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AN EVALUATION OF WHEY, COMPOST AND MINERAL FERTILIZERS USED IN AN ORGANIC FARMING SYSTEM

A thesis presented in partial fulfilment

of the requirements for the degree of

MASTER OF AGRICULTURAL SCIENCE

in Soil Science, Massey University

Palmerston North, New Zealand

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ABSTRACT

An evaluation of whey, compost and mineral materials as fertilizers for an organic farming system, was undertaken in an ongoing 3 year old field trial at the MAFTech Levin Horticultural Research Centre. Sweetcorn (var. Honey and Pearl) was grown as a summer crop (1989-1990) and responses to the three fertilizer forms were measured using fresh cob, plant dry matter and dried grain yield as production criteria. Plant uptake of N and K was measured along with soil inorganic and total N and mineralizable N.

The whey fertilizer gave the highest sweetcorn cob yield averaging 12 t/ha. All fertilizer forms at low and medium levels increased fresh cob yield above the control in the order of whey > mineral > compost. The increase in yield averaged over all levels was 26% for whey and 21% for compost. The mineral treatment at the high level gave a significant depression (-20%). Whey fertilizer also increased sweetcorn N and K uptake to a higher level than compost and mineral fertilizers. Nitrogen and K weed uptake, which was measured only on the control and high level of fertilizer addition, was considerable (26-46 kg N/ha and 83-143 kg K/ha).

Apparent plant N recovery from whey and compost treatment levels were low, 3-13% for compost and 12-22% for whey. Apparent plant K recovery ranged from 4-15% for whey rates, 10-43% for compost rates and 0-27% for the mineral rates.

Soil inorganic N levels, 20 DAS, relate well to plant N uptake which also showed a good relationship with plant K uptake. The mineralizable N potential of the soil associated with various treatments was measured by 3 methods. The anaerobic incubation appeared to relate well to N uptake by sweetcorn. At all levels, the whey treatment mineralized at a faster rate than either the compost or mineral treatments. It appeared that the N component of whey and compost was mainly responsible where yield increases were measured although, the P and K component of the fertilizers may have

contributed in some situations.

Some suggestions are made regarding the design and conduct of future trials i.e. use of plant nutrient analysis to monitor nutrient status and a treatment eliminating annual fertilizer application from part of the main treatment to allow measurement of the residual effects from previous applications.

Some guidelines for organic growers using whey, compost and mineral fertilizers were suggested. These include the continual/annual monitoring of the soil's nutrient status, the measurement of nutrient losses in produce, the construction of a simple nutrient balance for each crop and the suggestion that the fertilizer forms used could be altered when some soil nutrients are considered to be in excess of requirements.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

The present trend in intensive agricultural and horticultural systems, where high yielding and fertilizer responsive cultivars are used, will eventually exhaust the fertility of the soil unless proper soil and fertilizer management is practiced. Additional inputs of plant nutrients in the form of fertilizers, synthetic/chemical or natural, has over the years proved to be necessary to achieve and maintain high yields. Numerous trials have shown that no less than 30 per cent increase in yields can be attained by the proper use of chemical fertilizers (Flaig, *et al.*,1977).

Today, the spiralling cost of synthetic fertilizers and pesticides, brought about in part by the disruption in oil supply, is having a marked influence on the profitability in agriculture and horticultural enterprises. Consequently, there is increasing interest in more efficient fertilizer application rates, timing and methods of application along with the use of N fixing legumes in rotations. In addition, people are becoming more conscious of their health and are demanding "organically grown" foods. Organic farmers are turning their attention to the better utilization of rural wastes, farmyard manures and other agricultural wastes as sources of plant nutrients.

Organic farming systems have been practiced in New Zealand by a handful of farmers for some years now. The interest in bio-dynamic farming is also fast increasing. Both organic and bio-dynamic systems aim for a "balanced" and "sustainable" production system.

In many overseas grassland organic farms, where fertilizer N input is low, leguminous herbage together with excreta from housed livestock are the prime source of N. However, under intensive cropping (arable farming) where N is almost always limiting, brought-in organic farm supplements are necessary.

Many claims have been made concerning the advantages of organic fertilizers over inorganic sources. For instance, organic sources are claimed to slowly release nutrients at rates that match the uptake of the crop (Smith & Hadley,1988). Thus, there are less nutrient losses and the residual pool slowly increases. Organic fertilizers can also help improve soil structure as well as provide a source of trace elements.

There has been little experimental work done to evaluate the relative ability of different fertilizer sources used in organic production to supply plant nutrients. Variability in the composition of organic material often causes inconsistent crop and soil responses to organic materials(MacRae & Mehuys, 1985). Furthermore, the availability and cost of organic materials are important considerations in the choice of these materials.

The general aim of the research reported in this thesis is to evaluate the effects of whey, compost and mineral fertilizers, such as phosphate rock/dolomite and potassium sulphate, on the production of sweetcorn in an organic farming system.

More specifically the aims are to;

1. determine at various stages of growth the nitrogen and postassium uptake of sweet corn.

2. relate plant N and K uptake to the chemical composition of fertilizer and soil properties including soil inorganic N (NO_3 and NH_4), mineralizable nitrogen and K levels.

3. determine the effect of the fertilizer sources on the final yield of sweet corn.

4. provide guidelines on the use of fertilizer materials for organic growers.

CHAPTER 2

LITERATURE REVIEW

2.1 Organic Farming System

2.1.a. Definition

The United States Department of Agriculture (1989) defines an organic farming system as "a production system that avoids, or largely excludes the use of synthetic fertilizers and pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely on crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth to supply plant nutrients."

Currently, New Zealand has no legal definition for organic farming. In 1988, the New Zealand Ministry of Agriculture (MAFTech) and the New Zealand Biological Producers Council (NZBPC) jointly devised a revised set of standards (see Appendix 1.) for organic food production in New Zealand which they hope will be accepted by the International Federation of Agricultural Movement (IFOAM)). The IFOAM is an organization that links together organic farmers worldwide. It aims to create a common standard for organic produce and foster understanding of what the organic concept means.

2.1.b. Organic farming, an overview

Organic farming stresses the use of renewable resources; the need for conservation of resources such as energy, soil, and water; and the maintenance of environment quality.

It is apparent that converting or adopting to organic farming is not easy. In addition to the standards that farmers need to follow to be classified as an organic grower, there is a lack of technical information which acts as a barrier to the greater adoption of organic farming as an alternative to chemical-intensive or conventional farming (Roberts, 1989).

Soil health is of immense importance to organic farming and as a consequence, organic production systems should aim for maximum recycling of nutrients. However, most annual crops that are removed off the property to be sold represents net losses of nutrients which must be replaced to maintain the balance in the system.

Most often in an organic farming system, natural soil fertility is insufficient to supply the total plant needs for nutrients, and nutrient containing materials are needed to supplement losses. Therefore, an understanding of the characteristics and constituents of fertilizers acceptable to organic farming system is required for growers to gain the most benefit in their use.

2.2 Determination of fertilizer requirements in an organic farming system

Generally, fertilizer use practices under conventional arable farming are influenced by a number of considerations (Stanford, 1973) such as:

(1) recommendations based on field-plot research
(2) experience and preferences of growers
(3) crop yield expectations
(4) economic factors

Most of the field researches which established fertilizer amounts as well as time and method of application, are based on the use of synthetic inorganic fertilizers which have relatively 'fixed' nutrient contents and well understood availability indices.

Organic wastes/fertilizers application rates are generally based on crop yield goals and estimates of N availability from the waste during the growing season (King, 1984). However, compared with the well researched performance of chemical fertilizers, the performance of organic/natural fertilizer sources, particularly under an organic farming system is still not well documented (Briton, 1985). There is very little published information which describes the type of nutrient release pattern and crop response to be expected from organic materials (Flaig, *et al.*, 1977).

The variability of constituents/composition (as well as availability) of organic materials make determination of the actual rate to be applied difficult. Some studies using organic fertilizers (Briton, 1985; Pratt *et al.*, 1973; Castellanos and Pratt 1981; Smith and Hadley, 1988) approximate the rate of application based entirely on the amounts of inorganic fertilizer N needed in conventional farming systems.

Bitzer and Sims (1988) based their application rates on the predicted availability of N in poultry manures and a target yield. They predicted the available N (PAN) in stockpiled poultry manure and poultry houses using the equation, PAN = 80 % N_i + 60 % N_o where N_i= NH_4-N + NO_3-N and N_o = (Total N - N_i). This assumes that 60% of the manure organic N will be mineralized during the growing period and 80 % of the inorganic N would be recovered. The reported values range from 54 to 118 mg N/kg soil and include the actual available N, measured by 2M KCl extraction, plus N mineralized during a 140-d nonleached incubation study.

The above mentioned approaches in determining the application rates take into account only one of the major plant essential nutrients, mostly N, but trial results with organic fertilizers are confounded by the effects of the other nutrients present in the applied organic fertilizers. Consequently, the interpretation of results from these trials could be limited. The most effective way to determine the overall fertilizer value of an organic material is to construct a nutrient budget (Bitzer and Sims, 1988). The other major essential nutrients, P and K and their availability indices should be considered along with N. This way the total nutrient input is taken into account and it will be possible to determine whether the additional inputs are just adequate for long term increases in soil levels or more than needed. This approach depends on the availability of nutrients in various organic sources.

In the absence of availability information it is difficult for growers to choose correct rates of organic sources to meet plant nutrient requirements because there is no reliable data at hand to aid in choosing the correct rates (Briton, 1981). A further complication is that in organic growing system, restorative crops are used and when these are ploughed back into the soil, contribute to a nutrient pool for the following crop.

As a general rule, however, the nitrogen that should be applied (Stanford, 1973) in any given situation is dependent on:

(1) target yield of dry matter (Ydm)

(2) associated quantity of N in the crop at final harvest (Ny)

(3) amount of N supplied by the soil (mineralizable N plus initial inorganic N (Ns). If the amount of the soil-derived N is insufficient to supply crop demand, then fertilizer N can be supplied to meet the deficit : Nf = Ny - Ns, where Nf is the amount of fertilizer required.

New Zealand MAFTech (1986) recommends the application of 90 kg N/ha for sweetcorn for a 16 t/ha cob yield. Uptake of N, P and K for this yield will be equivalent to 3.9, 0.56 and 2.1 kg/t of cob yield respectively which would represent the net losses of these nutrients for this crop if the stover are turned back into the soil. About 112 kg N/ha, 13 kg P/ha and 84 kg K/ha will be added to the soil reservoir if stover are ploughed back.

Plants obtain its N requirements from mineral N which is present in the soil at planting, N which is mineralised during the growing period and from applied fertilizer N. An understanding of these factors is needed as well as the efficiency with which the crop can utilize soil and applied fertilizer N.

The N mineralization potentials of the soil during the growing season helps in predicting the fertilizer requirement as it determines the relative N supplying capacity of the soil. Keeney and Bremner (1966) stated that only 1-3% of the N in soils are mineralized during the growing period. In New Zealand the amount of mineralizable N varies between different cropping soils. Elliot and Gregg (1979) reported net mineralizable N in the range of 0.5 to 1.0 kg N/ha/d over the growing season for corn from field experiments conducted in the Manawatu district. Other studies reported 1 kg N/ha/d based on laboratory incubation (Ross *et al.*, 1982) to 1.5 kg N/ha/d (Hart *et al.*,1979) over the growing period. Bonoan (1991) using a horticultural soil in the Manawatu, reported the values for mineralizable N to be equal to N_s x 2.5 and N_s x 3.0 for unfertilized soils and inorganic N fertilized soils respectively where N_s is the soil mineral-N in the root zone of the crop at sidedressing time. These values were calculated based on an equation (Greenwood *et al.*, 1987)

$$dN_m/dt = (dN_u + dN_s + dN_l)/dt$$

where dN_u is net N uptake by the crop during the growing period, dt, is the time from sidedressing to the period shortly before harvest (60 days), dN_s is the change in inorganic soil N to depth taken (30 cm) and dN_l is the amount of estimated N leached below 30 cm.

Another important consideration in the fertilizer requirement determination is the efficiency by which plants can recover the plant nutrients. Stanford (1973) using inorganic fertilizers reported plant recoveries of N ranging from 50 - 70 % and Greenwood *et al.*, (1980) reported plant recoveries for K to vary between 8 - 70 %.

For manures, very low plant recoveries are reported i.e., 9.2% for composted manure and 28.2 % for fresh manure (Brinton, Jr. 1985); 13.8 % to 15.5 % for fresh and composted manures respectively are reported by Kirchmann

(1990); and an average of 35 % of the inorganic N from poultry manures (Bitzer and Sims, 1988).

Therefore, the most logical step to take in determining the rate of application of organic sources is to adopt the required inorganic fertilizer rate for N if it exists and/or use of a nutrient budget to take into account the other major nutrient supplied; an index of nutrient availability needs to be known and the N mineralizing capability of the soil considered. Furthermore, the likely effect of the previous crop residue as an addition to the nutrient pool be taken into account.

Since most of the organic sources have a very low content of major nutrients, growers are faced with problems associated with sourcing sufficient quantity of materials as well as effectively spreading these materials.

2.3 Organic fertilizers

'Organic fertilizers' are initially made from constituents of plants and animals and micro-organisms or their metabolic products (Flaig, *et. al.*, 1977). More often they contain very low amounts of nutrient elements which are mostly in insoluble forms.

Some of the more common organic sources are farmyard manure, animal manures, sewage sludge, and urban/municipal wastes. These organic sources can be applied singly or in combinations to increase the nutrient content.

Unfortunately, not all organic material sources are permitted in the standards set by the NZBPC (see Appendix 1B.).

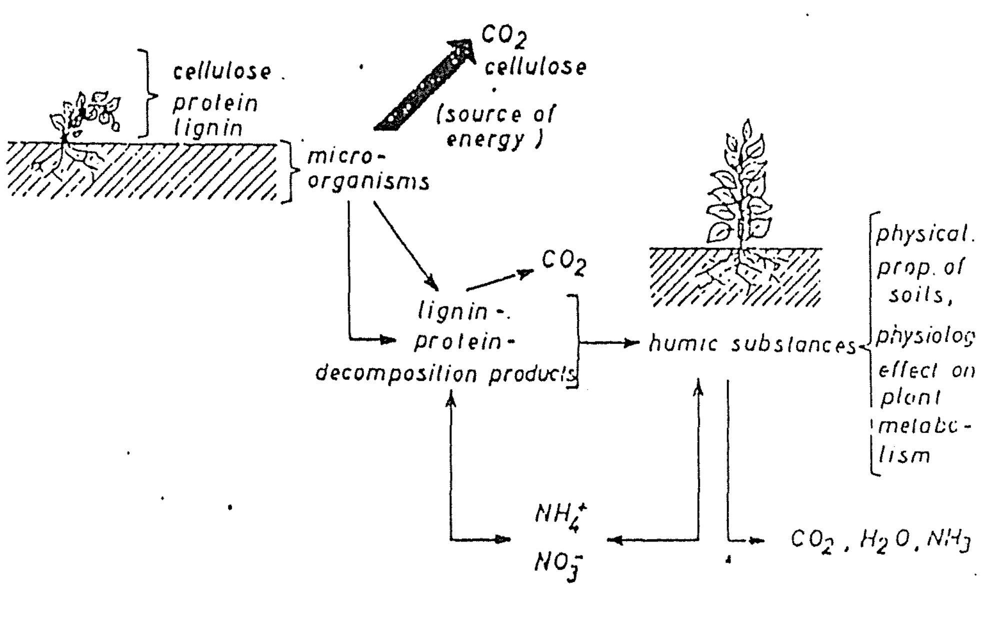
2.3.a. Characteristics and their reactions in the soil

Due to the low nutrient content of organic materials, it is necessary to add large amounts in order to influence plant growth via a fertilizer effect. Also, additions of organic materials should maintain, if not increase, organic matter content of the soil which acts as reservoir of nutrients. Other effects include improvement of soil structure, soil biological activity and formation of organo-metal complexes (Al, Fe and Cd) which helps reduce the toxic effects of these heavy metals to plants.

The amount of organic matter present in the soil at any one time depends on the accumulated balance between the quantity added and the rate of decay. Added organic materials undergo continuous decomposition and the stable end-product have similar composition to humic substances (FAO Bulletin, 1975).

Some processes involved during humification of dead plant material is summarized in the following scheme .

Fig.1. Scheme of formation of soil organic matter (FAO Bulletin, 1975)



Plants are mostly made up of cellulose, proteins and lignin. Cellulose is used by the microorganisms mainly as a source of energy and degraded to carbon dioxide. A part of the cellulose as well as the protein serve for formation of the mass of microorganisms (FAO Bulletin, 1975).

Variation in the final chemical and physical composition of the materials added is unavoidable because of different conditions during the humification of the organic substances. Some of these conditions include type of the material, cropping system, climate, temperature, precipitation, soil texture and aeration (Batey, 1988).

2.3.b. Composting

An important process in hastening the decomposition of these organic materials is composting. Gray and Biddlestone, (1981) define composting as the decomposition of organic wastes by mixed microbial population in a warm moist aerobic environment. Wastes are gathered into heaps in order to conserve heat, thereby raising the temperature and accelerating the basic degradation process which normally occurs slowly on the surface of the ground.

most organic waste materials such as cereal straw and animal manures produced in agriculture are suitable for compost production. Table 2.1 shows a list of the approximate composition of materials suitable for composting (Gray and Biddlestone, 1981).

The C/N ratio of manures is often below the optimum level (20:1) which leads to ammonia loss during composting. Thus, it is best to mix manures with materials of high C/N ratios such as straw and wood ash. A little soil or clay in the compost heap mixed throughout will help to hold any liberated ammonia within the heap until the microorganisms can immobilize it thereby reducing the nitrogen loss.

Compost is primarily a soil conditioner and to some extent a fertilizer (Gray and Biddlestone, 1981). When added to the soil it breaks down further releasing the major plant nutrients like N, P, K, and minor and trace elements. Soil fauna attacks it and the gummy constituents and fungal and actinomycetes mycelia help to bind the soil particles into crumbs while the organic components increase the water-holding capacity of the soil.

Table 2.1. Approximate composition of materials suitable for composting. (Gray and Biddlestone, 1981).

Material	Nitrogen (%)	C/N Ratio (dry wt. basis)
Urine	15-18	0.8
Dried Blood	10-14	3
Hoof and Horn Meal	12	na
Night soil, dung, s.sludge	5.5-6.5	8
Grass	4	20
Bone meal	4	8
Brewers wastes	3-5	15
Farmyard manure	2.2	14
Water hyacinths	2.2	20
Millet, pigeon pea stalk	0.7	70
Wheat, barley, rice stalks	0.4-0.6	80-100
Coconut fibre waste	0.5	300
Fallen leaves	0.4	45
Sugar -cane trash	0.3	150
Rotted sawdust	0.2	200
Fresh sawdust	0.1	500
Paper	nil	infinity

Several studies (Kimber, 1967; Patrich, 1971; Rao and Mikkelson, 1977; Tang and Waiss, 1978) have shown that during the early stages of decay of organic materials, particularly of crop residues, the toxins produced or liberated can retard plant development. Harper and Lynch (1981) and Lynch *et al.* (1981) further showed that phytotoxic microbial metabolites such as acetic acid may accumulate in wet soils which inhibits seedling development and result in lower yields. Consequently, it is often necessary to apply mature or well composted organic materials to avoid crop damage while at the same time supply enough energy for microbial activity.

Some advantages of composting are as follows (Gray and Biddlestone, 1981):

i). The final weight of compost is less than half of the original material with subsequent reduction in volume which can reduce the transport and spreading costs.

ii). Pathogenic organisms, weeds and other unwanted seeds are killed when temperatures of over 60^0C is reached.

iii). Mature composts quickly comes into equilibrium with the soil whereas raw organic wastes can cause a period of major disruption which are often detrimental to the soil processes.

iv). Compost heaps are free-standing, while manure slurries require tanks or pits for storage.

v). Different materials can be blended or mixed together which can increase the nutrient content of the end product.

Table 2.2. gives an indication of the composition range of composts which shows that farm/garden composts are more or less 'superior' than municipal composts in terms of nutrient contents.

Table 2.2. Chemical composition ranges of matured composts (Gray and Biddlestone, 1981).

Substance	Weight - % dry basis <------ Municipal wastes Farmyard manure----->
Organic matter	25 - 80
Carbon	8.0 - 50
Nitrogen (as N)	0.4 - 3.5
Phosphorous (asP_2O_5)	0.3 - 3.5
Potassium (as K_20)	0.5 - 1.8
Calcium (as CaO)	7.0 - 1.5
Ash	65 - 20

2.4. Effects of organic fertilizers on soil organic matter and soil physico-chemical and biological properties:

2.4.a. Soil Organic matter

Soil organic matter is regarded by some as the vital and essential link controlling soil productivity (Batey, 1988). The general statement being that, all other factors being equal, a soil with high organic matter level has a good physical condition. If organic materials/fertilizers are capable of increasing the soil organic matter level, then it could be expected that at least some of the soil's properties would be improved.

Organic matter to a great extent is responsible both directly and indirectly for making the soil environment suitable for plant growth through its effects on soil aggregation which in turn influences soil encrustation, water infiltration, moisture content, drainage, tilth, aeration, temperature, microbial activities and root penetration (Batey, 1988).

Cooke (1977) reported that in Broadbalk Wheat Experiments in Rothamstead, after 100 years of continuous annual application, farmyard manure-treated plots had 2.58% Carbon (C), fertilizer-treated plot had 1.19% and the untreated soil with 1.09%C. In another experiment in Woburn (Bedfordshire) on loamy sand soil, 75 t/ha of FYM applied annually from 1942-1967 raised % C in soil from 0.87% to 2.26% and the same weight of sewage sludge given only from 1942 to 1961 raised % C to 2.87% . However, there will be a point in time when an equilibrium is ultimately reached where %C in soil becomes constant after several yearly similar additions of manures.

Plaskett (1981) estimated that an application of farmyard manure at 35 t/ha/yr represents only about 4 t /ha/yr of organic carbon, the rest is moisture and non-carbon dry components. Thus, it would take about 11 years of such additions to increase soil carbon from 1 percent to 1.5 percent, even if none of the added carbon were lost.

In the Hoosfield Barley experiment which was continuously treated since 1852, Jenkinson and Johnston (1975) reported the following effects on soil properties:

	% C	% N	Bulk Density (g/cc)
Treated with NPK fert.	1.10	0.105	1.50
Treated with FYM	3.38	0.29	1.29

Some authors (Allison, 1973; Warman, 1980) stated that green manures will maintain or increase organic matter or maintain or increase soil nitrogen levels but not both at the same time. He further stated that plant materials typically low in N i.e., 1.5% N or less on a dry weight basis can be effective in improving the organic matter content of the soil.

Organic matter concentration in the soil is related to both the rate of addition and the rate of decomposition of organic residues. To create an increase may require a change in cropping system i.e. change in crops used in a rotation and the retention of more of the plant residues in the soil. Additions or application of brought-in farm manures are mainly for the purpose of augmenting the growing crops' requirement for nutrients which the soil could not supply and not necessarily to increase soil organic matter levels. It appears that additions of farmyard manures have to be frequent and large amounts of materials need to be applied to produce any significant change in the amount of soil organic matter. The availability of other bulky organic materials such as compost, sewage sludge as well as poultry manures are limited and their use would be restricted by transport and spreading costs as well as potential content of toxic metals.

From the literature it is evident that organic fertilizers that are applied in small quantities are not likely to have any significant effect on soil organic matter levels. Batey (1988) stated that after correction for the fraction decomposed, any ultimate addition to soil organic matter is likely to be less than 20% of that applied by the end of the first season. For example, after an application of 300 kg/ha of an organic fertilizer, a residue of about 60 kg/ha would have little influence when diluted with 2500 t/ha of topsoil which is a typical value. Batey (1988) further suggested that to make the most out of the added materials, one should reduce the depth of ploughing to avoid bringing up the subsoil which could dilute the organic concentration at the surface. In this way, the added materials are retained close to the soil surface where plant roots can utilize most of the released nutrients during mineralization.

2.4.b. Soil Biological Properties

The soil has many different microbial and other life forms. Soil biological activity which is dependent on the numbers and species diversity of microorganisms is crucial to soil productivity particularly on organic farms. Table 2.3. shows an approximate number of some organisms in a typical agricultural surface soil and their mass in a depth of 15 cm (Batey,1988).

Table 2.3. Approximate number of some organisms in a typical agricultural surface soil (Batey, 1988).

Soil organisms	Number per gram of dry soil	mass kg/ha
Bacteria	100 million	1600
Actinomycetes	2 million	1600
Fungi	0.2 million	2000
Algae	25,000	320
Protozoa	30,000	380
Nematodes	1.5	120
Earthworms	1 per kg	800

Plant residues, manures, composted organic materials etc., contain many different organic compounds, sugars, starches, proteins, waxes and other complex molecules which microorganisms attack. Only a small proportion of the nutrients which these sources contain is immediately available to the plants. The other constituents require the process of mineralization to breakdown the organic matter and convert the nutrients into soluble forms that can be taken up by the crop (FAO Bulletin, 1975).

Mineralization is microbial and the rate is therefore, governed by the factors affecting microbial growth. Foremost of which are temperature and aeration. Mineralization is very slow in dry soils. However, excess water such as in waterlogged conditions may suppress nitrification due to lack of oxygen. When moisture content of the soil is above 70% of the water holding capacity, Lewis (1986) observed that mineralization decreased due to poor aeration. In areas with wet-dry cycles, onset of rainfall increases the rate of mineralization. Soil aeration effect depends on whether the mineralizing organisms are aerobic or anaerobic.

Thermophilic organisms are mostly involved in the process of mineralization and the optimum temperature is usually between 40^0C and 60^0C for ammonification to occur (Lewis, 1986).

The decomposition rates of plant litter whether determined by weight loss (Standen, 1978) or by the release of mineral nutrients (Anderson *et al.*, 1983) is enhanced by the presence of invertebrates in soils. The ability of the soil fauna to comminute and incorporate organic matter and to increase the turnover of microbes (Malowe and Reichle, 1973) and alter the microbial population present justify their importance in the soil.

Earthworms can significantly affect the decomposition of organic matter in the agroecosystem. They accelerate organic matter decomposition directly by consumption and indirectly by incorporation of organic matter into the soil and stimulating microbial activity in the casts they produced and around burrows (Hamilton and Dindal, 1983; Shaw and Pauluk, 1986). Jensen (1985) reported that in barley fields, earthworms accounted for 5% to 21% (depending on the soil type) of the total mass loss from straw enclosed in litter bags. Mackay and Kladirko (1985) reported that Lumbricus rubellus increased the decomposition rate of soybean residues by 26% and maize by 33% in pot experiments. Parmelee (1990) studied earthworm and enchytraeid densities and biomass in conventional and no-tillage agroecosystems and reported that in the no-till system, earthworm densities were 70% greater than in the conventional while enchytraeid densities and biomass in the no-till system were 50-60% greater.

Bohac and Pokarzhensky (1987) studied the effect of manures and NPK on soil macrofauna in chernozem soil under barley and found that plots with farmyard manures had the maximum species density of soil macrofauna followed by plots fertilized with 300 kg/ha of NPK. The control or unfertilized plots had a more diverse species of soil macrofauna than plots fertilized with 600 kg/ha N which they explained could be due to increased pH, salinity, changes in osmotic potential and water regime.

Parallel to the above findings, Pokarzhensky *et al.*, (1987) reported that increased use of manures in agroecosystem increases soil animal population because manures induce the growth of cellulolytic microorganisms which in turn are the nutrient source for saprophages.

Long term fertilization of loamy sand with liquid manure caused marked accumulation of organic matter in the soil, improved its biological properties and consequently increased the soil's productivity (Myskow *et al.*, 1987).

Haystead (1987) conducted a survey comparing organic enterprises with conventional farms in New Zealand which commenced in 1984. It was reported that biological activity; earthworms, mesofauna and the soil microbiomass showed substantial differences between soils under permanent pastures and rotationally cropped soils. Earthworm biomass was found to be greater on two (out of 8 farms surveyed) of the organic dairy farms. In conventional farms, it was observed that the use of chemical fertilizers and pesticides does not seem to have any detrimental effects on the soil biomass. This is not surprising, however, since soil organisms thrive on plant and animal debris which are also present in conventional farms. Thus, if both systems could support active microbiomass, then the difference would lie in the species present and population diversity. Unfortunately, this was not measured in his study.

Shifts in microbial numbers and activity in soil are often related to changes in carbon inputs to soil as a result of management-related changes in crop type or residue addition. Soil microbial populations are increased by additions of animal manures or by synthetic fertilizers where crop residue and soil organic matter levels are simultaneously increased (Martynirik and Wagner, 1978).

