due to the drying of the manure on the soil surface and climatic conditions determining this rate of loss. Dairy cattle manure, when used as the only nitrogen source in corn production, can produce equivalent yields to commercial inorganic fertilization if it is applied in sufficient quantities (McIntosh and Varney 1972). Very little work has been carried out to examine the effects of using dairy manure as a nitrogen source for zero till corn.

With suboptimal nitrogen rates in no-tillage corn production, nitrogen deficiency symptoms have been found to be more severe throughout the season and the yields have tended to be lower than with the same rate applied to conventional tillage plots (Bandel et al. 1975 and Blevins et al. 1983). When nitrogen fertilizer was adequate, equal yields have been achieved between no-tillage and conventional tillage (Blevins et al. 1983 and Kang and Yanusa 1977). Lal (1979) however, attained higher corn yields for zero tillage versus conventional tillage at all levels of nitrogen applied.

Results from Kentucky, Maryland and Virginia show that nitrogen fertilizer is used more efficiently in no-tillage than in conventional tillage corn when evaluated on the basis of yield response (Frye et al. 1981, Moschler and Martens 1975, Phillips et al. 1980 and Stanford et al. 1979).

Gantzer and Blake (1978) reported a rapid rate of acidification of the soil surface layer with high rates of physiologically acid nitrogen fertilizer under no-tillage. Numerous other authors have also shown an increased acidification of the soil surface layer under no tillage corn (Moschler et al. 1973, Triplett and van Doren, 1969 and Blevins et al. 1977).

Several studies have shown that tillage has little influence on crop yield in the absence of weeds providing that a field has not been compacted excessively. Herbicides now give the farmer the option of controlling weeds with less tillage (Hinesly et al. 1967, Triplett and Lytle 1972 and Wimer 1946).

Ten to 15% more seed should be sown with zero tillage than with conventional tillage because trash may interfere with proper emergence of all plants. Use of a conservation type planter which can seed through sod, mulch or hard soil, is imperative to obtain the required seed-soil contact for proper germination (Nelson et al. 1976). In cases where conventional tillage yields exceeded those of zero tillage (Fink and Wesley 1974), a higher plant population was largely the reason. Corn populations were poor on the zero tilled seedbed due to heavy rains which occurred shortly after planting. Water concentrated in the no-till planting slits, flooding the young plants.

Because the research performed on zero and reduced tillage around the world is limited in its applicability to other parts of the world, due to soil and climatic differences, it is still not known how zero tillage will perform in Quebec. With this in mind, field experiments were conducted on two different soils to examine the effects of tillage practices and fertilizer methods on the growth and yield of silage corn in the eastern Canadian climate.

4.2 Materials and Methods

4.2.1 Experimental Design

This field study was established on two experimental sites located at the Macdonald College Research Station of McGill University in Ste. Anne de Bellevue, Quebec. The first site comprises a Macdonald clay, while the second site is on a St. Benoit light sandy loam. Figures 4.2.1 and 4.2.2 illustrate the particle size distributions for these two soils.

Prior to 1982, continuous corn (Zea mays L.) was grown under conventional tillage for approximately 20 years on the sandy loam soil, while corn was grown from 1970 to 1976 and alfalfa (Medicago sativa L.) from 1976 to 1981 on the clay soil. In the fall of 1981, a 2 X 3 factorial experiment was established. Six combinations of three levels of tillage and two different fertilizer sources were randomized in a complete block design with three replicates forming a total of 36 plots, (18 per experimental site), individual plots measuring 10 X 12 m.

The three levels of tillage were conventional, reduced and zero tillage. The conventional tillage treatment consisted of fall moldboard plowing to a depth of 15 to 20 cm followed by two passes of a disk harrow in the spring for seedbed preparation. The reduced tillage systems included fall chisel plowing with a five shank chisel plow with narrow spear pointed shovels spaced 30 cm apart, and operating at 15-20 cm depth, followed by

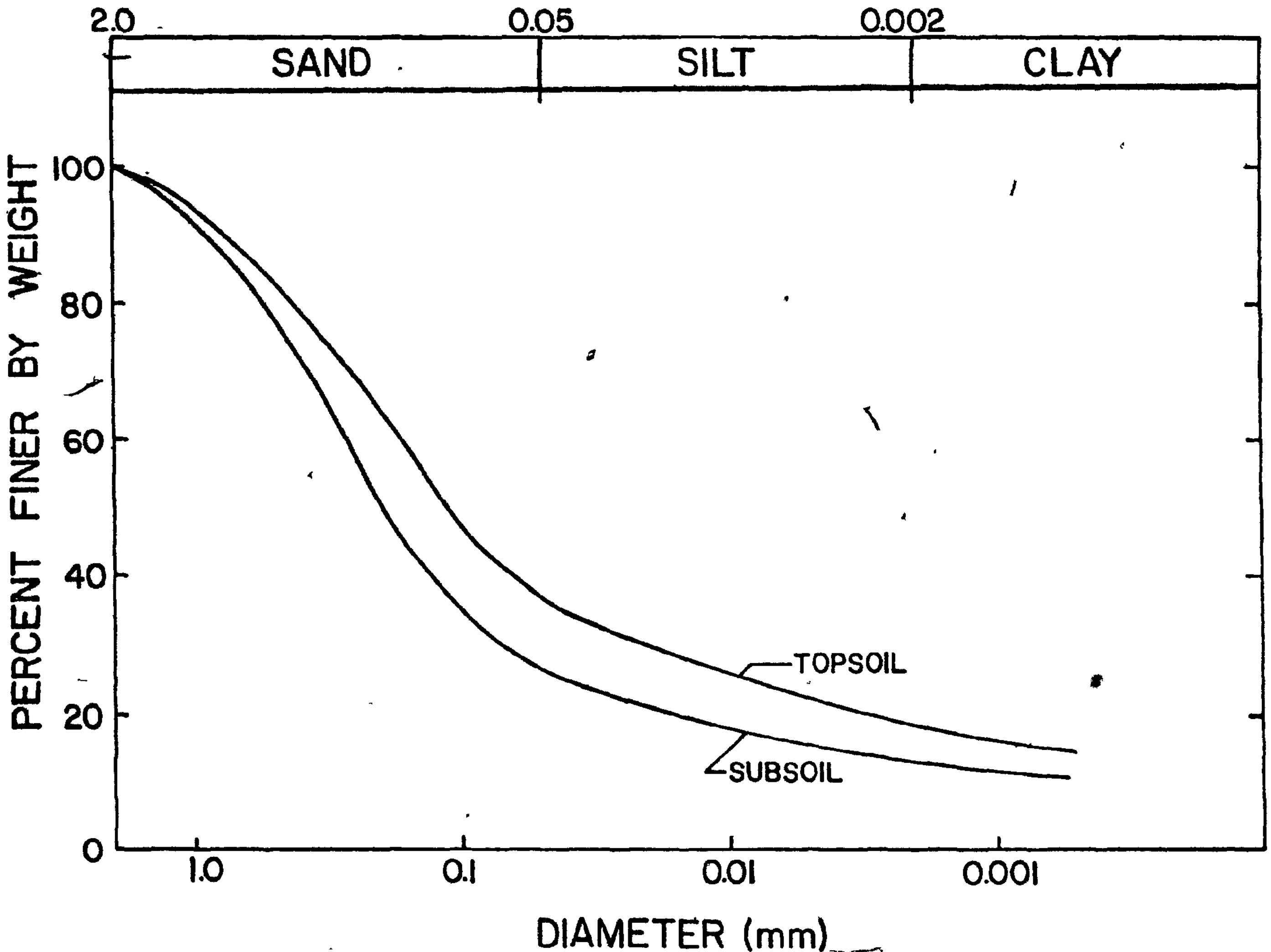


Figure 4.2.1. Sandy loam soil particle size analysis.

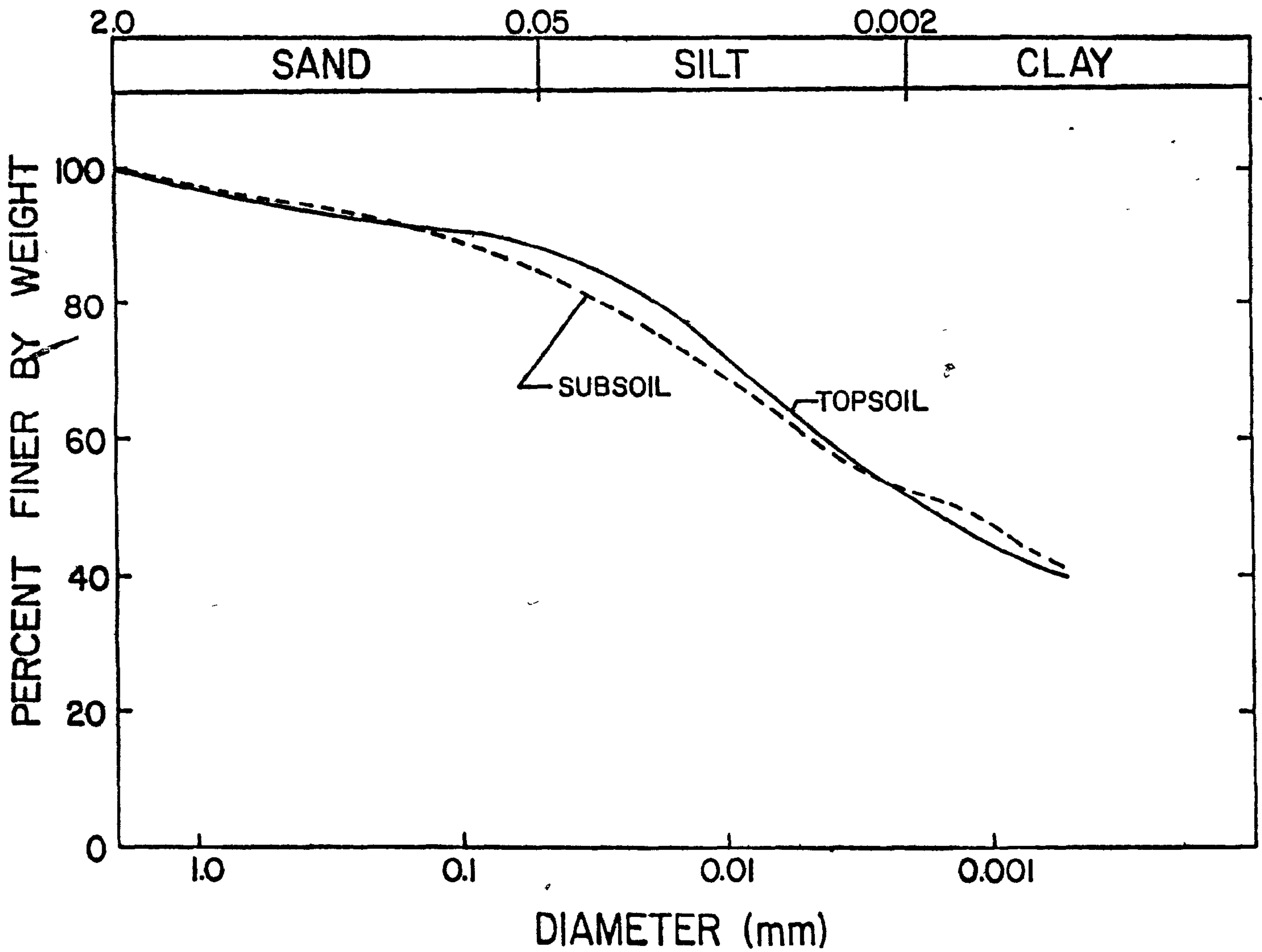


Figure 4.2.2. Clay soil particle size analysis.

only one pass of a disk harrow as secondary tillage in the spring. This method simply loosens the soil with a minimum of inversion of the surface and subsurface layers, and therefore results in only partial incorporation of crop residues. In the zero tillage plots, silage corn was planted directly into the previous years stubble. Post emergent inter-row cultivations were not used on any of the plots, as chemical herbicides alone were used to control the weed population.

Inorganic granular fertilizers (commercial) and dairy cow manure (organic) were the two fertilizer treatments. Both treatments were applied at rates dictated by prior soil chemistry assays and local recommendations. This paper presents the results of two years growth on the sandy loam soil (1982-83) and one years growth on the clay soil (1983). During the first year of the study (1982) severe problems were encountered with emergence in the clay site due to improper adjustment of the planter and very dry conditions.

4.2.2 Fertilizer Application

At the initiation of the experiment, soil test results indicated that the clay site had background levels of 322 kg P/ha. and 289 kg K/ha. Results from the sand site were higher; 479 and 386 kg P and K/ha, respectively. Based on these findings, and on Quebec Ministry of Agriculture, Food and Fisheries fertilizer recommendations, applications of 170, 75 and 80 Kg. of N, P_2O_5 and K_2O were advised for silage corn production. Phosphorus, in the form of triple superphosphate, was banded in both the inorganic and organic plots at 5 cm below and 5 cm beside the seed, since the dairy cow manure is very low in phosphorus. Muriate of Potash was used as the K source on the inorganic plots. Organic fertilizer plots received manure at the equivalent rate of 170 Kg/ha N based on the semi-micro Kjeldahl analysis of the manure two days prior to application. These plots received no inorganic N or K fertilizer.

Nitrogen was applied to the inorganic fertilizer plots using urea (45-0-0) on the reduced and conventionally tilled plots, and ammonium nitrate (34-0-0) on the zero tillage plots. Ammonium nitrate was selected as the N source on the zero tillage plots to eliminate the possibility of ammonia loss through the volatilization of transformed urea if applied and left at the soil surface.

Both the manure and inorganic fertilizers (nitrogen and potassium) were incorporated on the conventional and reduced tillage plots with a disk harrow using two and one pass respectively. On the zero tillage plots, ammonium nitrate and the manure were both left on the surface. Based on soil sample results in October 1982 (post-harvest), the same application rates were used in the spring of 1983.

4.2.3 Herbicide Application

Immediately prior to seeding, the herbicides Atrazine (90W) at a rate of 1.5 Kg/ha and Alachlor (Lasso) at 2.5 Kg/ha were applied and pre-plant incorporated in those plots receiving conventional tillage, and pre emergence non-incorporated in those plots receiving the reduced and no-tillage treatments. Bentazon (0.84 Kg/ha.) and Citowett TM were subsequently applied post-emergent to the entire plot area. (Two applications eight days apart were necessary). Atrazine and Kornoil TM were also applied to those plots in which volunteer grain was a problem. All plots received the same herbicide treatment in the first year. The results of weed density and biomass studies during the summer of 1982, dictated no change in herbicide application rates among the plots for the 1983 growing season.

Spot spraying of Killex brand herbicide was used in all plots in the clay site to control dandelions. This was necessary because this site is adjacent to a major highway, whose sides are laden with dandelions (Taraxacum officinale L.).

4.2.4 Seeding

Seeding of Warwick (Trojan) 844 silage corn took place on May 11, 1982, and again on May 22, 1983. An International Harvestor 800 conservation air planter was used to seed the corn in 76 cm rows with an inter-plant spacing of 16.5 cm to achieve the desired plant population of 80,000 plants/ha.

The planter used was a conservation type planter. Heavy duty coulters to open the narrow slot for seed placement, heavier frame than normal planters and down pressure springs (set to their maximum) on the planting units were required to enable the planter to penetrate the harder surface layers of the clay soil and the crop residues for those plots treated with zero tillage.

Each plot contained 12 rows 12 m long. The plot separation was equivalent to the space between corn rows. Four rows were planted on both ends of the group of six plots in each replicate to reduce edge effects.

4.2.5 Plant Growth

Following seeding, the number of days to 80 % emergence and tasselling was monitored. The final plant population in all plots was also observed to quantify the effects of surface residue and tillage systems on plant emergence. Leaf area index, number of leaves, plant height, dry matter accumulation and plant moisture content were the growth parameters measured at two week intervals. Of the 12 rows in each plot, the outside four rows on each side were reserved as buffer rows, and the middle four were harvested at the end of the growing season. The remaining four were used for plant growth parameter measurement throughout the growing season. Four plants were sampled at random, from these last four rows, five times during the growing season, to monitor growth rate and maturity.

The accumulated dry matter was obtained from the weight of these plants, calculated from the average moisture content obtained from oven drying 500 gm chopped samples at 80^{0}C for 24 hours, the average wet weight of each plant and the total number of plants per plot. Total dry matter in Mg/ha was determined from the following equation:

$$Yd = Wwet * \frac{(100 - MC)}{100} * \frac{Np}{Ap} * C$$

Where;

Yd = Plant yield (dry basis) (Mg/ha.)
Wwet = Average wet weight per plant (Kg.)
MC = Average moisture content (wet basis) per plant (%).

NP = Number of plants per plot
Ap = Area of the plot (10 X 12 m^2)
C = 10 (conversion from Kg/m^2 to Mg/ha).

Total leaf area was computed by summing the length of all leaves and multiplying by 6.67 (McKee 1964). The leaf area index was calculated by dividing the total leaf area per plant by the area occupied by one plant. The total number of leaves per plant was obtained at the same time. The average plant heights were measured at the beginning of the season, to the uppermost unfolded leaf, and later in the growing season to the top of the tassel.

4.2.6 Harvest and Tissue Analysis

The centre four rows of each plot were essentially undisturbed throughout the growing season. Human traffic was kept to an absolute minimum as all measurements during the summer were taken on the outside four rows. These middle four rows were harvested in the fall for silage corn with a John Deere, three point hitch mounted, single row forage harvester. The total weight per plot was obtained, and then 500 g subsamples were oven dried at 50°C for 48 hours to obtain the final moisture content and the final dry matter yield per plot. Using the area of the four rows harvested, the total dry matter measured per plot was converted to Mg/ha.

Plant tissue analyses were performed on each of the 36 dried subsamples to observe the effects of our treatments on plant nutrient content. Crude protein, percent calcium, phosphorus, magnesium, potassium as well as iron, manganese, copper and zinc parts per million were the macro and micro nutrients identified.

4.3 Results and Discussion

4.3.1 Climate Conditions

The distributions of rainfall throughout the 1982 and 1983 growing seasons are shown in Figures 4.3.1 and 4.3.2, respectively. The month of May, 1982 was one of the driest on record, receiving 72 % less rainfall than the 30 year average (Table 4.3.1). The extremely dry spring of 1982 contributed to the incomplete activation of the herbicides applied and consequently less than perfect weed control was achieved. Due to a month of June with 3.2 times the normal rainfall, the balance of the 1982 growing season finished slightly above average in total precipitation, with July, August and September receiving average rainfall amounts (Figure 4.3.3).

The spring of 1983, on the other hand, could be classified as very wet. In May, 62 % more rainfall than usual fell, while in June the precipitation was equal to the 30 year average (Table 4.3.1). Excellent weed control was achieved during the wet spring.

Conditions during July and August, however, were very dry. Total precipitation for this period was only 114.6 mm or 45 % lower than the 30 year average (Table 4.3.1). Most of this deficit took place during the grain filling stage in August which received 57 % less rainfall than average.

Over the course of the two growing seasons, a water table has never

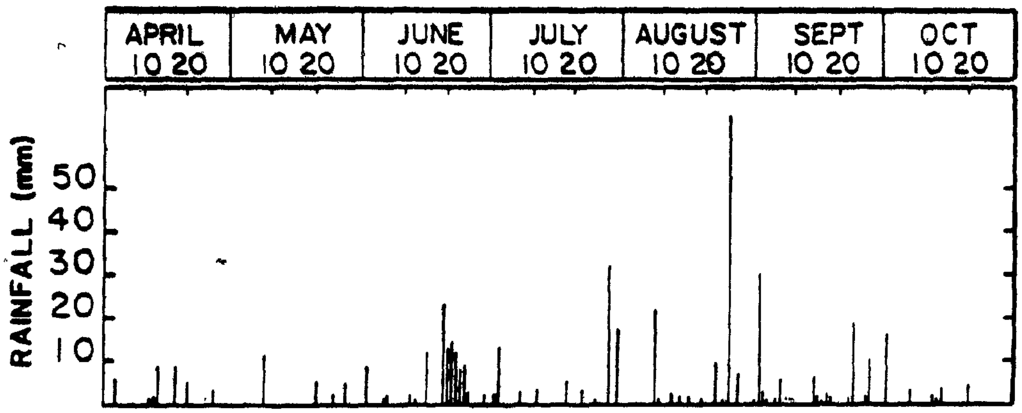


Figure 4.3.1. Daily rainfall record for the 1982 growing season.

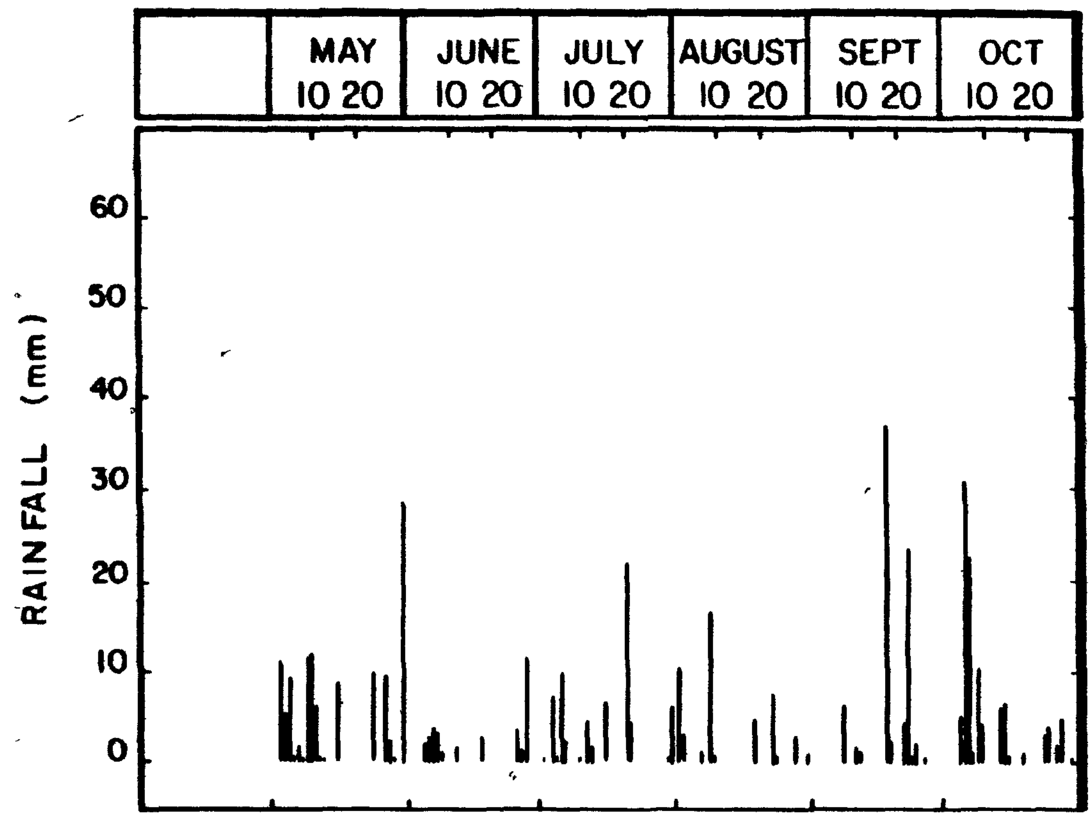


Figure 4.3.2. Daily rainfall record for the 1983 growing season.

Table 4.3.1 Rainfall data during the 1982 and 1983 growing seasons and the 30 year averages.

	1982 Rainfall (mm)	1982 Cummulative (mm)
May	22.1	22.1
June	117.6	139.7
July	83.3	223.0
August	136.8	359.8
September	86.3	446.1

	1983 Rainfall (mm)	1983 Cummulative (mm)
May	126.9	126.9
June	32.6	159.5
July	66.3	225.8
August	48.3	274.1
September	82.0	356.1

	30 year average Rainfall (mm)	30 year average Cummulative (mm)
May	78.4	78.4
June	37.3	115.7
July	94.5	210.2
August	111.9	322.1
September	85.1	407.2

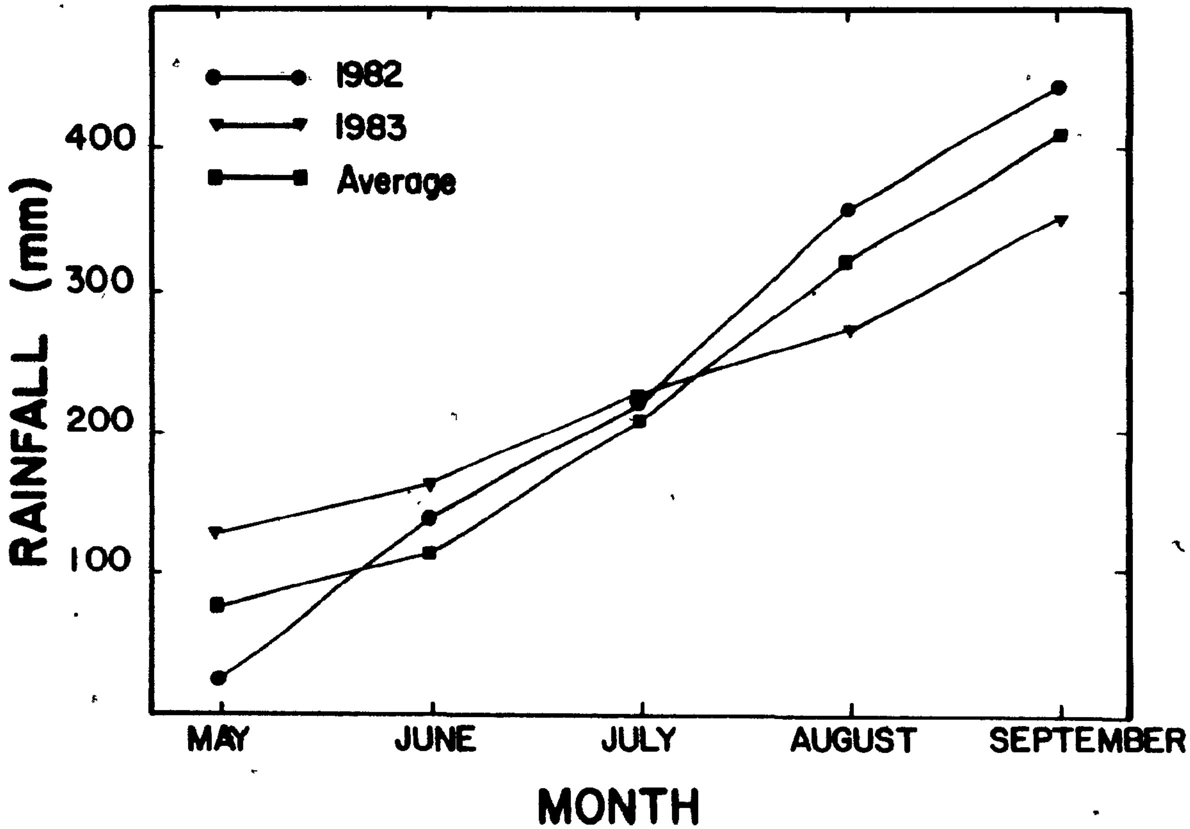


Figure 4.3.3. Cummulative rainfall for the 1982, 1983 and the 30 year average.

been measured at either site after the month of May. The sandy loam site has excellent natural drainage, while the clay site has a layer of broken limestone at a depth of approximately 0.8 to 1.5 m with a very high horizontal conduction rate. For these reasons, curves of water table position with time will not be presented.

4.3.2 Soil parameters

Results of soil analyses performed first at the end of the growing season in 1982 and then after the 1983 season indicated that the phosphorus and potassium levels in all plots on both soils were still above 200 kg/ha (Kelly and McKyes 1984). According to the Ministry of Agriculture, Fisheries and Food in Quebec (1984), this indicates that both soils are deemed rich in terms of these elements. No significant difference was found in the levels of phosphorus or potassium between plots due to the applied treatments of tillage or fertilizer (Kelly and McKyes 1984). For these reasons, the fertilizers (both organic and inorganic) were applied in the springs of 1983 and 1984 at the same rates as the initial application in 1982.

Salinity measurements in October of 1982 and 1983, indicated that salt accumulation was not a problem, values of conductivity were all less than 1.0 mmho/cm. Richards (1969) stated that salinity effects on all crops are mostly negligible when the conductivity of the saturation extract is less than 2.0 mmho/cm.

Organic matter percentages after two years of experimentation on the clay soil showed no effect due to either treatment. There was, however an interaction effect in the sandy soil. The combinations of conventional tillage with organic fertilizers and reduced tillage with organic fertilizers, produced significantly higher organic matter in the top soil than any of the other four treatment combinations (Kelly and McKyes 1984).

Soil dry bulk density measurements in 1983 revealed that the zero tilled plots were more compacted in the top 5 cm in both soil types, while the conventional tillage plots exhibited a dense plow layer at approximately 20 cm (Kelly and McKyes 1984).

Soil volumetric moisture content measurements revealed that the organic plots contained more water throughout the growing season than those plots fertilized from inorganic sources. This increased water availability was due to the mulching characteristics of the applied manure (Kelly and McKyes 1984).

4.3.3 Days to Emerge and Tassel

The number of days to emerge and tassel were observed in 1983 only. The results are presented in Tables 4.3.2 and 4.3.3, the corresponding analyses of variance are listed in Tables A4.3.1 and A4.3.2 in Appendix A. The tabular format used in Table 4.3.2 and all other mean value tables, presents both the treatment combination means and the means of the individual treatments, that is the main effect means. When no treatment interaction exists, Duncan's new multiple range test was performed on the means of each treatment and the letters denoting significant differences at

Table 4.3.2 Mean values of days to emerge
Sand and Clay Sites - 1983

Sand Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	14.67	14.67	13.67	14.33 a
	O:	14.67	14.33	14.67	14.56 a
	Mean:	14.67 a	14.50 a	14.17 a	

Clay Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	15.00	15.33	15.00	15.11 a
	O:	14.67	16.67	15.33	15.56 a
	Mean:	14.83 a	16.00 a	15.17 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.3 Mean values of days to tassel
Sand and Clay Sites - 1983

Sand Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	67.33 a	66.00 ab	65.67 ab	66.30
	0:	65.33 b	65.33 b	67.33 a	66.00
	Mean:	66.33	65.70	66.50	

Clay Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	67.00	68.00	68.00	67.67 a
	0:	67.33	69.00	69.33	68.56 a
	Mean:	67.17 a	68.50 a	68.67 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

an alpha level of 5% were placed adjacent to these main effect means. If, however, a treatment interaction does exist, Duncan's test was performed on the means of the six treatment combinations and the letters denoting significance were placed next to the combination means. This technique is illustrated in Table 4.3.3 where there was a treatment interaction on the number of days to tassel in the sand site and none in the clay site.

The number of days required for 80% of the final plant population to emerge was not affected by either of the two treatments. It is interesting to note that of the plants that did emerge, neither the organic fertilizer placed on the surface nor the increased density in the top layer of the zero tilled plots affected their rate of emergence. When the emergence rate was being measured, it appeared that tillage did in fact have an affect. The end result, however, was that the final plant population was affected by the tillage treatment and not the emergence rate. This result will be discussed in a later section.

The number of days required for 80% of the plants to initiate cob production (tasselling) was unaffected by the treatments in the clay site. In the sand site however, a fertilizer-tillage interaction effect existed. The largest difference among the treatment combinations was two days, which should not affect the final ear yield over the course of a 100 day growing season.

4.3.4 Final Plant Population

The final plant populations in the sand site during the 1982 season

Table 4.3.4 Mean values of final plant population
Sand Site - 1982

Sand Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	869.3	856.7	933.3	887.1 a
	O:	684.0	580.3	672.0	645.4 b
	Mean:	776.7 a	802.7 a	720.0 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.5 Mean values of final plant population
Sand and Clay Sites - 1983

Sand Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	912.0	864.0	818.0	864.7 a
	O:	864.0	870.0	737.0	823.7 b
	Mean:	888.0 a	867.0 a	777.5 b	

Clay Site

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	864.0	829.3	782.6	825.3 a
	O:	891.0	789.0	825.0	835.0 a
	Mean:	877.5 a	809.2 b	803.8 b	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

are shown in Table 4.3.4, while the same data from the sand and clay sites for 1983 are shown in Table 4.3.5. The corresponding analyses of variance are listed in Tables A4.3.3 and A4.3.4 in Appendix A.

Since 1982 was the first year of the experiment, it was not expected that the tillage treatments would affect the total number of plants per plot. There was no significant difference in plant populations due to tillage, but there was a difference due to the fertilizer treatment. Organic fertilizer plots yielded 27.2% less plants than the inorganic plots.

In 1983, the effects of the tillage treatments became significant in both the sandy loam and clay soils. The zero tillage plots in the sand site produced 10.8 and 12.5% less plants than the reduced and conventional plots respectively.

In the clay site, a very dense layer in the zero tillage plots, and a high proportion of large diameter (larger than 2 cm) clods in the reduced tillage plots, both caused inadequate seed soil contact to ensure complete germination. For these reasons, the plant populations in the zero and reduced tillage plots were not different from each other but were both significantly less than the conventional tillage plots, which yielded 9% more plants.

The fertilizer sources had no effect on plant population in the clay site, but in the sand site, as in 1982, the inorganic plots had significantly more (5%) plants than the organic plots. Since there was no fertilizer interaction with tillage and the effects only appeared in the sandy loam soil, the ammonium and salt contents of the fresh manure were believed to cause the reduced populations. These two components of the manure can become somewhat toxic to the germinating seed, causing a reduction in the number of successfully emerging plants. The greater adsorptive capacity of the clay soil prevented this problem in the clay site.

4.3.5 Plant Growth Parameters

Observations of dry matter yield, maturity (percent moisture), plant height and leaf area index were taken five times in the 1982 growing season. Mean values are presented in Tables 4.3.6 to 4.3.10 and the associated analyses of variance are listed in Tables A4.3.5 to A4.3.14 in Appendix A. In addition to these four parameters, the number of leaves per plant was measured five times during the 1983 growing season. During the first year of experimentation, tillage was not found to have an effect on the growth rate of the corn after the first set of plant parameter measurements. The inorganic fertilizer plots however, yielded consistently more than the organic plots (see Figure 4.3.4). Measurements of leaf area index (LAI) indicated that the treatment effects were not significant except on the 64th day after seeding when the organic plots had a LAI 15% greater than the inorganic plots (Table 4.3.8). This trend is supported by the plant height data (Figure 4.3.5) which demonstrates that the organic plots were 8% taller than the inorganic plots 64 days after seeding (DAS), but were significantly taller on only one occasion (76 DAS, Table 4.3.9). It is interesting to note that even though the organic plots were taller with a larger leaf area, the inorganic plots accumulated dry matter at a faster rate than the organic plots.

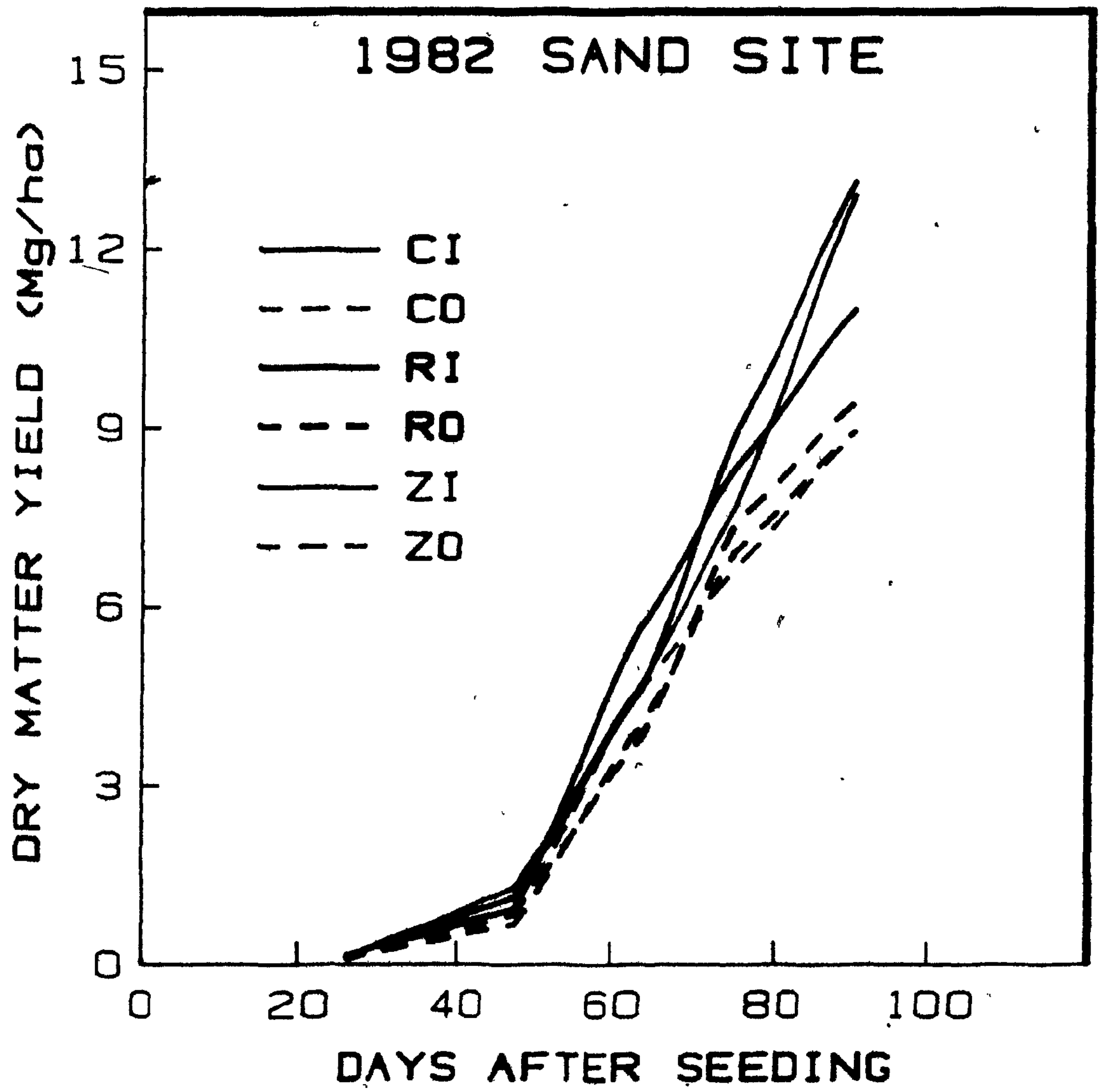


Figure 4.3.4. Variation in dry matter yield over the 1982 growing season for different treatment combinations in the Sand site.

