EFFECT OF CULTIVATION ON MAIZE RESPONSE TO NITROGEN FERTILISER

A thesis presented in partial fulfillment of the requirements for the
degree of
MASTERS IN APPLIED SCIENCE
in Soil Science

Institute of Natural Resources
Massey University, Palmerston North
NEW ZEALAND

Massey University

SULHADIANA MUNIR

2000

ABSTRACT

EFFECT OF CULTIVATION ON MAIZE RESPONSE TO NITROGEN FERTILISER

Continuous cultivation of arable soils results in the decline of 'soil quality' in terms of structural degradation and nutrient depletion. It decreases soil organic matter content, induces the leaching and gaseous losses of N through enhanced nitrification and denitrification, resulting in the depletion of nitrogen content of the soils. This will affect N availability, soil moisture retention, soil aeration and the activity of soil microorganisms. The objective of this study is to examine the effect of cultivation on the response of maize to N fertiliser.

A glass house experiment was conducted using four soils. The soils included a permanent pasture soil and three maize / barley grown soils which have been cultivated for 6, 17 and 34 years. Maize plants were grown at six levels of N applied as urea (0 – 500 kg N /ha).

The dry matter yield response to N application indicated higher maize growth for the pasture soil than for the cultivated soils at all levels of N application. Even at the highest level of N application (500 kg N/ha) the maize dry matter yield for the cultivated soil did not reach that for the unfertilised pasture soil. This indicates that N alone was not limiting the dry matter yield among the cultivated soils. It was hypothesised that the differences in the physical conditions among these soils may also be responsible for differences in dry matter yield.

In the second experiment, pasture and the 34 year cultivated soils were incubated with poultry manure for eight weeks. The addition of poultry manure was to improve the physical conditions of the soil. A glasshouse experiment was then conducted to examine the effect of poultry manure addition on the growth of maize at five levels of N (0-400 kg N/ha) applied as urea.

There was a clear visual indication of an improvement in the structure of the cultivated soil due to the incorporation of poultry manure. Addition of poultry manure increased the dry matter yields of maize plants both in the cultivated and the pasture soils. The dry matter yield of plants in the cultivated soils (in the presence of manure addition) was higher than the pasture soils at low levels of N application and similar yields were obtained at the higher rates of N application. Oxygen diffusion rate (ODR) values were higher for the pasture soil than the cultivated soil . The addition of poultry manure in the initial stages, however, decreased the ODR values in both soils which is attributed to the increased consumption of oxygen by the easily decomposable organic carbon in the poultry manure. With increasing time after incubation the ODR values slowly increased in the poultry manure treated soils indicating an improvement in soil structure. The study clearly demonstrated that the impact of cultivation on maize yield was partly due to poor soil physical conditions.

ACKNOWLEDGEMENTS

I would like to thank my supervisors, Associate Professor Nanthi S. Bolan and Dr. Surinder Saggar (Landcare Research) for their generous advise, thoughtful guidance, suggestions and for their numerous times of support throughout this study.

I wish to express my sincere thanks to Professor Russ Tillman, Head of Institute Natural Resources, Massey University, who gave me a chance to undertake postgraduate study.

I wish to express my thanks to all the staff in the Soil Science Group, particularly Bob Toes, Ian Furkert and Ross Wallace who assisted me during my study.

My thanks to Bhupinder Pal Singh, Stephen Trolove, Tin Maung Aye, and all other post-graduate students for their friendship and help with computer work and statistical analysis. Thanks are also to Denise Bunskill and Marian Trembath for their kindness.

I would like to thank the Ministry of Foreign Affairs and Trade, New Zealand for the Scholarship grant under NZ Overseas Development Assistance Programme (NZODA).

Finally, special thanks to my mother Hajjah Syamsiah Munir and my father late H.A.R. Munir for their endurance and support, also to my brothers and my sisters for their encouragement and care during my study.

TABLES OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER 1

INTRODUCTION

Proper cultivation has a beneficial influence on the yield and quality of the arable crops. The primary purposes of cultivation are destruction of weeds and production of a fine tilth. It loosens the surface of the soil by admitting air. In the cultivated soil, however, the destruction of aggregates and subsequent soil compaction can result in a rapid decrease of soil organic matter and turnover of the microbial biomass (Landina et al., 1984). Also continuous cropping with maize tends to deteriorate the physical conditions of the soils, and encourage weed growth to serious proportions (Berger, 1962). Cultivation is the principle agent promoting soil structure modification and increasing potential soil organic matter loss by erosion and biological decomposition (Carter et al., 1994).

Continuous cultivation of arable soils results in the decline of 'soil quality' in terms of structural degradation, soil organic matter loss and nutrient depletion. Cultivation has also been shown to induce the leaching losses of nitrogen (N) through enhanced nitrification.

Maize production is limited by N deficiency more often than by that of any other nutrient. The recommended level of N application for maize in New Zealand is 200 kg N/ha applied at three split doses (50 kg N pre-planting; 100 kg each at 60 and 180 days after sowing. For a maize crop of 6.3 tons/ha including stover, N uptake of 167-241 kg N/ha is required (Smith, 1952 as cited by Berger, 1962).

In New Zealand, conversion of pasture land to cropping by cultivation and reversion back to pasture for replenishment of nutrients and organic matter is a common practice. However, in the Manawatu region, some heavier textured soils are used for continuous (medium-to long-term) cropping. Such operations are not sustainable because continuous cropping of these soils causes a decline in soil physical and biological properties (Saggar et al., 1998). Consequently, soil fertility is decreased and maize yields are reduced. The poorly structured soils become compacted and difficult to cultivate (Shepperd et al., 2000). Changes in soil organic matter also result in the depletion of nutrient reserves, such as soil N. To maintain the maize yield farmers have to apply additional inorganic N fertilisers. However, it is not known if increased N fertilization alone is sufficient to maintain maize yields in these long-term cultivated soils of poor structure.

Since the crop production in these soils is limited by both chemical fertility (poor N status) and physical conditions (poor soil structure), there is a need to assess the extent to which each of these two influence the maize production. Therefore, the objectives of this study were:

1. To examine the effect of cultivation on N response of maize under glasshouse condition.
2. To assess the effect of incorporating poultry manure (PM) and N addition on maize growth and soil physical condition.

The overall structure of thesis is given in Figure 1.

Chapter 1 gives the background to the present study which was designed to examine the effect of cultivation on maize response to N fertiliser under glasshouse conditions.

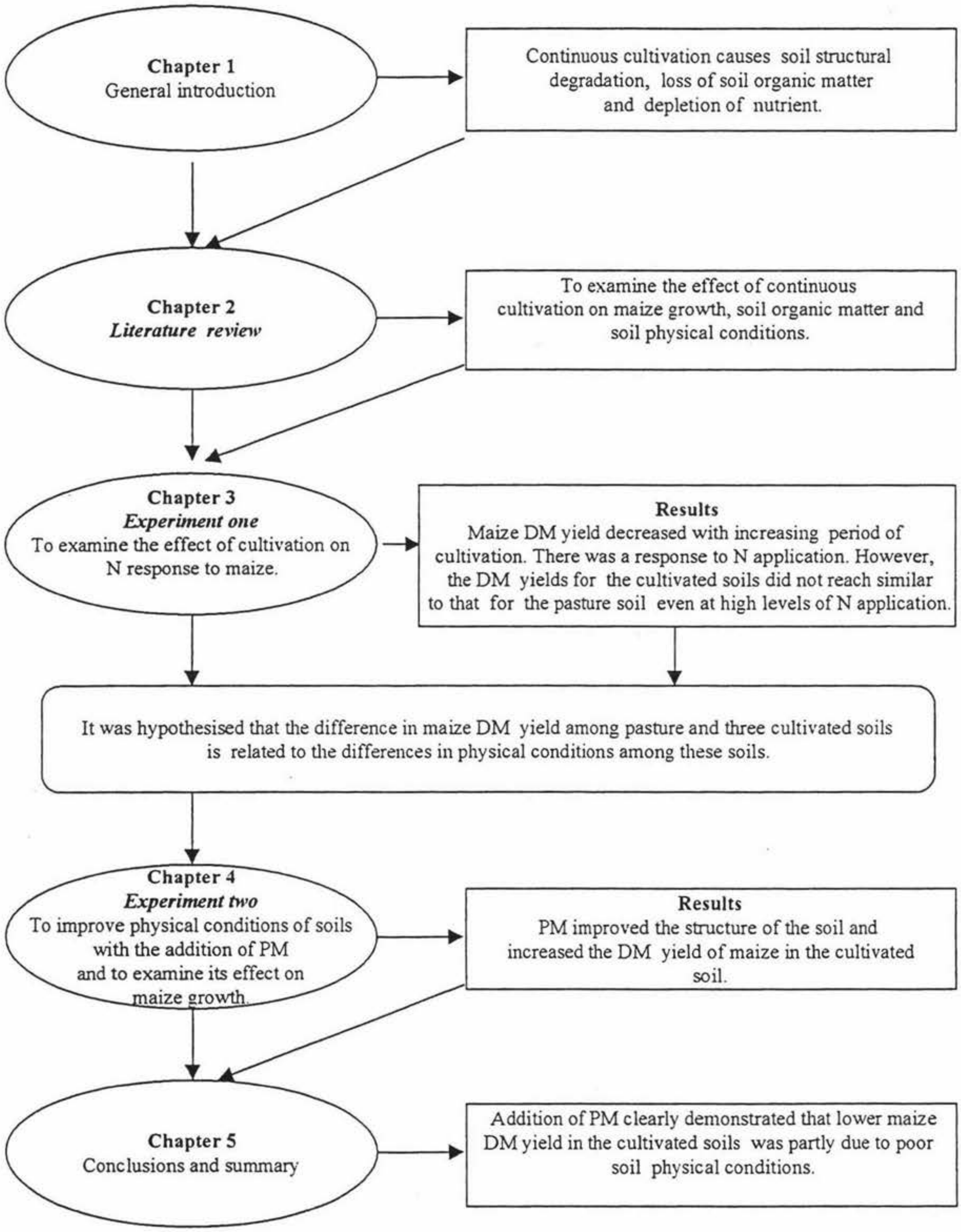
Chapter 2 presents a literature review on the effect of cultivation on soil properties and briefly outlines maize response to N fertiliser in cultivated soils.

In **Chapter 3,** the results of a glasshouse experiment (Experiment 1) are discussed. The aim of this glasshouse experiment was to examine the growth response of maize to increasing levels of N in four soils (three maize soils cultivated for different periods and one permanent pasture soil).

Chapter 4 describes the results obtained for the second glasshouse experiment (Experiment II). The aim of this experiment was to improve the physical conditions of the soil with addition of PM and then to examine its effect on the maize growth response to N.

From these glasshouse trials it was concluded (**Chapter 5**) that the decline in maize yield with cultivation was due partly to the structural degradation of the soil. It is possible to improve the physical conditions through incorporation of poultry manure.

Figure 1. Diagram of the logical structure of the thesis



CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

A number of studies examining the effect of cultivation, especially on maize crop growth, soil physical properties, soil organic matter and nutrient availability have been reported (Tisdale and Oades, 1980; Van Veen and Paul, 1981; Tisdale and Oades, 1982; Baldock and Kay, 1987; Griffith et al., 1988; Hart et al., 1988; Dick et al., 1992; Shepherd, 1992; Sparling et al., 1992; Addiscott and Dexter, 1994; Lipiec and Stepnieswki, 1995; Ball et al., 1997; Vanotti et al., 1997; Shepherd et al., 2000; Saggar et al., 2000). These studies conclusively demonstrated that continuous cultivation of land is resulting in decline of soil quality in terms of structural degradation, and soil organic matter and nutrient depletion in most agricultural systems. In this chapter, available literature on the impact of continuous cultivation on maize growth soil organic matter and physical properties is reviewed to assess the current knowledge and to develop a research topic to be pursued.

2.2 Changes in Maize Yield with Cultivation

Maize performs best on well-drained, aerated and deep, silt loam soils containing large amounts organic matter and well supplied with available nutrients (Berger, 1962). Maize growth varies widely depending upon the fertility level of the soil and the environmental conditions. However, with good management maize can be grown in any type of soil.

Cultivation methods for maize have been changing owing to improved farm power and machinary, availability of a wide variety of herbicides, and better understanding of tillage requirements. Different soil types and different climatic conditions result in different requirements for seedbeds and for effectively managing soil and water (Sprague, 1966).

Cultivation can effect crop yields depending on cropping system, residue management, soil type and climatic factors (Carefoot et al., 1990a; 1990b). Dick et al. (1997) have reported a greater corn yield no tillage than conventional ploughing. In silty clay loam soils conservation tillage practices resulted in greater maize yields (James and Bradford, 1997). However, the use of reduced tillage in clay soil has often resulted in lower corn yield compared compared to conventional ploughing (Vyn, 1988 as cited in Raimbault and Vyn, 1991; Griffith et al.,1988). John et al. (1995) have reported that in poorly drained clay soil continuous corn or corn following soybean resulted in a decreased yield with no tillage. McFarland et al. (1991) have reported that conventional tillage with dyking and reduced tillage, with or without dyking, significantly increased soil water content which reduced the corn yield in clay soil / silt loam soil. This is probably related to the poor root respiration due to lack of oxygen in the soil.

In cultivating the soil, sometime it is necessary to grow legume (e.g. alfalfa) in order to increase the yield in poorly drained soils (clay soils). The use of legumes as companion crop has often found to provide higher corn yield in poorly drained soils (Mohammedreza et al., 1997).

Cultivation can also influence the maize yield through crop rotation in heavy soils. Vyn (1988) (as cited in Raimbault and Vyn, 1991) and Griffith et al. (1988) found that growing corn in rotation rather than continuously has reduced or eliminated the adverse effect of minimum tillage system on corn yield in clay soils.

Maize production in the light soils does not have aeration problems, even when a compacted zone is present within the root zone (Taylor and Burnett, 1963). However, other researchers have found that excessive compaction on sandy soils resulted in lower crop yield owing to shallow rooting (Lipiec et al., 1991).

2.3 Changes in Soil Organic Matter with Cultivation

The term, soil organic matter (SOM) refers to the whole range of the organic materials in the soil. It includes, living microorganisms, and dead and decaying plant and animal remains. Soil organic matter is of great importance due to its influence on soil physical, chemical and biological properties and creating a favourable medium for biological reactions and life support in the soil environment (Aslam et al., 1999).

Soil organic matter content is the result of a steady-state equilibrium of formation and degradation, which can be affected by soil management practices such as cultivation. van Veen and Paul (1981) pointed out that cultivation of native prairie soils reduces the amount of organic matter and alters their structural stability. It also causes losses of the soil microbial component, which can adversely affect the physical, biological and nutrient status of soil. The loss of soil organic matter during cultivation can also influence the loss of organically bound nutrients and chemicals from the soil.

Cultivation of pastoral soils generally leads to a rapid loss of organic matter during the first few years of cropping as a result, of the removal of dry matter removed during harvesting and accelerated decomposition rate of labile organic matter caused by mixing (Rasmussen and Collins, 1991). The level of organic matter in cultivated soils controlled by the rate of addition and decomposition of organic residues can reflect the intensity of soil utilisation.

Studies from New Zealand have indicated a marked loss of soil organic matter with continuous maize cultivation in the Manawatu region (Sparling et al., 1992; Saggar et al., 2000; Shepherd et al., 2000). Maize grown with continuous cultivation on Kairanga silty clay loam for 11 years decreased the total C content in the top 20 cm of soil by 21 % compared to levels under long term pasture. Long-term cultivation resulted in up to 60 % loss in organic C in the top 10 cm of soil. Research in the Canterbury region of New Zealand, where grazed pastures are grown in rotation with arable crops of similar duration (each usually 2-4 years), has shown that short-term grass pasture leys in rotation with arable crops are particularly effective in improving soil organic matter levels and soil fertility, and increasing the size of microbial biomass (Haynes and Francis, 1993; Haynes and Beare, 1997; Haynes, 1999).

Furthermore, the impact of management on soil organic matter has also been researched extensively because different tillage operations and subsequent soil management are important factors for sustainable agriculture world-wide. Conservation or no-tillage has often been shown to increase soil organic matter content in the surface soil layers compared with conventional tillage (Doran, 1980; 1983; Dick, 1983; Rice and Smith, 1984). Soil management practices had a major influence on the changes in soil organic matter content (Vanotti et al.,1997). Loss of organic matter during cultivation can affect the soil physical, biological, and nutrient status of the soils (Carter, 1986; Carter and White, 1986). In a recent New Zealand study, Aslam et al. (1999) showed that within two years of converting permanent pasture to cropping with conventional tillage resulted in a 29 % decline in microbial biomass carbon and 32 % in microbial biomass nitrogen and phosphorous. But no such decline in microbial biomass occurred with no tillage. Similar but small changes in organic carbon were also observed (Aslam et al., 2000). Both short- and long term effects of soil management on the size and activity of microbial biomass have been found closely related to changes in total soil organic matter content in New Zealand (Sparling et al., 1992; Haynes and Beare, 1996; Aslam et al., 1999; Haynes, 1999; Saggar et al., 2000). These studies suggest that where pastures are grown as a restorative phase in rotation with arable crops, there is an improvement in soil organic matter and N status. However, continuous cultivation declines both organic matter and N reserves in soils resulting in poor N supply (Saggar et al., 2000).

The amount of organic matter present in a soil and the rate of turnover are further influenced by the length and intensity of cultivation (Tabatabai and Al Khafaji, 1980; Honeycutt et al., 1991; Saggar et al., 2000). In the Manawatu region, Saggar et al. (1998) showed that continuous cultivation of pasture resulted in a up to 60 % decline in surface soil organic N, had a significant influence on soil biological parameters and reduced mineralized N.

As the cultivation changes the size of organic matter pools it may reduce the soil organic C and N in the particulate organic matter. Consequently, soil N balance is modified. Cropping system can also influence the mineralisation of N in the soil. It can effect the N fertilisation through C : N ratios of plant residue decomposition. Residues with a low C : N ratios or high N content tend to be high in N mineralisation. Vanotti et al. (1997) have found that corn receiving low nitrogen fertiliser had the highest C : N ratio.

Cultivation can also effect the soil moisture which can influence the mineralisation of N. Moisture stress inhibits soil microbial growth. When soil moisture content increases, aeration decreases and microbial growth is also inhibited It has been found that cycles of wetting and drying tend to increase the amount of available substrate for (Haynes et al., 1986; Ball et al., 1997).

Cultivation can influence N mineralisation by rapid decomposition of soil organic matter through mixing. Faster mineralisation of organic N and subsequent nitrification may result in NO_3^- build up and leaching. Increased NO_3^- leaching will result in increased fertiliser N requirements.

Growing plants can also influence the N transformation in soils (Huntjens, 1971; Haynes et al., 1986; McLaren and Cameron, 1996). In the rhizosphere of cropped soil, the roots release exudates or sloughed off tissues as an energy source for microbial growth. This microbial activity may result in the release of the mineral N through the decomposition of these compounds. However, Huntjens (1971) reported net N mineralisation in soils containing dead grass roots but net N immobilisation in the presence of living roots. Clemant and Williams (1967) observed an accumulation of soil organic matter and soil N under permanent pasture.

Hesterman et al. (1992) have mentioned that when leguminous species are used, the biologically fixed N released during residue decomposition may reduce fertliser N requirements for a subsequent crop.

Ruselle et al. (1987) reported that maize yield was increased by up to 62 % following alfalfa; this was due to N supplied by the legume. Similarly Power and Broadbent (1989) reported that 50 % of legume N was mineralised during a subsequent summer growing season.

Maintenance of soil organic matter is vital to the ecosystem functioning due to its control on soil physical, chemical and biological properties. It is apparent from the above review that cultivation causes a decline in soil organic matter and reduces nutrient supply. To maintain soil organic matter levels in continuously cultivated soils they should either be reverted back to pastoral phase or amended with additions of organic materials such as plant residues, compost or poultry manure.

2.4 Changes in Soil Physical Properties with Cultivation

The main objective of cultivation is to provide a seedbed, which allows easy establishment and growth of a crop by incorporating previous crop residues and killing weeds. Cultivation can also change the physical properties of the soil such as structure, (aggregate size, and aggregate stability), pore space / aggregates, and hydraulic conductivity. Cultivation causes break down of the aggregate or clod which will usually provide the ability to store water and air as well as allowing drainage and root growth to occur (Sprague et al., 1966; Hilfiker and Lowery, 1988; Lal et al., 1989; Sharma, 1990; Kaspar et al., 1991). Cultivation can cause soil structure break down resulting in loss of macro-porosity of the soils, which would cause poor soil aeration. Use of heavy machinery during cultivation may result in soil compaction, which would cause difficulty for the plant root growth. Vertical cracking through the soil profile resulting from compaction may also damage roots.

In this section, research pertaining to cultivation effects on soil structure, soil compaction, and hydraulic conductivity is reviewed.

2.4.1 Soil Texture

Soil texture greatly affects the productivity and useability of a soil. There are four broad textural classes based on the amounts of sand, silt, and clay in the soil: clayey, silty, loamy, and sandy. Soils high in clay are known as heavy soils and low in clay are called light soils. Clay soils have a higher water holding capacity than light soils (Frederick and Thompson, 1993).

Soil texture is quite important in soil management and land use because it affects water movement and percolation, which in turn affect plant growth, erosion, and water management (Charles and Bair, 1982). For example, clay soils have a large surface area, which can hold more water and carry electrical surface charges. The charges give clay the capacity to attract plant nutrient ions (Frederick and Thompson, 1993). The clay soils generally have high total pore space, therefore, they hold a large amount of water which is very important for plant growth in terms of increased yield.

Cultivation can cause a problem in the availability of soil nutrients in heavy soils. Without any conservation tillage it can reduce the yield as Griffith et al. (1988) have reported that the use of reduced tillage system has often resulted in lower corn yields compared to conventional ploghing for continuous corn grown on clay loam or clay soils. Cultivation has a strong impact on nutrient mineralisation especially N in these heavy soils (Loll and Bolag, 1983).

On the other hand, sandy soils have less pore space than finer textured soils, but they are almost invariably well aerated. Water is easily lost in sandy soils because they have a rather low capacity for storing water for plant growth which can result in reduced yield (Frederick and Thompson, 1993). Frederick and Thompson (1993) mentioned that sandy soils have two limitations for cultivation; (1) they have relatively low water holding capacity; and (2) they are poor storage-houses for plant nutrients. The amount of nitrate leached is more in sandy soils than in clay soils (Kolenbrander, 1969; Cooke, 1976; Catraux and Schitzer, 1987).

To obtain maximum yields, cropping soils will require different amounts of cultivation practices depending on their texture. Heavier soils need more tillage to create good soil aeration and light soils need less tillage, no tillage or minimum tillage.

2.4.2 Soil Structure

Soil structure is usually referred to the spatial arrangement of soil particles and influences their size, shape, roughness, arrangement, and continuity of the soil pores between and within the particles (Buckman and Brady, 1969; McLaren and Cameron, 1996). Soil structure development is influenced by three steps; firstly, the soil must contain the proper elements (e.g. Ca); secondly, when the proper element are present, the soil particles will come together to form an aggregate; thirdly when the unstable aggregates are brought together they are then bound or cemented by clay, organic matter, Fe, and Al (Charles and Bair, 1982). The soil structure can be divided into three main aggregate forms namely are: Ped, Platy and Blocky (Buckman and Brady, 1969). The soil structure can exert a strong influence on many physical, chemical, and biological properties of the soil.

Soil structure is very important in the topsoil because it increases permeability (which decrease run-off), and decreases erosion. It enhances root growth by giving a more permeable soil through which roots can grow. Thus, it may increase the effective water holding capacity (Charles and Bair, 1982).

A number of studies have shown that cultivation resulted in a loss of macro-porosity, decreased soil aggregate stability and clod porosity, decrease the infiltration of water, hydraulic conductivity and soil aeration (van Veen and Paul, 1981; Elliot, 1986; Gupta and Germida, 1988; Haynes et al., 1990; Lipiec and Stepniewski, 1995). Cultivation alters structural stability and reduces the proportion of macro aggregates in the soil.

Aggregate stability has a strong relationship with soil organic matter because of its binding / cementing actions in the soil (Tisdall and Oades, 1982; Oades, 1984).

Decline in aggregate stability induces the production of a dense, massive plough layer (Haynes et al., 1990). Tisdal and Oades (1982) found that macroaggregates contained higher amount of organic matter as compared to microaggregates. However, reduction in the macroaggregates resulting from cultivation decreased aggregate stability. These conditions can combine to constrain soil management by limiting soil workability, thereby increasing the likehood of water logging and damage to soil structure. Such damage can impair crop growth, thus can reduce the yield.

The use of heavy machinery in cultivation can also influence the soil pore, soil aggregates, soil compaction, soil aeration, and soil water. Soil compaction through soil structural degradation can also influence the nutrient transport, absorption and transformation of nutrients and alteration of the soil aeration status (Glinski and Stepniewski, 1985).

Poor aeration induces the accumulation of reduced substances in soil, which may cause root death or interfere with water uptake, N_2 fixation and microbial activity (Canell and Jason, 1981). Bakken et al. (1987) reported that tractor traffic on a wet clay caused a significant reduction in pore volume and increase in aggregate size, which resulted in an increase in N loss through denitrification. The packing of soil particles closer together also affects nutrient uptake indirectly via the resulting changes in root configuration (Glinski and Lipiec, 1990; Lipiec and Simota, 1994), which can reduce yield.

This literature review clearly demonstrates that soil structural degradation during cultivation can influence soil aeration, and other soil physical and chemical properties such as soil erosion, soil water, soil nutrients, and nutrient uptake. The problems caused by continuous cultivation resulting in soil structural degradation, nutrient depletion, poor soil aeration, reduce soil porosity and hydraulic conductivity can impact the environment due to nutrient leaching, surface runoff and gaseous losses.

2.4.3 Pore space / aggregates:

Pore space is essential as it provides the soil with the ability to store water and air as well as allowing drainage and root growth to occur. When an aggregate or clod is broken during a tillage operation, it will break through a surface of weakness, which will usually be one or more micro-cracks. The resulting fragments have a smaller porosity because they no larger contain the pore space, which was previously on this surface of weakness. Currie (1966) (as cited by Addiscott, 1994) stated that porosity decreases or density increases with decreasing aggregates size.

According to McLaren and Cameron (1996) the smaller pores (< 30 um diameter) include those which are responsible for storing water in the soil. A consequence of cultivation is that the outsides of soil aggregates become physically, chemically and biologically different from the insides which depend on the heterogeneity of aggregates size.

2.4.4 Hydraulic conductivity:

The water movement in the soil is very important. This is related to the soil aggregates, soil pores and particle size. Addiscott et al. (1994) found that there are many effects of tillage and soil compaction on soil water. A loss of soil structure means a loss of soil pores and this can reduce the rate at which water can enter the soil as infiltration and the rate at which water can drain through the soil (McLaren and Cameron, 1996).

Infiltration or water movement can be increased by the presence of greater number of larger continuous pores, which connect to the soil surface (Addiscott et al., 1994). Tillage has a significant effect on the hydraulic conductivity. Tillage can increase the ability of the surface to store water temporarily in the depressions thereby delaying the onset of runoff water.

2.5 Amelioration of Soil Fertility and Organic Matter Content in Cultivated Soils

Much of agriculture throughout the world has developed by opening land to production. Many soil changes are associated with cultivation. Initially productivity is supported through the utilisation of nutrients released from the accumulated soil organic matter (Blair et al., 1994).

When the soil is cultivated, the soil physical, chemical and biological conditions are changed. Cultivation sometimes may leave a soil with unstable aggregates and a bare surface, both of which increase the runoff and erosion of soil. It causes the losses of nutrients continuously from the surface of the soil, and causes the soil to become acid (Buckman and Brady, 1969). This literature review clearly demonstrated that in New Zealand cultivation of the soils can change the soil physical and biological properties as well as changes the soil chemical fertility. Overall, there is a strong positive relationship between soil physical and biological conditions, and chemical fertility. These are very important for the productivity of cultivated soils.

To ameliorate the soil physical condition, it is important to buildup organic matter in order to improve the structural stability of the soil (Ball et al., 1994). Soil physical conditions can also be improved by minimising the intensity of cultivation, which can reduce the amount of soil organic matter and structure degradation. According to Dick et al. (1997) no tillage of corn fields results greater yields than where ploughing is practised.

A number of New Zealand studies by Haynes and co-workers (Haynes et al., 1990; Haynes and Swift, 1990; Haynes and Francis, 1990; 1991, 1993; Haynes and Beare, 1996), Sparling et al. (1992), Shepherd (1992), Shepherd et al. (2000), and Francis et al. (1999) show that soil organic matter levels can be increased by alternate periods of cropping with periods in which the soil is returned back to grass / clover pasture, crop rotation. This, helps to replace organic matter lost under cropping and restore any structural damage that may have occurred. The large plant mass returned to fields under appropriate rotations can improve 'soil quality' and promote root and microbial activities (Barber, 1972; Baldock et al., 1981; Bruce et al., 1990). Returns of organic residues to the soil are usually higher in grassland than in arable land (Ryden, 1984). A higher return of organic residues to the soil should lead to a higher content of soil organic C and N and hence, a higher mineralisation rate.

Mulch also has a positive effect the soil improvement, and benefits crop production through soil and water conservation, weed control, improved soil physical and chemical properties, and enhanced soil biological activity (Lal et al., 1989). Significant improvements in soil biological fertility have been achieved by these green manure and mulch technologies.