2.4.c. Soil physical properties

Greenland, Rimmer and Payne (1975) found that for many British arable soils, 2.5 per cent organic carbon was necessary to give a really stable soil structure. Batey (1988) estimated the weight of the ploughed layer of an arable field as about 2500 t/ha; 2.5% therefore, corresponds to 62.5 t/ha of organic carbon or 108 t/ha of soil organic matter. This suggests clearly that it is difficult to apply enough organic material to influence quickly the organic matter content of a soil (Plaskett, 1981) and subsequently soil physical properties.

MacRae and Mehuys (1985) gave a comprehensive review on the effect of green manuring on the physical properties of temperate-area soils. From the literature cited they concluded that:

1) Organic matter does not directly affect all physical parameters but most likely affected directly are aggregate stability and bulk density.

2) Green manures maintain soil organic matter levels under particular though not well defined conditions and that different plant species used as green manures vary widely in their effect. 3) Green manures do not necessarily improve the soil physical conditions even when total soil organic-matter levels are maintained or increased. There is, however, a need for more information on the relationship between green manuring, soil organic matter levels, and

soil physical properties before more meaningful conclusions could be made.
4) Even if the soil physical condition is improved, it does not necessarily follow that crop yield is also improved.

Not all kinds of organic matter act as effective stabilizing agents of soil aggregates. Materials such as peat, sawdust, and essentially all kinds of undecomposed crop residues have little effect in stabilizing of aggregates but they help to keep aggregates small (Allison, 1973). It is primarily the products of microbial and fungal activities that acts as stabilizers. Thus, well rotted manures and composts will not be active as stabilizing agents because microbial activity is reduced. This is parallel to the findings of Martin and Waksman (1940) who stated that organic matter additions have no effect on soil aggregate stabilization unless microorganisms are present. Similarly, Jenkinson and Johnston (1977) reported that soil improvements in physical properties result from fresh additions of organic materials; very old or mature organic matter has no marked effect on soil properties. This is because there is less biological activity which produces mucilages and gums (polysaccharides), etc. that binds soil particles together in older organic matter compared to fresh materials. It is the end product of decomposition or the result of microbial action that serve to cement or bind clay particles together into larger size particles. The increase in soil aggregate stability is directly related to the ease of microbial decomposition of the added organic material. For example, it has been found that additions of alfalfa are more effective than peat (Martin and Waksman, 1940). McCalla *et al.*, (1957) found that cereal straw or cellulose produced less stable aggregates in the same period of time than an easily decomposable substrate such as sucrose or glucose. Gilmour *et al.*, (1948) have pointed out that straw and other crop residues can provide substrate for microorganisms to produce agents to stabilize soil aggregates.

Chaney and Swift (1986) showed that soils amended with glucose produced stable aggregates and the stability was related to the natural soil organic matter levels and to the original stability of the natural aggregates. However, stability induced by incubation with glucose was transient and declined over a period of 12 weeks. This was attributed to microbial extracellular polysaccharides and their subsequent decomposition. Results of a 14 day incubation study by the same authors with and without glucose, suggests that humic substances were capable of stabilizing aggregates under different conditions where extracellular polysaccharides were ineffective.

The effect of cattle manures and its humic fractions on the aggregate stability of a sandy loam soil has been studied by Fortun *et al.,* (1989). Results showed that the addition of manure itself was not effective in producing water-stable aggregates but stability was significantly improved after two weeks incubation with organic fractions such as fulvic/humic acids.

Apparently, the effects and effectiveness of added organic matter vary with soil texture and the source and type of organic matter. Furthermore, the effects do not last long unless continuous additions are made (Batey, 1988; Plaskett, 1981).

2.4.d. Effect on Crop Productivity

When organic materials such as farmyard manure (FYM), liquid manures and slurries, poultry manures, composts or any other materials from plant and or animal wastes are added to the soil for the purpose of supplying the crops with nutrients then these materials could be classified as organic fertilizers. Cooke (1982) however, classifies organic fertilizers as only those wastes from processing animal and plant products which contain high percentages of N and P. Some of the materials are listed in table 2.4.

The value of any organic material as a fertilizer can only be evaluated through it effect on soil properties and consequently, crop performances i.e. yield increases, improvement in the quality of the produce i.e. increases in palatability, increased protein contents of grains, etc.

Early studies by Haworth (1966) have shown that Nitrochalk performed better than hoof and horn meal on spring and summer cabbage and potatoes. They attributed this result to hoof and horn meal having a slower rate of mineralization of its organic N. Unfortunately, the report did not give details on the analysis of the materials used and the basis for the chosen application rates.

Table 2.4. Some concentrated organic fertilizers (Cooke, 1982).

Type	Origin	Approx. amts. of the principal constituents (% of total)	
		Nitrogen	P_2O_5
Hoof & horm meal	slaughterhouses	10-12	-
Dried blood	slaughterhouses	12-14	-
Shoddy	wool wastes	3-12	
Meat & Bone meal, carcass meal	slaughterhouses	6-10	18
Fish meal, fish manures	fish processing	7-14	9-16
Leather wastes	leather making	7	-
Castor meal	residue from oil seed processing	5-6	1-2
Rape cake	oil-seed processing	5	-
Bone meal	grinding/crushing of bones	3	20
Steamed bone flour/meal	steaming bones	0.5-0.8	26-29
Guano	bird/bat/poultry excrement	10	12

Protox (derived from the activated sewage process), dried blood and feathermeal was compared with ammonium nitrate as base and surface applied topdressings in a study by Smith and Hadley (1988) on summer cabbages. Results of their study showed that at rates higher than 250 kg N/ha the base application of Protox and feathermeal to summer cabbages gave larger yields than ammonium nitrate but dried blood gave similar results from those of inorganic N treatments. However, yield response of summer cabbages with surface-applied top-dressings of organic N materials was only 10-50% of that with ammonium nitrate. They considered that ammonia volatilization from the organic N sources was responsible for the decreased yield.

Animal manures are another source of plant nutrients and ways of disposing of them as fertilizers are being studied. Evans *et al.,* (1977) compared the effects of solid and liquid beef manures and liquid hog manures against inorganic fertilizer on soil characteristics and growth, yield and composition of corn. Results of their study showed that a) corn grain yields from manure treated plots were not significantly different from the inorganic fertilizer treatment, b) all manure treatments significantly increased N, P and K levels and decreased the Ca and Mg levels in the plant tissues and grain in some year. There was, however, a rapid movement of NO_3-N below the rooting depth of corn on manure treated plots particularly at higher rates. Thus, continued annual application might prove detrimental even though grain yields were not affected. Similarly, it was reported by Mugiwra (1976) from his study that at high rates of dairy cattle manures, excessive accumulation of nitrate in plants and soils occurred. He suggested that 22-44 M t/ha of dairy cattle manure were more effective than higher rates in stimulating millet growth.

Injected liquid manures at the rate of 90 t/ha was reported to increase corn grain yield by 14% above that from the inorganic fertilizer treatment. Also there was higher concentrations of NH_4 and NO_3 together with build-up of P and K to a greater depth within the soil profile from injected manures compared to surface-applied manure (Sutton, *et al.*, 1982).

2.5. Synthetic/chemical and some natural inorganic fertilizers

Any fertilizer applied to the soil undergoes physical, chemical and biochemical reactions that could have both positive and negative results. Such reactions could lead to the formation of products more suited to the soil environment or can result in significant losses of nutrients from the soil-root zone after application. It is evident that the characteristics of the fertilizer added and the nature of the soil environment where the fertilizer particle were applied largely determines the nature of the reaction products that form in the soil.

In the following review only a few of the more commonly used chemical fertilizer grades/types will be considered.

2.5.a. Characteristics and their reactions in the soil

Chemical fertilizers are made up of highly soluble materials usually of high nutrient concentrations which the plants can uptake readily. Thus, crop response to chemical fertilization is rapidly observable particularly under deficient conditions. Once these fertilizers are applied to the soil, they undergo chemical reactions as illustrated below. Several of these reactions are also observed where organic fertilizers are added to the soils i.e. mineralization-immobilization.

i. Nitrogenous fertilizers

a. Ammonium suphate: $(NH_4)_2SO_4$ - contains 21% N

Reaction in soil:

$(NH_4)_2SO_4$ ------------> $NH_4^+ + SO_4^{2-}$ (1)

$NH_4^+ + 3/5\ O_2$ --------> $NO_2^- + H_2O + 2H^+$ (2)

$2NO_2^- + O_2$ -----------> $2NO_3^-$ (3)

net: $(NH_4)_2SO_4 + 4O_2$ ---> $2NO_3^- + 2H_2O + SO_4^{2-} + 4H^+$ (4)

b. Urea: $CO(NH_2)_2$ - contains 45-46% N

Reaction in soil:

$$CO(NH_2)_2 + 2H_2O \text{ --------->} (NH_4)_2CO_3 \quad (5)$$

$$(NH_4)_2CO_3 + H_2O \text{ --------->} NH_4OH + H_2CO_3 \quad (6)$$

$$\text{net: } (NH_4)_2CO_3 + 4O_2 \text{ ------>} 2NO_3^- + 3H_2O + CO_2 + 2H^+ \quad (7)$$

Nitrification occurs which is the oxidation of NH_4^+ to NO_3^- with NO_2 as an intermediate conversion. An important consideration in the reactions is the generation of $2H^+$ ions per NH_4 oxidized (2) in ammonium sulphate and 1 mole of H^+ per mole of NH_4 in urea (7). Thus, ammonium sulphate is sometimes known as "acid" fertilizer (During, 1984).

Rapid hydrolysis of urea in soils can result also in high pH values and high ammonium ion concentrations which are conducive to ammonia accumulation (Gould, *et al.*,1986). The major problems observed in urea fertilization are the loss of volatile ammonia gas and ammonia toxicity to germinating seedlings (Court *et al.*, 1964 cited from Gould, 1986). Furthermore, very high concentrations of applied urea could produce nitrite sufficient to cause gaseous losses of N_2 and N_2O (Christiansen *et al.*, 1979). The accumulation of nitrite in soils can be toxic to plants.

ii. Phosphatic fertilizers

a. Triple Superphosphate: $Ca(H_2PO_4)_2 * H_2O$ consists of water soluble monocalcium phosphate, some dicalcium phosphate and a little amount of unreacted rock phosphate. Typical examples contain 18% water soluble P and 20% total P (During, 1984).

Reaction in soil:

$$Ca(H_2PO_4)_2*H_{2O} \text{--------->} CaHPO_4*H_2O + H_3PO_4$$

b. Diammonium phosphate: $(NH_4)_2HPO_4$ - considered as ammonium orthophosphate, P is 100% water soluble and contains 19-21% N and 20-23% P.

Reaction in Soil:

$$(NH_4)_2HPO_4 \text{------------->} NH_4^+ + HPO_4^{2-}$$

Once applied to the soil and are dissolved by soil water, reactions occur among the phosphate, soil constituents and the nonphosphatic compounds. When soluble P forms are added to the soil, high P concentrations and very acid conditions occur near the fertilizer granules and forms $AlPO_4$ and $FePO_4$ which are amorphous and reverts to crystalline forms which are extremely insoluble (Englestad and Terman, 1980).

With diammonium phosphate, the pH of a saturated solution is about 9 and in calcareous soils a greater proportion of insoluble reaction products will be formed than would in triple superphosphate (Tisdale and Nelson, 1975). The released NH_4^+ can also react with $CaCO_3$ and is subject to NH_3 volatilization with simultaneous precipitation of calcium phosphate (Papadopoulos, 1985).

In alkaline and P deficient soils, the NH_4-N in diammonium phosphate may have a simulatory effect on P availability due to the temporary acidifying effect of the soil adjacent to the P granules which can stimulate root growth and increase in the metabolic activity of plants. Therefore, there is a higher early growth response and occasionally higher crop yields obtained from diammonium phosphates than calcium phosphates of similar P solubility (Englestad and Terman, 1980).

iii. Potassium fertilizers

Potassium chloride (KCl) known more commonly as muriate of potash and potassium sulphate (ca. 50% K or 60% K_2O). In pure form, potassium chloride is a very soluble crystalline white salt (During, 1984). However, when refined from sylvinite ore, a mechanical mixture of KCl (sylvite) and NaCl (halite), the salt is often reddish due to contamination with minor amounts of iron oxides that are occluded in the crystals of sylvinite ores (Dancy, 1984).

Reaction in soil:

$$KCl + H_2O \text{ --------- }> K_2O + HCl$$

The above reaction shows that soil acidity can be created with KCl application. During (1984) reported that in mowing experiments the application of 250 kg /ha potassium chloride each year sometimes increase soil acidity caused by preferential absorption of potassium by plants leaving a surplus of chlorine ions in the soil. Fortunately, this is not always the case and that pH changes are very small.

iv. Natural inorganic fertilizers

a. Gypsum ($CaSO_4*2H_2O$) - contains 16.8% S

The process is actually an acidifying reaction since $2H^+$ are generated for every S atom oxidized. A disadvantage is in the formation of acid clays or 'cat clays' soils where the process bring about extremely acid conditions particularly under submerge conditions.

Under anaerobic conditions, sulphates tend to be unstable where they are reduced to sulphides. Thus, sulphur oxidation-reduction in soils determine the quantity of $SO_4^=$ which is the available form of S to plants and the consequent degree of acidity produced.

b. Elemental sulphur (S) - contains 30-99.5% S;

Elemental sulphur must be oxidized by soil microbes before plants can utilize it because of its insolubility.

Reaction in soil:

$$S + 3/2\ O_2 + H_2O \text{ -----------> } H_2SO_4$$

Other natural inorganic fertilizers include dolomite and reactive phosphate rocks.

2.6. Major differences between organic, natural inorganic and inorganic/synthetic fertilizers.

Application of most chemical fertilizers which are highly soluble may give rise to soil acidity and some nutrient imbalances in the soil. In the same way that soil pH can change significantly, it can also alter the availability of some minor or trace elements. An imbalance created by chemical fertilizer application can make practically whatever quantity available of a trace element disappear even when there were originally adequate quantities of the element available in the soil (Voisin, 1965 cited from Hodges (1981)). Chemical fertilization practices generally only recommends the regular replacement of the four major elements, N, P, K, S except where there is a specific deficiency for a certain element.

On a nutrient per nutrient basis, it will take tons of organic fertilizer to meet recommended fertilization rates compared the weight of soluble inorganic fertilizers which range from 4-800 kg /ha depending on crops and soil. Studies by Gill and Muller (1982) on the substitution of N and P fertilizers with farmyard manure on loamy sand soil planted to rice-wheat rotation showed that the application of 80 kg N and 12 tons farmyard manure per ha was comparable to the yield of rice applied with 120 kg N per hectare alone. Therefore, 12 tons of farm yard manure per hectare could substitute for 40 kg N as inorganic fertilizer for rice.

It must be emphasized that large scale use of organic materials as fertilizers depend on a number of factors such as; climatic conditions, level of agricultural mechanization, availability of low cost organic materials in large quantities, specific needs of soils for amelioration of the its physical condition, influence of constraints such as water supply and transport charges and the substantial economic gain to the farmer by using them (Horn, 1977).

2.7. <u>Conclusion</u>

The philosophy and development of techniques to be used in organic farming systems, in New Zealand is in its infancy. Very limited published information have been found regarding the use and effectiveness of fertilizer materials that are accepted under the NZBPC. Furthermore, the large variability of components/ constituents of organic materials particularly compost and manures makes it difficult to establish the availability indices of the nutrients contained in these materials. It is therefore, difficult to make recommendations for growers regarding the correct application rates and timing of organic fertilizers to meet plant nutrient requirements because there is no reliable data at hand to aid in choosing the correct rates.

From the cited works, it can be inferred that additions of organic materials has two main effects; either to increase or maintain soil organic matter or these materials are added as fertilizers to provide crops with the required nutrients.

Organic farming practices such as green manuring and crop rotations are attempts either to maintain or increase organic matter levels in the soil and subsequently improve soil physical properties such as aggregate stability.

Additions of animal manures or wastes from plant and animal processing can provide crops with required nutrients particularly nitrogen. However, the plant recovery of N from organic sources are much lower compared with reported plant N recoveries from inorganic sources. There are very few instances reported where these materials gave comparable if not even better crop yields than inorganic sources.

Most of the studies undertaken were on the effect of organic materials on the organic matter level of the soil. There were very limited studies on the actual effects of organic materials on soil physical and chemical properties and crop productivity.

All normal surface soils contain organic matter and on several studies where organic matter was added, changes in organic matter levels were not detected. Where the effect of organic matter addition are to be assessed, it would seem profitable to use soil low in organic matter contents.

Some of the studies on organic fertilizers have been conducted for only a comparatively short time. There is much evidence that soil aggregation and stabilization are properties affected in the long term. Often there are inconsistencies in the results obtained in a one-month laboratory experiment or in one-season field experiment and in soils left undisturbed for many years. Newly formed aggregates are likely to be only moderately stable compared to old aggregates which are more firmly cemented and longer lasting (Allison, 1973).

From the literature survey insufficient information on the experimental conditions was given to determine reasons for inconsistency in results associated with organic fertilizers. In most of the studies on the fertilizing value of these organic materials, only the major elements, N, P, and K are studied and almost always the possibility of the effects of associated trace element present in the materials is overlooked.

CHAPTER 3

MATERIALS AND METHODS

3.1. Field Trial

3.1.a. Trial Site

In 1987, MAF (Tech) Horticultural Research Centre in Levin set up an organic farm trial to evaluate the performance of some possible fertilizer sources under an organic farming system. This trial is ongoing and compost, whey and mineral fertilizers have been added annually to the site for three years before this study commenced.

3.1.b. Soil Type

The soil in the trial site is Levin silt loam classified in USA taxonomy as an Umbric Dystrochrept which in the New Zealand soil classification is a moderately leached intergrade between the yellow-brown loams and yellow brown earths soil groups. It is fine silty, mixed, mesic, friable, freely draining soil to 80 cm., of moderate natural fertility, high % P retention with moderate reserves of K and Mg (A.Palmer, 1991, pers. comm.).

The parent material is greywacke alluvium overlain with some loess and volcanic ash material. These soils are not easily pugged making them suitable for cropping and intensive use (During, 1984).

3.1.c. Nutrient Status

Some soil characteristics at the commencement of the study are presented in table 3.1.

Table 3.1. Soil Characteristics at the start of the study.

Depth of sample	pH in water	Total		MAF Quick Tests (Ave. of control)				
		N(%)[1]	C(%)[2]	P	K	Ca	Mg	Na
0-15cm	5.8-6.1	0.47	4.4	24	8	6	10	9

[1]Kjeldahl digestion done on samples taken 20 days after sowing.
[2]Leco Combustion done on samples 20 days after sowing.

For the growing of sweetcorn, MAFTech (1986) recommend for this soil type that Olsen P should be 45 - 50 and K test 8 - 9. Whether these levels represent a non-responsive situation is unclear as no published information is available for sweetcorn P and K responsiveness.

3.1.d. Climate

The weather condition during the growing season (November 1989 - March 1990) are summarized as follows:

Table 3.2. Weather condition during the growing season (November 1989-March 1990).

	Nov	Dec	Jan	Feb	Mar
Rainfall Tot.(mm)	41.6	74.6	151.9	17.4	247.4
Mean Monthly (mm) *	89	104	84	70	76
Ave Temp Max	19.8	19.1	21.9	24	22
Ave Temp Min	11.9	11.5	13.3	15	13.4
Ave.S/shine Hrs	6.4	5.5	7.4	8.2	5.8

*Mean monthly 1949-1980. (NZ Met. Service Misc, Pub. 177). During the early growth of sweetcorn, rainfall was lower than average but in January and March, higher than average rainfall occurred.

3.1.e. Cropping History

The experimental site had previously been planted to the following crops following an unknown period in pasture:

1st crop	winter brassicas	1987(winter)
2nd crop	super sweetcorn	1987/88
3rd crop	vetch and ryecorn	1988(winter)
4th crop	squash	1988/89
5th crop	ryecorn	1989(winter)

After each summer crop the stubble is turned back into the soil. All winter crops are ploughed in.

3.1.f. Treatments

Treatments used for the trial are as follows:

a) Whey - is a liquid by-product of the dairy industry.

b) Compost - is a solid organic waste made up of the following materials under a windrow composting system;

Asparagus tops (green) -15%, Grass/pasture -15%, animal manure-30% and straw-40%.

c) Mineral fertilizers - which include potassium sulphate, North Carolina reactive phosphate rock (RPR) and dolomite. These mineral fertilizers are acceptable to the NZ Biological Producers Council.

The compost and mineral fertilizers were applied on 2/11/89 about four weeks before planting and whey was applied on 15-16/11/89, two weeks before planting. All fertilizers were applied only once and worked in the soil to a depth of 12 cm.

3.1.g. Application Rates

The materials were applied at the following rates:

Material added	Control	Low	Medium	High
whey (m^3/ha)	0	80	160	240
Compost(m^3/ha)	0	80	160	240
Mineral(kg/ha)				
RPR(NC)	0	375	750	1500
K_2SO_4	0	80	160	240
Dolomite	0	2	4	6

Table 3.3. Application rate based on nutrient analysis is as follows (in (kg/ha).

Level/Form		N	P	K	Ca	S	Mg	Cl
HIGH	Whey	336	156	360	300	36	24	216
	Comps	690	461	360	99	-	45	-
	Min	-	156	360	57	144	24	-
MED	Whey	224	104	240	200	24	16	144
	Comps	460	307	240	66	-	30	-
	Min	-	104	240	38	96	16	
Low	Whey	112	52	120	100	12	8	72
	Comps	230	154	120	33	-	15	
	Min	-	52	120	19	48	8	

3.1.h. Chemical analysis of compost and whey

3.1.h.1. NH_4-N and NO_3-N content

Whey and compost were analyzed for inorganic N content by the 2MKCl extraction procedure and NH_4-N and NO_3-N was determined using the AutoAnalyzer Machine.

3.1.h.2. Total N and P

2 g of compost and 1.0 g of whey were digested with 4ml of Kjeldahl digest mixture for Total N and P determination using the Autoanalyzer method (Twine & Williams, 1971; Technicon, 1976).

Analysis shows the following results:

Material	(%) Tot.N	(%) Tot.P	NH_4-N (ug/g)	NO_3-N (ug/g)	%N inorg.
compost	0.55	1.9	255	124	7
whey	0.12	0.41	18.01	neg.	1.6

Note: most of the P in the whey is inorganic (Radford et al, 1986. Compost P is mostly in organic form (Gray and Biddlestone, 1981).

3.1.i. Design and Layout

The trial design was a split-plot with three replications. The treatments are completely randomized (Appendix 1.) and each main plot was divided into nine plots measuring 15 m long and 16 m. Each of the 9 plots was subdivided into 4 subplots to allow for the four rates of application. There was one control for each fertilizer form. Each subplot had 8 rows of sweetcorn.

3.1.j. Planting

Variety Honey and Pearl sweetcorn seeds were mechanically sown on 29/11/89 about three weeks after compost and mineral fertilizer application at a spacing of 0.75 x 0.2m.

Weeding was done only once at the early stage of plant growth using a tyne weeder. Since it is an "organic trial" no pesticides or weedicides were applied.

3.2. Measurements

3.2.a. Plant Sampling

Whole corn plants (excluding roots) cut approximately 5 cm from the base were harvested at different dates as follows:

Sampling date	Days after Sowing	No.of Plts. sampled	Stage of Growth
19/12/89	20	10	Plt. emergence
11/1/90	40	10	Collar of 8th Leaf visible
31/1/90	60	6	Collar of 16th leaf visible
1/3/90	90	6	Silking
20/3/90	120	10	maturity

It can be noted that in two sampling periods only six plants were taken which was due to the limitation on total number of available plants in the rows.

Whole plants were taken randomly from each side of the inner guard row of the two guard rows of each subplot. This sampling pattern was necessary as the inner four rows were required by MAF for final sampling. Sampling was usually undertaken in the morning. The samples were cleaned and weighed fresh then sub-samples were taken for drying, dried weights recorded and the whole plant samples were ground and stored for chemical analysis. For the last/final harvest the plant parts were dried and ground separately into leaves, stalks, grains and cobs (less grain) respectively. MAF sampled the trial at final harvest by taking cobs from the inner four rows and graded them according to quality (grade 1- export; grade 2 - local market; and rejects).

3.2.b. Plant Chemical Analysis

Total N was determined using Kjeldahl digestion method as follows (Mckenzie & Wallace, 1954):

To 0.100g plant sample in a 100ml pyrex tube, 4ml of the Kjeldahl digest mixture (250g K2SO4 and 2.5g selenium powder to 2.5 li of H2SO4 in a 5 li pyrex beaker and heat it or a gas ring until the mixture becomes clear) is added to the tubes which are then placed in the digestion (aluminium) block at 350^{0}C for four hours. The digest is made up to 50ml, mixed with a vortex mixer, let stand for a few hours before total N is determined using the Autoanalyser machine (Technicon, 1976).

Herbage K was determined only on the final harvest samples by the nitric acid digestion method and K is measured using the Atomic Absorption Spectrophotometer.

Some leaf samples of the final harvest were analyzed for both macro and micro nutrients.

3.2.c. Soil Sampling

Soil samples were taken at the same time as the plant samples. Ten soil cores of 2.5 cm each in diameter were taken from each subplot in between the two outside guards row, 5 cores on each side of the subplot and bulked together.

The soil samples were wet sieved to pass through a 2mm mesh. Half of the sieved sample was air dried and stored for analysis of Total N and C and potentially mineralizable N. The sieved field moist soil was immediately extracted with 2M KCl for mineral N (NO3 and NH4-N) content. Soil moisture content was calculated after drying sub-samples at 105^{0}C.

The plots were soil sampled as follows:

Sampling date	No. of plots sampled	Sampling Depth
19/12/89	all plots	0-15 cm all plots
11/1/90	all, except med. rate	0-15 cm
31/1/90	all	0-15 cm all,15-30cm med.rate
1/3/90	all, except med. rate	0-15 cm
20/3/90	all	0-15 cm all,15-30 med.rate

3.2.d. Soil Chemical Analysis

3.2.d.1. pH measurement

For the top 0-15cm. soil, at 1:2.5 soil to solution ratio.

3.2.d.2. Extractable N (NO_3-N and NH_4-N)

To 2 g of soil, 40 ml of 2M KCl was added and the mixture was shaken 1 hour in an end-over-end shaker, then centrifuge for 3 min. at 9000 rpm. Filter through Whatman #40 and the filtrate collected. Mineral N is determined by Autoanalyser (Technicon, 1976).

3.2.d.3. Total Carbon

Total carbon was determined using the Leco Combustion method (Nelson and Sommers, 1982; Tabatabi and Bremner, 1970; Bremner and Tabatabai, 1970).

3.2.d.4. Total Nitrogen

Total N was determined using the Kjeldhal digestion method and total N measured using the autoanalyzer machine (Twine and Williams, 1971; Technicon, 1976).

3.2.d.5 Bulk Density Measurement

Soil samples taken on depths of 0-10 cm and 20-15cm using 2.5cm soil corers were oven dried at 105^{0}C. The weights of the samples plus corer were recorded before and after oven drying.

3.2.d.6. Water Balance

A water balance for the site was calculated using the PTaylor programme based on meteorological data of the site (see Appendix 2.) over the growing period.

3.3. N Mineralization Study.

To measure mineralization potential, two methods were evaluated.

3.3.a. H_2O_2 Extractable N (Saggar, 1990 pers. comm.)

a. To 1 g air dried soil add 2.5ml of 4%H_2O_2

b. Shake for a few seconds with a vortex mixer and stand for 30 minutes.

c. Add 17.5ml of 0.5M KCl

d. Shake for 16 hours in a rotary shaker

e. Centrifuge for 3 minutes at 9,000rpm then filter through a Whatman No. 41 filter paper.

f. Take 5 ml of the filtrate, add a drop of H_2SO_4 (To avoid NH_3-N loss) then oven dry (110^{0}C).

g. Make up the volume to 10 ml and determine mineral N (mostly NH_4-N) using the autoanalyser machine.

h. Subtract the measured NH_4-N from the control (no H_2O_2) to obtain the amount of N mineralized.

3.3.b. Anaerobic Incubation study (Waring & Bremner, 1964)

a. To 5 g soil add 15 ml of deionized water

b. Incubate at 30^{0}C for 7 days

c. At the end of the period, shake the tubes with a vortex mixer for a few seconds

d. Add 5 ml of 8M KCl and shake for one hour

e. Centrifuge at 9000rpm for 3 min and filter through Whatman No.41 filter paper

f. Collect filtrate and analyze for NH_4-N using the autoanalyser machine

g. Measured NH_4-N after incubation less NH_4 before incubation equals mineralized N.