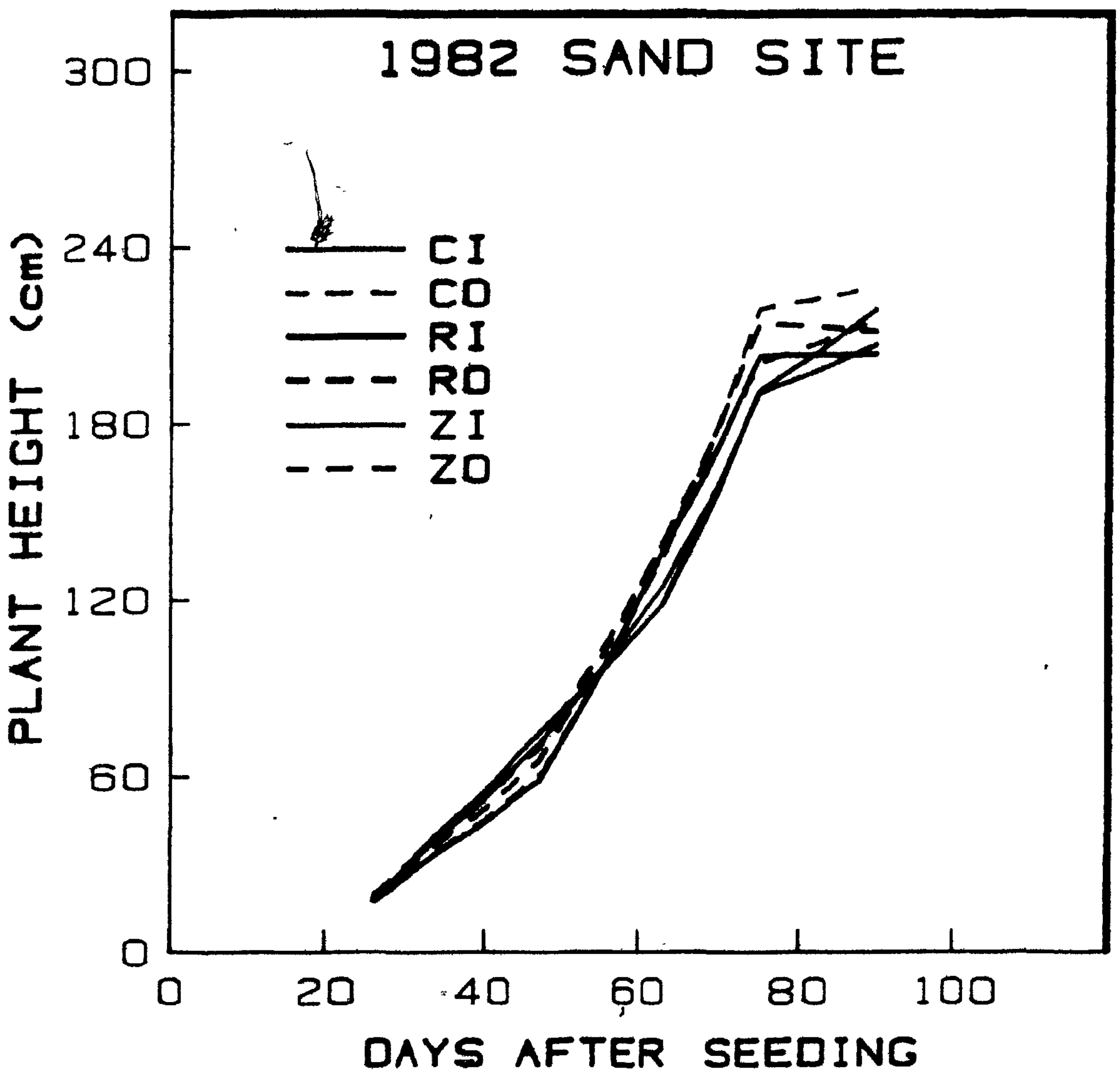


Figure 4.3.5. Variation in plant height over the 1982 growing season for different treatment combinations in the Sand site.

Plant maturity during 1982 was unaffected by either treatment until 76 DAS. At this stage, the plants started their drying process; the zero tillage plants had significantly higher moisture contents than the other two tillage treatments (Table 4.3.9). By the 91st DAS, a fertilizer tillage interaction developed and the zero organic plots had the highest moisture while the reduced organic plots were the driest (Table 4.3.10). These results seem to indicate that zero tillage retarded the maturation of the plants in the first year.

The five plant parameters measured in 1983 are presented in Tables 4.3.11 to 4.3.24 for the sand and clay sites. Analyses of variance for these plant parameter measurements can be found in Tables A4.3.15 to A4.3.40 in Appendix A.

In the sand site, during the early stages of development, the conventional organic and reduced organic plots yielded significantly more dry matter than any other treatment combination (Table 4.3.12). This interaction effect can be explained by the increased levels of organic matter in the topsoil of these two treatment combinations. As the plants matured and the root systems developed to deeper depths, this effect disappeared and differences between the means became nonsignificant (Figure 4.3.6).

The plant heights and leaf area indices followed a similar trend in the early growth stages, although their differences were not significant. Unlike the LAI's which did not show any treatment effects for the remainder of the year, the plant heights in the organic fertilizer plots were significantly taller (8%) than those in the inorganic plots (Figure 4.3.7) on

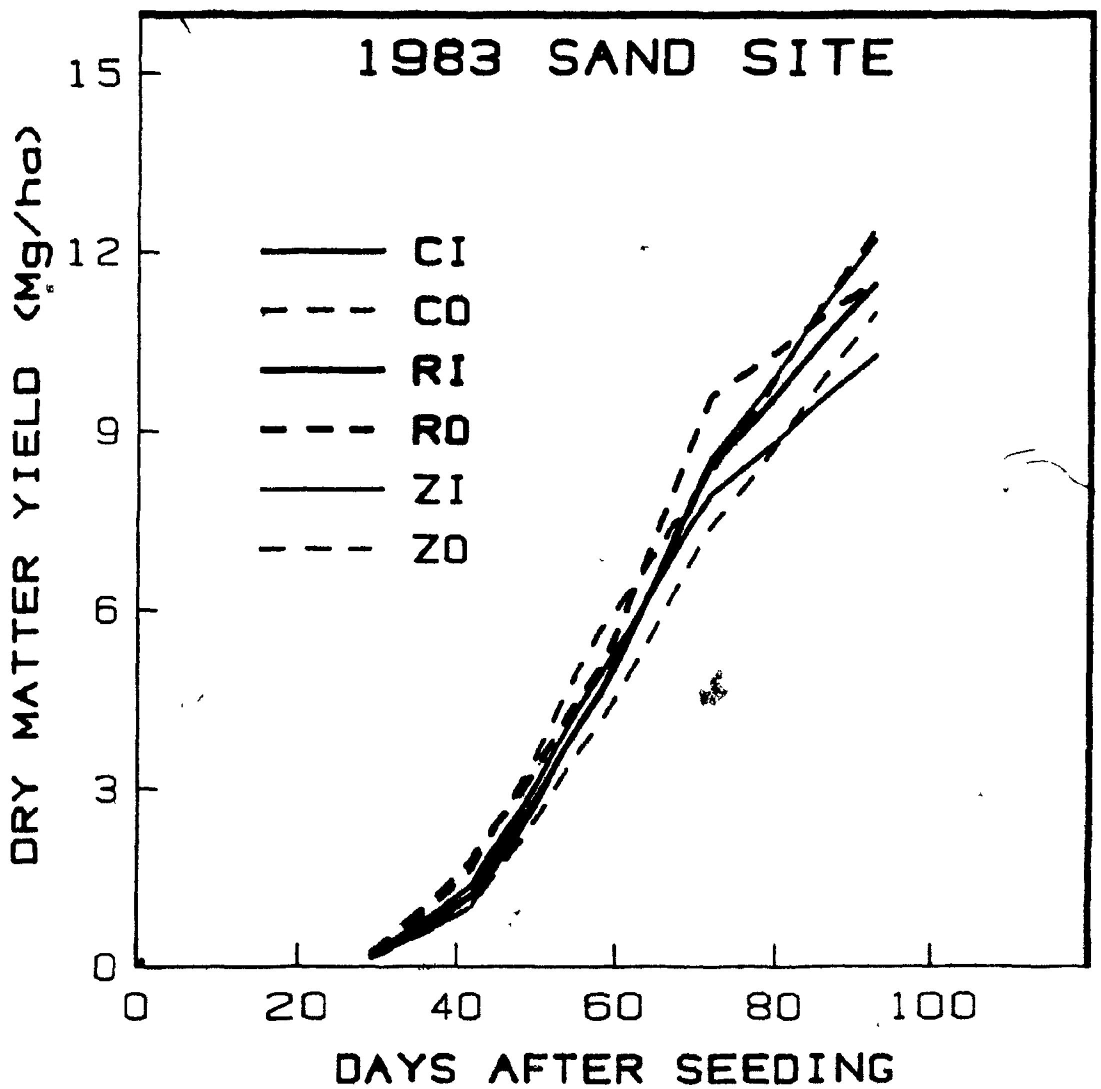


Figure 4.3.6. Variation in dry matter yield over the 1983 growing season for different treatment combinations in the Sand site.

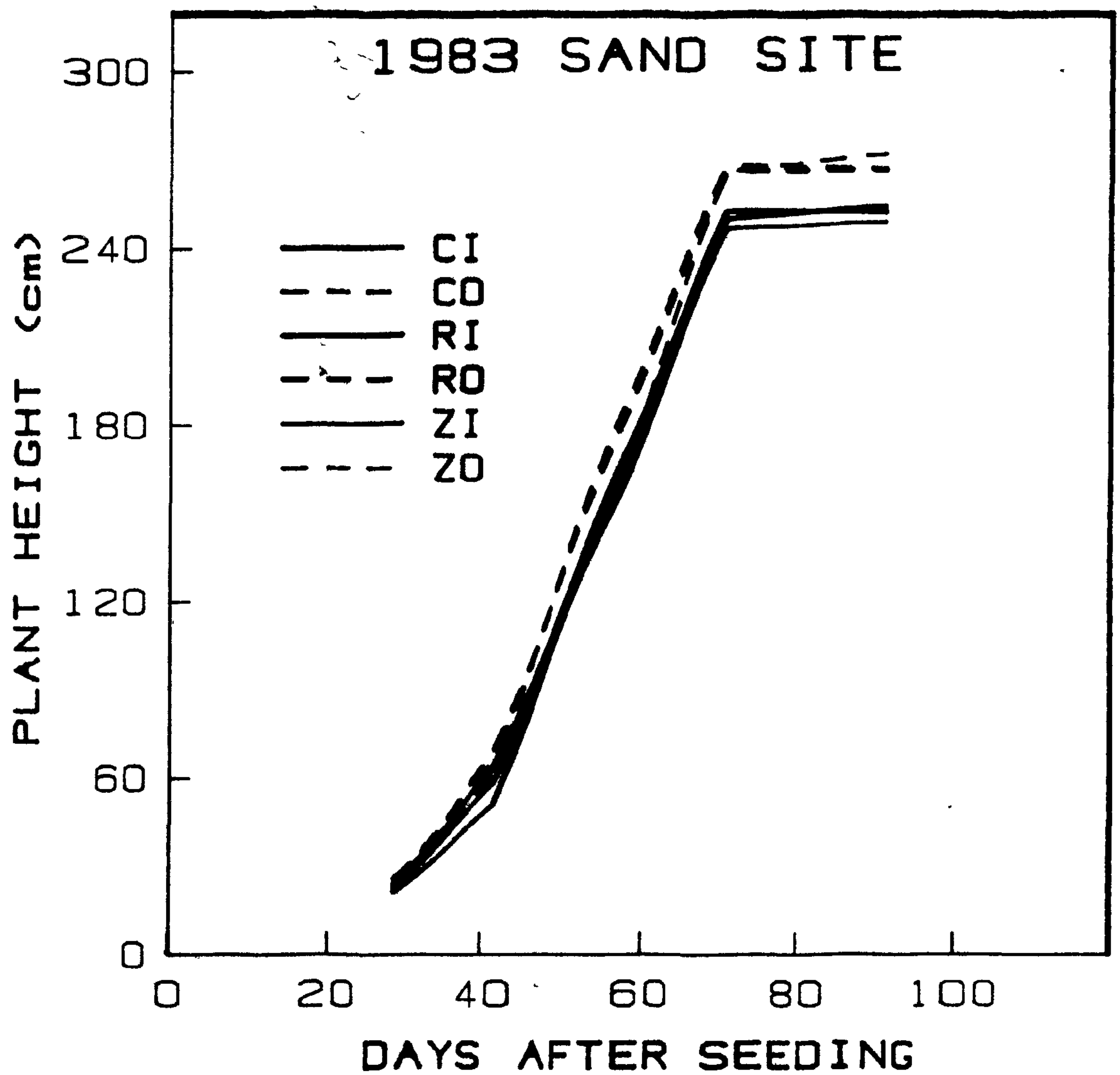


Figure 4.3.7. Variation in plant height over the 1983 growing season for different treatment combinations in the Sand site.

the last three parameter measurement days.

Early growth in the clay site was similar to that in the sand site. Tables 4.3.16 and 4.3.17 and Figure 4.3.8 show that the conventional organic plots had a much faster growth rate up to 42 DAS. The incorporation of manure also resulted in significantly taller plants and in plants with a larger LAI in the conventional organic plots 29 DAS (Table 4.3.16). There were no differences statistically for either of these parameters for the balance of the growing season. There was however, a very recognizable trend. Figure 4.3.9 illustrates that the zero tillage plants were approximately 12% shorter than the others. This was not found to be statistically significant because of the variability among the treatment combinations.

Plant maturity during the 1983 growing season in both the sand and clay sites showed no differences due to either treatment. The number of leaves was not affected in either site until 72 DAS (Figures 4.3.10 and 4.3.11). At this point in the sand site, the organic plots began to shed their bottom leaves significantly faster than the inorganic plots (Table 4.3.22). When corn plants abandon their bottom leaves, it is usually a result of either a moisture stress or a potassium deficiency. A potassium deficiency late in the season can result in the leaf tips and margins turning brown and dying (Larson and Hanway, 1976). Since moisture contents were actually higher in the organic plots, the cause for the loss of leaves was probably a nutrient stress not experienced in the inorganic plots. The plants in the organic plots relied on the fresh manure for their only source of potassium and it is likely that this caused the differences seen here. The clay site exhibited similar trends although they were not statistically significant.

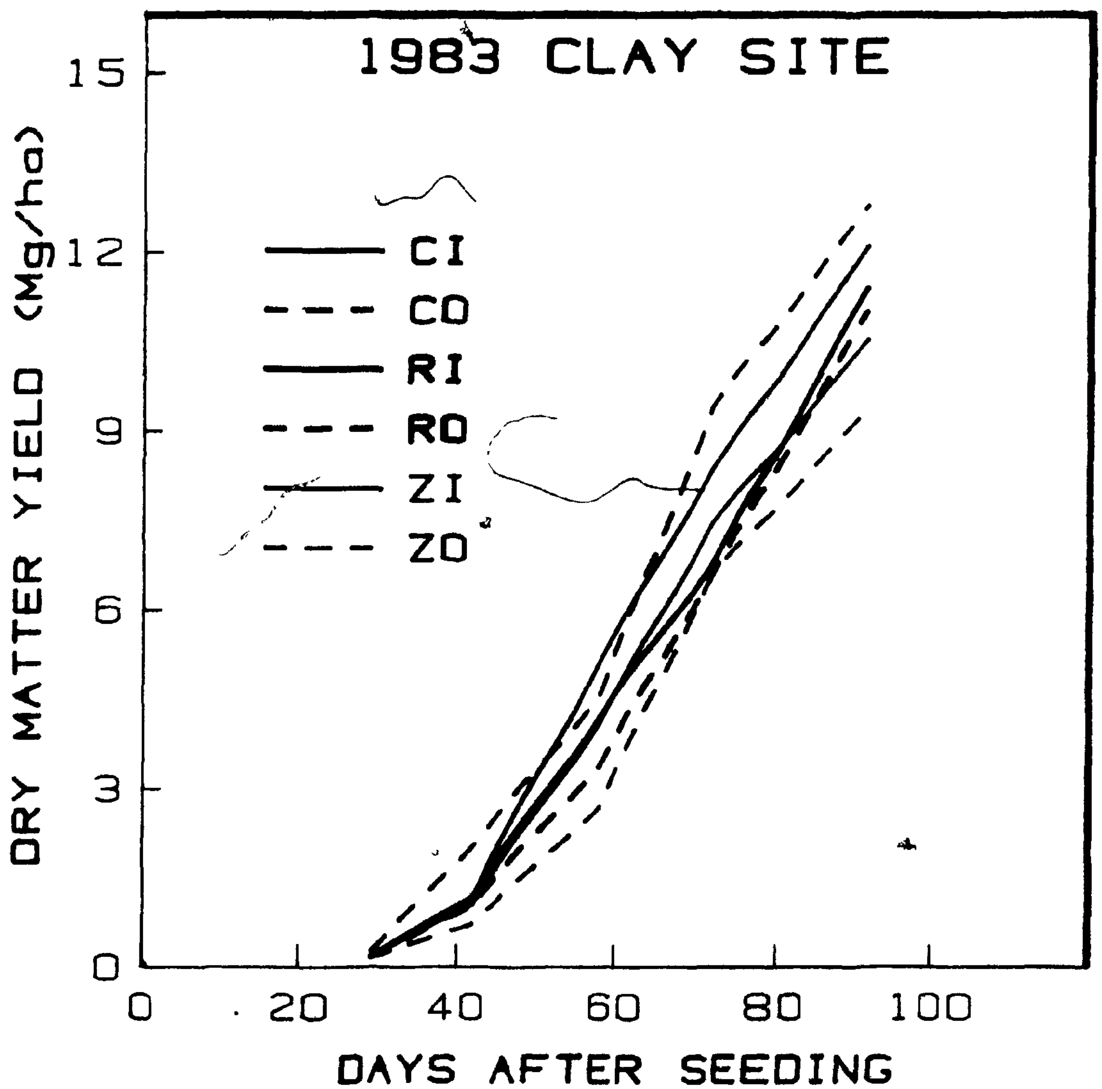


Figure 4.3.8. Variation in dry matter yield over the 1983 growing season for different treatment combinations in the Clay site.

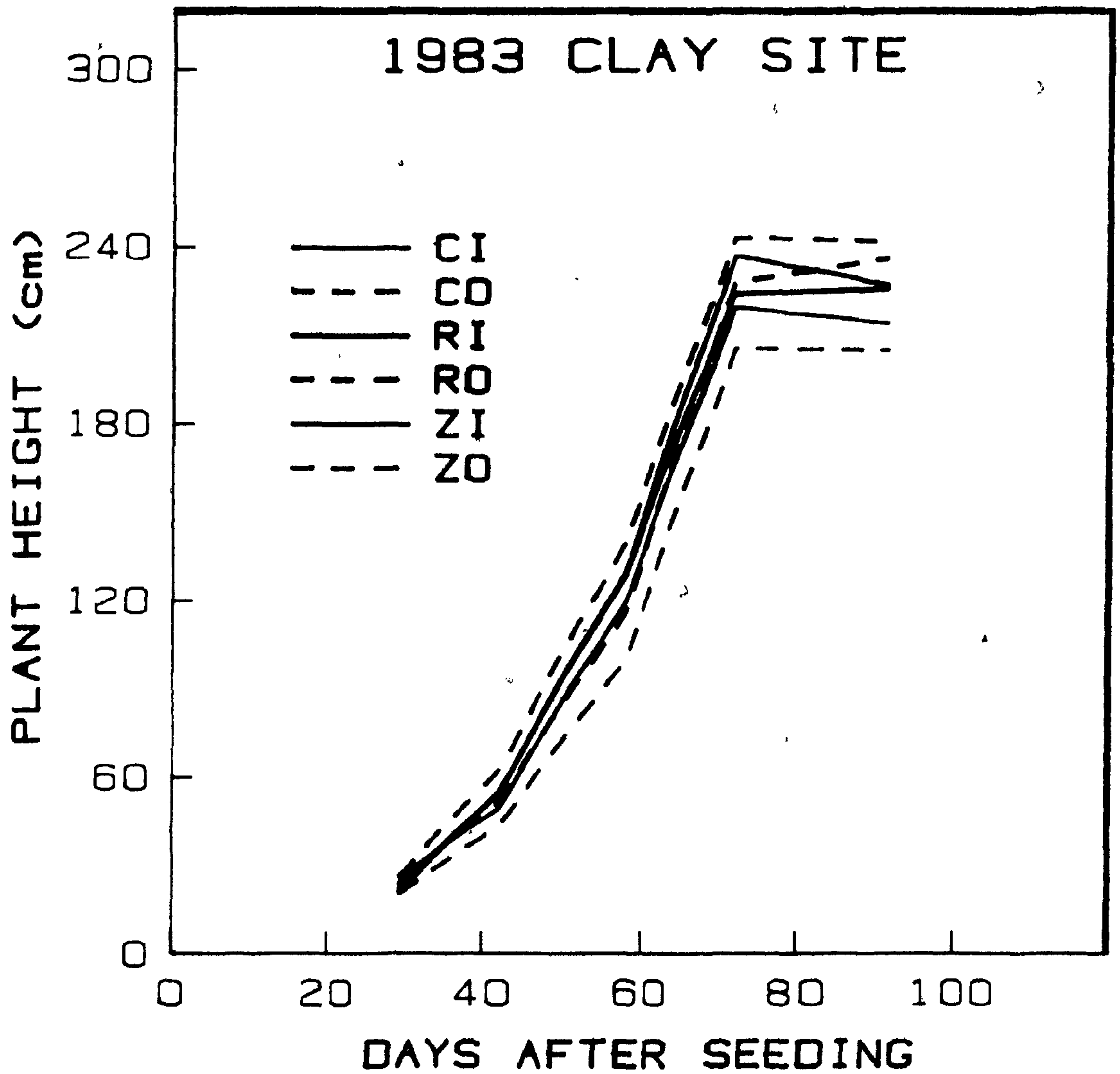


Figure 4.3.9. Variation in plant height over the 1983 growing season for different treatment combinations in the Clay site.

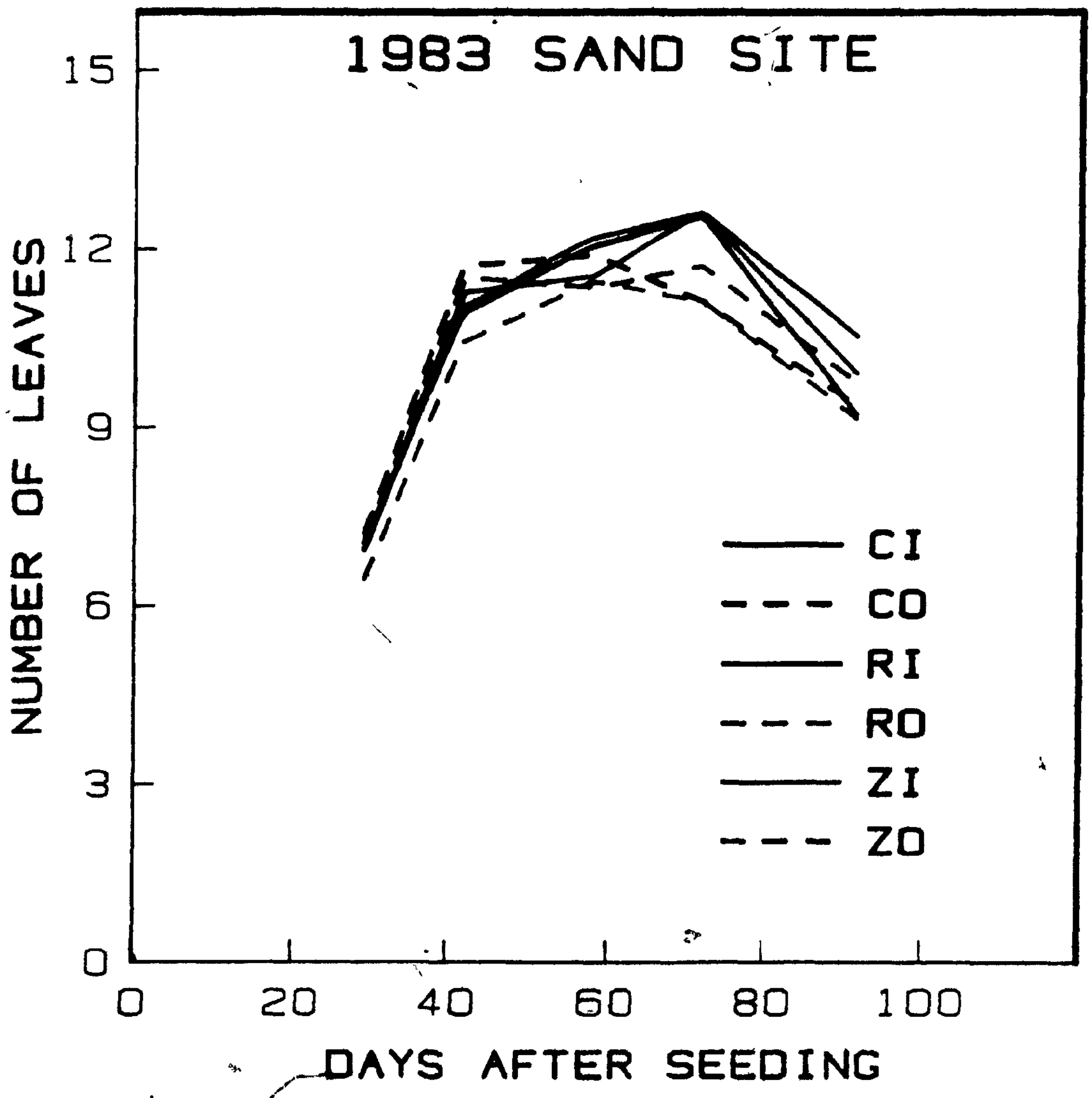


Figure 4.3.10. Variation in number of leaves over the 1983 growing season for different treatment combinations in the Sand site.

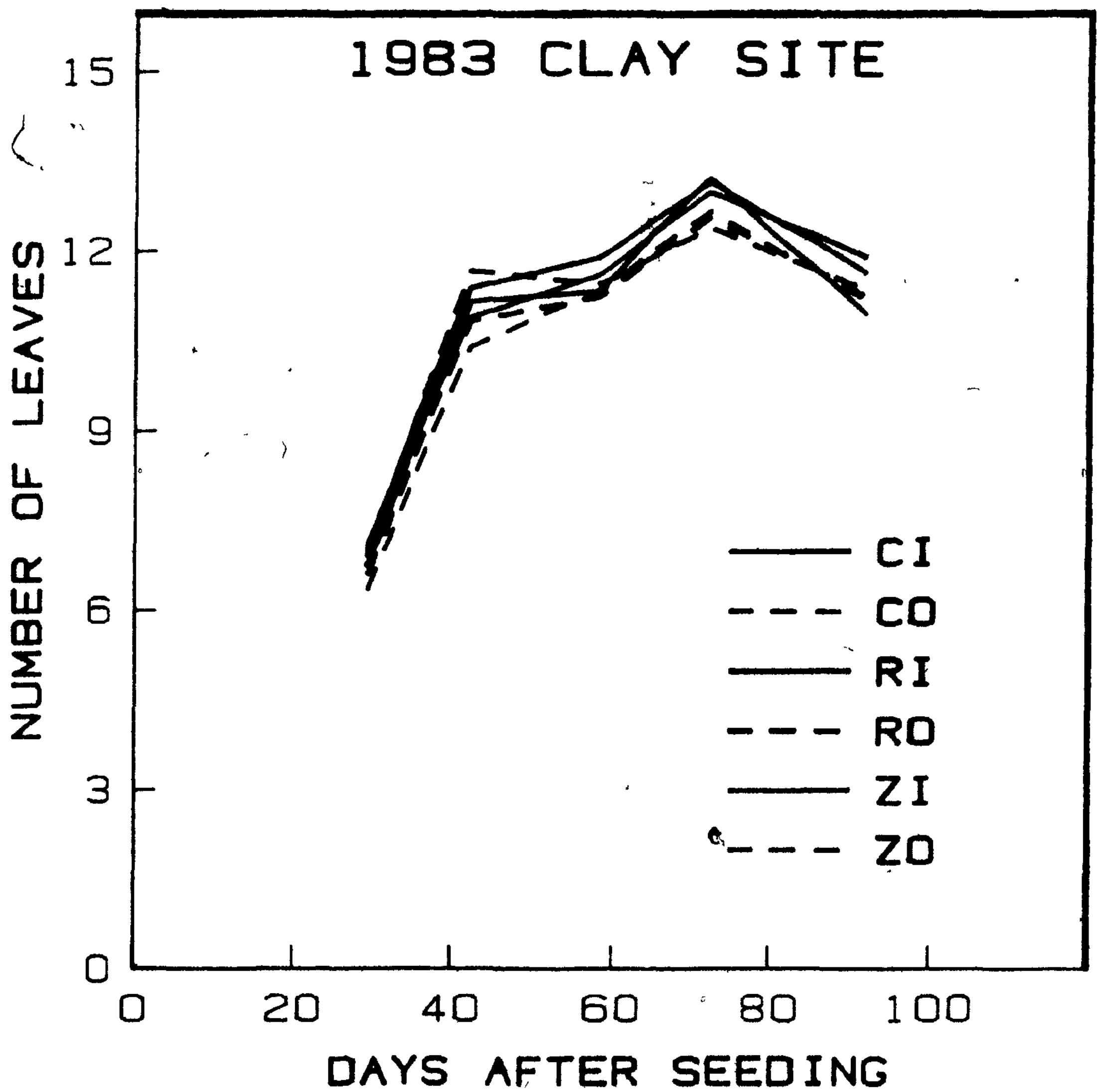


Figure 4.3.11. Variation in number of leaves over the 1983 growing season for different treatment combinations in the Clay site.

4.3.6 Harvest measurements

The corn crops were harvested for silage on October 7, 1982 in the sand site, September 13, 1983 in the clay site and September 20, 1983 in the sand site. Mean values of the harvest results in Mg/ha along with the associated moisture contents are presented in Tables 4.3.25 through 4.3.27. The corresponding analyses of variance are listed in Tables A4.3.41, A4.3.43 and A4.3.45 in Appendix A.

From the point of view of energy conservation and viability of reduced tillage the results for 1982 were very encouraging. The reduced tillage plots yielded significantly more (14%) than the conventional tillage plots, while the zero tillage plots produced silage at a rate not significantly different from the other two tillage treatments (Table 4.3.25). The plants receiving reduced tillage were also the driest, which indicates a more mature stand. In 1982, the inorganic plots had a 9.7% greater yield than the organic plots but this difference was not significant at the 5% level. Therefore, in the first year, the savings in labour and fuel realized with zero tillage were quite valuable, since yield levels were maintained at a reasonable level.

The results from 1983 were slightly less encouraging. In the sand site, the reduced tillage yields were not significantly different from the conventional but the zero tillage yields were significantly lower than both the reduced and conventional tillage plots (Table 4.3.26). In the clay site, the zero tillage yields were significantly lower than those under conventional

Table 4.3.25 Mean values of harvest results
Sand Site - 1982

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	15.10	16.51	15.42	15.68 a
	O:	13.29	15.95	13.64	14.29 a
	Mean:	14.20 b	16.23 a	14.53 ab	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	55.06	52.26	52.79	53.37 a
	O:	54.50	50.78	56.36	53.88 a
	Mean:	54.78 a	51.52 b	54.58 a	

Yield per Plant, gm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	210.4	212.3	220.2	214.3 b
	O:	233.6	286.2	283.7	267.8 a
	Mean:	222.0 a	249.3 a	252.0 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.26 Mean values of harvest results
Sand Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	10.01	10.82	9.62	10.15 a
	O:	11.29	11.06	9.57	10.64 a
	Mean:	10.65 a	10.94 a	9.60 b	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	42.25 b	39.85 b	40.91 b	41.00
	O:	42.79 b	43.88 b	49.11 a	45.26
	Mean:	42.52	41.86	45.01	

Yield per Plant, gm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	131.7	150.0	141.2	141.0 b
	O:	156.7	152.5	156.0	155.1 a
	Mean:	144.2 a	151.3 a	148.6 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.27 Mean values of harvest results
Clay Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	11.86	11.96	11.56	11.80 a
	O:	12.52	11.54	10.84	11.63 a
	Mean:	12.19 a	11.75 ab	11.20 b	

Percent Moisture

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	39.43	43.77	42.43	41.88 a
	O:	43.65	44.08	47.85	45.19 a
	Mean:	41.54 a	43.93 a	45.14 a	

Yield per Plant, gm

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	165.3	172.6	177.1	171.7 a
	O:	168.7	175.5	157.8	167.3 a
	Mean:	167.0 a	174.1 a	167.4 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

tillage and the reduced tillage plots were not significantly different from either the zero or conventional plots (Table 4.3.27). The fertilizer sources had no effect on total silage yield per plot in 1983. Even though no inorganic nitrogen was applied to the organic plots, they were still able to produce silage at the same rate as those plots that did receive inorganic nitrogen. It seems likely that the residual nitrogen from the alfalfa crop (1976-1981) coupled with the nitrogen in the fresh manure were sufficient to satisfy the needs of the corn plants during the first two years of experimentation.

It is interesting to note that although the yield differences in the sand site were not statistically significant, the organic plots with a population 5% less than the inorganic plots, actually produced 5% more silage than the inorganic plots. This would seem to indicate that, when applied at such high rates, the fresh manure is harmful to the emerging seedlings but is beneficial to the plants that do manage to become established.

Although no differences in plant moisture content appeared throughout the year, an interaction effect between zero tillage and organic fertilizer in the sand site, caused this treatment combination to be significantly less mature than any other combination at harvest (Table 4.3.26). The reduced growth rate of these zero tillage plots with organic fertilizer (Tables 4.3.11 - 4.3.15) was believed to be the cause of the increased moisture content at harvest.

It was initially thought the 9.8 and 8.1% yield reductions in the zero till plots in the sand and clay sites respectively, were attributable to the changes in soil structure, slightly increased weed populations and a slower rate of early growth. However, when one considers the final plant population in each of the plots and analyzes the harvest data in terms of grams of dry matter per plant, the results are quite different. The mean values of yield per plant are presented in Tables 4.3.25 through 4.3.27, and the associated analyses of variance are listed in Tables A4.3.42, A4.3.44 and A4.3.46 (Appendix A).

In both 1982 and 1983, tillage had no effect on the yield of dry matter per plant. The population differences between the plots, caused by the tillage treatments, was believed to be the sole cause for the final silage yield differences. Fertilizer source did however, have a significant effect on yield per plant in the sand site both years. Those plots receiving manure as the fertilizer source had 4.7% less plants than the inorganic plots but yielded 10% more dry matter on a per plant basis. It is not likely that reduced competition is the sole cause since the reduction in plant population was due to skips spaced randomly throughout the plots. The difference is probably due to increased organic fertilizer use efficiency in the sandy loam soil. This trend is not expected to continue after many successive years of fertilization with manure only. The sand plots also performed quite well due to the high background levels of nutrients present at the start of the experiment. The fertilizer source did not affect the yield per plant in the clay soil because the fertilizer source did not affect emergence in the clay soil.

These results become even more encouraging when one considers that the problem of plant population is easier to solve than is a situation of degrading soil structure. Modification of the planter to ensure proper loosening of the soil around the seed in the zero tillage plots and better seedbed preparation in the reduced tillage plots to provide adequate seed to soil contact, should result in equivalent yields for all tillage treatments.

To alleviate the issue of reduced emergence and populations in the sand plots fertilized from organic sources is a greater problem. The fact that the clay site was unaffected, suggests that the lower cation exchange capacity of the sandy loam soil was responsible for higher levels of ammonium and salt (both toxic to young plants) in the sand plots fertilized with fresh manure. Further research is necessary to be able to use manure as an alternate fertilizer source in corn production in sandy soils.