Green manure with relatively high nutrient contents which breakdown slowly should result in a significant input of carbon and other nutrients. This has a significant impact on soil fertility and the organic matter status of cultivated soils. If slowly decomposable residues are used, it may be necessary to supply an organic or inorganic source of more available nutrients to avoid the short-term immobilisation of nutrients from residues of low total nutrient content or which breakdown slowly for other reasons.

Farmyard or chicken manure used by farmers as an organic fertiliser can play an important role in sustaining soil productivity, especially in soil biological system. However, the nutrient contents of manures vary considerably with the species and the age of animal, the composition of feed and the manure storage (Faassen and Dijk, 1987). Appropriate management is required because organic fertiliser as manures are more slowly available to the plant compared to chemical fertilisers (McLaren and Cameron, 1996). Manures will become a potentially valuable resource in agricultural system if appropriate management strategies are developed especially for continuously cultivated soils.

In addition, the animal manures can replenish the supply of the humus and improve the biological and physical properties of the soil. Microbiological processes in soil are likely to be enhanced by the addition of manure. The manure undergoes biological decomposition immediately after excretion, and therefore its chemical, biological and physical properties continue to change, which also can affect the soil properties. All the soil organisms such as bacteria, fungi, worms, and insects are involved in the decomposition process. These microorganism would influence the soil fertility and organic matter status of the soils. Addition of poultry manure (10 t/ha) significantly decreased soil bulk density, increased soil organic matter content, total porosity, infiltration and hydraulic conductivity (Obi and Ebo, 1995). Poultry manure, regardless of long term management was found to have a large effect on soil biological response, and supported 80 to 400 % greater microbial biomass C than without poultry manure application (Fauci and Dick, 1994). However, farmers usually have access to relatively small amounts of manures. At best, manures can be used to improve the soil fertility of a small area of the farm, with little impact on overall crop production.

The decomposition of organic residues, which involves earthworms, nematodes, arthropods, molluscs, fungi, bacteria, algae, protozoa, and actinomycetes is very important to improve the soil biological fertility. The soil micro-organisms, especially fungi, may play an important role in the formation of macro-aggregates (Haris et al., 1963) several microbial species are thought to be involved in the binding together of micro-aggregates into macro-aggregates. Tisdal and Oades (1980) have reported that the greatest effects of cultivation on the nutrient and microbial characteristics of soil are observed in the C and N enriched small macroaggregate fraction (250-2000 um).

The effect of organic matter on soil physical, chemical, and biological properties should not be considered in isolation; they are interactive to a considerable extent (Lefroy et al., 1995). Organic matter stimulates the activity of fauna and micro-organisms in soil which contribute to nutrient release during the decomposition of plants and animal residues, which are important in relation to soil physical and chemical properties (Lefroy et al., 1995).

The physical condition of the soil could have an overriding effect on plant growth, irrespective of the chemical fertility of the soil (McLaren and Cameron, 1996). The difference in dry matter in cultivated soil is related to the difference in the physical condition such as soil texture and soil structure between soils.

To ameliorate soil physical conditions and improve soil fertility and organic matter levels in cultivated soils, it is better either to reduce the cultivation operations by adopting no-tillage, or incorporate organic residues and manures. The type and degree of cultivation also should be related to the soil type, soil texture/structure, plant growth requirement, and soil management practices.

This literature review indicated that continuous cropping maize crop causes a decline in soil organic matter and results soil structural degradation, which can reduce crop yield. The poorly structured soils become compacted and difficult to work. Changes in soil organic matter also result in the depletion of nutrient reserve such as N. To maintain maize yield farmers have to apply additional N fertilisers. However, it is not known if increased N fertilisation alone is sufficient to maintain maize yields in these long-term cultivated soils of poor structure.

CHAPTER III

EXPERIMENT ONE

3.1 MATERIALS AND METHODS

The first glass house experiment was conducted using four soils (a pasture soil treated three cropping soils with different periods of cultivation (6, 17 and 34 years) applied with six levels of nitrogen (0, 100, 200, 300, 400, and 500 kg N/ha). The overall aim of this experiment was to compare the growth response of maize to N fertiliser in these four soils.

3.1.1 Experimental Site:

A pot experiment was conducted at the Plant Growth Unit Research Centre, Massey University from 27 May to 27 August 1998. Four soils used were: 1. A permanent pasture soil, 2. Six years cultivation (short-term), 3. Seventeen years cultivation (medium-term), and 4. Thirty four years cultivation (long-term).

The soil samples were randomly collected at 0-20 cm depth from each of the 4 sites located within 10 km distance in the Kairanga region, Palmerston North, New Zealand (Plate 1).

The temperature in the glass house was maintained at 21- 23 ^{0}C. Measurements were recorded every two weeks, which include plant height, leaf length, and number of leaves. The plants were harvested nine weeks after sowing and the fresh weight and the dry matter weight were recorded.

Plate 1. Pasture and cultivated maize fields

In the Kairanga Region

3.1.2 Plant growth experiment:

The soil samples were air dried and passed through a 2 mm sieve. The soil samples were weighed into 4 kg pots. The soil samples were mixed with 6 levels of N fertilizer and were arranged in a randomized block design. Four replications were used.

The nitrogen treatments were :

1. Control (0 kg N/ha)
2. 100 kg N/ha = 217.3 mg urea / kg soil = 869.2 mg urea / 4 kg soil
3. 200 kg N/ha = 434.7 mg urea/kg soil = 1738.8 mg urea/ 4 kg soil
4. 300 kg N/ha = 625.2 mg urea/kg soil = 2500.7 mg urea / 4 kg soil
5. 400 kg N/ha = 869.6 mg urea/kg soil = 3478.3 mg urea / 4 kg soil
6. 500 kg N/ha = 1086 mg urea/kg soil = 4347.8 mg urea / 4 kg soil

All pots were placed in the glass house. Nitrogen as urea was applied in two split doses, 50 % before planting and the remaining 6 weeks after planting.

3.1. 3 Sowing and watering:

Four seeds of maize (*Zea mays*) hybrid 3902 were sown into each pot. Two weeks after sowing the pots were thinned to 2 seedlings per pot. The pots were watered three times per week with 20-40 ml of minus N nutrient solution (Midldleton, 1977). The moisture content of soil was maintained at Field capacity. A preliminary germination test has indicated 100 % germination of maize seeds (Plate 2).

3.1.4 Soil analysis:

Soil pH: 10 g of soil samples (sieved 2 mm) were taken in plastic beakers and mixed with 25 ml of water. The pH of the soil solution was measured with a pH meter.

Mineral N (KCl extractable): The field-moist soil samples were hand sieved through a 2 mm sieve, and analysed for 2 M KCl extractable ammonium and nitrate nitrogen. 3 g of soil samples were taken in 40 ml centrifuged tube and mixed with 30 ml of 2 M KCl. The samples were shaken in an end-oven-end shaker for 1 hour, centrifuged at 7000 rpm and filtered through No 41 Whatmann filter paper.

Mineralisable N: Mineralisable nitrogen is often measured using field moist soils. Since the soils were air dried, the soil samples were subsequently pre-incubated at field-moist condition to attain equiblirium. 100 g air dried soil samples were mixed with 30 ml of distilled water and incubated in 0.5 ml thickness plastic bags for 1 week. Plastic bags of this type allow sufficient oxygen to pass through the plastic film into the sample to maintain aerobic incubation, while adequately restricting the loss of moisture from the sample (Bremmer and Douglas, 1971).

Both the air-dried and the pre-incubated soil samples were used to measure mineralisable nitrogen. Anaerobic incubation technique was used to measure the mineralisable nitrogen (Goh and Haynes, 1986).

The mineralisable N can be calculated from the difference in the concentration of ammonium and nitrate between the incubated and the un-incubated soils.

$$\textit{Mineralisable } N = (NH_4\text{-}N + NO_3)\ \textit{incubated} - (NH_4\text{-}N + NO_3)\ \textit{unincubated.}$$

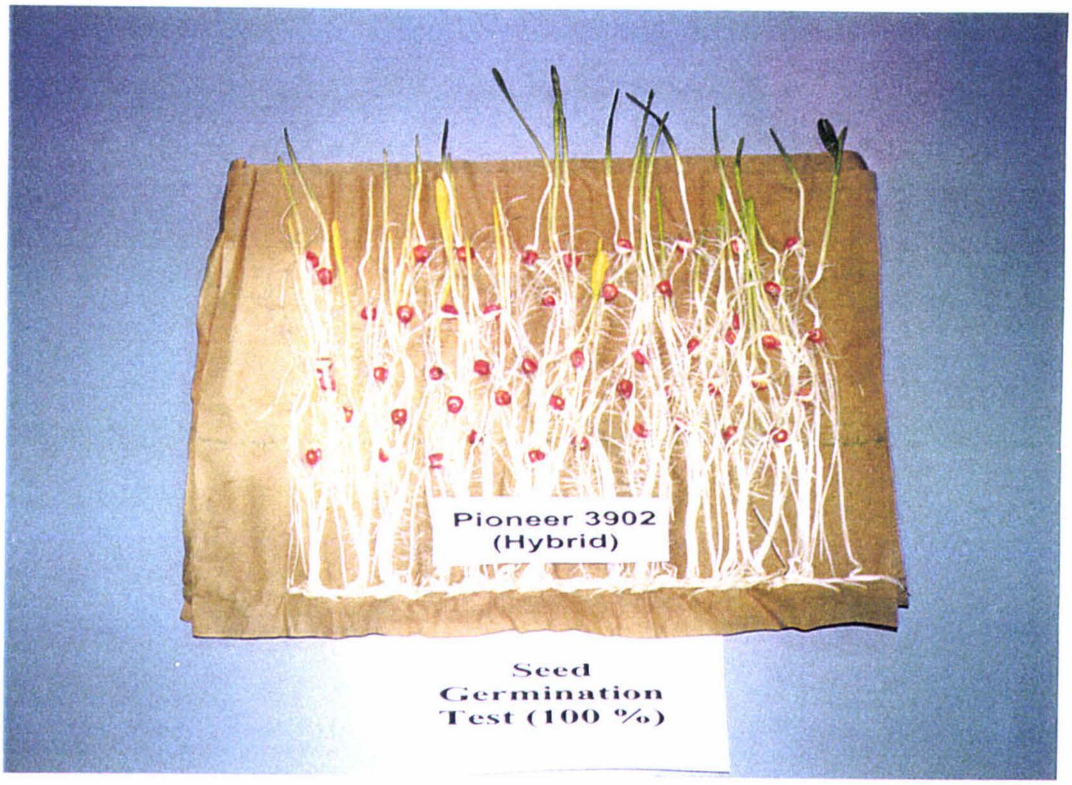


Plate 2. SEED GERMINATION TEST

The procedure for the extraction of ammonium and nitrate from the incubated and the unincubated soils is given below.

a. Un-incubated soils:

1. 3 g of air-dried and pre-incubated soil samples were mixed with 30 ml of 2 M KCl solution in 40 ml centrifugate tubes. Four replicates were used.
2. The soil samples were shaken for 1 hour, centrifuged at 7000 rpm for 3 minutes, then filtered through Whatmann No 41 filter paper.
3. The filtrate samples were collected in plastic vials, and stored at 4 ^{0} C or frozen until analysis.

b. Incubated soils:

1. Four replicates of pre-incubated and air-dried soil samples (3 g) were taken in 40 ml centrifugate tubes and 20 ml of distilled water was added to each tube.
2. The centrifugate tubes were kept air tight and incubated at 40 ^{0} C for 14 days.
3. After two week of incubation 10 ml of 3 M KCl solution was added to each tube and the tubes were shaken for 20 minutes.
4. The samples were centrifuged, then filtered, and collected in vials for analysis by auto-analyser.

Plant analysis:

Total N content of the plant material was determined using the Kjeldhal digestion method as described below (Mckenzie and Wallace, 1954):

To 0.100 g plant sample in a 100 ml pyrex tube, 4 ml of the kjeldhal digest mixture (250 g K_2SO_4 and 2.5 g selenium powder to 2.5 litre of H_2SO_4 in a 5 li pyrex beaker and heat it on a gas ring untill the mixture becomes clear) is added. The tubes are then placed in an aluminium heating block and the plant material is digested at 350^0 C for four hours. The digest is made up to 50 ml with deionised water, mixed with a vortex mixer and allowed to stand for a few hours before total N is determined using the Autoanalyser machine (Technicon, 1976).

3.1.5 Statistical analysis:

SAS program was used to perform analysis of variance (general linear models procedure), mean separations using t-test (LSD), and selected correlations using data means of plants from 96 pots. The analysis of variance was used to compare the difference between treatment means.

3.2 RESULTS

General Properties of soils:

3.2.1 Soil pH and moisture Content:

The pH of the pasture soil was higher (6.1) than the other three maize cultivated soils (5.9, 5.6 and 5.6 for the 6, 17 and 34 years cultivated soils) (Table 3.1). The field capacity of the pasture soil was the highest (31.7%), followed by 26.3% for 34 years soil, 24.9% and 24.4% for 17 years and 6 years soils, respectively.

3.2.2 Olsen P and SO_4 concentrations

The trend in Olsen P values was quite opposite to that of soil pH and soil moisture. Highest concentration (52. 9 mg kg^{-1}) was obtained for 17 years maize cultivated soil, followed by 30.9 mg kg^{-1} for 34 years soil, 29.9 mg kg^{-1} for 6 years soil, and 29.4 mg kg^{-1} for pasture soils (Table 3.1).

The concentrations of SO_4 also differed among these soils. The highest was 17.5 mg kg^{-1} for 34 years soil, followed by 16.5, 13.5 and 9.0 mg kg^{-1} for 6 years soil, 17 years and pasture soils, respectively.

3.2.3 K, Ca, Mg, Na and CEC concentrations

Generally, there was a decreasing trend of these nutrients with increasing period of cultivation (Table 3.2). The highest nutrient concentrations were found in the pasture soil, followed by 6 years, and 17 years soil. The 34 years maize cultivated soil had the least amount of these nutrient elements.

There was a decrease in CEC with increasing period of cultivation of soils. CEC was the highest in pasture soil (29 meq $100g^{-1}$), followed by the three maize cultivated soils (Table 3.2).

Table 3.1: Soil test before N fertilizer application.

Soil samples	PH	Moisture (%)	Olsen P (mg/kg)	SO_4 (mg/kg)
Pasture soil	6.1	31.7	29.4	9.0
Maize soil:				
(6 years)	5.9	24.4	29.9	16.5
(17 years)	5.6	24.9	52.9	13.5
(34 years)	5.6	26.3	30.9	17.5

Table 3.2: Soil test before N fertilizer application.

Soil samples	K	Ca	Mg	Na	CEC
	meq / 100 g				
Pasture soil	1.54	15.8	6.10	0.35	29
Maize soil					
(6 years)	0.77	14.9	2.63	0.72	23
(17 years)	0.94	10.8	3.50	0.20	22
(34 years)	0.65	10.8	3.08	0.22	16

3.2.4 N status of the soils :

Mineral nitrogen (KCl extractable NH_4-N and NO_3-N) and potential mineralisable nitrogen contents were measured both for the dry and the moist soils.

NH_4-N and NO_3-N concentrations in dry soils:

The concentration of NH_4-N was the highest in the pasture soil compared with the other three maize cultivated soils in the incubated soil treatments. Whereas, in un-incubated treatments, no NH_4-N was observed for the cultivated soils (Table 3.3).

After 2 weeks of incubation, NH_4^+-N concentration of the pasture soil increased rapidly from 9.0 mg NH_4^+-N / kg soil to 144 mg N / kg soil (Table 3.3). The increases in 6, 17, and 34 year maize soils were 31, 23, and 7 mg N/kg soil (Tables 3.3 and 3.4).

In the present study there was a very high mineralization of N in the pasture soil compared with the cultivated soils. The amount of N mineralised decreased with increasing period of cultivation (Table 3.3). Similarly Sparling et al. (1992) observed that continuous cultivation of maize soils resulted in a decrease in the C and N content in the Kairanga soil.

The highest NH_4-N concentration and mineralisable N content in the pasture soil were associated with the highest level of organic matter in the soil. Sparling et al., 1992 (1998) found higher mineralisable N, more biological activities and more biomass in pasture soil than any other land uses. Haynes et al. (1986) mentioned that soil moisture, soil pH and temperature are important factors that influence the rate of decomposition of organic matter and the subsequent release of mineral N.

The pasture soil has the highest field capacity compared with other maize cultivated soils. Also, the pH of pasture soil was higher than other soils. Smolander et al. (1995) in their study showed that the rate of mineralization and the concentration of N increased with an increase in soil pH through liming.

Table 3.3: Mineral N and Mineralised N in dry soil before N application:

Soil samples	Unincubated			Incubated			Mineralisable N *
	NH_4	NO_3	Mineral N	NH_4	NO_3	Mineral N	
	mg N/kg soil						
Pasture	9.0	30.1	39.1	144.8	2.5	147.3	135.7
6 years maize	0	39.0	39.0	31.4	2.5	147.2	31.4
17 years maize	0	47.5	47.5	23.1	2.5	33.9	23.1
34 years maize	0	19.3	19.3	7.0	3.2	10.2	7.0

** **Mineralisable nitrogen** = ($NH_4 + NO_3$) **incubated** - ($NH_4 + NO_3$) **unincubated.***

NH_4-N and NO_3-N concentrations in moist soil:

For the measurement of mineralisable N, the dry soil samples were incubated at field capacity for one week. After 1 week of incubation, the NH_4-N concentrations in all four soil samples increased (Tables 3.4). The increase in NH_4-N concentrations in all soil samples was mirrored by the decrease in NO_3-N concentrations (Table 3.4). The NH_4-N concentrations of the pasture soil increased rapidly from 2.3 mg N / kg soil to 55.2 mg N / kg soil. It was followed by 34 years soil (from 2.4 mg to 34.3 mg N), 6 years soil (from 1.3 mg to 12.5 mg N), and 17 years soil (from 1.3 mg to 9.3 mg N).

The NO_3-N concentration was higher in the unincubated than the incubated soils. Whereas, the NH_4-N concentration was higher in the incubated than the unincubated soils. Both the NO_3-N and NH_4-N concentrations were the highest in the pasture soils.

The mineralisable N was higher in the dry soil than in the moist soil (Tables 3.3 and 3.4). This was probably because in the incubated soil, the soil moisture content was too high which influenced the mineralisation of N in the soil. As moisture content increases, aeration decreases and microbial growth is inhibited (Goh and Haynes, 1986). Consequently, the ammonium and nitrate concentrations were low in the incubated moist soil. This resulted in higher mineralisable N in the dry soil compared to the moist soil.

Table 3.4: Mineral N and Mineralisable N in moist soil before N fertiliser application.

Soil samples	Unincubated			Incubated			Mineralisable N *
	NH_4	NO_3	Mineral N	NH_4	NO_3	Mineral N	
	mg N/kg soil			mg N/kg soil			
Pasture	2.3	66.6	68.9	55.2	1.0	56.2	52.9
6 years maize	1.3	46.5	47.8	12.5	1.3	13.8	11.2
17 years maize	1.3	47.6	48.9	9.3	1.3	10.6	8.0
34 years maize	2.4	54.8	57.2	34.3	0.8	35.1	31.9

** Mineralisable nitrogen = ($NH_4 + NO_3$) incubated - ($NH_4 + NO_3$) unincubated.*

Agronomic Characters:

3.2.5 Number of leaves:

The number of leaves was higher in the pasture soil than the cultivated soil. An increase in nitrogen level up to 300 kg N/ha resulted in an increase in the number of leaves in the maize plants grown in all the soils (Figure 3.1).

The number of leaves showed significant difference between soil treatments and N levels (Tables 3.5 and 3.6). The N levels above 300 kg/ha resulted in a slight decrease in the number of leaves. The means of the number of leaves followed: pasture soil = 6 years > 17 years > 34 years cultivation.

Table 3.5 . Effects of cultivation at 2 weeks to 8 weeks on number of leaves of maize crop

Soil Treatments	2 weeks	4 weeks	6 weeks	8 weeks
Pasture	2.5 a	4.4 a	6.0 a	7.9 a
6 years	2.3 b	4.1 b	5.2 b	6.8 b
17 years	2.3 b	4.1 b	4.7 c	5.9 c
34 years	2.1 b	4.0 b	4.7 c	5.3 d
CV =	12.6	7.0	8.9	10.6

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

Table 3.6. Effect of Nitrogen level at 2 weeks to 8 weeks on number of leaves of maize crop.

Nitrogen Levels (kg N/ha)	2 weeks	4 weeks	6 weeks	8 weeks
0	2.3 a	4.2 a	4.8 b	6.5 ab
100	2.3 a	4.1 a	5.3 a	6.7 ab
200	2.3 a	4.2 a	5.3 a	6.9 a
300	2.3 a	4.0 a	5.3 a	6.5 ab
400	2.3 a	4.2 a	5.1 ab	6.4 b
500	2.3 a	4.1 a	5.1 ab	5.8 c

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

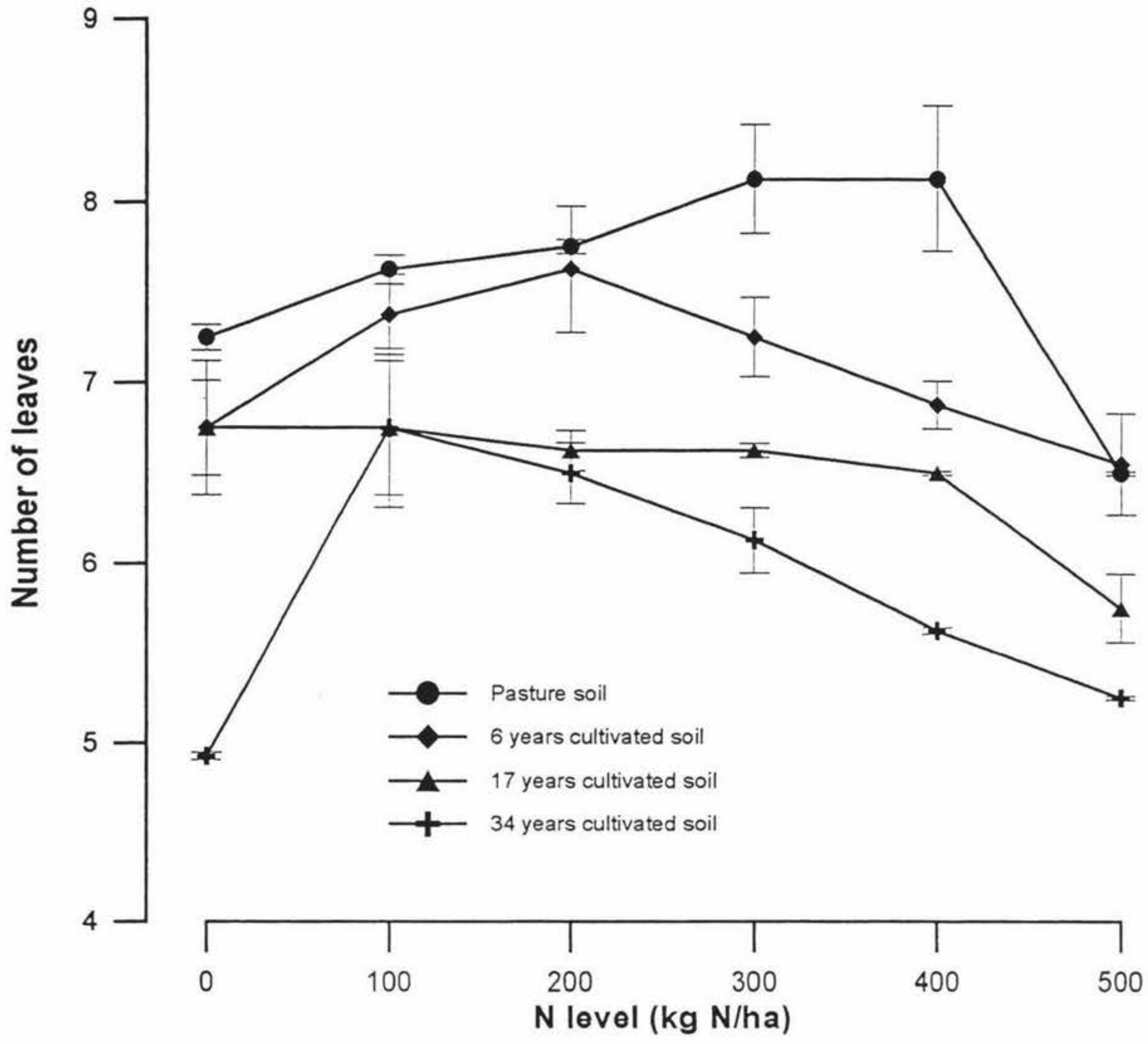


Figure 3.1 Effect of nitrogen levels on number of maize leaves at 9 weeks After sowing. The bar is 1 standard deviation.

3.2.6 Leaf length:

The leaf length was influenced by increasing levels of nitrogen, as shown in Figure 3.2. Generally leaf length tends to increase with increasing levels of nitrogen.

There was a significant difference in leaf length between N levels and soils (Tables 3.7 and 3.8 and Figure 3.2). The highest mean leaf length was obtained for the pasture soil at 400 kg N/ha (81 cm) and followed by > 6 years (74 cm) > 17 years (67 cm) > 34 years (66 cm) (Figure 3.2). Without N addition, however, the leaf length was very low for the 34 years soil (40 cm) (Figure 3.2).

Table 3.7. Effects of cultivation at 2 weeks to 8 weeks on leaf length of maize crop

Soil Treatments	2 weeks	4 weeks	6 weeks	8 weeks
Pasture	8.8 a	28.4 a	51.9 a	69.9 a
6 years	8.1 a	26.5 b	43.8 b	60.5 b
17 years	8.5 a	26.9 ab	41.6 b	54.0 c
34 years	7.2 b	25.3 b	42.3 b	54.1 c
CV =	17.2	10.2	11.8	8.3

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

Table 3.8. Effect of Nitrogen level at 2 weeks to 8 weeks on leaf length of maize crop.

Nitrogen Levels (kg N/ha)	2 weeks	4 weeks	6 weeks	8 weeks
0	7.9 a	25.1 b	38.4 b	52.9 b
100	8.1 a	27.0 ab	45.4 a	59.9 a
200	8.6 a	27.6 a	46.8 a	61.4 a
300	8.2 a	27.5 a	46.6 a	61.9 a
400	8.2 a	27.0 ab	46.1 a	61.0 a
500	8.2 a	26.7 ab	46.3 a	60.7 a

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

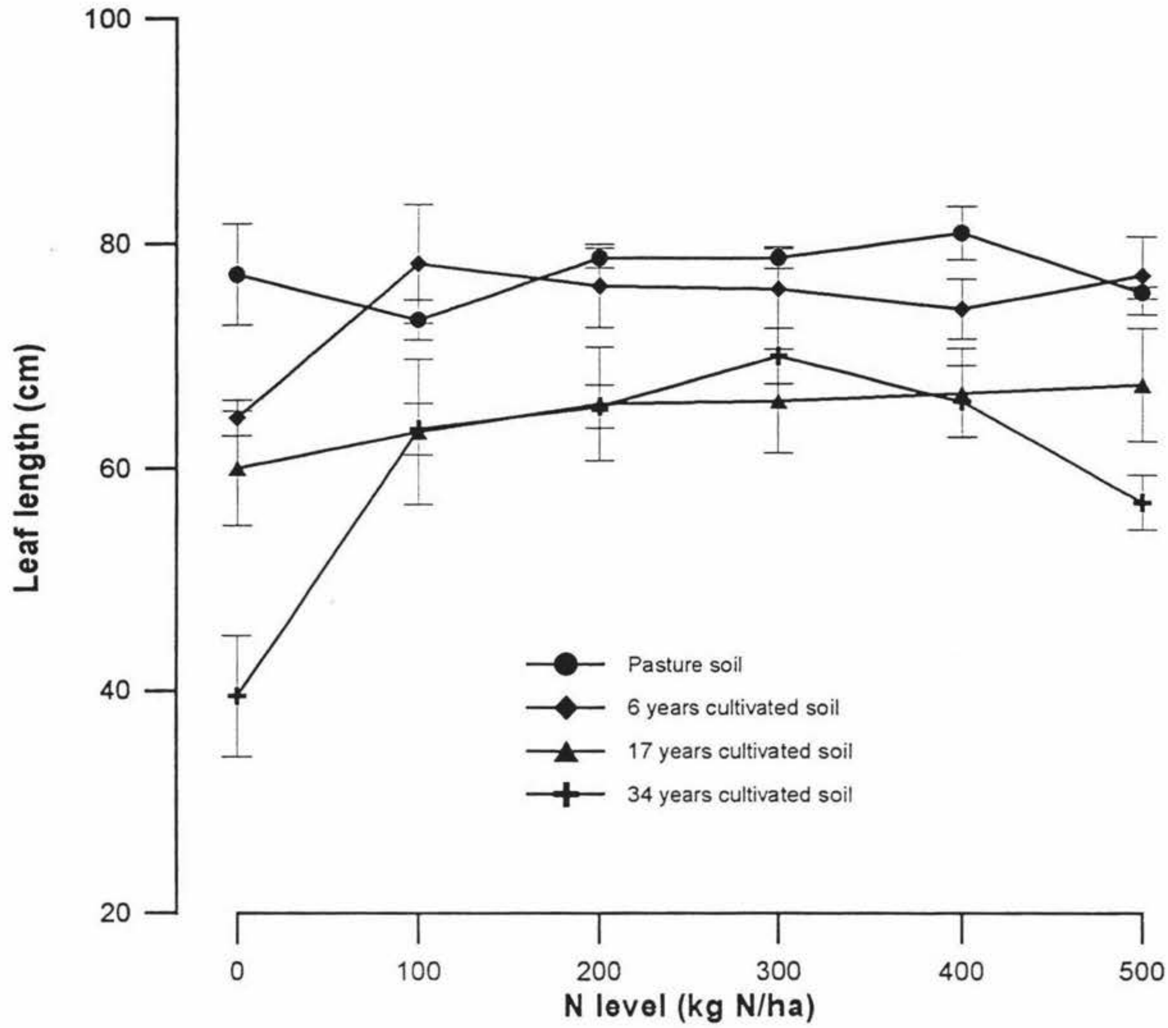


Figure 3.2 Effect of nitrogen levels on maize leaf length at 9 weeks After sowing. The bar is 1 standard deviation.