3.4. Data Analysis

Statistical analysis of the data was done using the SAS package programme for analysis of variance of treatment effects. The trial was analyzed as a split-plot design with treatments as main plots and levels as split-plot. Data are presented using Duncan level of significance at 5% probability.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Effect of fertilizer form and rate on the yield of sweetcorn variety honey and pearl

4.1.a. Fresh cob yield

Visual observations in the field showed that crops treated with whey were more vigorous and the leaves were greener compared to mineral and compost treatments where yellowing of leaves as well as stunting of growth were observed, particularly in the mineral treatment. (See plate 1).

Fresh cob yield data taken from the inner guard rows for each fertilizer form and rate is summarized in Table 4.1.

TABLE 4.1 Effect of fertilizer form and rate on the fresh cob yield (kg/ha). Values in () are weight per cob in kg

Rate	Form		
	whey	compost	mineral
control	10831 (.25) e	9907 (.23) f	12027 (.27) cd
low	13523 (.30) b	11029 (.25) e	14791 (.33) a
medium	13728 (.31) b	11777 (.26) d	13589 (.30) b
high	13024 (.29) b	12679 (.28) c	11557 (.26) de

Means followed by the same letter do not differ significantly (Duncan's Multiple Range Test at p=0.05).

In general, the additions of all treatment forms and levels had a positive effect on the yield of sweetcorn. An exception was the high mineral treatment level which was not significantly different from its respective control. At the medium level, whey treatment gave the highest fresh cob yield followed by mineral then compost. At high levels, the whey treatment gave the highest

Plate 1. Trial Site. Taken at tasselling and early silking stage of the sweetcorn plant.

Plate 2. Mature sweetcorn plants taken at final harvest (cobs taken out).

yield. Yields of compost treatment increased with an increase in level but the whey treatment did not.

TABLE 4.2 MAFTech fresh cob yield with actual MAFTech plant population and MAFTech's cob yield data. Values in ( ) are weight per cob

Rate	Fertilizer Form		
	whey	compost	mineral
control	9469 (.22) c	7646 (.19) d	10112 (.20) c
low	12013 (.28) ab	7359 (.18) d	11182 (.28) b
medium	12456 (.30) a	9266 (.23) c	9906 (.24) c
high	12295 (.28) a	11243 (.26) b	8051 (.20) d

Means followed by the same letter do not differ significantly (Duncan's Multiple Range Test at p=0.05).

A discrepancy was observed between the fresh cob yield data calculated in this study from the two inner guard rows (Table 4.1) and that obtained by MAFTech (Table 4.2). The difference probably relates to the method of assessment of plant population density used by MAFTech and that used in this study. Furthermore, for all treatment levels the weight per cob from the inner guard rows (Table 4.1), where destructive sampling was carried out over the growing period, were higher than that obtained from the four middle rows (Table 4.2) where plant sampling was done only at final harvest. This effect maybe due to less competition for nutrients and moisture by the plants from the inner guard rows as destructive sampling would have lowered the population per unit area.

In calculating the fresh cob yield from the guard rows (Table 4.1), the plant population density was assumed to be 44,000 plants per hectare irrespective of treatment. This value was calculated by averaging the number of plants per row from ten randomly selected plots which covered a range of treatments. No obvious treatment effect was apparent from this data.

However, examination of the MAFTech actual plant population per plot for the whole trial (Appendix 3) indicated that although there were significant differences in plant population between some treatments (particularly mineral) they were relatively minor but would have some effect on cob yield data. The MAFTech overall average population was measured as 42,000 plants per hectare which is slightly lower than that used (44,000) to determine cob yield in Table 4.1.

The MAFTech results most accurately reflect treatment yield data for the site as MAFTech was able to take more samples from a greater area per plot (i.e. 4 middle rows) and counted actual plant population per plot.

Based on MAFTech's actual yield data (weight per cob and actual plant population, Table 4.2.) the trend in decreasing order is as follows: medium whey > high whey > low whey > low mineral > high compost. No significant differences existed between whey treatment levels but yields of medium and high whey treatments were significantly higher than compost and mineral treatment yields.

The medium mineral and low compost treatment levels gave yields not significantly different to their respective controls with the high mineral treatment showing a significant depression in yield.

Although differences existed between the yield determined in the present study and actual MAFTech yield data, it is quite apparent that yields and weight per cob obtained have similar trends i.e. both whey and compost additions showed significant yield increases over control but overall, the whey treatment obtained the highest yields.

The mineral treatment showed the largest discrepancy between the two yield evaluations which could be a reflection of the difference in actual plant population density in this treatment.

The yields obtained from this trial using MAFTech data in Table 4.2., (excluding control yields) ranged from 7-12 t/ha which would be considered slightly lower than the average yield level for sweetcorn in New Zealand. Wallace (1987), reported a national average of sweetcorn yield for fresh market to be 12-15 t/ha. and for processing of about 10-12.5 t/ha. The lower yield from this trial maybe attributed to the weed population which competed for nutrients and moisture (see Section 4.2-3). It has been reported that weeds can take up about 65 kg N/ha when growing in association with maize (no value for K given) and as much as 100 kg N/ha and 180 kg K/ha when growing in association with wheat (FAO, 1975).

Reasons to explain yield differences between treatments and their respective levels are difficult to identify because each treatment had been applied over a period of 3 years and a range of summer and winter crops have been grown and their subsequent residues incorporated into the soil. This has created different fertility gradients across the trial site.

For instance, examination of soil test data prior to sowing of sweetcorn (Appendix 4) shows that for the two major nutrients P and K (Appendix 4 table 3 and 4), which are likely to be deficient, a range of availability status existed. For P, the control treatments had an Olsen P value averaging 24. With increasing levels of compost and whey, Olsen P values also increased and at high levels, Olsen P values were 45 for whey and 36 for compost. With the mineral treatment levels, Olsen P values ranged from 24-29 which were much lower than the whey and compost treatments. Low compost and medium whey levels, which have comparably similar N added, have Olsen P values of 34 and 43 respectively. However, the use of Olsen P to characterize available P status where reactive phosphate rocks are used has been shown to underestimate available P (Saggar *et al.,* 1991) further complicating interpretation of yield results in relation to P responsiveness.

For K, (Appendix 4, Table 5) control treatments had an average value of 4 prior to sweetcorn sowing, which from the New Zealand literature

(MAFTech, 1986) would indicate the likelihood of a K response. With increasing levels of whey and compost, K values increased with whey treatments increasing at a faster rate than the compost treatments. Mineral treatments only showed an increase over control at the high rate.

Mineral inorganic nitrogen (Ni), although determined 20 days after sowing (see Table 4.10, Section 4.4.), also showed a marked difference between treatments with control plots averaging 33 kg Ni/ha and whey treatments increasing to 132 kg Ni/ha at the high rate. Whether these differences exited between treatments prior to fertilizer application in 1990 is unknown as no measurements of Ni were taken at that time.

The compost treatment levels also showed an increase in Ni but the rate of increase was much lower than the whey treatment. Mineral treatment levels showed no differences in their Ni levels with increased rates.

Of the other soil chemical characteristics (Appendix 4, Table 1) 20 days after sowing, pH did not vary much (6.17-6.43) between treatment levels and are within the range recommended (pH 5.3-6.8) for sweetcorn by MAFTech (1986). Mg (Appendix 4, table 6) increased only at the high rates for all treatment forms, from an average control value of 9.4 to 11 for whey, 16 for compost and 13 for mineral. No information on Mg response in relation to soil Mg level appears to be available in the New Zealand literature.

Differences between treatments in relation to fresh cob yield are unlikely to be due to soil physical effects. From visual inspection of the soil and a limited number of physical measurements (Appendix 5) which include bulk density (average 1.08 g/cc for the top 0-15 cm) and gravimetric water content (0.40), there does not appear to be any treatment effects on soil physical properties even though a high number of earthworms were observed in all whey treatments (MAFTech Annual Report, 1990).

Another factor that makes it difficult to identify reasons for treatment differences was that each treatment applied contained nutrients in varying degrees of availability and different ratios of total nutrient levels (see Chapter 3 Section 3.1.g.) with only K as the common nutrient added at an equal level for the different treatment forms. Therefore, to assess the effects of added nutrients in any treatment on yield is difficult as its effects are due not only to the actual fertilizer treatment but also due to the residual effects in the soil from previous applications.

To determine whether N additions from the different fertilizer forms influenced yields, a comparison can be made between whey and mineral treatments at all levels as the mineral treatment had no added N but has equivalent levels of P and K. However, the P additions from each of these two treatment, although similar at each level, may differ in their P availability. Olsen P values, as stated previously, do not reflect the true P status of the mineral treatments and therefore, cannot be used to determine whether P additions from whey and mineral are equally effective.

MAFTech recommendations for sweetcorn (MAFTech, 1986) indicates that a 16 ton fresh cob yield would have P uptake of only 9 kg P/ha or 1.8 kg P/ton while N cob uptake was 62 kg N/ha or 4 kg N/t indicating that sweetcorn is not particularly demanding of P as it is for N. Thus, the difference in P availability of the 2 treatments (whey and mineral) may be of little consequence.

To determine whether N form is of importance, a comparison can be considered between low compost (230 kg N/ha) and medium whey (224 kg N/ha) treatments. However, these treatments have variable total amounts and availability of K and P.

Examination of Olsen P data from these treatments prior to sowing of sweetcorn indicates a difference of 10 units (Appendix 4, Table 3). The lower value of 34 for compost, however, is still likely to provide sufficient P to be considered non-limiting in these treatment comparison.

On the other hand, with respect to K, high amounts have been applied over the period of 2 years of whey additions; 240 kg K/ha compared to 120 kg K/ha from low compost additions. Soil test results in Appendix 4 Table 4 show that the medium whey treatment had a K value of 11 compared with 5 in the compost treatment thus, providing a differential K status which consequently, would mean that the compost treatment is more likely to be K responsive and the whey treatment will not be as K responsive.

Therefore, if the medium whey treatment had a greater yield than the low compost the effect may be due not only to a higher N availability of the added whey but also due to a possible K deficiency on the compost treatment. This will be discussed more fully in Section 4.3.

Data in Table 4.2 showed a difference between yields of control treatments. The compost control yield was lower than the controls of whey and mineral treatments. This may be a positional effect related to the initial lower K status of the control compost treatment prior to sowing and the initially lower Ni values 20 days after sowing (Section 4., Table 4.10) or simply be due to a lower plant population density (Appendix 3).

With regard to N responsiveness, comparison between whey and mineral treatment yields indicate that at all levels, whey performed significantly better than the mineral treatment. The added N from the whey maybe the major reason since equivalent levels had similar amounts of added K and a large difference in N uptake existed (see Section 4.2). Furthermore, at all levels, whey had initial soil quick test K values higher than the mineral treatment (Appendix 4, Table 4) which suggests that whey treatment levels are not likely to be very K responsive initially. Whether N from the application of whey prior to sowing in 1990 is mainly responsible for the high yield or due to the cumulative effect of whey additions from three years application cannot be resolved as Ni levels were not measured on the whey and mineral treatments prior to fertilizer application in 1990.

One cannot fully eliminate the possibility of the yield difference between the mineral and whey treatment being due in part to added P. Even though similar in amount added, the P availability may not be the same. Olsen P values in Appendix 4, Table 3, show that the mineral treatment had lower values than the whey treatments. As previously stated, Olsen P values do not truly reflect the P status of mineral plots where reactive phosphate rock was added.

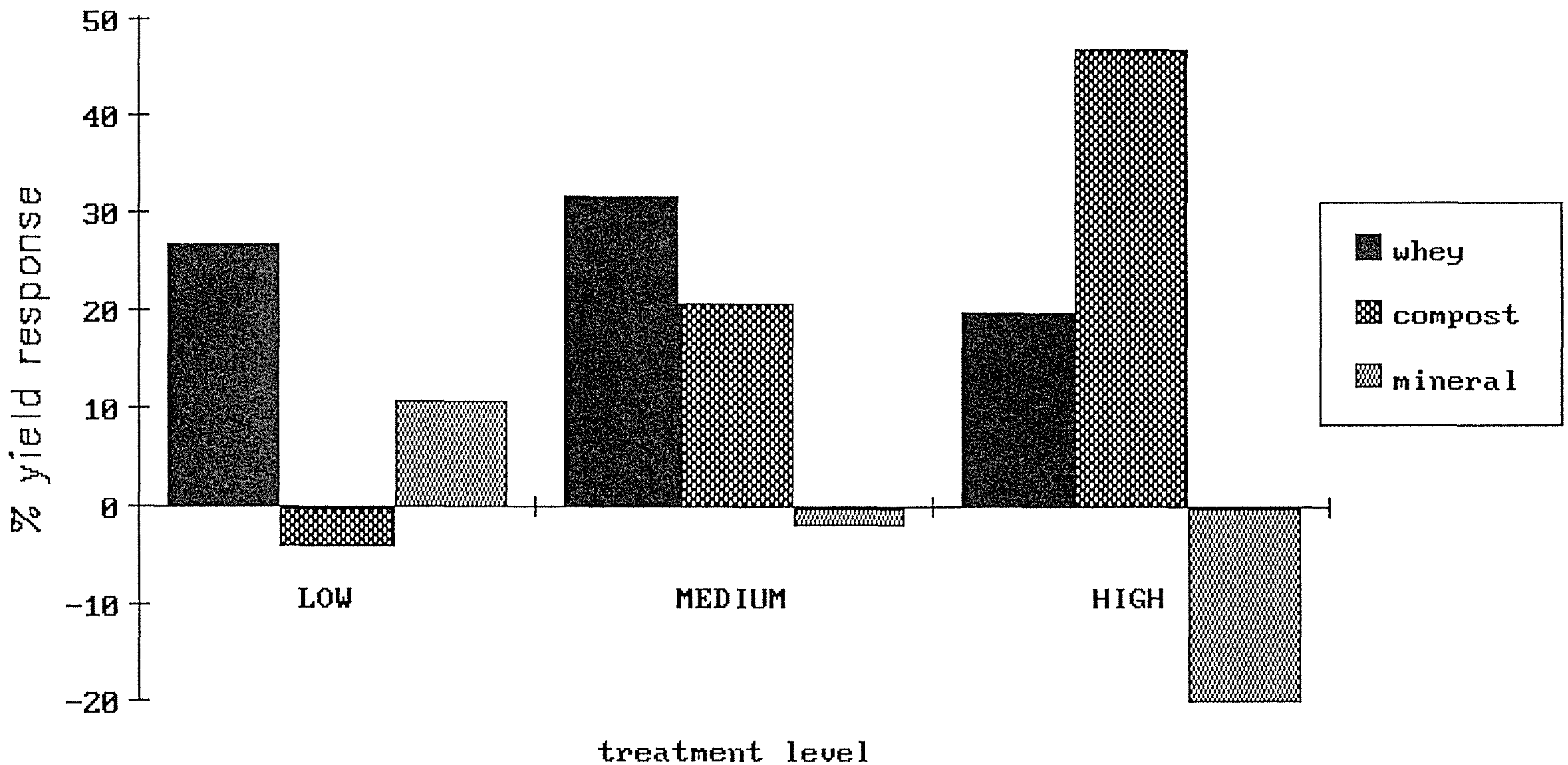
The extent of yield responses for each main treatment was calculated from the control of each treatment (Figure 4.1). Data showed that for whey treatment, average response was 26% from its control. Medium level gave highest response (32%) followed by low level (27%) and the high level gave the lowest yield response (20%).

For the compost treatment, yield response increased with an increase in level (-4% to 47%) where high level gave a response of 47% which was probably due to the low yield value of its control compared to controls of whey and compost. Overall average response of the compost treatment over its control was 21%.

For the mineral treatment, yield response decreased with an increase in level, with overall average of -4%. The high mineral level gave a negative yield response of -20% over its control although the weight per cob was not significantly different. The unusually high plant population of one replication of the control mineral treatment maybe the main reason for this finding along with soil nutrient interactions (see Section 4.2-3).

Overall, the whey treatment gave a better yield response than the compost and mineral treatments. Comparison of the yield levels and percentage responses of medium whey and low compost treatments, which have equivalent N levels, showed that yields and percentage response of medium whey was significantly higher than the low compost (Table 4.2). This difference maybe due to differences in the N availability from the two treatments. Montagu and Goh

Fig. 4.1. Relationship between yield response and treatment level.



(1989), reported that the poor yield of tomatoes treated with compost was assumed to be due to the low availability of N in compost. However, whether the difference was due to the high N availability and/or high K status of the whey treatment cannot be resolved as no plant leaf analysis were taken to identify adequacy of K levels at silking in the two treatments.

4.1.b. Graded fresh cob yield

As organically grown sweetcorn has export potential, MAFTech graded the fresh cobs from each treatment and classified them into different grades based on the percentage filled grains of each cob. Grade 1 is export grade; grade 2 for local market and deformed or cobs with mostly unfilled grains were graded as rejects (Table 4.3.).

Results show that the whey treatment had the greatest number of exportable grade cobs relative to its total yield compared with compost and mineral treatments. Total exportable grade cobs from the whey treatment averages 4.9 t/ha for all levels, excluding control, grade 2 cobs 1.6 t/ha and total rejected cobs had an average of 5.6 t/ha. These grading correspond to an average of 41%, 13% and 46% of the total yield, respectively.

The compost treatment had an average of 2.4 t/ha of grade 1 cobs, 1.8 t/ha of grade 2 cobs and average rejected cobs of 4.6 t/ha from all levels corresponding to 26%, 23% and 52% of total yield respectively.

The mineral treatment had the lowest number of grade 1 cobs averaging 1.8 t/ha, 2.4 t/ha of grade 2 cobs and 5.4 t/ha of rejected cobs from all levels which corresponds to 19%, 24% and 57% of the total yield respectively.

TABLE 4.3 Graded fresh cob yield (kg/ha). Figures in () are percentage of total yield based on MAFTech actual yield (Table 4.2).

Form/Rate	Control	Low	Medium	High
Whey				
Grade 1	2024 (21)	5133 (43)	4888 (39)	4925 (40)
Grade 2	1676 (18)	1583 (13)	1987 (16)	1217 (9)
Rejects	5769 (61)	5297 (44)	5581 (45)	6152 (50)
Compost				
Grade 1	1829 (23)	896 (12)	2465 (27)	4286 (38)
Grade 2	1141 (14)	1642 (22)	2579 (28)	2059 (18)
Rejects	4676 (61)	4821 (66)	4222 (46)	4898 (44)
Mineral				
Grade 1	2440 (24)	2115 (19)	2113 (21)	1363 (17)
Grade 2	2534 (25)	3053 (27)	2482 (25)	1618 (20)
Rejects	5138 (51)	6013 (54)	5311 (54)	5070 (63)

The above data have not been statistically analyzed. However, the mean values are from replicates that varied < 10% in yield.

The results further showed that the mineral treatment had the most number of rejected cobs in relation to its total yield. The high mineral level contributing the largest number of rejected cobs (63% of total yield). This effect may be related to the poor total yield of high mineral level, the reason for which had been discussed in the previous Section (4.1).

These results for grading are parallel to the trend and differences observed in fresh cob yield between treatments.

4.1.c. Dry matter yield (total plant less roots)

The total dry matter harvested from the two inner guard rows for all treatments are reported in Table 4.4. All treatments showed a yield response over the control with the highest yields from medium and high whey > high compost > medium mineral. In the whey treatment, dry matter yield of the low level was significantly lower than medium and high level. The high mineral treatment yield did not differ significantly from the control.

The dry matter yield, in general, relate to fresh cob yield data presented in Table 4.2. The pattern of gain in dry matter yield is shown in Figure 4.2. Prior to 60 days, dry matter yield increase was slow but from the 60th to the 80th day after sowing was rapid and the growth rate slowed after the 80th day till maturity. This pattern of dry matter accumulation is consistent with that shown for maize (Zea Maize) reported by Hanway (1962), although the length of time that sweetcorn is grown is shorter by 2-3 months.

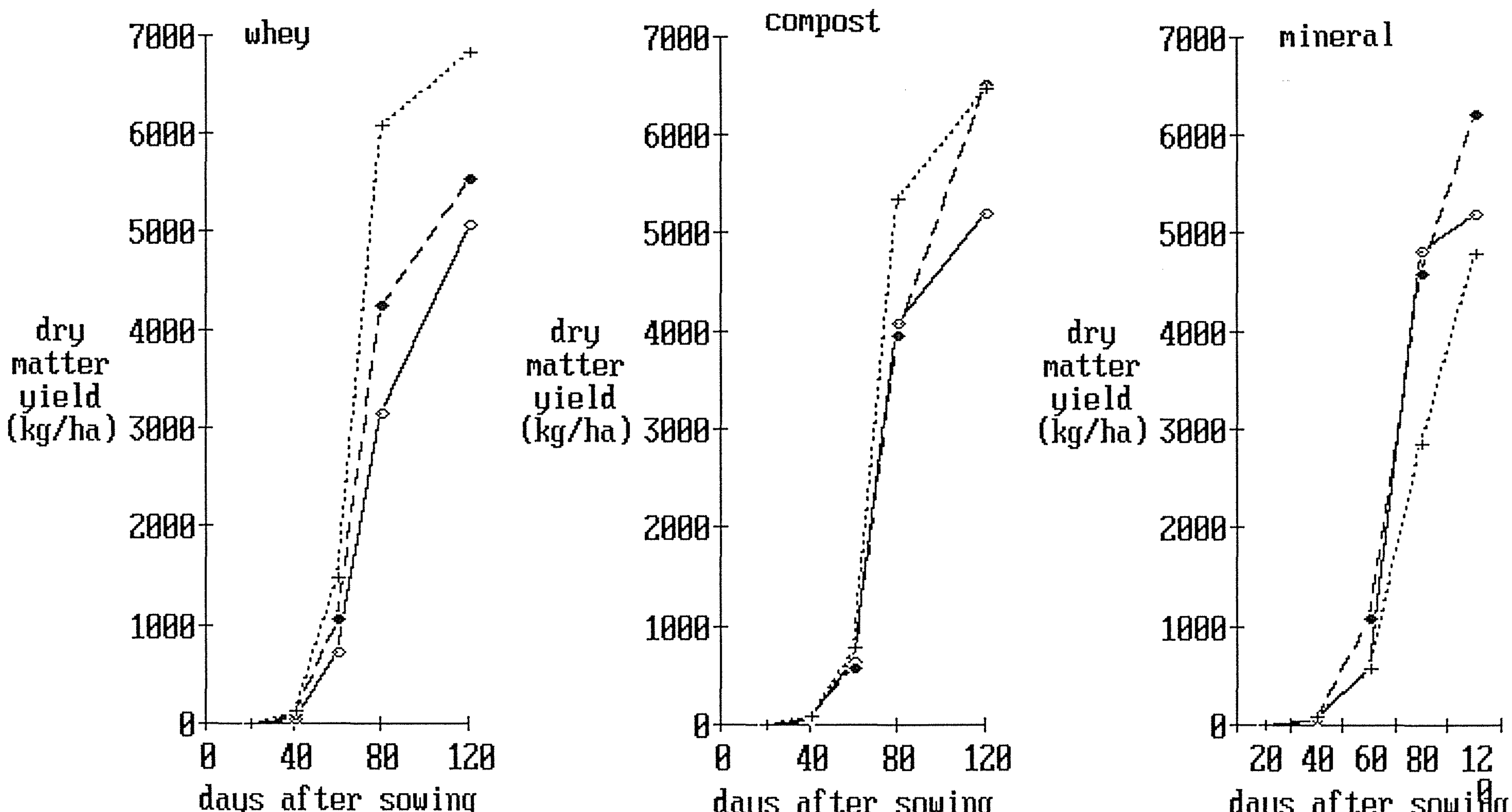
TABLE 4.4. Dry matter yield of whole plant at final harvest (kg/ha).

Rate	Fertilizer Form		
	whey	compost	mineral
control	5060e	5192e	4811ef
low	5529d	6512bc	6204cd
medium	7010a	5573d	7040a
high	6820ab	6482c	4796f

Means followed by the same letter do not differ significantly. (Duncan's Multiple Range Test at p=0.05)

At any one time, the whey treatment showed higher gains in dry matter yield compared with the compost and mineral treatments. Increasing the level of whey and compost treatments increased the rate of gain in dry matter yield over time. The mineral treatment, however, differed in the pattern of dry

Fig.4.2. Dry Matter Yield over time for control (o), low (●), high (+) levels.



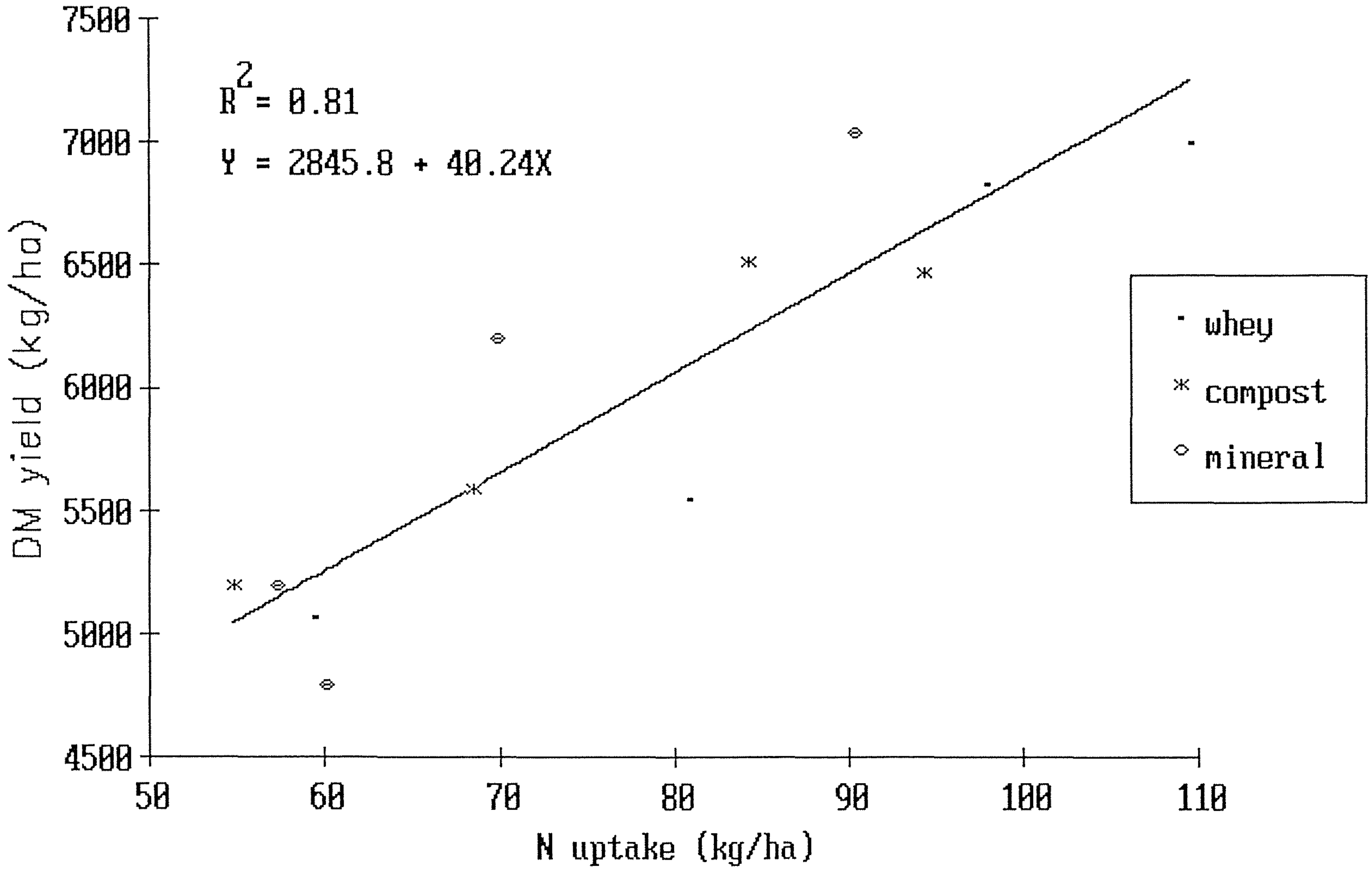
matter yield as low levels gave relatively higher gains compared to the high level.