4.3.7 Plant Tissue Analysis

At the end of two years of tillage and fertilizer treatments, dried samples of the corn silage from the 1983 harvest were analyzed for micro and macro nutrient contents. Mean values of the results of percentage crude protein, calcium, phosphorus, magnesium and potassium as well as the iron, manganese, copper and zinc contents in parts per million are presented in Tables 4.3.28 through 4.3.32. The corresponding analyses of variance are listed in Tables A4.3.47 to A4.3.56 in Appendix A.

The use of dairy manure as the only nitrogen source in the organic plots significantly reduced the percentage of crude protein present in the plants at harvest. This reduction amounted to 22 and 13% in the sand and clay sites respectively. The amount of nitrogen taken up by the plants was

Table 4.3.28 Mean values of plant tissue analysis
Sand Site - 1983

Crude Protein, %

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	8.00	7.43	8.17	7.87 a
	O:	6.50	6.27	5.57	6.11 b
	Mean:	7.25 a	6.85 a	6.87 a	

Calcium, %

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.270	0.273	0.247	0.263 a
	O:	0.210	0.193	0.187	0.197 b
	Mean:	0.240 a	0.233 a	0.217 a	

Phosphorus, %

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.260	0.243	0.253	0.250 a
	O:	0.260	0.273	0.280	0.270 a
	Mean:	0.260 a	0.258 a	0.267 a	

Magnesium, %

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.130	0.237	0.146	0.171 a
	O:	0.143	0.126	0.163	0.144 a
	Mean:	0.137 a	0.182 a	0.155 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.29 Mean values of plant tissue analysis
Sand Site - 1983

Potassium, %

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.96	1.82	1.15	1.31 a
	O:	1.42	1.21	1.19	1.27 a
	Mean:	1.19 a	1.51 a	1.17 a	

Iron, ppm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	67.67	63.00	48.33	59.67 a
	O:	58.67	61.00	47.33	55.67 a
	Mean:	63.17 a	62.00 a	47.83 a	

Manganese, ppm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	25.3	23.0	24.3	24.2 a
	O:	16.3	14.3	14.7	15.1 b
	Mean:	20.8 a	19.5 a	18.7 a	

Copper, ppm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	8.00	9.67	7.33	8.33 a
	O:	8.67	9.67	9.00	9.11 a
	Mean:	8.33 a	9.67 a	8.17 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.30 Mean values of plant tissue analysis
Clay Site - 1983

Crude Protein, %

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	7.53	7.80	7.87	7.73 a
	0:	6.73	6.70	6.67	6.70 b
	Mean:	7.13 a	7.25 a	7.27 a	

Calcium, %

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	0.236	0.263	0.250	0.251 a
	0:	0.247	0.283	0.257	0.263 a
	Mean:	0.241 a	0.272 a	0.251 a	

Phosphorus, %

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	0.230	0.243	0.253	0.242 a
	0:	0.263	0.257	0.220	0.247 a
	Mean:	0.247 a	0.250 a	0.237 a	

Magnesium, %

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	0.257	0.280	0.297	0.278 a
	0:	0.233	0.307	0.267	0.269 a
	Mean:	0.245 a	0.293 a	0.282 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.31 Mean values of plant tissue analysis
Clay Site - 1983

Potassium, %

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.927	1.003	0.903	0.944 a
	0:	1.030	0.917	1.113	1.020 a
	Mean:	0.978 a	0.960 a	1.010 a	

Iron, ppm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	67.67	58.67	68.00	64.78 a
	0:	50.67	54.00	67.67	57.44 a
	Mean:	59.17 a	56.33 a	67.83 a	

Manganese, ppm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	20.00	16.00	21.33	19.11 a
	0:	13.33	13.67	16.33	14.44 a
	Mean:	16.67 a	14.83 a	18.83 a	

Copper, ppm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	8.33	9.67	8.67	8.89 a
	0:	8.00	11.33	11.33	10.22 a
	Mean:	8.17 a	10.50 a	10.00 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.32 Mean values of plant tissue analysis, Zinc(ppm)
Sand and Clay Sites - 1983

Sand Site

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	28.3	28.0	28.3	28.2 a
	O:	26.7	28.0	28.7	27.8 a
	Mean:	27.5 a	28.0 a	28.5 a	

Clay Site

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	22.3	22.7	25.3	23.4 a
	O:	20.3	25.3	29.0	24.9 a
	Mean:	21.3 b	24.0 ab	27.2 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

lower in these organic plots probably because of the increased leaching and volatilization of the fresh manure, and the lower nitrogen availability as compared to the inorganic source of nitrogen. Visual observations supported these results in that these particular plots were a pale yellowish green while the corresponding inorganic plots were the proper dark green colour.

All other nutrient contents in the clay soil were not affected by either treatment, except for zinc concentration. The zero tillage plots had a significantly higher zinc concentration than the other two tillage treatments. In the sand site, tillage did not affect plant nutrient content and the fertilizer source only affected the calcium and manganese contents. Their concentrations were 25 and 37% less, respectively, in the organic plots.

4.4 Summary and Conclusions

The spring of 1982 was one of the driest on record, while that of 1983 was one of the wettest. These differences allow us to evaluate the different tillage and fertilizer treatments under varying weather conditions. The balance of the 1982 growing season could be considered average, but the July-August period of 1983 received 45% less rain than the 30 year average.

Background soil levels of phosphorus and potassium were both greater than 200 kg/ha after the first two years of experimentation. Salinity levels were very low and showed no difference due to the applied treatments.

Soil organic matter levels in the clay also showed no differences, but in the sand an interaction between tillage and fertilizer appeared at the end of 1983. Those plots receiving incorporated manure (conventional and reduced organic) had significantly higher organic matter levels than the inorganic fertilizer treatments, or the zero tilled organic plots.

The zero tillage plots were significantly more dense in the top 5 cm layer of soil and the conventional plots produced a dense plow pan at a depth of approximately 20 cm. These differences were statistically significant after the second year only.

The rate of emergence of the young seedlings was unaffected by either of the applied treatments in 1983, and the number of days after seeding required for tasselling to occur was similarly unaffected in the clay site. A two day significant difference did occur in the sand site, but this was considered negligible when compared to the length of the overall growing season.

The organic fertilizer significantly reduced the plant population in the sand site in both 1982 and 1983, but did not affect the population in the clay site. Tillage method did not affect the number of plants emerged per plot in the first year (1982), but no tillage significantly reduced the number of plants in the zero tillage plots in both the sand and clay plots in 1983.

In 1982, in the sand site, the organic fertilizer treatment resulted in taller plants with a larger leaf area, but a slower rate of dry matter accumulation than the plants fertilized from inorganic sources. Tillage treatments did not affect any of the parameters except moisture content. Zero tillage caused the plants to dry down at a slower rate than the other tillage treatments.

In 1983, the plant percent moisture content during the growing season was unaffected by both treatments in either site. A tillage-fertilizer interaction effect caused the conventional and reduced organic plots in the sand site and the conventional organic plots in the clay site to accumulate dry matter at a faster rate in the early stages of growth. Plant heights in those plots receiving organic fertilizer were again significantly taller in the sand site in 1983. Unlike 1982, however, these plants did accumulate more dry matter than those under inorganic fertilizer. In the clay site, both plant height and leaf area index were not influenced by treatment.

Towards the end of 1983, the number of leaves per plant in the sand site was significantly reduced due to the organic fertilizer treatment. The clay site followed the same trend although the differences were not statistically significant. A lower availability of potassium due in part to the very dry soil conditions, was believed to be the cause for the reduction in the number of leaves in those plots fertilized with dairy cattle manure.

First year harvest results were encouraging for reduced tillage practices, in that the reduced tillage plots produced a significantly higher amount of silage, while the conventional and zero tillage plots were not different from each other. Those plots receiving the inorganic fertilizer treatment yielded 9.7% more crop than the organically fertilized plots. The variability among treatments was such that this difference was not statistically significant.

At first glance, the 1983 harvest results were less encouraging.

There were 8.1 and 9.8% reductions due to the zero tillage treatment in the clay and sand sites respectively (both statistically significant). There was no effect, however, due to either of the two fertilizer treatments. If, however, one considers the final plant populations, the harvest results in terms of grams of dry matter per plant are very promising. Tillage had no effect and plants in the sand site fertilized with organic material yielded significantly more than those fertilized from inorganic sources.

A reduction of available nitrogen in those plots fertilized with dairy cattle manure caused a decrease in the percentage of crude protein present in the silage at harvest in both the sand and clay sites (22 and 13%). This reduction however, was not sufficient to prevent the plants from producing more dry matter than the plants fertilized inorganically, as was mentioned above. No other plant nutrient contents were affected by treatment except for zinc in the clay site and calcium and manganese in the sand site. The former was reduced by the zero tillage treatment, while the latter two were decreased in the organic plots.

On the basis of this study, the following conclusions can be drawn:

1. Using the methodology described herein, the use of zero tillage is likely to reduce the final plant population significantly.

2. The use of fresh dairy cattle manure on a sandy loam soil as the only source of nitrogen and potassium caused a decrease in the final plant population.

3. The incorporation of manure in conventional and reduced tillage plots

significantly increased the soil organic matter content in the top 20 cm.

4. Sandy loam soils fertilized organically tended to produce taller plants, but accumulated dry matter slower than if fertilized inorganically.

5. Zero tillage significantly reduced the plant populations in both sites in 1983. These final plant populations were seen to be the cause of the reduced yields in the zero tillage plots. Tillage treatment had no effect on the yield of dry matter per plant.

6. Fertilizer source did not affect the yield per plot or per plant in a clay soil. In a sandy loam soil, the organic fertilizer did not affect the yield per plot but significantly increased the yield per plant.

7. The use of dairy cattle manure as the sole source of nitrogen, significantly reduced the percentage of crude protein in the silage at harvest in both a clay and a sandy loam soil.

8. It would seem from the experiments reported that by solving the problem of reduced plant populations, the zero or reduced tillage techniques with either organic or inorganic fertilizer sources would be viable alternative corn production system components, which could be considered for practical application in southwestern Quebec and eastern Ontario.

4.5 References

Bandel, V.A., S. Dzienia, G. Stanford and J.O. Legg. 1975. N behavior under no-till vs. conventional corn culture. I: First year results using unlabelled N fertilizer. Agron. J. 67: 782-786.

Bandel, V.A., S. Dzienia and G. Stanford. 1980. Comparison of N fertilizer for no-till corn. Agron. J. 72: 337-341.

Barclay, J., G.S.V. Raghavan and E. McKyes. 1983. Zero/Minimum tillage techniques for corn production in Quebec. Vol. 2. Progress Report for Quebec Ministry of Agriculture. Grant Number MCA-83-1008. 127 pp.

Bennett, O.L.. 1977. Conservation tillage in the northeast. In: Conservation tillage : Problems and potentials. Soil Cons. Soc. Amer. E20, Ankeny, Iowa 50021

Blevins, R.L., D. Cook, S.H. Phillips and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 593-596.

Blevins, R.L., G.W. Thomas, M.S. Smith, W.W. Frye and P.L. Cornelius. 1983. Changes in soil properties after 10 years continuous non-tilled and conventionally tilled corn. Soil Tillage Res. 3: 135-146.

Blevins, R.L., G.W. Thomas and P.L. Cornelius. 1977. Influence of no-tillage and nitrogen fertilization on certain soil properties after 5 years of continous corn. Agron. J. 69: 383-386.

Brar, S.S., J.S Dhaliwal, G.S. Gill, H.S. Sandhu and G.K. Singh. 1983. Continuous maize and wheat production under no-tillage and conventional tillage systems: a ten year study. In: F. Voigt (ed.), Proceedings of the 2nd international seminar on energy conservation and use of renewable energies in the bio-industries. Trinity College, Oxford, Britain. pp 100-107.

Estes, G.O. 1972. Elemental composition of Maize grown under no-till and conventional tillage. Agron. J. 64: 733-735.

Fenster, C.R. and G.A. Wicks. 1976. Minimum tillage systems reduce wind erosion. ASAE Paper No. 76-2032.

Fink, R.J. and D. Wesley. 1974. Corn yield as affected by fertilization and tillage system. Agron. J. 66: 70-71.

Fox, R.H. and L.D. Hoffman. 1981. The effect of N fertilizer source on grain yield, N uptake, soil pH, and lime requirement in no-till corn. Agron. J. 73: 891-895.

Frye, W.W., R.L. Blevins, L.W. Murdock and K.L. Wells. 1981. Energy conservation in no-tillage production of corn. In: Crop porduction with conservation in the 80's. ASAE St. Joseph, Michigan. Publ 7-81: 255-262.

Gantzer, C.J. and G.R. Blake. 1978. Physical characteristics of LeSueur clay loam soil following no-till and conventional tillage. Agron. J. 70: 853-857.

Griffith, D.R. 1974. Fertilization and no-plow tillage. Proc. Indiana Plant Food and Agr. Chemical Conf., Dept. Agron., Purdue Univ., West Lafayette, Indiana.

Griffith, D.R., J.V. Mannering and W.C. Moldenhauer. 1977. Conservation tillage in the Eastern corn belt. In: Conservation tillage: problems and potentials. Soil Cons. Soc. Amer. Spec. Publ. 20; Ankeny, Iowa.

Griffith, D.R., S.D. Parsens, J.V. Mannering and D.H. Daster. 1982. Estimating yield variations due to changing tillage. ASAE Paper No. 82-1510.

Harrold, L.L., G.B. Triplett, Jr. and W.M. Edwards. 1970. No-tillage corn - characteristics of the system. Agric. Eng. 51(3): 128-131.

Hinesly, T.D., E.L. Knake and R.D. Seif. 1967. Herbicide versus cultivation for corn with two methods of seedbed preparation. Agron. J. 59: 509-512.

Jones, J.N. Jr., J.E. Moody and J.H. Lillard. 1969. Effects of tillage, no-tillage and mulch on soil water and plant growth. Agron. J. 61: 719-721.

Kang, B.T. and M. Yunusa. 1977. Effect of tillage methods and phosphorus fertilizer on maize in the humid tropics. Agron. J. 69: 291-294.

Kelly, J.K. and E. McKyes. 1984. The effects of tillage, zero tillage and fertilizer sources on soil structure, nutrient and moisture distribution in silage corn production. In Press.

Ketcheson, J.W. 1977a. Conservation tillage in eastern Canada. J. Soil Water Conservation. 32: 57-60.

Ketcheson, J.W. 1977b. Effect of tillage on fertilizer requirements for corn on a silt loam soil. Agron. J. 72: 540-542.

Ketcheson, J.W. 1980. Tillage effects on fertilizer requirements for corn. Agr. J. 72: 540-542.

Klausner, S.D. and R.W. Guest. 1981. Influence of NH_3 conservation from dairy manure on the yield of corn. Agron. J. 73: 720-723.

Lal, R. 1976. No-tillage effects on soil properties under different crops in western Nigeria. Soil Sci. Soc. Amer. J. 40: 762-768.

Lal, R. 1979. Influence of six years of no-tillage and conventional plowing on fertilizer response of maize (Zea mays L.) on an alfisol in the tropics. Soil Sci. Soc. Amer. J. 43:399-403.

Larson, W.E. and J.J. Hanway. 1976. Corn and corn improvement. ASA monograph É18. Madison, Wisconsin. Chap. 11: 625-669.

Lauer, D.A., D.R. Bouldin and S.D. Klaisner 1976. Ammonia volatilization from dairy manure spread on the soil surface. J. Environ. Qual. 2: 134-141.

Lindsay, J.I., S. Osei-Yebook and F.A. Gumbs. 1983. Effect of different tillage methods on maize growth in a tropical inceptisol with impeded drainage. Soil Tillage Res. 3: 185-196.

McIntosh, J.L. and K.E. Varney. 1972. Accumulative effects of manure and N on continuous corn and clay soil. 1. Growth, yield and nutrient uptake of corn. Agron. J. 64: 374-379.

McKee, G.W. 1964. A coefficient for computing leaf area in hybrid corn. Agron J. 56: 240-241.

McKyes, E., S. Negi, E. Douglas, F. Taylor and G.S.V. Raghavan. 1979. The effect of machinery traffic and tillage operations on the physical properties of a clay and on yield of silage corn. J. Agric. Eng. Res. 24(2): 143-148.

Mengel, D.B., D.W. Nelson and D.M. Huber. 1982. Placement of nitrogen fertilizer for no-till and conventional till corn. Agron. J. 74: 515-518.

Ministere de l'Agriculture des Pecheries et de l'Alimentation. 1984. Conseil des productions vegetales du Quebec: Mais culture. CPVQ-1984 21pp.

Moschler, W.W., D.C. Martens, C.I. Rich and G.M. Shear. 1973. Comparative lime effects on continuous no-tillage and conventional tilled corn. Agron. J. 65: 781-783.

Moschler, W.W., G.M. Shear, D.C. Martens, G.D.Jones and R.R. Wilmouth. 1972. Comparative yield and fertilizer efficiency of no-tillage and conventionally tilled corn. Agron. J. 64: 229-231.

Moschler, W.W. and D.C. Martens. 1975. Nitrogen, phosphorus and potassium requirements in no-tillage and conventionally tilled corn. Proc. Soil Sci. Amer. 39(5): 886-891.

Negi, S.C., E. McKyes, F. Taylor, E. Douglas and G.S.V. Raghavan. 1980. Crop performance as affected by traffic and tillage in a clay soil. Trans. of ASAE 23(6): 1364-1368.

Nelson, J.V., L.S. Robertson, M.H. Erdmann, R.G. White and D. Quisenberry. 1976. No-till corn: 1 - Guidelines. Mich. State Univ. Extension Bulletin E-904. 4pp.

Phillips, R.E., R.L. Blevins, G.W. Thomas, W.W. Frye and S.H. Phillips. 1980. No-Tillage agriculture. Science 208: 1108-1113.

Raghavan, G.S.V., F. Taylor, S. Negi, E. Douglas, E. McKyes, S. Tessier, J. Burrows and A.K. Watson. 1981. Zero-tillage and corn production in eastern Canada. In ASAE National Energy Symposium. ASAE publication 4-81. Vol. 2: 433-441.

Richards, L.A. 1969. Diagnosing and improvement of saline and alkai soils. Agriculture handbook No. 60 USDA. 160pp.

Shear, G.M. and W.W. Moschler. 1969. Continous corn by the no-tillage and conventional tillage methods: A six year comparison. Agron. J. 61: 524-526.

Stanford, G., V. A. Bandel, J.J. Meisinger, and J.O. Legg. 1979. N behavior under no till and conventional corn culture. II: Grain and forage yields in relation to amount's of N applied and total N uptake. Agron. Abs. p 183.

Taylor, F., G.S.V. Raghavan, S.C. Negi, E. McKyes, B. Vigier and A.K. Watson. 1981. Feasibility of minumum tillage in Quebec. ASAE Paper No. 81-322.

Triplett, G.B., Jr., D.M. Van Doren, Jr. and W.H. Johnson. 1964. Non-plowed, strip tilled corn culture. Trans. ASAE 7: 105-107.

Triplett, G.B., Jr., and D.M. Van Doren, Jr. 1969. Nitrogen, phosphorus, and potassium fertilization of non-tilled maize. Agron. J. 61: 637-639.

Triplett, G.B., Jr. and G.D. Lytle. 1972. Control and ecology of weeds in continuous corn grown without tillage. Weed Sci. 20: 453-457.

Triplett, G. and D.M. Van Doren. 1977. Agriculture without tillage. Scientific Amer. 236: 28-33.

Unger, P.W. and T.M. McCalla. 1980. Conservation tillage systems. In: Advances in Agronomy.

van Doren, D.M., G.B. Triplett and J.E. Henry. 1977. Influence of long-term tillage and crop rotation combinations on crop yields and selected soil parameters for an Aeric Ochraqualf soil. Ohio Agric. and Res. Development Centre Bulletin No. 1091. 27pp.

Vitosh, M.L. and D.D. Warncke. 1976. No-till corn: 2 - Fertilizer and liming practices. Mich. Stat Univ. Extension Bulletin E-905. 2pp.

Wimer, D.C. 1946. Why cultivate corn? Ill Circ. 597.

Table 4.3.6 Mean values of plant parameters 26 days after seeding Sand Site - 1982

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.071	0.090	0.066	0.076 a
	0:	0.053	0.068	0.036	0.052 b
	Mean:	0.062 ab	0.079 a	0.051 b	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	72.72	69.61	73.86	72.06 a
	0:	67.67	72.37	71.04	70.36 a
	Mean:	70.20 a	70.99 a	72.45 a	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	17.20	17.00	17.37	17.19 a
	0:	17.93	19.03	17.03	18.00 a
	Mean:	17.57 a	18.02 a	17.20 a	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	0.126	0.131	0.122	0.126 a
	0:	0.121	0.176	0.127	0.141 a
	Mean:	0.124 a	0.154 a	0.124 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.7 Mean values of plant parameters 48 days after seeding
Sand Site - 1982

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	1.09	0.88	1.26	1.08 a
	O:	0.63	0.85	0.79	0.75 b
	Mean:	0.86 a	0.86 a	1.02 a	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	92.19	92.88	92.22	92.43 a
	O:	92.53	91.91	92.86	92.43 a
	Mean:	92.36 a	92.40 a	92.54 a	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	74.60 a	58.47 c	71.23 ab	68.10
	O:	64.90 abc	69.57 abc	60.13 bc	64.87
	Mean:	69.75	64.02	65.68	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	1.54	1.40	1.74	1.56 a
	O:	1.34	1.90	1.72	1.65 a
	Mean:	1.44 a	1.65 a	1.73 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.8 Mean values of plant parameters 64 days after seeding Sand Site - 1982

Dry Matter Yield, Mg/ha

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	4.55	5.62	4.65	4.94 a
	0:	3.95	3.73	4.61	4.10 b
	Mean:	4.25 a	4.67 a	4.63 a	

Percent Moisture

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	86.68	87.33	87.14	87.05 a
	0:	87.58	87.55	88.24	87.79 a
	Mean:	87.13 a	87.44 a	87.69 a	

Plant Height, cm

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	118.3	136.6	124.9	126.6 a
	0:	139.2	138.9	134.8	137.6 a
	Mean:	128.8 a	137.8 a	129.9 a	

Leaf Area Index

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	3.28	3.84	3.17	3.43 a
	0:	3.60	3.77	4.41	3.93 b
	Mean:	3.44 a	3.81 a	3.79 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.9 Mean values of plant parameters 76 days after seeding Sand Site - 1982

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	8.88	8.30	7.64	8.27 a
	O:	6.91	7.37	6.62	6.97 a
	Mean:	7.89 a	7.83 a	7.13 a	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	79.18	78.97	80.17	79.44 a
	O:	79.62	79.84	80.89	80.11 a
	Mean:	79.40 b	79.40 b	80.53 a	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	191.5	203.2	190.8	195.2 b
	O:	200.7	214.2	219.5	211.5 a
	Mean:	196.1 a	208.7 a	205.2 a	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	3.90	3.77	3.56	3.74 a
	O:	3.66	3.89	4.34	3.96 a
	Mean:	3.78 a	3.83 a	3.95 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.10 Mean values of plant parameters 91 days after seeding Sand Site - 1982

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	13.15	10.99	12.92	12.35 a
	O:	8.93	9.41	8.91	9.08 b
	Mean:	11.04 a	10.20 a	10.92 a	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	77.48 ab	76.24 bc	76.63 abc	76.78
	O:	75.86 bc	74.07 c	79.57 a	76.50
	Mean:	76.67	75.15	78.10	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	219.0	203.6	207.2	209.9 a
	O:	215.2	211.1	226.8	217.7 a
	Mean:	217.1 a	207.4 a	217.0 a	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	3.75	3.07	3.63	3.48 a
	O:	3.38	3.35	3.92	3.55 a
	Mean:	3.56 a	3.21 a	3.77 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.11 Mean values of plant parameters 29 days after seeding Sand Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	0.168	0.154	0.136	0.153 a
	O:	0.169	0.203	0.119	0.163 a
	Mean:	0.169 a	0.178 a	0.127 a	

Percent Moisture

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	75.84	75.69	73.92	75.15 a
	O:	79.88	75.38	76.84	77.37 a
	Mean:	77.86 a	75.54 a	75.38 a	

Plant Height, cm

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	20.60	23.00	21.63	21.74 a
	O:	24.87	22.77	21.87	23.17 a
	Mean:	22.73 a	22.88 a	21.75 a	

Leaf Area Index

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	0.596	0.583	0.533	0.571 a
	O:	0.636	0.612	0.538	0.596 a
	Mean:	0.616 a	0.598 a	0.536 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.12 Mean values of plant parameters 42 days after seeding Sand Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	1.38 bc	1.20 cd	1.02 d	1.20
	O:	1.64 ab	1.80 a	1.01 d	1.48
	Mean:	1.51	1.50	1.01	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	89.11	89.11	89.11	89.11
	O:	89.11	89.11	89.11	89.11
	Mean:	89.11	89.11	89.11	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	60.47	62.27	57.17	59.97 b
	O:	64.47	66.97	59.30	63.58 a
	Mean:	62.47 ab	64.62 a	58.23 b	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	2.52	2.29	2.47	2.43 b
	O:	3.12	3.09	2.49	2.90 a
	Mean:	2.82 a	2.69 a	2.48 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.13 Mean values of plant parameters 58 days after seeding Sand Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	4.92	4.59	4.62	4.71 a
	O:	5.65	5.01	4.10	4.92 a
	Mean:	5.29 a	4.80 ab	4.36 b	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	87.78	87.12	86.88	87.26 a
	O:	88.30	86.77	89.62	88.23 a
	Mean:	88.04 a	86.95 a	88.25 a	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	165.3	159.1	154.6	159.7 b
	O:	180.8	177.0	159.8	172.5 a
	Mean:	173.0 a	168.0 a	157.2 b	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	4.66	4.31	4.68	4.55 a
	O:	4.87	4.47	5.02	4.79 a
	Mean:	4.77 a	4.39 a	4.85 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.14 Mean values of plant parameters 72 days after seeding Sand Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	7.93	8.42	8.52	8.29 a
	O:	8.30	9.58	7.36	8.41 a
	Mean:	8.12 a	9.00 a	7.94 a	

Percent Moisture

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	84.45	83.81	83.24	83.83 a
	O:	83.81	83.43	84.45	83.90 a
	Mean:	84.13 a	83.62 a	83.85 a	

Plant Height, cm

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	249.5	252.1	246.1	249.2 b
	O:	267.3	265.3	265.4	266.0 a
	Mean:	258.4 a	258.7 a	255.7 a	

Leaf Area Index

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	4.87	4.78	4.67	4.77 a
	O:	4.23	5.01	4.57	4.60 a
	Mean:	4.55 a	4.89 a	4.62 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.15 Mean values of plant parameters 92 days after seeding Sand Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	10.25	11.46	12.21	11.31 a
	0:	12.36	11.52	10.97	11.62 a
	Mean:	11.31 a	11.49 a	11.59 a	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	76.93	76.10	74.51	75.85 a
	0:	75.27	77.12	76.04	76.14 a
	Mean:	76.10 a	76.61 a	75.27 a	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	253.7	251.1	248.2	251.0 b
	0:	265.9	265.7	271.4	267.6 a
	Mean:	259.8 a	258.4 a	259.8 a	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	3.11	3.59	3.40	3.37 a
	0:	3.14	3.17	3.16	3.16 a
	Mean:	3.13 a	3.38 a	3.28 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.16 Mean values of plant parameters 29 days after seeding Clay Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	0.126 b	0.125 b	0.129 b	0.127
	O:	0.225 a	0.110 b	0.114 b	0.149
	Mean:	0.176	0.118	0.122	

Percent Moisture

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	77.77	79.73	79.53	79.01 a
	O:	75.63	78.79	75.22	76.55 a
	Mean:	76.70 a	79.26 a	77.38 a	

Plant Height, cm

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	20.77 c	21.50 bc	25.47 ab	22.58
	O:	26.23 a	23.53 abc	20.40 c	23.39
	Mean:	23.50	22.52	22.93	

Leaf Area Index

		TILLAGE C	TILLAGE R	TILLAGE Z	Mean
FERTILIZER	I:	0.559 bc	0.586 abc	0.624 ab	0.589
	O:	0.667 a	0.557 bc	0.513 c	0.579
	Mean:	0.613	0.571	0.568	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.17 Mean values of plant parameters 42 days after seeding Clay Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	1.17	1.13	1.03	1.11 a
	O:	1.98	1.00	0.69	1.22 a
	Mean:	1.58 a	1.07 a	0.86 a	

Percent Moisture

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	85.70	85.70	85.70	85.70
	O:	85.70	85.70	85.70	85.70
	Mean:	85.70	85.70	85.70	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	55.10	54.27	49.40	52.92 a
	O:	61.70	51.13	43.16	52.00 a
	Mean:	58.40 a	52.70 a	46.28 a	

Leaf Area Index

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	2.08	2.10	2.06	2.08 a
	O:	2.75	2.17	1.66	2.19 a
	Mean:	2.42 a	2.14 a	1.86 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.18 Mean values of plant parameters 58 days after seeding Clay Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	5.11	4.15	4.08	4.45 a
	O:	4.53	3.33	2.66	3.50 a
	Mean:	4.82 a	3.74 a	3.37 a	

Percent Moisture

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	84.13	85.00	84.99	84.71 a
	O:	85.48	85.73	85.70	85.64 a
	Mean:	84.80 a	85.36 a	85.35 a	

Plant Height, cm

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	129.7	128.1	119.2	125.7 a
	O:	139.3	114.8	99.3	117.8 a
	Mean:	134.5 a	121.4 a	109.2 a	

Leaf Area Index

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	4.47	4.26	4.33	4.35 a
	O:	4.39	3.97	3.32	3.89 a
	Mean:	4.43 a	4.12 a	3.83 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.19 Mean values of plant parameters 72 days after seeding Clay Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	8.34	6.71	7.43	7.49 a
	O:	9.39	6.53	6.58	7.50 a
	Mean:	8.86 a	6.62 b	7.01 b	

Percent Moisture

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	82.66	84.26	82.92	83.28 a
	O:	83.37	82.98	82.98	83.11 a
	Mean:	83.01 a	83.62 a	82.95 a	

Plant Height, cm

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	237.0	224.1	219.4	226.9 a
	O:	243.2	227.9	205.3	225.5 a
	Mean:	240.1 a	226.0 a	212.4 a	

Leaf Area Index

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	4.68	4.52	4.75	4.65 a
	O:	4.67	4.38	3.96	4.34 a
	Mean:	4.67 a	4.45 a	4.36 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.20 Mean values of plant parameters 92 days after seeding Clay Site - 1983

Dry Matter Yield, Mg/ha

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	12.09	11.38	10.51	11.33 a
	O:	12.77	10.98	9.35	11.03 a
	Mean:	12.43 a	11.18 a	9.93 a	

Percent Moisture

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	76.04	75.85	76.35	76.08 a
	O:	76.42	77.50	76.86	76.93 a
	Mean:	76.23 a	76.68 a	76.61 a	

Plant Height, cm

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	226.8	225.8	213.7	222.1 a
	O:	241.6	236.0	204.5	227.4 a
	Mean:	234.2 a	230.9 a	209.1 a	

Leaf Area Index

		TILLAGE C	R	Z	Mean
FERTILIZER	I:	4.19	3.97	4.00	4.05 a
	O:	4.00	3.75	3.46	3.73 a
	Mean:	4.09 a	3.86 a	3.73 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.21 Mean values of number of leaves for 29, 42, and 58 days after seeding. Sand Site - 1983

29 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	7.03	6.93	6.93	6.97 a
	O:	7.20	7.03	6.43	6.89 a
	Mean:	7.11 a	6.98 a	6.68 a	

42 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	10.93	11.27	11.03	11.08 a
	O:	11.70	11.50	10.43	11.21 a
	Mean:	11.32 a	11.38 a	10.73 a	

58 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	12.03	11.53	12.17	11.91 a
	O:	11.87	11.33	11.43	11.54 a
	Mean:	11.95 a	11.43 a	11.80 a.	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.22 Mean values of number of leaves for 72 and 92 days after seeding. Sand Site - 1983

72 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER*	I:	12.53	12.60	12.60	12.58 a
	O:	11.10	11.70	11.10	11.30 b
	Mean:	11.82 a	12.15 a	11.85 a	

92 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	9.17	10.50	9.87	9.84 a
	O:	9.30	9.70	9.10	9.37 b
	Mean:	9.23 b	10.10 a	9.48 b	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.23 Mean values of number of leaves for 29, 42, and 58 days after seeding. Clay Site - 1983 *

29 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	6.77	7.13	7.03	6.98 a
	O:	6.93	6.83	6.37	6.64 a
	Mean:	6.85 a	6.88 a	6.70 a	

42 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	11.20	11.43	10.93	11.19 a
	O:	11.70	10.87	10.43	11.00 a
	Mean:	11.45 a	11.15 a	10.68 a.	

Plant Height, cm

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	11.37	11.93	11.63	11.64 a
	O:	11.47	11.27	11.37	11.37 a
	Mean:	11.42 a	11.60 a	11.50 a.	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 4.3.24 Mean values of number of leaves for 72 and 92 days after seeding. Clay Site - 1983

72 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	13.27	13.20	13.03	13.17 a
	O:	12.43	12.60	12.70	12.58 a
	Mean:	12.85 a	12.90 a	12.87 a	

92 Days After Seeding

		TILLAGE			
		C	R	Z	Mean
FERTILIZER	I:	10.97	11.67	11.93	11.52 a
	O:	11.37	11.27	11.20	11.28 a
	Mean:	11.17 a	11.47 a	11.57 a	

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Chapter 5

The Effects of Tillage, Zero Tillage and Fertilizer Sources on Soil Structure, Nutrient and Moisture Distribution in Silage Corn Production

5.1 Introduction

In most areas of the world, the no tillage system is being considered seriously as an alternative to conventional tillage methods in crop production. Reduced labour and fuel requirements, wind and water erosion control as well as the prospect of preventing soil degradation and maintaining equivalent yields are some of the reasons for the move away from conventional tillage to zero tillage production of row crops. (Triplett and van Doren 1977, McGregor & Greer 1982, Phillips et al. 1984). The use of herbicides has eliminated much of the need for cultivation in row crops (Triplett 1973 and Moomaw and Martin 1978).

Most of the research performed in evaluating alternative tillage systems is quite dependent on the individual climatic and soil conditions. Successful techniques in one area do not necessarily succeed elsewhere.

Long term studies in certain geographical regions have shown that no tillage corn production can produce equal or better yields than conventional tillage (Brar et al. 1983, Shear and Moschler 1969 and Moschler et al. 1972), while not significantly increasing soil compaction (Shear and Moschler 1969 and Blevins et al. 1977). Lower yields have been experienced with zero tillage (Ketcheson 1977 and Fink and Wesley 1973), with restricted root development in medium to fine textured soils being cited as one of the major causes (Ketcheson 1977). Voorhees (1982), on work performed in Minnesota, stated that a no tillage system may be undesirable on fine textured soil.

Soil compaction is generally viewed as being a cause of reduced plant root activity (Gaultney et al 1980). Trause (1971) observed that even with relatively low levels of compaction, roots elongate more slowly in unplowed soils, with resulting slower plant development.

Bauder et al. (1981) and Pope (1982) showed that no tillage had the greatest soil density and least soil porosity when compared to other tillage systems used for 10 years on a clay loam soil. Numerous other authors have reported increased bulk density and reduced total air filled pore space in the top 20 cm of soil under zero tillage systems. (Brar et al. 1983, Ehlers et al. 1983, Van Ouerkerk and Boone 1970, Pidgeon and Soane 1977 and Triplett and van Doren 1969). Conventional tillage, however, does usually produce a layer of soil at a certain depth having higher density and penetration resistance than any layer of untilled soil (Ehlers et al. 1983). This denser layer, often called a plow pan, occurs just below the plowing depth, which is usually around 20 cm in depth.

After several years of continuous zero tillage, many soils tend to be compacted to an equilibrium value of bulk density and strength. Unless the soil is very wet, further normal traffic is not likely to cause further compaction. Soils under zero tillage, therefore, seem to be more resistant to compaction changes than plowed soils, (Baeumer 1970 and Pidgeon and Soane 1977). The fact that poorly drained soils tend to compact to injuriously high densities (Cannell et al. 1978) and that the accompanying lower air filled porosities will cause restricted gas exchange in the spring, when soil water contents are ordinarily high, are some of the reasons why poorly drained soils have been labelled as unsuitable for no tillage crop production (Gantzer and Blake 1978).

Under certain soil and climatic conditions, several studies have reported no significant difference in soil bulk density with zero tillage conditions when compared to conventional tillage. Brar et al (1983), working in Punjab, India, observed that the increased bulk density in the zero tillage plots was not enough to restrict yields since it only affected the frequency of the relatively large pores in the soil aggregates. The increased number of smaller pores in the zero tillage plots retained more water resulting in higher moisture contents and concommitant high moisture use efficiency and ultimately higher grain yields. Restriction to root development, expected due to increased bulk density, was not found because the root channels made by previous crops remained undisturbed in these plots.

Ehlers et al. (1983) and Cannell et al. (1978) both showed that the increase in bulk density, associated with zero tillage, was of minor importance for root growth. In fact, in well structured soils and especially in some clay soils, this was a poor index of the suitability of the soil for root growth. On such soils which have been direct drilled for two or three years, there are changes in soil conditions which may lead to an improvement in root growth. (Cannell et al. 1978).