3.2.7 Plant height:

There was a significant difference in plant height between N levels and soil treatments (Tables 3.9 and 3.10). An increase in nitrogen level up to 300 kg N/ha resulted in an increase in plant height in the pasture soil and 34 years soil. The plant height decreased with further increase in N level. The plant height increased up to 400 kg N/ha in the 6 years and 17 years cultivated soil, then it decreased with further increases in N level (Figure 3.3).

The mean plant height followed: pasture soil (69 cm) > 6 years soil (61 cm) > 17 years soil (54 cm) > 34 years soil (53 cm).

Table 3.9. Effects of cultivation at 2 weeks to 8 weeks on plant height (cm) of maize crop.

Soil Treatments	2 weeks	4 weeks	6 weeks	8 weeks
Pasture	10.4 a	25.9 a	50.5 a	68.9 a
6 years	9.8 ab	23.9 b	42.9 b	60.5 b
17 years	10.5 a	22.6 b	38.5 c	53.9 c
34 years	9.0 b	22.9 b	38.8 c	53.4 c
CV =	13.9	11.5	11.8	10.9

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

Table 3.10. Effect of Nitrogen level at 2 weeks to 8 weeks on plant height (cm) of maize crop.

Nitrogen Levels (kg N/ha)	2 weeks	4 weeks	6 weeks	8 weeks
0	9.9 a	21.4 b	36.7 b	54.8 b
100	9.9 a	23.1 ab	43.4 a	58.6 ab
200	9.6 a	23.8 a	44.4 a	59.8 ab
300	10.1 a	25.2 a	43.2 a	62.1 a
400	10.1 a	25.0 a	44.1 a	60.1 a
500	9.9 a	24.3 a	44.3 a	59.7 ab

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

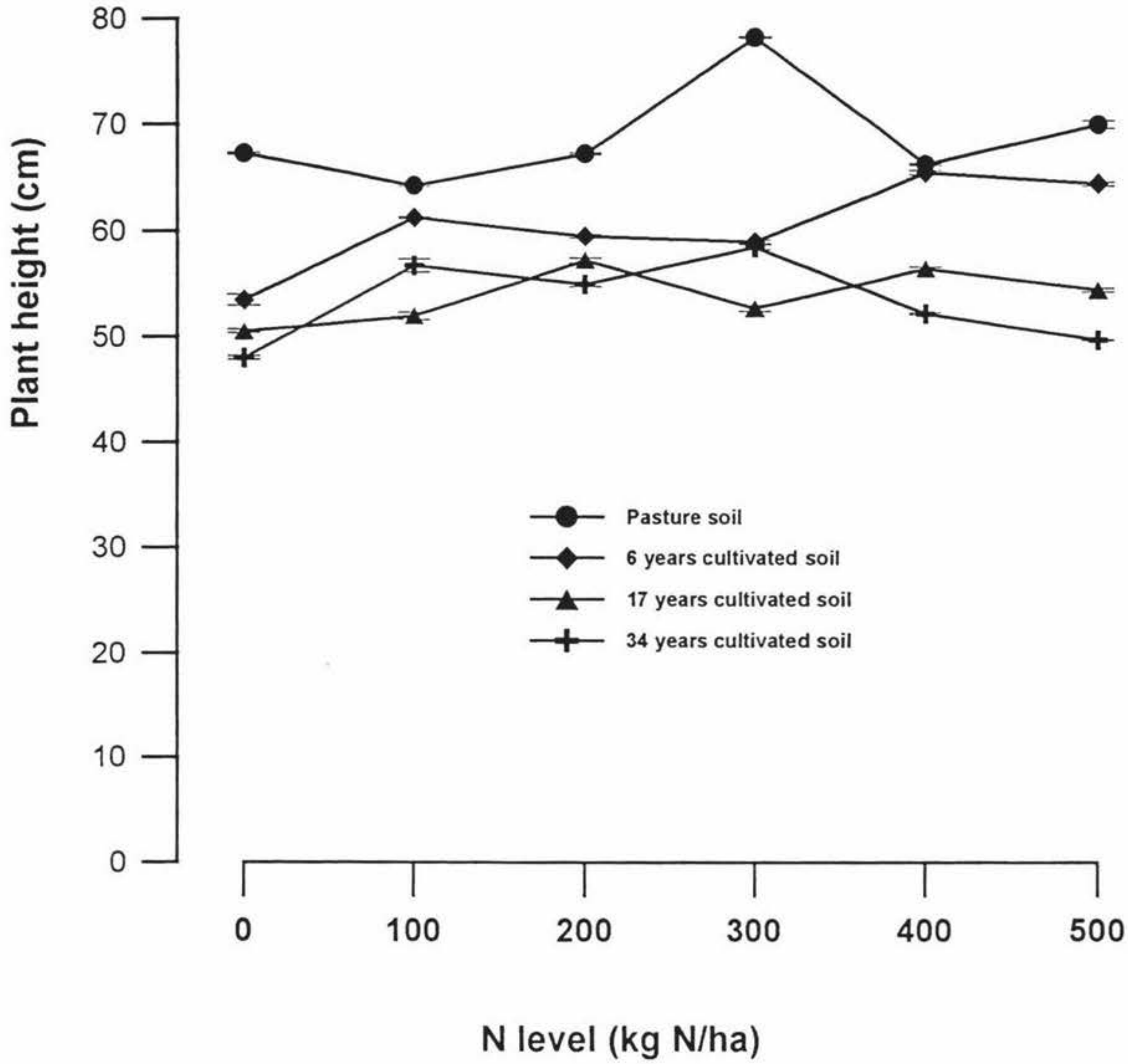


Figure 3.3 Effect of nitrogen levels on maize plant height at 9 weeks after sowing. The bar is 1 standard deviation.

3.2.8 Dry matter yield:

The dry matter yield also showed that there was a significant difference between soil treatments and N levels (Tables 3.11 and 3.12). The average dry weights per pot of pasture soil, 6 years , 17 years, and 34 years cultivated soils are presented in Figure 3.4. Results show that the average dry weight in all soils increased with increasing level of nitrogen up to 200 of kg N/ha except 34 years soil in which the highest was obtained at

100 kg N/ha (Figure 3.4). Above this level of N the dry weight decreased with further increases in N levels (Figure 3.4).

The highest dry weight was recorded at 200 kg N/ha level and it followed: pasture soil (18 g) > 6 years (13 g) > 17 years (9 g). However, the highest dry weight of 34 years soil was 9 g at 100 kg N/ha (Figure 3.4).

The mean dry weight followed: pasture soil (16.5 g) > 6 years soil (11 g) > 17 years soil (8 g) > 34 years soil (7 g).

Table 3.11. Effects of cultivation at 9 weeks on dry matter yield (g) of maize crop

Soil Treatments	9 weeks
Pasture	16.5 a
6 years	11.0 b
17 years	7.5 c
34 years	6.8 c
CV =	14.9

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

Table 3.12. Effect of Nitrogen level at 9 weeks on dry matter yield (g) of maize crop.

Nitrogen Levels (kg N/ha)	9 weeks
0	8.5 c
100	11.6 a
200	12.1 a
300	11.2 a
400	10.1 b
500	9.3 bc

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

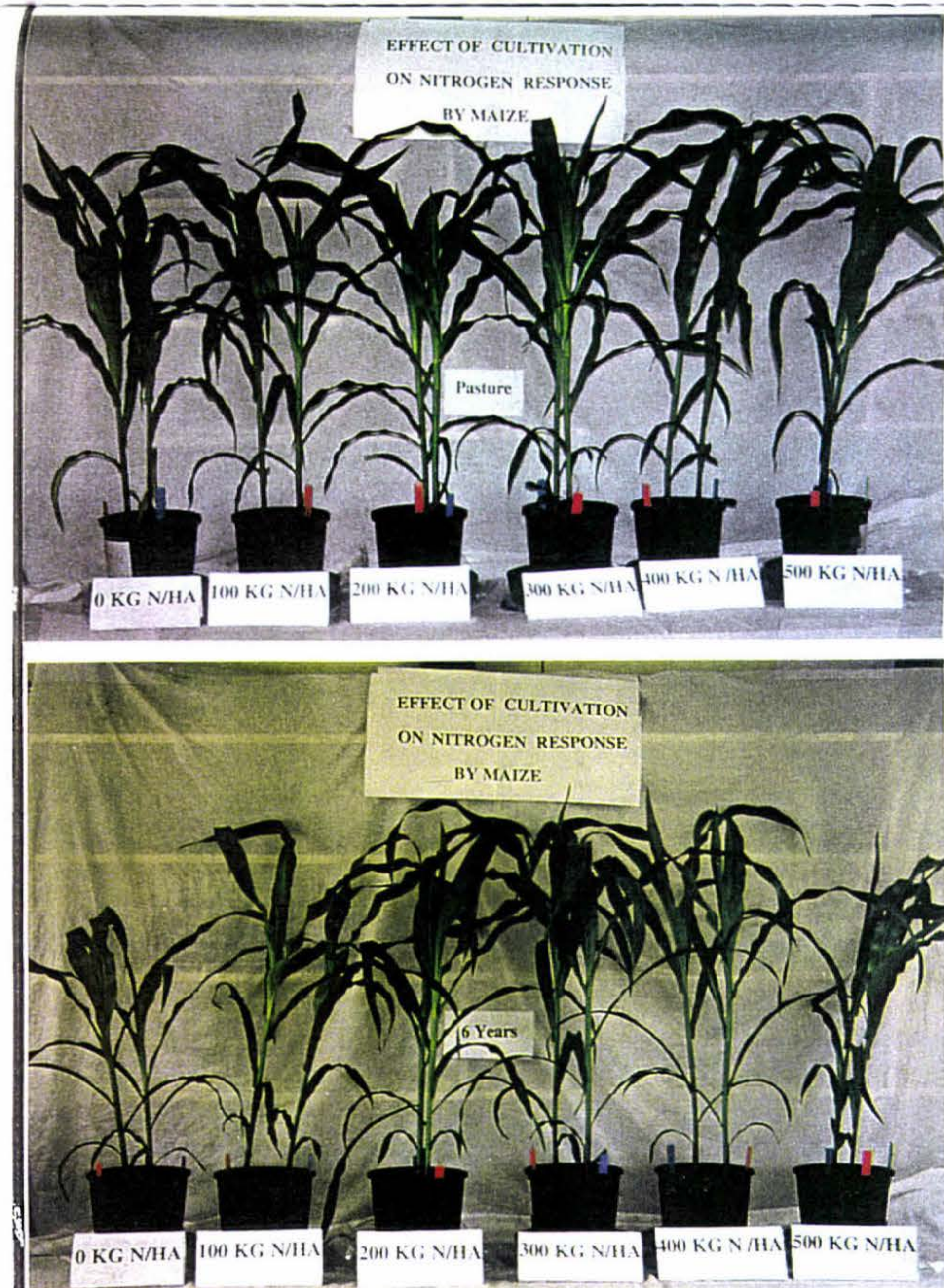


Figure 1. Above: Effect of different N levels on maize crop under pasture soil.
Below: Effect of different N levels on maize crop under 6 years maize cropping soil.

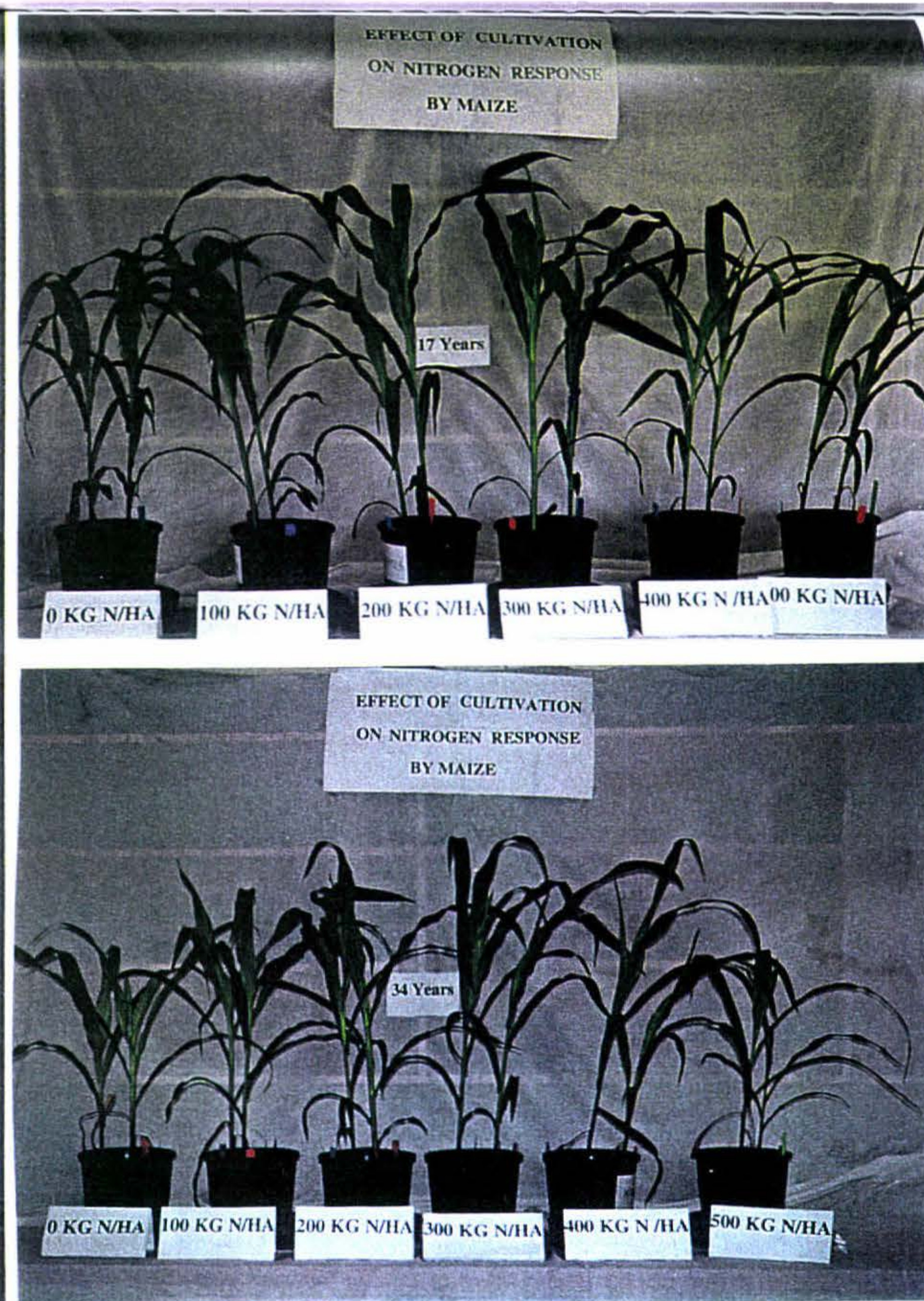


Figure 3. Above: Effect of different N levels on maize crop under 17 year maize cropping soil.
Below: Effect of different N levels on maize crop under 34 years maize cropping soil.

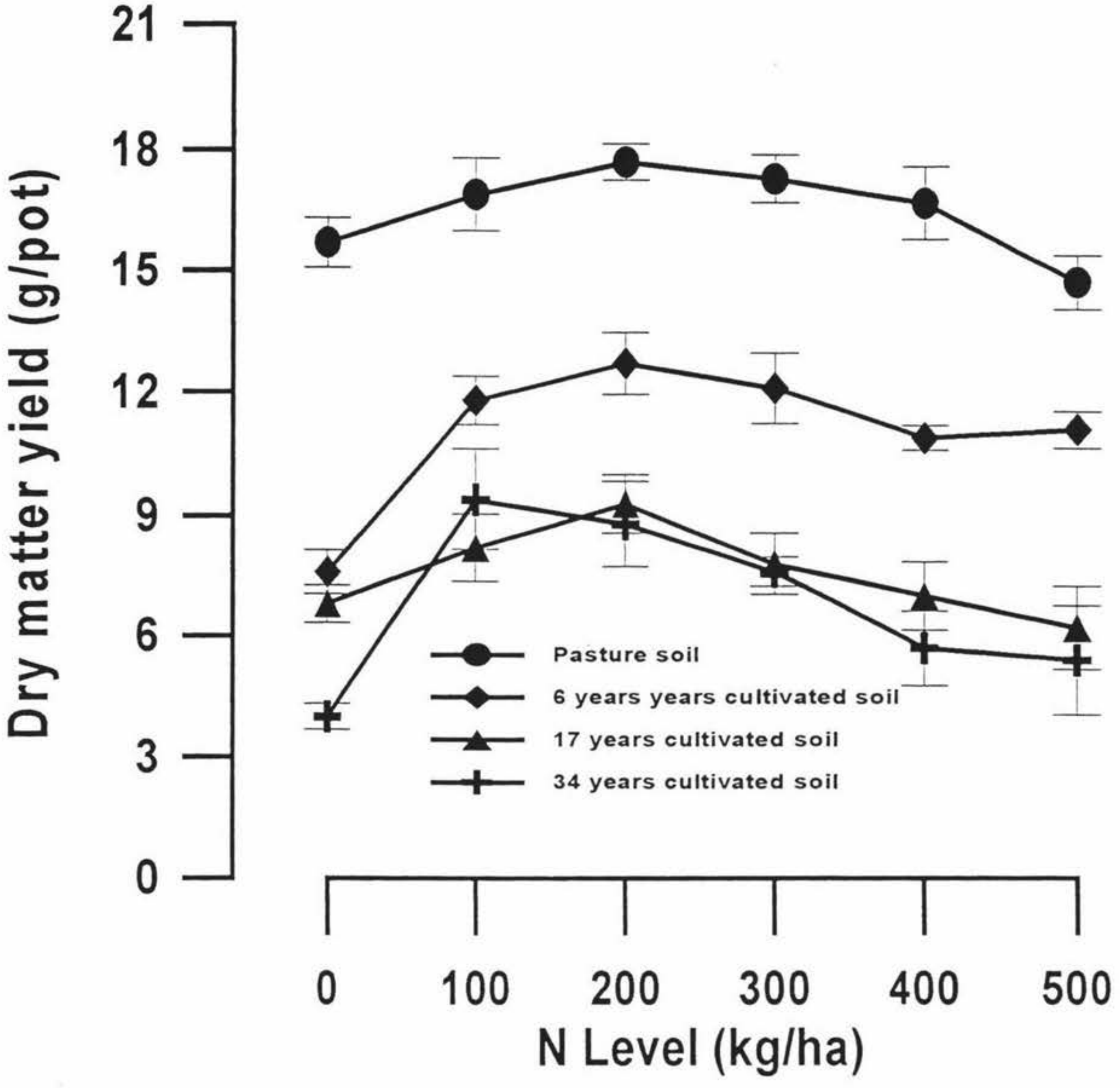


Figure 3.4 Effect of nitrogen levels on maize dry matter yield at 9 weeks after sowing. The bar is 1 standard deviation.

3.2.9 Dry root weight:

There was a significant difference in root dry weight between the pasture soil and the three cultivated soils (Tables 3.13 and 3.14). However, there was no significant difference between the cultivated soils and the N levels. The effect of N levels on root dry weight was not consistent. Except for the 6 years cultivated soil the lowest root dry weight was obtained at the highest level (500 kg N/ha) of N application (Figure 3.5).

The mean dry root weight followed: pasture soil (13.4 g) > 6 years soil (8.8 g) > 17 years soil (8.5 g) > 34 years soil (8.4 g).

Table 3.13. Effects of cultivation at 9 weeks on root dry weight (g) of maize crop

Soil Treatments	9 weeks
Pasture	13.4 a
6 years	8.8 b
17 years	8.5 b
34 years	8.4 b
CV =	38.2

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

Table 3.14. Effect of Nitrogen level at 9 weeks on root dry weight (g) of maize crop.

Nitrogen Levels (kg N/ha)	9 weeks
0	9.8 ab
100	11.5 a
200	9.9 ab
300	10.6 ab
400	9.5 ab
500	7.3 b

In a column, means followed by a same letter are not significantly different at the 5 % level by Duncan's multiple range test (DMRT).

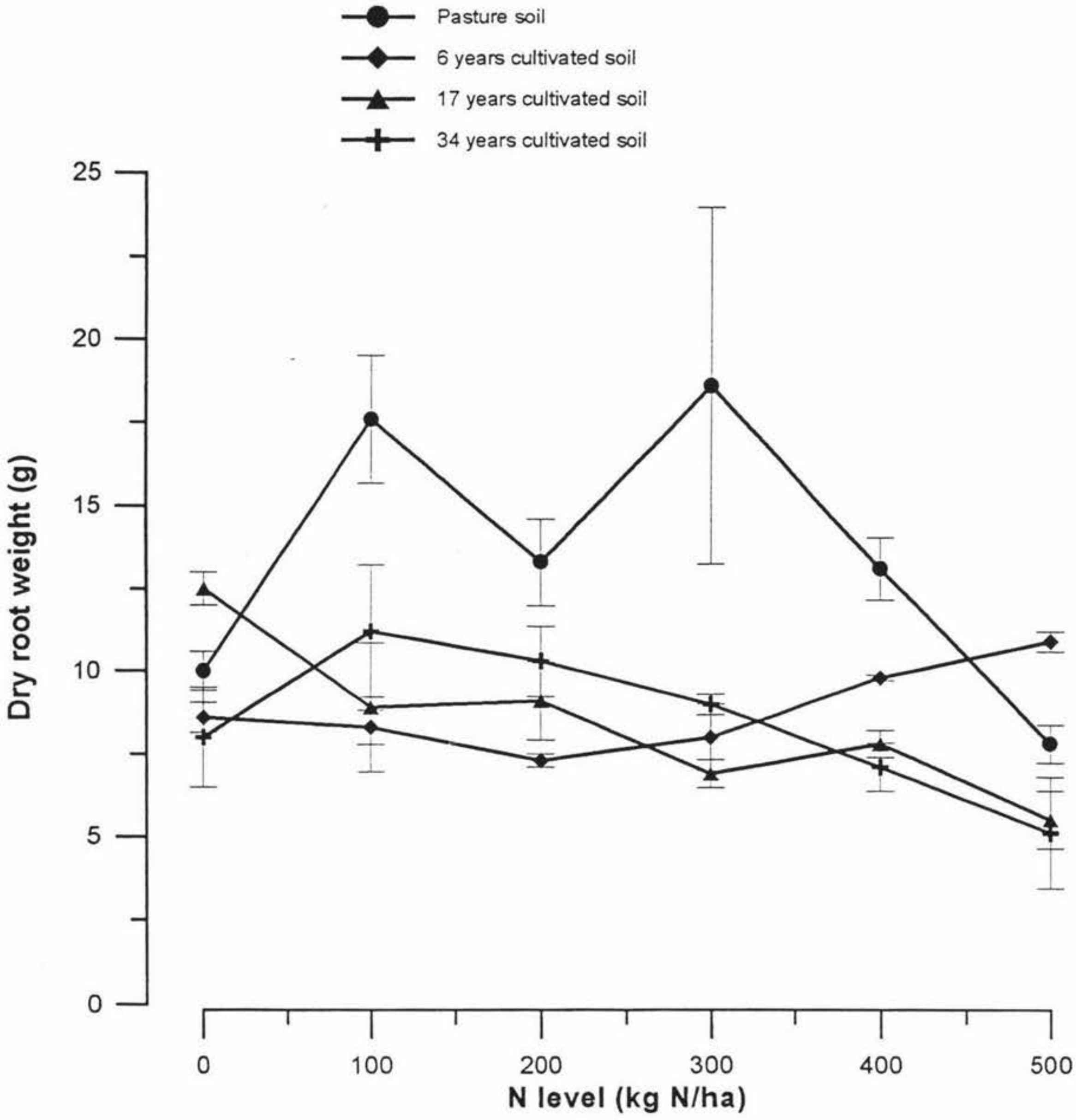


Figure 3.5 Effect of nitrogen levels on maize dry root weight at 9 weeks after Planting. The bar is 1 standard deviation.

3.2.10 N uptake by shoot:

In all soils, the shoot N concentration in general increased with increasing levels of N application (Figure 3.6). In the 34 years cultivated soil there was a sharp drop in N concentration at the highest level of N application. Except for the 34 years cultivated soil at the 0 and 400 kg N levels, the N concentration was higher in the cultivated soils than the pasture soil. However, the N uptake was highest in the pasture soil and followed by 6 years cultivated soil > 17 years cultivated soil > 34 years cultivated soil (Figure 3.7).

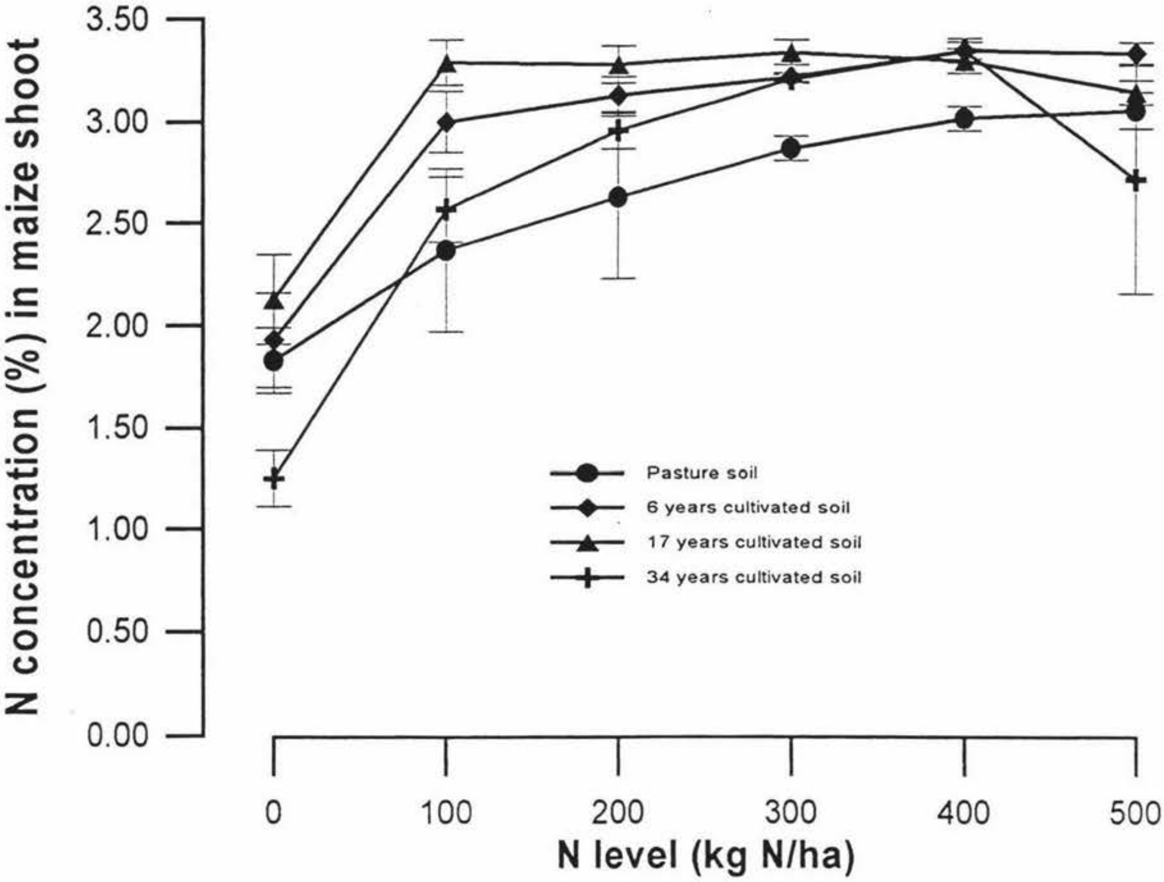


Figure 3.6 Relationship between N levels and N concentration (%) At 9 weeks after sowing. The bar is 1 standard deviation.

There was highly significant difference in N uptake between soil treatments and N levels. The average N uptake by shoot in all soils generally increased as dry matter increased (Figure 3.7). The trend is similar to that of plant height, dry matter yield, and fresh weight. The highest N uptake was obtained at 400 kg N/ha (504 mg) in pasture soil, then decreased at 500 kg N/ha (451 mg). Cultivated soils showed that the highest N uptake was obtained at 200 kg N/ha (395 mg, 306 mg, 261 mg for 6 years, 17 years, and 34 years respectively. The N uptake decreased at levels greater than 200 kg N/ha (Figure 3.7).