This pattern of response by the high mineral treatment is similar to the fresh cob yield data for this treatment. As indicated previously, there is a difference in the plant population between these 2 treatments. In addition, evaluation of the N and K uptake data for all mineral levels (Section 4.2-3) suggests a lower uptake at the high mineral level. It is possible that in the high mineral level the high amounts of added K_2SO_4 (360 kg K/ha) may have generated salt toxicity. Corn plants appears to be sensitive to high salt concentrations (Mengel and Kirkby, 1978). However, no measurement on electrical conductivity was made and this reason must remain speculative. Leaf analysis done from samples taken at the final harvest (Appendix 6) showed relatively high K concentration (1.09% K) in the high mineral treatment which might have depressed yields.

Pooling all data from the trial, a significant linear correlation existed between dry matter yield and sweetcorn N uptake as shown in Figure 4.3. Individual treatments showed significant linear relationships with $R^2 = 0.94$ (whey) and $R^2 = 0.92$ (compost) respectively while mineral treatment had $R^2 = 0.89$ and overall correlation coefficient (r) of 90, signifying the importance of N uptake in determining dry matter yield of sweetcorn.

Stanford (1975), gave N concentrations in the range of 1.16% N to 1.25% N (ave. 1.2%) in total maize dry matter (stover and grain) associated with near maximum yields (maize grain yield of 6.3 t/ha). He further pointed out that the percentage N in total dry matter at maximum yield is unaffected by variety, location, climate or level of attainable yield. In the present study percentage N concentration of the treatment associated with highest yield (medium whey) was 1.7% N in the whole plant for a 7 t/ha dry matter yield. Therefore, the findings in this trial in relation to yields may have a wider applicability.

Fig.4.3. N uptake against dry matter yield of sweetcorn plant.



4.1.d. Grain Yield

Grain yield results (Table 4.5.) showed that control plots gave significantly lower yields than the 3 treatment levels. Results show similar pattern to fresh cob yield (Table 4.1) i.e. medium mineral > medium whey > low and high compost > high whey > low mineral > low whey.

Medium levels of mineral and whey had the highest grain yield of 1911 kg/ha and 1829 kg/ha respectively while medium level of compost gave the lowest grain yield of 1254 kg/ha which is not different from yields obtained with high mineral.

TABLE 4.5 Grain yield (dry wts. kg/ha)

Rate	Fertilizer Form		
	whey	**compost**	**mineral**
control	685h	907g	999g
low	1429de	1722c	1557d
medium	1829ab	1254ef	1911a
high	1690c	1720c	1338ef

Means followed by the same letter do not differ significantly (Duncan's Multiple Range Test at p=0.05).

Medium whey when compared with low compost treatment gave a significantly higher grain yield which is consistent with that observed for fresh cob yield and total plant dry matter yield. Possible reasons for this were discussed in earlier sections (Section 4.1.).

4.2 Plant N uptake

4.2.a. N uptake of sweetcorn overtime

Plant N uptake over the growing period is shown in Figure 4.4. The curve for N uptake parallels that of the dry matter production as shown in Figure 4.2. Hanway (1962), also found a similar relationship between N uptake and dry matter for maize. After day 40, all treatments showed an increasing trend in N uptake of the whole plant over time. Overall, sweetcorn plants took up more N from the whey treatment at all levels compared to compost and mineral treatments.

In both the whey and compost treatments, N uptake increased with an increase in levels. However, for the mineral treatment, low levels provided a higher N uptake than at high levels.

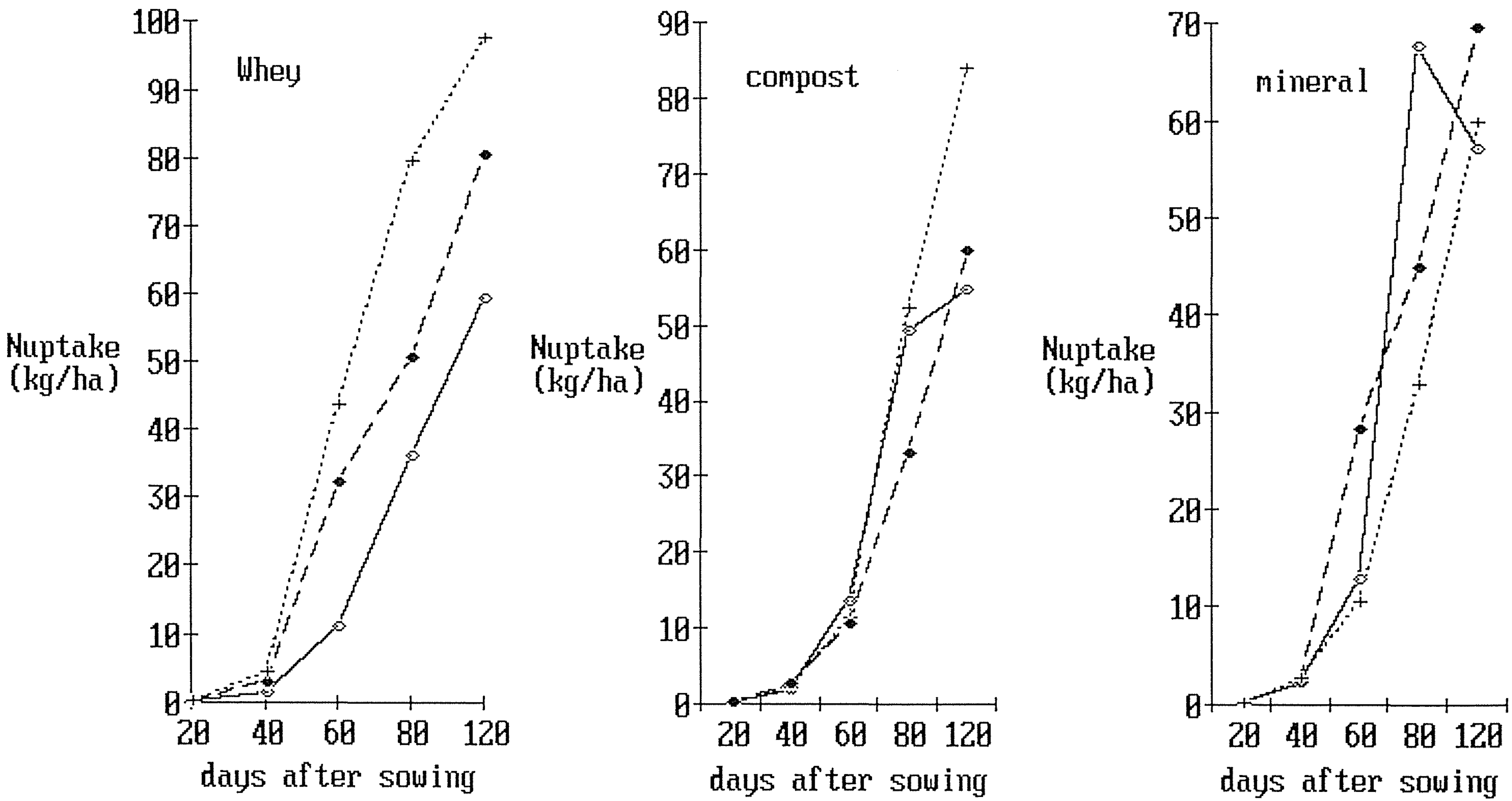
The highest N uptake of 106 kg N/ha by the whole plant was obtained at the medium level of whey which is significantly different from both high and low levels. The compost treatment at the high level had a total N uptake of 91 kg N/ /ha which is significantly higher than low and medium levels. For mineral treatment, medium level gave the highest uptake (87 kg N/ha) and the lowest N uptake of 59 kg/ha N at the high level which is not significantly different from the control.

The percentage increase of plant N uptake when whey was added at 224 kg N/ha over the control plots was 46% and 42% when applied at the rate of 336 kg N/ha.

Compost, when applied at medium rate of 460 kg N/ha increased plant N uptake by 35% and at the high rate of 690 kg/ha N uptake was further increased by 42%.

Although the mineral treatment had no external source of N added, there was

Fig.4.4 Plant N uptake over the growing period for control (o), low (o) and high (+) level



an increase in plant N uptake of 22% at the low level and a 37% increase at the medium level but at the high level there was no difference in N uptake from the control. On this treatment the amount of N availability to plants will depend entirely on mineralization of the fresh residue added from previous crops, particularly the winter crop of 1989.

The differences in the N uptake occurring between the controls and the mineral treatment at all levels would be expected to relate to differences in mineralization rate and availability of organic substrate. It might be expected that if P and K deficiencies are likely on this soil type, then increasing levels of added P and K in the mineral treatment might be expected to effect an increase in dry matter production of plants grown in the rotation, particularly in the winter crop of 1989. However, yield data of the 1989 winter crop (Appendix 7) show little difference in dry matter yield which suggests that increased N uptake of the low and medium levels was due to more favourable P and K status allowing greater plant growth and N uptake.

The reduced N uptake at the high mineral level is unexpected and may be due to the high amounts of added K_2SO_4 which might have influenced the mineralization ability of the microorganisms due to high salt content or possibly a phosphate induced Zn deficiency (Mengel and Kirkby 1978).

Comparison between the whey and mineral treatments showed significantly higher N uptake in the whey treatments which indicates that the sweetcorn is responsive to the added N from whey. However, whether the P in the whey treatment also had an effect on the sweetcorn yield is unclear. An attempt was made to measure Resin P from the soil samples taken 20 days after sowing of the mineral treatment to assess the availability of P between the whey and mineral treatments. The Resin P is reported to give a better indication than Olsen P of the actual soil P status where phosphate rock had been applied (Saggar, 1991 pers. comm.). The Resin P and Olsen P values measured at approximately the same period are reported in Appendix 8 and Appendix 4, Table 3. Results, however, showed that Resin P only slightly increased with an increase in level of PR added and therefore, do not appear to reflect a much higher available P status than that indicated by the Olsen P test.

The data on N uptake indicate that losses of N due to product (cob and grains) removal will vary from 32 kg N to 77 kg N /ha depending on the treatment. These N removals represent the net N loss from each treatment level, since the stovers are turned back into the soil, and therefore they represent the amount needed to be replaced to sustain the N status of each treatment.

At maturity, a large proportion of the N taken up by the plants was in the grain component. This is as expected since similar findings are reported for maize (Hanway, 1962). On average, about 46% of the total N uptake was in the grains, 24.5% in the cobs (less grains), 19% in the leaves and 10% in the stalks/stems. (See Table 4.6.).

4.2.b. N uptake by weeds

New Zealand MAFTech (1986), reported that sweetcorn N uptake for a 16 t/ha cob yield is about 62 kg N/ha or 4 kg/t and for the whole plants is about 112 kg N/ha. With some exception (medium whey and mineral and at the high levels of the three forms) data reported in this present study are generally lower than the above values and may be due to the competition by weeds at the site.

Uptake of N by weeds was measured only in some treatments and mean values are reported in Table 4.6. Data showed that weeds of different varieties had taken up 35%, on average, of the total sweetcorn N uptake. In the high level of whey, weeds had taken up as much as 47% of the total crop N uptake.

N uptake data of weeds, although limited, showed that the amounts of N taken up was substantial. While not representing a loss from the plant-soil system,

TABLE 4.6 N uptake of sweet corn parts at harvest (kg/ha)

Treatment/rate	Plant Part				Total Plant	Weed	Total plant + weed
	grain	leaf	cob (-grain)	stover			
Control							
Whey	25.2	11.4	13.5	7.3	57.4g	35.4	92.86
Compost	20.3	13.9	12.0	6.4	52.7g	26.1	78.79
Mineral	26.5	10.5	13.7	4.6	55.2g	nd	-
Low							
Whey	33.7	15.8	20.8	7.4	77.7de	nd	-
Compost	42.0	11.6	21.3	6.5	81.4cd	nd	-
Mineral	34.3	9.4	15.8	8.3	67.7ef	nd	-
Medium							
Whey	44.3	18.5	32.8	9.9	105.5a	nd	-
compost	28.7	15.1	15.4	6.8	66.0ef	nd	-
Mineral	44.9	13.6	21.5	7.5	87.4bc	nd	-
High							
Whey	42.5	19.1	22.6	14.5	98.7b	46.9	145.7
compost	43.9	6.3	23.2	7.6	91.1b	43.4	134.5
Mineral	29.8	13.9	11.8	3.4	59.1fg	29.4	88.5

d=not determined

as all weeds are returned back into the soil, considerable competition for N during the growing period may have existed between the weeds and the sweetcorn. The competitiveness of the weeds is probably of more importance in the early growth stages of the sweetcorn. Unfortunately, only the sweetcorn N uptake was measured in early stages of growth while the N uptake of the weeds was measured only at the final harvest period in some treatment levels only.

In this particular year, weed competition for soil moisture was probably not crucial as water balance data indicate soil water deficit condition only for 17 days in the first 60 days of growth, which are not likely to affect growth Appendix 9).

Visual estimates by MAFTech of the weed population showed that the low compost treatment had the largest number of weeds (Appendix 10). There was also differences in the weed species present in each organic source. Amaranths were more dominant in the whey treatments, polygons were more dominant in mineral treatments and compost treated plots have more of other weed species not specifically identified.

4.2.c. Plant N recovery from whey and compost fertilizers

N recovered by plants is derived from both the soil and the added fertilizers. Apparent plant N recovery from the two fertilizer forms was determined for sweetcorn on the whey and compost treatments and weeds only in the high levels of both fertilizers (Table 4.7)

The net N uptake from each treatment form are on average, 37 kg N/ha for whey and 26 kg N/ha for compost. Apparent recovery of N from the fertilizer sources are low. These values are also likely to be an overestimation as plant N uptake from each treatment is not only a reflection of the fertilizer added in the 1989 but also probably from the residual effects of the previous two years addition.

In comparing the low compost and medium whey, which received equal amounts of added N, the apparent recovery of applied N showed that medium whey treatment had recovery of 22% of the applied N compared with only 12% of compost treatment.

TABLE 4.7 Apparent N recovery from whey and compost fertilizers

Treatment/Form	Net N uptake[1] (kg/ha)		% Plant N Recovery[2]	
	Sweetcorn	Weeds	Sweetcorn	Weeds
Whey				-
Low	21	-	18.7	-
Medium	49	-	21.9	-
High	42	54	12.5	16
Compost				
Low	28	-	12.5	-
Medium	13	-	3	-
High	38	55	5.5	7.9

1Treatment N uptake minus N uptake of control treatment

2* Recovery = N <u>Uptake of fertilized plant-control</u> X 100/1
amount of applied fertilizer N

*(Greenwood and Draycott, 1988).

This recovery difference further indicates that the N components in compost are not readily available to plants. When apparent N recovery by weeds was added to the apparent N recovery by sweetcorn, percentage recovery for both the high whey and compost treatments increased, but N recovery by sweetcorn for the two fertilizers remained low.

4.3 Plant K uptake

Plant uptake of potassium was only measured at the time of final harvest and results are shown in Table 4.8 for all treatments. Based on the rates of K added, results showed that in the whey treatment, plant K uptake increased with an increase in level added. While in the compost treatment, K uptake was high at the low level then decreased at the medium level and again increased at the high level. In the mineral treatment, K uptake increased with an increase in level up to the medium level but decreased at the high level.

Table.4.8 K uptake of sweet corn parts at harvest. (kg/ha)

Trt / rate	Plant Part				Total Plant	Weed	Total plant + weed
	grain	cob*	leaf	stover			
Control							
Whey	18.7	13.7	11.6	40.3	84.4	82.9	167.3
Compost	10.6	7.7	11.9	26.9	57.1	143.0	200.1
Mineral	18.4	12.4	10.6	26.1	67.5	nd	-
Low							
Whey	24.9	17.2	13.6	33.7	89.4	nd	-
Compost	31.2	21.9	10.5	44.7	108.3	nd	-
Mineral	26.6	16.7	9.5	45.3	98.1	nd	-
Medium							
Whey	33.6	26.1	16.4	45.2	121.3	nd	-
Compost	19.9	13.7	13.1	34.6	81.3	nd	-
Mineral	19.2	12.8	13.2	55.2	100.4	nd	-
High							
Whey	33.3	22.0	13.7	56.9	125.9	137.4	263.3
Compost	25.7	18.2	15.2	33.8	92.9	85.9	178.8
Mineral	13.3	7.5	15.7	25.3	61.8	141.5	203.3

*nd=not determined   cob (less grains)

For the compost treatment, low levels gave the highest K uptake which was an 89% increase over the control and the medium rate gave the lowest uptake of 81.3 kg K/ha which is about 42% increase over the control. In the mineral treatment K uptake increased at low and medium level by 45% and 49% respectively over the control. Similar to N uptake, the uptake of K by sweetcorn at the high level of mineral treatment was no different from the control.

Figure 4.5 shows the effect of added K from the different fertilizer on fresh cob yield (MAFTech data). As had been discussed in previous sections, these response differences may not be due only to the K component of the fertilizer form. Compost and mineral treatments showed contrasting results i.e. at rates of more than 112 kg K/ha fresh cob yield increased with increase in rate for compost while a decrease was observed for mineral. This effect could be related to previous explanation given in Section 4.1.

K uptake is correlated well with dry matter yield (Figure 4.6). The correlation coefficient obtained for individual treatments are as follows: whey (r=.94), compost (r=.92) and mineral (r=.97). These correlation values however, are derived from a limited number of observations. Also, a linear relationship was observed with N uptake and K uptake with $R^2 = 0.79$. This good relationship is as expected as both K and N are needed by the growing crops in more or less similar amounts. As reported by Mengel and Kirkby (1978), for grain crops, an intensive rate of grain filling is obtained if the level of N-nutrition is high during the grain filling period and the K status of the plant is also at an optimum level.

K uptake by weeds was measured in selected treatments and data (Table 4.8) showed that their K uptake was surprisingly high. Based on equivalent K additions at high rates of whey and mineral treatments, K uptake of weeds were as high as 137.4 and 141.5 kg K/ha respectively which are 52% and 69% of the total crop K uptake. Like N uptake by weeds, these values indicate that weeds are also competitive for K particularly where the initial

Fig.4.5. The effect of added K in the fertilizer on fresh cob yield of sweetcorn.

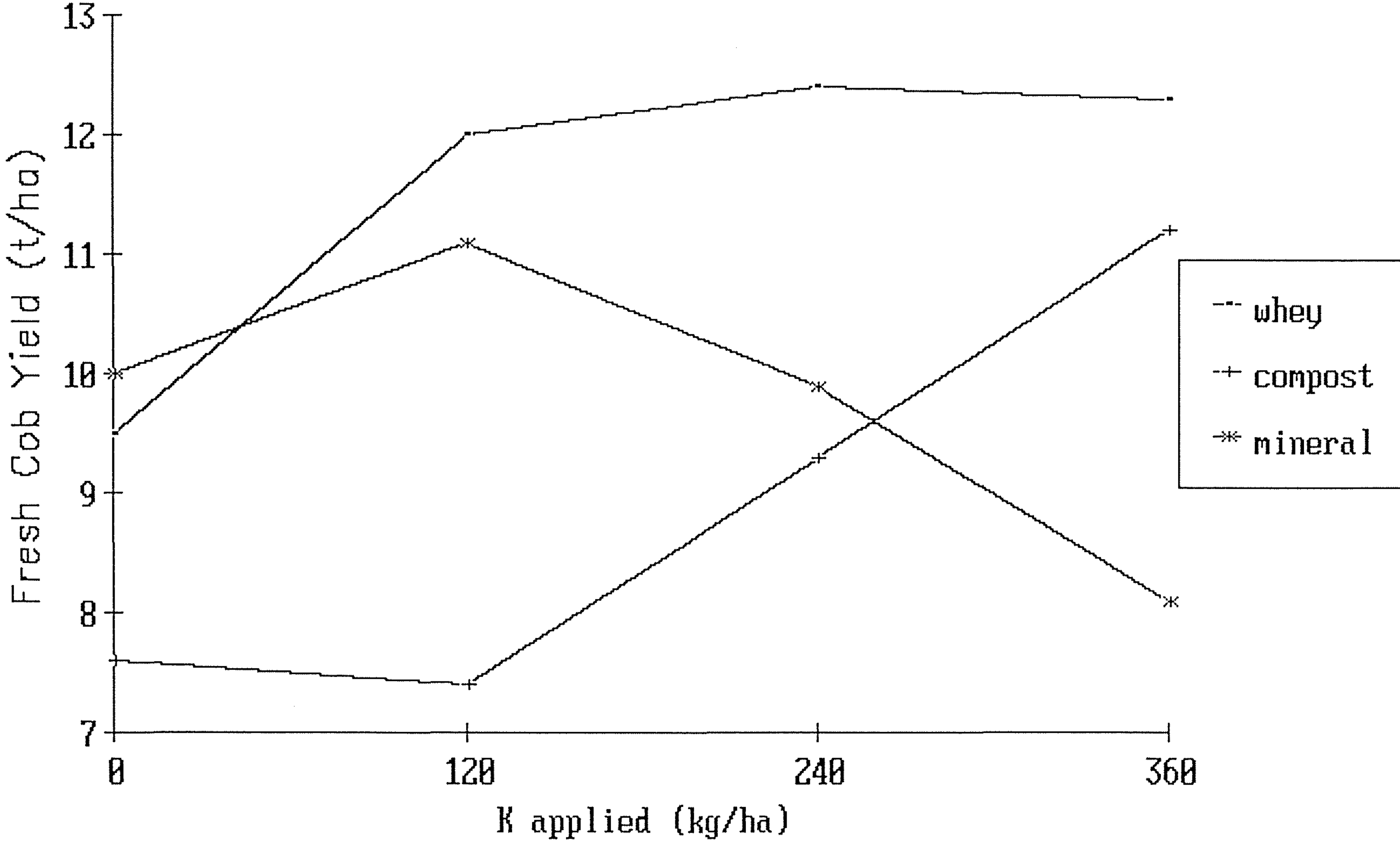


Fig.4.6 K uptake against the dry matter yield of sweet corn

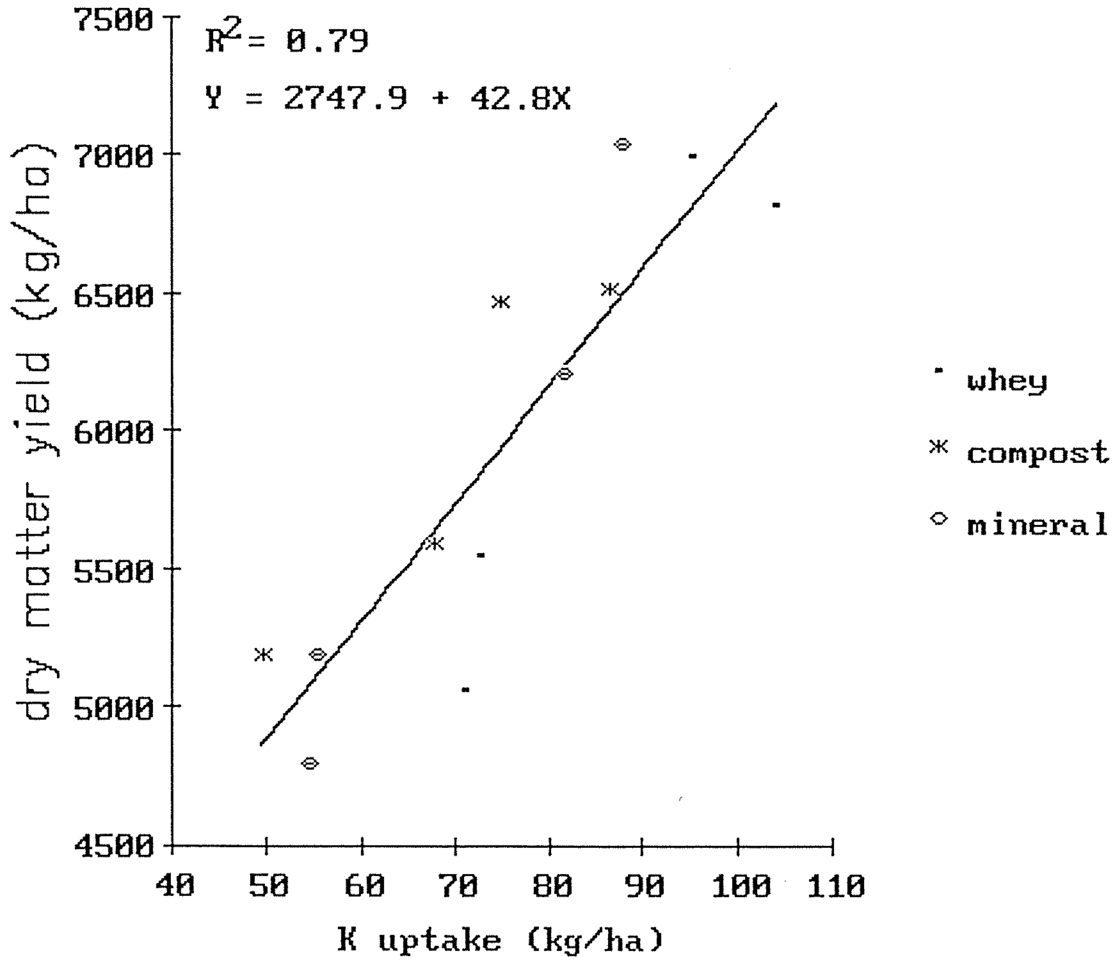
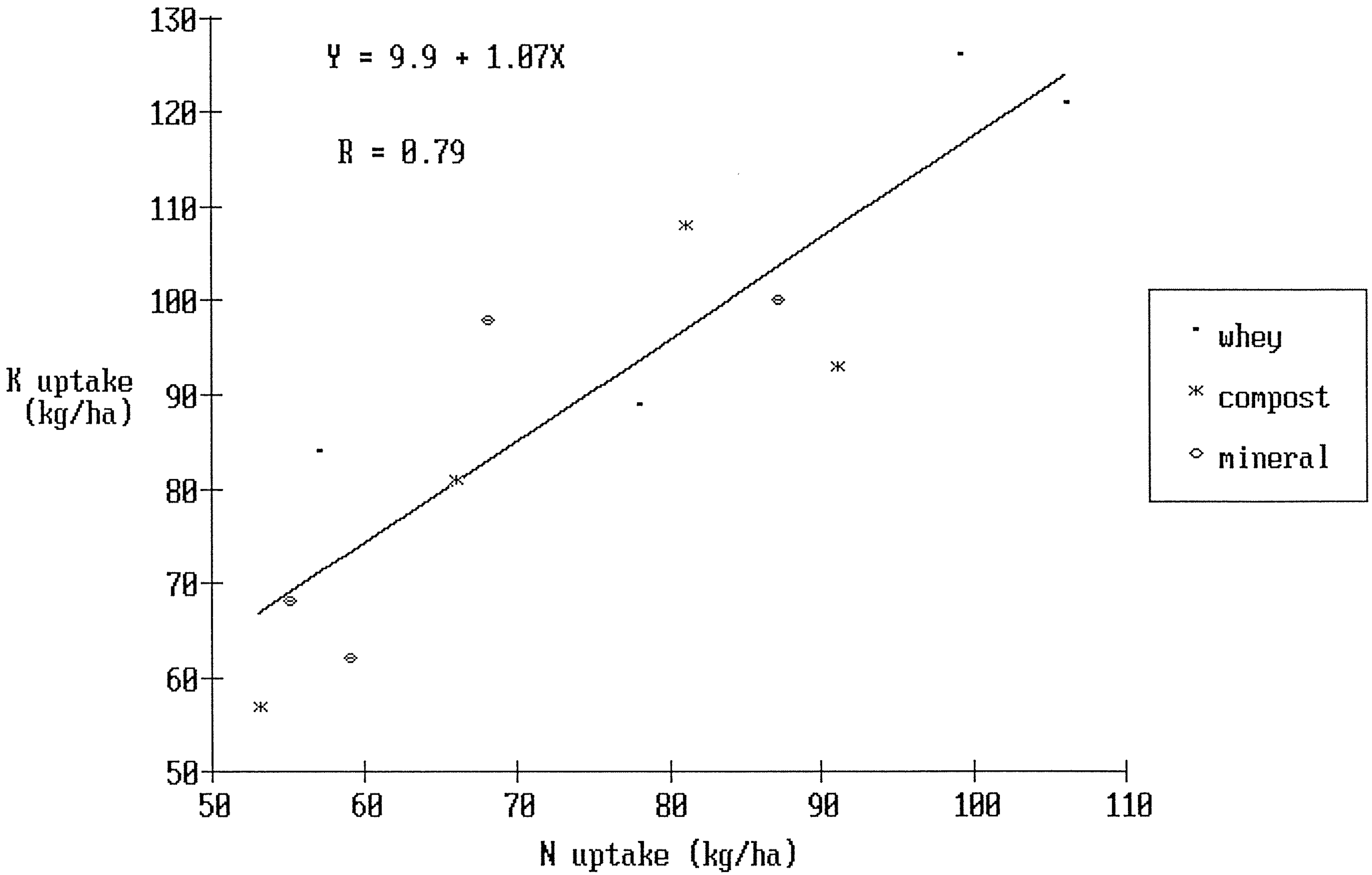


Fig.4. 7 Relationship between N uptake and K uptake



soil K level were low prior to sowing of sweetcorn. These situations include the control treatments, the mineral and compost treatment at all levels and possibly low whey treatment.