Some investigators have found that roots may be more abundant in subsoil horizons (below 25-30 cm) after a period of zero tillage, than after plowing (Ellis and Barnes 1980, Cannell et al. 1978, O'Sullivan 1983 and Ehlers et al. 1983), with the increase being explained by the buildup of a continuous pore system in untilled soil created by earthworms and the roots from preceeding crops. (Gerard and Hay 1979, Ehlers 1975, Barnes and Ellis 1979 and Taylor et al. 1980). In clay soils, no tillage may also intensify the shrinking process creating vertical planes of weakness and cracks, which may aid root elongation (Ellis & Barnes 1980).

The planting of corn directly into a killed sod can also prove to be beneficial. Almost total reduction of wind and/or water soil erosion, opening to cropping of rolling grasslands that were previously suitable for only pastures and increased grain yields are some of the advantages that have been realized. In some parts of North America and other semi-arid climates, soil-water evaporation at planting and during early growth after conventional tillage can be so great as to create a severe moisture deficiency which carries on to the plants' reproductive period. Planting into the killed sod or retaining the previous years crop residues on the surface provides a mulch which greatly reduces water evaporation and runoff and increases infiltration, thereby increasing water available to the plants and causing increased grain yields. (Hill and Blevins 1973, Blevins et al. 1971, Weatherley and Dane 1979, Estes 1972 and Barclay et al. 1983). Lower water availability has been reported for zero tillage when all crop-residues were removed, which stresses the importance of crop residue management (Black & Power 1965).

Negi et al. (1981) showed that after a number of years of zero tillage on a clay soil, the size distribution of pores was such that a greater portion of the water was held at moderate suctions of 0.5 - 5 m than was in tilled soils. In other words, water was more available to the plants when it was needed. Tollner and Hargrove (1982), however, found that this same decline in the pore size of soils under no tillage caused a decreased ability to retain plant available water. The water retention curve shifted to higher moisture contents at higher suction values and lower moisture contents at lower suction values. The key to water availability seems to be the reduction in pore sizes. Most direct drilled soils do exhibit a greater ability to store moisture, by containing less water at high potentials and more water at low potentials (Ball 1981, O'Sullivan 1983, Ehlers 1976, Van Ouerkerk and Boone 1970 and Blevins et al. 1971).

In Great Britain, one of the main reasons for adopting direct drilling is the advantage that large clay loam farms can be drilled closer to the optimum sowing date. In addition, cultivations in wet conditions, which cause damage to soil structure and subsequent yield reductions are avoided (Ellis and Barnes 1980 and Cannell et al. 1978).

Tollner and Hargrove (1982), realizing that both zero and conventional tillage management approaches can have undesirable effects in the long term, suggested that theses effects could be minimized by an appropriate tillage rotation program. Other research conducted to evaluate tillage rotations showed that periodic use of the moldboard plow could result in statistically higher yields (Dickey 1983).

Since all of the abovementioned observations appear to be quite dependent on the particular soil type involved, and on the climatic region in each case, it is difficult to determine whether or not specific recommendations provided by professional researchers can be applied successfully in another geographical area. Southern Quebec and southeastern Ontario, in particular have a cooler, wetter climate than most of the areas in which extensive testing has been conducted on reduced and zero tillage systems.

With this in mind, field experiments were conducted on two different eastern Canadian soils to examine the effects of tillage practices in combination with fertilizer sources on soil structure, moisture distribution, and yields of silage corn. The purpose was to ascertain whether alternative tillage systems are a viable and economical management choice for farmers in this particular location, or whether prohibitively deliterious effects would be observed in the soil structure and quality over a period of time.

5.2 Materials and Methods

5.2.1 Experimental Design

This field study was established on two experimental sites located at the Macdonald College Research Station of McGill University in Ste. Anne de Bellevue, Quebec. The first site comprises a Macdonald clay, while the second site is on a St. Benoit light sandy loam. Figures 5.2.1 and 5.2.2 illustrate the particle size distributions for these two soils.

Prior to 1982, continuous corn (Zea mays L.) was grown under conventional tillage for approximately 20 years on the sandy loam soil, while corn was grown from 1970 to 1976 and alfalfa (Medicago sativa L.) from 1976 to 1981 on the clay soil. In the fall of 1981, a 2 X 3 factorial experiment was established. Six combinations of three levels of tillage and two different fertilizer sources were randomized in a complete block design with three replicates forming a total of 36 plots, (18 per experimental site), individual plots measuring 10 X 12 m.

The three levels of tillage were conventional, reduced and zero tillage. The conventional tillage treatment consisted of fall moldboard plowing to a depth of 15 to 20 cm followed by two passes of a disk harrow in the spring for seedbed preparation. The reduced tillage systems included fall chisel plowing with a five shank chisel plow with narrow spear pointed shovels spaced 30 cm apart, and operating at 15-20 cm depth, followed by

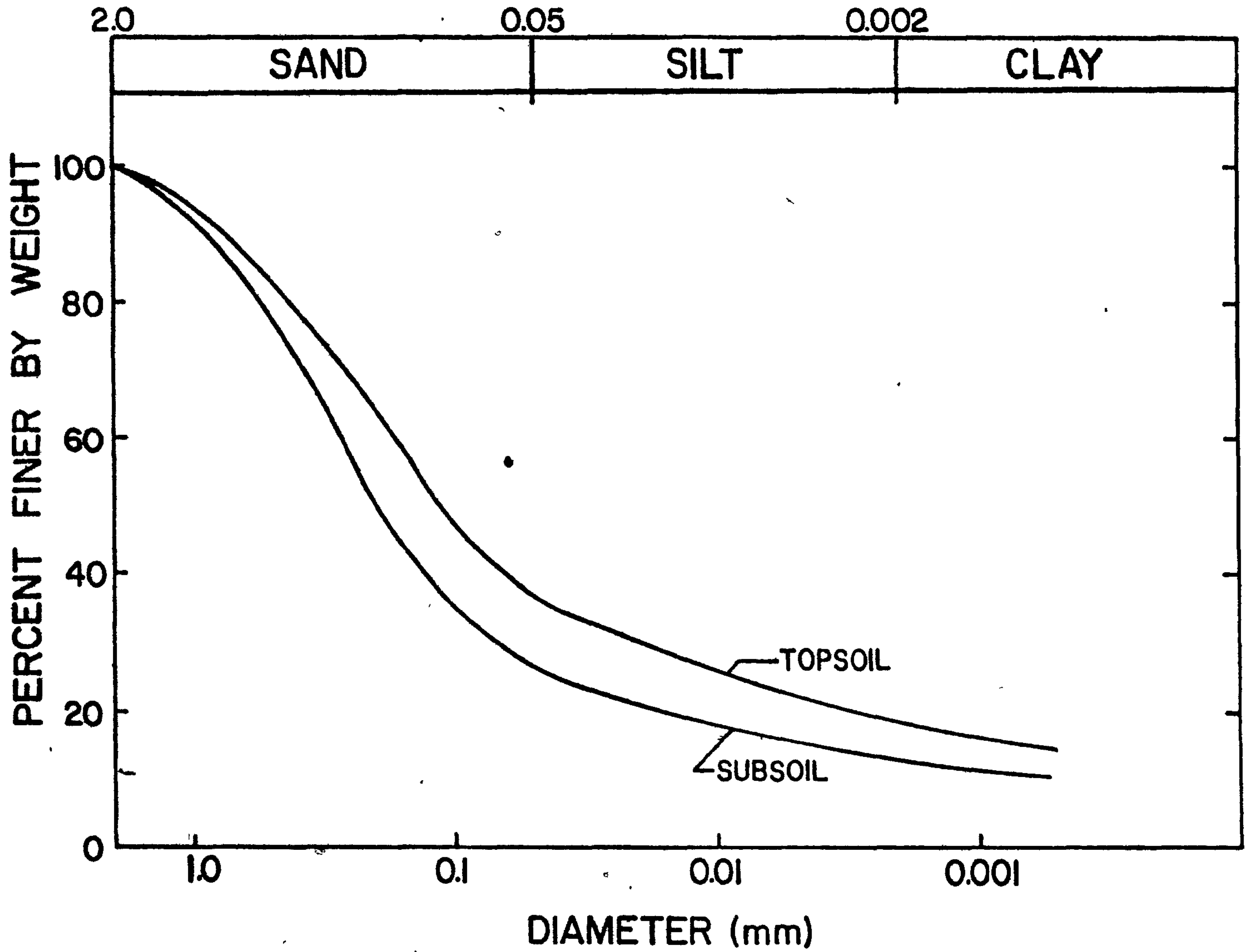


Figure 5.2.1. Sandy loam soil particle size analysis.

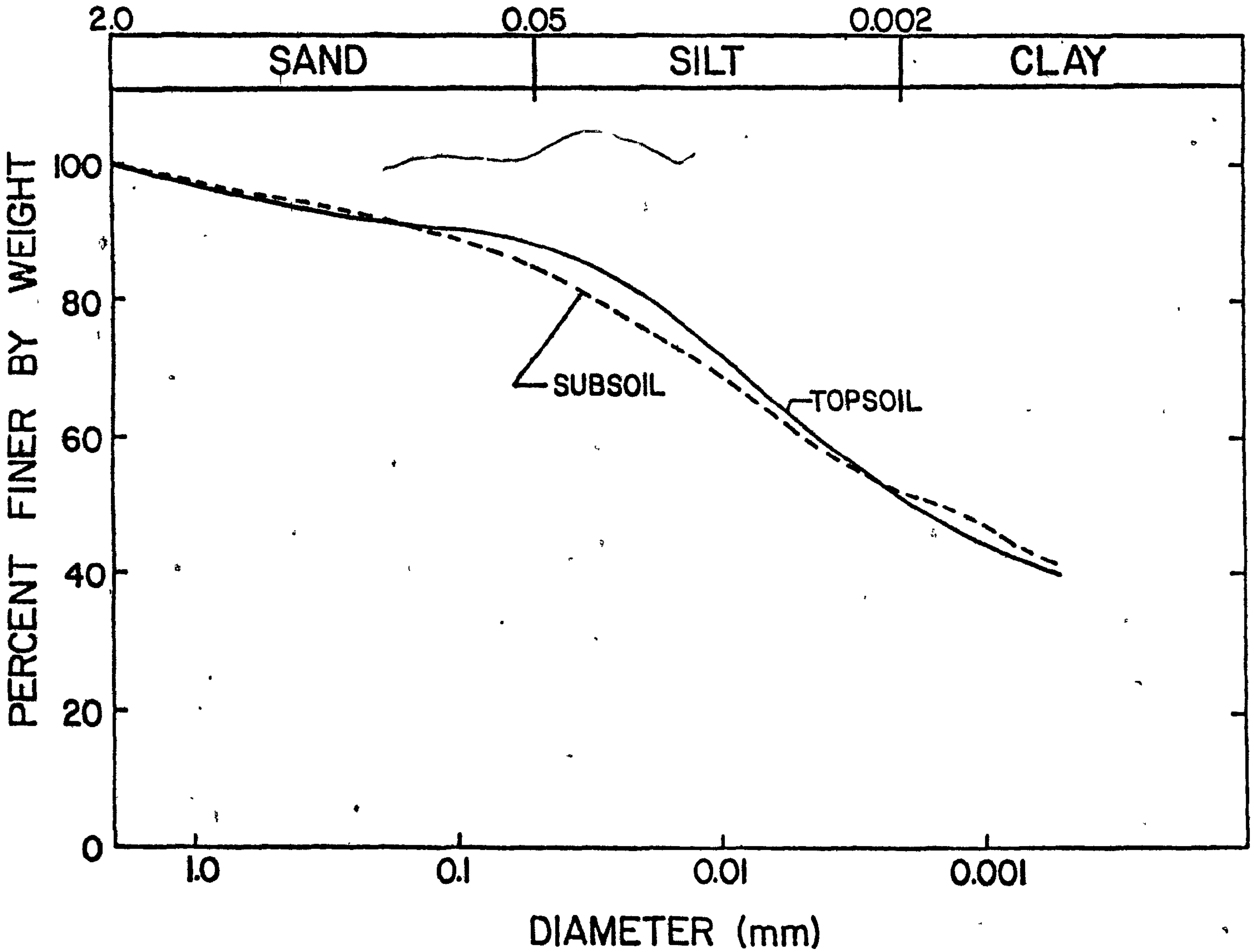


Figure 5.2.2. Clay soil particle size analysis.

only one pass of a disk harrow as secondary tillage in the spring. This method simply loosens the soil with a minimum of inversion of the surface and subsurface layers, and therefore results in only partial incorporation of crop residues. In the zero tillage plots, silage corn was planted directly into the previous years stubble. Post emergent inter-row cultivations were not used on any of the plots, as chemical herbicides alone were used to control the weed population.

Inorganic granular fertilizers (commercial) and dairy cow manure (organic) were the two fertilizer treatments. Both treatments were applied at rates dictated by prior soil chemistry assays and local recommendations. This paper presents the results of two years growth on the sandy loam soil (1982-83) and one years growth on the clay soil (1983). During the first year of the study (1982) severe problems were encountered with emergence in the clay site due to improper adjustment of the planter and very dry conditions.

5.2.2 Fertilizer Application

At the initiation of the experiment, soil test results indicated that the clay site had background levels of 322 kg P/ha. and 289 kg K/ha. Results from the sand site were higher; 479 and 386 kg P and K/ha, respectively. Based on these findings, and on Quebec Ministry of Agriculture, Food and Fisheries fertilizer recommendations, applications of 170, 75 and 80 Kg. of N, P_2O_5 and K_2O were advised for silage corn production. Phosphorus, in the form of triple superphosphate, was banded in both the organic and inorganic plots at 5 cm below and 5 cm beside the seed, since the dairy cow manure is very low in phosphorus. Muriate of Potash was used as the K source on the inorganic plots. Organic fertilizer plots received manure at the equivalent rate of 170 Kg/ha N based on the semi-micro Kjeldahl analysis of the manure two days prior to application. These plots received no inorganic N or K fertilizer.

Nitrogen was applied to the inorganic fertilizer plots using urea (45-0-0) on the reduced and conventionally tilled plots, and ammonium nitrate (34-0-0) on the zero tillage plots. Ammonium nitrate was selected as the N source on the zero tillage plots to eliminate the possibility of ammonia loss through the volatilization of transformed urea if applied and left at the soil surface.

Both the manure and inorganic fertilizers (nitrogen and potassium) were incorporated on the conventional and reduced tillage plots with a disk harrow using two and one pass respectively. On the zero tillage plots, ammonium nitrate and the manure were both left on the surface. Based on soil sample results in October 1982 (post-harvest), the same application rates were used in the spring of 1983.

5.2.3 Herbicide Application

Immediately prior to seeding, the herbicides Atrazine (90W) at a rate of 1.5 Kg/ha. and Alachlor (Lasso) at 2.5 Kg/ha. were applied and pre-plant incorporated in those plots receiving conventional tillage, and pre emergence non-incorporated in those plots receiving the reduced and no tillage treatments. Bentazon (0.84 Kg/ha.) and Citowett TM were subsequently applied post-emergent to the entire plot area (two applications eight days apart were neccessary). Atrazine and Kornoil TM were also applied to those plots in which volunteer grain was a problem. All plots received the same herbicide treatment in the first year. The results of weed density and biomass studies during the summer of 1982, dictated no change in herbicide application rates among the plots for the 1983 growing season.

Spot spraying of Killex brand herbicide was used in all plots in the clay site to control dandelions. This was neccessary because the site is adjacent to a major highway, whose side are laden with dandelions.

5.2.4 Seeding

Seeding of Warwick (Trojan) 844 silage corn took place on May 11, 1982, and again on May 22, 1983. An International Harvestor 800 conservation air planter was used to seed the corn in 76 cm rows with an inter-plant spacing of 16.5 cm to achieve the desired plant population of 80,000 plants/ha.

The planter used was a conservation type planter. Heavy duty coulters to open the narrow slot for seed placement, heavier frame than normal planters and down pressure springs (set to their maximum) on the planting units were required to enable the planter to penetrate the harder surface layers of the clay soil and the crop residues for those plots treated with zero tillage.

Each plot contained 12 rows 12 m long. The plot separation was equivalent to the space between corn rows. Four rows were planted on both ends of the group of six plots in each replicate to redude edge effects.

5.2.5 Soil Density and Moisture Content

Prior to the introduction of the experiment in the fall of 1981, soil bulk density readings were taken in both the clay and sandy loam sites. Subsequently, three measurements were repeated in each of the plots during the early part of the 1982 growing season. A total of seven readings were obtained per plot at the beginning and near the end of the 1983 growing season.

Average wet bulk densities were measured to six depths ranging from 5 to 30 cm in 5 cm increments by means of a Troxler 3401 nuclear density gauge. The gauge consisted of a probe housing a Cesium 137 radioactive source and a geiger counter built into the body of the gauge. The probe was inserted into the soil and the wet bulk density was determined from the quantity of gamma rays which traveled through the soil and were recorded by the geiger counter at the soil surface.

Concurrently, soil samples of about 50 g mass were taken with an auger at 5 cm intervals, weighed and oven dried at 105°C for 24 hours to determine the gravimetric moisture content. Using the measured gravimetric moisture contents, the wet bulk density measurements were converted to dry density values.

These measured bulk densities were the averages to each depth. If however, one desires to examine discrete changes in the dry bulk density at various depths, as is helpful in a tillage experiment, the layer dry bulk densities are more useful. To obtain the layer densities using the average density to each depth, the following formula was used:

$$\bar{\gamma}_2 = \frac{\gamma_2 z_2 - \gamma_1 z_1}{z_2 - z_1}$$

where, γ_1 = average dry bulk density to depth z_1

$\bar{\gamma}_2$ = dry bulk density of the layer between z_1 and z_2

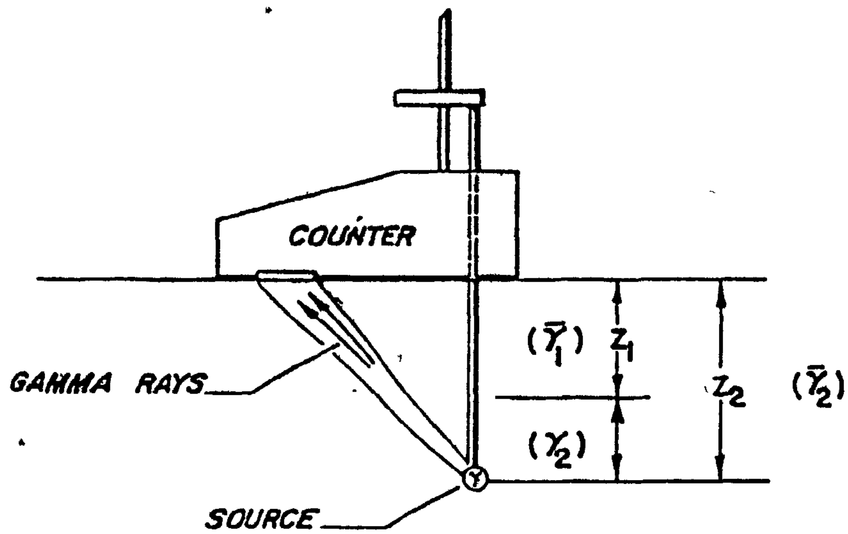
γ_2 = average dry bulk density to depth z_2

Figure 5.2.3 shows a schematic diagram of the density gauge and summarizes these relationships (Taylor et al. 1981).

It was desired also to observe the changes in moisture content of the soil layers continuously with time, and for this purpose aluminum access tubes were installed in 16 of the 36 plots. The probe of Troxler 3222 moisture gauge was lowered into the access tubes and readings were taken to a depth of 82.5 cm at increments of 15 cm.

5.2.6 Rainfall and Water Table

Water table tubes were installed in the same 16 plots to monitor the position of the water table throughout the growing season. Rainfall data, along with any other meteorological data required, were obtained from the Macdonald College weather station, located within three km of the experimental sites.



Average density of layer to $Z_1 = \bar{\gamma}_1$

Density of layer between Z_1 and $Z_2 = \gamma_2$

<u>Density measurement</u> at Z_2 = Average over $Z_2 = \bar{\gamma}_2$

$$= \frac{\bar{\gamma}_1 Z_1 + \gamma_2 (Z_2 - Z_1)}{Z_2}$$

Thus

$$\boxed{\gamma_2 = \frac{\bar{\gamma}_2 Z_2 - \bar{\gamma}_1 Z_1}{Z_2 - Z_1}}$$

Figure 5.2.3. Calculation of dry bulk density over small depth ranges (Taylor et al., 1981).

5.2.7 Harvest

The centre four rows of each plot were essentially undisturbed throughout the growing season. Human traffic was kept to an absolute minimum as all measurements during the summer were taken on the outside four rows. These middle four rows were harvested in the fall for silage corn with a John Deere, three point hitch mounted, single row forage harvester. The total weight per plot was obtained, and then 500 g subsamples were oven dried at 50^{0}C for 48 hours to obtain the final moisture content and the final dry matter yield per plot. Using the area of the four rows harvested, the total dry matter measured per plot was converted to Mg/ha.

5.3 Results and Discussion

5.3.1 Climate Conditions

The distributions of rainfall throughout the 1982 and 1983 growing seasons are shown in Figures 5.3.1 and 5.3.2, respectively. The month of May, 1982 was one of the driest on record, receiving 72 % less rainfall than the 30 year average (Table 5.3.1). As a result, emergence in the clay site was much below normal. For this reason, only those data obtained in the sand site during 1982, in addition to the 1983 data from both sites will be reported here. The extremely dry spring of 1982 also contributed to the incomplete activation of the herbicides applied and consequently less than perfect weed control was achieved. Due to a month of June with 3.2 times the normal rainfall, the balance of the 1982 growing season finished slightly above average in total precipitation, with July, August and September

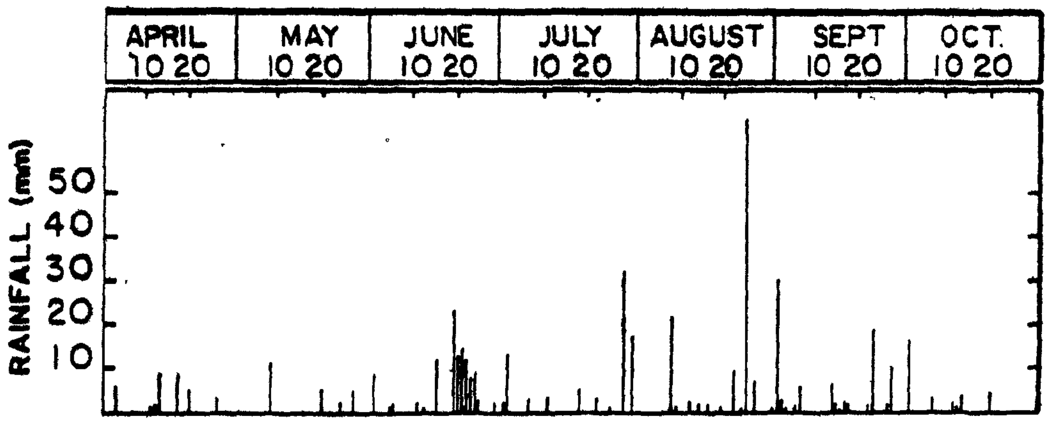


Figure 5.3.1. Daily rainfall record for the 1982 growing season.

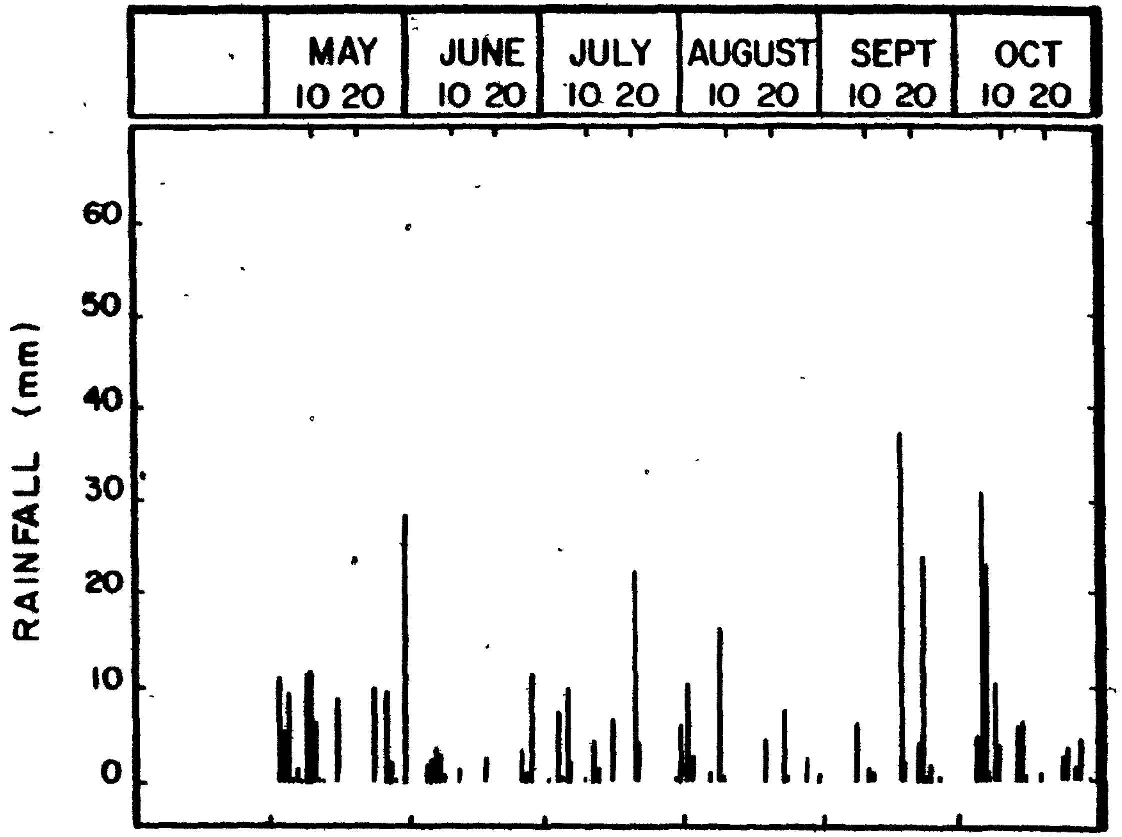


Figure 5.3.2. Daily rainfall record for the 1983 growing season.

Table 5.3.1 Rainfall data during the 1982 and 1983 growing seasons and the 30 year averages.

	1982 Rainfall (mm)	1982 Cummulative (mm)
May	22.1	22.1
June	117.6	139.7
July	83.3	223.0
August	136.8	359.8
September	86.3	446.1

	1983 Rainfall (mm)	1983 Cummulative (mm)
May	126.9	126.9
June	32.6	159.5
July	66.3	225.8
August	48.3	274.1
September	82.0	356.1

	30 year average Rainfall (mm)	30 year average Cummulative (mm)
May	78.4	78.4
June	37.3	115.7
July	94.5	210.2
August	111.9	322.1
September	85.1	407.2

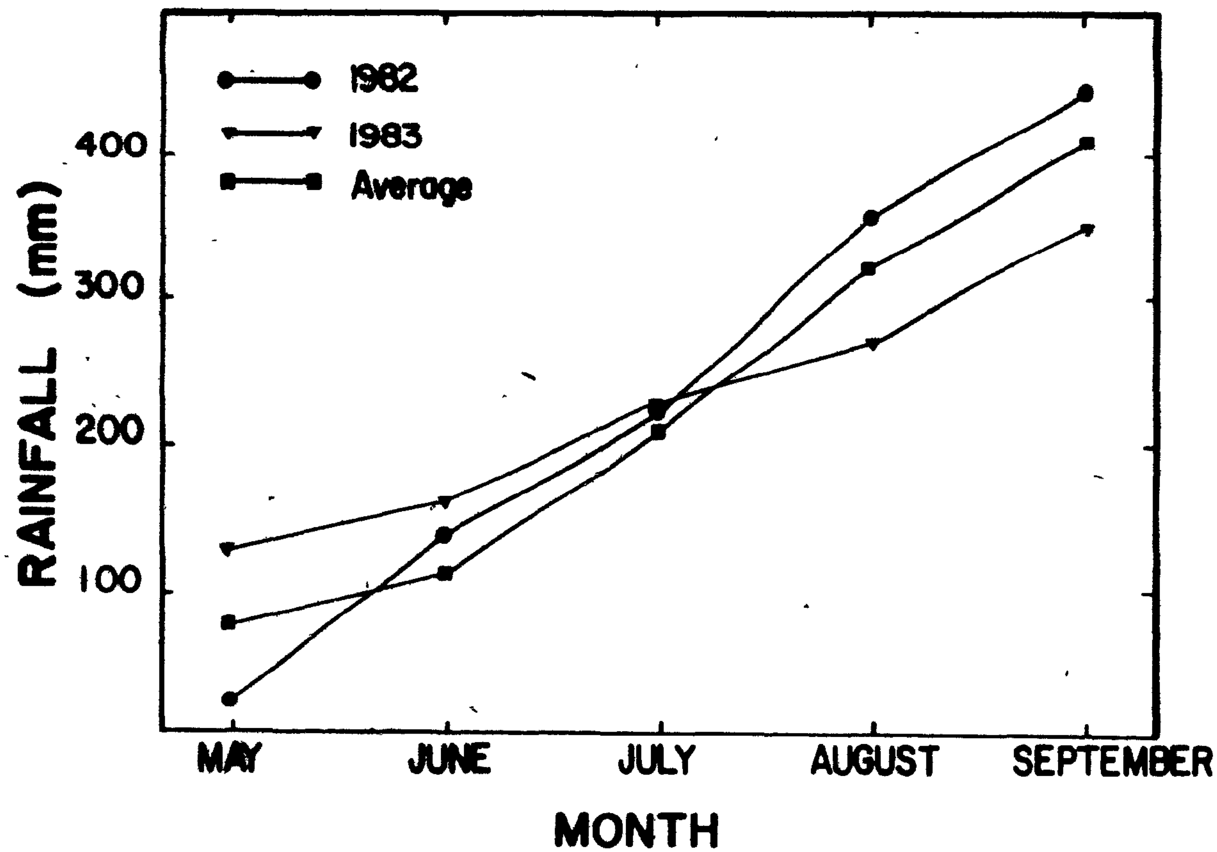


Figure 5.3.3. Cummulative rainfall for the 1982, 1983 and the 30 year average.

receiving average rainfall amounts (Figure 5.3.3).

The spring of 1983, on the other hand, could be classified as very wet. In May, 62 percent more rainfall than usual fell, while in June the precipitation was equal to the 30 year average (Table 5.3.1). Excellent weed control was achieved during the wet spring.

Conditions during July and August, however, were very dry. Total precipitation for this period was only 114.6 mm or 45 % lower than the 30 year average (Table 5.3.1). Most of this deficit took place during the grain filling stage in August which received 57 % less rainfall than average.

Over the course of the two growing seasons, a water table has never been measured at either site after the month of May. The sandy loam site has excellent natural drainage, while the clay site has a layer of broken limestone at a depth of approximately 0.8 to 1.5 m with very a high horizontal conduction rate. For these reasons, curves of water table position with time will not be presented.

5.3.2 Soil Nutrient Status

Soil analysis for potassium and phosphorus were performed on both the clay and sand sites in the fall of 1981 to determine the initial application rates of the inorganic fertilizers. Mean values of the potassium and phosphorus contents in the topsoil and subsoil are presented in Table 5.3.2, while the corresponding analysis of variance can be found in Tables B5.3.1 to B5.3.4 in Appendix B. According to the Ministry of Agriculture, Fisheries and Food in Quebec (1984), a soil is deemed rich in terms of these

Table 5.3.2 Mean values of soil analysis
Sand and Clay Sites - 1981

Sand Site

	PHOSPHORUS (kg/ha)		POTASSIUM (kg/ha)	
	Depth (cm)			
	0-20	20-40	0-20	20-40
TILLAGE				
C	569.0 a	365.5 a	321.2 a	235.8 a
R	541.7 a	363.5 a	319.3 a	248.7 a
Z	553.0 a	316.5 a	346.7 a	265.2 a
FERTILIZER				
I	570.0 a	349.6 a	352.9 a	263.0 a
O	539.1 a	347.4 a	305.2 a	236.8 a

Clay Site

	PHOSPHORUS (kg/ha)		POTASSIUM (kg/ha)	
	Depth (cm)			
	0-20	20-40	0-20	20-40
TILLAGE				
C	272.0 a	184.0 a	336.5 a	260.3 b
R	250.2 a	160.5 a	407.2 a	295.2 ab
Z	252.8 a	124.5 a	456.5 a	313.7 a
FERTILIZER				
I	252.2 a	160.0 a	427.9 a	278.8 a
O	264.4 a	152.7 a	372.2 a	300.7 a

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

elements if the residual levels in the topsoil are more than 200 kg/ha. All plots were therefore rich in potassium and phosphorus (Table 5.3.2) and were fertilized accordingly.

In the fall of 1982 and 1983, the soils were analyzed for potassium, phosphorus, organic matter and salinity. The salinity measurements indicated that salt accumulation was not a problem. Values of conductivity were all less than 1.0 mmho/cm. Richards (1969) stated that salinity effects in all crops were mostly negligible when the conductivity of the saturation extract is less than 2.0 mmho/cm. For this reason, salinity results will not be presented here.

Mean values of potassium and phosphorus levels as well as organic matter percentages for the sand and clay sites are presented in Table 5.3.3 for the 1982 data and in Table 5.3.4 for the 1983 data. The associated analyses of variance are presented in Tables B5.3.5 through B5.3.16 in Appendix B.

After two full years of experimentation, both the potassium and phosphorus levels were still greater than 200 kg/ha in the topsoil and no significant differences have appeared due to either the tillage or fertilizer treatments at either of the depths presented (Table 5.3.4).

The organic matter contents of both the sandy loam and clay soils were not affected by treatment (Table 5.3.3) after the first year. The same was true for the clay site in 1983 (Table 5.3.4). The sand site, however, in 1983 exhibited the start of a predictable trend. An interaction effect between fertilizer and tillage developed in the top 20 cm. Table 5.3.5

Table 5.3.3 Mean values of soil analysis
Sand and Clay Sites - 1982

Sand Site

	PHOSPHORUS (kg/ha)		POTASSIUM (kg/ha)		ORGANIC MATTER (%)	
	---------- Depth (cm)					
	0-20	20-40	0-20	20-40	0-20	20-40
TILLAGE						
C	556.8 a	373.7 a	406.3 a	326.2 a	4.87 a	2.88 a
R	580.7 a	448.3 a	379.2 a	342.2 a	4.72 a	2.52 a
Z	457.0 b	367.2 a	413.3 a	354.7 a	4.86 a	3.40 a
FERTILIZER						
I	543.7 a	392.4 a	342.4 b	307.1 a	4.86 a	2.79 a
O	526.0 a	400.3 a	456.8 a	374.9 a	4.77 a	3.08 a

Clay Site

	PHOSPHORUS (kg/ha)		POTASSIUM (kg/ha)		ORGANIC MATTER (%)	
	---------- Depth (cm)					
	0-20	20-40	0-20	20-40	0-20	20-40
TILLAGE						
C	459.0 a	254.8 a	431.3 a	733.2 a	4.42 a	2.76 a
R	439.2 a	255.2 a	431.8 a	753.8 a	4.04 a	2.13 a
Z	503.3 a	267.3 a	449.0 a	807.5 a	4.79 a	1.57 a
FERTILIZER						
I	486.8 a	257.6 a	423.3 a	760.7 a	4.58 a	2.26 a
O	447.6 a	260.7 a	451.4 a	769.0 a	4.25 a	2.04 a

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 5.3.4 Mean values of soil analysis Sand and Clay Sites - 1983

Sand Site

	PHOSPHORUS (kg/ha)		POTASSIUM (kg/ha)		ORGANIC MATTER (%)	
	Depth (cm)					
	0-20	20-40	0-20	20-40	0-20	20-40
TILLAGE						
C	656.0 a	369.0 a	287.8 a	196.8 a	See Table 5.3.5	2.17 a
R	644.2 a	274.7 a	216.3 a	209.3 a		2.76 a
Z	706.3 a	276.8 a	229.8 a	196.2 a		2.42 a
FERTILIZER						
I	644.2 a	290.7 a	216.8 a	200.9 a		2.29 a
O	693.4 a	323.0 a	272.6 a	200.7 a		2.60 a

Clay Site

	PHOSPHORUS (kg/ha)		POTASSIUM (kg/ha)		ORGANIC MATTER (%)	
	Depth (cm)					
	0-20	20-40	0-20	20-40	0-20	20-40
TILLAGE						
C	324.8 a	245.8 a	331.8 a	330.0 a	4.05 a	2.41 a
R	288.7 a	226.7 a	379.5 a	346.5 a	4.21 a	2.98 a
Z	449.3 a	254.0 a	403.3 a	352.0 a	4.05 a	2.63 a
FERTILIZER						
I	336.9 a	227.7 a	367.9 a	331.2 a	4.22 a	2.64 a
O	371.7 a	256.7 a	375.2 a	354.4 a	3.99 a	2.70 a

*Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

Table 5.3.5 Mean values of organic matter percentage
Sand site - 1983 - Interaction effect.