The mean N uptake followed: pasture soil (434 mg) > 6 years soil (338 mg) > 17 years soil (234 mg) > 34 years soil (187 mg).

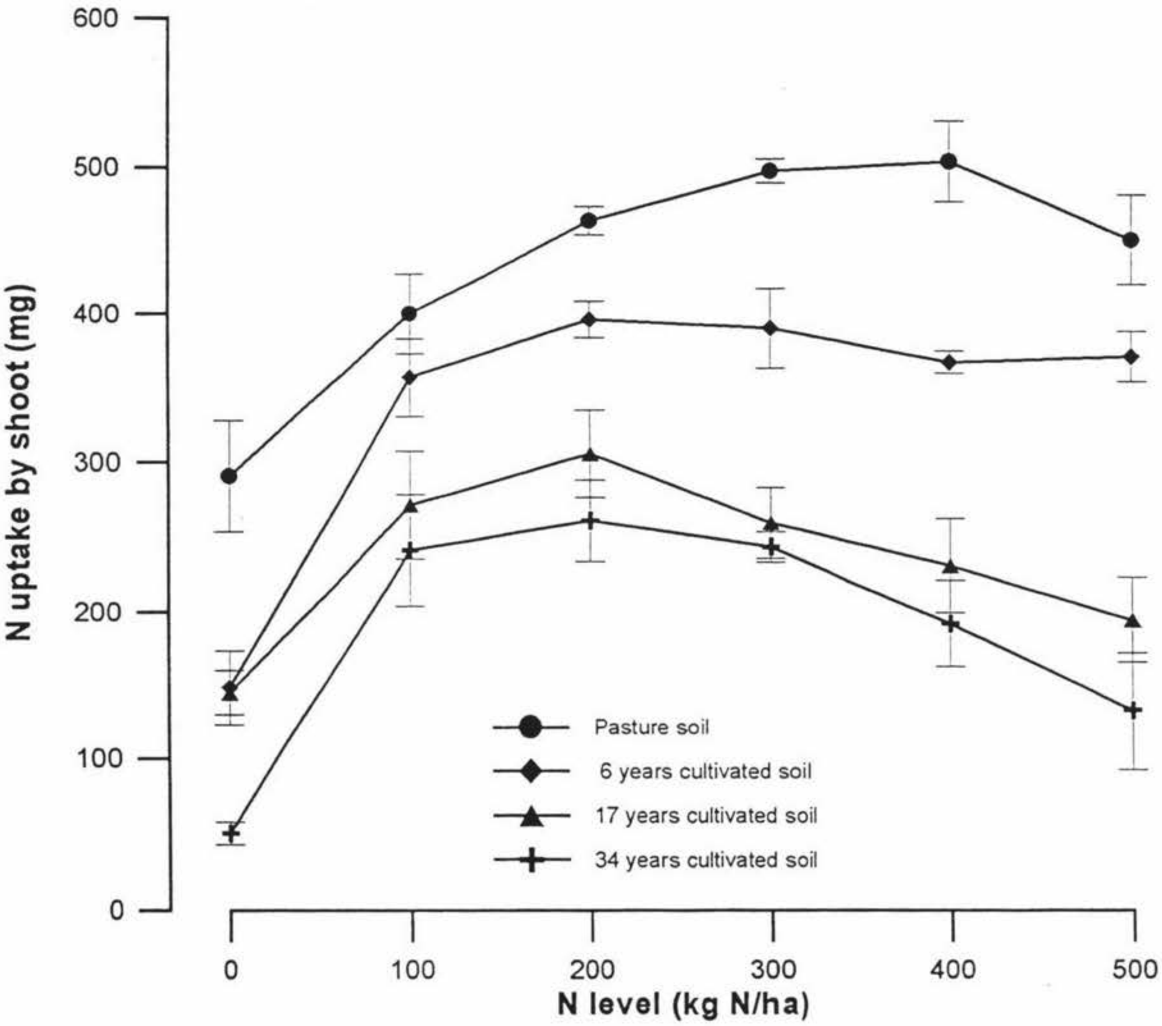


Figure 3.7 Effect of nitrogen levels on N uptake by maize shoot at 9 weeks After sowing. The bar is 1 standard deviation.

3.2.11 N uptake by root:

There was significant difference in N uptake by root between soil treatments and N levels (Figure 3.8). The highest N uptake was found at 300 kg N/ha (182 mg) in the pasture soil, then decreased at 500 kg N/ha (85 mg). In 6 years cultivated soil the highest N uptake was obtained at 500 kg N/ha (121 mg). The 17 years and 34 years soils showed the highest N uptake at 200 kg N/ha (Figure 3.8).

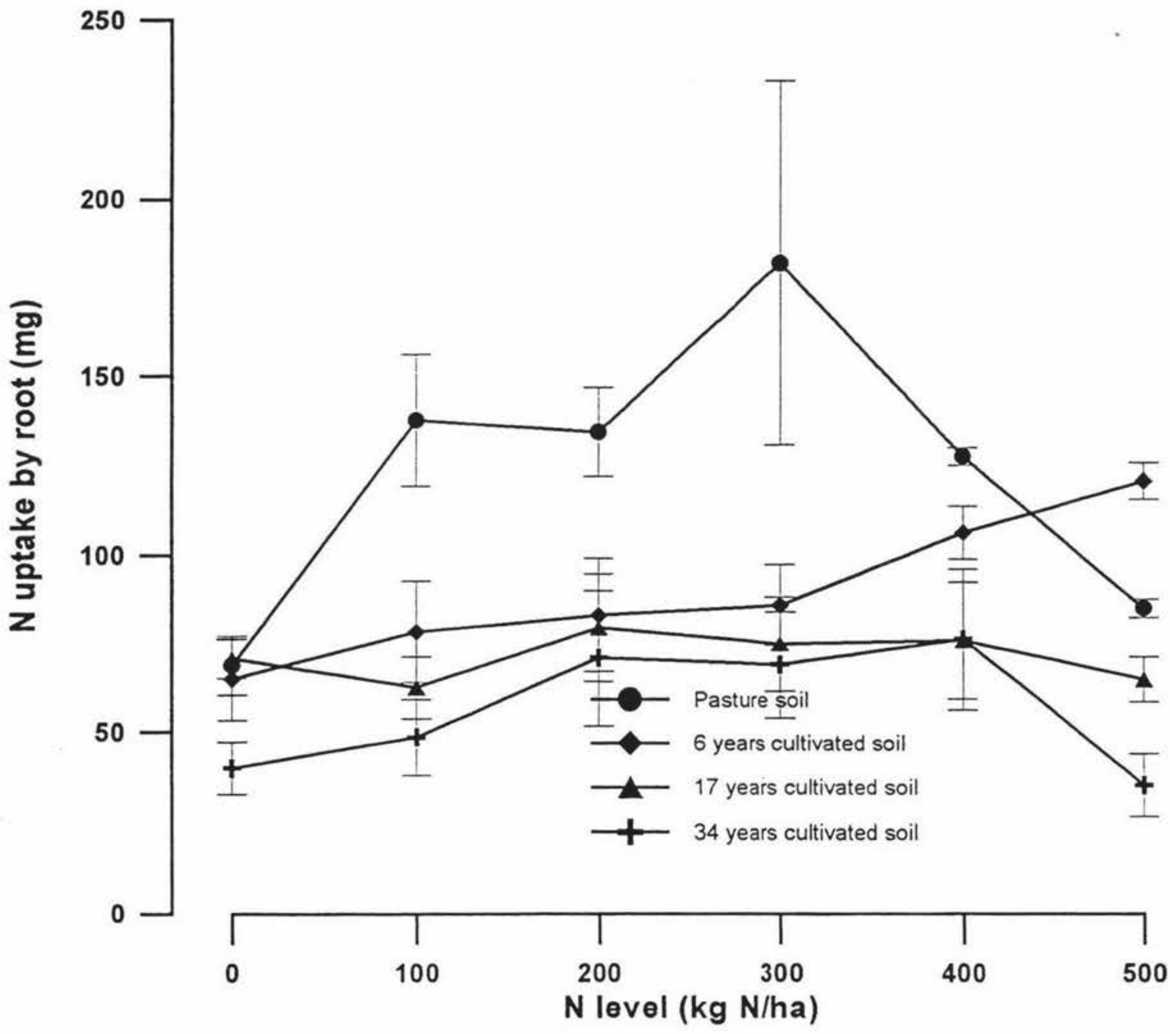


Figure 3.8 Effect of nitrogen levels on N uptake by root at 9 weeks After sowing. The bar is 1 standard deviation.

The mean N uptake by root followed: pasture soil (123 mg) > 6 years soil (90 mg) > 17 years soil (71 mg) > 34 years soil (57 mg).

3.3 DISCUSSION

The results of the first glasshouse experiment have indicated the following important points:

- **The pH and the mineralisable nitrogen contents were higher in the pasture soil than the cultivated soils.**
- **The Olsen P and sulphate sulphur levels were higher in the cultivated soils than the pasture soil and the levels increased with increasing period of cultivation.**
- **The dry matter yield of maize without N application decreased with increasing period of cultivation.**
- **The maximum dry matter yield (with N fertilizer application) was recorded in the pasture soil and it decreased with increasing period of cultivation.**
- **In three soils (pasture soil, 6 years, and 17 years cultivated soils) the dry matter yield increased with increasing levels of N up to 200 kg N (34 years cultivated soil increased up to 100 kg N/ha), above which the yield decreased with further increase in N levels.**
- **The yield response to nitrogen fertilizer (maximum yield – yield at 0 N level) increased with increasing period of cultivation.**

The reasons for these observations are discussed below:

3.3.1 Soil pH and Mineralisable N:

The present study has shown that cultivation affected the amount of mineralizable N in the soil. Lyon et al. (1997) have shown that nitrogen available to crops through mineralisation of organic matter is likely to decrease as organic matter is lost through oxidation as a result of tillage. Carbon and nitrogen continue to be lost from soil as a result of tillage and crop production. Ordie et al. (1986) observed that when native grassland is cultivated for crop production, the rate of yield decline is influenced by crop rotations, crops grown, tillage practices, soil characteristics and fertilizer applications.

Management practices (crop rotation, weed control, fertilization, and tillage practices) influence soil physical, biological, and chemical properties which in turn impact soil organic matter characteristics (Peters et al., 1997). These findings suggest that the cultivation practices can have a major impact on soil organic matter, cultivation increase soil organic matter decomposition and the release of nutrients.

Juma et al. (1997) in their study found that soil moisture related problems, such as crusting and low water holding capacity, result from the low organic matter content of the A horizon. Haynes and Swift (1990) also observed that moisture content of the soils is one of the most important factors affecting wet-sieving, and the effect of moisture is related to soil organic matter content.

Gary and Doran (1997) have shown that the soil pH in the continuous corn has been consistently low due to annual application of commercial fertilizer over the 16 years period for the continuous corn compared to less intense fertilizer application for the crop rotation. In the present study, soils under continuous maize cultivation receive regular application of nitrogen fertilizer which may be one of the reasons for lower pH in the cultivated soils than in the pasture soil.

Furthermore, the marked effect of the lowest N content in the maize cultivated soils due to long period of cultivation was probably related to the losses of nitrogen in the soil through leaching, plant uptake, denitrification, volatilisation. According to Saggar et al. (1998) both the amount and proportion of mineralisable nitrogen also reduced with cultivation in the Kairanga silt clay loam. It would be seen that the greater the period of cultivation of the soil the higher the decrease in mineralisable nitrogen in the soil. In this study, the dry matter yield of maize was found to decrease with increasing periods of cultivation (Figure 3.4).

The concentrations of NH_4^+-N in pasture soil during anaerobic decomposition were the highest compared with the other three maize cultivated soils. The higher levels of NH_4^+-N in pasture soil could be attributed to high returns of NH_4^+-N through animal dung and urine and also through biological N_2 fixation by legumes (McLaren and Cameron, 1996).

3.3.2 Olsen P and SO_4 concentrations

Generally the Olsen P and SO_4 concentrations increased with increasing the period of cultivation. Greater amounts of P and S fertilizer were added to the maize growing soils than the pasture soil. This may be the reason for the higher levels of these nutrients. Further, most of the P and S in the pasture soil remain in the organic matter which is not measured by the Olsen P test and the inorganic sulphate soil test.

3.3.3 The dry matter yield without N addition

Generally, the results showed that at zero level of N application there was a trend of decreasing dry matter yield with increasing period of cultivation. The highest dry matter yield was in the pasture soil followed by 6 years > 17 years > 34 years soils (Figure 3.4). This may indicate that the nutrient status of the soils is influenced by the management practices. Pasture soil has higher N nutrient content than the maize soils because the pasture soil receives N from legumes by N fixation process. Pasture soil contains more soil organic matter than the maize cultivated soil. Campbell et al. (1991) also reported significant correlation between soil organic carbon and cumulative amounts of crop residues returned to soil over the long term. A higher return of organic residues to the soil should lead to a higher mineralization rate and increased nutrient concentrations in the soil. It means that the cultivated soils contain varying amounts of nitrogen depending on the period of cultivation.

It is important to point out that all treatments received minus N nutrient solution. So the difference in dry matter yield between the soils at zero level of N application may be attributed to the difference in the level of native nitrogen in the soils and /or the differences in the physical conditions of the soils. As discussed below the dry matter for the cultivated soil did not reach that for the pasture soil even at high levels of N application. This indicates that the difference in dry matter yield between the pasture soil and the cultivated soils is attributed to the difference in the physical conditions of the soil.

3.3.4 The dry matter yield increased up to 100 and 200 kg N/ha

In three soils the dry matter yield increased up to 200 kg N level above in which the yield decreased with further increase in N level. In the 34 years cultivated soil the highest yield was obtained at 100 kg N level. This may be related to the plant nutrient requirements, soil nutrient availability, soil management, soil conditions and soil organic matter level.

Steele (1985) observed that under field conditions maximum maize yield was obtained at 200 kg N/ha level. In the present study mostly the dry matter increased up to 200 kg N /ha level except at 34 years cultivated soil (100 kg N level). The decrease in dry matter yield above 200 kg /ha may be attributed to a high salt concentration resulting from the excessive amount of N, which affected the other availability of plant nutrients. Also this might have may be restricted the root development (Berger, 1962; McLaren and Cameron, 1996).

3.3.5 The maximum dry matter yield and yield response to N application

The maximum dry matter yield obtained with N application was affected by the period of cultivation. The maximum dry matter yield decreased with increasing the period of cultivation, and followed: pasture soil > 6 years > 17 years > 34 years. This may be related to the soil organic matter content. The yield response to N fertilizer, as measured by the difference in maximum dry matter yield and yield at zero level N, was the lowest in the pasture soil and it increased with increasing period of cultivation (Table 3.15). The increased dry matter yield up to 200 N level is related to the increase in N uptake with inorganic N fertiliser application. Madhavi et al. (1996) indicated that dry matter yield of maize increased with increasing N uptake. Toor and Bishnoi (1996) mentioned that application of inorganic N increased available N content in the soil which can be available for the maize crop. On the other hand, the decreased dry matter yield at N levels > 200 is probably related to high levels of nitrate or nitrite concentrations in the plant which may cause toxicity problems (McLaren and Cameron, 1996), and reduce the dry matter yield.

The result are in agreement with the results obtained by Nafzinger (1984) where the dry matter yield of maize responded less to applied nitrogen when the crop was grown following a legume than a cereal crop. Russelle et al. (1987) found that 62 % of the maize yield following alfalfa was due to N supplied by the legume.

Continuous maize cropping can damage the physical condition of the soils (Berger, 1962; Sparling et al., 1992; Saggar et al., 1998) thereby reducing the dry matter yield of crops grown in cultivated soil. Evaluation of the susceptibility of agricultural soil to compaction as a result of cultivation is often based on soil physical parameters. For example, degradation and deterioration of soil structure occur due to cultivation. The higher dry matter yield in the pasture soil can also result from the higher soil moisture content, soil pH and the others soil nutrients available in the soil (Tables 3.1 and 3.2).

In addition, Saggar et al. (1998) indicated that cultivation reduces both soil and microbial biomass carbon and nitrogen. This means cultivated soils are less alive, and contain fewer micro-organisms. Thus, this experiment showed that the dry matter yield in the cultivated soils was mostly lower than the pasture soil. Doran and Power (1983) reported that the differences in soil aeration, water content, and temperature in cultivated soil influenced microbial numbers and activity, hence, N mineralisation which can affect the yield. Also, intensive cultivation can cause excessive breakdown of soil aggregates resulting in very fine and loose tilth which induces the loss of nutrients (McLaren and Cameron, 1996).

Table 3.15. Mean dry matter weight (g) and N response:

Soil samples	Yield at low level	Maximum yield	% Response
Pasture	15.7	17.7	12.7
6 years	7.6	12.7	66.3
17 years	6.8	9.3	36.7
34 years	4.0	8.8	120

Hesterman et al. (1992) in their study found that when leguminous species were used, the biologically fixed nitrogen released during decomposition helped to reduce fertilizer N requirements for a subsequent crop. In our study the pasture soil showed the highest maximum dry matter yield with nitrogen application compared with other maize cultivated soils, but produced the lowest N response.

Sparling et al. (1992) also found that continuous maize cropping for 14 years on average decreased total C by 49 % and microbial C by 60 % as compared with the levels under pasture. This was probably the reason why the dry matter decreased significantly under long period of cultivation in maize cultivated soil. Also cultivation usually results in a marked decline in the soil organic matter. Consequently, loss of organic matter during cultivation, in particular, loss of soil microbial component, can adversely affect both the physical, biological and nutrient status of the soils (Carter et al., 1986). Cothing et al. (1979) stated that a decline in organic matter and deterioration in soil structure following maize cropping of Waikato soils in New Zealand. It was supported by Sparling et al (1992) who observed that continuous corn has repeatedly resulted in lower yields than corn in rotation.

3.3.6. Effect of cultivation on N uptake by maize

The relationship between N added and shoot N uptake by maize at vegetative growth was highly correlated (R^2= 0.90 **) (Figure 3.9). There was a consistent linear decrease in N uptake with increasing period of cultivation (Tables 3.16 and 3.17).

The resluts in this experiment showed that the highest N uptake was obtained at 400 kg N/ha in the pasture soil, but in the cultivated soils it occurred at 200 kg N/ha (Figure 3.9). The highest dry matter yield was produced by 200 kg N/ha in all soil treatments excepted the 34 years cultivated soil (Table 3.12 and Figure 3.9). There was a linear relationship between N uptake and dry matter yield in this experiment (Figure 3.9).

Table 3.16. The relationship between N level and N uptake of maize growth

N level (kg/ha)	Shoot N uptake (mg)	Root N uptake (mg)	Total N uptake (mg)
0	110 d	83 b	187 d
100	223 c	110 ab	333 bc
200	255 a	123 a	384 a
300	249 ab	138 a	394 a
400	210 c	133 a	364 ab
500	210 c	106 ab	307 c

LSD = 19.9 at $p < 0.05$.

Table 3.17. The relationship between pasture and three cultivated soils and maize N uptake

Soil sample	Shoot N uptake (mg)	Root N uptake (mg)	Total N uptake (mg)
Pasture	308 a	170 a	476 a
6 years	242 b	120 b	365 b
17 years	166 c	95 c	260 c
34 years	135 d	76 c	210 d

LSD = 24.4 at $P < 0.05$.

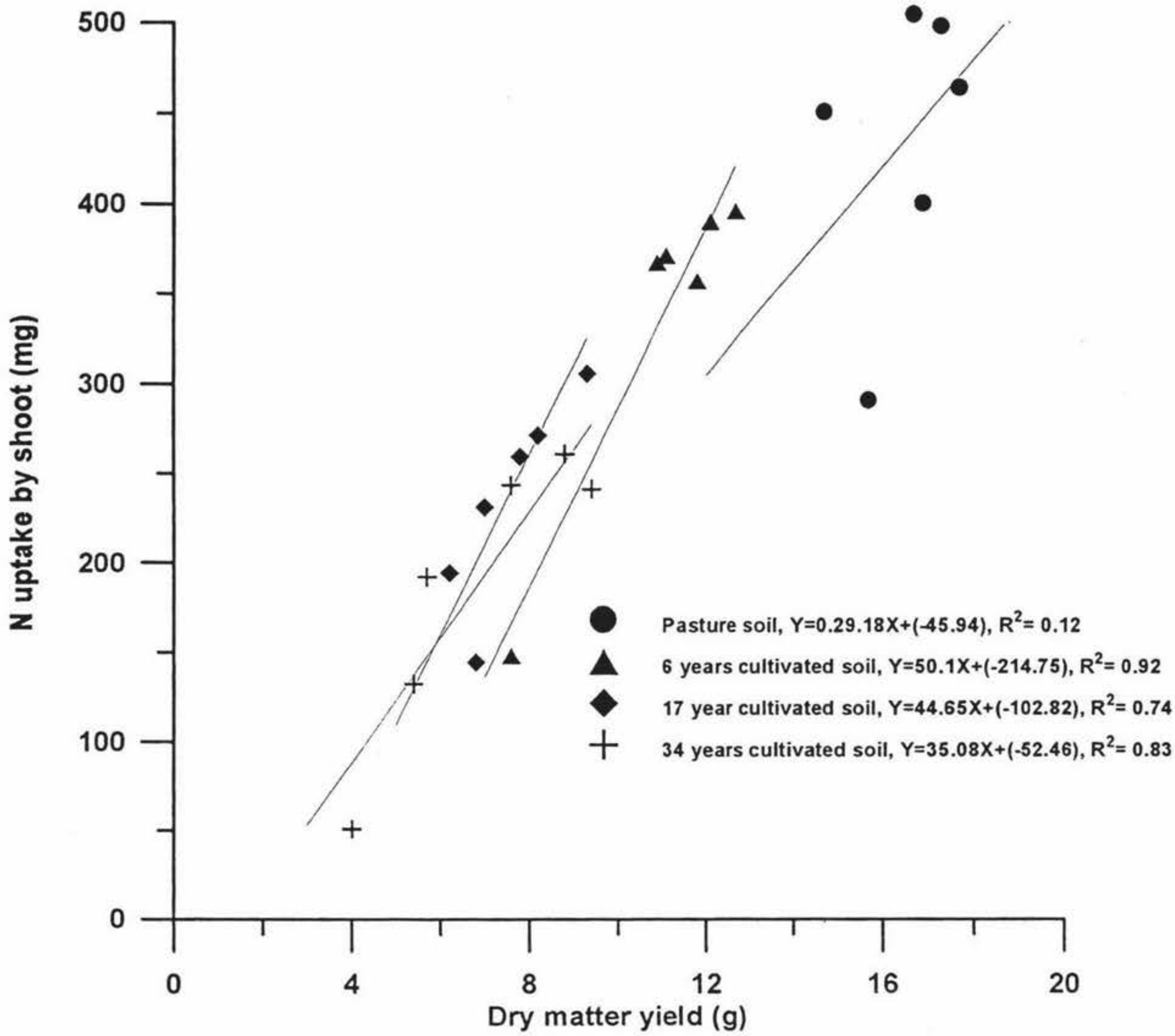


Figure 3.9 Relationship between N uptake and dry matter yield in 6 levels of N

3.4 SUMMARY AND CONCLUSIONS

The potentially mineralisable nitrogen content decreased with increasing periods of cultivation in dry soil condition (not in moist soil). The high soil mineral nitrogen in the pasture soils indicates that there is a scope for reducing N fertilizer inputs and improving N use efficiency.

The dry matter yields increased up to 200 kg N/ha (pasture soil and 6 years and 17 years cultivated soils), up to 100 kg N/ha in the 34 years cultivated soil, then decreased with increasing levels of nitrogen in the all soil samples.

Overall the results clearly demonstrated that both dry matter yield and N uptake for the cultivated soils never reached similar to that of the permanent pasture soil even by increasing the addition of nitrogen fertilizer.

These results indicate that, apart from N fertility the soil physical conditions may have restricted the maize growth. A second experiment was conducted in which poultry manure was added to ameliorate the physical conditions of the cultivated soil.

CHAPTER FOUR

EXPERIMENT TWO:

EFFECT OF POULTRY MANURE (PM) ON THE RESPONSE OF MAIZE TO N FERTILISER

4.1 INTRODUCTION

The objective of Experiment I was to examine the effect of cultivation on the response of maize to N fertiliser under glass house conditions. In Experiment I, we found that the dry matter of maize decreased with increasing period of cultivation. Application of N fertiliser increased the yield in all soil samples. However, the cultivated soils did not achieve the same yield as the permanent pasture soil. We assumed that this is related to the soil physical condition of the soil. In Experiment II we used poultry manure in order to improve the soil structure as well as nutrient levels of the soil and to examine its effect on maize growth.

4.2 MATERIALS AND METHODS

4.2.1 Experimental site:

A second pot experiment was conducted at the Plant growth Unit Research Centre, Massey University from 21 June until 2 October 1999. The two soils used were: Permanent pasture soil and 34 years cultivated soil (see Chapter 3).

The sub samples of soil collected for Experiment I were incubated with poultry manure (PM) for 8 weeks. The poultry manure was added at a rate of 200 g / kg soil. The incubated soils were used to compare maize growth. Measurements were recorded every two weeks, which include plant height, leaf length, stem diameter, number of leaves and chlorophyll. The plants were harvested nine weeks after planting and the fresh weight, the dry matter weight, the root length, the fresh root weight and the dry root weight were recorded.

4.2.2 Plant growth experiment:

Treatments:

The treatments include 5 levels of N (0, 100, 200, 300, and 400 kg N/ha) for the pasture soil (without PM addition) and the cultivated soil (with PM addition), and zero level of N addition for the pasture soil (with PM addition) and the cultivated soil (without PM addeition). Three replications were used (total pot = 36). To all pots minus N nutrient solution was added three times per week.

The treatments were:

1. 34 years soil + PM + 0 kg N /ha (control)
2. 34 years soil + PM + 100 kg N/ha = 217.3 mg urea / kg soil = 869.2 mg urea / 4 kg soil.
1. 34 years soil + PM + 200 kg N/ha = 434.7 mg urea/kg soil = 1738.8 mg urea/ 4 kg soil
2. 34 years soil + PM + 300 kg N/ha = 625.2 mg urea/kg soil = 2500.7 mg urea / 4 kg soil
3. 34 years soil + PM + 400 kg N/ha = 869.6 mg urea/kg soil = 3478.3 mg urea / 4 kg soil
6. 34 years soil – PM
7. Pasture soil + 0 kg N /ha (control)
8. Pasture soil + 100 kg N/ha = 217.3 mg urea / kg soil = 869.2 mg urea / 4 kg soil
9. Pasture soil + 200 kg N/ha = 217.3 mg urea / kg soil = 869.2 mg urea / 4 kg soil
10. Pasture soil + 300 kg N/ha = 217.3 mg urea / kg soil = 869.2 mg urea / 4 kg soil

11. Pasture soil + 400 kg N/ha = 217.3 mg urea / kg soil = 869.2 mg urea / 4 kg soil

12. Pasture soil + PM

All pots were placed in the glasshouse. Nitrogen as urea was applied in two split doses, 50 % as a basal fertilizer and the remaining 6 weeks after planting as a side dressing.

Four seeds of maize (*Zea mays*) hybrid 3902 were sown into each pot. These seeds were tested and the germination rate was 100 %. Four weeks after sowing the pots were thinned to 2 seedlings per pot.

4.2.3 Oxygen diffusion rates (ODR) and leaf chlorophyll:

The oxygen diffusion rate (ODR) was measured by using the 'Jensen Instruments Microelectrodes'. It was measured two times at 4 weeks and 6 weeks after planting.

ODR = 0.059 X observed microelectrode current in microampheres (ug/cm^2/minute)
(Glinski and Stepniewski., 1985).

Leaf chlorophyll was measured by using a portable photometer. Intact leaves were for chlorophyll measurements (ug chlorophyll / cm^2) (Hardacre et al., 1984).

4.2.4 Soil and herbage analysis:

Soil pH and total N in plant samples were measured as described in chapter 3 (section 3.1.4).

4.2.5 Statistical analysis:

SAS program was used to perform analysis of variance (ANOVA) (general linear models procedure), mean separations using t-test (LSD) at 5 % confidence level (P=0.05), and selected correlations, using plot means from all 36 pots. The analysis of variance was used to compare the difference between treatment means. The trial was analysed as a randomised block design with two factors.

4.3 RESULTS

4.3.1 Dry matter yield:

Dry matter yield showed highly significant difference between soil treatments and N levels. The means values of the dry matter are reported in Table 4.1.

At zero level of N application, addition of PM in the pasture soil achieved the highest dry matter yield (147 g/pot) followed by the cultivated soil with PM (103 g/pot) and the pasture soil without PM addition (71 g/pot). However, the lowest was observed in the 34 years cultivated soil without PM addition (37 g/pot) (Figure 4.1).

The application of N showed increased dry matter yield in the pasture soil without PM addition up to 300 kg N/ha and the yield decreased with further increase in the N level. In the cultivated soil (without PM addition) the dry matter yield increased up to 200 kg N/ha and decreased with further increase in N level (Table 4.1).