It can also be observed from Table 4.8 that the control for the compost treatment had the highest weed K uptake of 143 kg K/ha which is 72% of the total plant uptake signifying that in this control treatment, the competitiveness of the weeds may have influenced sweetcorn K uptake and yield.

Therefore, the weed population at the trial site is likely to have a marked influence on the K uptake of sweetcorn on some treatments and their levels. When at early stages of growth, competition for K is of importance (FAO Bull., 1973; Nelson, 1956), weed K uptake was not measured in this study and the significance of K uptake by weeds on sweet corn yield is difficult to evaluate.

Obviously, weed productivity in any system is a function of crop management practices. In an organic farming system, weed control is more difficult as chemical weedicides are prohibited. Evidence from the sweetcorn trial indicates that weed control was limited (see plates) and total uptake of both N and K by weeds were high and similar to those reported (180 kg K/ha) when weeds are growing in association with a wheat crop (FAO Bulletin, 1973) in a conventional farming system. These weeds in wheat decreased yields by as much as 40%. Therefore, in an organic farming system, higher inputs of nutrients to gain higher yields maybe required, if a high yield is a management objective.

Net K uptake and plant recovery of K from all fertilizer treatments was determined, like N recoveries and values are shown in Table 4.9.

At a low level of added K (120 kg K/ha), the compost treatment had the highest % plant K recovery of 43% compared to 4% and 27% for whey and mineral treatments, respectively. At medium level of K addition (240 kg

K/ha) all treatments had similar percentage recovery in the range of 10-15%. At the high level of K addition (360 kg K/ha), the whey treatment had 12% recovery which more than doubled when weed uptake was added. However, the compost control (sweetcorn plus weeds) had a higher K uptake (200 kg K/ha), which was mainly from the K uptake of the weeds (72% of the total K uptake), than the high level (179 kg K/ha) that net K uptake became negative (-21). Similarly, the high mineral treatment which had a negative net K uptake showed virtually, no recovery.

TABLE 4.9. Apparent K recovery of the different fertilizer forms

Treatment/Form	Net K uptake (kg/ha)		% Plant K recovery	
	Sweetcorn	Weeds	Sweetcorn	Weeds
Whey				
Low	5	-	4	-
Medium	37	-	15	-
High	42	96	12	27
Compost				
Low	51	-	43	-
Medium	24	-	10	-
High	36	(-21)	10	-
Mineral				
Low	32	-	27	-
Medium	34	-	14	-
High	(-4)	0	0	-

Generally, the trend for the efficiency of plant K recovery decreased with an increase in amount of applied K (with an exception for the low whey). However, these percentage recoveries from the applied fertilizers might have been overestimated as the residual effect from the previous fertilizer applications and turned over organic materials could not be accounted for.

4.4 Soil N

4.4.a. Soil inorganic N (2M KCl extractable N)

Mean values of the measured inorganic N (NO_3-N and NH_4-N) at 5 sampling times are reported in Table 4.10. In all the treatments and levels, NO_3-N is the dominant nitrogen form (Table 4.10a and b) during the entire growing period. This suggests that the soil used for this trial may have developed the ability to quickly nitrify NH_4-N to NO_3-N (Amberger, 1983). In contrast, Smith and Hadley (1988) indicated that NH_4-N dominated inorganic N forms after incorporation of the organic fertilizer into a peat-based growing medium.

TABLE 4.10 Total Soil inorganic N (NH_4 and NO_3). kg/ha

Treatment		time (days after sowing)				
		20	40	60	80	120
Control	whey	36.07	33.19	14.99	12.49	7.60
	compost	31.99	30.50	15.94	10.15	7.75
	mineral	35.08	24.91	12.57	9.26	8.45
Low	whey	47.80	44.80	41.17	14.03	9.15
	compost	40.89	37.66	21.22	12.18	8.16
	mineral	34.72	42.43	27.89	12.19	9.16
Medium	whey	88.79	-	46.50	-	8.93
	compost	48.16	-	32.01	-	10.44
	mineral	35.96	-	17.77	-	8.73
High	whey	132.08	72.45	45.69	43.83	16.25
	compost	69.04	53.17	39.08	22.75	13.85
	mineral	36.19	22.07	21.11	21.53	8.73
Medium 15-30cm	whey	31.62	42.45	17.39	-	10.36
	compost	24.97	40.53	18.03	-	9.18
	mineral	21.10	23.46	11.42	-	10.05

Generally, the whey treatment had the highest initial (20DAS) inorganic N

Table 4.10a. Soil NO_3-N (kg/ha) over time.

treatment		time (days after sowing)				
		20	40	60	80	120
Control	Whey	25.55	29.33	8.19	6.47	5.70
	Compost	20.08	26.68	8.99	5.47	5.24
	Mineral	23.8	20.11	6.64	4.28	5.86
Low	Whey	37.16	37.54	34.79	8.93	7.41
	Compost	29.64	29.82	12.76	6.83	6.03
	Mineral	24.01	39.06	17.39	7.42	5.64
Medium	Whey	79.48	-	40.18	-	6.80
	Compost	37.7	-	18.90	-	7.35
	Mineral	32.93	-	10.06	-	5.85
High	Whey	124.08	64.12	39.06	38.7	12.39
	Compost	57.65	49.83	25.64	17.53	7.44
	Mineral	25.75	18.93	9.31	15.5	5.68

Table 4.10b. Soil NH_4-N (kg/ha) over time.

treatment		time (days after sowing)				
		20	40	60	80	120
Control	Whey	10.52	3.86	6.81	6.01	1.90
	Compost	11.92	3.81	6.96	4.69	2.43
	Mineral	11.28	3.83	5.94	4.98	2.58
Low	Whey	10.63	7.27	6.37	5.08	1.73
	Compost	11.26	7.85	8.46	5.35	2.12
	Mineral	10.71	3.38	10.49	4.79	3.53
Medium	Whey	9.30	-	6.33	-	2.14
	Compost	10.46	-	13.12	-	3.08
	Mineral	9.51	-	7.72	-	2.88
High	Whey	8.02	8.31	6.63	5.13	3.87
	Compost	11.5	3.34	13.45	5.22	6.41
	Mineral	10.44	3.15	11.81	6.04	4.51

(Ni) followed by compost and, as expected the mineral treatment had the lowest N_i levels. Soil Ni levels decreased over the growing period. A rapid decrease for almost all treatments and levels was observed between the 40th and 60th day after sowing. This period coincided with the rapid N uptake by the crop (Figure 4.7 a-c).

The high whey treatment had the highest Ni and NO_3-N level at the start of the trial and at the end of the trial still had the highest level compared to compost and mineral levels. Although the compost treatment had lower amounts of Ni at all levels at any one time compared with the whey treatment, the same pattern existed i.e. increasing amounts of soil Ni with increased rates which decreased over time at all levels.

With the mineral treatment, the initial (20DAS) amounts of Ni are similar for all levels (35-36 kg N/ha). However, at 40 DAS, Ni (NO_3-N) at the low rate increased which might suggest that mineralization (and nitrification) of organic N occurred at a faster rate during this period for this treatment level. The high mineral treatment showed almost no change in Ni levels from 40-80 DAS (21-22 kg N/ha) but dropped considerably at 120 DAS. This may further explain the low treatment yield, since for some reason the plant was not able to take up much of the N at the stage of growth when the crop needs it most (Hanway, 1962).

Figure 4.8 shows the relationship between the applied N rates for the compost and whey fertilizer forms and soil Ni levels 20 days after sowing. It can be seen that the whey treatment had a higher amount of available Ni in relation to any level of added N. The whey treatment also had a greater rate of increase in Ni with increasing levels added. This effect may be due not only to the current application of whey fertilizer but also to the residual effect from previous applications. The differences in the amounts of Ni between the 2 fertilizer forms over time may reflect a different mineralizable N rate at any one time. The mineralizable N data from an incubation study using whey and compost treatments as shown in Table 4.12 supports this hypothesis and is

Figure 4.7a. Total Inorganic Soil N (Ni) (dashed line) in relation to N uptake (solid line) of sweetcorn over time (Whey)

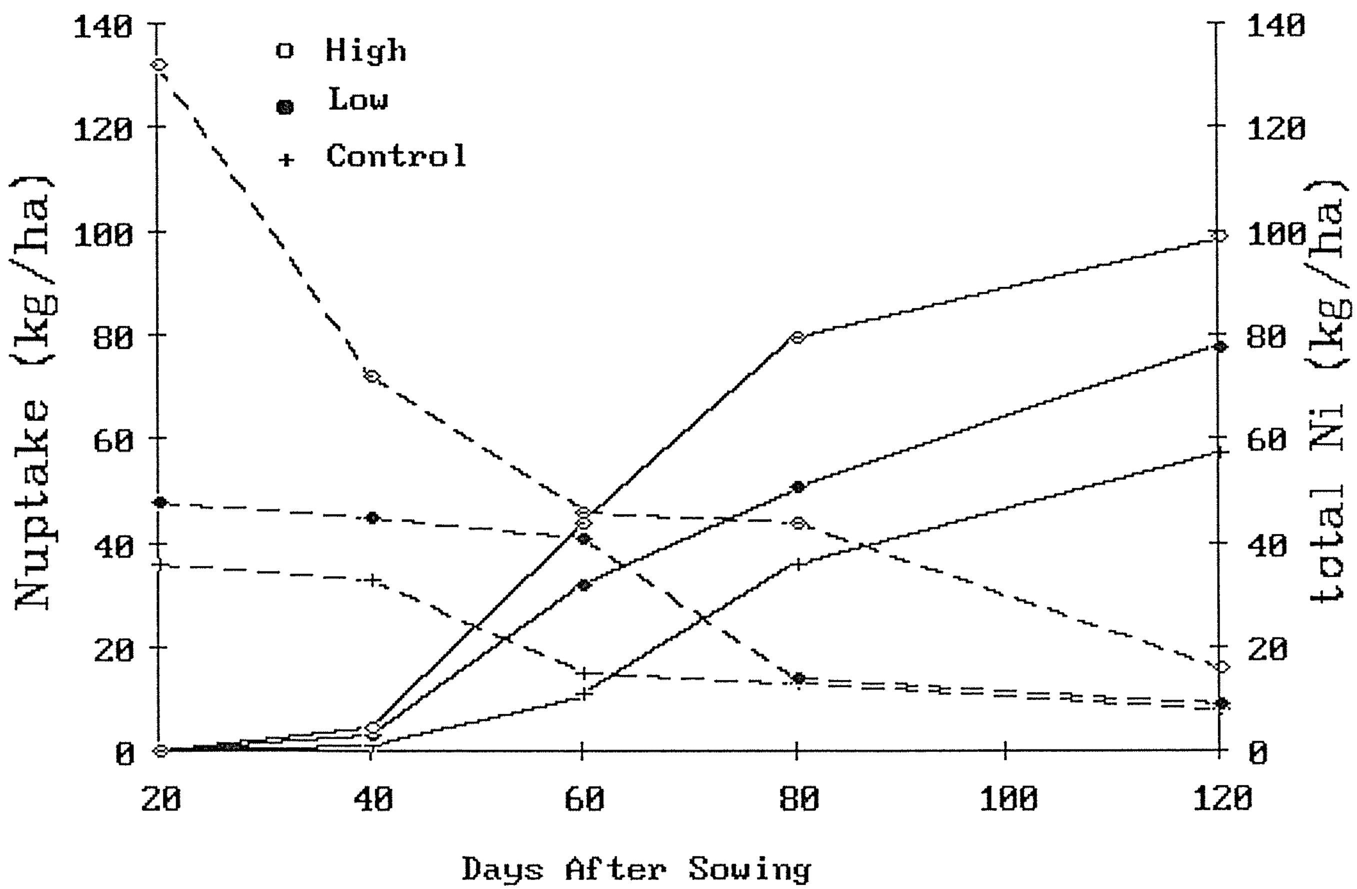


Figure 4.7b. Total Inorganic Soil N (Ni) (dashed line) in relation to N uptake (solid line) of sweetcorn over time (Mineral)

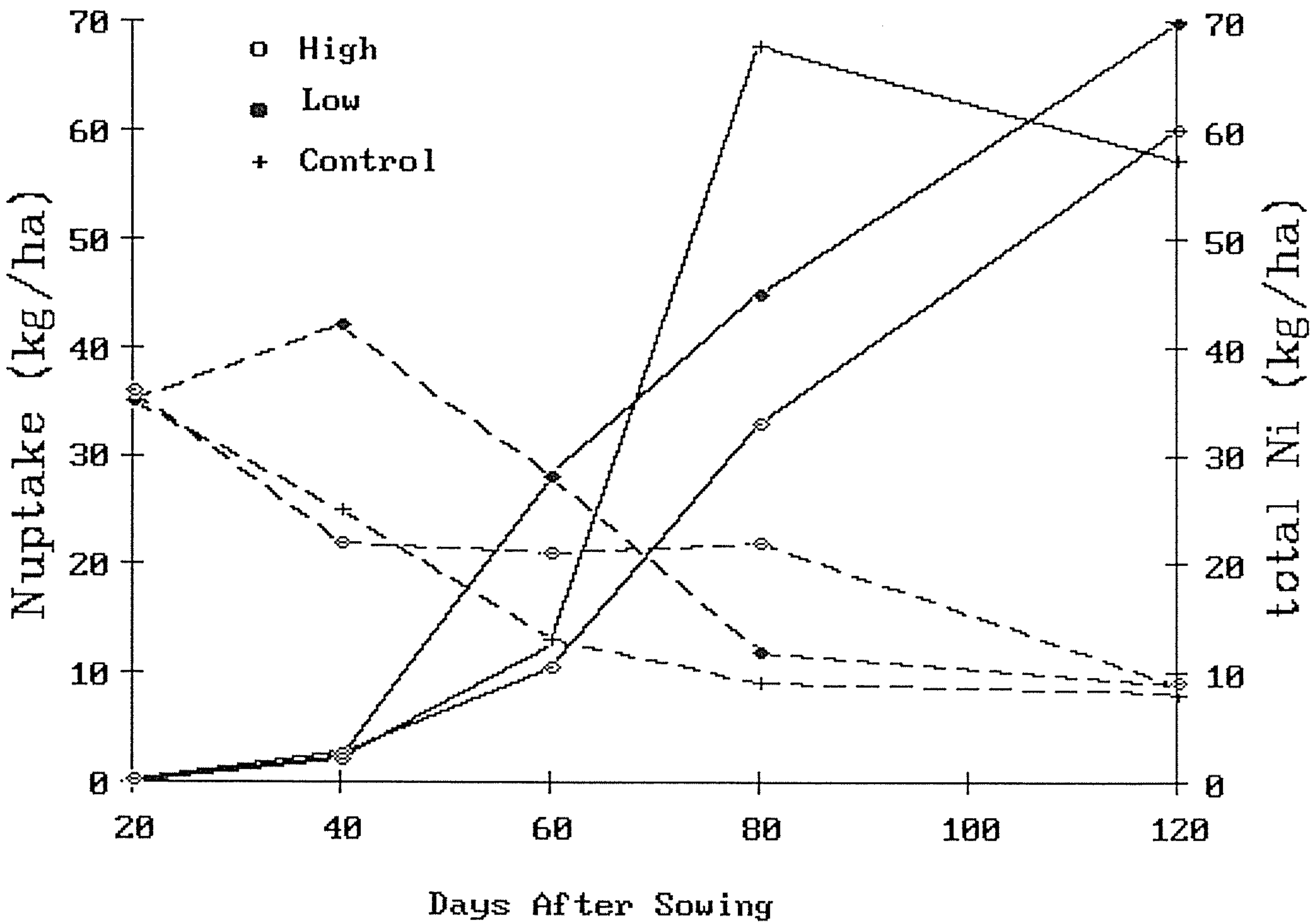


Figure 4.7.c. Total Inorganic Soil N (Ni) (dashed line) in relation to N uptake (solid line) of sweetcorn over time (Compost)

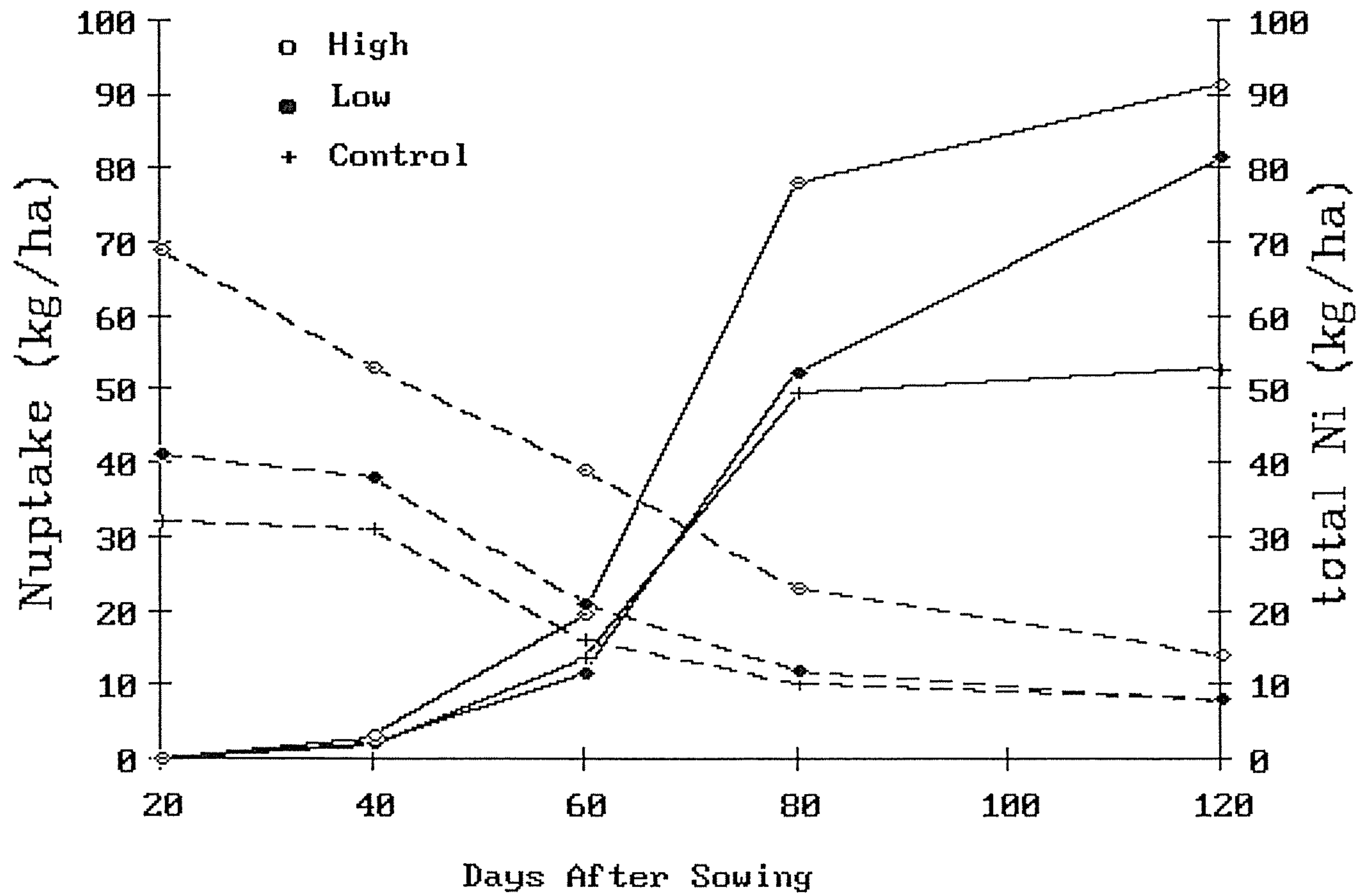
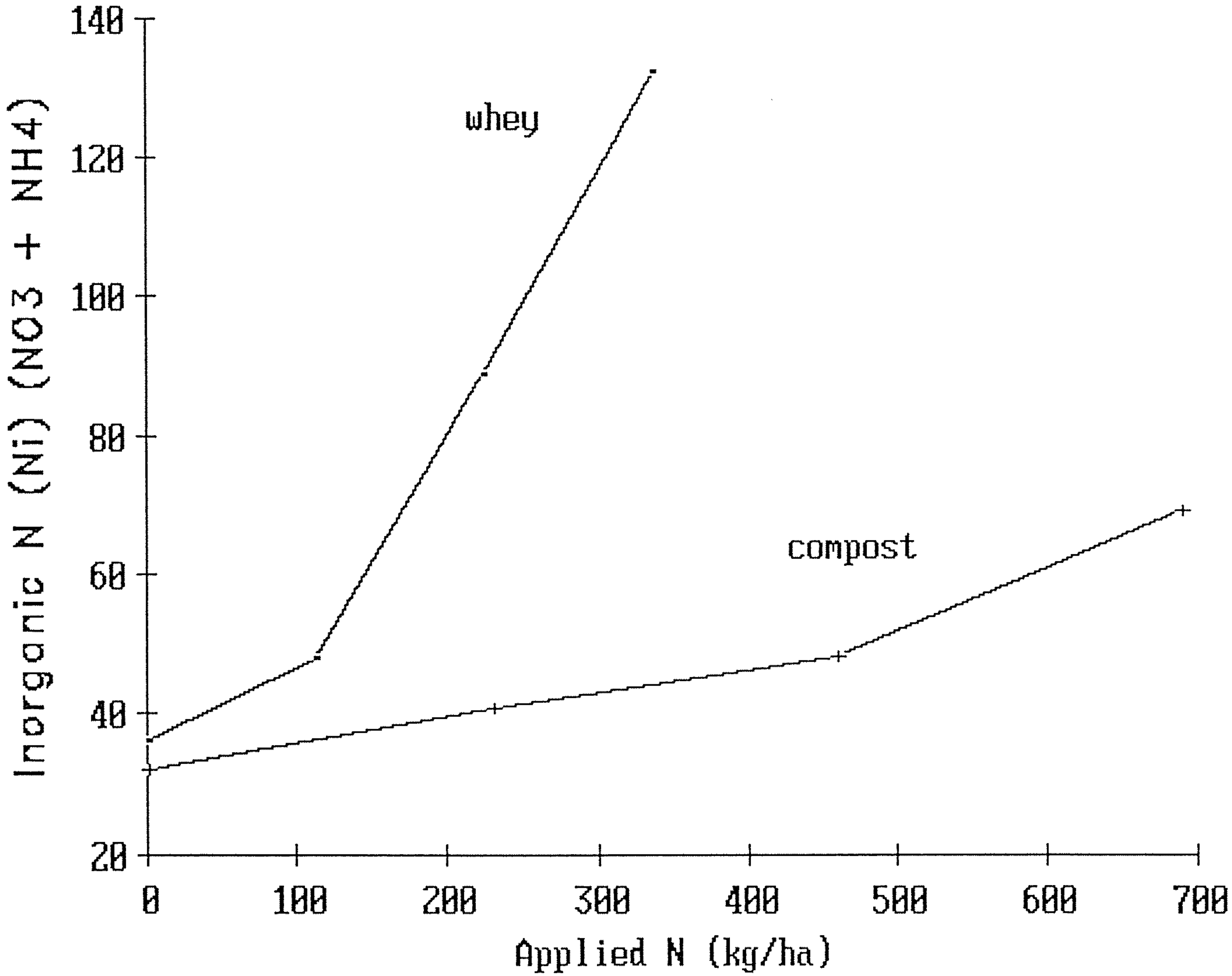


Fig. 4.8. Applied N from compost and whey in relation to soil Ni taken 20 DAS.



discussed further in Section 4.5.

4.4.a.1. Relationship between applied N, dry matter yield, fresh cob yield and plant N uptake.

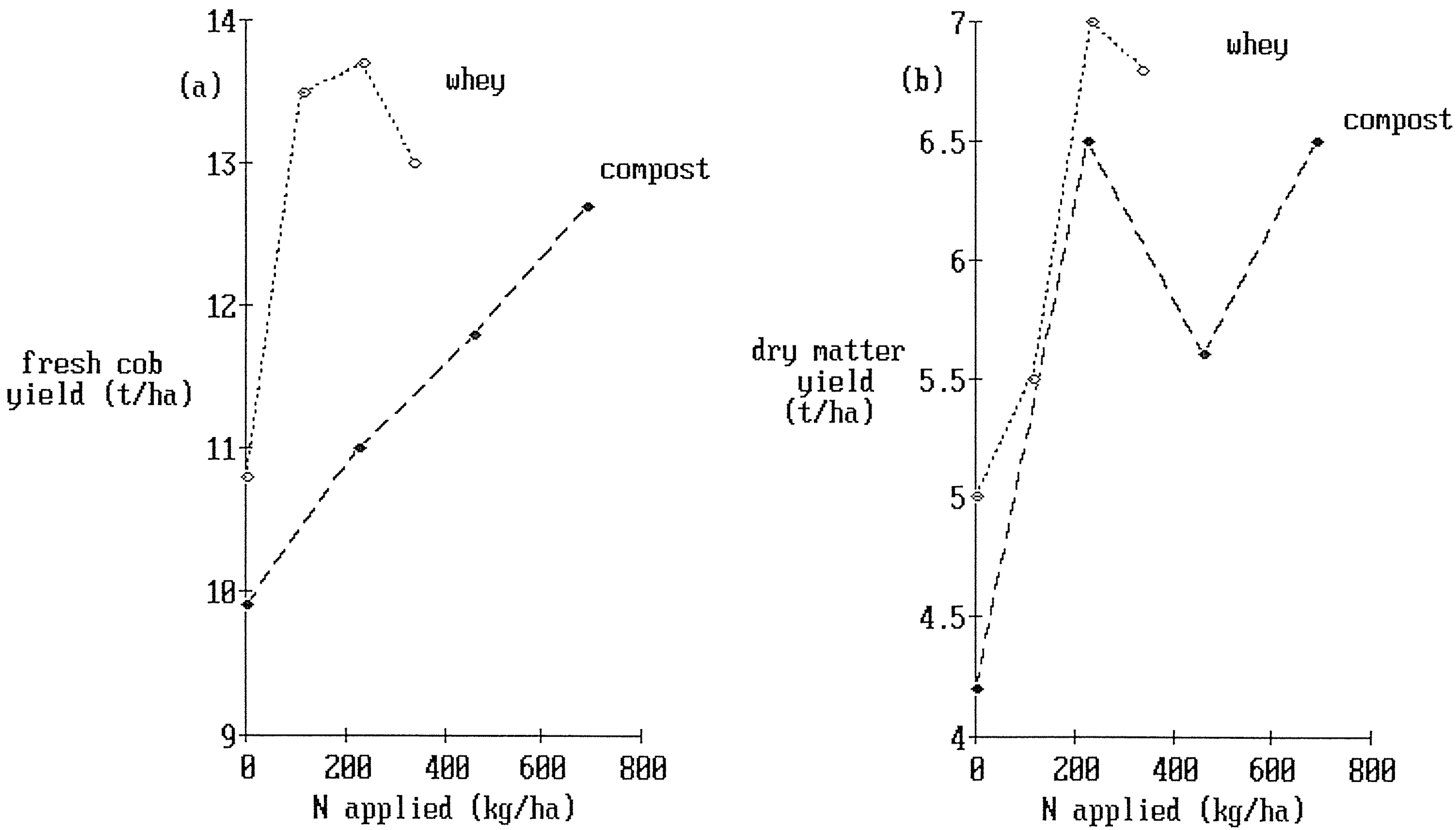
The relationship between applied N from the whey and compost and dry matter and fresh cob yield are shown in Figure 4.9a and b. Only the two treatments, whey and compost are compared since the mineral treatment had no N input. The figure showed thet a high fresh cob yield of 13 t/ha was attained when N was applied as whey at 112 kg N/ha.

Gains in fresh cob yield subsequently decreased (but not significantly) as the rate increased. This may, therefore, mean that optimum yield was attained at the low level of whey treatment. However, no initial soil N_i was determined prior to planting such that the actual effect of the added N in 1989 cannot be fully assessed as responses may be due in part to previous applications.

It must be pointed out that whey contained other nutrients (P and K) which might have contributed also to the increase in yield. Examination of soil tests before planting (Appendix 4 Table 3) shows Olsen P value at the low level of 30 which increased to 43 and 45 at medium and high levels respectively indicating that the low level could be responsive to P additions and the medium and high levels are not using MAFTech criterion (Chapter 3 Section 3.1.c). The same trend was observed with initial soil K levels before planting. The low level had K value of 8 compared to 11 and 14 of medium and high levels which suggests that the low level whey may be slightly responsive to K additions in the whey.