TREATMENT	ORGANIC MATTER(%) (0-20 cm)
CO	4.82 a
RO	4.22 ab
ZI	3.89 b
RI	3.88 b
ZO	3.67 b
CI	3.38 b

presents the mean values for the treatment combinations of organic matter contents in the sand site topsoil at the end of the 1983 growing season. The incorporation of the dairy cattle manure (organic fertilizer) in the conventional and reduced tillage plots has carried a significant increase in their organic matter contents. There was no significant difference between any of the inorganically fertilized plots or the zero tillage plots fertilized with organic fertilizer. The latter showed no difference since the manure was not incorporated.

5.3.3 Soil Moisture Content

In order to observe the changes in soil volumetric moisture content, neutron probe readings were taken on 12 occasions from 20 to 97 days after seeding in the sand site during 1982. Observations were made to obtain the average water contents for each of three seperate layers, namely 0-30 cm, 30-60 cm, 60-90 cm. In 1983, readings were taken with the neutron probe in both the sand and clay sites eight times during the growing season from 30 to 65 days after seeding. Mechanical difficulties were encountered with the probe on July 22, 1983, preventing any further readings. Gravimetric moisture measurements in the topsoil, obtained while sampling for soil density 80 and 93 days after seeding, were converted to volumetric moisture content using the soil's bulk density, and are included in the presentation of the 1983 soil moisture results. The shallow bed of broken limestone present in the clay site precluded the measurement of volumetric moisture in the 60-90 cm range.

The changes in moisture content with time at each individual depth for the sand site 1982, sand site 1983 and clay site 1983 are presented graphically in Figures 5.3.4, 5.3.5 and 5.3.6, respectively. Observations were made for all tillage treatments receiving the inorganic fertilizer treatment and for the reduced and zero tilled plots receiving organic fertilizer, resulting in a total of five treatment combinations.

Figure 5.3.4 shows that in the first year, the conventional inorganic plots contained the least amount of water throughout most of the growing season. It does not appear that the treatments affected water use during the growing season through either evaporation or transpiration. The differences in volumetric moisture content between the five treatment combinations remained essentially the same throughout the year. The initial moisture contents however, were affected by the treatments, since it was at this time (20-30 days after seeding, Figure 5.3.4) that the differences first appeared. The reduced and zero tillage plots contained 2 to 6% greater moisture contents than the conventionally tilled plots. This increased moisture availability contributes to the plants increased resistance to prolonged periods without rainfall. The greater initial moisture contents in the spring and greater moisture retention during rainfalls, resulted from the presence of surface residues in the inorganic plots and from the application of manure on the organic plots. The manure acts in the same manner as would a surface residue, reducing evaporation and increasing infiltration.

The results from 1983, the second consecutive year of experimentation, were far more pronounced. In the sand site at 0-30 cm, the organic plots contained more moisture than the inorganic plots throughout the growing season (Figure 5.3.5). While the reduced and zero tillage plots

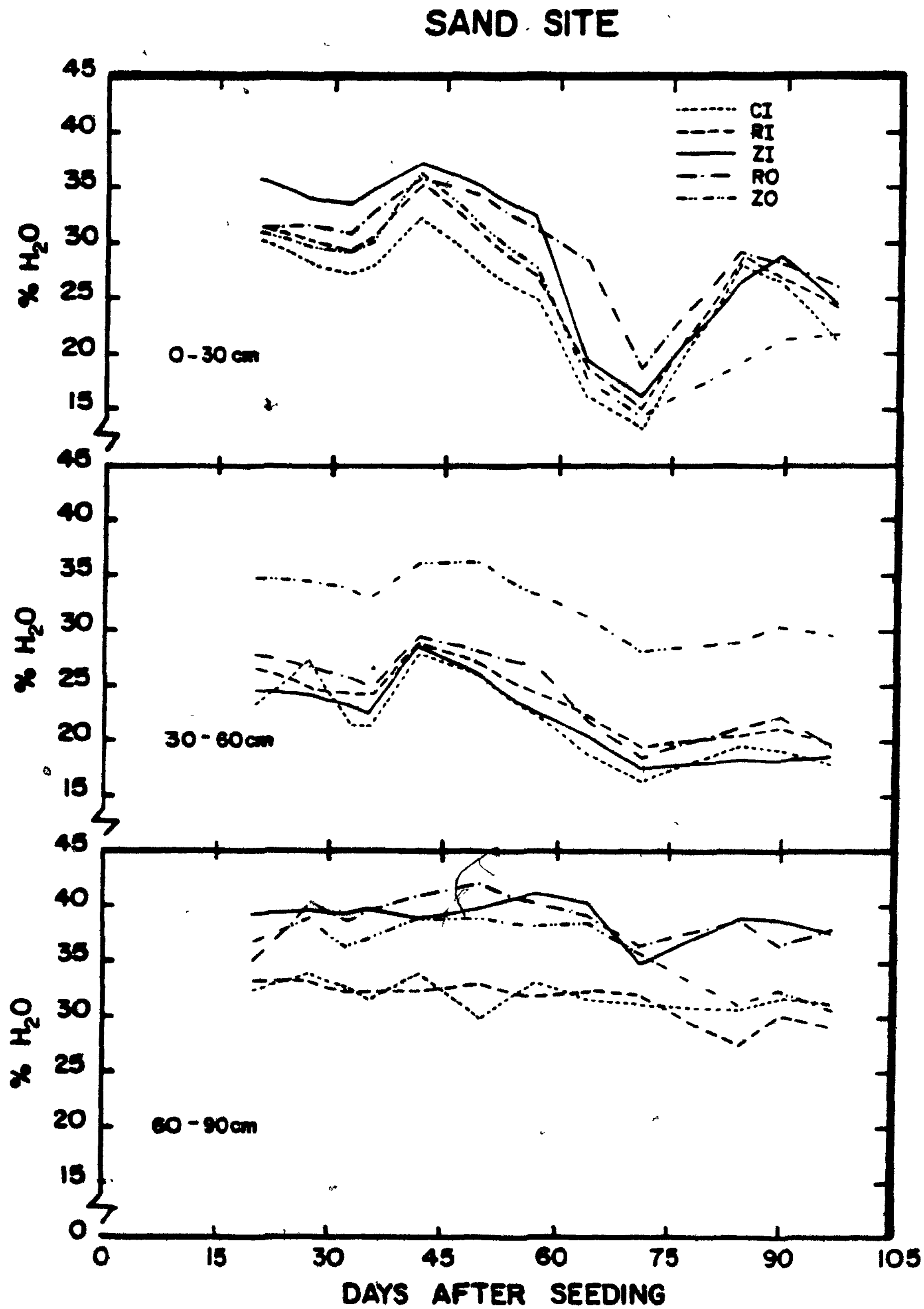


Figure 5.3.4. Soil volumetric moisture content with soil depth throughout the 1982 growing season under five different treatment combinations in the Sand site.

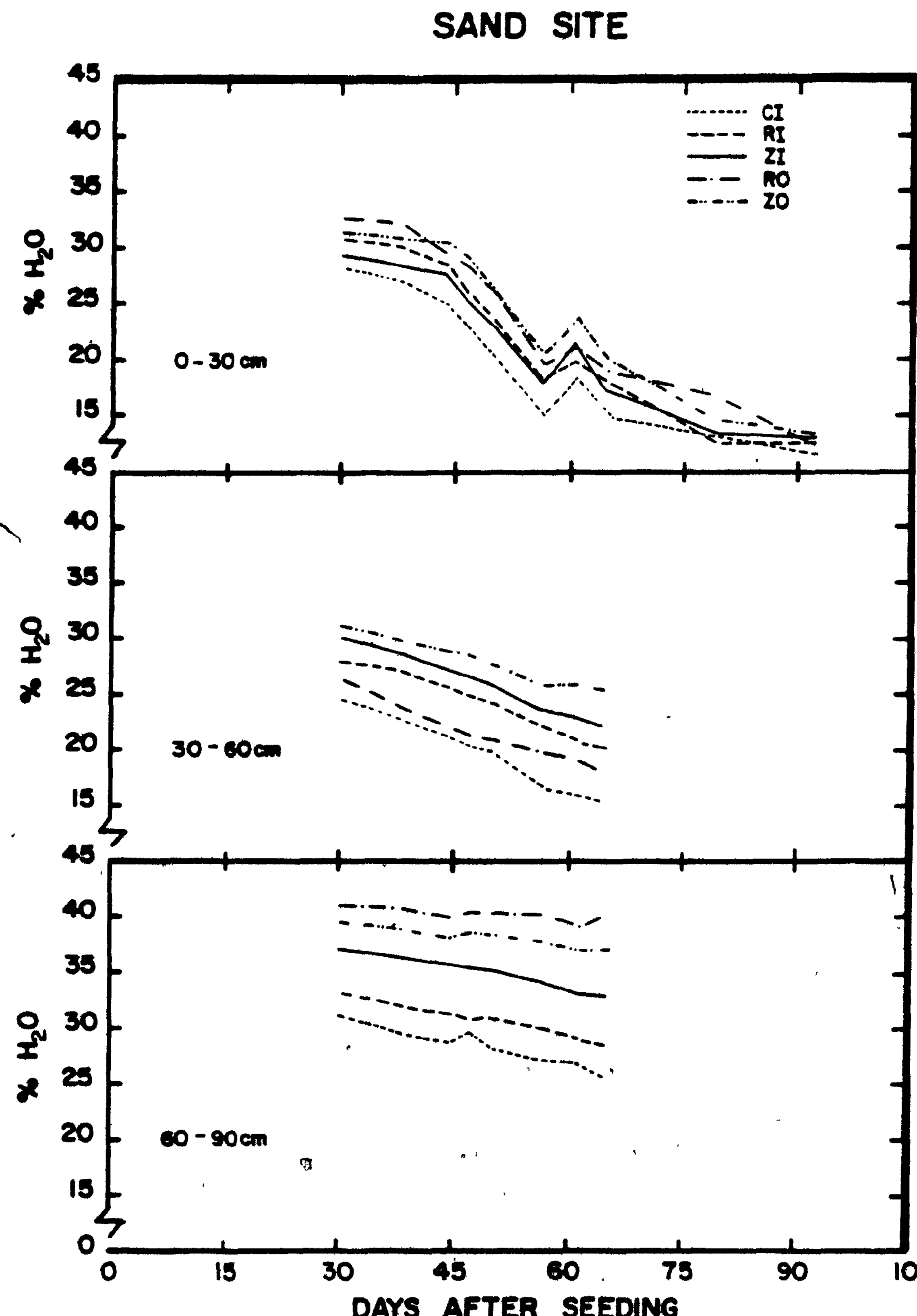


Figure 5.3.5. Soil volumetric moisture content with soil depth throughout the 1983 growing season under five different treatment combinations in the Sand site.

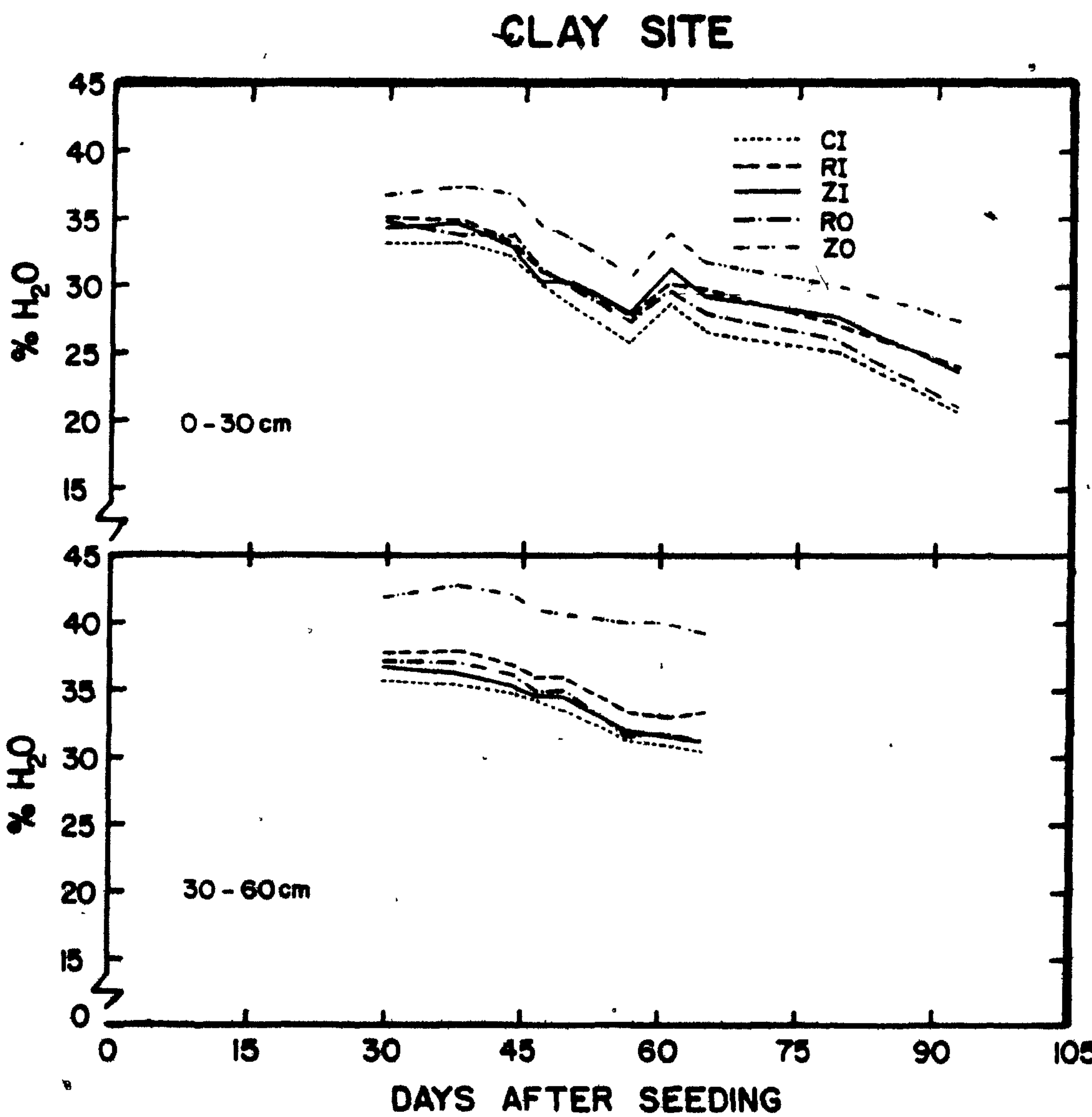


Figure 5.3.6. Soil volumetric moisture content with soil depth throughout the 1983 growing season under five different treatment combinations in the Clay site.

were not different from each other, the conventionally tilled inorganic plots were consistently 2-3% lower in moisture content. As was the case in 1982, these differences developed very early in the growing season due to the applied tillage and fertilizer treatments. In both the 30-60 and 60-90 cm layers similar trends were found (Figure 5.3.5). The results do not indicate a difference in rooting distribution, since water use during the season was almost the same under each treatment combination.

In the clay site (1983), the patterns of water removal were very similar to those in the sand site. Once the initial differences in moisture content were established, the curves of moisture content versus time remained essentially parallel (Figure 5.3.6). Once again, the zero tillage organic plots contained the most amount of water and the conventional inorganic plots held the least.

5.3.4 Soil Dry Bulk Density

Prior to the initiation of the experiment in April, 1982, soil dry bulk density measurements were taken in both the sand and clay sites. The means of three sets of readings are presented graphically in Figure 5.3.7. The sand site ranged from dry bulk density values of 1.07 to 1.17 t/m^3, while the clay site lay between 1.04 and 1.23 t/m^3.

In June 1982, three sets of density measurements were taken to depth of 25 cm in the clay and sand sites. Mean values of these dry bulk densities are presented in Table 5.3.6 and the corresponding analysis of

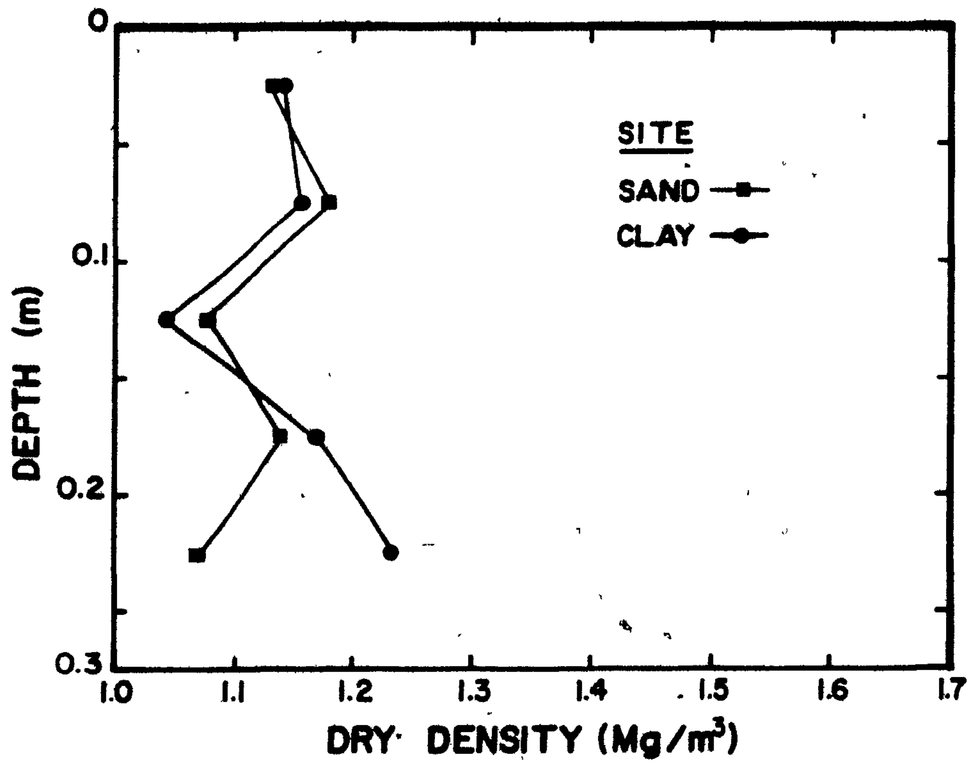


Figure 5.3.7. Variation in dry density with depth for the two experimental sites prior to initiation of the study - April 1982.

Table 5.3.6 Mean values of dry bulk density (g/cc)
Clay and Sand Sites - 1982

Clay Site

TILLAGE	DEPTH (cm) 0-5	5-10	10-15	15-20	20-25
C	1.19 a	1.25 a	1.19 a	1.35 a	1.31 a
R	1.14 b	1.22 a	1.18 a	1.25 b	1.17 b
Z	1.12 b	1.21 a	1.18 a	1.25 b	1.13 b
FERTILIZER					
I	1.15 a	1.23 a	1.20 a	1.27 a	1.20 a
O	1.15 a	1.23 a	1.17 a	1.30 a	1.21 a

Sand Site

TILLAGE	DEPTH (cm) 0-5	5-10	10-15	15-20	20-25
C	1.16 a	1.22 a	1.22 a	1.22 a	1.21 a
R	1.16 a	1.21 a	1.16 a	1.25 a	1.18 a
Z	1.18 a	1.20 a	1.14 a	1.22 a	1.11 b
FERTILIZER					
I	1.16 a	1.20 a	1.16 a	1.24 a	1.16 a
O	1.17 a	1.23 a	1.19 a	1.23 a	1.18 a

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

variance are in Tables B5.3.17 to B5.3.22 in Appendix B. In the clay site, the conventionally tilled plots were significantly more dense than either the reduced or zero tilled plots at depths 0-5, 15-20 and 20-25 cm. The increase at plowing depth can be explained by the action of the moldboard plow, but the difference in the topsoil is thought to be due to chance alone in as much as it was only the first year of measurements. The only statistically significant difference between the tillage treatments in the sand site was located at 20-25 cm, where the zero tillage plots were less dense. Graphs of these are presented in Figure 5.3.8. There were no effects of fertilizer source on dry bulk density in either site in 1982 (Table 5.3.6). Figure 5.3.9 shows graphs of density versus depth for the fertilizer treatments.

Seven sets of density measurements were taken during July and August 1983, to a depth of 30 cm. The mean values are presented in Table 5.3.7, and the corresponding analyses of variances are found in Table B5.3.23 through B5.3.28 in Appendix B.

The tillage effects on dry bulk density became very apparent in the second year of testing. In the top soil (0-5 cm) the zero tillage plots were significantly more dense than the conventional plots in both the clay and sand sites. These differences however were only 7 and 8% respectively, and in both cases less than a 0.10 t/m^3 increase in density. This increase, resulted from a lack of soil loosening and did not appear to be detrimental to the growth and development of the plant root system. The increased top soil density did however, cause problems in the clay soil in the spring, when the differences were more pronounced. Plant emergence was reduced by 9%

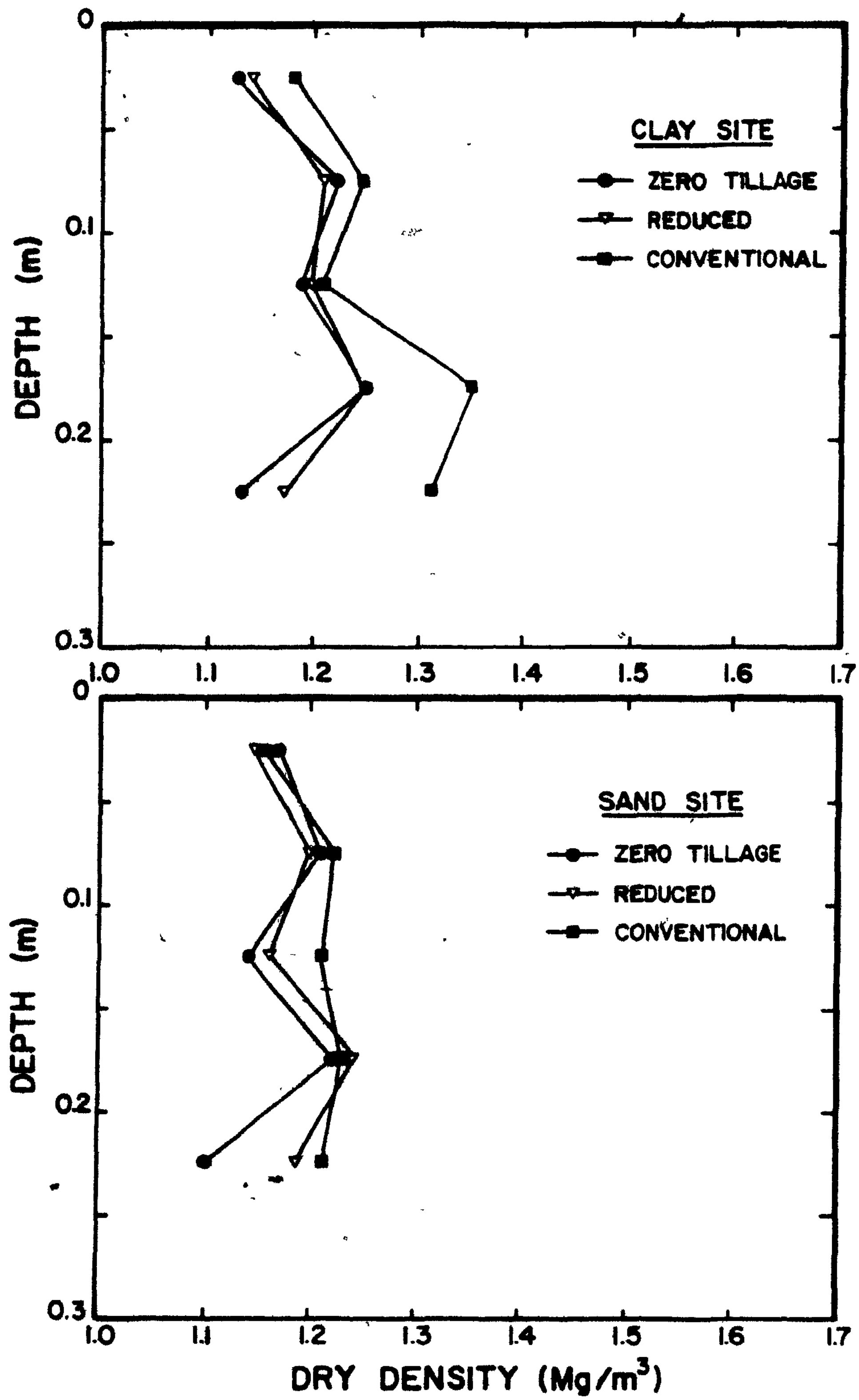


Figure 5.3.8. Variation in dry density with depth for different tillage treatments in the two experimental sites - 1982.

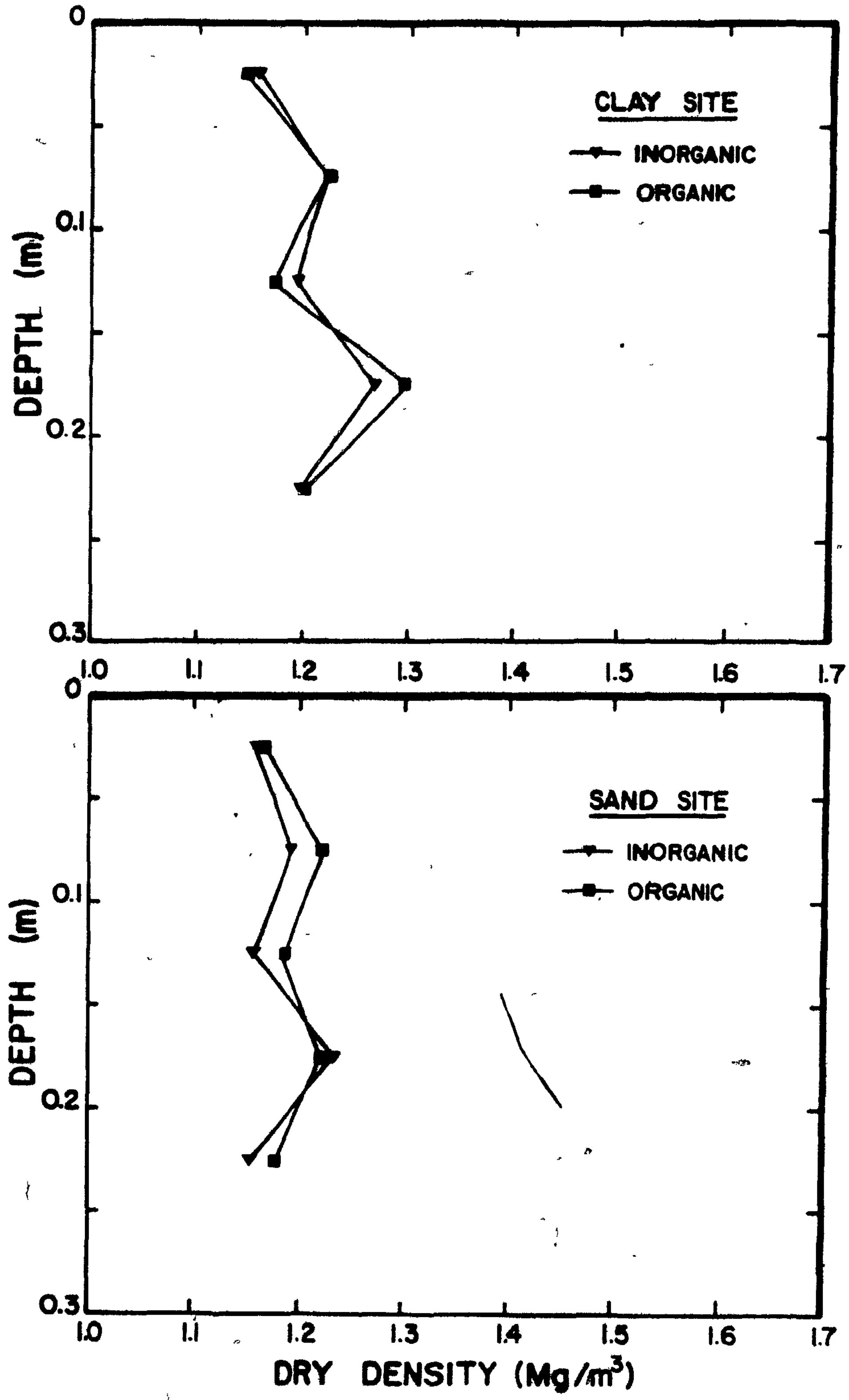


Figure 5.3.9. Variation in dry density with depth for different fertilizer treatments in the two experimental sites - 1982.

Table 5.3.7 Mean values of dry bulk density (g/cc)
Clay and Sand Sites - 1983

Clay Site

TILLAGE	DEPTH (cm) 0-5	5-10	10-15	15-20	20-25	25-30
C	1.19 b	1.32 a	1.35 a	1.46 a	1.43 a	1.54 a
R	1.22 ab	1.38 a	1.36 a	1.41 b	1.41 a	1.48 a
Z	1.27 a	1.33 a	1.32 a	1.37 c	1.38 a	1.51 a
FERTILIZER						
I	1.24 a	1.34 a	1.34 a	1.41 a	1.40 a	1.50 a
O	1.22 a	1.35 a	1.35 a	1.41 a	1.41 a	1.52 a

Sand Site

TILLAGE	DEPTH (cm) 0-5	5-10	10-15	15-20	20-25	25-30
C	1.15 b	1.24 c	1.24 a	1.38 a	1.28 a	1.41 a
R	1.14 b	1.28 b	1.29 a	1.36 b	1.29 a	1.40 a
Z	1.24 a	1.32 a	1.27 a	1.35 b	1.25 b	1.40 a
FERTILIZER						
I	1.22 a	1.29 a	1.28 a	1.39 a	1.30 a	1.42 a
O	1.13 b	1.26 b	1.25 a	1.34 b	1.25 b	1.39 a

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

in the zero tillage plots due to inadequate seed to soil contact caused by the lack of a perfect planting mechanism for these conditions (Kelly and McKyes 1984).

The development of a dense layer at 15-20 cm in the conventionally tilled plots, was seen in the second year in both sites (Table 5.3.7). This layer resulted from the action of the moldboard plow. Similar to the top soil effects observed in the zero tilled plots, these increases were less than 0.10 tk/m^3 and were not seen to cause any significant change in plant development. Perhaps in subsequent years, these differences could become magnified. Graphical presentation of the effects of tillage on the dry bulk density can be found in Figure 5.3.10.

Fertilizer source also had a very clear effect on soil density in 1983. In the sand site, the presence of organic fertilizer significantly reduced the bulk density at all but two depths (Table 5.3.7). Figure 5.3.11 depicts this trend graphically. The organic matter reduces the bulk density in the sandy loam soil, but to date has had no effect on density in the clay soil (Table 5.3.6 and Figure 5.M). This increased organic matter and reduced density results in a very favorable root zone condition for plant growth and nutrient uptake.

5.3.5 Harvest Results

The detailed results of harvest and plant population measurements are presented in Kelly and McKyes 1984. Table 5.3.8 shows a summary of these results. In 1982, in the sand site, the zero tillage dry matter yields were

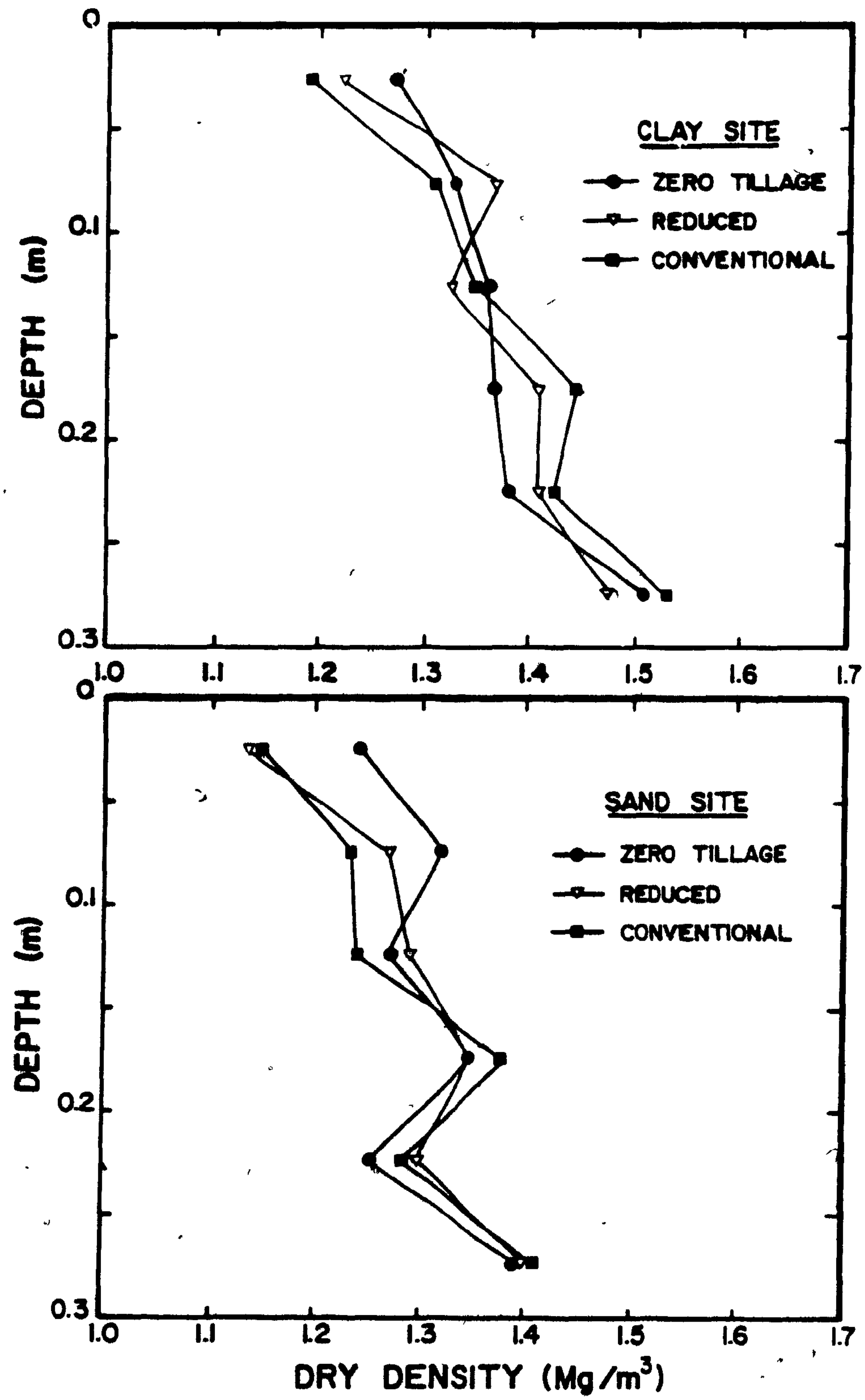


Figure 5.3.10. Variation in dry density with depth for different tillage treatments in the two experimental sites - 1983.

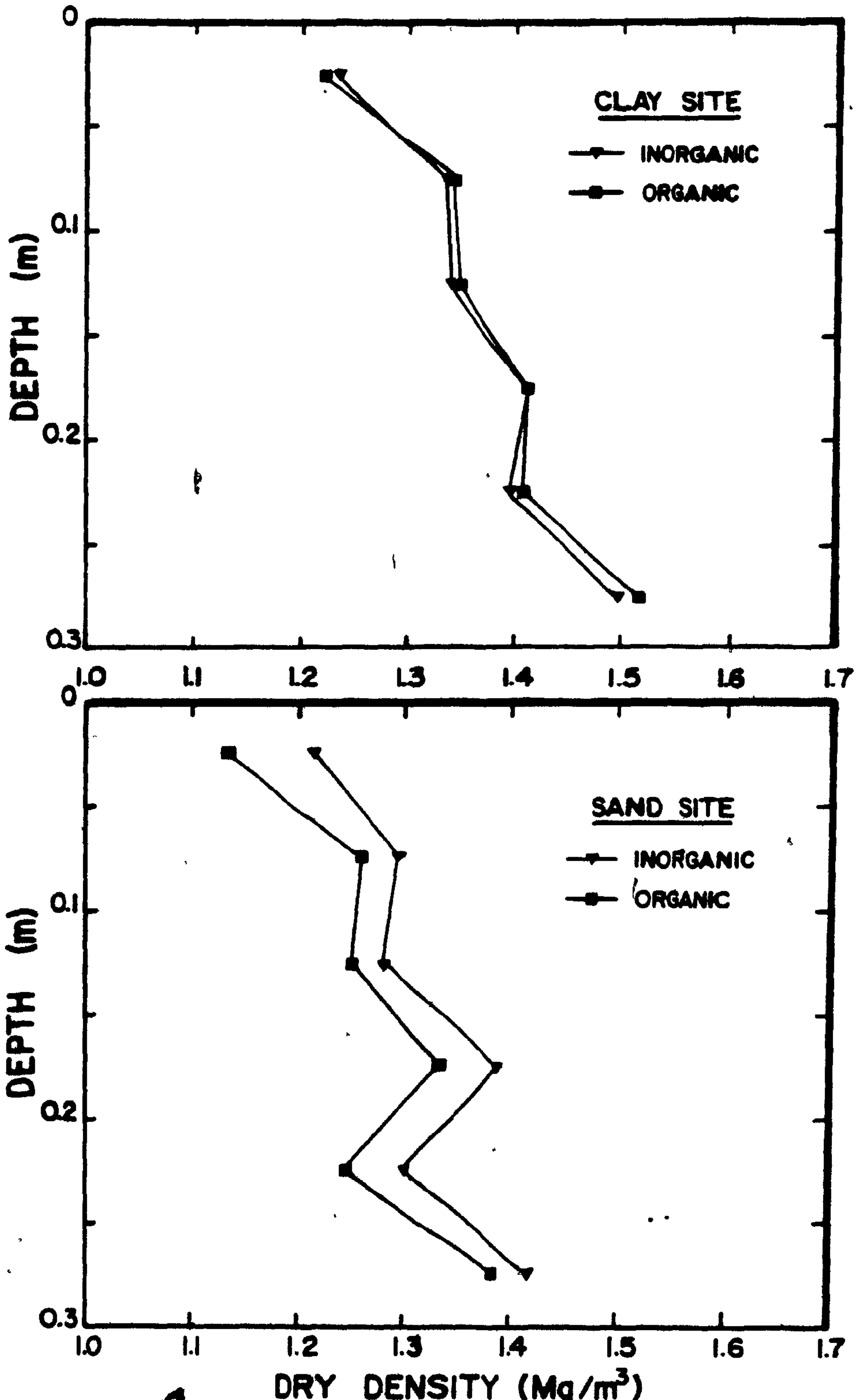


Figure 5.3.11. Variation in dry density with depth for different fertilizer treatments in the two experimental sites - 1983.