Table 4.1. Dry matter yield (g/pot) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil with PM addition	34 years maize cultivated soil without PM addition
0	71 Dc	103 *B*b	148 a	37 d
100	115 C	141 *AB*		
200	135 B	155 *A*		
300	149 A	147 *A*		
400	147 A	132 *AB*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

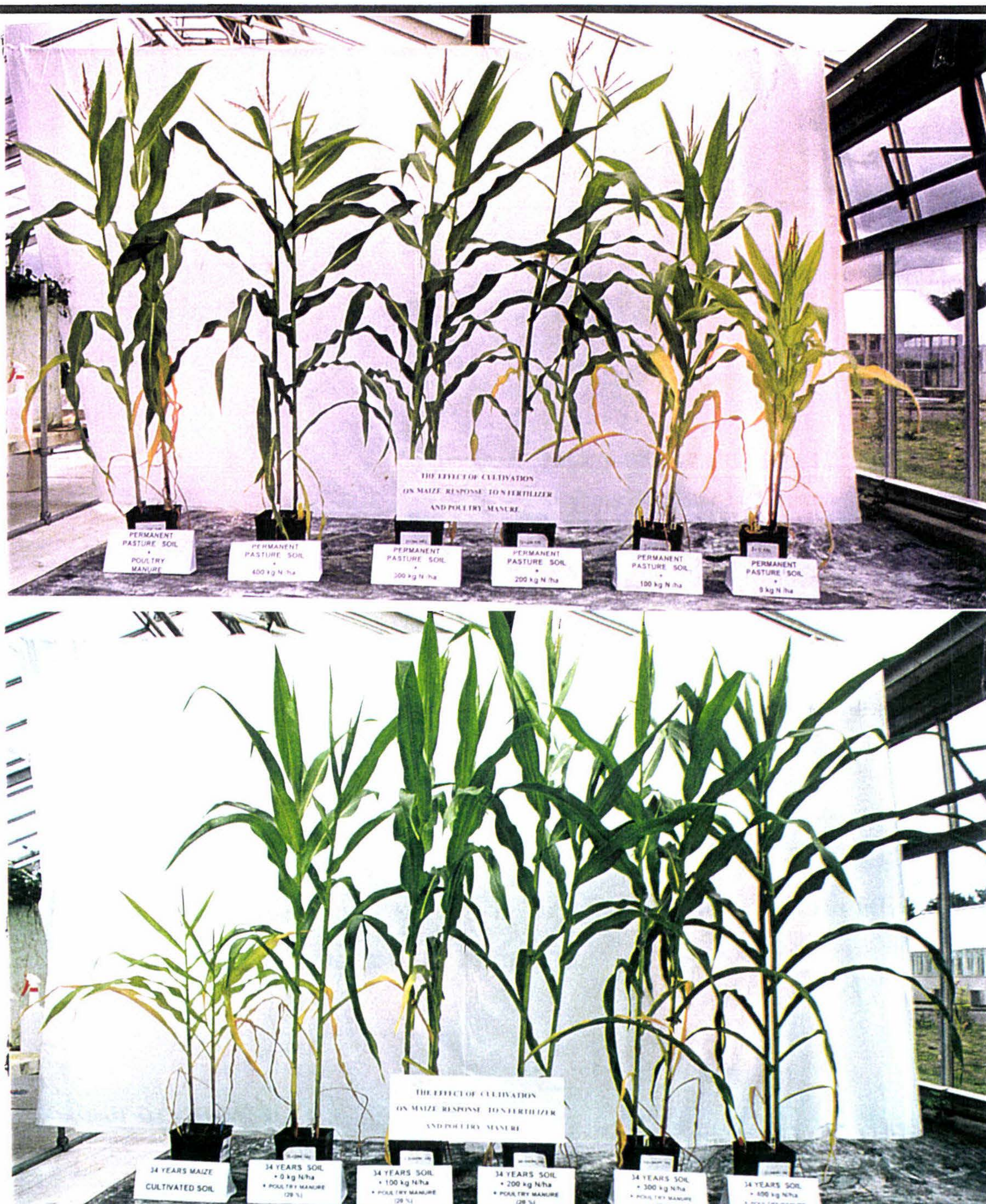


Plate 3. Plant height of maize crop in Pasture soil and 34 years cultivated soil with and without PM addition

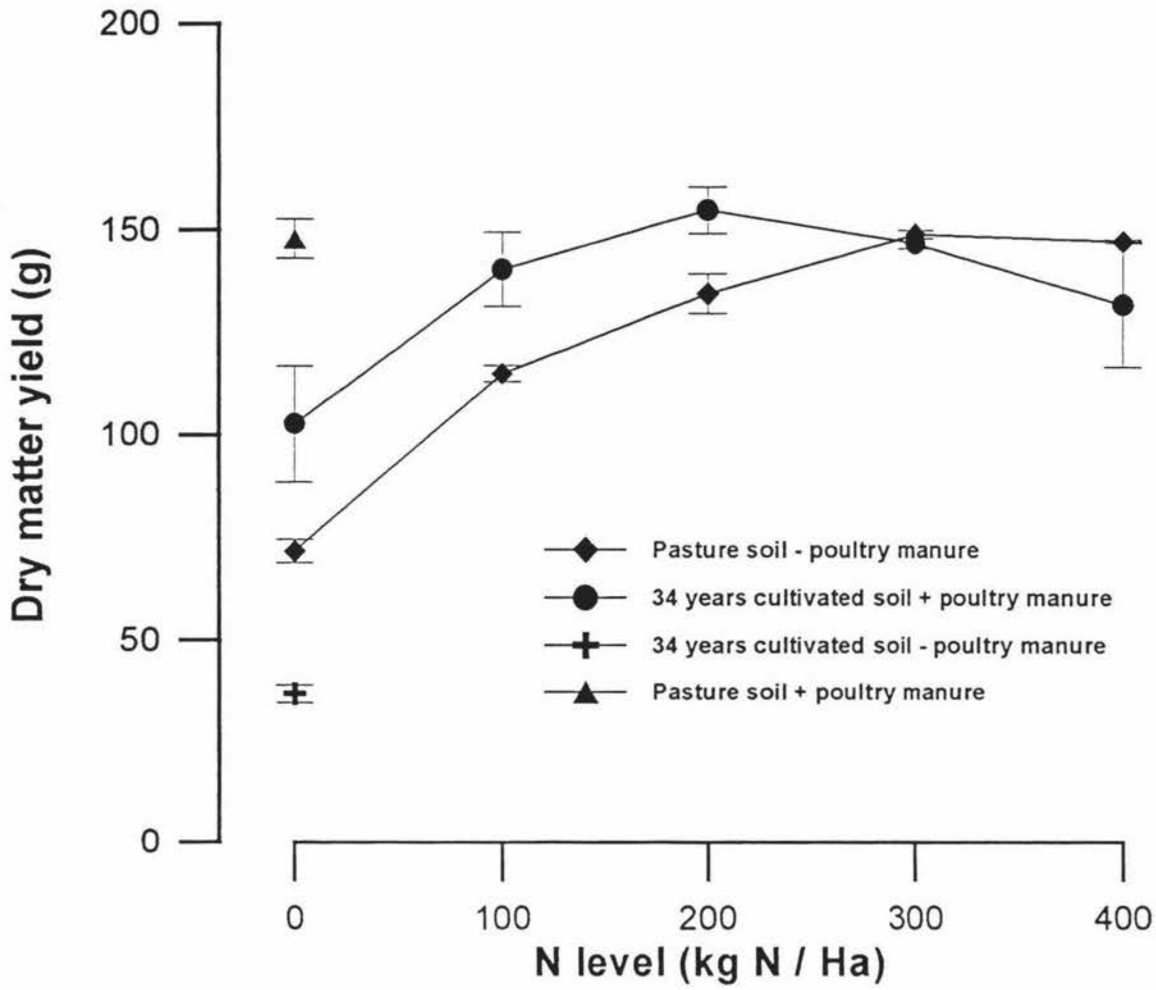


Figure 4.1 Effect of N levels and PM on maize dry matter yield at 9 weeks after sowing. Error Bars: ± S. E. of means.

4.3.2 Root dry weight:

The root dry weight showed no significant difference between the two soils. The root dry weights showed no significant difference at all levels of N application. The mean values of the root dry weights are reported in Table 4.2.

Without N application, the highest root dry weight was obtained in the pasture soil with PM addition followed by the cultivated soil with the addition of PM and the pasture soil without PM addition. The lowest was obtained in the cultivated soil without PM addition (Table 4.2).

In the case of the pasture soil (without PM addition) the root dry weight increased with increased N level up to 100 kg N/ha. There was a slight decrease in the dry weight of root at 200 kg N/ha level and the dry weight at 300 and 400 were similar to that of 100 kg N/ha level. In the case of cultivated soil, however, with the addition of PM root dry weight increased up to 300 kg N/ha and decreased with further increase in N level (Table 4.2).

Table 4.2. Root dry matter weight (g/pot) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil with PM addition	34 years maize cultivated soil without PM addition
0	27 Aa	53 *A*a	57 a	21 a
100	51 A	64 *A*		
200	34 A	117 *A*		
300	51 A	74 *A*		
400	51 A	32 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at $p = 0.05$). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

4.3.3 Plant height:

The plant height has shown significant difference between the two soils at 0 level of N application and between 0 and other levels of N. The means of plant height are given in Figure 4.2 and Table 4.3.

At zero N level the plant height has shown a similar trend to all other parameters such as dry matter yield and root dry weight. The highest plant height was achieved in the pasture soil with PM addition, followed by cultivated soil with PM addition, then the pasture soil without PM addition. The lowest was the cultivated soil without PM addition (Table 4.3).

In the case of cultivated soil (with PM) the plant height increased up to 200 kg N/ha, then decreased with further increase in N level. In the case of the pasture soil (without PM addition) the plant height increased up to 100 kg N/ha and then decreased with further increase in N level (Table 4.3).

Table 4.3. Plant height (cm) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil With PM addition	34 years maize cultivated soil without PM addition
0	148 Bb	164 *Bb*	200 a	88 c
100	198 A	193 *A*		
200	197 A	200 *A*		
300	194 A	192 *A*		
400	185 A	182 *AB*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

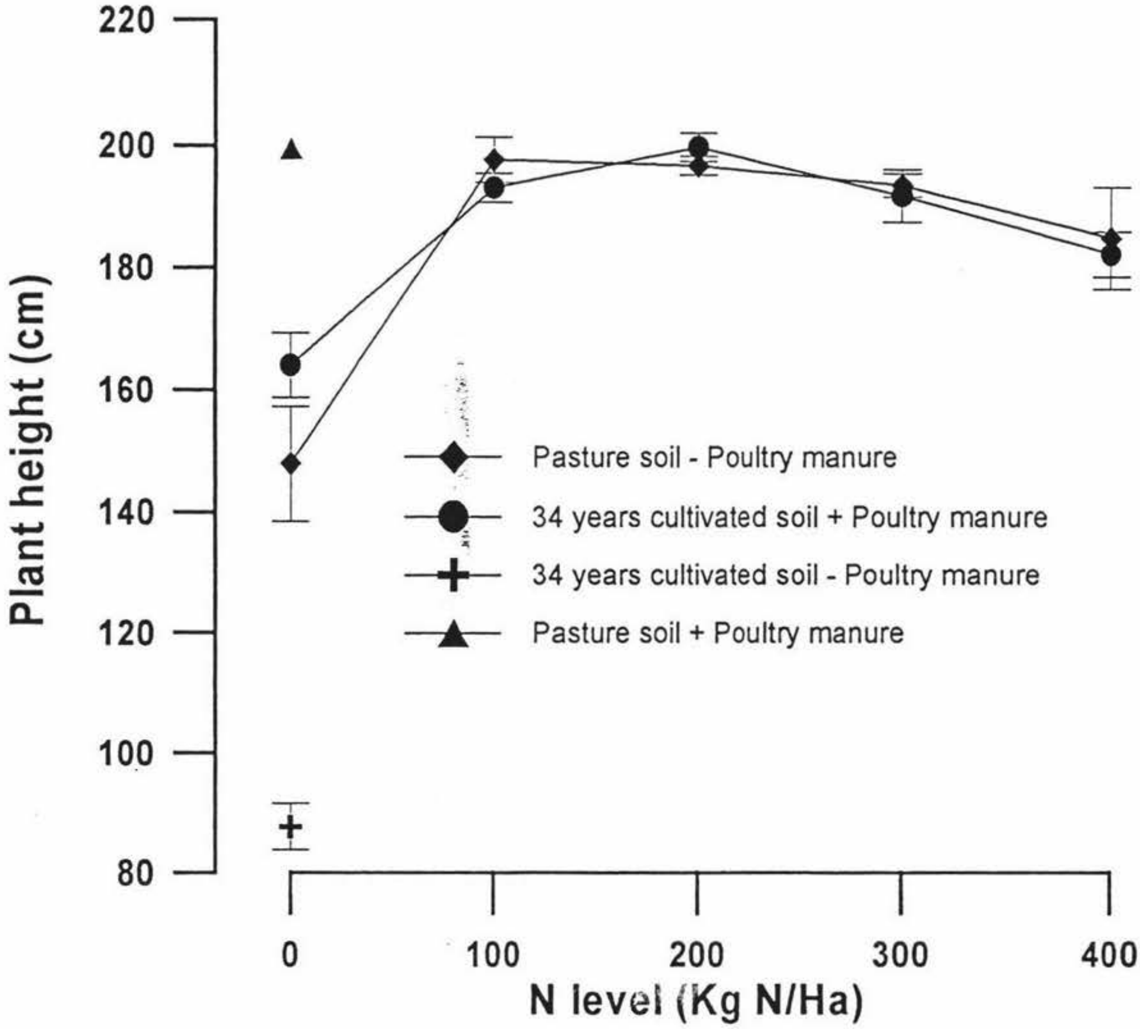


Figure 4.2 Effect of N levels and PM on maize plant height at 9 weeks after sowing.
Error Bars: ± S. E. of means.

4.3.4 Stem diameter:

The stem diameter of plant has also shown significant difference between the two soils and N levels for the 34 years cultivated soil. The means of stem diameter are given in Table 4.4.

At zero N level the stem diameter was the highest in the pasture soil with PM addition (13.4 mm), followed by 34 years cultivated soil with PM addition (12.8 mm) and the pasture soil without PM (11.7 mm). The lowest was 9.2 mm at cultivated soil without PM addition (Table 4.4).

In the case of the pasture soil (without PM addition) stem diameter increased only up to 100 kg N/ha and remained constant above that level. In the case of the cultivated soil, the stem diameter increased up to 100 kg N/ha and decreased with further increase in N level (Table 4.4).

Table 4.4. Stem diameter (mm) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil with PM addition	34 years maize cultivated soil without PM addition
0	11.7 Aa	12.8 *AB*a	13.4 a	9.2 b
100	12.2 A	13.8 *A*		
200	12.3 A	12.8 *AB*		
300	12.4 A	12.7 *B*		
400	12.4 A	12.3 *B*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

4.3. 5 Leaf chlorophyll:

The leaf chlorophyll has shown significant difference between the two soils at all levels of N. The means of leaf chlorophyll are shown in Table 4.5 and Figure 4.3.

At zero N level, the leaf chlorophyll has shown the highest in the pasture soil with PM addition (16.3 μg/cm^2/minute) followed by the cultivated soil with addition of PM (14.6 μg/cm^2/minute) and the pasture soil without PM (12 μg/cm^2/minute). The lowest was in the cultivated soil without PM addition (9 μg/cm^2/minute) (Table 4.5 and Figure 4.3).

In the case of the pasture soil (without PM addition) the leaf chlorophyll increased up to 100 kg N/ha and decreased with further increase in N application. In the case of the cultivated soil, the leaf chlorophyll increased up to 200 kg N/ha and decreased with further increase in N level (Table 4.5).

Table 4.5. Leaf chlorophyll (μg/cm^2/minute) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil With PM addition	34 years maize cultivated soil without PM addition
0	12.0 Ac	14.6 *A*b	16.3 a	9.0 d
100	14.1 A	15.8 *A*		
200	13.0 A	16.2 *A*		
300	13.9 A	15.4 *A*		
400	13.7 A	14.9 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

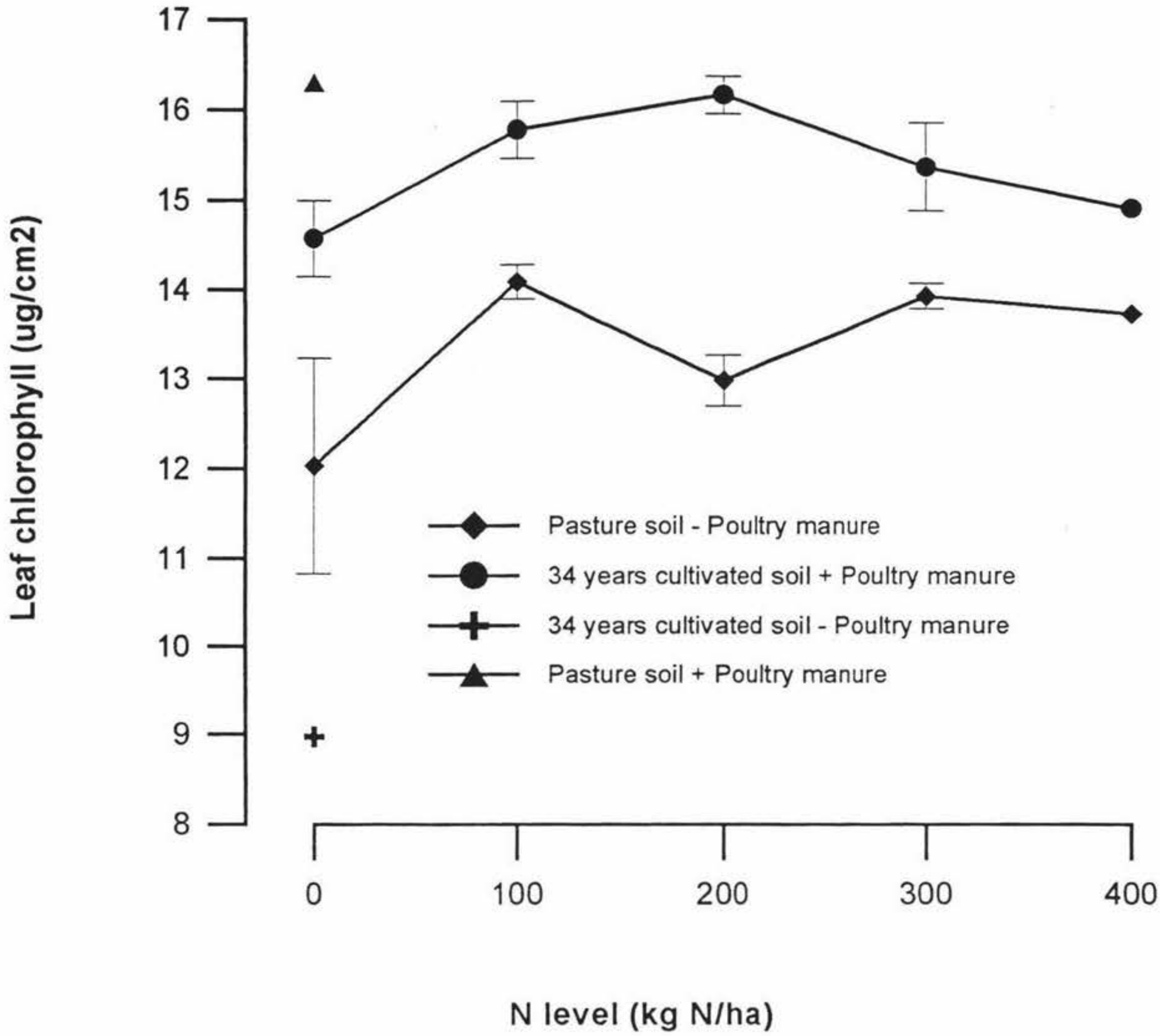
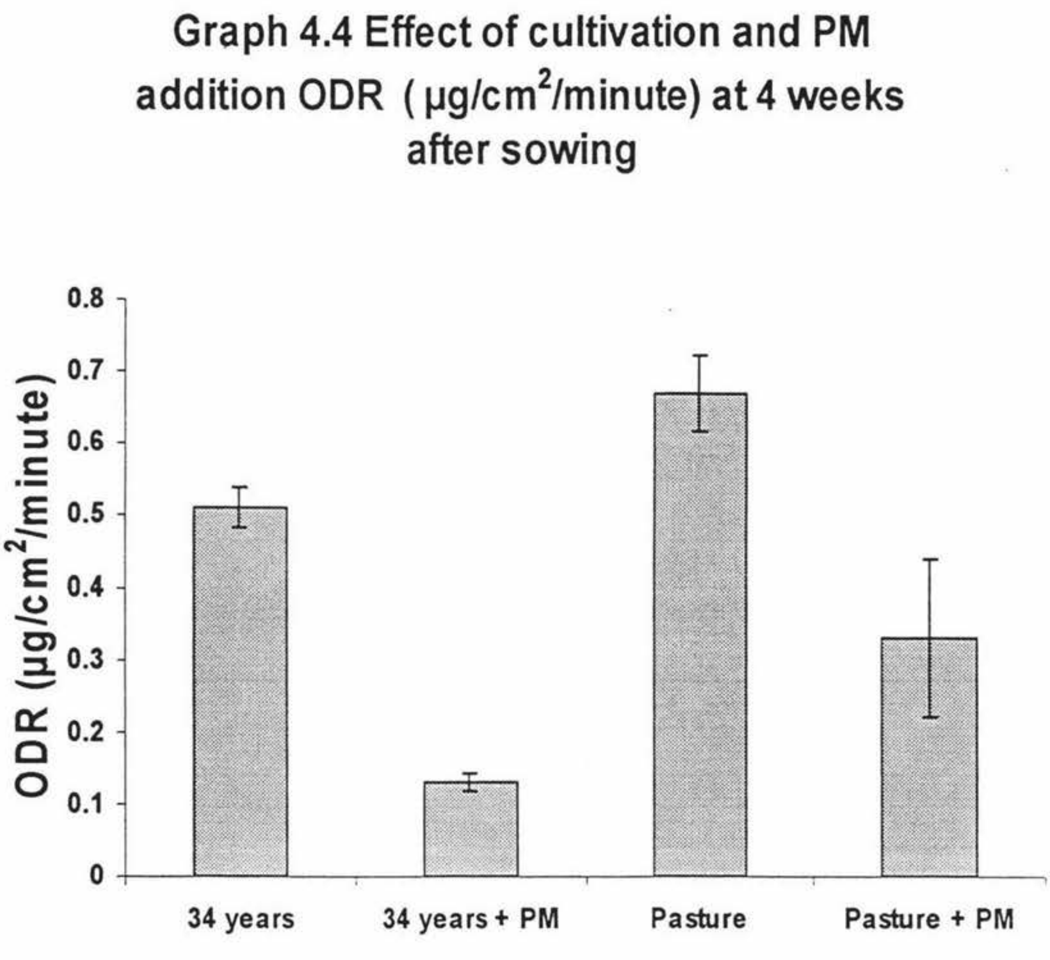


Figure 4.3 Effect of N levels and PM on maize leaf chlorophyll at 9 weeks after sowing.

Error Bars: ± S. E. of means.

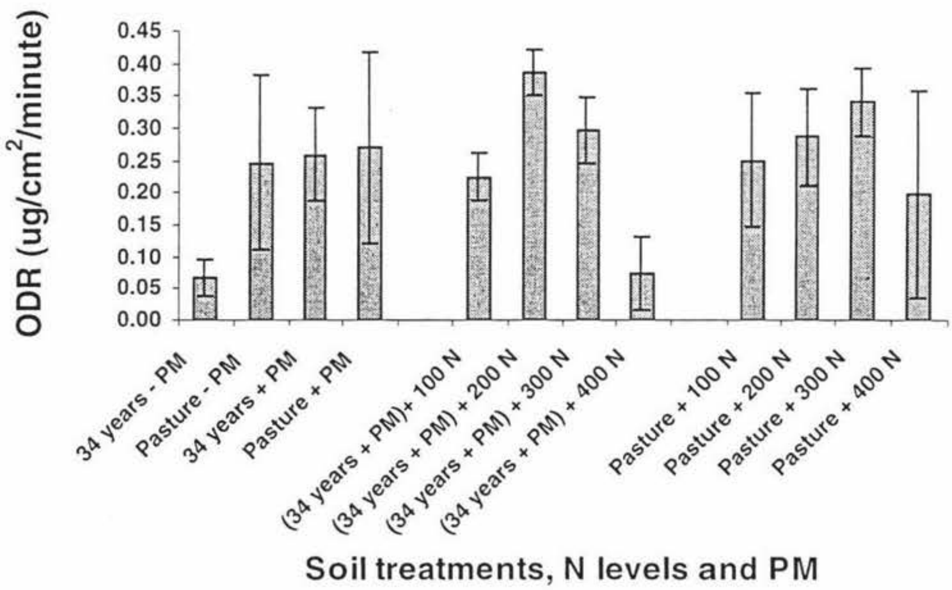
4.3.6 Oxygen diffusion rates (ODR):

The ODR values were measured 4 and 6 weeks after sowing (Figures 4.4 and 4.5).



Addition of PM siginificantly reduced the oxygen diffusion rate (ODR) in both soils at 4 weeks after sowing. The ODR values were higher for the pasture soil than the cultivated soil. The ODR values followed: pasture without PM (0.67 µg/cm²/minute) > 34 years soil without PM application (0.51 μg/cm^2/minute) > pasture soil with PM (0.33 μg/cm^2/minute) > 34 years cultivated with PM (0.13 μg/cm^2/minute) (Figure 4.4).

Figure 4.5 The effect of cultivation and N fertiliser on the ODR on maize crop (6 weeks)



However, 6 weeks after sowing the ODR has changed in Figure 4.5. The means of ODR are given in Table 4.6. At zero N level the highest ODR was observed in the cultivated soil with the addition of PM (0.26 μg/cm^2/minute), followed by pasture soil with PM addition (0.27 μg/cm^2/minute) and pasture soil without PM addition (0.25 μg/cm^2/minute). The lowest was in the cultivated soil without PM addition (0.07 μg/cm^2/minute) (Table 4.6 and Figure 4.5). The effect of N levels on ODR values was not consistent in both soils.

Table 4.6. Oxygen diffusion rate ($\mu g/cm^2/minute$) at six weeks after sowing.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil With PM addition	34 years maize cultivated soil without PM addition
0	0.25 Aa	0.26 *A*a	0.27 a	0.07 a
100	0.25 A	0.23 *A*		
200	0.29 A	0.39 *A*		
300	0.34 A	0.30 *A*		
400	0.20 A	0.07 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

4.3.8 Soil analysis:

With the addition of PM, the ammonium, nitrate, total N, total C, and soil pH increased in both soils (Table 4.7; Figure 4.6).

Table 4.7. Total nitrogen, total carbon, and soil pH after two months incubation.

No	Soil sample	NH_4^+ (mg/kg)	NO_3^- (mg/kg)	Total N (%)	Total C (%)	Soil pH
1	34 years + PM	127	0.8	0.6	3.6	6.7
2	Pasture + PM	150	1.3	0.9	6.1	6.6
3	34 years – PM	5	0.6	0.2	1.7	5.7
4	Pasture – PM	7	1.1	0.4	4.1	5.8
5	Poultry manure	-	-	3.73	18.51	-

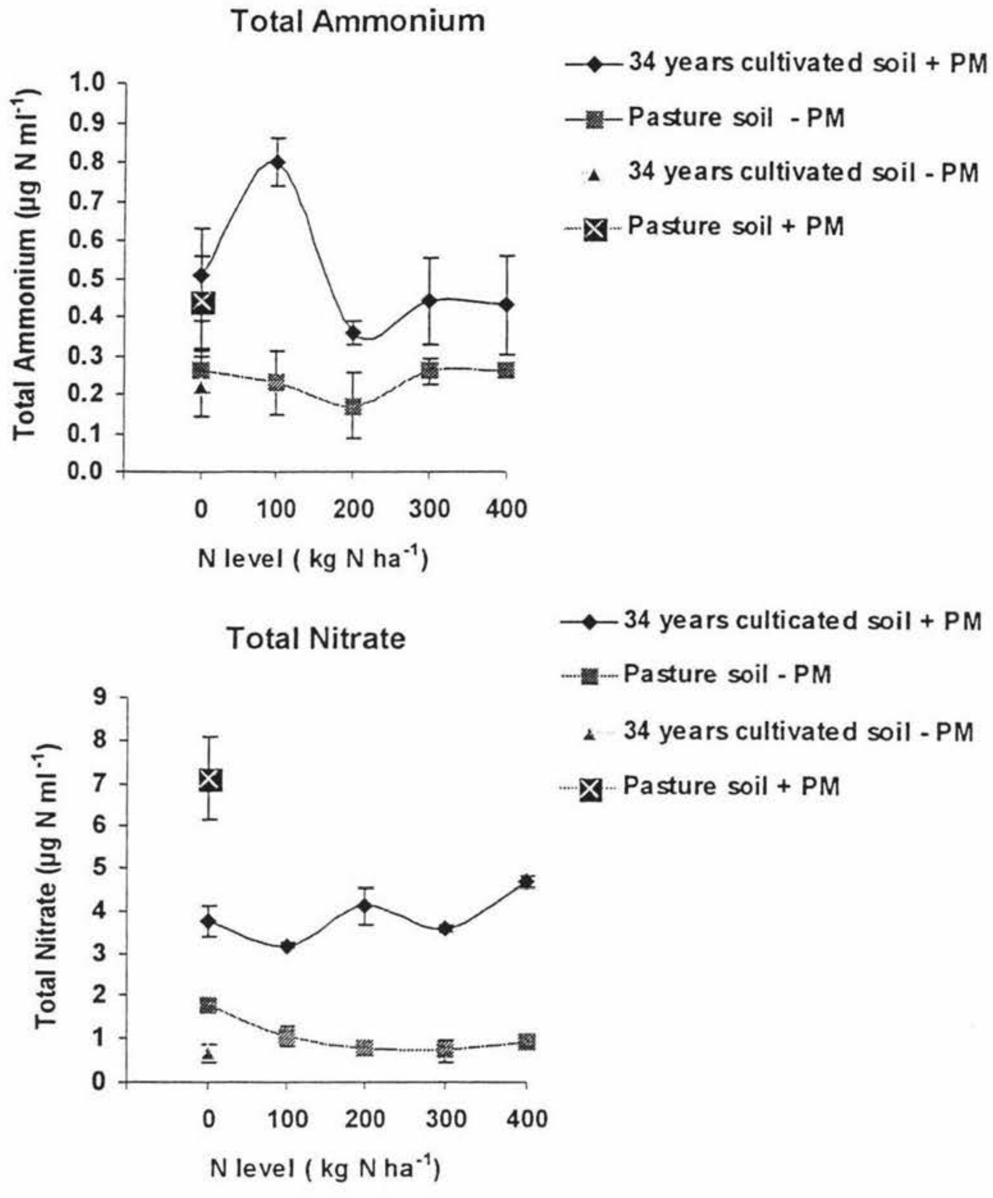


Figure 4.6 The effect of the addition of PM and N fertiliser on the concentration of KCl extractable NH_4^+ and NO_3^- in the soil. Error Bars: ± S. E. of means.