For the compost treatment, highest yield was about 12 t/ha at the highest level of 690 kg N/ha which is equivalent to 12.5 t compost/ha applied. This yield figure suggests that the highest attainable yield might not have been reached by the maximum compost treatment level. The need for high additions of

Fig. 4.9. Effect of applied N from compost and whey on a)fresh cob and b)dry matter yield



compost agrees with the conclusion by Batey (1989), that large quantities (approx. 10 t/ha or more) of composts/manures were needed to be applied to get positive yield responses. This high requirement indicates that the nutrients contained in composts must be tied-up with organic compounds and mineralization is slow (Smith and Hadley, 1988).

4.4.a.2. Relationship between initial (20DAS) N_i, mineralizable N and plant N uptake.

It might be expected that a relationship between plant N uptake and the initial soil inorganic N levels measured at 20 DAS would exist. The relationship found in Figure 4.10. shows a reasonable correlation with $R^2 = 0.66$.

Using an anaerobic incubation technique to determine mineralizable N, it was shown that a good relationship with Ni was also evident with a linear correlation $R^2 = 0.89$. A similar finding was reported by Bonoan (1990), in a cabbage trial using inorganic N sources. Plant N uptake would be expected to relate to both Ni (20DAS) and mineralizable N. However, Figure 4.13. shows a poor relationship ($R^2 = 54$). This suggests that N was probably not the limiting nutrient.

Most studies relating initial Ni to crop N responsiveness are conducted with the knowledge that no other nutrients are limiting (Greenwood and Draycott, 1988). However, in this study, N was probably not the only factor that was limiting N uptake and consequently, yield. In the whey treatment, however, sufficient P and K were probably supplied at all levels.

4.4.b. Total soil N (Kjeldahl N)

The amount of total soil N (inorganic and organic N) from the upper 15 cm of soil at the first soil sampling (20 days after sowing) and the final sampling are presented in Table 4.11. These calculations have assumed that over the growing period there was no change in bulk density as indicated by the data

Figure 4.10. Relationship between Soil N level and Plant N uptake

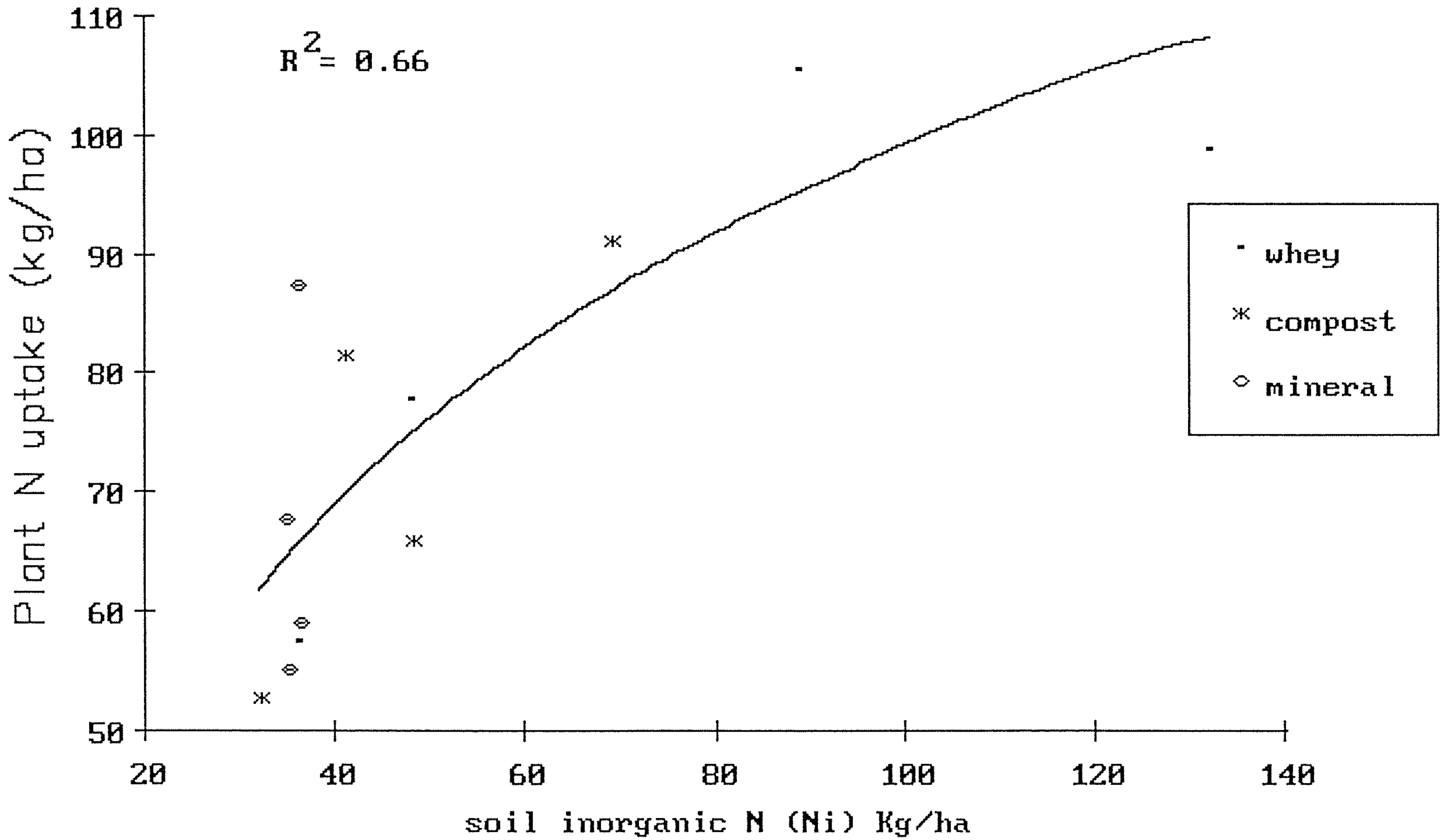


Fig. 4.11. Relationship between plant N uptake and Soil Ni + mineralizable N (anaerobic incubation)

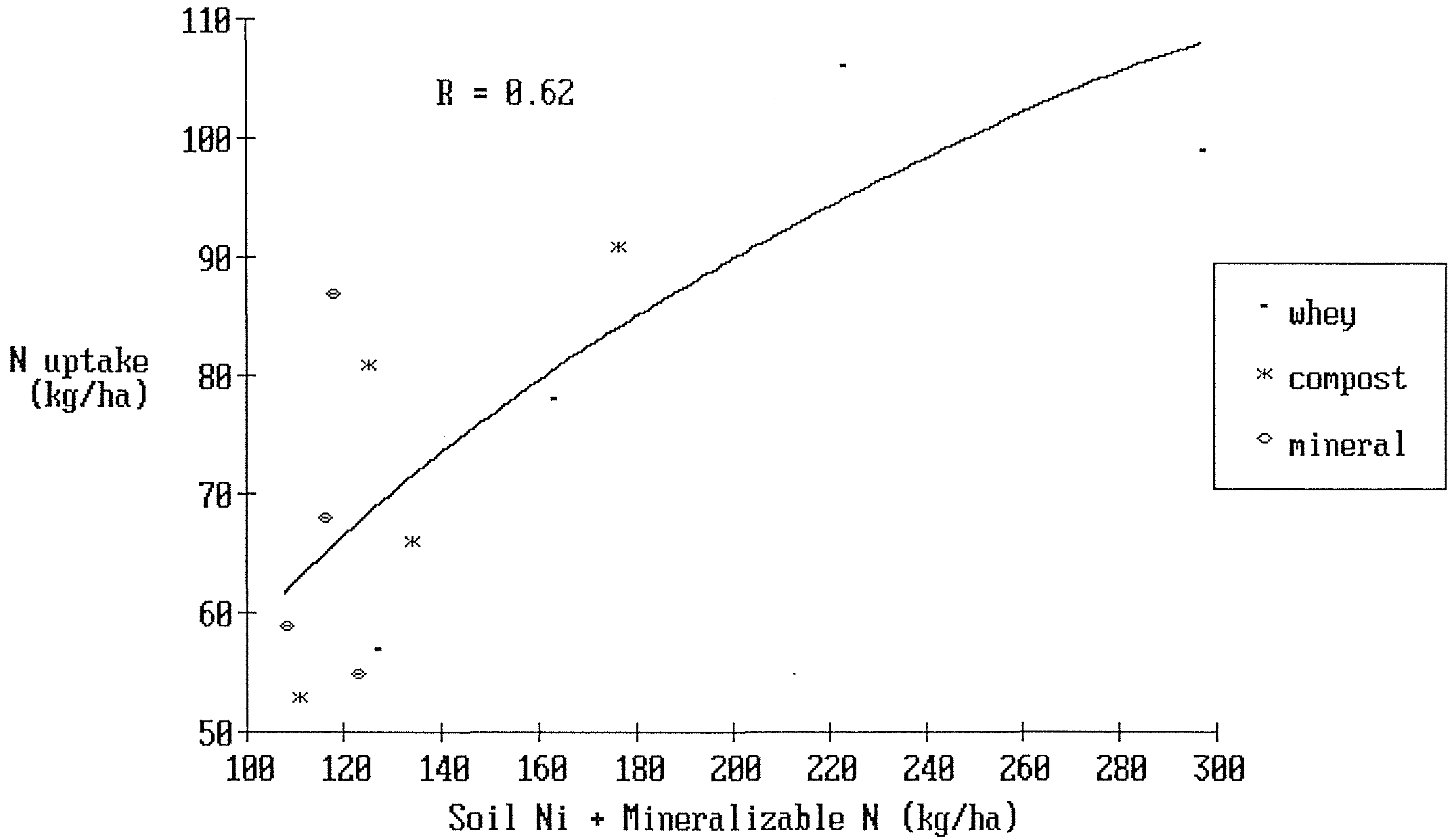


Fig. 4.12. The relationship between soil Ni and mineralizable N from anaerobic incubation from samples taken 20 DAS.

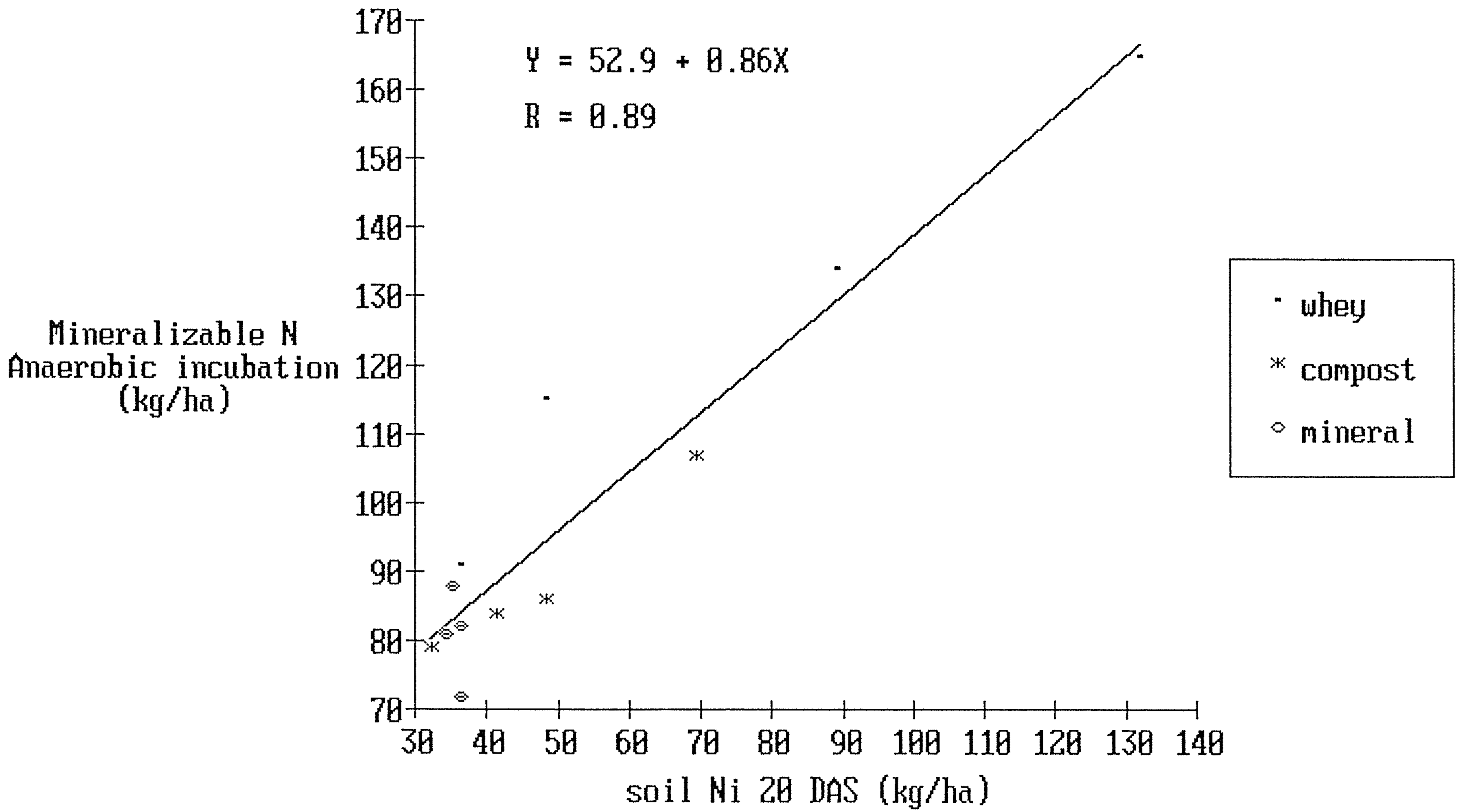
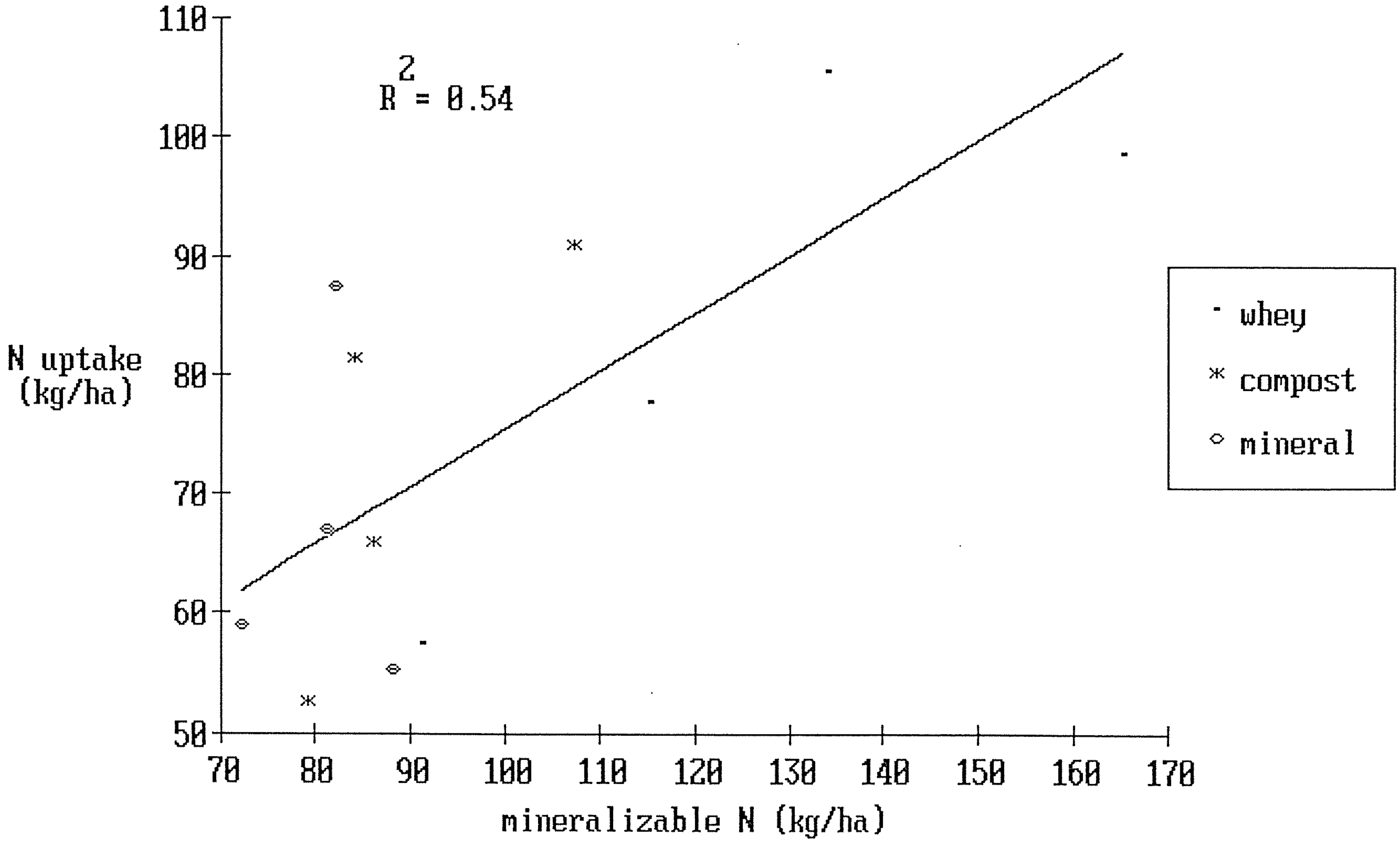


Fig.4.13. Relationship between N uptake
and mineralizable N (anaerobic incubation)



shown in Appendix 5.

TABLE 4.11 Total soil N at the start (S_i) and end of the trial (S_f) (kg/ha)

Treatment/ rate	Stage of sampling	Whey	Compost	Mineral
Control	S(i)	8215cd	7783ef	7740f
	S(f)	8213cd	7704f	7589f
Low	S(i)	8126cd	8005de	7913ef
	S(f)	7971e	8169cd	7818ef
Medium	S(i)	8501b	8303bc	7970e
	S(f)	8206cd	8452b	7542f
High	S(i)	8688ab	8732a	7695f
	S(f)	8226cd	8767a	7559f

Means followed by the same letter do not differ significantly (Duncan's Multiple Range Test at p=0.05).

Total soil N in the whey treatment showed significant decreases over time at all levels but compost treatments showed no significant changes. Similarly, the mineral treatment also showed no change in total soil N except at the medium level which showed a significant decrease.

In the whey treatment, the decrease between total N at the start and end of the sweetcorn growing season averaged 304 kg N/ha which must have resulted in net mineralization. For the medium whey, mineralization of organic N was about 3% or an equivalent of 2.45 kg N /ha /day was mineralized over the growing period. This value is relatively high compared with that reported in the literature (0.5-1.5 kg N/ha/day) for many NZ soils. On the other hand, in the compost treatment no net mineralization occurred.

Generally, the mineral treatment had lower total soil N values, at the start of the sweetcorn growing period compared to the whey and compost treatments particularly at the medium and high levels. These differences are obviously a reflection of the amounts of N added over a three year period. This increase in total soil N on the whey and compost treatments can be clearly seen when the total N of the control for each treatment is contrasted with increasing levels.

On the whey treatment a high level of addition has resulted in an increase of 473 kg N/ha. On the compost treatment the corresponding increase was 1051 kg N/ha. On the high whey treatment, a total of 1008 kg N/ha had been added over a period of 3 years while 2070 had been added on the compost treatment. Although a greater amount of N had been added on the compost treatment, both treatments have increased soil N by about 50% of the N added in their respective treatments.

4.5. Soil mineralizable N

To assess the ability of the soil to supply the plant with nitrogen, three methods of estimating mineralizable nitrogen (N-min) was evaluated; chemical extraction with hydrogen peroxide, anaerobic incubation and apparent mineralization. Results are presented in Table 4.12.

Results from the anaerobic incubation show that the high whey level produced the highest amount of mineralizable N. Both the whey and compost treatments showed an increase in mineralizable N with an increase in level. The rate of increase was much higher with whey. The mineral treatment showed little difference in mineralizable N with a decrease at the high level. The whey treatment generally showed higher mineralizable N than the compost and mineral treatments. The mineral treatment showed the lowest N-min levels compared with compost and whey with the highest level having the lowest N-min value which was even lower than the control.

The residual and current effect of the continuous application of the mineral treatment must have had a negative plant growth effect in the soil environment most particularly at the high level of addition. This effect could be due to a reduced activity and/or change in the balance of the soil micro-organisms that influences mineralization rate.

The hydrogen peroxide extraction methods at 4% generally gave the highest amount of mineralizable N for any one treatment level and at 6% concentration, extractable N was very low compared to the 4% H^2O_2 At 4% concentration, for the whey treatment, mineralizable N increased with an increase in the level added. At 2% and 6% concentrations, increasing rates did not show consistent pattern with the mineral and compost treatments. The variable result for the hydrogen peroxide extraction might have been due to the leaking of the gases during extraction particularly at the high concentration of 6%. Also, the possibility exists that the H_2O_2 was not completely removed during drying. The determination of NH_4-N and NO_3-N levels would be detrimentally affected with H_2O_2 in the extracts (Saggar, 1991 pers. comm.).

A linear relationship between the mineralizable N from the anaerobic incubation and N uptake of sweetcorn for all treatments and levels gave a correlation coefficient value of $r=0.74$. The whey and compost treatments gave correlation coefficient values of $r=0.85$ and $r=0.81$ respectively but the number of observations used were low. The mineralizable N in the anaerobic incubation for mineral treatment correlated poorly with sweetcorn N uptake ($r=0.013$).

TABLE 4.12 Soil mineralizable N from hydrogen peroxide extraction method, anaerobic (30^{0}C) incubation and apparent mineralizable N

treatment		N Mineralized				
		H2O2 Extraction (kg/ha)			Apparent Min.-N (kg/ha)	Anaerobic Incubation (kg/ha)
		2%	4%	6%		
Control	whey	273	534	425	63	91
	Compost	264	838	394	55	79
	Mineral	125	243	303	48	88
Low	whey	204	884	345	66	115
	compost	458	1732	406	77	84
	mineral	212	210	400	66	81
Medium	whey	570	1185	400	63	134
	compost	431	1058	458	51	86
	mineral	258	249	356	91	82
High	whey	562	1280	401	30	165
	compost	493	1380	548	79	107
	mineral	339	659	485	61	72

Note: The values reflected for H_2O_2 and anaerobic incubation are means of two reps. Apparent mineralizable N calculations are shown in Appendix 11. Values shown in Table are means of 3 reps.

With the hydrogen peroxide extraction method, the 2% concentration has a higher correlation coefficient value (r=0.72) when related to sweetcorn N uptake, than the 4% concentration (r=.53) and the 6% concentration correlated poorly. The mineral treatment had a very poor correlation between N uptake and mineralizable N.

Results from a preliminary investigation with hydrogen peroxide extraction but using lower concentrations (1.0% and 1.5%) for some of the whey treatment are presented as follows:

Treatment	1.0 % H_2O_2	1.5 % H_2O_2
	(kg/ha)	
Whey-Control	104	116
Whey-Low	91	128
Whey-Medium	136	138
Whey-High	142	124

It seems that 1% concentration of hydrogen peroxide is more closely related quantitatively to the anaerobic incubation method in estimating the mineralizable N pool. However, the relationship between these two methods cannot be fully established as only the whey treatment was evaluated. It would appear worthwhile to further research the use of 1% H_2O_2 method in estimating mineralizable N as this method is faster than the incubation technique.

The calculated apparent mineralizable N do not display obvious trends. In the whey treatment the high level gave the lowest apparent mineralizable N (30 kg N/ha) while the control, low and medium levels had similar values 63, 66 and 62 kg N/ha respectively. In the compost treatment high level gave the highest value which is similar to the medium level while the medium level and control are similar. In the mineral treatment, the medium level gave the highest (91 kg N/ha) apparent mineralizable N with high and low levels being similar and the control had the lowest value. Since estimates were required to be made of losses due to leaching as well as the weed N uptake for the low and medium treatments, the apparent mineralizable N data are obviously subjected to considerable error and this will contribute to the lack of any consistent patterns.

4.6 Fate of nitrogen added

An estimate was made of the fate of the added N in the whey and compost treatments at low and high levels of addition using several assumptions. Firstly, it was assumed that N was taken up from only the 0-15 cm soil depth; secondly, it was assumed that fertilizer N recovery was the difference in plant N uptake between the treatment levels and the control. Losses through leaching from the 0-15 cm depth was also assessed by a similar method. Plant root N uptake was assumed to be 20% of N uptake by the tops. Results of these estimations are shown in Table 4.13.

TABLE 4.13 Estimation of the fate of added N from fertilizers

	N added (kg/ha)	Plant Uptake* (kg/ha)	Leaching (kg/ha)	Balance (kg/ha)
Whey (low)	112	50	1	+61 (-155)
Whey (high)	360	59	18	+283 (-462)
Compost (low)	224	34	2	+188 (+164)
Compost (high)	690	13	12	+665 (+35)

*Sweetcorn plus weeds.
Values in ( ) are the difference between initial total soil N and the start and end of trial (Table 4.11.).

If the assumptions made are reasonable, it could be expected that the differences found between total soil N at the commencement and end of the trial would be at a similar magnitude. Examination of the data in Table 4.13. indicates only one good relationship (low compost) with both whey levels showing negative balances and surprisingly, the high compost treatment did not reflect the expected increase in N.

Some of the whey losses might be due to volatilization as whey is in liquid form. Beauchamp (1983, 1986), reported that there was more N losses through volatilization when manures were applied in liquid forms.

CHAPTER 5

GENERAL DISCUSSION

5.1. Effectiveness of fertilizer forms

Results from the MAFTech trial with sweetcorn var. honey and pearl, showed that whey was an effective fertilizer and superior to the compost and mineral fertilizers at all levels of addition. In New Zealand, whey is most commonly used as a fertilizer, at the rate of 40-45 m^3/ha on pastures rather than in horticulture or cropping (Radford *et al.*, 1986).

Whether whey can be used as a fertilizer in an organic farming system, based on cropping, will depend on the closeness of the property to a whey source. The results from the experiment suggest that the application of 80 m^3/ha to 160 m^3/ha of whey are adequate for achieving reasonable sweetcorn yields.

Results also showed that additions of the more traditionally used compost and mineral fertilizers over a period of three years had significantly improved sweetcorn yields over the control (no fertilizer) although the increase in yield was lower than the whey treatment.

Based on all the sweetcorn production parameters measured, the mineral treatment, particularly at the high level (0-156-360 kg/ha of N-P-K), performed poorly and generally yielded less than the control. Reasons for this treatment effect are unclear but maybe due to the high soil P availability possibly causing a trace element deficiency such as Zn (Mengel and Kirkby, 1978), or an initial salt effect due to the K_2SO_4 additions resulting in salt toxicity of the crop.

In relation to high soil P availability it has been reported (MAF, 1986) that with maize, if the Olsen P value is > 22, a depression in yield will occur if more than 20 kg P/ha is applied. The Olsen P value of the high mineral treatment was 25 indicating the potential for depressed yields. However, the Olsen P test does not truly reflect the P status of the soil where phosphate rock had been added. Thus, the available P status is likely to be higher than that reflected in the Olsen P test (Saggar *et al.*, 1991) and a depression in yield is more likely to occur if sweetcorn and maize react similarly to high soil P levels.

The yield responses of the whey and compost treatments were closely related to plant N and K uptake and the total soil inorganic N (NO_3-N and NH_4-N) levels. The total soil Ni taken at any one time was higher in the whey treatments at all levels of addition. This would indicate that the N content of the whey is more readily available than that in the compost treatment and may be the reason for its superior performance.

There was also some evidence that net mineralization had occurred in the whey treatment while net immobilization occurred in the compost treatment. The organic carbon levels of the soil 20 days after sowing (appendix 2 table 5) showed similar values for the different treatments which suggests no difference in the amount of substrate for mineralizing organisms. However, whey N is mainly protein N (Radford *et al.*, 1986) and has a lower C/N ratio (6:1) and therefore, is likely to mineralize at a faster rate than the compost which has a higher C:N ratio (20:1).

With respect to attributing sweetcorn yield responses to the N component of fertilizer treatments, it was not clear whether the response was due to the fertilizer addition just prior to sowing in 1989 or to the cumulative residual effect from the previous additions, as no soil Ni measurements were made prior to the 1989 fertilizer addition to assess any treatment differences.