Table 5.3.8 Summary of harvest and plant population measurements Sand and Clay Sites - 1982 and 1983.

		1982 Sand Site	1983 Sand Site	1983 Clay Site
Harvest Yield (Mg/ha) (Dry Matter)				
TILLAGE				
	C	14.20 b	10.65 a	12.19 a
	R	16.23 a	10.94 a	11.75 ab
	Z	14.53 ab	9.60 b	11.20 b
FERTILIZER				
	I	15.68 a	10.15 a	11.80 a
	O	14.29 a	10.64 a	11.63 a
Plant Population (Per plot)				
TILLAGE				
	C	777 a	888 a	878 a
	R	803 a	867 a	809 b
	Z	720 a	777 b	804 b
FERTILIZER				
	I	887 a	865 a	825 a
	O	645 b	824 b	835 a
Yield / Plant (g)				
TILLAGE				
	C	222.0 a	144.2 a	167.0 a
	R	249.3 a	151.3 a	174.1 a
	Z	252.0 a	148.6 a	167.4 a
FERTILIZER				
	I	214.3 a	141.0 b	171.7 a
	O	267.8 b	155.1 a	167.3 a

* Means with the same letter are not significantly different at the 0.05 level using Duncan's new multiple range test.

not significantly different from either the reduced or conventional tillage plots. The reduced tillage plots did, however, yield significantly more than the conventional tillage plots, probably as a result of the increased moisture availability.

In 1983, fertilizer had no effect on the yield per plot, but tillage treatment significantly affected the dry matter yields. The zero tillage plots yielded 10 and 8% less than the conventional plots in the sand and clay sites respectively (Table 5.3.8). When one considers that the final plant populations were 12 and 8% less in zero tillage in plots (sand and clay sites) as compared to the conventional tillage plots, the yield per plant does not show any effect due to the tillage treatments (Table 5.3.8). In fact, the conventional tillage plots yielded the least amount of dry matter per plant. It is felt that this is a result of the reduced moisture availability in the critical growth stages during the very dry months of July and August 1983. It appears that, after two years, the changes in soil structure did not significantly affect plant growth or development.

Fertilizer source had no effect on plant yield, plot yield or plot population in the clay soil. In the sand site, although there was no significant yield difference between the two fertilizer treatments, the population was reduced by 4.7% in the organic plots. The increased organic matter and reduced bulk density contributed to an improved root zone, which resulted in 10% greater yields per plant in the organic plots. This increase in yield per plant does not seem to be caused by reduced interplant competition, since the population was only reduced by 4.7% and each plant produced 10% more dry matter. In addition,the reduction in population was caused by skips spaced randomly throughout the plot and not by increased interplant spacings.

5.4 Summary and Conclusions

The first two years of conventional, reduced and no tillage experiments provided contrasting weather conditions. The spring of 1982 was one of the driest on record while 1983 was one of the wettest. The balance of the 1982 growing season could be considered average, but the July-August period of 1983 received 45% less rain than the 30 year average.

Soil nutrient assays revealed levels of at least 200 kg/ha phosphorus and potassium in all plots at the end of two years of investigations and there were no differences present between any of the treatments. Salinity levels in all plots were well below 1 mmho/cm, which is the conductivity value when plant growth is affected by salt concentration in the soil.

An interaction effect between the tillage and cow manure fertilizer treatments on the organic matter content of the top soil (0-20 cm) appeared in the sand site at the end of 1983. Those plots receiving incorporated manure (conventional and reduced organic plots) had significantly higher organic matter levels than the inorganic fertilizer treatments, or the zero tilled organic plots.

The conventional inorganic plots contained less moisture than the other treatment combinations throughout both the 1982 and 1983 growing season in both the sand and clay sites. In 1983, the accumulation of more residues on the surface of the organic plots resulted in higher moisture contents than in the inorganic plots, due to reduced evaporation and increased infiltration early in the season.

In both years, the rooting distribution appeared to be the same between the plots since the rate of water removal from each layer determined from measurements in all treatment combinations was essentially the same. The initial differences in volumetric moisture content persisted through the entire growing season.

After the first two years of investigations, significant differences in layer dry bulk densities appeared in both the clay and sandy loam soils. In the top soil (0-5 cm) of both sites, the zero tillage plots were more dense than either the reduced or conventional tillage plots. The cause of this increase was implement traffic without any soil loosening. As a result, plant emergence problems were created in the clay soil only. At the depth of plowing (15-20 cm), the conventional plots were more dense than the zero tillage plots due to the action of the moldboard plow at that depth. This was seen to occur in both the sand and clay sites. The magnitude of the increase in dry density was less than 0.1 t/m^3 and was therefore considered not yet detrimental to root growth.

The organic fertilizer source reduced the dry bulk density in the sand site at four of the six depth layers measured. The organic matter addition in the clay soil did not affect its dry bulk density.

The first year's harvest results were encouraging for reduced tillage practices in that the reduced tillage plots produced a significantly higher amount of silage while the conventional and zero tillage plots were not significantly different from each other. In 1983, there were 8.1 and 9.8% reductions in yield due to the zero tillage treatment in the clay and sand sites respectively (both significant). The corresponding reductions in plot plant populations were 12 and 8%, resulting in no tillage effect on the yield of dry matter per plant.

There were no fertilizer effects on the harvest results in the clay soil in 1983. Those plots in the sand site fertilized with dairy cattle manure did however, produce more per plant than the inorganic plots.

On the basis of this study, the following conclusions can be drawn:

1. The incorporation of manure in conventional and reduced tillage plots significantly increased the organic matter content in the top soil.

2. Levels of phosphorus and potassium as well as salt concentrations were not affected in the first two years by the applied treatments.

3. Volumetric moisture contents early in the growing season were lower in conventionally tilled plots than in the reduced or zero tillage plots.

4. Soil moisture contents were higher in the reduced and zero tillage plots receiving the organic fertilizer treatment than in those plots receiving the inorganic fertilizer, due to the surface residues.

5. Zero tillage significantly increased the dry bulk density in the top soil (0-5 cm) in both the clay and sandy loam soils; as a result, plant

emergence and consequently plant population were reduced in both soils.

6. Conventional tillage plots contained a significantly more dense layer at 15-20 cm than the reduced or zero tillage plots, due to the action of the moldboard plow.

7. Although the zero tillage treatment reduced the plot yield in both soils in 1983, there was no tillage effect on the yield of dry matter per plant.

8. Fertilizer source did not affect the yield per plot or per plant in the clay soil. In the sandy loam soil, the organic fertilizer significantly increased the yield per plant but did not affect the total plot yield.

9. It would seem from the experiments reported, which were conducted with close to actual farming techniques and machinery, and in years of differing rainfall patterns, that both reduced and zero tillage are viable alternative silage corn production system components, which could be considered for practical application in southern Quebec and eastern Ontario. The results indicate, in addition, that it is possible to combine reduced energy input soil preparation systems with dairy cattle manure as the principal fertilizer source, without any deliterious effects on soil quality or sizeable reductions in crop yields.

5.5 References

Baeumer, K. 1970. First experiences with direct drilling in Germany. Neth. J. Agric. Sci. 18: 283-292.

Ball, B.C. 1981. Pore characteristics of soils from two cultivation experiments as shown by gas diffusivities and permeabilities and air-filled porosities. J. Soil Sci. 32: 483-489.

Barclay, J., G.S.V. Raghavan and E. McKyes. 1983. Zero/Minimum tillage techniques for corn production in Quebec. Vol. 2. Progress Report for Quebec Ministry of Agriculture. Grant Number MCA-83-1008. 127 pp.

Barnes, B.T. and F.B. Ellis. 1979. Effects of different methods of cultivation and direct drilling, and disposal of straw residues, on population of earthworms. J. Soil Sci., 3: 669-679

Bauder, J.W., G.W.Randell and J.B. Swan. 1981. Continuous tillage: what it does to the soil. Crops and Soils 34(3): 15-17.

Black, A.L. and J.F. Power. 1965. Effect of chemical and mechanical fallow methods on moisture storage, wheat yields and soil erodibility. Soil Sci. Soc. Amer. Proc. 29: 465-468

Blevins, R.L., D. Cook, S.H. Phillips and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 593-596.

Blevins, R.L., G.W. Thomas and P.L. Cornelius. 1977. Influence of no-tillage and nitrogen fertilization on certain soil properties after 5 years of continous corn. Agron. J. 69: 383-386.

Brar, S.S., J.S Dhaliwal, G.S. Gill, H.S. Sandhu and G.K. Singh. 1983. Continuous maize and wheat production under no-tillage and conventional tillage systems: a ten year study. In: F. Voigt (ed.), Proceedings of the 2nd international seminar on energy conservation and use of renewable energies in the bio-industries. Trinity College, Oxford, Britain. pp 100-107.

Cannell, R.Q., P.B. Davis, D. Mackney and J.D. Pidgeon. 1978. The suitability of soils for sequential direct drilling of combine harvested crops in Britain: a provisional classification. Outlook on Agriculture 9: 305-316.

Dickey, E.C. 1983. Yield comparisons between continuous no-till and tillage rotations. Trans. of the ASAE 26(6): 1682-1686.

Ehlers, W. 1975. Observations on earthworm channels and infiltration on tilled and untilled loess soil. Soil Sci. 119: 242-249.

Ehlers, W. 1976. Water infiltration and redistribution in tilled and untilled loess soil. Gattinger Boenkundliche Berichte, 44: 137-156.

Ehlers, W., U. Kopke, F. Hesse and W. Bohm. 1983. Penetration resistance and root growth of oats in tilled and untilled loess soil. Soil Tillage Res. 3: 261-275.

Ellis, F.B. and B.T. Barnes. 1980. Growth and development of root systems of winter cereals grown after different tillage methods including direct drilling. Plant and Soil 55: 283-295.

Estes, G.O. 1972. Elemental composition of Maize grown under no-till and conventional tillage. Agron. J. 64: 733-735.

Fink, R.J. and D. Wesley. 1973. Corn yield as affected by fertilization and tillage system. Agron. J. 65: 70-71.

Gantzer, C.J. and G.R. Blake. 1978. Physical characteristics of LeSueur clay loam soil following no-till and conventional tillage. Agron. J. 70: 853-857.

Gaultney, L., G.W. Krutz, G.C. Steinhardt and J.B. Liljedahl. 1980. Effects of subsoil compaction on corn yield i Indiana. ASAE Paper 80-1011, St. Joseph, Michigan 49085.

Gerard, B.M. and R.K. Hay. 1979. The effect on eartyworms of ploughing, tined cultivation, direct drilling and nitrogen in a barley monoculture system. J. Agric. Sci. 93: 147-155.

Hill, J.D. and R.L. Blevins. 1973. Quantitative soil moisture use in corn grown under conventional and no-tillage methods. Agron J. 65: 945-949.

Kelly, J.K. and E. McKyes. 1984. The influence of tillage, zero tilage and fertilizer sources on corn growth and yield. In Press.

Ketcheson, J.W. 1977. Effect of tillage on fertilizer requirements for corn on a silt loam soil. Agron. J. 72: 540-542.

McGregor, K.C. and J.D. Greer. 1982. Erosion control with no-till and reduced till corn for silage and grain. Trans. of the ASAE 25(1): 154-159.

Ministere de l'Agriculture des Pecheries et de l'Alimentation. 1984. Conseil des productions vegetales du Quebec: Mais culture. CPVQ-1984 21pp.

Moomaw, R.S. and A.R. Martin. 1978. Weed control in reduced tillage corn production system. Agron. J. 70: 91-94.

Moschler, W.W., G.M. Shear, D.C. Martens, G.D.Jones and R.R. Wilmouth. 1972. Comparative yields and fertilizer efficiency of no-tillage and conventionally tilled corn. Agron. J. 64: 229-231.

Negi, S.C., G.S.V. Raghavan and F. Taylor. 1981. Hydraulic characteristics of conventionally and zero tilled field plots. Soil and Tillage Rès. 2: 281-292.

O'Sullivan, M.F. 1983. Water regimes in ploughed and direct drilled soils under cereals: a literature review. Dep. Note SIN/381 Scot. Inst. Agric. Eng. Penicuik (unpubl).

Phillips, S.H. and R.E. Phillips. 1984. No tillage agriculture: Principles and practices. Van Nostrand Reinhold Co. New York. 306pp.

Pidgeon, J.D. and B.D. Soane. 1977. Effects of tillage and direct drilling on soil properties during the growing season in a long-term barley monoculture system. J. Agric. Sci. 88(2): 431-442.

Pope, R.A. 1982. Soil compaction. Conservation tillage for crop production. Inst. of Ag. and Nat. Res., Univ. of Nebraska, Lincoln. Tillage conf. proc. No 1.

Richards, L.A. 1969. Diagnosing and improvement of saline and alkai soils. Agriculture handbook No. 60 USDA. 160pp.

Shear, G.M. and W.W. Moschler. 1969. Continous corn by the no-tillage and conventional tillage methods: A six year comparison. Agron. J. 61: 524-526.

Taylor, F., G.S.V. Raghavan, E. McKyes, S. Negi, E Douglas and E. Stemshorn. 1980. Soil structure and corn (maize) yields under conventional and minimum tillage methods. ASAE Paper 80-1025, St. Joseph Michigan 49085. 10pp.

Taylor, F., S. Negi, G.S.V. Raghavan and E. McKyes. 1981. The effects of minimum tillage on corn growth in eastern Canadian agricultural soils. Final report, Engineering and Statistical Research Institute. Agriculture Canada, Ottawa (Ontario) 143pp.

Tollner, E.W. and W.L. Hargrove. 1982. Assesing the physical condition of a Piedmont soil under long term conventional and no tillage. ASAE Paper 82-1514, St. Joseph Michigan 49085. 15pp.

Triplett, G.B. 1973. An evaluation of Ohio soils in relation to no-tillage corn production. Wooster. pp 20.

Triplett, G.B. and D.M. van Doren. 1969. Nutrient utilization of no-tillage corn. Ohio Rep. Res. Develop. Agri. Home Econ. Natur. Resor. 54(4): 59-60.

Triplett, G. and D.M. Van Doren. 1977. Agriculture without tillage. Scientific Amer. 236: 28-33.

Trouse, A.C. 1971. Soil conditions as they affect plant establishment, root conditions and yield. In: K.K. Barnes (ed.) Compaction of agricultural soils. ASAE Monograph. St. Joseph Michigan 49085. 306pp.

van Ouerkerk, C and F.R. Boone. 1970. Soil physical aspects of zero tillage experiments. Neth. J. Agric. Sci. 18: 247-261.

Voorhees, W.B. 1982. Soil compaction may cause a problem with conservation tillage. Research News, USDA-ARS, NC-106.

Weatherley, A.B. and J.H. Dane. 1979. Effect of tillage on soil-water movement during corn growth. Soil Sci. Soc. Amer J. 43: 1222-1225.

Chapter 6

Overall Conclusions

The results presented here encompass the first two years of an experiment which could hold promise for alterations to the well accepted farming techniques practiced in southwestern Quebec and eastern Ontario. For almost 100 years, routine moldboard plowing and successive diskings of the land have been carried out in the fall and spring preparing for the planting and growth of almost every field crop. The advent of commercially manufactured fertilizers enabled farmers to dramatically increase their yields. The economic cost of this increased yield rises each year as the cost of manufacturing increases.

This study chose to examine the production of silage corn, since nearly all the farmers in this area produce some silage corn and the input costs in terms of fuel, fertilizer and herbicides are among the highest for any field crop. In addition to the potential savings to be derived from alternate tillage systems or alternate fertilizer sources, the transition from conventional or accepted farming techniques to these alternate corn production systems is relatively simple.

Perhaps the most important element involved in this transition is the corn planter. A conservation type planter or a standard planter with a heavy frame and heavy duty coulters for both seed trench opening and fertilizer placement is necessary to cut through the previous year's trash and to penetrate the more dense surface layers (0-5 cm) usually experienced with zero tillage. Proper adjustment of each planting unit's down pressure springs aids greatly in achieving the desired objectives. The problem of reduced plant populations due to the tillage treatments, seen in this experiment, could be alleviated in this way.

The results of this two year study also indicated no effect of reduced or zero tillage on soil nutrient content. Therefore, no change in the application rate of the macro nutrients (N, P, K) is required with these alternate systems. Weed densities were also studied and no large differences appeared, therefore, herbicide application rates should be the same for all of the alternate production schemes studied here.

The use of dairy cattle manure as the only N source proved to be very successful in the clay soil with all three tillage treatments. Yield levels were maintained and organic matter levels were increased in those plots where the manure was incorporated. The only problem associated with the use of organic fertilizer in the clay soil was a 13% reduction (1% absolute) in crude protein content of the silage as compared to the inorganically fertilized plots. In the sandy loam soil, however, the use of these quantities of fresh manure caused a reduction in overall plant population. It was believed that the low adsorptive capacity of these soils (not found in a clay soil) allowed the manure to become toxic to a small percentage of the seedlings. In addition, the crude protein content was reduced by 22% in those sandy loam plots fertilized organically. Care should therefore be exercised in utilizing manure as the only N source on sandy soils.

By removing the effects of the reduced populations (due to the zero and reduced tillage treatments), and looking at the yield on a per plant basis, it can be seen that dry matter yield levels can be maintained through the use of zero or reduced tillage.

In conclusion, one important point must be emphasized. This was a two year study and the results are not necessarily extendable to the long term use of these techniques. Instead, these recommendations are intended to provide information for the farmers or researchers about the performance of these systems only in the first two years of their usage.

Both reduced and zero tillage systems with inorganic fertilizer are therefore viable alternative corn production system components. The use of dairy manure as the principal fertilizer source, with conventional, reduced or zero tillage in a clay soil and with either conventional or reduced tillage in a sandy loam soil would also be feasible in southwestern Quebec and eastern Ontario. None of the above alternative systems should have any detrimental effects on soil quality or cause any sizeable reductions in crop yields. These systems should also provide large economic, energy and equipment savings which will prove to be very beneficial to the farmer in the short term.

Chapter 7

Suggestions for Further Research

On the basis of this study, it is recommended that the following investigations be carried out in order to gain further knowledge of the use of alternate corn production systems:

1. An experiment should be set up to investigate grain corn production with the use of these alternate tillage and fertilizer techniques. The large volume of surface trash remaining after harvest, will give rise to a whole new set of problems. Seeding will be much more difficult and weeds, diseases and insects will be present in larger quantities than found when investigating silage corn production. The potential for savings, however, is greater than for silage corn since the total number of acres devoted to grain corn exceeds the total for silage corn.

2. In order to make long term recommendations, the experiment must be continued, and investigations made on the cumulative effects of several years of continuous application of these alternate corn production systems.

3. Soil moisture characteristic curves should be obtained to aid in understanding the differences found in volumetric moisture contents throughout the growing season.

4. An experiment should be set up to investigate the effects of applying fresh dairy cattle manure on a sandy soil. Soil nutrient levels, acid content and salinity levels should be closely monitored immediately after application until two to three weeks after emergence of the corn plants.

5. Infiltration measurements should be taken to quantify the effects of surface residue and tillage system on both infiltration and runoff.

6. A new experiment should be set up to develop different application techniques of organic fertilizer (manure) on zero tillage plots. This procedure would involve ways of incorporating the manure into the surface layers to reduce the nitrogen losses to the atmosphere.

7. Development of a small plot manure spreader, to accurately and evenly dispense known quantities of manure, would greatly reduce the input labour requirements in this type of research project.

REFERENCES

Baeumer, K. 1970. First experiences with direct drilling in Germany. Neth. J. Agric. Sci. 18: 283-292.

Ball, B.C. 1981. Pore characteristics of soils from two cultivation experiments as shown by gas diffusivities and permeabilities and air-filled porosities. J. Soil Sci. 32: 483-489.

Bandel, V.A., S. Dzienia, G. Stanford and J.O. Legg. 1975. N behavior under no-till vs. conventional corn culture. I: First year results using unlabelled N fertilizer. Agron. J. 67: 782-786.

Bandel, V.A., S. Dzienia and G. Stanford. 1980. Comparison of N fertilizer for no-till corn. Agron. J. 72: 337-341.

Barclay, J., G.S.V. Raghavan and E. McKyes. 1983. Zero/Minimum tillage techniques for corn production in Quebec. Vol. 2. Progress Report for Quebec Ministry of Agriculture. Grant Number MCA-83-1008. 127 pp.

Barnes, B.T. and F.B. Ellis. 1979. Effects of different methods of cultivation and direct drilling, and disposal of straw residues, on population of earthworms. J. Soil Sci., 3: 669-679

Bauder, J.W., G.W.Randell and J.B. Swan. 1981. Continuous tillage: what it does to the soil. Crops and Soils 34(3): 15-17.

Bennet, O.L. 1977. Conservation tillage in the northeast. In: Conservation tillage: problems and potentials. Publ. by Soil Cons. Soc. Amer. Spec. Publ. 20, 7515 Northeast Ankeny, Road, Ankeny, Iowa 50021.

Black, A.L. and J.F. Power. 1965. Effect of chemical and mechanical fallow methods on moisture storage, wheat yields and soil erodibility. Soil Sci. Soc. Amer. Proc. 29: 465-468

Blevins, R.L., D. Cook, S.H. Phillips and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 593-596.

Blevins, R.L., G.W. Thomas, M.S. Smith, W.W. Frye and P.L. Cornelius. 1983. Changes in soil properties after 10 years continuous non-tilled and conventionally tilled corn. Soil Tillage Res. 3: 135-146.

Blevins, R.L., G.W. Thomas and P.L. Cornelius. 1977. Influence of no-tillage and nitrogen fertilization on certain soil properties after 5 years of continous corn. Agron. J. 69: 383-386.

Blevins, R.L., L.W. Murdock and G.W. Thomas. 1978. Effect of Lime application on no-tillage and conventionally tilled corn. Agr. J. 70: 322-326.

Brar, S.S., J.S Dhaliwal, G.S. Gill, H.S. Sandhu and G.K. Singh. 1983. Continuous maize and wheat production under no-tillage and conventional tillage systems: a ten year study. In: F. Voigt (ed.), Proceedings of the 2nd international seminar on energy conservation and use of renewable energies in the bio-industries. Trinity College, Oxford, Britain. pp 100-107.

Cannell, R.Q., P.B. Davis, D. Mackney and J.D. Pidgeon. 1978. The suitability of soils for sequential direct drilling of combine harvested crops in Britain: a provisional classification. Outlook on Agriculture 9: 305-316.

Cannell, R.Q. and F.B. Ellis. 1979. Simplified cultivation: effects on soil conditions and crop yield. Letcombe Laboratory, Letcombe Regis, Wantage, Oxon. OX12 9JT.

Chase, R.W., and W.F. Meggit. 1976. No till corn. 4. Weed control. Michigan State University Cooperative Extension Service Bulletin E-907. pp. 2.

Davies D.B., D.J. Eagle and J.B. Finney. 1979. Soil management. Farming Press Ltd., Suffolk, U.K. pp. 254.

Dickey, E.C. 1983. Yield comparisons between continuous no-till and tillage rotations. Trans. of the ASAE 26(6): 1682-1686.

Doleski, J.D., J.J. Rappa and C. Smith. 1981. Ontario County 1980 No-Till Project final report. USDA Service Center Canandaigui, New York. 62pp.

Dull, S. 1979. Tillage: More interest in less. The Furrow 84: 2-5.

Ehlers, W. 1975. Observations on earthworm channels and infiltration on tilled and untilled loess soil. Soil Sci. 119: 242-249.

Ehlers, W. 1976. Water infiltration and redistribution in tilled and untilled loess soil. Gattinger Boenkundliche Berichte, 44: 137-156.

Ehlers, W., U. Kopke, F. Hesse and W. Bohm. 1983. Penetration resistance and root growth of oats in tilled and untilled loess soil. Soil Tillage Res. 3: 261-275.

Elliot, J.G., F.B. Ellis and F. Pollard. 1977. Comparison of direct drilling, reduced cultivation and ploughing on the growth of cereals. 1. Spring barley on a sandy loam soil: Introduction, aerial growth and agronomic aspects. J. Agric. Sci. Camb. 89: 621-629.

Ellis, F.B. and B.T. Barnes. 1980. Growth and development of root systems of winter cereals grown after different tillage methods including direct drilling. Plant and Soil 55: 283-295.

Erbach, D.C. 1982. Tillage for continuous corn and corn-soybean rotation. Trans. of A.S.A.E. 25(4): 906-918.

Estes, G.O. 1972. Elemental composition of Maize grown under no-till and conventional tillage. Agron. J. 64: 733-735.

Fenster, C.R. 1977. Conservation tillage in the northern plains. In: Conservation tillage: problems and potentials. Publ. by Soil Cons. Soc. Amer. Spec. Publ. 20, 7515 Northeast Ankeny Road, Ankeny, Iowa 50021.

Fenster, C.R. and G.A. Wicks. 1976. Minimum tillage systems reduce wind erosion. ASAE Paper No. 76-2032.

Fink, R.J. and D. Wesley. 1974. Corn yield as affected by fertilization and tillage system. Agron. J. 66: 70-71.

Fox, R.H. 1978. Nitrogen on no-till corn creates acid soil surface. Scince in Agr. 25: 14.

Fox, R.H. and L.D. Hoffman. 1981. The effect of N fertilizer source on grain yield, N uptake, soil pH, and lime requirement in no-till corn. Agron. J. 73: 891-895.

Frye, W.W., R.L. Blevins, L.W. Murdock and K.L. Wells. 1981. Energy conservation in no-tillage production of corn. In: Crop porduction with conservation in the 80's. ASAE St. Joseph, Michigan. Publ 7-81: 255-262.

Gantzer, C.J. and G.R. Blake. 1978. Physical characteristics of LeSueur clay loam soil following no-till and conventional tillage. Agron. J. 70: 853-857.

Gaultney, L., G.W. Krutz, G.C. Steinhardt and J.B. Liljedahl. 1980. Effects of subsoil compaction on corn yield i Indiana. ASAE Paper 80-1011, St. Joseph, Michigan 49085.

Gerard, B.M. and R.K. Hay. 1979. The effect on eartyworms of ploughing, tined cultivation, direct drilling and nitrogen in a barley monoculture system. J. Agric. Sci. 93: 147-155.

Greacen, E.L. 1983. Tillage research in semi-arid environment. Guest Editorial. Soil and Tillage Res. 3:107-109.

Griffith, D.R. 1974. Fertilization and no-plow tillage. Proc. Indiana Plant Food and Agr. Chemical Conf., Dept. Agron., Purdue Univ., West Lafayette, Indiana.

Griffith, D.R., J.V. Mannering and W.C. Moldenhauer. 1977. Conservation tillage in the Eastern corn belt. In: Conservation tillage: problems and potentials. Soil Cons. Soc. Amer. Spec. Publ. 20; Ankeny, Iowa.

Griffith, D.R., S.D. Parsens, J.V. Mannering and D.H. Daster. 1982. Estimating yield variations due to changing tillage. ASAE Paper No. 82-1510.

Griffith, D.R. and S.D. Parsons. 1980. Energy requirements for various tillage-planting systems. (Tillage) ID-141. Cooperative Extension Service, Purdue University, W. Layfayette Indiana.

Harrold, L.L., G.B. Triplett, Jr. and W.M. Edwards. 1970. No-tillage corn - characteristics of the system. Agric. Eng. 51(3): 128-131.

Harrold, L.L. and W.M. Edwards. No-tillage system reduces erosion from continuous corn watersheds. Trans. of the ASAE 17(3): 414-416.

Hill, J.D. and R.L. Blevins. 1973. Quantitative soil moisture use in corn grown under conventional and no-tillage methods. Agron J. 65: 945-949.

Hinesly, T.D., E.L. Knake and R.D. Seif. 1967. Herbicide versus cultivation for corn with two methods of seedbed preparation. Agron. J. 59: 509-512.

Jones, J.N. Jr., J.E. Moody and J.H. Lillard. 1969. Effects of tillage, no-tillage and mulch on soil water and plant growth. Agron. J. 61: 719-721.

Kang, B.T. and M. Yunusa. 1977. Effect of tillage methods and phosphorus fertilizer on maize in the humid tropics. Agron. J. 69: 291-294.

Kelly, J.K. and E. McKyes. 1984. The effects of tillage, zero tillage and fertilizer sources on soil structure, nutrient and moisture distribution in silage corn production. In Press.

Kelly, J.K. and E. McKyes. 1984. The influence of tillage, zero tilage and fertilizer sources on corn growth and yield. In Press.

Ketcheson, J.W. 1977. Conservation tillage in eastern Canada. J. Soil Water Conservation. 32: 57-60.

Ketcheson, J.W. 1980. Tillage effects on fertilizer requirements for corn. Agr. J. 72: 540-542.

Klausner, S.D. and R.W. Guest. 1981. Influence of NH_3 conservation from dairy manure on the yield of corn. Agron. J. 73: 720-723.

Lal, R. 1976. No-tillage effects on soil properties under different crops in western Nigeria. Soil Sci. Soc. Amer. J. 40: 762-768.

Lal, R. 1979. Influence of six years of no-tillage and conventional plowing on fertilizer response of maize (Zea mays L.) on an alfisol in the tropics. Soil Sci. Soc. Amer. J. 43:399-403.

Larson, W.E. and J.J. Hanway. 1976. Corn and corn improvement. ASA monograph É18. Madison, Wisconsin. Chap. 11: 625-669.

Lauer, D.A., D.R. Bouldin and S.D. Klaisner 1976. Ammonia volatilization from dairy manure spread on the soil surface. J. Environ. Qual. 2: 134-141.

Lindsay, J.I., S. Osei-Yebook and F.A. Gumbs. 1983. Effect of different tillage methods on maize growth in a tropical inceptisol with impeded drainage. Soil Tillage Res. 3: 185-196.

McGregor, K.C., J.D. Greer and G.E. Gurley. 1975. Eroision control with no-till cropping practices. A.S.A.E. Trans. 18: 918-920.

McGregor, K.C. and J.D. Greer. 1982. Erosion control with no-till and reduced till corn for silage and grain. Trans. of the ASAE 25(1): 154-159.

McIntosh, J.L. and K.E. Varney. 1972. Accumulative effects of manure and N on continuous corn and clay soil. 1. Growth, yield and nutrient uptake of corn. Agron. J. 64: 374-379.

McKee, G.W. 1964. A coefficient for computing leaf area in hybrid corn. Agron J. 56: 240-241.

McKyes, E., S. Negi, E. Douglas, F. Taylor and G.S.V. Raghavan. 1979. The effect of machinery traffic and tillage operations on the physical properties of a clay and on yield of silage corn. J. Agric. Eng. Res. 24(2): 143-148.

Mengel, D.B., D.W. Nelson and D.M. Huber. 1982. Placement of nitrogen fertilizer for no-till and conventional till corn. Agron. J. 74: 515-518.

Meyer, L.D. and J.V. Mannering. 1967. Tillage and land modification for water erosion control. In: Tillage for greater crop production. ASAE Publication Proc. 168.

Ministere de l'Agriculture des Pecheries et de l'Alimentation. 1984. Conseil des productions vegetales du Quebec: Mais culture. CPVQ-1984 21pp.

Moomaw, R.S. and A.R. Martin. 1978. Weed control in reduced tillage corn production system. Agron. J. 70: 91-94.

Moschler, W.W., D.C. Martens, C.I. Rich and G.M. Shear. 1973. Comparative lime effects on continuous no-tillage and conventional tilled corn. Agron. J. 65: 781-783.

Moschler, W.W., G.M. Shear, D.C. Martens, G.D.Jones and R.R. Wilmouth. 1972. Comparative yields and fertilizer efficiency of no-tillage and conventionally tilled corn. Agron. J. 64: 229-231.

Moschler, W.W. and D.C. Martens. 1975. Nitrogen, phosphorus and potassium requirements in no-tillage and conventionally tilled corn. Proc. Soil Sci. Amer. 39(5): 886-891.

Musick, G.J. and H.B. Petty. 1979. Insect control in conservation tillage systems. In: Conservation tillage. A handbook for farmers. Publ. by Soil Cons. Soc. Amer. Ankeny, Iowa 50021.

Negi, S.C., E. McKyes, F. Taylor, E. Douglas and G.S.V. Raghavan. 1980. Crop performance as affected by traffic and tillage in a clay soil. Trans. of ASAE 23(6): 1364-1368.

Negi, S.C., G.S.V. Raghavan and F. Taylor. 1981. Hydraulic characteristics of conventionally and zero tilled field plots. Soil and Tillage Res. 2: 281-292.

Nelson, J.V., L.S. Robertson, M.H. Erdmann, R.G. White and D. Quisenberry. 1976. No-till corn: 1 - Guidelines. Mich. State Univ. Extension Bulletin E-904. 4pp.

O'Sullivan, M.F. 1983. Water regimes in ploughed and direct drilled soils under cereals: a literatúre review. Dep. Note SIN/381 Scot. Inst. Agric. Eng. Penicuik (unpubl).

Olson, T.C. and S. Schoeberl. 1970. Corn Yields, soil temperature and water use with four tillage methods in the western corn belt. Agron. J. 62: 229-232.

Papendick, R.I. and D.E. Miller. 1977. Conservation tillage in the pacific northwest. In: Conservation tillage: problems and potentials. Publ. by Soil Cons. Soc. Amer. Spec. Publ. 20, Ankeny, Iowa 50021.

Phillips, R.E., R.L. Blevins, G.W. Thomas, W.W. Frye and S.H. Phillips. 1980. No-Tillage agriculture. Science 208: 1108-1113.

Phillips, S.H. and R.E. Phillips. 1984. No tillage agriculture: Principles and practices. Van Nostrand Reinhold Co. New York. 306pp.

Pidgeon, J.D. 1979. Tillage in the 80's. Agri-Book Magazine 5: 116-118.

Pidgeon, J.D. and B.D. Soane. 1977. Effects of tillage and direct drilling on soil properties during the growing season in a long-term barley monoculture system. J. Agric. Sci. 88(2): 431-442.

Pope, R.A. 1982. Soil compaction. Conservation tillage for crop production. Inst. of Ag. and Nat. Res., Univ. of Nebraska, Lincoln. Tillage conf. proc. No 1.

Raghavan, G.S.V., F. Taylor, S. Negi, E. Douglas, E. McKyes, S. Tessier, J. Burrows and A.K. Watson. 1981. Zero-tillage and corn production in eastern Canada. In ASAE National Energy Symposium. ASAE publication 4-81. Vol. 2: 433-441.

Reicosky, D.C., D.K. Cassel, R.L. Blevins, W.R. Gill and G.C. Naderman. 1977. Conservation tillage in the southwest. In: Conservation tillage: problems and potentials. Publ. by Soil Cons. Soc. Amer. Spec. Publ. 20, Ankeny, Iowa 50021.

Richards, L.A. 1969. Diagnosing and improvement of saline and alkai soils. Agriculture handbook No. 60 USDA. 160pp.

Robertson, L.S. and A.E. Erikcson. 1978. Soil compaction: symptoms, causes, remedies: Crops and Soils (30(6)): 8-10.

Shear, G.M. and W.W. Moschler. 1969. Continous corn by the no-tillage and conventional tillage methods: A six year comparison. Agron. J. 61: 524-526.

Soane, B.D. and J.D. Pidgeon. 1975. Tillage requirement in relation to soil physical properties. Soil Sci. 119(5): 376-384.

Southwell, P.H. and J.W. Ketcheson. 1978. Energy and tillage practices. University of Guelph. Notes on Agric. XIV(1): 17-21.

Stanford, G., V. A. Bandel, J.J. Meisinger, and J.O. Legg. 1979. N behavior under no till and conventional corn culture. II: Grain and forage yields in relation to amounts of N applied and total N uptake. Agron. Abs. p 183.

Taylor, F., G.S.V. Raghavan, E. McKyes, S. Negi, E Douglas and E. Stemshorn. 1980. Soil structure and corn (maize) yields under conventional and minimum tillage methods. ASAE Paper 80-1025, St. Joseph Michigan 49085. 10pp.

Taylor, F., G.S.V. Raghavan, S.C. Negi, E. McKyes, B. Vigier and A.K. Watson. 1981. Feasibility of minumum tillage in Quebec. ASAE Paper No. 81-322.