4.3.9 Pot water holding capacity (%):

Addition of PM increased pot 'water holding capacity' in the pasture soil and the cultivated soil. The water holding capacity in the pasture soil is higher than the cultivated soil (Table 4.8).

Table 4.8 Pot water holding capacity (%).

Soil treatment	**Pot water holding capacity (%)**
Pasture soil with PM addition	70.9
Pasture soil without PM addition	63.4
34 years cultivated soil with PM addition	58.6
34 years cultivated soil without PM addition	51.6

4.3.10 N uptake by shoot and root:

Plant N uptake showed highly significant difference between the two soils and N levels. The means of N uptake are given in Table 4.9. The plant N uptake has shown a similar trend to that of the dry matter yield (Table 4.9).

At zero N level the highest plant N uptake by shoot was found in the pasture soil with addition of PM (1.1 g/pot) followed by cultivated soil with addition PM (0.76 g/pot) and the pasture soil without addition of PM (0.43 g/pot). The lowest (0.21 g/pot) was obtained in the cultivated soil without PM (Table 4.9).

In the case of the pasture soil (without PM addition) the plant N uptake increased with increasing level of N application. In the case of the cultivated soil, however, the plant N uptake increased up to 300 N level and decreased at the highest N level (Table 4.9).

Table 4.9. Shoot N uptake (g/pot) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil with PM addition	34 years maize cultivated soil without PM addition
0	0.43 Cb	0.76 *B*a	1.06 a	0.21 a
100	0.88 B	1.26 *AB*		
200	1.23 A	1.55 *A*		
300	1.43 A	1.72 *A*		
400	1.53 A	1.60 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

Plant N uptake by root was significantly different between the soils at 0 N level. The means of N uptake by roots are given in Table 4.10.

At zero N level the N uptake by root was highest in the cultivated soil with PM addition (0.50 g/pot) followed by pasture soil with PM addition (0.45 g/pot) and the cultivated soil without PM addition (0.38 g/pot). The lowest was in the pasture soil without PM addition (0.12 g/pot).

In the case of the pasture soil (without PM addition) the N uptake by root increased with increasing level of N application. In the case of cultivated soil, however, the N uptake by root increased up to 200 kg N/ha and decreased with further increase in N level (Table 4.10).

Table 4.10. Means of root N uptake (g/pot) at final harvest of 12 soil treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil with PM addition	34 years maize cultivated soil without PM addition
0	0.19 Aab	0.37 *A*a	0.45 a	0.12 b
100	0.36 A	0.52 *A*		
200	0.23 A	1.05 *A*		
300	0.40 A	0.72 *A*		
400	0.38 A	0.47 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

4.3.11 P uptake by shoot and root:

Plant P uptake by shoot was significantly different between two soil samples and N levels. The P uptake by shoot was higher in the cultivated soil with PM addition than in the pasture soil without addition of PM. The means of P uptake are given in Table 4.11.

At zero N level the highest P uptake by shoot was found in the pasture soil with PM addition (0.29 g/pot), followed by cultivated soil with PM addition (0.15 g/pot), and pasture soil without PM addition (0.12 g/pot). The lowest was found in the cultivated soil without PM addition (0.07 g/pot) (Table 4.11).

In the case of the pasture soil (without PM addition) P uptake increased up to 200 kg N/ha and decreased with further increase in N application. In the case of the cultivated soil, the P uptakes was almost twice that of the pasture soil. However, P uptake in the cultivated soil increased up to 200 kg N/ha and decreased with further increase in N application (Table 4.11).

Table 4.11. Shoot P uptake (g/pot) at harvest for different treatments

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil With PM addition	34 years maize cultivated soil without PM addition
0	0.12 Bbc	0.15 *A*b	0.29 a	0.07 c
100	0.15 AB	0.21 *A*		
200	0.19 A	0.25 *A*		
300	0.17 A	0.26 *A*		
400	0.17 A	0.21 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

Plant P uptake by root showed significant different between the two soils at 0 N levels. The means of P uptake by roots are given in Table 4.12.

At zero N level P uptake by root showed the highest in the pasture soil with PM addition (0.26 g/pot) followed by the cultivated soil with PM addition (0.19 g/pot) and the pasture soil without PM addition (0.04 g/pot). The lowest was in the cultivated soil without PM addition (0.03 g/pot) (Table 4.12).

In the case of the pasture soil (without PM addition) the P uptake was not affected by the N levels. In the case of the cultivated soil, however, the P uptake increased up to 200 kg N/ha and decreased with further increase in N level (Table 4.12).

Table 4.12. Root P uptake (g/pot) at harvest for different treatments.

N level (kg /ha)	Pasture soil without PM addition	34 years maize cultivated soil with PM addition	Pasture soil with PM addition	34 years maize cultivated soil without PM addition
0	0.04 Ab	0.19 *A*ab	0.26 a	0.03 b
100	0.07 A	0.28 *A*		
200	0.07 A	0.42 *A*		
300	0.07 A	0.24 *A*		
400	0.07 A	0.11 *A*		

Means followed by the same latter do not differ significantly (Duncan's Multiple Range Test at p= 0.05). Capital letters are for differences between N levels for pasture soils, and capital italicised letters are for the cultivated soil. Lower case letters are for the 0 N treatments.

4.4 DISCUSSION

The result of the second glasshouse experiment indicated the following important points:

- **The oxygen diffusion rate (ODR) was higher with the addition of poultry manure than without poultry manure.**
- **Addition of poultry manure increased the water holding capacity of the cultivated soil.**
- **Addition of poultry manure increased the total N, total C and mineralisable N content of the soil.**
- **The dry matter yield was higher in the cultivated soil with the addition of poultry manure than the pasture soil without poultry manure addition.**

Addition of poultry manure to the cultivated soil increased the dry matter yield, which could be attributed to the increased nutrient levels and improvement in soil physical conditions. These are discussed below:

4.4.1 Increase in Nutrient Levels:

4.4.1.1. Mineralisable N:

The addition of PM to the cultivated soil and pasture soil increased NH_4^+ and NO_3^- concentrations compared to the treatment without PM addition (Table 4.7).The increase in mineral N (NH_4^+ and NO_3^- concentrations) in the cultivated soil after addition of PM (Table 4.7 and Figure 4.6) is probably due to the organic N content in the poultry manure, which could release large amount of nutrients during the mineralisation process (Faassen and Dijk, 1987). Other studies (Hadas et al.,1983; Sims, 1986; Stolyarenko et al.,1992) have shown that PM contains 70 % - 80 % organic matter, 3 – 7 % N, and 2 – 4 % P, which could influence the amount of mineralisable N in the soil. They have shown that 34 – 44 % of the total N in poultry manure is mineralised during the first month when it is incorporated into soil.

The results indicated that addition of PM to the soils increased the soil organic matter content, which resulted in increased microorganism activity. Thus, mineralisable N in the pasture and the cultivated soils increased by the PM addition (Table 4.7).

The lowest mineralisable N in the cultivated soil was probably related to the effect of long term cultivation on soil organic matter (refer to chapter 3). The long-term cultivation resulted in a decrease in total N and total C in the soil (Sparling et al., 1992; Saggar et al., 1998). Thus, in the cultivated soil the mineralisable N was very low (Table 4.7). The increased mineralisable N in the pasture soil was probably due to high decomposition rate of dead plants, deposition of animal excreta, and N fixation by legumes. Thus, the mineralisable N in the pasture soil was higher than the cultivated soil, which can enhance higher plant vegetative growth than the cultivated soil without PM addition at the same N level (result of Experiment I given in Table 3.3).

The addition of PM and N fertiliser in the cultivated soil markedly increased mineral N (total and ammonium and nitrate concentrations) after harvest compared to the pasture soil without PM addition and N fertiliser (Figure 4.6).

The decrease in NO_3^- with increasing levels of N in the pasture soil (Figure 4.6) was probably due to N gaseous losses through the biological denitrification process. McLaren and Cameron (1996) have indicated that as the nitrate concentrations increase in the soil, the denitrification process would be increased. Karl Guillard et al. (1995) found that application of nitrogen fertiliser greater than 336 kg N/ha in the maize soil increased the NO_3^- losses.

$$2\,NO_3^- \rightarrow 2\,NO_2^- \rightarrow 2NO^- \rightarrow N_2O \rightarrow N_2$$

Nitrate Nitrite Nitric Oxide Nitrous Oxide Di-nitrogen

This experiment clearly indicates that the application of PM to the cultivated soil resulted in an increase in mineral N which is very important for the maize plant growth.

4.4.1.2. N and P concentrations of maize shoot:

Application of PM increased the concentration of N of maize, especially in the cultivated soil at 0 level of N application (Figure 4.7). Whereas, it decreased the concentration of P in maize (Figure 4.8). However, there was a positive relationship between N uptake and dry matter yield (Figure 4.9). Hanway (1962) found a relationship between N uptake and dry matter yield for maize.

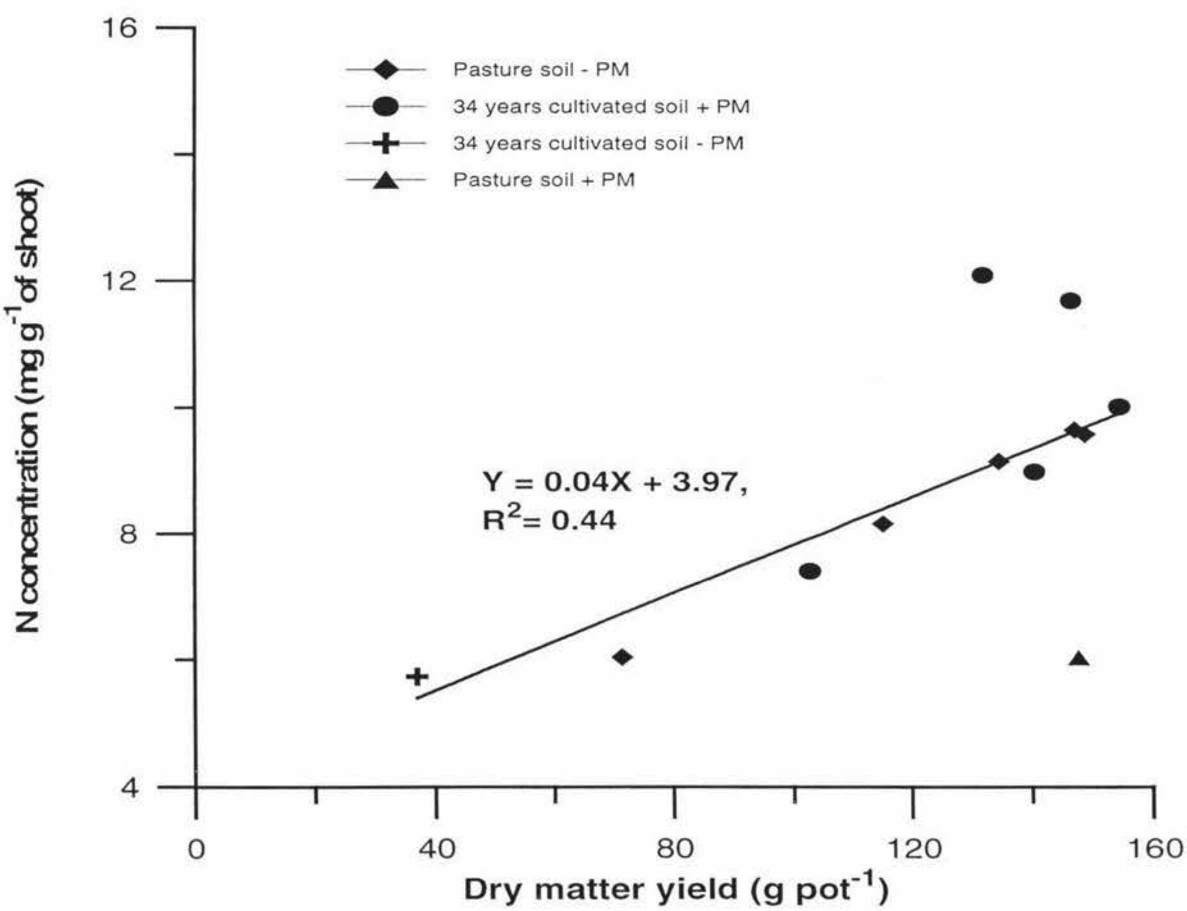


Figure 4.7 The relationship between N concentration and dry matter yield.

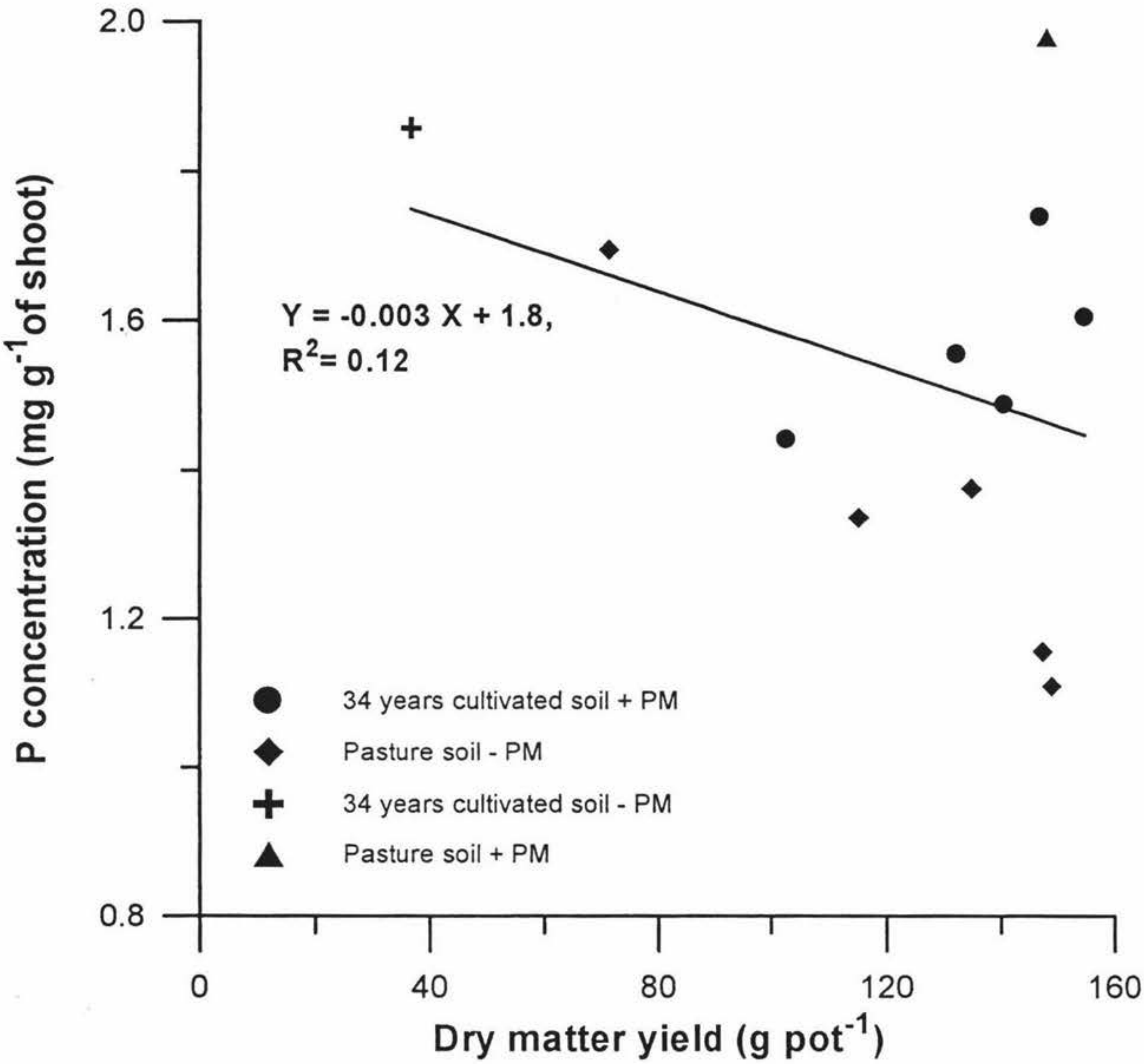


Figure 4.8 The relationship between P concentration and dry matter yield.

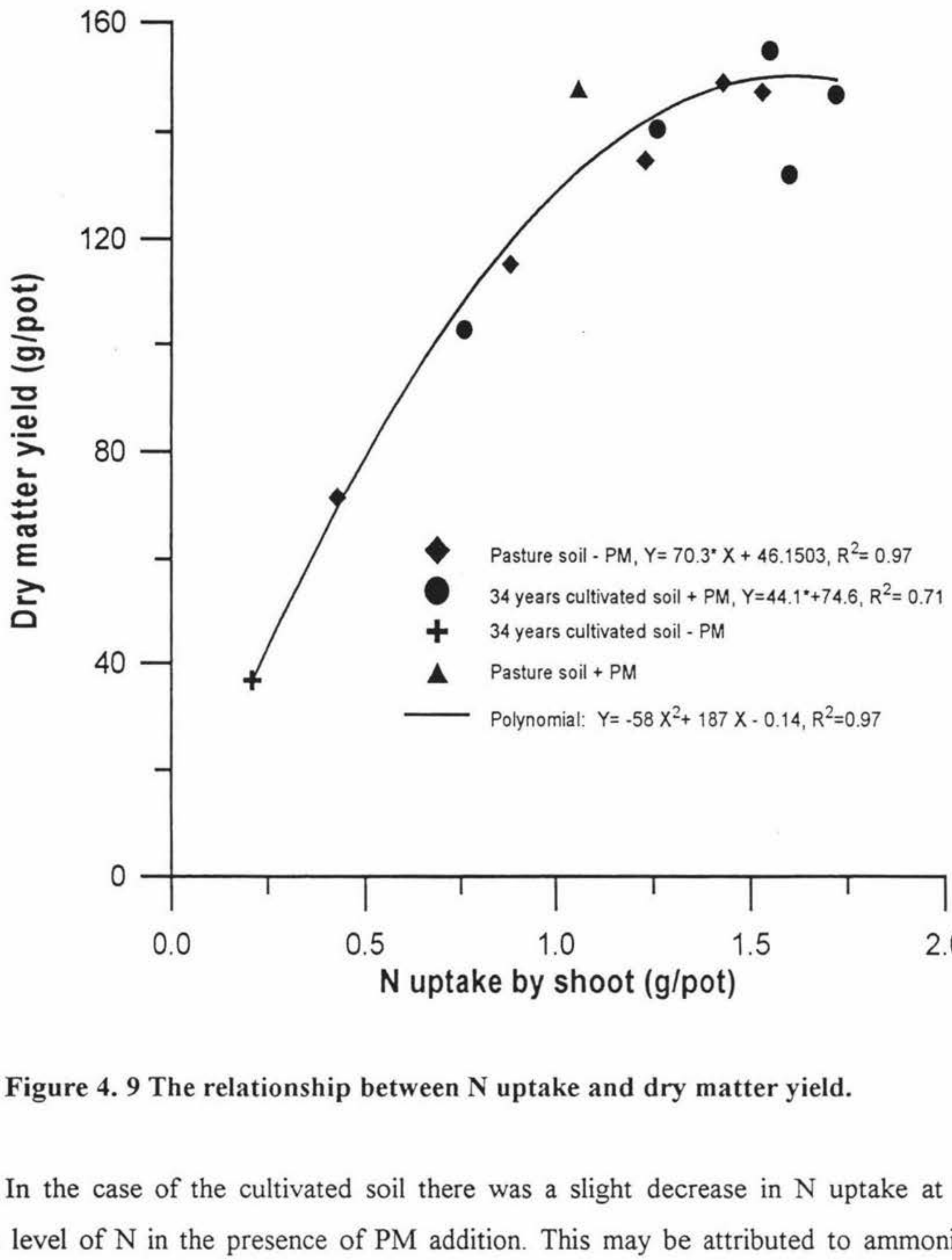


Figure 4. 9 The relationship between N uptake and dry matter yield.

In the case of the cultivated soil there was a slight decrease in N uptake at the highest level of N in the presence of PM addition. This may be attributed to ammonium toxicity.

The highest N uptake by maize in the cultivated soil with PM addition compared to the pasture soil (Table 4.9) was probably due to the higher total N content in the PM (Table 4.7).

In the absence of PM addition the N uptake was higher in pasture soil than the cultivated soil. This was probably due to higher levels of N returned back to the soil through dung, urine, legumes, and dead plants and roots residue. The lowest N uptake by maize at zero level in the cultivated soil could be related to the break down of soil structure due to long term cultivation resulting in a loss of macroporosity of the soil. This can affect the total N and C in the soil. Thus, the difference in N uptake between all the treatments at zero N level may be related to the differences in the mineralisation rate and the availability of N in the soil.

The addition of PM to the pasture and the cultivated soils increased the N uptake by maize plant indicating that the addition of PM could supply more N to the soil (Table 4.9), which increased the N uptake in the pasture soil and cultivated soil.

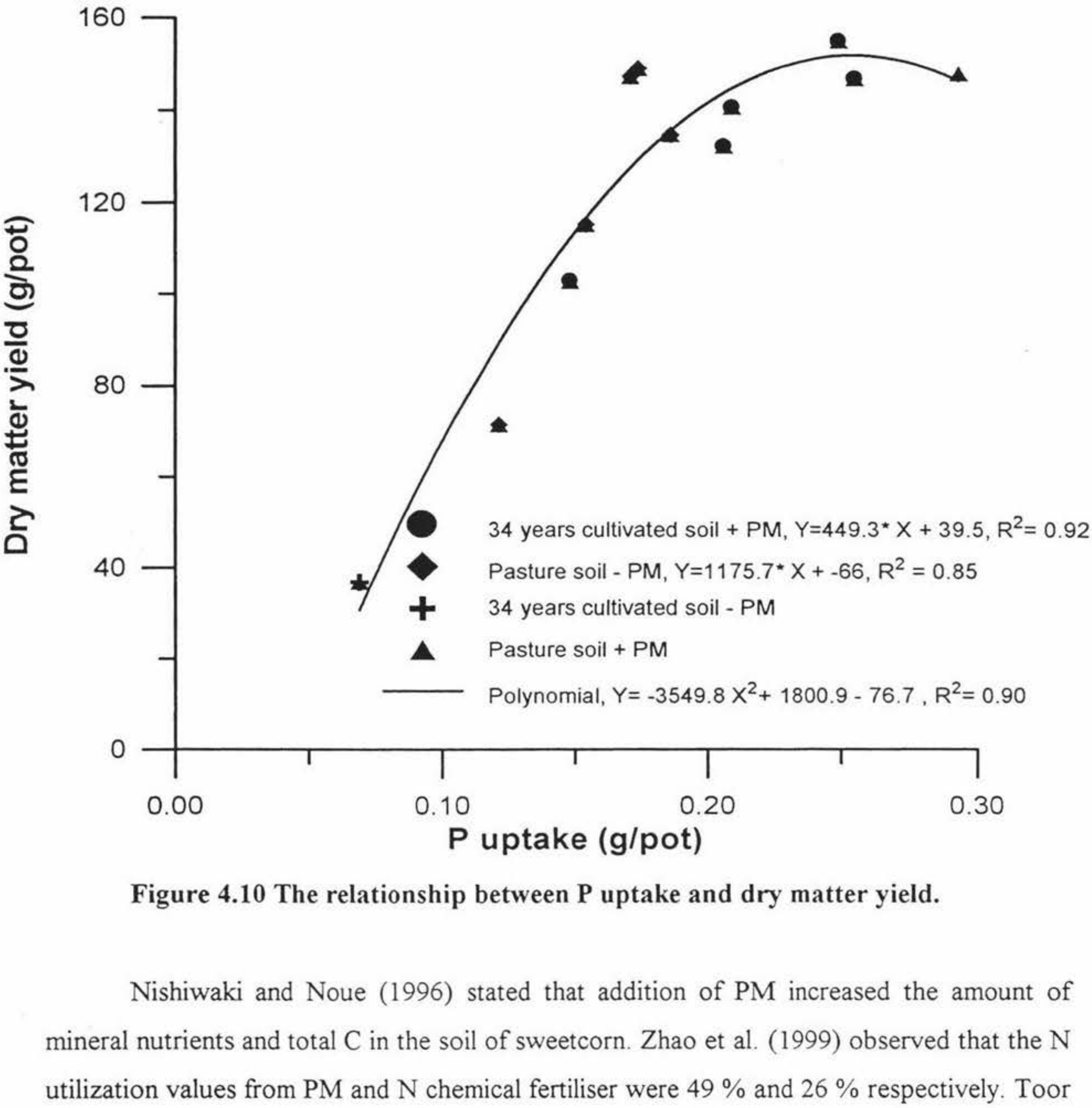


Figure 4.10 The relationship between P uptake and dry matter yield.

Nishiwaki and Noue (1996) stated that addition of PM increased the amount of mineral nutrients and total C in the soil of sweetcorn. Zhao et al. (1999) observed that the N utilization values from PM and N chemical fertiliser were 49 % and 26 % respectively. Toor and Bishoi (1996) also mentioned that the application of inorganic N alone increased the available N content but decreased the available P and K content of the soil. The addition of PM combined with N fertiliser increased N uptake more than N fertiliser alone (Table 4.9) for two reasons: (i) N supplied by the PM is slowly available so is less susceptible to leaching or volatilisation; (ii) PM supplies P and K, which stimulates plant growth leading to increased N uptake. Therefore, this experiment clearly showed that the addition of PM combined with N fertiliser increased N uptake more than N fertiliser alone.

The 2-fold increase in P uptake by maize grown in the cultivated soil with PM addition was due to high P nutrient content of poultry manure (Faassen and Dijk, 1987). This is also supported by Gijsman and Sanz (1998) who reported that PM addition could increase the available P and organic P in maize soil. The uptake of P was also affected by N levels.

There was a positive relationship between P uptake and dry matter yield (Figure 4.10). This is supported by Das et al. (1991) who mentioned that organic manures increased P uptake, grain / seed yield of maize and soil available P.

4.4.2 Improvement in Soil Physical Condition:

4.4.2.1 ODR values:

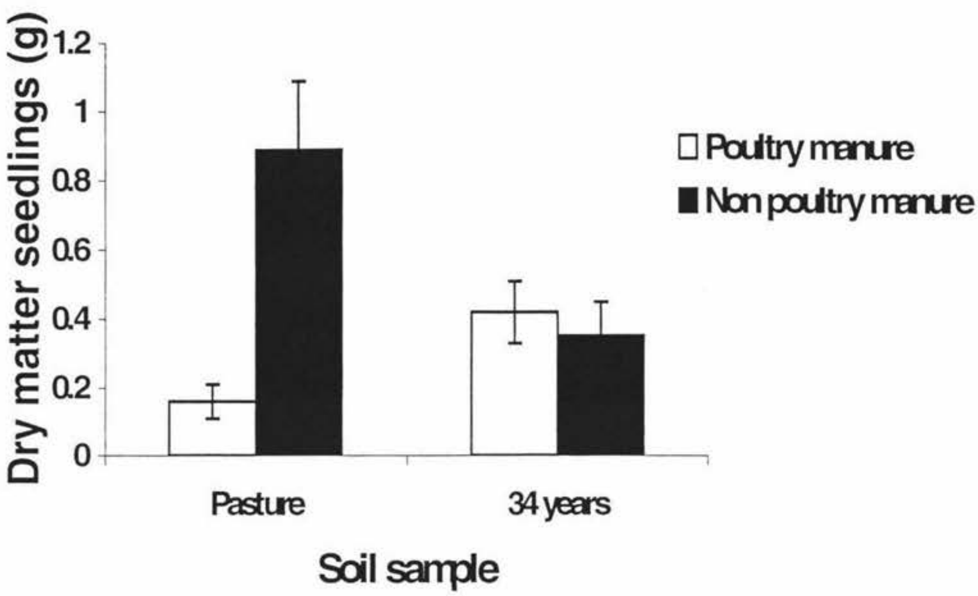
The ODR measurement was recorded to examine the effect of PM addition on soil pore space. An increase in pore space provides evidence for an improvement in soil structure.