Results showed that the apparent recovery from the two N fertilizers used i.e. whey and compost was low (3-22%), with the compost N being particularly low (3-13%). However, compared with other studies using organic sources, the recovery values appear to be more or less similar. For instance, Kirchmann (1990) using manures reported 15.5% and 13.8 % recoveries by ryegrass and 9.2 and 28.2% recoveries by maize was reported by Briton,Jr. (1985) from fresh and composted manures respectively. On the other hand, Stanford (1973) reported N recoveries in the range of 50-60% by corn grain and stover from inorganic N sources. Similarly, Bonoan (1990) reported 62% and 65% recovery of N by cabbages at final harvest from inorganic fertilizers applied as side dressings at rates of 100 kg N /ha and 200 kg N/ha respectively.

Apparent K recoveries by sweetcorn from compost and whey fertilizers ranged from 0-43%. Since K is not organically bound, recoveries would be expected to be similar to that found using inorganic fertilizers. Greenwood *et al.,* (1980) determined the percentage recovery from 100 kg K/ha of inorganic K fertilizer applied to 23 vegetable crops but sweetcorn was not included. Values ranged between 8-70%. No published information on plant K recoveries from organic fertilizers has been found.

The K uptake by crops depends to a considerable extent on the level of N nutrition (Mengel and Kirkby, 1978). Thus, the better the crop is supplied with N the greater is the yield increase influenced by K (Gartner, 1969). N is only fully utilized for crop production when K supply is adequate (Mengel and Kirkby, 1978).

5.2. The evaluation of fertilizer forms - problems and possible solutions.

The present study was conducted as part of an ongoing trial based on MAF's objectives of creating a long term organic vegetable producing area using 3 different fertilizers acceptable to the New Zealand BPC standards. For the whole trial site to be considered as a 'full' organic farm, no conventionally used artificial/chemical fertilizer (nor pesticides/weedicides) could be applied and this prevented an assessment of whether the highest yielding fertilizer treatments were comparable with yields from conventionally applied inorganic fertilizers such as urea and superphosphate or compound NPK fertilizers. Comparisons could only be made with local yields from conventional farming systems growing sweetcorn (Chap.4. sect.4.1.a.).

The continuous application of the different treatment forms (whey, compost and mineral fertilizers) at different levels over a period of three years as well as the rotation of winter and summer crops had created a fertility gradient in the trial site. This fertility gradient made it difficult to identify which nutrient elements were limiting on any one fertilizer treatment after 3 annual fertilizer applications. Potassium level was the basis for the application rates because of the low initial K status of the trial site.

However, after three years addition of the treatments, the residue from each years' addition has elevated the K status (appendix 2. table 4) to the extent that the present sweetcorn crop grown on some treatment levels responded mainly to fertilizer additions of N and/or P rather than the K component. Also, the effect of residues from the ploughed in winter and summer crops would have influenced N, P and K status of all treatments and their respective levels of addition.

For sweetcorn, MAF (1986) recommend, for the soil type at the trial site, Olsen P values in the range of 45-50 and K test 8-9. Several treatment levels were similar, or exceed these values of soil P and K availability prior to sowing sweetcorn. Whether these levels represent a non-responsive situation is unclear as no published information is currently available for sweetcorn P and K responsiveness particularly under an organic system. No soil N non-limiting values have been reported for sweetcorn but MAF recommendation (1986) suggests the application of about 90 kg N/ha which indicates that N responses are always expected.
If the current fertilizer forms and levels are continually added annually, ultimately, some imbalances in nutrients are likely to occur in the soil and this will eventually influence plant productivity (Mengel and Kirkby, 1978).

There is, therefore, a need to monitor the adequacy of nutrients in the growing crop using chemical leaf analysis from a range of treatments. These values can be compared with standard analysis and would assist in indicating the adequacy of nutrient status. This analytical information would also aid in determining whether the various treatments have overcome nutrient limitations, whether yields have been maximized and whether imbalances are occurring. Emphasis should be placed on treatments receiving the highest nutrient input.

The soil type (Levin silt loam) is recognized as a highly favourable soil for vegetable production. The fact that the site was in pasture prior to the establishment of the trial in 1989 had created a relatively fertile soil especially, in terms of organic matter status and physical fertility.

This fertility situation reduces the likelihood of treatments giving large differences in terms of crop response in the short term. Soil physical properties i.e. bulk density and moisture retention, which are likely to have an effect on crop performance, were found not to have any influence 3 years after trial initiation. This finding relates well to that reported in the literature (Chap.2 sec.2.4.a.;2.4.c.) which indicates that soil physical properties will be affected only with (long term > 10 years) continuous annual additions of organic materials. It is suggested that in 4-5 years time, soil physical properties be reexamined for any changes. Priority should be given to the measurement of aggregate shape and stability, water holding capacity, macroporosity and bulk density.

The weed population in the trial site added to the difficulty in the proper evaluation of each treatment form as substantial amounts of N and K, and presumably P, were taken up from the soil. While weeds compete with the crop for nutrients and moisture, they also serve as a retaining system for mobile nutrients and possibly reduce nutrient losses for an organic system.
It has been stated (Holzner and Numata, 1982) that the competitive effect of weeds on crops cannot be estimated by the determination of nutrient levels in

the plants. It is the relationship between the availability of the nutrients and the needs of the crop which vary with season and stages of development that is of importance, and not the absolute uptake of nutrients by the weeds.

Thus, to effectively evaluate the effect of weeds in this organic farming system, an appropriate balance between weed growth and crop productivity requires to be researched. It is suggested that the role of weed competition be examined at the trial site particularly at initial stages of crop growth. This may involve dry matter determinations at early stages of a crop's growth till maturity/harvest. Weeds may have a very important role in the cycling of nutrients in organic systems especially in the recovery of nutrients which may be positionally unavailable to the crop.

The current trial design does not allow for an evaluation of the plant residue returned on the different treatments. It may be possible to delineate areas in a treatment where future residues will not be returned and these sites can be compared (in crop productivity and nutrient uptake) with the remainder of the treatment plot where residues are returned.

Similarly, the current influence of a fertilizer form cannot be separated from residual effects. Omission of a fertilizer treatment from part of some treatment plots would assist in evaluating the influence of the current application on both plant nutrient uptake and crop productivity.

5.3. Some guidelines for organic growers in the use of these fertilizer materials

From the trial data, after three years of continually adding a range of organic fertilizers at various levels, some guidelines in the use of these fertilizers in an organic farming system are emerging.

Every effort should be made to monitor at least, annually, the level of available nutrients in the soil. Some changes in nutrient levels may be quite rapid depending on the composition and quantity of the material added and crop demands. For example, the use of whey at an addition of 240 m^3/ha has elevated K levels from 8 to 19 after two and a half years addition, but K status within this period fluctuated depending on the time of sampling. There may be some merit in changing fertilizer forms from year to year when some soil nutrients are considered to be in excess of requirements.

Plant nutrient levels of both summer and winter crops should also be monitored to detect both the adequacy of plant nutrition and also to detect any nutrient imbalance problems developing.

Weed control would allow for greater availability of nutrients for the intended productive crop and if not practised, higher rates of fertilizer maybe required to be added.

Whey appears to be a useful organic fertilizer source containing N which readily mineralizes. Time of application may be of some importance and it is possible that N might be lost if the whey is applied before plant roots are active and well distributed. Alternatively, it may be more effectively used as a sidedressing injected along sweetcorn rows.

It would also be wise for growers to obtain information on the nutrient content of crop produce removed from a paddock. At the very least, this would provide a basis for determining amounts of organic material that maybe required to replace these losses. An accurate assessment of crop produce yield is required. Information from the current trial could be used to give an approximate availability index for at least N and K in compost and whey fertilizers.

CHAPTER 6

SUMMARY AND CONCLUSIONS

1. The review of literature indicated the importance of soil management in organic farming systems. There appears to be a lack of published literature evaluating the effectiveness of NZBPC accredited fertilizers.

The addition of organic material and management practices such as green manuring and crop rotation in an organic farming system are attempts either to maintain or increase organic matter levels in the soil or supply the crops with the needed nutrients.

Due to the lack of information regarding the availability of nutrients in most organic materials and the inconsistencies in their components, it is difficult to determine application rates for these materials. For organic fertilizers, application rates appear to be based on the requirements of crops fertilized with inorganic sources.

The literature indicated that organic materials can provide crops with the required nutrients but recoveries of N from the organic fertilizers are much lower (9 - 35 %) than that from inorganic fertilizer sources (50-70%).

Overall, the literature survey showed a need for research into the effectiveness of NZBPC accredited organic fertilizers under New Zealand conditions.

2. An ongoing field trial using whey, compost and mineral materials as possible fertilizers for organic cropping at the MAFTech Levin Horticultural Research Centre, offered an opportunity to evaluate their effects on crop productivity, plant nutrient (N & K) uptake, and available soil nutrient status.

3. All treatment forms and levels, except at the high mineral rate, were

shown to improve the fresh cob yield of sweetcorn harvested in 1990. In almost all yield parameters measured, (fresh cob, total dry matter, dried grain) the whey treatment was superior to the compost and mineral treatments. This was also the situation for plant uptake of N and K.

4. Plant N recoveries from the different levels of compost and whey treatments were determined. N recoveries from whey were in the range of 13-22% and from 3-13% for compost. Plant K recovery ranged from 4-15% for whey rates, 10-43% for compost rates and 0-27% for the mineral fertilizer rates.

5. Soil inorganic N (Ni) levels, measured 20 DAS, showed that the whey treatment contained more Ni than the other treatments and therefore, the crop was able to take up more N from the whey treatment particularly at the medium level. Most of the soil Ni, predominantly in the NO_3-N form, was in the top 15 cm of the soil where most of the sweetcorn roots were concentrated.

6. Three methods were used to determine mineralizable N (apparent mineralizable N, anaerobic incubation and hydrogen peroxide extraction). The anaerobic incubation method appeared to relate better to the plant N uptake than the other two methods. Increases in whey levels were associated with increases in mineralization. Both compost and mineral treatments displayed an inconsistent pattern of mineralization.

7. The weed density in the trial site considerably affected the N and K uptake of the sweetcorn. Recoveries of N from the whey and compost fertilizers more than doubled when weed uptake was added to sweetcorn uptake. Although the competitiveness of the weeds for nutrients was not determined at the critical growing periods of sweetcorn (i.e. silking), the data taken at final harvest has shown considerable K uptake by weeds and in some instances (high mineral and whey treatments) the weed uptake exceeded the uptake by sweetcorn.

8. A simple N balance of estimated gains and losses on the whey and compost low and high levels, all showed a net increase in total soil N over the growing season. However, substantial losses of soil N were measured for whey and little change was measured in the high compost treatment. Large losses from the whey may have been due to volatilization during application. It is unclear as to why no increase in soil total N was measured on the high compost treatment.

9. Several problems associated with the trial design made it difficult to determine reasons for the treatment effects on yield. Nitrogen was probably the major fertilizer nutrient of importance, although, on some treatment levels, applications of K and probably P could have been effective. Differences in soil physical properties were discounted as no major changes had been detected.

10. Some suggestions were made to modify the trial design. Information is needed on the relative importance of residue return and annual fertilizer applications. Additionally, to assess residual fertilizer effects, a treatment omitting the annual fertilizer application should be included. It was also suggested that in the conduct of the trial, plant (including weeds) nutrient levels of both summer and winter crops be monitored on selected treatments. Particular attention should be paid at times of growth that are used to calibrate adequacy of nutrient levels.

11. Even though the duration of the trial has been only three years, several guidelines for organic growers using the fertilizer forms of whey, compost and mineral can be formulated. These include the use of both soil and plant analysis to predict nutrient imbalances and assess adequacy of amounts applied in researching yield objectives.

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Appendix 1.

New Zealand
BIOLOGICAL PRODUCERS
COUNCIL (INC)

PRODUCTION STANDARDS FOR ORGANIC FOODS

Published AUGUST 1988

P.O.Box 2824
AUCKLAND
NEW ZEALAND

SECTION 1 - DEFINITIONS

1.1 DEFINITION OF ORGANIC AGRICULTURE

Organic agriculture, sometimes referred to as biological husbandry, agro-ecology, eco-agriculture, natural, sustainable and including Bio-dynamic agriculture, seeks to produce food of optimum quality and quantity, and to manage productive ecosystems according to a total concept that endeavours to make them sustainable and non-polluting of the environment. Some of the main principles and methods that are employed aim to:

1. Foster beneficial processes and interactions that are naturally occurring in agro-ecosystems - thus encouraging a farms internal mechanism to achieve stability rather than relying heavily on external control measures.

2. Reduce external control to the absolute minimum required for maintaining the chosen state of production. Inputs used, should aim to work as far as possible, in conjunction with natural cycles, rather than trying to dominate such cycles.

3. Achieve cycles/flows of nutrients and materials that have as few losses as possible. This requires the conservation and re-cycling of nutrients and organic material.

4. Enhance soil fertility - its life supporting ability including biological, physical and chemical components. Great emphasis is placed on the importance of soil organic matter, and soil organisms (especially soil bacteria and earthworms).

5. Minimise any deleterious environmental effects of particular management practices.

Therefore, appropriate stocking rates, consideration of animal welfare, sound rotations using diverse stock and cropping strategies with the extensive but rational use of animal manure and other vegetative residues, the use of appropriate cultivation techniques, the avoidance of soluble mineral salt fertilisers, and the prohibition of agro-chemical pesticides, form the basis of organic agriculture (and horticulture).

1.2 DEFINITIONS OF TERMS USED IN THESE STANDARDS

1.2.1 STANDARDS

Wherever the words "Standard or Standards" appear in this document, this means the Standards for certified Bio-Gro organic products of the New Zealand Biological Producers Council (Inc.).

1.2.2 CERTIFYING AUTHORITY

Wherever the words, "Certifying Authority", appear in this document, this means the New Zealand Biological Producers Council (Inc.).

1.2.3 BIO-GRO

Is a property or product that fully meets the management practices as defined in these standards and has satisfied the certifying authority's requirements for inspection and verification. In addition, the certifying authority may require that produce from any production unit be analytically determined as acceptably free of chemical residues.

1.2.4 TRANSITION BIO-GRO

A property not using prohibited materials as defined in these standards and is working towards meeting the full requirements of these standards over a minimum of twenty-four months.

1.2.5 PARTIAL CERTIFICATION

When considered appropriate as a means of facilitating and encouraging the conversion of an entire property to Bio-Gro, a designated portion of the property may be awarded Transition Bio-Gro or Bio-Gro. A condition of this will be the implementation of an agreed plan to convert the entire property to Bio-Gro within a prescribed period. Other conditions also apply (See Section 1.2 and 2.)

1.2.6 PARALLEL PRODUCTION

Where partial certification of a property has been awarded, then no produce of the same type may be grown or produced on both the Bio-Gro and non Bio-Gro sections of that property, in the same year, UNLESS IT HAS CLEARLY DISCERNIBLE CHARACTERISTICS DUE TO VARIETY, TYPE OR BREED. Special conditions apply for parallel processing.

1.2.7 DRUGS

Any registered animal health remedy used for the treatment of ill health or disease and is administered, orally, dermally, or by injection or as a feed additive.

1.2.8 PERMITTED MATERIALS

It is desirable that Bio-Gro certified materials be used. If materials or products do not have Bio-Gro, certified analytical evidence of their freedom from unacceptable residue contamination may be required.

1.2.8.1 Manure and composts - cycled internally

Manures both solid and liquid, composts and plant material produced on the property.

1.2.8.2 Manures, compostable and mulching materials brought in

Manures both solid and liquid, and plant and other organic material for use as mulches can be brought onto an organic farm providing that,

a) All materials with the exception of mulches will have gone through an acceptable composting procedure before use.

b) Every effort has been made to ensure that material is free from contamination from prohibited chemicals, particular attention should be paid to heavy metal contamination.

c) That the use of such materials, which may include dairy whey and Blood and Bone, do not exceed the capacity of the land to absorb them.

d) That mulching materials come from an acceptable source documented as free from all pesticides and heavy metals contamination.

It should be noted that organic materials from factory type animal production may be excluded in the future. A review of organic standards occurs every two years under existing international regulations.

1.2.8.3 Biological Activators

Microbial activators
Various plant based preparations
Bio-dynamic preparations

1.2.8.4 Additives for Mineral Supplementation

Rock phosphate
Feldspar
Magnesium limestone (dolomite)
Calcium sulphate (gypsum)
Limestones
Elemental sulphur
Glauconite - greensands
Rock minerals
Unadulterated seaweed and fish products

1.2.8.5 Pest and Disease Control

Mechanical controls (traps, barriers, sound scares)
Pheromones but not directly on the plants
Herbal sprays
Water glass (sodium silicate)
Soft soaps
Steam sterilisation
Biological control with parasites, predators or disease organisms
Natural purgatives
Homoeopathic preparations

1.2.9 RESTRICTED MATERIALS

Those materials which may be used but only in accordance with the principles laid down in the standards. This should lead to a gradual reduction in dependence on such materials.

1.2.9.1 Fertilisers

Potassium sulphate - Only until such time as more acceptable alternatives are available and only after consultation with an accepted advisor. Use of Potassium sulphate may preclude transition to full Bio-Gro.
Trace elements
Basic slag

1.2.9.2 Insecticides

Pyrethrum - both pure and in combination with the synergist Piperonylbutoxide.
Ryania
Rotenone (derris)
Quassia
Diatomaceous earth
Metaldehyde - in closed containers only
Potassium permanganate
Mineral oils

1.2.9.3 Fungicides

Copper hydroxide, Bordeaux mixture, Burgundy
Sulphur preparations

1.2.9.4 Animal Health Remedies

Mineral supplements
Iodine preparations
Zinc oxide and zinc sulphate
Copper sulphate
Vaccines
Sulphonilamide as spot treatment for external use only.

1.2.10 INTERIM ANIMAL HEALTH REMEDIES

1.2.10.1 Permitted interim use of animal health remedies subject to section 4.1.3.1 are as follows:

Anthelmintics -	Levamisole based drenches withholding period <u>2 days</u> Morantel citrate based drenches withholding period <u>3 days</u>
Cyromazine -	withholding period 21 days
Antibiotics -	withholding period 90 days.
Pyrethroids -	Cypermethrin - withholding period 21 days
	Deltamethrin - withholding period 9 days.
<u>Withholding Periods</u>:	Are normally set at THREE TIMES the label recommendation. Always check the product label.

ALL STOCK SO TREATED LOSE <u>Bio-Gro</u> STATUS for a period of 12 months from last treatment.

1.2.11 PROHIBITED MATERIALS

All other materials are prohibited unless cleared with the certifying authority.

Prohibited materials are those materials which shall not be used on Bio-Gro properties. Their use will cancel an existing Bio-Gro certification. The farm will be required to go through a 12 month conversion period before organic status is regained.

SECTION 2 - LOCATION AND LAND CONVERSION

2.1 LOCATION AND QUALITY OF LAND

An acceptable farm plan of the land to be farmed organically must be supplied to the certifying authority.

Boundaries and buffer zones
The boundaries of the land to be certified as Bio-Gro must be clearly defined by permanent structures (roads, fences, hedges, streams, shelterbelts).

Provided that no contamination of the land area, or produce, can occur through the common use of farm equipment and facilities, Transition Bio-Gro or Bio-Gro, may be awarded if the requirements of section 1.2.5 and 1.2.6 (partial certification, and parallel production) are complied with.

2.2 CONVERSION TO ORGANIC AGRICULTURE

Conversion of a property from conventional to Bio-Gro management must be in accordance with the requirements of these Standards. This will usually require attention to:

a) The productive capacity of the land.
b) Diversity of the cropping and pastoral aspects of the property.
c) Herbage composition, with a view to incorporating a greater range of grasses, legumes and herbs.
d) Cropping rotations that balance fertility building and exploitive phases.
e) Grazing systems that seek to control animal parasites, as well as achieve effective utilisation of fodder and management of the pastures.
f) Appropriate manure and fertiliser input strategies.
g) General environmental enhancement that reduces livestock and crop (weather and pest) stress by the provision of living shelter for shade, wind protection, and parasite/predator habitat, etc.

The conversion will be monitored by the certifying authority on an annual basis.

SECTION 3 - PERMISSIBLE RESIDUE LEVELS

3.1 PERMISSIBLE RESIDUE LEVELS OF PESTICIDES IN SOIL AND HERBAGE

Conversion of a property to Transition Bio-Gro, or Bio-Gro status will depend on the successful implementation of a production system that is based on the Standards of the Certifying Authority. At the sole discretion of the Certifying Authority, analysis of produce MAY be required. The Certifying Authority may also require the results of such analyses to be declared to purchasers of such produce.

Excessive residues as determined by the best currently available techniques for minimum detectable levels may well preclude produce from Transition Bio-Gro, or Bio-Gro certification. (Refer appendix for details on residue levels).

3.2 HEAVY METALS AND OTHER POTENTIALLY TOXIC ELEMENTS

Heavy metals and other metallic elements can be essential to plants and animals in trace amounts (zinc selenium and copper) and toxic at higher concentrations or may simply be toxic (cadmium, mercury, lead). Where a trace element essential for plant and animal health is deficient this deficiency may be corrected by the application of approved materials at specified amounts. In the case of toxic heavy metals every effort must be made not to add to these levels.

SECTION 4 - LIVESTOCK FARMING

4.1 PRODUCTION METHODS

Animals may be associated with pastoral or mixed cropping systems. Whatever the system employed the following methods will apply.

4.1.1 Grazing and Housing

Animals sold for slaughter must be born and raised on Transition Bio-Gro, or Bio-Gro properties. Factory farming methods of intensive livestock rearing (until slaughter) in enclosures are prohibited.

All stock shall be managed with respect to their welfare. Animals grazed off the property must be grazed on Transition Bio-Gro, or Bio-Gro pastures.

4.1.2 Supplementary Feeding

Supplementary feed grown on certified Transition Bio-Gro, or Bio-Gro farms is allowed, but not in contravention of section 2.2a. Subject also to section 2.2a, feed from non - Transition Bio-Gro or Bio-Gro sources is permitted up to a maximum of 15% of the total annual dry matter intake of the animal. (This percentage may be reviewed as sources of certified feed increase). Commercially prepared feeds containing growth promotants, preservatives and antibiotics are prohibited. Caution should be exercised in buying in feeds from non Bio-Gro sources. (Refer sections 3.1, 3.2). Pursuant to the requirements of section 2.2, mineral licks are permitted.

Young animals, including calves, must receive colostrum, for a minimum of five days after birth. If they are to be retained in the herd, they must receive natural milk until weaning.

4.1.3 Animal Health

4.1.3.1 Requirement to treat

Producers of meat and dairy products shall market only healthy animals and their products and shall never allow a diseased or severely infected animal to go untreated in order that it may be called Bio-Gro.

Any animal treated with a material as defined under Interim Animal Health Remedies (Refer Section 1.2.10.1) shall lose Bio-Gro status for 12 months from the last treatment. A quarantine area shall be used to hold treated stock for the designated period. Any stock so treated may be returned to the main flock or herd provided they are clearly and permanently marked. Routine or scheduled use of anthelmintics is prohibited.

Facial excema:
Zinc or copper sulphate may be used in cases of need. Routine use is, however, not allowed.

Navel ill:
Where it is likely to occur, iodine may be used to prevent infection.

Induction of parturition:
Natural prostaglandins may be used only when essential for veterinary reasons.

Metabolic disorders:
Magnesium salt may be used to treat grass staggers. Calcium boroglutamate or natural Vitamin D may be used to treat milk fever. (Although, in neither case is routine or schedule administration allowed.)

Hygiene:
Subject to the certifying authorities approval, standard MAF recommendations for dairy shed hygiene should be followed.

Mineral deficiencies:
When a deficiency persists after conversion to Transition Bio-Gro, or Bio-Gro status, trace elements may be applied to pastures as natural mineral fertilisers, rock dusts, or sea products of either fish and/or seaweed combinations. Multiple pasture species should be planted, especially those plants known to accumulate the deficient element. To prevent stock ill-health, mineral licks may be used. Routine use of such supplements is discouraged in Bio-Gro properties. Such deficiencies should be corrected by soil amendments so that the animals' intake is in a natural (plant) form.

4.1.4 Soil Fertility

Permanent pastures which rely on nitrogen fixation by legumes, and are used for all year grazing can fulfill the requirements for maintenance of soil structure and organic matter return in organic agriculture, in that it maximises nutrient cycling, accumulation of organic matter and increases soil biological activity within the farm. (Refer section 2.2c).

However, as the commercial farm situation is one of net export of nutrients in the product, replacements of nutrients may be required. Subject always to the provisions of these standards, the timing and method of fertiliser use should be determined according to soil type, stock type and climate. (Refer section 1.2.8.4 and 1.2.9.1)

Livestock can be reared as part of a mixed cropping rotation which includes grazed pasture. This system more adequately meets the definition of organic agriculture in Section 1.1 and fulfills the organic farming requirements for soil structure maintenance, organic matter returns, nutrient cycling and increased biological activity (Refer section 2.2).

4.1.3.2 Specific Diseases and Remedies

In cases where specific diseases or health problems are known to occur control measures may be used subject to the approval of the inspector.

Internal Parasites:
An objective of organic agriculture is to eliminate the need for animal health remedies by breeding resistant animals, and using grazing management and non-chemical procedures (Refer section 2.2). The level of worm inoculum present in pastures must be reduced or eliminated by cropping, cross-grazing, rotations, or the use of browse fodder. Natural purgatives and homoeopathic remedies are permitted. Those stock known to be carrying an unacceptable worm burden must be dealt with in accordance with section 4.1.3.1.

Ectoparasites and Flystrike:
Dipping for lice and other ectoparasites may be carried out only if the welfare of the animal is under threat. Where control is necessary refer Section 4.1.3.1 and methods for using restricted materials refer Interim Animal Health Remedies (Section 1.2.10.1). Routine or scheduled use of dips is prohibited.

Footrot:
* Zinc or copper sulphate treatment.

Coccidiosis:
* No acceptable organic remedy known at present.

Vaccinations:
In all cases, selection and breeding to obtain stock with high levels of natural immunity is an objective of organic agriculture. In the case of an outbreak of mutant strains, vaccines which stimulate the animals' natural immune system, and are prepared from naturally occurring organisms may be used. Routine, or scheduled vaccination is prohibited. Use is permitted where a property has a known disease history.

Docking, Dehorning, Tailing:
De-tailing of pigs and cattle, and de-beaking of poultry is prohibited. De-horning of cows and cattle, if necessary, should occur during bud stage, bluntening of horns, in as humane a fashion as possible, is permitted.

Calf Scours:
Oral rehydration with glucose electrolyte solution is allowed. Infected animals are to be isolated from the herd until cured. Homoeopathic, chalk and fine clay remedies are allowed.

Mastitis:
Use of homoeopathic and naturopathic remedies is allowed. All antibiotics are prohibited from use on any cow, except those that have been culled from the herd. (See section 4.1.3.1). Drying-off mildly infected quarters is permitted.

Bloat:
Vegetable oils, and parrafin may be used. Routine use is not allowed.

4.1.5 Weed Control

Weeds must be controlled by grazing management of one or more classes of stock by maintaining a vigorous sward. Mowing, before seeding for thistles, or pulling at early flowering for ragwort is suggested to prevent reinfestation of the farm and neighbouring properties. In systems where livestock is part of a rotation then management of the rotation as a whole becomes the main weed control method.

4.1.6 Stock Replacement Policy

Many New Zealand farmers replace stock from within the farm. This procedure is encouraged. When replacement stock are bought in they should be obtained from Transition Bio-Gro, or Bio-Gro properties. When Transition Bio-Gro, or Bio-Gro breeding stock are not available, any such additions shall not exceed 10% of the capital stock figures. Any breeding stock so purchased shall be held in quarantine at the discretion of the certifying authority. (Refer section 4.1.3).

In the case of stock bought in from non Bio-Gro properties, pursuant to the previous paragraph, a full year must elapse before any meat fibre, milk or related by-products can be sold as Transition Bio-Gro or Bio-Gro.

Where it can be shown that dairy replacement heifers can not be obtained from a certified property, calves not exceeding 10% of the herd, can be bought in from non-certified sources, provided the quarantine requirements of section 4.1.3.1 are adhered to.

4.2 KILLING, CUTTING, PACKING AND FURTHER PROCESSING OF ORGANIC MEAT PRODUCTS

Abattoir Procedures (General): The Meat Act 1981 and its regulations (1969), the Food and Drug Act (1969) and its regulations (1973) and the Stock Regulations (Insecticides and Oestrogens) (1961) define the procedures and materials which may be used in New Zealand killing, cutting and freezing works. The Meat Division Manuals 8, 9, 10 and 11 which provide the detailed information for use in abattoirs, packaging areas to cope with changing situations. The regulations are comprehensive and stringent and in most cases adequate for the treatment of Bio-Gro products. Some further restrictions apply however which are described in the following sections.