Taylor, F., S. Negi, G.S.V. Raghavan and E. McKyes. 1981. The effects of minimum tillage on corn growth in eastern Canadian agricultural soils. Final report, Engineering and Statistical Research Institute. Agriculture Canada, Ottawa (Ontario) 143pp.

Tollner, E.W. and W.L. Hargrove. 1982. Assesing the physical condition of a Piedmont soil under long term conventional and no tillage. ASAE Paper 82-1514, St. Joseph Michigan 49085. 15pp.

Triplett, G.B. 1973. An evaluation of Ohio soils in relation to no-tillage corn production. Wooster. pp 20.

Triplett, G.B., Jr., D.M. Van Doren, Jr. and W.H. Johnson. 1964. Non-plowed, strip tilled corn culture. Trans. ASAE 7: 105-107.

Triplett, G.B., Jr., and D.M. Van Doren, Jr. 1969. Nitrogen, phosphorus, and potassium fertilization of non-tilled maize. Agron. J. 61: 637-639.

Triplett, G.B., Jr. and G.D. Lytle. 1972. Control and ecology of weeds in continuous corn grown without tillage. Weed Sci. 20: 453-457.

Triplett, G.B. and D.M. van Doren. 1969. Nutrient utilization of no-tillage corn. Ohio Rep. Res. Develop. Agri. Home Econ. Natur. Resor. 54(4): 59-60.

Triplett, G. and D.M. Van Doren. 1977. Agriculture without tillage. Scientific Amer. 236: 28-33.

Trouse, A.C. 1971. Soil conditions as they affect plant establishment, root conditions and yield. In: K.K. Barnes (ed.) Compaction of agricultural soils. ASAE Monograph. St. Joseph Michigan 49085. 306pp...

Unger, P.W. and T.M. McCalla. 1980. Conservation tillage systems. In: Advances in Agronomy.

van Doren, D.M., G.B. Triplett and J.E. Henry. 1977. Influence of long-term tillage and crop rotation combinations on crop yields and selected soil parameters for an Aeric Ochraqualf soil. Ohio Agric. and Res. Development Centre Bulletin No. 1091. 27pp.

van Ouerkerk, C and F.R. Boone. 1970. Soil physical aspects of zero tillage experiments. Neth. J. Agric. Sci. 18: 247-261.

Vitosh, M.L. and D.D. Warncke. 1976. No-till corn: 2 - Fertilizer and liming practices. Mich. Stat Univ. Extension Bulletin E-905. 2pp.

Voorhees, W.B. 1976. Plant response to wheel traffic induced soil compaction in the northern corn belt of the United States. Proc. 7th Conf. Intern. Soil Tillage Res. Organ. 44: 1-6

Voorhees, W.B. 1982. Soil compaction may cause a problem with conservation tillage. Research News, USDA-ARS, NC-106.

Vyn, T.J., T.B. Daynard and J.W. Ketcheson. 1979. Tillage practices for field crops in Ontario. Ontario Agric. College, Univ. of Guelph, Guelph, Ontario. 49pp.

Weatherley, A.B. and J.H. Dane. 1979. Effect of tillage on soil-water movement during corn growth. Soil Sci. Soc. Amer J. 43: 1222-1225.

Webber, L.R. 1964. Soil physical properties and erosion control. J. Soil and Water Cons. 19: 28-30

Wimer, D.C. 1946. Why cultivate corn? Ill Circ. 597.

Wittmuss, H., L. Olson and D. Lane. 1975. Energy requirements for conventional versus minimum tillage for cultural operations in corn and sorghum production. J. Soil and Water Cons. 30(2): 72-75

APPENDIX A

STATISTICAL ANALYSIS OF PLANT GROWTH AND YIELD PARAMETERS

Table A4.3.1 Analysis of variance of days to emerge
Sand and Clay Sites - 1983

Sand Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3.889	0.556	1.22	0.375	0.461
Error	10	4.556	0.456			
Corr. Tot.	17	8.444				

C.V. = 4.673
Std. Dev. = 0.675
Mean = 14.44

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.444	1.59	0.252
Fertilizer	1	0.222	0.49	0.501
Tillage	2	0.778	0.85	0.455
Fert * Till	2	1.444	1.59	0.252

Clay Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	9.667	1.381	1.66	0.226	0.537
Error	10	8.333	0.833			
Corr. Tot.	17	18.000				

C.V. = 5.95
Std. Dev. = 0.913
Mean = 15.333

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2.333	1.40	0.291
Fertilizer	1	0.889	1.07	0.326
Tillage	2	4.333	2.60	0.123
Fert * Till	2	2.111	1.27	0.323

Table A4.3.2 Analysis of variance of days to tassel
Sand and Clay Sites - 1983

Sand Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	13.167	1.881	2.56	0.086	0.642
Error	10	7.333	0.733			
Corr. Tot.	17	20.500				

C.V. = 1.294
Std. Dev. = 0.856
Mean = 66.17

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.000	0.00	1.000
Fertilizer	1	0.500	0.68	0.428
Tillage	2	2.333	1.59	0.251
Fert * Till	2	10.333	7.05	0.012

Clay Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	16.556	2.365	1.37	0.313	0.490
Error	10	17.222	1.722			
Corr. Tot.	17	33.778				

C.V. = 1.927
Std. Dev. = 1.312
Mean = 68.11

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	4.111	1.19	0.343
Fertilizer	1	3.556	2.06	0.181
Tillage	2	8.111	2.35	0.145
Fert * Till	2	0.778	0.23	0.802

Table A4.3.3 Analysis of variance of final plant population Sand Site - 1982

Sand Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	317071	45296	6.23	0.005	0.813
Error	10	72750	7275			
Corr. Tot.	17	389821				

C.V. = 11.13
Std. Dev. = 85.29
Mean = 766.3

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	25180	1.73	0.226
Fertilizer	1	262812	36.13	0.000
Tillage	2	21721	1.49	0.271
Fert * Till	2	7357	0.51	0.618

Table A4.3.4 Analysis of variance of final plant population
Sand and Clay Sites - 1983

Sand Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	56898.5	8128.4	7.54	0.003	0.841
Error	10	10784.0	1078.4			
Corr. Tot.	17	67682.5				

C.V. = 3.890
Std. Dev. = 32.84
Mean = 844.17

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2224.0	1.03	0.392
Fertilizer	1	7564.5	7.01	0.024
Tillage	2	41323.0	19.16	0.000
Fert * Till	2	5787.0	2.68	0.117

Clay Site

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	30663.2	4380.5	4.77	0.014	0.769
Error	10	9187.3	918.7			
Corr. Tot.	17	39850.5				

C.V. = 3.651
Std. Dev. = 30.31
Mean = 830.17

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	4192.0	2.28	0.153
Fertilizer	1	420.5	0.46	0.514
Tillage	2	20249.3	11.02	0.003
Fert * Till	2	5801.3	3.16	0.087

Table A4.3.5 Analysis of variance of dry matter yield and percent moisture, 26 days after seeding. Sand Site - 1982

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.006	0.001	3.62	0.033	0.717
Error	10	0.002	0.000			
Corr. Tot.	17	0.009		C.V. = 24.34		
				Std. Dev. = 0.016		
				Mean = 0.064		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	2.39	0.142
Fertilizer	1	0.002	9.90	0.010
Tillage	2	0.002	5.08	0.030
Fert * Till	2	0.000	0.24	0.788

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	548.654	78.379	12.11	0.000	0.894
Error	10	64.731	6.473			
Corr. Tot.	17	613.385		C.V. = 3.573		
				Std. Dev. = 2.544		
				Mean = 71.213		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	471.428	36.41	0.000
Fertilizer	1	13.056	2.02	0.186
Tillage	2	15.718	1.21	0.337
Fert * Till	2	48.452	3.74	0.061

Table A4.3.6 Analysis of variance of plant height and leaf area index, 26 days after seeding. Sand Site - 1982

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	13.347	1.907	0.47	0.832	0.250
Error	10	40.142	4.014			
Corr. Tot.	17	53.489		C.V. = 11.39		
				Std. Dev. = 2.003		
				Mean = 17.594		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	4.164	0.52	0.611
Fertilizer	1	2.961	0.74	0.411
Tillage	2	2.008	0.25	0.784
Fert * Till	2	4.214	0.52	0.607

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.008	0.001	2.30	0.112	0.617
Error	10	0.005	0.001			
Corr. Tot.	17	0.014		C.V. = 17.11		
				Std. Dev. = 0.023		
				Mean = 0.134		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.002	1.80	0.215
Fertilizer	1	0.001	1.82	0.207
Tillage	2	0.004	3.36	0.076
Fert * Till	2	0.002	1.99	0.188

Table A4.3.7 Analysis of variance of dry matter yield and percent moisture, 48 days after seeding. Sand Site - 1982

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.819	0.117	1.50	0.271	0.512
Error	10	0.781	0.078			
Corr. Tot.	17	1.600				
				C.V. = 30.46		
				Std. Dev. = 0.279		
				Mean = 0.917		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.045	0.29	0.755
Fertilizer	1	0.480	6.15	0.033
Tillage	2	0.104	0.66	0.536
Fert * Till	2	0.190	1.22	0.336

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3.049	0.436	0.75	0.637	0.345
Error	10	5.793	0.579			
Corr. Tot.	17	8.842				
				C.V. = 0.823		
				Std. Dev. = 0.761		
				Mean = 92.432		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.740	0.64	0.548
Fertilizer	1	0.000	0.00	0.988
Tillage	2	0.110	0.09	0.910
Fert * Till	2	2.199	1.90	0.200

Table A4.3.8 Analysis of variance of plant height and leaf area index. 48 days after seeding. Sand Site - 1982

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	932.28	133.18	3.94	0.025	0.734
Error	10	337.88	33.79			
Corr. Tot.	17	1270.17		C.V. = 8.743		
				Std. Dev. = 5.813		
				Mean = 66.483		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	317.143	4.69	0.037
Fertilizer	1	47.045	1.39	0.265
Tillage	2	104.373	1.54	0.260
Fert * Till	2	463.720	6.86	0.013

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.808	0.115	0.79	0.613	0.356
Error	10	1.464	0.146			
Corr. Tot.	17	2.272		C.V. = 23.79		
				Std. Dev. = 0.383		
				Mean = 1.608		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.118	0.40	0.679
Fertilizer	1	0.038	0.26	0.621
Tillage	2	0.263	0.90	0.437
Fert * Till	2	0.389	1.33	0.308

Table A4.3.9 Analysis of variance of dry matter yield and percent moisture, 64 days after seeding. Sand Site - 1982

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	7.941	1.134	1.85	0.183	0.564
Error	10	6.140	0.614			
Corr. Tot.	17	14.081				
				C.V. = 17.34		
				Std. Dev. = 0.784		
				Mean = 4.519		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.350	1.10	0.370
Fertilizer	1	3.216	5.24	0.045
Tillage	2	0.643	0.52	0.608
Fert * Till	2	2.732	2.22	0.159

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	4.447	0.635	1.15	0.406	0.446
Error	10	5.524	0.552			
Corr. Tot.	17	9.971				
				C.V. = 0.850		
				Std. Dev. = 0.743		
				Mean = 87.42		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.398	0.36	0.707
Fertilizer	1	2.464	4.46	0.061
Tillage	2	0.945	0.86	0.454
Fert * Till	2	0.640	0.58	0.578

Table A4.3.10 Analysis of variance of plant height and leaf area index, 64 days after seeding. Sand Site - 1982

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3356.42	479.49	2.87	0.064	0.667
Error	10	1672.68	167.27			
Corr. Tot.	17	5029.10				

C.V. = 9.788
Std. Dev. = 12.93
Mean = 132.13

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2261.21	6.76	0.014
Fertilizer	1	545.60	3.26	0.101
Tillage	2	288.11	0.86	0.452
Fert * Till	2	261.49	0.78	0.483

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	4.096	0.585	2.65	0.079	0.650
Error	10	2.210	0.221			
Corr. Tot.	17	6.306				

C.V. = 12.77
Std. Dev. = 0.470
Mean = 3.680

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.104	2.50	0.132
Fertilizer	1	1.108	5.01	0.049
Tillage	2	0.521	1.18	0.347
Fert * Till	2	1.364	3.09	0.090

Table A4.3.11 Analysis of variance of dry matter yield and percent moisture, 76 days after seeding. Sand Site - 1982.

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	16.239	2.320	1.06	0.452	0.426
Error	10	21.901	2.190			
Corr. Tot.	17	38.140		C.V. =	19.42	
				Std. Dev. =	1.480	
				Mean =	7.619	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	5.463	1.25	0.328
Fertilizer	1	7.623	3.48	0.092
Tillage	2	2.166	0.49	0.624
Fert * Till	2	0.988	0.23	0.802

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	10.692	1.527	2.51	0.091	0.637
Error	10	6.082	0.608			
Corr. Tot.	17	16.774		C.V. =	0.978	
				Std. Dev. =	0.780	
				Mean =	79.776	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	3.393	2.79	0.109
Fertilizer	1	2.060	3.39	0.096
Tillage	2	5.093	4.19	0.048
Fert * Till	2	0.146	0.12	0.888

Table A4.3.12 Analysis of variance of plant height and leaf area index, 76 days after seeding. Sand Site - 1982

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	2649.31	378.47	2.12	0.136	0.597
Error	10	1786.27	178.63			
Corr. Tot.	17	4435.58				

C.V. = 6.574
Std. Dev. = 13.37
Mean = 203.31

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	592.87	1.66	0.239
Fertilizer	1	1197.24	6.70	0.027
Tillage	2	507.97	1.42	0.286
Fert * Till	2	351.23	0.98	0.408

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.845	0.264	1.11	0.423	0.438
Error	10	2.364	0.236			
Corr. Tot.	17	4.209				

C.V. = 12.62
Std. Dev. = 0.486
Mean = 3.853

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.722	1.53	0.264
Fertilizer	1	0.218	0.92	0.360
Tillage	2	0.094	0.20	0.823
Fert * Till	2	0.811	1.71	0.229

Table A4.3.13 Analysis of variance of dry matter yield and percent moisture, 91 days after seeding. Sand Site - 1982

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	83.373	11.910	1.61	0.238	0.530
Error	10	73.889	7.389			
Corr. Tot.	17	157.262				

C.V. = 25.36
Std. Dev. = 2.718
Mean = 10.718

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	26.377	1.78	0.217
Fertilizer	1	48.125	6.51	0.029
Tillage	2	2.468	0.17	0.849
Fert * Till	2	6.404	0.43	0.660

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	52.077	7.440	2.80	0.069	0.662
Error	10	26.611	2.661			
Corr. Tot.	17	78.688				

C.V. = 2.129
Std. Dev. = 1.631
Mean = 76.641

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2.033	0.38	0.692
Fertilizer	1	0.361	0.14	0.720
Tillage	2	26.027	4.89	0.033
Fert * Till	2	23.655	4.44	0.042

Table A4.3.14 Analysis of variance of plant height and leaf area index, 91 days after seeding. Sand Site - 1982

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1105.81	157.97	1.15	0.407	0.445
Error	10	1376.82	137.68			
Corr. Tot.	17	2482.63		C.V. = 5.488		
				Std. Dev. = 11.73		
				Mean = 213.81		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	46.854	0.17	0.846
Fertilizer	1	273.001	1.98	0.189
Tillage	2	375.098	1.36	0.300
Fert * Till	2	410.858	1.49	0.271

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.654	0.236	1.19	0.390	0.453
Error	10	1.994	0.199			
Corr. Tot.	17	3.648		C.V. = 12.70		
				Std. Dev. = 0.447		
				Mean = 3.516		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.221	0.56	0.591
Fertilizer	1	0.024	0.12	0.736
Tillage	2	0.976	2.45	0.136
Fert * Till	2	0.433	1.09	0.374

Table A4.3.15 Analysis of variance of dry matter yield and percent moisture, 29 days after seeding. Sand Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.014	0.002	0.91	0.536	0.389
Error	10	0.022	0.002			
Corr. Tot.	17	0.037				

C.V. = 30.02
Std. Dev. = 0.047
Mean = 0.158

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.33	0.727
Fertilizer	1	0.001	0.24	0.637
Tillage	2	0.009	1.97	0.191
Fert * Till	2	0.003	0.77	0.490

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	77.862	11.123	1.15	0.406	0.446
Error	10	96.745	9.674			
Corr. Tot.	17	174.607				

C.V. = 4.079
Std. Dev. = 3.110
Mean = 76.261

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	17.251	0.89	0.440
Fertilizer	1	22.111	2.29	0.162
Tillage	2	23.195	1.20	0.341
Fert * Till	2	15.305	0.79	0.480

Table A4.3.16 Analysis of variance of plant height and leaf area index, 29 days after seeding. Sand Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	39.766	5.681	1.88	0.177	0.568
Error	10	30.259	3.025			
Corr. Tot.	17	70.024				
				C.V. = 7.746		
				Std. Dev. = 1.740		
				Mean = 22.456		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	7.748	1.28	0.320
Fertilizer	1	9.102	3.01	0.114
Tillage	2	4.548	0.75	0.497
Fert * Till	2	18.368	3.04	0.093

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.029	0.004	0.99	0.490	0.409
Error	10	0.042	0.004			
Corr. Tot.	17	0.072				
				C.V. = 11.17		
				Std. Dev. = 0.065		
				Mean = 0.583		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.004	0.50	0.619
Fertilizer	1	0.003	0.65	0.439
Tillage	2	0.021	2.52	0.130
Fert * Till	2	0.001	0.11	0.895

Table A4.3.17 Analysis of variance of dry matter yield and percent moisture, 42 days after seeding. Sand Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.669	0.238	9.40	0.001	0.868
Error	10	0.254	0.025			
Corr. Tot.	17	1.923				

C.V. = 11.88
Std. Dev. = 0.159
Mean = 1.341

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.061	1.20	0.341
Fertilizer	1	0.353	13.89	0.004
Tillage	2	0.966	19.02	0.000
Fert * Till	2	0.290	5.72	0.022

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0	0	99999	0	0
Error	10	0	0			
Corr. Tot.	17	0				

C.V. = 0
Std. Dev. = 0
Mean = 89.11

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0	.	.
Fertilizer	1	0	.	.
Tillage	2	0	.	.
Fert * Till	2	0	.	.

Table A4.3.18 Analysis of variance of plant height and leaf area index, 42 days after seeding. Sand Site - 1983.

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	203.881	29.126	2.65	0.079	0.650
Error	10	109.976	10.998			
Corr. Tot.	17	313.856		C.V. = 5.369		
				Std. Dev. = 3.316		
				Mean = 61.772		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	13.338	0.61	0.564
Fertilizer	1	58.681	5.34	0.044
Tillage	2	126.581	5.75	0.022
Fert * Till	2	5.281	0.24	0.791

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.891	0.270	2.35	0.106	0.622
Error	10	1.148	0.115			
Corr. Tot.	17	3.039		C.V. = 12.72		
				Std. Dev. = 0.339		
				Mean = 2.664		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.034	0.15	0.863
Fertilizer	1	1.006	8.76	0.014
Tillage	2	0.353	1.54	0.262
Fert * Till	2	0.498	2.17	0.165

Table A4.3.19 Analysis of variance of dry matter yield and percent moisture, 58 days after seeding. Sand Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	4.126	0.589	2.06	0.146	0.590
Error	10	2.868	0.287			
Corr. Tot.	17	6.994		C.V. = 11.12		
				Std. Dev. = 0.536		
				Mean = 4.814		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.076	0.13	0.877
Fertilizer	1	0.206	0.72	0.417
Tillage	2	2.575	4.49	0.041
Fert * Till	2	1.269	2.21	0.160

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	20.456	2.922	2.13	0.135	0.598
Error	10	13.727	1.373			
Corr. Tot.	17	34.184		C.V. = 1.335		
				Std. Dev. = 1.172		
				Mean = 87.744		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2.694	0.98	0.408
Fertilizer	1	4.263	3.11	0.109
Tillage	2	5.891	2.15	0.168
Fert * Till	2	7.608	2.77	0.110

Table A4.3.20 Analysis of variance of plant height and leaf area index, 56 days after seeding. Sand Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1727.18	246.74	5.04	0.011	0.779
Error	10	489.39	48.94			
Corr. Tot.	17	2216.57				

C.V. = 4.212
Std. Dev. = 6.996
Mean = 166.11

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	61.888	0.63	0.551
Fertilizer	1	746.267	15.25	0.003
Tillage	2	781.954	7.99	0.009
Fert * Till	2	137.074	1.40	0.291

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.163	0.166	0.64	0.713	0.311
Error	10	2.578	0.258			
Corr. Tot.	17	3.741				

C.V. = 10.87
Std. Dev. = 0.508
Mean = 4.669

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.162	0.32	0.737
Fertilizer	1	0.246	0.95	0.352
Tillage	2	0.729	1.41	0.288
Fert * Till	2	0.025	0.05	0.952

Table A4.3.21 Analysis of variance of dry matter yield and percent moisture, 72 days after seeding. Sand Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	10.983	1.569	2.07	0.144	0.591
Error	10	7.589	0.759			
Corr. Tot.	17	18.573				

C.V. = 10.43
Std. Dev. = 0.871
Mean = 8.353

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2.900	1.91	0.198
Fertilizer	1	0.068	0.09	0.772
Tillage	2	3.835	2.53	0.129
Fert * Till	2	4.180	2.75	0.112

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	5.329	0.761	0.95	0.513	0.399
Error	10	8.023	0.802			
Corr. Tot.	17	13.352				

C.V. = 1.068
Std. Dev. = 0.896
Mean = 83.866

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.520	0.95	0.420
Fertilizer	1	0.018	0.02	0.884
Tillage	2	0.784	0.49	0.627
Fert * Till	2	3.007	1.87	0.204

Table A4.3.22 Analysis of variance of plant height and leaf area index, 72 days after seeding. Sand Site.- 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1396.44	199.49	4.24	0.020	0.748
Error	10	470.71	47.07			
Corr. Tot.	17	1867.15				

C.V. = 2.663
Std. Dev. = 6.861
Mean = 257.59

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	72.86	0.77	0.487
Fertilizer	1	1261.69	26.80	0.000
Tillage	2	31.47	0.33	0.724
Fert * Till	2	30.41	0.32	0.731

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.171	0.167	1.10	0.431	0.435
Error	10	1.521	0.152			
Corr. Tot.	17	2.691				

C.V. = 8.322
Std. Dev. = 0.390
Mean = 4.686

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.063	0.21	0.817
Fertilizer	1	0.133	0.88	0.371
Tillage	2	0.402	1.32	0.309
Fert * Till	2	0.573	1.88	0.202

Table A4.3.23 Analysis of variance of dry matter yield and percent moisture, 92 days after seeding. Sand Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	13.913	1.988	1.45	0.285	0.504
Error	10	13.666	1.367			
Corr. Tot.	17	27.579		C.V. = 10.19		
				Std. Dev. = 1.169		
				Mean = 11.462		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	4.677	1.71	0.230
Fertilizer	1	0.436	0.32	0.585
Tillage	2	0.254	0.09	0.912
Fert * Till	2	8.546	3.13	0.088

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	15.516	2.217	1.73	0.209	0.547
Error	10	12.848	1.285			
Corr. Tot.	17	28.363		C.V. = 1.492		
				Std. Dev. = 1.133		
				Mean = 75.995		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.849	0.33	0.726
Fertilizer	1	0.402	0.31	0.588
Tillage	2	5.462	2.13	0.170
Fert * Till	2	8.802	3.43	0.074

Table A4.3.24 Analysis of variance of plant height and leaf area index, 92 days after seeding. Sand Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1360.07	194.30	2.18	0.128	0.604
Error	10	892.77	89.28			
Corr. Tot.	17	2252.84				

C.V. = 3.644
Std. Dev. = 9.449
Mean = 259.31

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	5.74	0.03	0.969
Fertilizer	1	1246.67	13.96	0.004
Tillage	2	7.75	0.04	0.958
Fert * Till	2	99.91	0.56	0.589

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.602	0.086	1.99	0.157	0.582
Error	10	0.433	0.043			
Corr. Tot.	17	1.035				

C.V. = 6.381
Std. Dev. = 0.208
Mean = 3.262

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.041	0.48	0.634
Fertilizer	1	0.202	4.65	0.056
Tillage	2	0.200	2.31	0.150
Fert * Till	2	0.159	1.83	0.210

Table A4.3.25 Analysis of variance of dry matter yield and percent moisture, 29 days after seeding. Clay Site - 1983.

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.032	0.005	3.24	0.046	0.694
Error	10	0.014	0.001			
Corr. Tot.	17	0.047		C.V. =	27.31	
				Std. Dev. =	0.038	
				Mean =	0.138	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.004	1.50	0.270
Fertilizer	1	0.002	1.59	0.236
Tillage	2	0.013	4.45	0.042
Fert * Till	2	0.013	4.59	0.039

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	76.410	10.916	1.41	0.301	0.497
Error	10	77.458	7.746			
Corr. Tot.	17	153.868		C.V. =	3.578	
				Std. Dev. =	2.783	
				Mean =	77.777	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	19.201	1.24	0.331
Fertilizer	1	27.257	3.52	0.901
Tillage	2	21.168	1.37	0.299
Fert * Till	2	8.783	0.57	0.585

Table A4.3.26 Analysis of variance of plant height and leaf area index, 29 days after seeding. Clay Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	108.529	15.504	4.90	0.012	0.774
Error	10	31.615	3.161			
Corr. Tot.	17	140.145				

C.V. = 7.736
Std. Dev. = 1.778
Mean = 22.983

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	16.071	2.54	0.128
Fertilizer	1	2.961	0.94	0.356
Tillage	2	2.923	0.46	0.643
Fert * Till	2	86.574	13.69	0.001

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.053	0.008	3.35	0.042	0.701
Error	10	0.023	0.002			
Corr. Tot.	17	0.075				

C.V. = 8.127
Std. Dev. = 0.047
Mean = 0.584

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.008	1.81	0.213
Fertilizer	1	0.001	0.22	0.646
Tillage	2	0.007	1.64	0.242
Fert * Till	2	0.037	8.14	0.008

Table A4.3.27 Analysis of variance of dry matter yield and percent moisture. 42 days after seeding. Clay Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	2.954	0.422	1.41	0.300	0.497
Error	10	2.992	0.299			
Corr. Tot.	17	5.946		C.V. =	46.85	
				Std. Dev. =	0.547	
				Mean =	1.168	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.152	0.25	0.781
Fertilizer	1	0.055	0.18	0.677
Tillage	2	1.632	2.73	0.113
Fert * Till	2	1.114	1.86	0.205

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0	0	99999	0	0
Error	10	0	0			
Corr. Tot.	17	0		C.V. =	0	
				Std. Dev. =	0	
				Mean =	85.700	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0	.	.
Fertilizer	1	0	.	.
Tillage	2	0	.	.
Fert * Till	2	0	.	.

Table A4.3.28 Analysis of variance of plant height and leaf area index, 42 days after seeding. Clay Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	625.11	89.301	1.09	0.435	0.433
Error	10	818.70	81.870			
Corr. Tot.	17	1443.80		C.V. = 17.25		
				Std. Dev. = 9.048		
				Mean = 52.461		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	45.803	0.28	0.762
Fertilizer	1	3.827	0.05	0.833
Tillage	2	440.954	2.69	0.116
Fert * Till	2	134.521	0.82	0.467

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.963	0.280	0.84	0.582	0.369
Error	10	3.356	0.336			
Corr. Tot.	17	5.319		C.V. = 27.10		
				Std. Dev. = 0.579		
				Mean = 2.138		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.127	0.19	0.830
Fertilizer	1	0.058	0.17	0.686
Tillage	2	0.917	1.37	0.299
Fert * Till	2	0.861	1.28	0.319

Table A4.3.29 Analysis of variance of dry matter yield and percent moisture, 58 days after seeding. Clay Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	15.058	2.151	1.43	0.293	0.500
Error	10	15.043	1.504			
Corr. Tot.	17	30.101				

C.V. = 30.86
Std. Dev. = 1.227
Mean = 3.975

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	3.674	1.22	0.335
Fertilizer	1	4.005	2.66	0.134
Tillage	2	6.824	2.27	0.154
Fert * Till	2	0.554	0.18	0.835

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.629	0.947	0.61	0.739	0.298
Error	10	15.580	1.558			
Corr. Tot.	17	22.209				

C.V. = 1.466
Std. Dev. = 1.248
Mean = 85.171

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.104	0.35	0.710
Fertilizer	1	3.901	2.50	0.145
Tillage	2	1.229	0.39	0.684
Fert * Till	2	0.395	0.13	0.882

Table A4.3.30 Analysis of variance of plant height and leaf area index, 58 days after seeding. Clay Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3644.54	520.65	1.42	0.298	0.498
Error	10	3678.70	367.87			
Corr. Tot.	17	7323.24				

C.V. = 15.76
Std. Dev. = 19.18
Mean = 121.71

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	732.77	1.00	0.403
Fertilizer	1	280.06	0.76	0.403
Tillage	2	1910.86	2.60	0.124
Fert * Till	2	720.86	0.98	0.409

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	4.574	0.653	1.36	0.318	0.488
Error	10	4.807	0.481			
Corr. Tot.	17	9.380				

C.V. = 16.81
Std. Dev. = 0.693
Mean = 4.124

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.826	1.90	0.200
Fertilizer	1	0.949	1.97	0.190
Tillage	2	1.100	1.14	0.357
Fert * Till	2	0.699	0.73	0.507

Table A4.3.31 Analysis of variance of dry matter yield and percent moisture, 72 days after seeding. Clay Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	23.468	3.353	2.33	0.109	0.620
Error	10	14.361	1.436			
Corr. Tot.	17	37.829				

C.V. = 15.99
Std. Dev. = 1.198
Mean = 7.496

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	3.399	1.18	0.346
Fertilizer	1	0.000	0.00	0.994
Tillage	2	17.265	6.01	0.019
Fert * Till	2	2.804	0.98	0.410

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	5.140	0.734	1.48	0.277	0.509
Error	10	4.957	0.496			
Corr. Tot.	17	10.097				

C.V. = 0.846
Std. Dev. = 0.704
Mean = 83.196

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.305	0.31	0.742
Fertilizer	1	0.130	0.26	0.620
Tillage	2	1.642	1.66	0.239
Fert * Till	2	3.063	3.09	0.090

Table A4.3.32 Analysis of variance of plant height and leaf area index, 72 days after seeding. Clay Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3810.12	544.30	1.17	0.398	0.450
Error	10	4663.69	466.37			
Corr. Tot.	17	8473.80				

C.V. = 9.549
Std. Dev. = 21.60
Mean = 226.16

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1116.84	1.20	0.342
Fertilizer	1	8.68	0.02	0.894
Tillage	2	2313.15	2.48	0.134
Fert * Till	2	371.44	0.40	0.682

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.734	0.248	1.81	0.190	0.559
Error	10	1.366	0.137			
Corr. Tot.	17	3.101				

C.V. = 8.228
Std. Dev. = 0.370
Mean = 4.492

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.462	1.69	0.233
Fertilizer	1	0.432	3.16	0.106
Tillage	2	0.316	1.16	0.353
Fert * Till	2	0.524	1.92	0.198

Table A4.3.33 Analysis of variance of dry matter yield and percent moisture, 92 days after seeding. Clay Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	29.369	4.196	1.03	0.467	0.419
Error	10	40.701	4.070			
Corr. Tot.	17	70.070		C.V. = 18.05		
				Std. Dev. = 2.017		
				Mean = 11.179		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	7.656	0.94	0.422
Fertilizer	1	0.389	0.10	0.764
Tillage	2	18.750	2.30	0.150
Fert * Till	2	2.573	0.32	0.736

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.305	0.901	0.89	0.548	0.384
Error	10	10.132	1.013			
Corr. Tot.	17	16.437		C.V. = 1.316		
				Std. Dev. = 1.007		
				Mean = 76.504		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.881	0.43	0.659
Fertilizer	1	3.251	3.21	0.104
Tillage	2	0.697	0.34	0.717
Fert * Till	2	1.476	0.73	0.507

Table A4.3.34 Analysis of variance of plant height and leaf area index, 92 days after seeding. Clay Site - 1983

Plant Height, cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	4920.46	702.92	1.39	0.309	0.493
Error	10	5069.52	506.95			
Corr. Tot.	17	9989.98				
				C.V. = 10.02		
				Std. Dev. = 22.52		
				Mean = 224.73		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2071.58	2.04	0.180
Fertilizer	1	126.94	0.25	0.628
Tillage	2	2232.28	2.20	0.161
Fert * Till	2	489.66	0.48	0.631

Leaf Area Index

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.442	0.206	0.81	0.601	0.361
Error	10	2.554	0.255			
Corr. Tot.	17	3.996				
				C.V. = 12.98		
				Std. Dev. = 0.505		
				Mean = 3.894		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.471	0.92	0.429
Fertilizer	1	0.456	1.79	0.211
Tillage	2	0.406	0.80	0.478
Fert * Till	2	0.109	0.21	0.811

Table A4.3.35 Analysis of variance of number of leaves, 29 and 42 days after seeding. Sand Site - 1983

29 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.471	0.210	0.94	0.520	0.396
Error	10	2.246	0.225			
Corr. Tot.	17	3.716				

C.V. = 6.840
Std. Dev. = 0.474
Mean = 6.928

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.448	1.00	0.403
Fertilizer	1	0.027	0.12	0.735
Tillage	2	0.591	1.32	0.311
Fert * Till	2	0.404	0.90	0.437

42 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	10.452	1.493	4.74	0.014	0.768
Error	10	3.152	0.315			
Corr. Tot.	17	13.604				

C.V. = 5.038
Std. Dev. = 0.561
Mean = 11.144

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	7.414	11.76	0.002
Fertilizer	1	0.080	0.25	0.625
Tillage	2	1.534	2.43	0.138
Fert * Till	2	1.423	2.26	0.155

Table A4.3.36 Analysis of variance of number of leaves, 58 and 72 days after seeding. Sand Site - 1983

58 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.757	0.251	0.88	0.551	0.382
Error	10	2.839	0.284			
Corr. Tot.	17	4.596				

C.V. = 4.543
Std. Dev. = 0.533
Mean = 11.73

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.00	0.998
Fertilizer	1	0.605	2.13	0.175
Tillage	2	0.848	1.49	0.271
Fert * Till	2	0.303	0.53	0.602

72 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	9.764	1.395	3.63	0.032	0.718
Error	10	3.839	0.384			
Corr. Tot.	17	13.603				

C.V. = 5.190
Std. Dev. = 0.620
Mean = 11.939

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.688	2.20	0.162
Fertilizer	1	7.347	19.14	0.001
Tillage	2	0.404	0.53	0.606
Fert * Till	2	0.324	0.42	0.667

Table A4.3.37 Analysis of variance of number of leaves, 92 days after seeding. Sand Site - 1983

92 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	4.844	0.692	4.54	0.016	0.760
Error	10	1.526	0.153			
Corr. Tot.	17	6.369		C.V. = 4.066		
				Std. Dev. = 0.391		
				Mean = 9.606		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.588	1.93	0.196
Fertilizer	1	1.027	6.73	0.027
Tillage	2	2.388	7.83	0.009
Fert * Till	2	0.841	2.76	0.111

Table A4.3.38 Analysis of variance of number of leaves, 29 and 42 days days after seeding. Clay Site - 1983

29 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.500	0.214	1.05	0.456	0.424
Error	10	2.038	0.204			
Corr. Tot.	17	3.538				

C.V. = 6.628
Std. Dev. = 0.451
Mean = 6.811

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.302	0.74	0.501
Fertilizer	1	0.500	2.45	0.148
Tillage	2	0.114	0.28	0.761
Fert * Till	2	0.583	1.43	0.284

42 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3.163	0.452	0.94	0.515	0.398
Error	10	4.786	0.479			
Corr. Tot.	17	7.949				

C.V. = 6.236
Std. Dev. = 0.692
Mean = 11.09

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.141	0.15	0.865
Fertilizer	1	0.161	0.34	0.575
Tillage	2	1.791	1.87	0.204
Fert * Till	2	1.071	1.12	0.364

Table A4.3.39 Analysis of variance of number of leaves, 58 and 72 days after seeding. Clay Site - 1983

58 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	2.533	0.362	0.72	0.657	0.336
Error	10	4.997	0.500			
Corr. Tot.	17	7.529		C.V. = 6.144		
				Std. Dev. = 0.707		
				Mean = 11.51		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.643	1.64	0.241
Fertilizer	1	0.347	0.69	0.424
Tillage	2	0.101	0.10	0.905
Fert * Till	2	0.441	0.44	0.655

72 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.804	0.258	0.73	0.650	0.339
Error	10	3.512	0.351			
Corr. Tot.	17	5.316		C.V. = 4.604		
				Std. Dev. = 0.593		
				Mean = 12.87		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.048	0.07	0.935
Fertilizer	1	1.561	4.44	0.061
Tillage	2	0.008	0.01	0.989
Fert * Till	2	0.188	0.27	0.771

Table A4.3.40. Analysis of variance of number of leaves, 92 days after seeding. Clay Site - 1983

92 Days After Seeding

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3.137	0.448	0.91	0.538	0.388
Error	10	4.943	0.494			
Corr. Tot.	17	8.080		C.V. = 6.167		
				Std. Dev. = 0.703		
				Mean = 11.40		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.330	1.35	0.304
Fertilizer	1	0.269	0.54	0.478
Tillage	2	0.520	0.53	0.607
Fert * Till	2	1.018	1.03	0.392

Table A4.3.41 Analysis of variance of dry matter yield and percent moisture at harvest. Sand Site - 1982