The ODR values measured 4 weeks after sowing decreased with PM addition to soil. The ODR affected the seed germination in the pasture and the cultivated soils (Figure 4.4). The low ODR with PM addition at 4 weeks after sowing was probably due to the higher soluble C content in the soil. O'Dell et al. (1960) have reported that a large proportion of total N (80 %) in PM was in the form of $C_5H_4N_4O_3$ which could produce NH_3 and CO_2 through microorganisms activity.

$$C_5H_4N_4O_3 + 2\,H_2O + 1\tfrac{1}{2}\,O\,2 \rightarrow 2\,CO\,(NH_2)_2 + 3\,CO_3 \quad \text{.......................(1)}$$

$$CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2\,CO_3 \rightarrow 2\,NH_3 + CO_2 + H_2O \quad \text{.....................(2)}$$

Figure 4.11. Effect of poultry manure on maize seedlings (19 dap)



The high carbon content in the PM acts as an energy source for soil microorganisms, which is likely to lead to increased CO_2 concentrations. The increase in the concentrations of CO_2 and NH_3 is likely to decrease the ODR values.

The present experiment showed that PM addition caused poor seed germination. Addition of PM inhibited the germination of maize seeds and the seedlings were stunted and the effect was more pronounced in the pasture soil than the cultivated soil. The dry weight of the seedlings obtained during thinning were recorded (Figure 4.11). The lower oxygen concentrations in the soil reduced the root respiration, which caused the slow establishment of maize (Figure 4.11). The lowest ODR values in the 34 years cultivated soil with PM is below the critical ODR level for the plant growth (< 2 μg/cm2/minute) (McLaren and Cameron, 1996). These results agreed with Mukhtar et al. (1990) who found that an ODR below the critical level for maize might have restricted the supply of oxygen to the roots, resulting in low dry matter yields in clay soil. The second reason for poor seed germination was that PM produced high $(NH_4)_2CO_3$ concentrations resulting in ammonia toxicity (Figure 4.11 and Table 4.7).

$NH_4^+ + OH^- \leftrightarrow NH_3 + H_2O$ .... (3)

Six weeks after sowing, the ODR values slightly increased with the addition of PM in the pasture soil and dramatically increased in the cultivated soil (Figure 4.5). The higher ODR in the PM treatment compared to the unamended soil is probably due to the large addition of organic carbon in the PM, which increased the soil organic matter content. The increase in the soil organic matter content resulted in an improvement in soil structure, soil pores, and infiltration due to increased soil microorganism activity. It is assumed that by this time all the CO_2 and NO_3 released from PM would have escaped to atmosphere.

Also, the slow release of N from the PM increased the amount of N available to the microorganisms. High soil N concentrations support plant growth and microbial activity, factors, which help to improve the structure of the soil. Improved soil structure leads to an increase in the ODR. Thus, ODR increased with addition of PM up to the certain level of N.

The highest ODR in the cultivated soil + PM treatment (Table 4.6) compared with the control is probably related to the good soil structure (Picture 3). This may be one of the reasons for the increase in plant growth with PM addition in this soil. The growth of most plants is limited when the ODR < 0.2 $\mu g/ cm^2/$ minute (McLaren and Cameron, 1996)

The ODR was higher in the pasture soil than the 34 years cultivated soil in the absence of PM in the 4 weeks after sowing (Figure 4.4). This result was also probably related to the higher soil organic matter in the pasture soil. This result is supported by Lal (1986) who found that the ODR was higher in no tillage than in the cultivated soils. The difference in ODR between the pasture soil and the cultivated soil might be related to the structure of the soil. Sparling et al., (1992), Saggar et al. (1998) and Aslam et al. (2000) found that cultivated soil contained less water stable aggregates, less total C, and less total N than the pasture soil due to a low soil organic matter content. The 34 years soil was more rapidly saturated during watering, which indicated poor soil structure. This result is similar to Rajeev and Singh (1998) who found that ODR decreased at saturation (30 % soil moisture), and thereby decreased the seed germination rates.

In general, 2 months after sowing, the addition of PM to all treatments had a positive effect on the ODR during maize growth. The results showed that the addition of poultry manure to the soil increases the agronomic effectiveness (Mahimairaja et al., 1995) due to soil structure improvement.

4.4.2.2 Water holding capacity:

Water holding capacity was affected by the addition of PM to the pasture soil and the cultivated soil (Table 4.8).

In the absence of PM addition, the lower water holding capacity in the cultivated soil was probably related to the loss of macroaggregates and microaggregates in the soil during cultivation. A low amount of microaggregates in the soil resulted in loss of labile organic matter, which can influence the soil moisture (Tisdal and Oades 1980; Elliot, 1986). In addition, cultivation of soil alters the structural stability and reduces the amount of organic matter (van Veen and Poul , 1981; Saggar et al., 1998). It also reduces the proportion of macroaggregates in soils. Hence the reason for the low yield of maize in the cultivated soil compared to the pasture soil (Figure 4.10) is attributed partly due to poor soil physical conditions.

The lower soil water holding capacity with PM addition and soil moisture content of the cultivated soil is also related to less soil pores and this can reduce the rate at which water can enter the soil (infiltration) and the rate at which water can drain through the soil (hydraulic conductivity) (McLaren and Cameron, 1996).

The increased soil water holding capacity in this experiment clearly demonstrated that addition of PM influenced the soil microbial activity which in turn increased the dry matter yield of maize through soil structure improvement (Plate 4.). The increased water holding capacity resulted in increased soil microbial activity, transformation of soil nutrients, and can also enhance other soil physical factors such as soil aggregation and oxygen diffusion rate.

The water stability of soil aggregates is a very important soil property that can influence the soil chemical and biological properties. Low stability of aggregates in water can increase the bulk density of the soil (Dalal and Mayer, 1986) and lower aggregate stability may have affected crop production. The decreased water stability probably caused a decline in the water holding capacity of the soil.

Cultivation often results in a decline in organic C, microbial C, water stable aggregates, reduced macroaggregates, nutrient contents and increased soil compaction (Gupta and Germida, 1988; Sparling et al., 1992; Ball et al., 1997; Saggar et al., 1998). It also decreases the water holding capacity (Table 4.8). Accumulation of soil organic matter through continuous breakdown of pasture litter and deposition of animal excreta in the pasture soil was one of the main reasons for the increase in water holding capacity to the soil.

Overall, the cultivated soil needs more organic matter application in order to improve the soil physical, biological and chemical properties. This experiment clearly showed that after the application of PM the water holding capacity was increased (Table 4.8) which was related to the soil structure improvement (See Plate 3). Also, this experiment clearly showed that without PM addition the cultivated soil showed poor soil structure.

Pinzariu and Toniuc (1987) suggested that higher maize grain yield (9.5 – 10 t/ha) could be achieved with irrigation to 50 – 70 % field capacity. Moraru et al. (1986) found that maize grain yields were lower (6.82 ton/ha) with no irrigation compared to 12.85 ton/ha with irrigation treatment at 50 % of field capacity. The total root dry weight was found to be

Plate 4. Soil structure appearance in before and after incubation of the soil with poultry manure

higher in the crop irrigated to 85 % field capacity at all stages compared to the control which received no irrigation (Giralt, 1987).

The addition of PM in both pasture and cultivated soils increased pot water holding capacity (Table 4.8). Thus the addition of PM is the best way to increase the dry matter yield in cultivated soils with poor structure.

4.4.3 Dry matter yield:

4.4.3.1. The effect of adding PM and N fertiliser on cultivated soil:

Addition of poultry manure increased the dry matter yield in both soils. This result was probably related to the higher N uptake (Figures 4.1 and 4.8) resulting from increased soil mineral N, total N and C (Table 4.7) by addition of PM. The high available mineral N would probably increase the plant height, leaf chlorophyll (Figures 4.2 and 4.3). This result is similar to that of Otani et al. (1982) and Madhavi et al., (1995; 1996) who observed that the addition of PM increased dry matter yield and nutrient uptake. Also, Tuivavalagi and Silva (1996) reported that the addition of PM (16.8 t/ha) increased maize grain yield, kernel weight, plant height, ear-leaf weight, and aboveground biomass. It also significantly increased plant growth rate and reduced the period required for silking, tasselling, and physiological maturity. Thus, the highest dry matter yields, plant height, stem diameter, and chlorophyll content observed in soils incubated with PM were achieved due to soil structure improvement through the increased level of soil organic matter.

The highest dry matter yield at the 200 N level with addition PM in the cultivated soil indicated that the soil nutrient status was optimum at this N level. The highest dry matter yield at 200 kg N/ha in the cultivated soil means that maximum yields can not be obtained by PM alone without N fertilizer application. This is probably related to the N matching of the plant requirement and the amount of N available in the soil. The application of N chemical fertiliser would be more rapidly available to the plant growth. The organic N in the PM is not readily available for the plant as organic N takes a longer time to be decomposed, thus, organic N could be released slowly and available for the plant at later stage. Sims (1987) reported that soil N levels and N leaching were generally higher with ammonium nitrate fertiliser than PM with no tillage maize. Serna and Pomares (1991) found that PM gave high mineralisation rates, also the mineralised N became immobilised during the incubation process, which showed an initially rapid then a slow release of mineral N. N supplied by PM is less susceptible to leaching.

The addition of PM also increased the N availability in the soil (Table 4.7), thus, the dry matter yield in the cultivated soil + PM was higher than the pasture soil without PM. Also it was probably related to the increased available P (Table 4.11) in the soil from PM decomposition (O'Hallorans et al., 1997). Nishiwaki and Noue (1996) have reported that the dry matter yield increased due to low total C/N ratio in the soil through PM addition.

The increase in dry matter yield after the addition of PM is also probably related to the increase in the soil organic matter content as PM contains 70 % - 80 % organic matter (Stolyarenko et al., 1992). Obi and Ebo (1995) have reported that PM addition significantly improved maize height and maize grain yield due to soil organic matter improvement.

Experiment showed that N uptake by the 34 years cultivated soil was the lowest compared to the pasture soil without PM addition (Figure 3.9). This clearly demonstrated that the addition of PM to the cultivated soil increased N uptake by the plant (Figure 4.8). The dry matter yield in the cultivated and pasture soils also showed that there was a strong linear relationship between dry matter yield and N uptake due to N fertiliser application (Tables 4.1 and 4.9).

Scherer (1995) reported that application of urea and PM increased grain yields of maize, and that manure could partially or totally substitute for mineral N in the soil. Sharaiha and Hattar (1993) have reported that the dry matter yield of maize increased by 45 % - 66 % through the addition of PM.

The pasture soil responded to N application up to 300 kg N/ha without PM addition (Figure 4.1). The increased dry matter yield up to 300 kg N/ha was also probably related to the plant N requirement through the increased production of leaf chlorophyll (Figure 4.3).

The plant height and leaf chlorophyll concentrations in the pasture soil showed there was only a small response to N fertiliser application (Figures 4.2 and 4.3). This result was probably due to the high mineral N content in the pasture soil. Ammonium and nitrate, total N and C in the pasture soil was higher than the cultivated soil (Table 3.3).

Overall, the maize plant in the pasture and cultivated soils showed there was a strong linear relationship between N uptake and dry matter yield of maize due to N fertiliser application (Figures 4.1 and 4.9).

4.4.3.2. PM response to the maize yield in the pasture and cultivated soils without N.

There was a greater growth response to PM addition in the cultivated soil than the pasture soil. The difference in response to PM addition between the pasture and the cultivated soils was probably related to the N mineralisation rates from PM and the initial N content of the soil (Figure 4.6 and Table 4.7). The PM contains a large amount of organic materials (Table 4.7). The pasture soil contains more N, which originates from plant residues (dead roots and legumes), which can supply soil mineral N in the soil (Figure 4.6). Therefore, the pasture soil showed lower response to the PM addition compared to the cultivated soil (Tables 4.13). The lower N response in the cultivated soil (Table 4.14) could be related to the negative effect of long term cultivation through the soil structural degradation as well as a decrease in soil aggregate stability (Sparling et al., 1992; Saggar et al., 1998). This is also supported by Baldock and Kay (1987) who found that 15 years continuous maize crop reduced wet aggregate stability compared to 15 years of brome-grass.

Table 4.13 PM response to the maize yield in the pasture and cultivated soils without N.

Treatments	With PM addition (g/pot)	Without PM addition (g/pot)	PM response (%)
34 years cultivated soil	37	103	178
Pasture soil	71	148	109

Addition of PM and N fertiliser in the cultivated soil increased dry matter yield (Table 4.14). This is probably due to a large amount of mineral N in the PM which could increase the mineralisable N in the soil. Thus, N response was low in the cultivated soil compared to the pasture soil (Table 4.14).

Table 4.14 The 200 N level response to the maize yield in the pasture and cultivated soils.

Soil treatments	DM yield without N (g/pot)	Maximum DM yield (at 200 N level) (g/pot)	N response (%)
34 years cultivated soil + PM + N fertiliser	103	155	51
Pasture soil + N fertiliser	71	135	90

It is well known that many long-term cultivated soils contain very low soil organic matter and have poor soil structure. Experiment I showed that the maize yield in the 34 years cultivated soil was very low compared to the pasture soil. Experiment II clearly indicated that PM addition in the cultivated soil could help improve soil properties, such as soil organic matter and soil structure. The experiment II showed that the addition of PM increased the mineral N, total N and total C, soil pH (Table 4.7), soil structure (Plate 3), and soil water holding capacity. After application of PM in Experiment II, the maize yields reached closer and even higher than in the pasture soil without PM addition. This clearly indicates that PM addition helps the soil to be more productive, and enhance the soil microorganism activity through the increased soil nutrients and thereby increased the maize yield. It is supported by Mahimairaja (1993) who found that the organic matter in the manure could replenish the supply of humus and improve the physical properties of soils.

The result showed that there was a positive response of maize crop to the addition of PM especially with the addition of 200-kg N/ha, which increased N uptake and dry matter yield (Tables 4.1 and 4.9).

Over all, PM addition clearly showed that there was a highly positive response in maize growth due to increased soil nutrients, especially N available for plant growth. About 35 % of total N from poultry manure is available for the plant (Chambers et al., 1996). Lande Cremer (1985) observed that 65 % of the plant requirements from PM was observed in the first year, which then increased to 76 % in the second year because of the residual effect (Lande Cremer, 1985).

The present study showed that the addition of 4 tonnes of poultry manure with 200 kg N /ha in 34 years maize cultivated soil gave a similar yield to pasture soil with 300 kg N/ha without PM addition. Chambers et al. (1996) mentioned that poultry manure N application at rates < 400 kg /ha total N had no significant effect on soil mineral N supply or yield of following cereal crops. The findings of this experiment indicate that PM addition of 4 tons/ha and 200 kg N/ha to cultivated soil may have a wider applicability in increasing the N soil availability and soil structure improvement.

4.4.3.3. The effect of poultry manure on soil physical properties:

The measurement of ODR values in this experiment clearly demonstrated that the addition PM as an organic amendment improved the soil physical properties, such as soil structure. Other researchers have also found that the addition organic amendments, such as sewage sludge, PM, and farm yard manure helps to improve the physical condition of the soils (Table 4.15).

Table 4.15 Effect of organic amendments on physical properties of the soils.

Organic Amendment	Level	Improvement in soil physical condition	Reference
Composted sewage sludge	50 t/ha	Ameliorating the compacted soil, increased soil pH.	Weir and Allen (1997)
Farm yard manure	10 t/ha	Reduced bulk density, improved infiltration, reduced soil strength	Reddy (1991)
Organic amendments mixed with sand soil	70 : 30 mixed	Decreased bulk density, increased soil pH from 4.6-6.6/8.4	Cook and Baker (1998)
Farm yard manure + Urea	20 t/ha + 60 kg N/ha	Reduced bulk density	Aggrawal et al. (1995)
Poultry manure	10 t/ha	Decreased bulk density, increased total porosity and hydraulic conductivity, increased field capacity	Kimpre (1984)
Organic amendments (peat or manure)	10 t/ha	Bulk density decreased 9 %.	Laverdiere and Kimpe (1984)
Sewage sludge	96 t/ha	Reduced potential acidity	Favaretto et al. (1997)
Sewage sludge compost and beef cattle manure	33 t/ha	Reduced bulk density, increased soil water content, modified pH soil to greater depth	Tester (1990)

Organic Amendment	Level	Improvement in soil physical condition	Reference
Sludge	22.4 t/ha	Decreased bulk density, improved soil permeability, increased aggregate stability, increased moisture content	Wei et al. (1985)
Sewage sludge	150-300 t/ha	Increased soil pH, decreased bulk density	Darmody et al. (1983)
Digested sludge	19 t/ha	Increased soil water holding capacity	Hall and Coker (1982)
Sewage sludge + limestone	225 t/ha and 45 t/ha	Decreased Bulk density, increased retention of water, improved physical properties of the soil	Joost et al. (1981)
Anaerobic digested sewage sludge	22.5 t/ha	Reduced bulk density	Sposito et al. (1982)
Waste water sludge	56 t/ha	Increased of water stable aggregate, large pore space, decreased bulk density	Kladivko and Nelson (1979)

In New Zealand, under arable cropping soil structural degradation is caused by excessive repeated cultivation resulting in soil compaction. In the Manawatu region, soils with poor structure are more susceptible to compaction. Compacted soils are more susceptible to water logging and runoff, less well aerated and more difficult to cultivate (Young and McNeill, 1999). Soil loss from Manawatu cropland through soil erosion in 1999 was almost 1.1 mm/year (Table 4.15).

Table 4.16 Soil loss from the Manawatu Region (Young and McNeill, 1999).

Site soil type	Cropping history	Average soil loss	Soil lost (mm/year cropped)
1. Manawatu silt loam	16 years in maize	1.7 cm	1.1 mm
2. Kairanga silty loam	23 years in barley then 3 years in maize	2.3 cm	0.9 mm
3. Kairanga silty clay loam	11 years in maize	1.2 cm	1.1 mm

To improve poor soil structure, one approach to land use that is based on principles of sustainable cropping, pastoral and horticultural production is organic farming, which is gaining momentum in New Zealand. The organic farming standards are based on:

1. Sustaining natural processes of nutrient cycling.
2. Soil structure is maintained through regular input of organic matter.
3. Biodiversity of habitats, and species is used as a tool of pro active land management.

Even though the use of organic manure has shown to be successful in maintaining good soil structure, further research is required to identify the most efficient organic amendments to improve the soil physical conditions. This experiment has found that poultry manure could be used both as a nutrient source and organic amendment to improve the soil physical conditions.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS:

- The review of literature indicated that continuous cultivation of arable soils is likely to enhance structural degradation and nutrient depletion of soils. It also decreases soil organic matter and soil nitrogen availability.

- In the Manawatu region, it has often been observed that maize crop grown on soils that have undergone continuous cultivation for a long period tends to produce less grain yield than when it is grown on a pasture soil.

- It is important that factors contributing to the yield decline in cultivated soil need to be examined in detail so that appropriate management strategies could be devised to overcome or minimize this effect.

- Two glasshouse experiments were conducted to examine (i) the effect of cultivation on N response in maize (Experiment I) and (ii) the effect of poultry manure addition on growth response (Experiment II).

- Experiment I indicated that there was a decrease in the dry matter yield of maize with increasing period of cultivation. The highest dry matter yield was observed in the pasture soil, which was attributed to high mineral N, soil nutrients, and good soil physical conditions.

- The dry matter yield increased with increasing levels of N up to 300 kg N/ha. However, the dry matter yield of maize in the cultivated soils did not reach that of the pasture soil even at the highest levels of N addition. This indicates that the dry matter yield in the cultivated soils was not limited only by nitrogen availability.

- The dry matter yield of maize decreased at high levels of N (> 300 kg /ha) which may be related to salt injury and /or nitrate toxicity.

- It was concluded that the difference in dry matter yield between the soils is related to the difference in the physical conditions between the soils. Therefore, Experiment II was conducted to examine the effect of poultry manure on the response of maize to N fertiliser addition. It was hypothesised that addition of PM to the cultivated soils improves the physical condition of the soil.

- The review of literature indicated that the addition of organic amendments, such as PM to soils provides organic matter and plant nutrients and thereby improves soil structure.

- Addition of poultry manure inhibited the growth of maize seedlings in the early stages and the effect was more pronounced in the pasture soil. The inhibition of seedling growth was attributed to ammonia toxicity resulting from excessive poultry manure application.

- The oxygen diffusion rate (ODR) values were higher for the pasture soil than the cultivated soil. This indicates that the former soil contains greater pore space resulting from good soil structural conditions.

- Soon after the addition of poultry manure, the ODR values decreased both in the pasture and the cultivated soils and the effect was more pronounced in the cultivated soil. The decrease in ODR values with poultry manure addition is attributed to the release of ammonia and carbon dioxide during the decomposition of poultry manure.

- The decrease in ODR values affected the seed germination. The dry weight of seedlings (19 days after sowing) in the pasture and the cultivated soils decreased due to the addition of poultry manure. This probably related to high ammonium concentrations in the soil. However, at later stage, the seedlings in the poultry manure treatments grew faster than the treatments without poultry manure for the pasture and the cultivated soils.

- The ODR values measured at later stages indicated that the addition of poultry manure increased the ODR values in both soils. This was probably related to the increase in the activity of soil microorganisms activities. This also indicated that the addition of poultry manure improved the soil structure.

- In the absence of poultry manure addition the dry matter yield for the cultivated soil was less than the permanent pasture soil, and in the presence of poultry manure the dry matter yield for the cultivated soil reached close to that of permanent pasture soil.

- Addition of poultry manure to the cultivated soil improved the soil structure and increased the nutrient content.

- The increase in dry matter yield due to poultry manure addition in the cultivated soil clearly demonstrated that the impact of cultivation on maize yield was partly attributed to its effect of soil physical conditions. It is possible to improve the physical conditions of the soil through the addition of soil amendments rich in organic matter.

REFERENCES

Addiscott, T.M. and Dexter, A.R. 1994. Tillage and crop residue management effect on losses of chemicals from soils. Soil and Tillage Research **30**, 125-168.

Aggrawal, G.C. Sidhu, A.S., Sekhon, N.K., Sandhu, K. S. and Sur, H.S. 1995. Puddling and N management effects on crop response in a rice wheat cropping system. Soil and Tillage Research **36**, 129-139.

Aslam, T., Choudhary, M.A. and Saggar, S. 1999. Tillage impacts on soil microbial biomass C, N, and P, earthworms, and agronomy after two years of cropping following permanent pasture in New Zealand. Soil and Tillage Research **50**, 103-111.

Aslam, T., Choudhary, M.A. and Saggar, S. 2000. Influence of land-use management on CO_2 emissions from a silt loam soil in New Zealand. Agriculture, Ecosystems and Environment **77**, 257-262.

Bakken, R., Borreson, T. and Njos, A. 1987. Effect of soil compaction by tractor traffic on soil moisture, denitrification, and yield of wheat. Journal of Soil Science **38**, 541-552.

Baldock, B.O., Higgs, R.L., Paulson, W.H., Jackobs, J.A. and Shrader, W.D. 1981. Legume and mineral fertiliser effects on crop yields in several crop sequences in the upper Missisipi Valley. Agronomy Journal **73**, 885-890.

Baldock, J.A., Kay, B.D. and Schitzer, M. 1987. Influence of cropping treatments on the monosacharide content of the hydrolysates of a soil its aggregate fractions. Canadian Journal of Soil Science **67**, 489-499.

Ball, B.C., Campbell, D.J., Henshall, J.K. and Sullivan, M.F.O. 1997. Soil structural quality, compaction and land management. European Journal of Soil Science **48,** 593-601.

Ball, B.C., Glasbey, C.A. and Robertson, E.A.G. 1994. Measurement of soil gas diffusivity in situ. European Journal of Soil Science **45**, 3-13.

Bansal, R.K. and Eagles. H. A. 1985. History and present status of maize production in New Zealand. *In*: Maize Management to Market (Eds. H.A. Eagles and G.S. Wartt). pp. 3-6. Agronomy Society of New Zealand, No. 4.

Barber, S.A. 1972. Relation of weather to the influence of hay crops on subsequent corn yields on a Chalmers Silt Loam. Agronomy Journal **64,** 8-10.

Barrow, N.J. 1957. Renovation of phalaris pastures with special reference to nitrogen and sulphur relationship. Australian Journal of Agriculture Research **8**, 617-634.

Berger, J. 1962. History and origin of maize. *In:* Maize Production and the Manuring of Maize. (Centre d'Etude de L'Azote, Geneva. pp 11-92.

Blair, G.J, Conteh, A. and Lefroy, R.D.B. 1994. Fate of organic matter and nutrients in Upland Agricultural Systems. Department of Agronomy and Soil Science, University of New England, Armidale, NSW 2351, Australia.

Broadbent, F.E. 1989. Variables affecting a values as a measure of soil nitrogen availability. Journal of Soil Science **110,** 19-23.

Bruce, R.R., Lang dale, G.W. and Dillard, A.L. 1990. Tillage and rotation effect on characteristics of a sandy surface soil. Soil Science Society of America Journal **54,** 1744-1747.

Buckman, 0.H and Brady. N.C. 1969. Nature and Properties of Soils. Macmillan, New York.

Campbell, C.A., Biederbeck, V.O., Zentner, R.P. and Lafond, G.P. 1991. Effects of crop rotations and cultural practices on soil organic matter, Microbial Biomass and Respiration in a Thin Black Chernozem. Canadian Journal of Soil Science **71**, 363-376.

Cannell, R.Q. and Jackson, M.B. 1988. Alleviating aeration stresses. *In:* Modifying the Root Environment to Reduce Crop Stress (Eds. A.F. Arkin and H.M. Taylor). American Society of Agricultural Engineering Monograp **4**,141-192.

Carefoot, J.M., Nyborg, M. and Lindwall, C.W. 1990a. Tillage induced soil changes and related grain yield in a semi-arid region. Canadian Journal of Soil Science **70**, 203-214.

Carefoot, J.M., Nyborg, M. and Lindwall, C.W. 1990b. Differential fertilizer N immobilization in two tillage systems influences grain N concentration. Canadian Journal of Soil Science **70,** 215-225.

Carter, M.R. 1986. Microbial biomass as an index for tillage induced changed in soil biological properties. Soil and Tillage Research **7,** 29-40.

Carter, M.R. and White, R.P. 1986. Determination of variability in soil physical properties and microbial biomass under continuous direct planted corn. Canadian Journal of Soil Science **66,** 757-750.

Catroux, G. and Schitzer, M. 1987. Chemical, spectroscopic and biological characteristics of the organic matter in particle size fractions separated from a quoll. Soil Science Society of America Journal **51**, 1200-1207.

Chae, Y.K. and Tabatabai, M.A. 1985. Mineralisation of nitrogen in soils amended with organic waste. Journal of Environmental Quality **15**, 193-198.

Chambers, B.K., Smith, K.A. and Williams, J.R. 1996. Residual effects of poultry manure and fertiliser nitrogen applications. ADAS Arable Research Centre, UK.

Charles, D.S., Bair, J.V. 1982. Soils and Soil Management. Second edition. Reston Publishing company, Inc. Reston, Virginia.

Charles, F., Yamoah., G.E.V., William, J., Wattman., and Francis, A. 1998. Long term nitrogen use and nitrogen removal index in continuous crops and rotations. Field Crops Research **57**, 15-27.

Clark, R.N., Hudspeth, E.B. 1976. Runoff control for summer crop production in the Southern Plains. Paper No. 76-2008. American Society of Agricultural Engineering St. Joseph, MI.

Clement, C.R. and Williams, W.E. 1967. Leys and soil organic matter. II. The accumulation of nitrogen in soils under different leys. Journal of Agricultural Science **69**, 133-138.

Cook, A. and Baker, S.M. 1998. Effects of organic amendments on selected physical and chemical properties of root zones for golf greens. Journal of Turfgrass Science **74**, 2-10.

Cooke, G.W. 1976. A review of the effects of agriculture on the chemical composition and quality of surface and underground waters. *In:* Agriculture and Water Quality. MAF Technical Bulletin **32**, 5-57.

Cortelline, L. Toderi, G., Baldoni, G. and Nassisi, A. 1996. Effects on the content of organic matter, nitrogen, phosphorous and heavy metals in soil and plants after application of compost and sewage sludge. *In*: The Science of composting, Part 1. Blackie Academic and Professional, Glasgow, UK.

Cothing, W.E. Allbrook, R.F. and Gibbs, H.S. 1979. Influence of maize cropping on the soil structure of two soils in the Waikato district, New Zealand Journal of Agricultural Research **22**, 431-438.

Dalal, R.C. and Maye, R.J. 1986. Long term trends in fertility of soils under continuous cultivation and cereal cropping in Southern Queensland. 1. Overall changes in soil properties and trends in winter cereal yields. Australian Journal of Soil Research **24**, 265-279.

Darmody, R.G., Foss, J.E., McIntosh, M., Wolf, D.C. 1983. Municipal sewage sludge compost amended soils: some spatio-temporal treatment effects. Journal of Environmental Quality **12,** 231-236.

Das, M., Singh, B. P., Ram, M. and Prasad, R. N. 1991. Response of maize to phosphorus-enriched manures grown in P deficient Alfisols on terraced land in Meghalaya. Indian Journal of Agricultural Sciences **61**, 383-388.

Dick, W.A. 1983. Organic carbon, nitrogen, and phosphorus concentrations and pH in soil profiles as affected by tillage intensity. Soil Science Society of America Journal **47,** 102-200.

Dick, W.A., Edwards, W.F. and McCoy, E.L. 1997. Continuous application of no-tillage to Ohio soils; changes in crop yields and organic matter related soil properties. *In*; Soil Organic Matter in Temperate Agroecosystems: (Ed. E.A. Paul) pp. 171-182. CRC Press. Boca Raton, Florida.

Dick, W.A., Edwards, W.M., Stehouwer, R.C. and Echer, D.J. 1992. Maize yield and nitrogen uptake after established no-tillage fields are plowed. Soil and Tillage Research **24,** 1-10.

Dick,W.A. and Daniel, T.C. 1997. Soil chemical and biological properties as affected by conservation tillage: Environmental Implications. *In:* Effects of Conservation Tillage on Ground Water Quality.(Eds. T.J. Logan, J.M. Davidson, J.L. Baker, and M.R. Overcash). pp. 125-147.

Doran, J.W. 1980. Soil microbial and chemical changes associated with reduced tillage. Soil Science Society of America Journal **44,** 765-771.

Doran, J.W. and Power, J.F. 1983. The effects of tillage on the nitrogen cycle in corn and wheat production. *In*: Nutrient cycling in agricultural ecosystems (Eds. R.R. Lowrence, R.L. Todd., L.E. Asmussen, and R.A. Leonard). 441-455. University of Georgia.

Ekwue, E.I. and Stone, R.J. 1995. Organic matter effects on the strength properties of compacted agricultural soils Transactions of the ASAE **38**, 357-365.

Elliot, E.T. 1986. Aggregates structure and C, N, and P in native and cultivated soils. Soil Science Society of America Journal **50**, 627-633.

Faasen, H. G. and Dijk, H. van. 1987. Manure as a source of nitrogen and phosphorus in soils. *In:* animal manure on grassland and fodder crops: fertiliser or wastes (Eds. H.G. van der. Meer., R. J. Unwin., van. T. A Dijk, and G. C. Ennik,). pp. 27- 45. Nijhoft publishers, Dordrecht:

Fauci, M. F. and Dick, R.P. 1994. Soil microbial dynamics; short- and long term effects of inorganic and organic nitrogen. Soil Science Society of America Journal **58**, 801-806.

Favaretto, N., Deschamps, C., Daros, E. and Pissaia, A. 1997. Effects of sewage sludge on soil fertility and on growth and yield of maize. Arquivos de Biologia e Tecnologia **40**, 837-848.

Francis, G.S., Tabley, F.J. and White, K.M. 1999. Restorative crops for the amelioration of degraded soil conditions in New Zealand. New Zealand Institute for Crop and Food Research. Journal of Soil Research **37,** 1017-34.

Francis, J. L., Bremer, E., Janzen, H.H., Johnston, A.M. and Lindwall, C.W. 1997. Changes in total, mineralisable and light fraction soil organic matter with cropping and tillage intensities in semiarid southern Alberta, Canada. Soil Tillage Research Journal **42,** 229-240.

Frederick, R.T. and Thompson, L. M. 1993. Soils and Soil Management. College of Agriculture Iowa State University, New York, Oxford University Press.

Gary, W. L. and Doran, J. W. 1997. Crop rotation, manure and agricultural chemical effects on dryland crop yield and soil organic matter over 16 Years in Eastern Nebraska. *In:* Soil Organic Matter in Temperate Agroecosystems. pp. 7-204. CRC Press, Boca Raton, Florida.

Gijsman, A.J. and Sanz, J.I. 1998. Soil organic matter pools in a volcanic- ash under fallow or cultivation. European Journal of Soil Science **49**, 427-436.

Giralt, E. 1987. Performance of the root system of maize with three sowing dates and with or without irrigation. Inst. Investigacious de Riego, Cuba. Agrotecnia de Cuba **19**, 95-101.

Glinski, J. and Lipiec, J. 1990. Soil Physical Conditions and Plant Roots. CRC Press Boca Raton. Florida.

Glinski,J. and Stephanie, W. 1985. Soil Aeration and its Rate for Plants. CRC Pres, Boca Raton, Florida.

Goh, K.M. and Haynes, R.J. 1986. Nitrogen and agronomic practice. *In:* Mineral Nitrogen in the Plant -Soil System (Eds. R. J. Haynes, K.C. Cameron, K.M. Goh and R.R. Sherlock). Academic Press, Inc.

Griffith, D.R. Kladivko, E.J. Mannering, J.V. West, T.D. and Parsons, S.D. 1988. Long-term tillage and rotation effects on corn growth and yield on high and low organic matter, poorly drained soils. Journal of Agronomy **80,** 599-605.

Gupta, V.V.S.R. and Germida, J.J. 1988. Distribution of microbial biomass and its activity in different soil aggregate size classes as affected by cultivation. Soil Biology and Biochemistry **20**, 777-786.

Hadas, A., Bar-Yosef, B., Davidov, S. and Sofer, M. 1983. Effect of pelleting, temperature and soil type on mineral nitrogen release from poultry and dairy manures. Soil Science Society of America Journal **47,** 1129-1133.

Hall, J.E. and Coker, E.G. 1982. Some effects of sewage sludge on soil physical conditions and plant growth. The influence of sewage sludge application on physical and biological properties of soils. (Eds.G. Catroux, P. L'Hermite, and E. Suess). Proceedings of a seminar organized jointly by the Commission of the European Communities, Directorate-General for Science, Research, and Development and the Bayerische Landesanstalt für Bodenkultur und Pflanzenbau, Munich, Federal Republic of Germany, held in Munich, June 23-24, 1981. pp. 43-60.

Hanway, J.J. 1962. Corn growth and composition in relation to soil fertility. I. Growth of different plants parts and relation between leaf weight and grain yield. Agronomy Journal **54,** 143-146.

Hardacre, A.K., Nicholson, H.F. and Boyle, M.L.P. 1984. A potbale photometer for the measurement of chlorophyll in intact leaves. New Zealand Journal of Experimental Agriculture **12**, 257-362.

Harris, R.F., Allen, O,N., Chesters, G. and Attoe, O.J. 1963. Evaluation of microbial activity in soil aggregate utilisation and degradation by the use of artificial aggregates. Soil Science Society of America Journal **27,** 542-545.

Hart, P.B.S., August, J.A., Ross, C.W. and Julian, J.F. 1988. Some biochemical and physical properties of Tokomaru Silt Loam under pasture and after 10 years of cereal cropping. New Zealand Journal of Agriculture **31**, 77-86.

Haslett, S (Ed.). 1997. Massey University Block Course on Experimental Design for Researchers. Department of Statistics of Information and Mathematical Sciencies, Massey University, Palmerston North, New Zealand.

Haynes, R. J., Cameron. K.C., Goh. K.M. and Sherlock. R.R. (Eds.). 1986. Mineral Nitrogen in the Plant-Soil System. Academic Press, Inc.

Haynes, R.H. 1999. Size and activity of the soil microbial biomass under grass arable management. Biology and Fertility of Soils **30**, 210-216.

Haynes, R.J. and Beare, M.H. 1996. Aggregation on organic matter storage in meso-thermal, humid soils. *In:* Structure and Organic Matter Storage in Agricultural Soils (Eds: M.R. Carter and B.K. Stewart). pp. 213 –62. Lewis Publisher, Boca Raton, Florida.

Haynes, R.J. and Beare, M.H. 1997. Influence of six crops species on aggregate stability and some labile organic matter fractions. Soil Biology and Biochemistry **29**, 1647-53.

Haynes, R.J. and Francis, G.S. 1990. Effects of mixed cropping farming systems on changes in soil properties on the Canterbury Plains. New Zealand Journal of Ecology **14**, 73-82.

Haynes, R.J. and Francis, G.S. 1991. Towards sustainable cropping rotations. *In:* Proceedings of the International Conference on Sustainable Land Management, Napier, Hawke's Bay, New Zealand. (Ed. Henriques). pp. 134-140. Hawke's Bay Regional Council, Napier.

Haynes, R.J. and Francis, G.S. 1993. Changes in microbial biomass C, soil carbohydrate composition and aggregate stability induced by growth of selected crop and forage species under field conditions. Journal of Soil Science **44**, 665-75.

Haynes, R.J. and R.S, Swift. 1990. Stability of soil aggregates in relation to organic constituents and soil water content. Journal of Soil Science **41**, 73-83.

Haynes, R.J., R.S, Swift. and Stephen, R.C. 1990. Influnce of mixed cropping rotations pasture arable on organic matter content, water stable aggregation and clod porosity in a group of soils. Journal of Soil and Tillage Research **19**, 77-87.

Hedley, M.J. and Turner, M.A. 1997. Soil Fertility and Fertilisers. 89.251 Course Notes. Department of Soil Science, Massey University. New Zealand.

Hesterman, O.B., Griffin, T.S., Williams, P.T., Harris, G.H. and Christenson, D.R. 1992. Forage legume-small grain intercrops: nitrogen production and response of subsequent corn. Journal of Production and Agriculture **5**, 340-348.

Hilfiker, R.E. and Lowery, B. 1988. Effect of conservation tillage systems on corn root growth. Soil and Tillage Research **12**, 269-283.

Hoglund, J.H., Crush, J.R., Brock, J.L. and Ball, R. 1979. Nitrogen fixation in pasture. XII General discussion. New Zealand Journal of Experiment Agriculture 7, 45-51.

Holderbaum, J.F., Decker, A.M., Meisinger, J.J., Mulford, F.R. and Vough, L.R. 1990. Fall seeded legume cover crops for no-tillage corn in the humid East. Agronomy Journal **82**, 117-124.

Honeycutt, C.W., Potaro, L.J. and Haltemann, W.A. 1991. Predicting nitrate formation from soil, fertiliser, crop residue and sludge with thermal units. Journal of Environmental Quality **20**, 850-856.

Hornick, S.B. 1998. Use of organic amendments to increase the productivity of sand and gravel spoils: effect on yields and composition of sweet corn **3,** 156-162.

Huntjens, J.L.M. 1971. The influences of living plants on mineralisation and immobilisation of nitrogen. Journal of Plant and Soil. **35**, 77-94.

James, A.T., Beverly, R.B. and Radcliffe, D.E. 1991. Mulch effect on soil properties and tomato growth using micro irrigation. Agronomy Journal **83**, 1028-1034.

James, R,S. and Joe, M.B. 1997. Conservation tillage corn production for a semiarid subtropical environment. Agronomy Journal **91**, 116-121.

Jhon, A, S., Daryl, D., Buchholz, R., Hanson, G., Nyle, C. and Kent, A, M. 1995. Tillage and rotation effects on corn yield response to fertiliser N on Aqual soils. Agronomy Journal **87**, 409-415.

John, R. W (Ed.). 1978. Plant Relations in Pastures. Commemwealth Scientific and Industrial Research Organization. Australia.

Joost, R.E., Jones, J. H. and Olsen, F.J. 1981. Physical and chemical properties of coal refuse as affected by deep incorporation of sewage sludge and limestone. Proceeding, on Surface Mining Hydrology, Sedimentology and Reclamation. University of Kentucky, USA, 307-312.

Juma, N.G., Izaurralde, R.C., Robertson, J.A. and McGill, W.B. 1997. Crop yield and soil organic matter trends over 60 years in a Typic Cryoboralf at Breton, Alberta. *In:* Soil Organic Matter in Temperate Agroecosystems: long-term Experiments in North America (Ed. E.A. Paul). pp 273. CRC Press, Boca Raton, Florida.

Karl, G., Gary, F.G., Derek, W.A., William, R.Y., Moosa, M.R. and Stephen, W.P. 1995. Nitrogen utilization of selected cropping systems in the U.S. Northeast: II. Soil profile nitrate distribution and accumulation. Agronomy Journal **87**, 199-207.

Kaspar, T.C., Brown, H.J. and Kassmeyer, E.M.1991. Corn root distribution as affected by tillage wheel traffic and fertiliser placement. Soil Science Society of America Journal **55,** 1390-1394.

Khaleel, R., Reddy, K.R. and Overcash, M,R. 1981. Changes in soil physical properties due to organic waste applications: a review. Journal of Environmental Quality **10**, 133-141.

Kimpe, C.R. de. 1984. Change of dry bulk density and K after incubation of a soil in the presence of organic amendments. Communications in Soil Science and Plant Analysis **15**, 787-798.

Kladivko, E.J. and Nelson, D.W. 1979. Changes in soil properties from application of anaerobic sludge. Journal of Water Pollution Control Federation **51**, 325-332.

Kolenbrander, G.J. 1969. Nitrate content and nitrogen loss in drain water. Netherlands Journal of Agricultural Science **17**, 246-255.

Lal, R. 1986. Effect of eight tillage treatments on a tropical alfisol: maize growth and yield. Journal of the Science of Food and Agriculture **37**, 1073-1082.

Lal, R., Logan, T.J. and Fausey, N.R. 1989. Long-term tillage and wheel traffic effects on a poorly drained Mollic Ochraqualf in Nortwest Ohio: I Soil physical properties, root distribution and grain yield of corn and soybean. Soil and Tillage Research **14**, 341-358.

Lande Cremer, L.C.N. 1985. Long term effects of farm slurry applications in the Netherlands. *In*: Long Term Effects of Sewage Sludge and Farm Slurry Applications (Eds. J.H. Williams, G. Guidi, and P. L'Hermite). pp. 84-90. Elsevier Applied Science Publishers. New York, USA

Landina, M.M. and Klenvenskaya, I.L. 1984. Effect of soil compaction and moisture content on biological activity, nitrogen fixation, and compaction of soil air. Soviet Soil Science **16**, 46-54.

Laverdiere, M. R. and Kimpe, C.R.de. 1984. Agronomic use of clay soils from Abitibi, Quebec: 2. Effects of organic amendments and cultivation on crop production. Soil Science **137**, 128-133.

Lefroy, R.D.B., Blair, G.J. and Craswell, E.T. (Eds.). 1995. Role of Soil Organic Matter in Sustainable Agricultural System. Soil Organic Matter Management for Sustainable agriculture. A workshop held in Ubon, Thailand, 24-26 August, 1994. Australian Centre for International Agricultural Research. Canberra.

Liang, J., Zhang, J. and Wong, M.H. 1996. Effects of air filled soil porosity and aeration on the initiation and growth of secondary roots of maize. Plant and Soil **186**, 245-254.

Liepiec, J. and Simota, J. 1994. Role of soil climate factors influencing crop responses to compaction in central and Eastern Europe. *In:* Soil Compaction in Crop Production (Eds: B.D. Soane. and C. van, Ouwerker) pp. 365-390. Elsevier, Amsterdam.

Liepiec, J. and W. Stephiewski. 1995. Effects of soil compaction and tillage system on uptake and losses of nutrients. Soil and Tillage Research **35**, 37-52.

Liepiec, J., Szustak, A., Szatanik-Kloc, A. and Ksiezopolska, A. 1994. Effect of soil compaction on the growth and nutrient uptake of barley and maize. *In:* Soil Tillage for Crop Production and Protection of the Environment. Proceeding. 13 th. Cont. int. Soil Tillage Research Organisation (ISTRO) 24-29 July 1994, Denmark, 683-689.

Lipiec, J., Hakansson, I., Tarkiewics, S. and Kossowski, J. 1991. Soil physical properties and growth of spring barley related to the degree of compactness of two soils. Soil and Tillage Research **19**, 307-317.

Loll, M. J. and Bollag, J.M. 1983. Protein transformation in soil. Advance in Agronomy **36**, 351-382.

Lyon, D.J., Monz., C.A., Brown, R.E. and Metherell, Aik. 1997. Soil organic matter changes over two decades of winter wheat-fallow cropping in Western Nebraska. *In:*

Soil Organic matter in Temperate Agroecosystems: Long Term Experiments in North America. (Ed. E.A Paul) CRC Press. Boca Raton, Florida.

Madhavi, B. L., Reddy, M. S. and Rao, P. C. 1995. Integrated nutrient management using poultry manure and fertilisers for maize. Indian Journal of Research Apu **23**, 1-4.

Madhavi, B.L., Reddy, M.S. and Reddy, B.G. 1996. Effect of poultry manure and fertiliser on yield and micronutrients uptake by maize. Dept of soil science and agricultural chemistry, College of Agriculture, Rajendranagar, India. Journal of research Apu **24**, 154-156.

Mahimairaja, S. 1993. An investigation of composting poultry manure in relation to nitrogen conservation and phosphate rock dissolution. PhD. thesis. Massey University. Palmerston, New Zealand.

Mahimairaja, S., Bolan, N. S. and Hedley, M. J. 1995. Agronomic effectiveness of poultry manure composts. Communications in Soil Science and Plant Analysis **26**, 1843-1861.

McFarland, M.L., Hous, F.M. and Saladiko, V.A. 1991. Effects of furrow diking and tillage on corn grain yield and nitrogen accumulation. Agronomy Journal **83**, 382-386.

McKenzie, H.A. and Wallace, H.S. 1954. The Kjeldhal determination of nitrogen: A critical study of digestion conditions-temperature, catalyst, and oxidising agent. Australian Journal of Chemistry **7**, 55-70.

McLaren, R.G. and Cameron, K.C. 1996. Soil Science: Sustainable Production and Environmental Protection. Oxford University Press, New Zealand.

Middleton. 1977. A revised version of plant and soil **38**, 129 (1973). Plant nutrition group.

Mohammedreza, G., Fernado, G.P. and Richard, M.C. 1997. Tillage effect on soil water content and corn yield in a trip in a strip intercropping system. Agronomy Journal **89**, 893-899.

Moraru, G., Nicolae, H. and Visinc, I. 1986. Irrigation regime of the principal crops in South Easth Baragan. Romania Productiva Vegetala Cereale Si Plante Tehnice **38**, 7, 34-43.

Mukhtar, S., Baker, J. L. and Kanwar, R. S. 1990. Soil aeration as affected by excess water. Proceedings of the International Agricultural Engineering Conference and Exhibition. Volume III Soil and Water Engineering. Asian Institute of Technology, Bangkok, Thailand. 859-868.

Nafzinger, E.D., Mulvaney, R.L., Mulvaney, D.L. and Paul, L.E. 1984. Effect of previous crop on the response of corn to fertilizer nitrogen. Journal of Fertilizer Issues CAB abstract.

Nishiwaki, K. and Noue, T.I. 1996. The effect of animal manure compost applications on reducing the leaching of soil nutrients from mineral soils of vegetable upland fields. Research Bulletin of the Aichi-Ken Agricultural Research Center **28**, 171-176.

O'Dell, B.L., Woods, W.D., Lacrdal, O.A., Jeffay, A.M. and Savage, J.F. 1960. Distribution of the major nitrogenous compounds and amino acids in chicken urine. Poultry Science **39**, 426-432.

O'Hallorans, J.M., Munaz, M.A. and Marquez, P.E. 1997. Chicken manure as an amendment to correct soil acidity and fertility. Journal of Agriculture of the University of Puerto Rico. **81**, 1-8.

Oades, J.M. 1984. Soil organic matter and structural stability: mechanism and implications for management. Plant and Soil **76**, 319-337.

Obi, M.E. and Ebo, P.O. 1995. The effects of organic and inorganic amendments on soil physical properties and maize production in a severely degraded sandy soil in southern Nigeria. Bio-resource Technology **51**, 2-3, 117-123.

Ordie, R.J., Bobby, A.S. and Paul.W.U. 1986. Management of dry-farmed Southern Great Plains Soils for Sustained Productivity. *In*: Soil Organic Matter in Temperate Agroecosystems. (Ed. E.A. Paul) CRC Press, Boca Raton, Florida.

Otani, T., Sato, M., Kawashima, S., Yoshiba, M. and Awaya, K. 1982. Studies on the growth of forage crops with application of fresh domestic animal wastes to soils. 5. Growth of dent maize and nitrate nitrogen level in the plant tissue with tillage using different implements. Journal of Agricultural Science **27**, 124-131.

Pearson, A.J., Spiers, T. M. and Cant, G. 1998. Crop uptake of nitrogen, phosphorus and potassium from soil amended with chicken manure and green waste compost. Annual Conference-Agronomy Society of New Zealand **28**, 31-34.

Peters, S.E., Wander, M.M., Saparito, L.S., Harris, G.H. and Friedman, D.B. 1997. Management impacts on soil organic matter and related soil properties in long term farming systems trial in Pennsylvania. 1981-91 *In:* Soil Organic Matter In Temperate Agroecosystems. (Ed. E.A. Paul). CRC Press. Boca Raton, Florida.

Pinzariu, D. and Toniuc, I. A. 1987. Influence of some phytotechnical parameters on the yields of maize in on irrigated system. Cercetari Agronomice in Moldova **20**, 97-104.

Power, J.F. and Broadbent, F. E. 1989. Proper accounting for N in cropping systems. P. 160-182. *In*: Nitrogen management and groundwater protection. (Ed. R.F. Follet). Elsevier Science Publ. Co. New York.

Raimbault, B.A. and Vyn, T.J. 1991. Crop rotation and tillage effects on corn growth and soil structural stability. Agronomy Journal. **83**, 979-985.

Rajeev, S. and Singh, R. K. 1998. Effect of calcium peroxide application on oxygen diffusion rate and growth of maize under different soil moisture regimes. Journal of Research, Birs. Agricultural University **10**, 2, 193-196.

Rasmussen, P.E. and Collins, H.P. 1991. Long-term impacts of tillage, fertiliser, and crop residue on soil organic matter in temperate semiarid regions. Advances in Agronomy **45**, 93-134.

Reddy, M. S. 1991. Effects of soil amendments on the hardening of red sandy loams of Andhra Pradesh. Annals of Agricultural Research **12**, 2, 174-176.

Rice, C.W. and Smith, M.S. 1984. Denitrification in no tillage and plowed soils. Soil Science Society of America Journal **46**, 1168-1173.

Russelle, M.P., Hesterman, O.B., Sheapper, C.C. and Heichel, G.H. 1987. Estimating nitrogen and rotation effects in legume corn rotations. *In*: The Role of Legumes in Conservation Tillage Systems. (Ed. J.F. Power). 41-42. Proc. Natl. Conference. University of Georgia. Athens. Soil Conservation Society. American. Anheny.

Ryden, J.C. 1984. The flow of nitrogen in grassland. Proceeding No. 224, The Fertilizer Society, London.

Saggar, S., Hedley, C.B., Salt, G. and Shepherd, T.G. 1998. Cultivation effects on soil organic matter dynamics. *In:* Proceedings of New Zealand Soil Science Conference. Extended abstract, Gisborne, 16-19 November, 1998, 45-46.

Saggar,S., G.W.Veates. and T.G. Shepherd. 2000. Cultivation effects on soil biological parameters and organic matter dynamics. Soil and Tillage Research (To be submitted).

Sanchez, P.A. 1940. Properties and Management of Soils in the Tropics, Department of Soil Science North Carolina State University.

Scherer, E. E. 1995. Evaluation of poultry manure and of urea as sources of nitrogen for the maize crop EPAGRI, Centro de Pesquisa para Pequeas Propiccdades, Brazil. Agrorecuiraria Catarinense **8**, 4, 15-18.

Serna, M.D. and Pomares, F. 1991. Comparison of biological and chemical methods to predict nitrogen mineralization in animal wastes. Biology and Fertility of Soils **12**, 2, 89-94.

Sharaiha,R. K. and Hatta, B. 1993. Inter-cropping and poultry manure effects on yields of corn, water melon and soybean grown in calcareous soil in the Jordan valley. Journal of Agronomy and Crop Science **171**, 4, 260-267.

Sharma, B.R. 1990. Effect of different tillage practices, mulch and nitrogen on soil properties, growth and yield of fodder maize. Soil and Tillage Research **19**, 55-66.

Shepherd, T.G., Saggar, S., Newman, R.H., Ross, C.W. and Dando, J.L. 2000. Tillage induced changes to soil structure and soil organic matter fractions. Australian Journal of Soil Research (submitted March, 2000).

Sims, J. T. 1986. Nitrogen transformations in a poultry manure amended soil: Temperature and moisture effects. Journal of Environmental Quality **15**, 59-63.

Sims, J. T. 1987. Agronomic evaluation of poultry manure as a nitrogen source for convetional and no-tillage corn. Agronomy Journal **79**, 563-570.

Smith K.A. 1991. Waste Production from UK Livestock. Internal report to the UK Ministry of Agriculture Fisheries and Food, London, UK.

Smolander. A., Priha.O., Paavolainen. L., Steer. J. and Malkanen. E. 1995. Nitrogen transformation in limed and nitrogen fertilized soil in norway spruce stands. Plant and Soil **172**, 107-115.

Sopper, W.P. 1992. Reclamation of mine land using municipal sludge. Advances in Soil Science **17**, 351-431.

Sparling, G.P., Shepherd, T.G. and Kettley, H.A. 1992. Changes in soil organic C, microbial C and aggregate stability under continuous maize and cereal cropping and after restoration to pasture in soils from the Manawatu Region, New Zealand. Soil and Tillage Research **24**, 225-241.

Sposito, G., Lund. L.J. and Chang, A.C. 1982. Trace metal chemistry in arid zone field soils amended with sewage sludge: I. Fractionation of Ni, Cu, organic, and Cd, and Pb carbonate. Soil Science Society of America Journal **46,** 260-264.

Sprague, G. F. 1966. Corn production. United States Department of Agriculture. Washington D.C.

Steele, K.W. 1985. Fertilizer management for grain maize. *In*: Maize Management to Market. (Eds. H.A. Eagles and G.S. Wratt). pp. 29-36. Agronomy Society of New Zealand, No. 4.

Stolyarenko, V.S., Kovalenko, V.E., Bondar, P.S., Samoshkin, A.A. and Pashova, V.T. 1992. Growth, development and macroelement content in maize seedlings manured with organic waste bioconversion products. Fiziologiya I Biokhimiya Kul Turnykh Rastenii **24,** 476-482.

Stolyarenko, V.S., Kovalenko, V.E., Chernousova, N.M., Bondar, P.S. and Samoshkin, A.A. 1994. Effect of vermiculture products on chlorophyll and nitrate content and productivity of maize. Fiziologiya i Biokhimiya Kul'Turnykh Rastenii. **26,** 77-83.

Tabatabai, M.A. and Al Kafajii, A.A. 1980. Comparison of nitrogen and sulfur mineralisation in soils. Soil Science Society of America Journal **44**, 1000-1006.

2

Taylor, H.M. and Burnett, E. 1963. Some effects of compacted soil pans on plant growth in the southern Great Plains. Journal of Soil Water Conservation **18**, 235-236.

Tester, C.F. 1990. Organic amendment effects on physical and chemical properties of sandy soil. Soil Science Society of America Journal **54,** 827-831.

Tisdale, J.M. and Oades, J.M. 1982. Organic matter and water stable aggregates in soils. Journal of Science **33**, 141-163.

Toor, A.S. and Bishnoi, S.R. 1996. Effect of application of poultry manure, farm yard manure and urea on available nutrient status of soil in maize-wheat rotation. Indian Journal of Ecology **23**, 99-103.

Tuivavalagi, N.S. and Silva, J.A. 1996. The effect of chicken manure and inorganic fertilisers on soil properties and the growth and yield of maize grown on a Hawaiian oxisol. Journal of South Pacific Agriculture **3,** 37-41.

Van Doren, D.M., Triplett, R.L. and Henry, J.E. 1976. Influence of long-term tillage, crop rotation, and soil type combinations on corn yield. Soil Science Society of America Journal **40**, 100-105.

Van Veen, J.A. and Paul, E.A. 1981. Organic carbon dynamics in grassland soils. I. Background information and computer simulation. Canadian Journal of Soil Science **61**, 185-201.

Vanotti, M.B., Bundy, L.G. and Peterson, A.E. 1997. Nitrogen fertiliser and legume-cereal rotation effects on soil productivity and organic matter dynamics in Wisconsin. *In:* Soil Organic Matter in Temperate Agroecosystems. (Ed. E.A. Paul). CRC Press. Boca Raton, Florida.

Wei, Q.F., Lowery, B. and Peterson, A.E. 1985. Effect of sludge application on physical properties of a silty clay loam soil. Journal of Environmental Quality **14,** 2, 178-180.

Weir, C.C. and Allen, J.R. 1997. Effects of using organic wastes as soil amendments in urban horticultural practices in the District of Columbia. Journal of Environmental Science and Health, Part A: Environmental Science and Engineering and Toxic Hazardous Substance Control **32,** 323-332.

Young, D. and McNeill, J. (Eds.). 1999. Measures of a Changing Landscape: State of the Environment Report Manawatu-Wanganui Region. Manawatu-Wanganui Regional Council.

Zhao, J., Yin, Y., Zheng, J. and Xiao, H. 1999. Studies on increasing nitrogen utilisation rate of chemical fertilisers by application of organic wastes as additives II. Effects of application of organic wastes as additives on utilization rate of N from chemical fertilizer. Acta Agriculture Shanghai **15,** 1, 69-72.