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	31.127	4.447	2.41	0.101	0.628
Error	10	18.463	1.846			
Corr. Tot.	17	49.590		C.V. =	9.067	
				Std. Dev. =	1.359	
				Mean =	14.986	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	6.685	1.81	0.213
Fertilizer	1	8.639	4.68	0.056
Tillage	2	14.269	3.86	0.057
Fert * Till	2	1.534	0.42	0.671

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	77.390	11.056	2.98	0.058	0.676
Error	10	37.158	3.716			
Corr. Tot.	17	114.549		C.V. =	3.595	
				Std. Dev. =	1.928	
				Mean =	53.625	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	14.366	1.93	0.195
Fertilizer	1	1.181	0.32	0.585
Tillage	2	40.071	5.39	0.026
Fert * Till	2	21.773	2.93	0.100

Table A4.3.42 Analysis of variance of yield per plant (gm), at harvest. Sand Site - 1982

Yield per Plant, gm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	26877.4	3839.6	7.60	0.003	0.842
Error	10	5050.2	505.0			
Corr. Tot.	17	31927.6				
				C.V. = 9.322		
				Std. Dev. = 22.47		
				Mean = 241.08		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	8537.5	8.45	0.007
Fertilizer	1	12886.7	25.52	0.001
Tillage	2	3297.3	3.26	0.081
Fert * Till	2	2155.9	2.13	0.169

Table A4.3.43 Analysis of variance of dry matter yield and percent moisture at harvest. Sand Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	11.297	1.614	3.14	0.050	0.687
Error	10	5.144	0.514			
Corr. Tot.	17	16.441				

C.V. = 6.901
Std. Dev. = 0.717
Mean = 10.394

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2.782	2.70	0.115
Fertilizer	1	1.090	2.12	0.176
Tillage	2	5.974	5.81	0.021
Fert * Till	2	1.451	1.41	0.289

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	188.278	26.897	5.13	0.011	0.782
Error	10	52.456	5.246			
Corr. Tot.	17	240.735				

C.V. = 5.310
Std. Dev. = 2.290
Mean = 43.131

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	29.414	2.80	0.108
Fertilizer	1	81.579	15.55	0.003
Tillage	2	33.165	3.16	0.086
Fert * Till	2	44.120	4.21	0.047

Table A4.3.44 Analysis of variance of yield per plant (gm), at harvest. Sand Site - 1983

Yield per Plant, gm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1715.64	245.09	3.60	0.033	0.716
Error	10	680.56	68.06			
Corr. Tot.	17	2396.20		C.V. =	5.574	
				Std. Dev. =	8.250	
				Mean =	148.01	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	288.671	2.12	0.171
Fertilizer	1	893.156	13.12	0.005
Tillage	2	153.441	1.13	0.362
Fert * Till	2	380.373	2.79	0.109

Table A4.3.45 Analysis of variance of dry matter yield and percent moisture at harvest. Clay Site - 1983

Dry Matter Yield, Mg/ha

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	17.274	2.468	8.45	0.002	0.855
Error	10	2.919	0.292			
Corr. Tot.	17	20.193				

C.V. = 4.613
Std. Dev. = 0.540
Mean = 11.713

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	12.583	21.55	0.000
Fertilizer	1	0.121	0.42	0.534
Tillage	2	2.965	5.08	0.030
Fert * Till	2	1.604	2.75	0.112

Percent Moisture

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	145.835	20.834	1.42	0.295	0.499
Error	10	146.310	14.631			
Corr. Tot.	17	292.146				

C.V. = 8.786
Std. Dev. = 3.825
Mean = 43.537

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	34.849	1.19	0.344
Fertilizer	1	49.402	3.38	0.096
Tillage	2	40.177	1.37	0.297
Fert * Till	2	21.408	0.73	0.505

Table A4.3.46 Analysis of variance of yield per plant (gm), at harvest. Clay Site - 1983

Yield per Plant, gm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	2824.59	403.51	4.02	0.024	0.738
Error	10	1004.37	100.44			
Corr. Tot.	17	3828.97		C.V. = 5.912		
				Std. Dev. = 10.02		
				Mean = 169.50		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2051.23	10.21	0.004
Fertilizer	1	84.10	0.84	0.382
Tillage	2	187.40	0.93	0.425
Fert * Till	2	501.87	2.50	0.132

Table A4.3.47 Analysis of variance of plant tissue analysis for percent protein and percent calcium. Sand Site - 1983

Percent Protein

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	16.179	2.311	10.51	0.001	0.880
Error	10	2.199	0.220			
Corr. Tot.	17	18.378		C.V. = 6.710		
				Std. Dev. = 0.469		
				Mean = 6.989		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.008	0.02	0.983
Fertilizer	1	13.869	63.07	0.000
Tillage	2	0.614	1.40	0.292
Fert * Till	2	1.688	3.84	0.058

Percent Calcium

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.023	0.003	2.15	0.132	0.601
Error	10	0.016	0.002			
Corr. Tot.	17	0.039		C.V. = 17.15		
				Std. Dev. = 0.039		
				Mean = 0.230		

Source	D:F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.42	0.670
Fertilizer	1	0.020	12.85	0.005
Tillage	2	0.002	0.56	0.590
Fert * Till	2	0.000	0.13	0.881

Table A4.3.46 Analysis of variance of plant tissue analysis for percent phosphorous and percent magnesium. Sand Site - 1983

Percent Phosphorous

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.003	0.000	1.13	0.418	0.441
Error	10	0.004	0.000			
Corr. Tot.	17	0.007		C.V. =	7.801	
				Std. Dev. =	0.020	
				Mean =	0.262	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.76	0.493
Fertilizer	1	0.002	3.85	0.078
Tillage	2	0.000	0.28	0.762
Fert * Till	2	0.001	0.97	0.411

Percent Magnesium

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.028	0.004	1.15	0.404	0.447
Error	10	0.034	0.003			
Corr. Tot.	17	0.062		C.V. =	37.20	
				Std. Dev. =	0.059	
				Mean =	0.158	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.003	0.42	0.670
Fertilizer	1	0.003	0.93	0.358
Tillage	2	0.006	0.89	0.440
Fert * Till	2	0.016	2.27	0.154

Table A4.3.49 Analysis of variance of plant tissue analysis for percent potassium and iron, ppm. Sand Site - 1983

Percent Potassium

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1.964	0.281	0.74	0.645	0.341
Error	10	3.788	0.379			
Corr. Tot.	17	5.752		C.V. = 47.61		
				Std. Dev. = 0.615		
				Mean = 1.293		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.640	0.84	0.458
Fertilizer	1	0.006	0.02	0.902
Tillage	2	0.446	0.59	0.573
Fert * Till	2	0.872	1.15	0.355

Iron, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1035.67	147.95	0.96	0.504	0.403
Error	10	1536.33	153.63			
Corr. Tot.	17	2572.00		C.V. = 21.49		
				Std. Dev. = 12.39		
				Mean = 57.667		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	32.333	0.11	0.901
Fertilizer	1	72.000	0.47	0.509
Tillage	2	874.333	2.85	0.105
Fert * Till	2	57.000	0.19	0.834

Table A4.3.50 Analysis of variance of plant tissue analysis for manganese, ppm, and copper, ppm. Sand Site - 1983

Manganese, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	599.667	85.667	5.94	0.006	0.806
Error	10	144.333	14.433			
Corr. Tot.	17	744.000				

C.V. = 19.32
Std. Dev. = 3.799
Mean = 19.667

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	211.000	7.31	0.011
Fertilizer	1	373.556	25.88	0.001
Tillage	2	14.333	0.50	0.623
Fert * Till	2	0.778	0.03	0.974

Copper, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	25.389	3.627	1.29	0.347	0.474
Error	10	28.222	2.822			
Corr. Tot.	17	53.611				

C.V. = 19.26
Std. Dev. = 1.680
Mean = 8.722

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	12.444	2.20	0.161
Fertilizer	1	2.722	0.96	0.349
Tillage	2	8.111	1.44	0.283
Fert * Till	2	2.111	0.37	0.697

Table A4.3.51 Analysis of variance of plant tissue analysis for zinc, ppm. Sand Site - 1983

Zinc, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	48.667	6.952	0.38	0.897	0.208
Error	10	185.333	18.533			
Corr. Tot.	17	234.000				
				C.V. = 15.38		
				Std. Dev. = 4.305		
				Mean = 28.000		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	41.333	1.12	0.366
Fertilizer	1	0.889	0.05	0.831
Tillage	2	3.000	0.08	0.923
Fert * Till	2	3.444	0.09	0.912

Table A4.3.52 Analysis of variance of plant tissue analysis for percent protein and percent calcium. Clay Site - 1983

Percent Protein

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	5.142	0.735	4.47	0.017	0.758
Error	10	1.643	0.164			
Corr. Tot.	17	6.785				

C.V. = 5.617
Std. Dev. = 0.405
Mean = 7.217

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.143	0.44	0.658
Fertilizer	1	4.805	29.24	0.000
Tillage	2	0.063	0.19	0.828
Fert * Till	2	0.130	0.40	0.683

Percent Calcium

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.011	0.002	1.02	0.474	0.416
Error	10	0.016	0.002			
Corr. Tot.	17	0.027				

C.V. = 15.63
Std. Dev. = 0.040
Mean = 0.256

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.008	2.34	0.146
Fertilizer	1	0.001	0.42	0.532
Tillage	2	0.003	0.96	0.415
Fert * Till	2	0.000	0.05	0.956

Table A4.3.53 Analysis of variance of plant tissue analysis for percent phosphorous and percent magnesium. Clay Site - 1983

Percent Phosphorous

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.010	0.001	1.13	0.417	0.441
Error	10	0.013	0.001			
Corr. Tot.	17	0.023				

C.V. = 14.74
Std. Dev. = 0.036
Mean = 0.244

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.006	2.34	0.147
Fertilizer	1	0.000	0.07	0.799
Tillage	2	0.001	0.22	0.804
Fert * Till	2	0.004	1.35	0.302

Percent Magnesium

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.011	0.002	0.76	0.630	0.348
Error	10	0.021	0.002			
Corr. Tot.	17	0.032				

C.V. = 16.61
Std. Dev. = 0.045
Mean = 0.273

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.000	0.03	0.968
Fertilizer	1	0.000	0.17	0.687
Tillage	2	0.008	1.85	0.207
Fert * Till	2	0.003	0.70	0.520

Table A4.3.54 Anaalysis of variance of plant tissue analysis for percent potassium and iron, ppm. Clay Site - 1983

Percent Potassium

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.125	0.018	0.98	0.496	0.406
Error	10	0.182	0.018			
Corr. Tot.	17	0.307		C.V. = 13.75		
				Std. Dev. = 0.135		
				Mean = 0.982		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.024	0.66	0.536
Fertilizer	1	0.026	1.41	0.263
Tillage	2	0.007	0.20	0.825
Fert * Till	2	0.068	1.86	0.206

Iron, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	2468.56	352.65	2.29	0.114	0.616
Error	10	1541.22	154.12			
Corr. Tot.	17	4009.78		C.V. = 20.31		
				Std. Dev. = 12.41		
				Mean = 61.111		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1571.44	5.10	0.030
Fertilizer	1	242.00	1.57	0.239
Tillage	2	430.78	1.40	0.292
Fert * Till	2	224.33	0.73	0.507

Table A4.3.55 Analysis of variance of plant tissue analysis for manganese, ppm, and copper, ppm. Clay Site - 1983

Manganese, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	165.889	23.698	0.62	0.733	0.301
Error	10	385.222	38.522			
Corr. Tot.	17	551.111				

C.V. = 36.99
Std. Dev. = 6.207
Mean = 16.778

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	5.444	0.07	0.932
Fertilizer	1	98.000	2.54	0.142
Tillage	2	48.111	0.62	0.555
Fert * Till	2	14.333	0.19	0.833

Copper, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	41.889	5.984	0.82	0.589	0.366
Error	10	72.556	7.256			
Corr. Tot.	17	114.444				

C.V. = 28.19
Std. Dev. = 2.694
Mean = 9.556

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	8.778	0.60	0.565
Fertilizer	1	8.000	1.10	0.318
Tillage	2	18.111	1.25	0.328
Fert * Till	2	7.000	0.48	0.631

Table A4.3.56 Analysis of variance of plant tissue analysis for zinc, ppm. Clay Site - 1983

Zinc, ppm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	204.500	29.214	2.56	0.086	0.642
Error	10	114.000	11.400			
Corr. Tot.	17	318.500				
				C.V. = 13.97		
				Std. Dev. = 3.376		
				Mean = 24.167		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	65.333	2.87	0.104
Fertilizer	1	9.389	0.82	0.386
Tillage	2	102.333	4.49	0.041
Fert * Till	2	27.444	1.20	0.340

APPENDIX B

STATISTICAL ANALYSIS OF SOIL PARAMETERS

Table B5.3.1 Analysis of variance of soil nutrients.
Sand Site - 1981

Potassium, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	57664.4	8237.8	3.07	0.053	0.683
Error	10	26796.6	2679.7			
Corr. Tot.	17	84460.9		C.V. =	15.73	
				Std. Dev. =	51.77	
				Mean =	329.06	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	36612.1	6.83	0.014
Fertilizer	1	10224.5	3.82	0.079
Tillage	2	2801.4	0.52	0.608
Fert * Till	2	8026.3	1.50	0.270

Potassium, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	9843	1406.2	0.16	0.989	0.098
Error	10	90605	9060.5			
Corr. Tot.	17	100447		C.V. =	38.09	
				Std. Dev. =	95.19	
				Mean =	249.89	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	4102.78	0.23	0.801
Fertilizer	1	3094.22	0.34	0.572
Tillage	2	2594.78	0.14	0.868
Fert * Till	2	51.44	0.00	0.997

Table B5.3.2 Analysis of variance of soil nutrients.
Sand Site - 1981

Phosphorous, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	66570	9510.1	2.75	0.072	0.658
Error	10	34560	3456.0			
Corr. Tot.	17	101130				

C.V. = 10.60
Std. Dev. = 58.79
Mean = 554.56

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	57744.1	8.35	0.007
Fertilizer	1	4293.6	1.24	0.291
Tillage	2	2263.1	0.33	0.728
Fert * Till	2	2269.8	0.33	0.728

Phosphorous, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	99886	14269	0.40	0.880	0.220
Error	10	354874	35487			
Corr. Tot.	17	454761				

C.V. = 54.05
Std. Dev. = 188.4
Mean = 348.50

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	38486.3	0.54	0.598
Fertilizer	1	20.1	0.00	0.982
Tillage	2	9228.0	0.13	0.880
Fert * Till	2	52152.4	0.73	0.504

Table B5.3.3 Analysis of variance of soil nutrients.
Clay Site - 1981

Potassium, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	198607	28372	0.95	0.514	0.398
Error	10	299934	29993			
Corr. Tot.	17	498541		C.V. =	43.29	
				Std. Dev. =	173.2	
				Mean =	400.06	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	32778	0.55	0.595
Fertilizer	1	13945	0.46	0.511
Tillage	2	43655	0.73	0.507
Fert * Till	2	108229	1.80	0.214

Potassium, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	25420.4	3631.5	3.03	0.055	0.680
Error	10	11989.2	1198.9			
Corr. Tot.	17	37409.6		C.V. =	11.95	
				Std. Dev. =	34.63	
				Mean =	289.72	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1344.8	0.56	0.588
Fertilizer	1	2156.1	1.80	0.210
Tillage	2	8800.1	3.67	0.064
Fert * Till	2	13119.4	5.47	0.025

Table B5.3.4 Analysis of variance of soil nutrients.
Clay Site - 1981

Phosphorous, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	24279	3468.4	0.41	0.875	0.223
Error	10	84583	8458.3			
Corr. Tot.	17	108862				

C.V. = 35.60
Std. Dev. = 91.97
Mean = 258.33

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	13009.0	0.77	0.489
Fertilizer	1	672.2	0.08	0.784
Tillage	2	1702.3	0.10	0.905
Fert * Till	2	8895.4	0.53	0.607

Phosphorous, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	19822.3	2831.8	1.23	0.372	0.462
Error	10	23113.7	2311.4			
Corr. Tot.	17	42936.0				

C.V. = 30.75
Std. Dev. = 48.08
Mean = 156.33

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	5167.0	1.12	0.365
Fertilizer	1	242.0	0.10	0.753
Tillage	2	10777.0	2.33	0.148
Fert * Till	2	3636.3	0.79	0.482

Table B5.3.5 Analysis of variance of soil nutrients.
Sand Site - 1982

Potassium, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	107256	15322	4.11	0.022	0.742
Error	10	37247	3724			
Corr. Tot.	17	144504		C.V. =	15.27	
				Std. Dev. =	61.03	
				Mean =	399.61	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	13254.1	1.78	0.218
Fertilizer	1	58824.5	15.79	0.003
Tillage	2	3908.8	0.52	0.607
Fert * Till	2	31269.0	4.20	0.048

Potassium, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	82947	11849	1.50	0.270	0.512
Error	10	78933	7893			
Corr. Tot.	17	161880		C.V. =	26.05	
				Std. Dev. =	88.84	
				Mean =	341.00	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	56758.3	3.60	0.067
Fertilizer	1	20672.2	2.62	0.137
Tillage	2	2449.0	0.16	0.858
Fert * Till	2	3067.4	0.19	0.826

Table B5.3.6 Analysis of variance of soil nutrients.
Sand Site - 1982

Phosphorous, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	143684	20526	3.06	0.054	0.682
Error	10	67118	6712			
Corr. Tot.	17	210803				

C.V. = 15.32
Std. Dev. = 81.93
Mean = 534.83

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	74629.0	5.56	0.024
Fertilizer	1	1404.5	0.21	0.657
Tillage	2	55096.3	4.10	0.050
Fert * Till	2	12554.3	0.94	0.424

Phosphorous, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	47571	6795	0.48	0.826	0.253
Error	10	140478	14048			
Corr. Tot.	17	188048				

C.V. = 29.90
Std. Dev. = 118.5
Mean = 396.39

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	15477.8	0.55	0.593
Fertilizer	1	280.1	0.02	0.891
Tillage	2	24410.8	0.87	0.449
Fert * Till	2	7402.1	0.26	0.774

Table B5.3.7 Analysis of variance of soil nutrients.
Sand Site - 1982

Organic Matter, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.669	0.096	0.20	0.977	0.124
Error	10	4.723	0.472			
Corr. Tot.	17	5.392				

C.V. = 14.27
Std. Dev. = 0.687
Mean = 4.816

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.065	0.07	0.934
Fertilizer	1	0.032	0.07	0.800
Tillage	2	0.091	0.10	0.909
Fert * Till	2	0.480	0.51	0.616

Organic Matter, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.107	0.872	0.47	0.838	0.246
Error	10	18.709	1.871			
Corr. Tot.	17	24.816				

C.V. = 46.60
Std. Dev. = 1.368
Mean = 2.935

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.965	0.26	0.778
Fertilizer	1	0.402	0.21	0.653
Tillage	2	2.366	0.63	0.551
Fert * Till	2	2.373	0.63	0.550

Table B5.3.8 Analysis of variance of soil nutrients.
Clay Site - 1982

Potassium, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	49702	7100	0.56	0.773	0.281
Error	10	126864	12686			
Corr. Tot.	17	176566		C.V. = 25.75		
				Std. Dev. = 112.6		
				Mean = 437.39		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2544.8	0.10	0.906
Fertilizer	1	3556.1	0.28	0.608
Tillage	2	1214.1	0.05	0.953
Fert * Till	2	42387.4	1.67	0.237

Potassium, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	1252263	178895	0.58	0.759	0.289
Error	10	3086885	308689			
Corr. Tot.	17	4339149		C.V. = 72.64		
				Std. Dev. = 555.6		
				Mean = 764.83		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	427161	0.69	0.523
Fertilizer	1	313	0.00	0.975
Tillage	2	17665	0.03	0.972
Fert * Till	2	807124	1.31	0.313

Table B5.3.9 Analysis of variance of soil nutrients.
Clay Site - 1982

Phosphorous, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	90360	12909	2.08	0.142	0.593
Error	10	62145	6214			
Corr. Tot.	17	152505				

C.V. = 16.87
Std. Dev. = 78.83
Mean = 467.17

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	28548.0	2.30	0.151
Fertilizer	1	6922.7	1.11	0.316
Tillage	2	12952.3	1.04	0.388
Fert * Till	2	41936.8	3.37	0.076

Phosphorous, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	43245.9	6178.0	1.34	0.326	0.484
Error	10	46129.9	4613.0			
Corr. Tot.	17	89375.8				

C.V. = 26.21
Std. Dev. = 67.92
Mean = 259.11

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	6863.4	0.74	0.500
Fertilizer	1	43.6	0.01	0.925
Tillage	2	608.8	0.07	0.937
Fert * Till	2	35730.1	3.87	0.057

Table B5.3.10 Analysis of variance of soil nutrients.
Clay Site - 1982

Organic Matter, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.551	0.936	1.10	0.431	0.435
Error	10	8.508	0.851			
Corr. Tot.	17	15.059				
				C.V. =	20.89	
				Std. Dev. =	0.922	
				Mean =	4.415	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.537	0.90	0.436
Fertilizer	1	0.510	0.60	0.457
Tillage	2	1.725	1.01	0.397
Fert * Till	2	2.779	1.63	0.243

Organic Matter, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.084	0.869	0.93	0.521	0.395
Error	10	9.307	0.931			
Corr. Tot.	17	15.391				
				C.V. =	44.85	
				Std. Dev. =	0.965	
				Mean =	2.151	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.036	0.02	0.981
Fertilizer	1	0.231	0.25	0.629
Tillage	2	4.266	2.29	0.152
Fert * Till	2	1.551	0.83	0.463

Table B5.3.11 Analysis of variance of soil nutrients.
Sand Site - 1983

Phosphorous, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	561059	80151	1.05	0.457	0.423
Error	10	764447	76444			
Corr. Tot.	17	1325506				

C.V. = 41.34
Std. Dev. = 276.5
Mean = 668.83

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	509389	3.33	0.078
Fertilizer	1	10902	0.14	0.714
Tillage	2	13076	0.09	0.919
Fert * Till	2	27691	0.18	0.837

Phosphorous, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	95527	13646	0.92	0.527	0.393
Error	10	147537	14753			
Corr. Tot.	17	243064				

C.V. = 39.59
Std. Dev. = 121.5
Mean = 306.83

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	33829.3	1.15	0.356
Fertilizer	1	4704.5	0.32	0.585
Tillage	2	34796.3	1.18	0.347
Fert * Till	2	22197.0	0.75	0.496

Table B5.3.12 Analysis of variance of soil nutrients.
Sand Site - 1983

Potassium, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	79410	11344	2.61	0.083	0.646
Error	10	43523	4352			
Corr. Tot.	17	122934		C.V. = 26.96		
				Std. Dev. = 65.97		
				Mean = 244.67		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	36222.3	4.16	0.048
Fertilizer	1	14000.2	3.22	0.103
Tillage	2	17317.0	1.99	0.187
Fert * Till	2	11870.8	1.36	0.300

Potassium, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	25934.2	3704.9	0.80	0.605	0.359
Error	10	46282.9	4628.3			
Corr. Tot.	17	72217.1		C.V. = 33.88		
				Std. Dev. = 68.03		
				Mean = 200.78		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	19415.1	2.10	0.174
Fertilizer	1	0.2	0.00	0.995
Tillage	2	660.1	0.07	0.932
Fert * Till	2	5858.8	0.63	0.551

Table B5.3.13 Analysis of variance of soil nutrients.
Sand Site - 1983

Organic Matter, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	5.468	0.781	3.33	0.042	0.700
Error	10	2.343	0.234			
Corr. Tot.	17	7.811		C.V. = 12.16		
				Std. Dev. = 0.484		
				Mean = 3.981		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.762	3.76	0.061
Fertilizer	1	1.222	5.21	0.046
Tillage	2	0.352	0.75	0.497
Fert * Till	2	2.132	4.55	0.039

Organic Matter, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.740	0.963	0.95	0.513	0.399
Error	10	10.153	1.015			
Corr. Tot.	17	16.893		C.V. = 41.21		
				Std. Dev. = 1.008		
				Mean = 2.445		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	4.635	2.28	0.153
Fertilizer	1	0.451	0.44	0.520
Tillage	2	1.052	0.52	0.611
Fert * Till	2	0.602	0.30	0.750

Table B5.3.14 Analysis of variance of soil nutrients. Clay Site - 1983

Phosphorous, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	185521	26503	0.65	0.709	0.312
Error	10	408587	40858			
Corr. Tot.	17	594108				
				C.V. = 57.06		
				Std. Dev. = 202.1		
				Mean = 354.28		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	36894.1	0.45	0.649
Fertilizer	1	5442.7	0.13	0.723
Tillage	2	85244.1	1.04	0.388
Fert * Till	2	57940.1	0.71	0.515

Phosphorous, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	84106	12015	2.12	0.136	0.597
Error	10	56690	5669			
Corr. Tot.	17	140797				
				C.V. = 31.09		
				Std. Dev. = 75.29		
				Mean = 242.17		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	18156.3	1.60	0.249
Fertilizer	1	3784.5	0.67	0.433
Tillage	2	2362.3	0.21	0.815
Fert * Till	2	59803.0	5.27	0.027

Table B5.3.15 Analysis of variance of soil nutrients.
Clay Site - 1983

Potassium, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	34915	4987.9	0.70	0.675	0.328
Error	10	71457	7145.7			
Corr. Tot.	17	106372				

C.V. = 22.75
Std. Dev. = 84.53
Mean = 371.56

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	2272.1	0.16	0.856
Fertilizer	1	242.0	0.03	0.858
Tillage	2	15904.8	1.11	0.366
Fert * Till	2	16496.3	1.15	0.354

Potassium, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	29705.5	4243.6	0.95	0.515	0.398
Error	10	44891.0	4489.1			
Corr. Tot.	17	74596.5				

C.V. = 19.54
Std. Dev. = 67.00
Mean = 342.83

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	17787.0	1.98	0.189
Fertilizer	1	2426.7	0.54	0.479
Tillage	2	1573.0	0.18	0.842
Fert * Till	2	7918.8	0.88	0.444

Table B5.3.16 Analysis of variance of soil nutrients.
Clay Site - 1983

Organic Matter, 0-20 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	3.197	0.457	0.51	0.808	0.263
Error	10	8.960	0.896			
Corr. Tot.	17	12.157		C.V. = 23.08		
				Std. Dev. = 0.947		
				Mean = 4.102		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	1.373	0.77	0.490
Fertilizer	1	0.233	0.26	0.621
Tillage	2	0.099	0.06	0.946
Fert * Till	2	1.491	0.83	0.463

Organic Matter, 20-40 cm.

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	6.965	0.995	1.37	0.314	0.490
Error	10	7.262	0.726			
Corr. Tot.	17	14.227		C.V. = 31.88		
				Std. Dev. = 0.852		
				Mean = 2.673		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	5.730	3.95	0.055
Fertilizer	1	0.015	0.02	0.889
Tillage	2	1.003	0.69	0.524
Fert * Till	2	0.217	0.15	0.863

Table B5.3.17 Analysis of variance of density at depths of 0-5 cm and 5-10 cm, Clay Site - 1982.

Depth = 0-5 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.018	0.003	3.18	0.048	0.690
Error	10	0.008	0.001			
Corr. Tot.	17	0.026				
				C.V. = 2.464		
				Std. Dev. = 0.028		
				Mean = 1.151		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.000	0.12	0.889
Fertilizer	1	0.000	0.33	0.578
Tillage	2	0.012	7.69	0.010
Fert * Till	2	0.005	3.15	0.087

Depth = 0-10 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.016	0.002	0.82	0.595	0.363
Error	10	0.028	0.003			
Corr. Tot.	17	0.043				
				C.V. = 4.282		
				Std. Dev. = 0.052		
				Mean = 1.226		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.004	0.68	0.531
Fertilizer	1	0.000	0.00	0.986
Tillage	2	0.004	0.72	0.511
Fert * Till	2	0.008	1.46	0.278

Table B5.3.18 Analysis of variance of density at depths of 10-15 cm and 15-20 cm, Clay Site - 1982

Depth = 10-15 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.028	0.004	1.11	0.423	0.438
Error	10	0.036	0.004			
Corr. Tot.	17	0.064				

C.V. = 5.067
Std. Dev. = 0.060
Mean = 1.184

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.021	2.89	0.103
Fertilizer	1	0.002	0.57	0.466
Tillage	2	0.000	0.00	0.996
Fert * Till	2	0.005	0.72	0.509

Depth = 15-20 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.070	0.010	2.48	0.094	0.634
Error	10	0.040	0.004			
Corr. Tot.	17	0.110				

C.V. = 4.941
Std. Dev. = 0.063
Mean = 1.284

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.011	1.38	0.295
Fertilizer	1	0.004	1.08	0.324
Tillage	2	0.044	5.50	0.025
Fert * Till	2	0.010	1.26	0.326

Table B5.3.19 Analysis of variance of density at a depth of 20-25 cm
Clay Site - 1982

Depth = 20-25 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.160	0.023	8.23	0.002	0.852
Error	10	0.028	0.003			
Corr. Tot.	17	0.188				

C.V. = 4.377
Std. Dev. = 0.053
Mean = 1.204

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.034	6.06	0.019
Fertilizer	1	0.000	0.09	0.772
Tillage	2	0.106	19.01	0.004
Fert * Till	2	0.020	3.68	0.064

Table B5.3.20 Analysis of variance of density at depths of 0-5 cm and 5-10 cm. Sand Site - 1982

Depth = 0-5 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.005	0.001	0.32	0.927	0.184
Error	10	0.021	0.002			
Corr. Tot.	17	0.025				

C.V. = 3.887
Std. Dev. = 0.045
Mean = 1.165

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.003	0.64	0.549
Fertilizer	1	0.000	0.08	0.787
Tillage	2	0.001	0.26	0.776
Fert * Till	2	0.001	0.19	0.831

Depth = 5-10 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.010	0.001	0.52	0.798	0.268
Error	10	0.027	0.003			
Corr. Tot.	17	0.037				

C.V. = 4.297
Std. Dev. = 0.052
Mean = 1.212

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.003	0.62	0.559
Fertilizer	1	0.004	1.54	0.242
Tillage	2	0.001	0.24	0.789
Fert * Till	2	0.001	0.20	0.820

Table B5.3.21 Analysis of variance of density at depths of 10-15 cm and 15-20 cm, Sand Site - 1982

Depth = 10-15 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.026	0.004	0.59	0.753	0.291
Error	10	0.063	0.006			
Corr. Tot.	17	0.089		C.V. = 6.782		
				Std. Dev. = 0.080		
				Mean = 1.173		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.000	0.02	0.985
Fertilizer	1	0.004	0.65	0.440
Tillage	2	0.018	1.44	0.281
Fert * Till	2	0.003	0.27	0.768

Depth = 15-20 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.045	0.006	0.95	0.512	0.399
Error	10	0.068	0.007			
Corr. Tot.	17	0.114		C.V. = 6.713		
				Std. Dev. = 0.083		
				Mean = 1.230		

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.019	1.39	0.293
Fertilizer	1	0.001	0.08	0.780
Tillage	2	0.003	0.24	0.794
Fert * Till	2	0.023	1.66	0.239

Table B5.3.22 Analysis of variance of density at a depth of 20-25 cm
Sand Site - 1982

Depth = 20-25 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.079	0.011	3.74	0.030	0.724
Error	10	0.030	0.003			
Corr. Tot.	17	0.109				

C.V. = 4.707
Std. Dev. = 0.055
Mean = 1.167

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.039	6.53	0.015
Fertilizer	1	0.003	0.91	0.363
Tillage	2	0.035	5.88	0.021
Fert * Till	2	0.001	0.23	0.797

Table B5.3.23 Analysis of variance of density at depths of 0-5 cm and 5-10 cm, Clay Site - 1983

Depth = 0-5 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.031	0.004	1.63	0.232	0.533
Error	10	0.027	0.003			
Corr. Tot.	17	0.057				

C.V. = 4.209
Std. Dev. = 0.052
Mean = 1.229

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.009	1.72	0.229
Fertilizer	1	0.001	0.36	0.564
Tillage	2	0.020	3.71	0.063
Fert * Till	2	0.001	0.11	0.894

Depth = 5-10 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.024	0.003	1.40	0.305	0.494
Error	10	0.024	0.002			
Corr. Tot.	17	0.048				

C.V. = 3.657
Std. Dev. = 0.049
Mean = 1.342

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.008	1.75	0.223
Fertilizer	1	0.001	0.31	0.592
Tillage	2	0.010	2.14	0.169
Fert * Till	2	0.004	0.84	0.459

Table B5.3.24 Analysis of variance of density at depths of 10-15 cm and 15-20 cm. Clay site - 1983

Depth = 10-15 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.017	0.002	2.02	0.152	0.586
Error	10	0.012	0.001			
Corr. Tot.	17	0.029				

C.V. = 2.559
Std. Dev. = 0.034
Mean = 1.345

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.007	3.10	0.090
Fertilizer	1	0.001	0.75	0.408
Tillage	2	0.005	2.02	0.183
Fert * Till	2	0.004	1.57	0.255

Depth = 15-20 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.033	0.005	4.44	0.017	0.757
Error	10	0.011	0.001			
Corr. Tot.	17	0.044				

C.V. = 2.317
Std. Dev. = 0.033
Mean = 1.411

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.009	4.16	0.049
Fertilizer	1	0.000	0.01	0.912
Tillage	2	0.024	11.01	0.003
Fert * Till	2	0.001	0.38	0.693

Table B5.3.25 Analysis of variance of density at depths of 20-25 cm and 25-30 cm. Clay Site - 1983

Depth = 20-25 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.016	0.002	0.65	0.712	0.311
Error	10	0.036	0.004			
Corr. Tot.	17	0.052				
					C.V. = 4.250	
					Std. Dev. = 0.060	
					Mean = 1.408	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.004	0.58	0.576
Fertilizer	1	0.000	0.08	0.777
Tillage	2	0.007	0.92	0.431
Fert * Till	2	0.005	0.72	0.512

Depth = 25-30 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.039	0.006	0.82	0.591	0.365
Error	10	0.068	0.007			
Corr. Tot.	17	0.108				
					C.V. = 5.471	
					Std. Dev. = 0.083	
					Mean = 1.510	

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.013	0.93	0.426
Fertilizer	1	0.001	0.19	0.672
Tillage	2	0.009	0.68	0.529
Fert * Till	2	0.016	1.17	0.349

Table B5.3.26 Analysis of variance of density at depths of 0-5 cm and 5-10 cm, Sand Site - 1983

Depth = 0-5 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.078	0.011	4.26	0.020	0.749
Error	10	0.026	0.003			
Corr. Tot.	17	0.104				

C.V. = 4.361
Std. Dev. = 0.051
Mean = 1.173

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.21	0.811
Fertilizer	1	0.034	12.90	0.005
Tillage	2	0.039	7.48	0.010
Fert * Till	2	0.004	0.76	0.492

Depth = 5-10 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.025	0.004	8.15	0.002	0.851
Error	10	0.004	0.000			
Corr. Tot.	17	0.029				

C.V. = 1.637
Std. Dev. = 0.021
Mean = 1.278

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.000	0.15	0.861
Fertilizer	1	0.005	10.35	0.009
Tillage	2	0.020	22.85	0.000
Fert * Till	2	0.000	0.36	0.705

Table B5.3.27 Analysis of variance of density at depths of 10-15 cm and 15-20 cm. Sand Site - 1983

Depth = 10-15 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.013	0.002	1.42	0.296	0.499
Error	10	0.013	0.001			
Corr. Tot.	17	0.025				

C.V. = 2.807
Std. Dev. = 0.036
Mean = 1.266

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.000	0.14	0.872
Fertilizer	1	0.003	2.49	0.146
Tillage	2	0.006	2.53	0.129
Fert * Till	2	0.003	1.07	0.380

Depth = 15-20 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.020	0.003	6.50	0.005	0.820
Error	10	0.004	0.000			
Corr. Tot.	17	0.024				

C.V. = 1.535
Std. Dev. = 0.021
Mean = 1.364

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.75	0.495
Fertilizer	1	0.015	33.17	0.000
Tillage	2	0.003	3.78	0.060
Fert * Till	2	0.001	1.63	0.244

Table B5.3.28 Analysis of variance of density at depths of 20-25 cm and 25-30 cm, Sand Site - 1983

Depth = 20-25 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.023	0.003	5.99	0.006	0.808
Error	10	0.005	0.001			
Corr. Tot.	17	0.028				

C.V. = 1.835
Std. Dev. = 0.023
Mean = 1.275

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.001	0.81	0.474
Fertilizer	1	0.015	27.46	0.000
Tillage	2	0.006	5.42	0.025
Fert * Till	2	0.001	1.02	0.395

Depth = 25-30 cm

Source	D.F.	S.S.	M.S.	F Value	Pr F	R Sq.
Model	7	0.019	0.003	0.59	0.753	0.291
Error	10	0.046	0.005			
Corr. Tot.	17	0.065				

C.V. = 4.837
Std. Dev. = 0.068
Mean = 1.403

Source	D.F.	Anova S.S.	F Value	Pr F
Block	2	0.003	0.31	0.741
Fertilizer	1	0.006	1.35	0.273
Tillage	2	0.001	0.09	0.913
Fert * Till	2	0.009	0.98	0.409