Killing Methods: Slaughter of Bio-Gro stock should be carried out in a way which minimises physical pain and distress to the animals.

Chemicals: Manual 10 of the MAF Meat Division Manuals lists the chemicals which may be used in edible product areas in abattoirs. The following further restrictions apply when organic stock is being processed.

SECTION 5 - MIXED CROPPING AND LIVESTOCK FARMING

5.1 PRODUCTION METHODS

The integration of grazed pasture and the growing of crops provides for many beneficial interactions in an organic agriculture system.

5.1.1 Rotation

A sound rotation is important to successful organic agriculture. Grazed pasture from a well composed ley builds a well structured and nitrogen rich soil and helps mobilise soil nutrients for the following crops. Nutrient cycling within the farm with minimum soil and plant nutrient losses should be the aim.

5.1.2 Soil Fertility

Maintenance of soil organic matter and soil structure are of paramount importance. When correctly managed, pasture can aid in building up soil organic matter and improving soil structure.

The use of green cover crops during winter, the practice of mulching straw, the growing of multi species pasture, the optimal utilization of pasture and the avoidance of soil compaction all aid in maintaining soil fertility.

Mineral fertilizers should be regarded as a supplement to, and not a substitute for nutrients cycled via organic matter return.

Permitted and restricted materials for use in fertility building are listed - Refer section 1.2.8.4 and 1.2.9.1.

5.1.3 Weed Control

Satisfactory weed control depends on timely management techniques which includes rotation, and the use of mechanical, hand or thermal means. Mulches may be used for weed control. Organic mulches must be from an approved source (Refer section 1.2.8.2). Plastic and biodegradable mulches may be used.

5.1.4 Pest and Disease Control

All equipment used for spraying must never be used for prohibited substances. The main aim of organic agricultural production is to build an environment based on good husbandry practice that prevents the build up of pest and disease problems.

Insecticides: Only insecticides which have rapid 'knockdown' and no residual activity can be used in Bio-Gro edible product areas provided that:

a. only the limited range of products permitted in the standards for processing are used (see below).

b. no Bio-Gro meat is in the area during application.

c. all contact areas are washed down with water prior to the introduction of Bio-Gro edible product to the area.

At present time only 'use Category A' pyrethrins can be used for insect control in Bio-Gro edible product areas.

Restrictions on insecticide odours, confinement of sprays and mists, labelling and storage of insecticides and the use of insecticidal fume bombs as described in Manual 10 apply in full.

Rodenticides: Not to be used in Bio-Gro edible product areas within five days of the commencement of Bio-Gro meat slaughter and processing. Only products containing Brodifacoum, Bromadiolone, Maldison and Warfarin may be used. Contact surfaces must be thoroughly washed before Bio-Gro meat is reintroduced to the area.

Sanitising and Cleaning Materials, Adhesives and others: Appendix E of Manual 10 lists permitted products edible and non-edible product areas.

No chemicals may be sprayed or otherwise applied when Bio-Gro edible product is in the area. All contact areas must be washed down with potable water after the use of any sanitising or cleaning materials if edible Bio-Gro product is to be processed.

Carcass Marking: Until a suitable Bio-Gro marking agent is identified only Methyl Violet (C142535) which is acceptable in the EEC may be used to mark Bio-Gro carcasses or meat. The feasibility of using non-coal colouring agents such as cochineal, chlorophyll, saffron or liquid nitrogen branding should be investigated.

Food Additives: Smoke distillate, curing agents and other food additives may not be used on Bio-Gro meat.

Preservatives: Insecticides and Antibiotics may not be used as preservatives on Bio-Gro meat.

Withholding Periods: Appendix C of Meat Division Manual 10 defines withholding period for stock after the use of a wide range of animal health remedies. If emergency use of such remedies has been made then that product shall be removed from Bio-Gro status.

Routine problems indicate a failure to identify the main cause. Control measures permitted and under restriction are listed in Section 1.2.8.5, 1.2.9.2 and 1.2.9.3.

5.1.5 Harvesting

Machinery used for harvesting Bio-Gro grown crops should ideally only be used on such crops. If machinery has previously been used for harvesting conventional crops, then it must be thoroughly cleaned, so that there is no danger of contaminating Bio-Gro produce, nor of bringing weeds or pests onto the property.

5.2 TRANSPORT, STORAGE AND PROCESSING

5.2.1 Transport and Storage

All grain or other arable products should be stored in containers used only for Bio-Gro produce. Transport and storage containers should be thoroughly cleaned before use. Natural pyrethrum can be used in buildings but must not be applied directly to the grain. Rodenticides must only be used outside the storage containers. The addition of Co_2 to stored grain is allowed.

PROHIBITED

- Spraying and fumigation with insecticides or any synthetic chemical either on the harvested crop or in storage.

5.2.2 Processing

Processing equipment should be self-cleaning. Daily and weekly cleaning by scraping, brushing, aspirating and washing should be employed to avoid problems. Steam cleaning is recommended if problems should arise. When products other than those of the Certifying Authority's standards are processed, the initial batch produced when changing to those standards may not be sold as Bio Gro.

Processing should not diminish the quality of the material being processed. When fumigation is required, special application must be made to the Certifying Authority. After fumigation, the system must be run for two hours or longer, as determined by the Certifying Authority, before the product can be sold as Bio-Gro. Any self raising or other agents added must be clearly identified on packaging.

PROHIBITED

- Chemical additives
- Gluten powder or other flour improver
- Bleaching agents

5.2.3 Bread and Flour Products

Bread must be made entirely with Bio-Gro Standard flo
milk and bean flours. Any other ingredients, includi
oil, must also be Bio-Gro Standard.

For pasta, Bio-Gro Standard flour, semolina and eggs

PERMITTED

- Yeast and natural leavening
- Natural rock salt or sea salt

PROHIBITED

- Gluten powder and bread improver
- Artificial emulsifiers, colouring agents, prese
- All chemical and synthetic additions
- Mineral oils

SECTION 6 - HORTICULTURE - VEGETABLE AND FRUIT CROPS

6.1 PRODUCTION METHODS

An essential feature of Bio-Gro horticulture holdings is their intensive nature which may involve the incorporation of organic materials from outside the property. Rotations usually exclude grazed pasture and livestock.

6.1.1 Soil Fertility

The intensive nature of horticulture requires in particular that sufficient quantities of organic material must be returned to the soil to maintain its organic matter.

Depending on the net output of produce and the cropping intensity, organic material produced on the property is rarely sufficient to maintain soil organic matter levels and or acceptable soil nutrient levels. On such properties this leads to the bringing in of considerable quantities of organic material.

6.1.2 Off-farm Organic Material

All bought in organic materials must meet the standards approved by the Certifying Authority (Refer section 1.2.8.2). Materials may be required to undergo chemical analysis and be approved by the certifying authority. (See appendix).

6.1.3 Soil Management

Due to extensive production of composts and use of manures and composts care must be taken to avoid leaching of nutrients with consequent environmental pollution.

Excessive use of manures in particular must be avoided. The certifying authority reserves the right to introduce limitations on tonnage of manuerial applications in any one year to reduce risk of environmental pollution and possible excessive nitrate contamination of water courses and foodstuffs.

6.1.4 Crop Rotation

The development of a rotation with a diverse range of crops is fundamental to successful organic intensive cropping and should receive careful attention.

The use of minimal tillage and extensive use of green crops between main crops is also considered an important part of good rotational practice.

6.1.5 Mineral Nutrition

On intensive vegetable production units using organic additions any further mineral enrichment is unlikely. Less intensive units for vegetables and in particular orchards may require to supplement organic inputs with some mineral additions. Permitted and restricted minerals are listed (Refer section 1.2.8.4 and 1.2.9.1).

6.1.6 Weed Control

Satisfactory weed control depends on timely management techniques which includes rotation and the use of mechanical, hand or thermal means. Mulches may be used for weed control, organic mulches must be from an approved source (Refer section 1.2.8.2). Plastic and bio-degradable mulches may be used.

6.1.7 Pests and Disease Control

All equipment used for spraying must never be used for prohibited substances.

The main aim of Bio-Gro production is to build an environment based on good husbandry practice that prevents the build up of pest and disease problems (Refer section 2.2). Routine problems indicate a failure to identify the main cause resulting in the need to use other control measures.

For permitted and restricted materials (refer section 1.2.8.5 and 1.2.9.2 and 1.2.9.3).

6.1.8 Propagation of Horticultural Material

The buying in of plant material from uncertified sources will be allowed subject to the approval of the certifying authority.

Full Bio-Gro producers will be expected to take steps to ensure that all propagated material is grown in media free of prohibited materials. Such plant materials should also be raised in an environment free of prohibited materials. Inspection of the propagation area will be required.

6.2 TRANSPORT, STORAGE AND PROCESSING

6.2.1 Transport and Storage

Fruit and vegetables may only be treated or packed with other produce which has been treated with any of the methods listed below.

RECOMMENDED

- Refrigerated containers
- Atmospherically controlled environments
- Pure ice
- Dry ice

PROHIBITED

- All fumigants.

6.2.2 Fresh Fruit and Vegetables

During sorting, washing and grading etc., Bio-Gro products should in no way be able to come into contact with or be confused with non-Bio-Gro goods. No prohibited materials should be used while preparing produce for sale.
The visual enhancement of produce for sale, e.g. waxing of fruit, maybe carried out with materials and processes acceptable to the certifying authority.

6.2.3 Dried Fruit and Vegetables

The commodities must have been grown in accordance with Certifying Authority Standards.

RECOMMENDED

- Sun drying and de-hydration

RESTRICTED

- Preserving in sugar syrup or honey

PROHIBITED

- All other methods

6.2.4 Fruit or Vegetable Juices and Wines

All produce used to make fruit and vegetable juices and wines must be of Certifying Authority Standard. Equipment and bottles should be copiously washed or heat and steam cleaned prior to use.

RECOMMENDED

- The use of stainless steel or glass equipment.

PROHIBITED

- All other containers and equipment.

6.2.4.1 Fruit and Vegetable Juices

RECOMMENDED

- Untreated lemon juice as a preservative
- Stainless steel, muslin and kieselguhr for filtration
- Centrifuging

PERMITTED

- Sea salt, rock salt or low sodium salt in vegetable juices
- Citric acid

RESTRICTED

- Ascorbic acid

PROHIBITED

- All other materials.

6.2.4.2 Wine Making

Certifying Authority quality fruits and juices must be used.

RECOMMENDED

- Cultured or Natural yeasts
- Centrifuging
- Natural ageing

PERMITTED

- Chaptalisation with 100% pure sugar
- The addition of unfermented grape juice - only where the grape juice is of Certifying Authority Standard quality.
- Natural lemon juice
- Clarification may be assisted using fresh egg whites, pure casein, food quality natural gelatine, bentonite and kaolin and calcium carbonate.

RESTRICTED

- Ascorbic acid
- Sulphur dioxide either as gas or metabisulphite can only be used if the final SO_2 concentration is below those indicated.

SECTION 7 - INSPECTION AND CONTROL

In order to protect both the consumer and the producer, all Transition Bio-Gro, or Bio-Gro produce/food must come from properties and/or processing facilities that have been verified as meeting the requirement standards of the Certifying Authority. Any such produce/food, must, as a minimum, be packaged so as to carry the registered number of the producer and/or processor, and preferably the name as well. Provided all fees and ancillary requirements have been met, it shall also be entitled to carry the registered trademark of the Certifying Authority. Subject to satisfactory inspection and verification, a licence to use the trademark will be issued by the Certifying Authority. The licence will be issued jointly to a property or processing facility, AND a responsible individual, who shall directly control the day-to-day operations of the unit.

7.1 INSPECTORS

Inspectors shall usually hold a relevant tertiary qualification in some aspect of environmental or biological science and/or experience in some aspect of primary production. They will need to satisfy the Certifying Authority that they are familiar with the Standards for organic produce, and have a demonstrable interest in the philosophy of organic agriculture. Each new inspector will be required to attend a training course, and meet the required standards of the Certifying Authority.

The purpose of the inspection is to ensure that the requirements and limitations set in the organic production standards are respected. Both the inspector and the producer must be familiar with these standards. Producers will be issued with a set of standards when they apply for certification of their property. When the appropriate questionnaires are completed and returned, and the fees paid, the Certifying Authority shall appoint an inspector to visit the property. The decision of the Certifying Authority will be based on the farm details and history supplied by the applicant, together with the inspector's report.

Before application, it may be appropriate for the applicant to seek advice from relevant sources.

7.2 THE PROPERTY QUESTIONNAIRE

The annual inspection of the property will rest primarily on the description of the farm and farming practices, produced by the farmer on registration with the Certifying Authority.

The property owner/manager will be required to provide information on:

1. The nature of the farming operation:
   Livestock, Mixed cropping and livestock,
   Horticulture - Vegetable and Fruit Crops?

Maximum permissible Total SO_2 levels in Bio-Gro wine.

Sugar		Total SO_2 mg/litre
<5 $g.l^{-1}$	(Dry)	90 - 110
$>5 < 30$ $g.l^{-1}$	(Medium)	110 - 200
>30 $g.l^{-1}$	(Sweet)	250

6.2.5 Jams and Chutneys

The ingredients for jams and chutneys must be derived from Certifying Authority Standards quality produce. Reductions, pasteurisation and pureers are all recommended.

6.2.6 Spreads

All ingredients used to make spreads must be derived from Certifying Authority Standards quality produce.

RECOMMENDED

- Certifying Authority Standards oils, herbs and spices

PERMITTED

- Natural methods of preserving and pasteurising.
- Unrefined sea salt or refined rock salt

PROHIBITED

- Emulsifiers, thickeners, anti-oxidents, flavour enhancers and all chemical and synthetic additives

2. An acceptable farm plan, drawn to scale and showing:

   a) All paddock boundaries fully named or numbered for easy reference.

   b) The nature of the boundaries should be indicated e.g. hedge, tree line, shelterbelt, fencing (closed or open), stone walls, no visible boundary.

   c) Particular note should be made of the nature and condition of the property boundary.

   d) The presence and composition of woodlot plantings or natural areas should be noted.

   e) Major soil types within the property should be indicated on the plan.

   f) Natural drainage patterns should also be indicated.

3. Areas adjacent to the property being inspected require attention with regard to possible sources of pollution. Of special importance will be:

   a) Fruit orchards, - spray drift danger.

   b) Hill and river bed country liable to aerial spraying with herbicides and consequent spray drift and polluted water run off.

   c) Major roads which could lead to heavy metal pollution of adjacent production areas.

   d) Polluting industry - aerial drift and water contamination.

   e) Polluted water as a source for irrigation

4. The general principles of production methods on the property in the past. These will include:

   a) Past use of organochlorines.

   b) Livestock management with details of stock held.

   c) Rotation cycles with details of crops grown.

   d) Soil fertility maintenance.

   e) Weed control techniques.

   f) Pest and disease control.

   g) Harvest procedures.

   h) Storage facilities.

5. On properties involving livestock special attention needs to be given to:

   a) Supplementary feeding.

   b) Use of veterinary medicine.

The producer should keep good records of the use of veterinary products in particular and be familiar with the requirements of Section 4.1.3 of the standards.

7.3 THE PROPERTY INSPECTION AND REPORT

The inspection will be carried out by an inspector of the certifying authority accompanied by a member of the Biological Producers Council (Inc) who is familiar with the type of property to be inspected.

The purpose of the inspection is to clarify and verify the information contained in the property questionnaire. In addition a full inspection tour of the farm is carried out to examine the well being of the production system and to establish the status of the property under inspection. At this time there may be occasion to call for certain analytical tests on soil, plant or product. Any such tests required will be at the expense of the applicant.

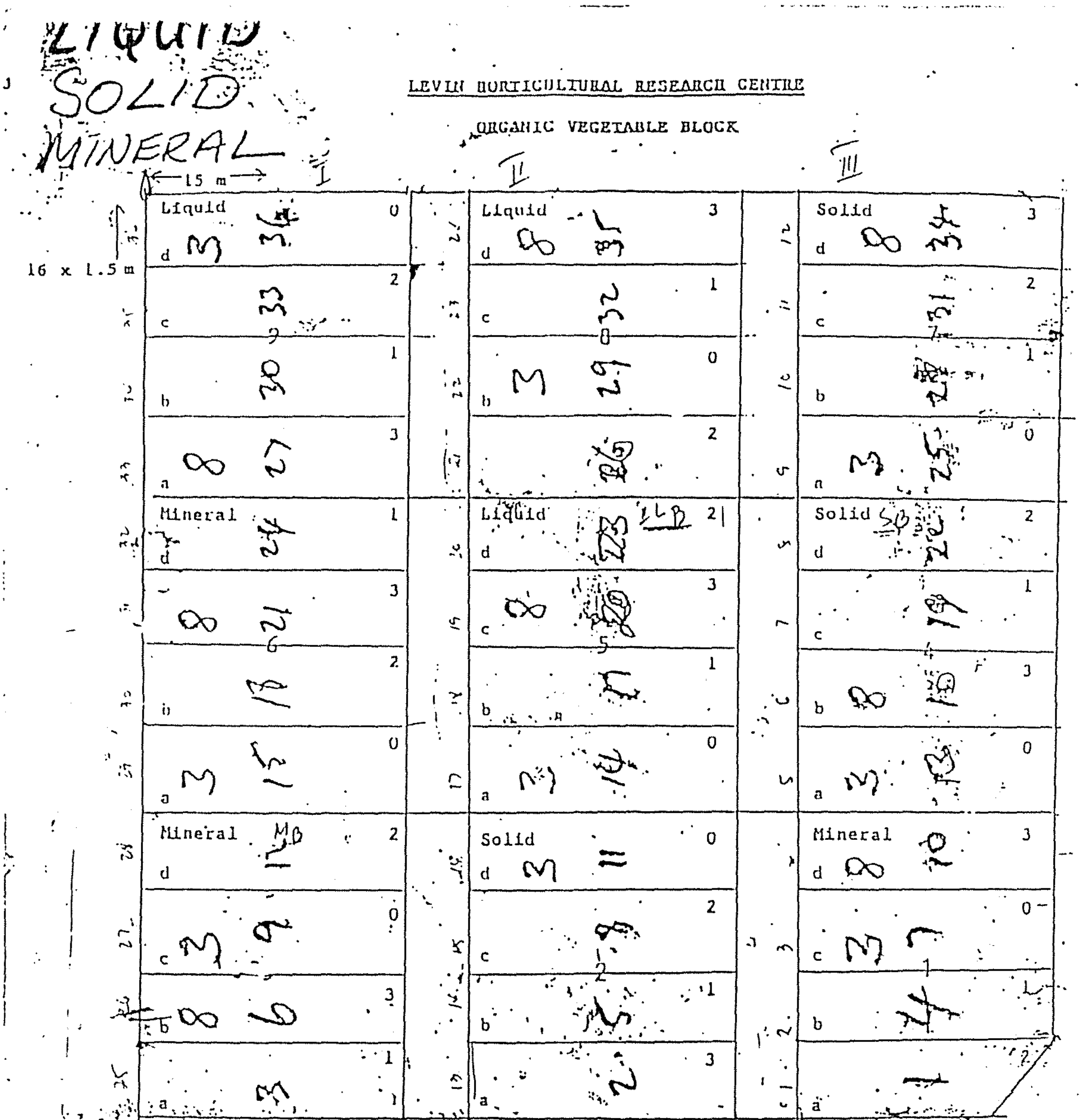
7.4 PROPERTY STATUS - BIO-GRO OR TRANSITION BIO-GRO CONTRACTURAL OBLIGATIONS

The property owner/manager signs the farm questionnaire as a guarantee that the information is correct. With the signature on the questionnaire or a separate contract the farm manager undertakes to farm according to the standards stipulated and to inform the Council or regional inspector in writing, if any changes occur in the circumstances stated should these changes be of such a nature that they may materially vary from the answers in the farm questionnaire.

Appendix 2.

LEVIN HORTICULTURAL RESEARCH CENTRE

ORGANIC VEGETABLE BLOCK



Plot Number

1 Mineral
2 Solid
3 Mineral
4 Solid
5 Liquid
6 Mineral
7 Solid
8 Liquid
9 Liquid

Rates 0, 1, 2 and 3 on sub plots a, b, c and d

* treatments randomised over whole plots

* rates randomised over sub plots

Appendix 3. Actual plant population density of sweetcorn plant. (MAF)

Treatment	level	repliction			
		I	II	III	Mean
Whey	control	40444	40666	49333	43481 b
	low	39111	44888	46222	43407 b
	medium	43555	37333	44888	41925 b
	high	47111	39777	44888	43925 b
Compost	control	40888	41555	37777	40073 bc
	low	41110	40666	41555	41110 bc
	medium	50444	29111	40000	39851 c
	high	39333	45555	42444	42444 b
Mineral	control	62668	41111	40888	48221 a
	low	40444	38444	39333	39407 c
	medium	44222	34222	46666	41703 bc
	high	35555	48666	35333	39851 c

Appendix 4. MAF SOIL ANALYSIS

SAMPLING DATE

6/1/88	1st crop corn, post sow, post fertilizer
23/3/88	1st crop cron, post harvest
12/10/88	1st cover crop, vetch, post incorporation
9/12/88	2nd crop-squash, post sow, post fertilizer
16/4/89	2nd crop-squash, post harvest
26/9/89	2nd green crop, tama rye, post incorporation (pre-trial 1989)****
13/12/89	3rd crop sweetcorn, post sow, post fertilizer
1/4/90	3rd crop sweetcorn, post harvest

Appendix.4 Table.1 MAF Soil pH measurement.

Sampling date	6/1/88	23/3/88	12/10/88	9/12/88	16/4/89	26/9/89	13/12/89	1/4/90
CONTROL								
whey	5.73	5.83	5.83	5.67	5.95	6.20	5.87	6.20
compost	5.60	5.80	5.83	5.70	6.00	6.20	5.87	6.17
mineral	5.70	5.83	5.87	5.73	5.90	6.23	5.93	6.17
LOW								
whey	5.77	5.77	5.77	5.80	6.05	6.23	5.83	6.17
compost	5.60	5.77	5.83	5.90	6.10	6.23	5.90	6.17
mineral	5.77	5.87	5.87	5.83	6.10	6.27	5.93	6.17
MEDIUM								
whey	5.83	5.80	5.80	6.07	6.15	6.30	6.00	6.23
compost	5.63	5.70	5.73	6.00	6.13	6.30	5.90	6.17
mineral	5.70	5.77	5.80	5.80	6.03	6.17	5.93	6.13
HIGH								
whey	5.80	5.83	5.87	6.17	6.10	6.30	6.00	6.23
compost	5.87	5.83	5.87	6.23	6.20	6.43	6.07	6.30
mineral	5.80	5.90	5.87	6.03	6.23	6.27	6.03	6.20

Appendix 4 Table 2. MAF Soil measurement for Organic Carbon.

Sampling date	9/12/88	16/4/89	26/9/89	13/12/89	1/4/90
CONTROL					
whey	4.0	4.1	4.2	5.3	4.8
compost	3.9	4.1	4.2	5.1	4.5
mineral	4.2	4.1	4.2	5.1	4.5
LOW					
whey	3.9	4.1	4.2	5.5	4.8
compost	3.9	4.2	4.1	5.1	4.6
mineral	4.1	3.9	3.9	5.3	4.6
MEDIUM					
whey	3.8	4.1	4.2	5.6	4.6
compost	4.0	4.2	4.1	5.4	4.8
mineral	4.3	4.3	4.2	5.2	4.7
HIGH					
whey	4.1	4.2	4.0	5.5	4.9
compost	4.4	4.1	4.1	5.5	4.7
mineral	3.9	4.2	4.2	5.0	4.4

Appendix. 4 Table.3 MAF Soil measurement, Olsen P.

Sampling date	6/1/88	23/3/88	12/10/88	9/12/88	16/4/89	26/9/89	13/12/89	1/4/90
CONTROL								
whey	30	26	27	29	26	25	22	23
compost	36	37	36	34	28	29	27	28
mineral	28	26	26	30	22	23	23	22
LOW								
whey	34	29	30	38	31	31	26	26
compost	39	38	34	43	35	34	30	31
mineral	34	31	31	33	28	29	27	27
MEDIUM								
whey	38	35	36	57	46	43	38	37
compost	39	40	39	52	39	41	34	33
mineral	29	29	28	30	23	24	24	25
HIGH								
whey	41	38	38	62	44	45	42	42
compost	42	48	47	58	40	37	37	37
mineral	30	32	30	32	27	27	26	27

Appendix 4. Table 4 . MAF Soil measurement for K.

Sampling date	6/1/ 88	23/3/ 88	12/10/ 88	9/12/ 88	16/4/ 89	26/9/ 89	13/12 /89	1/4 /90
CONTROL								
whey	8	5	5	16	10	5	9	6
compost	7	3	4	11	6	3	7	4
mineral	6	4	5	12	6	4	8	3
LOW								
whey	10	6	6	21	12	8	11	7
compost	10	6	7	15	10	5	10	6
mineral	10	5	6	15	9	6	12	7
MEDIUM								
whey	12	10	10	30	19	11	20	14
compost	10	6	6	20	12	8	11	8
mineral	9	6	6	19	11	4	12	7
HIGH								
whey	15	10	10	32	26	14	26	19
compost	10	6	5	22	13	7	15	7
mineral	12	8	8	24	15	8	14	9

Appendix.4. Table 5. MAF Soil measurement, Ca.

Sampling date	6/1/88	23/3/88	12/10/88	9/12/88	16/4/89	26/9/89	13/12/89	1/4/90
CONTROL								
whey	7	6	7	7	8	6	6	5
compost	6	6	7	6	6	6	6	5
mineral	7	6	7	7	7	6	7	5
LOW								
whey	6	6	6	7	8	6	7	5
compost	6	5	6	7	8	6	7	5
mineral	7	6	6	7	7	7	7	5
MEDIUM								
whey	7	6	7	8	8	7	7	5
compost	6	6	6	8	8	6	7	6
mineral	8	6	7	8	8	6	7	6
HIGH								
whey	7	7	7	8	9	6	8	6
compost	7	7	6	10	9	8	8	7
mineral	7	6	7	8	8	6	7	6

Appendix.4 Table.6 MAF Soil measurement, Mg.

Sampling date	6/1/8 8	23/3/8 8	12/10/ 88	9/12/8 8	16/4/ 89	26/9/ 89	13/12 /89	1/4/90
CONTROL								
whey	8	7	7	13	12	10	11	11
compost	8	6	6	10	10	9	9	9
mineral	8	7	7	12	11	9	11	10
LOW								
whey	8	7	8	13	12	10	11	10
compost	9	7	7	14	13	10	12	11
mineral	9	7	8	13	12	11	13	12
MEDIUM								
whey	9	7	8	14	13	10	13	11
compost	8	7	8	18	16	12	13	13
mineral	9	9	8	16	14	11	15	13
HIGH								
whey	10	8	8	15	16	11	15	13
compost	11	9	9	22	17	16	18	16
mineral	11	9	10	20	18	13	17	16

Appendix 5. a.

Bulk density Measurement of the 3rd Samples

PLOT	Rep I	Rep II	$\bar{x}$	PLOT	Rep I	Rep II	$\bar{x}$
5-10 cm				20-25 cm			
HIGH				HIGH			
SOLID 1	1.09	1.01		SOLID 1	1.05	1.10	
(sub samples) 2	1.12	1.07		(sub samples) 2	1.04	0.98	
3	1.15	1.12		3	1.17	1.12	
$\bar{x}$	1.12	1.07	1.10	$\bar{x}$	1.09	1.07	1.0~~7~~6
WHEY 1	1.09	1.09		WHEY 1	1.06	1.15	
2	1.14	1.03		2	1.10	1.02	
$\bar{x}$	1.12	1.06	1.087	$\bar{x}$	1.08	1.09	1.08
CONTROL				CONTROL			
SOLID 1	1.14	1.06		SOLID 1	1.04	1.09	
2	1.09	1.08		2	1.10	1.40	
3	1.15	1.04		3	1.11	1.12	
$\bar{x}$	1.13	1.06	1.093	$\bar{x}$	1.08	1.20	1.143
WHEY 1	1.08	1.10		WHEY 1	1.16	1.04	
2	1.02	0.98		2	0.99	1.02	
$\bar{x}$	1.05	1.04	1.045	$\bar{x}$	1.08	1.03	1.05
			1.081				1.087

Appendix 5.b.

GRAVIMETRIC WATER CONTENT : 3rd soil sample 60 DAE

PLOT/SAMPLE	Reps I	II	III	$\bar{X}$		Reps I	II	$\bar{X}$	
	I	II	III			I	II	~~III~~	
HIGH SOLID					HIGH LIQUID				
5-10 cm	0.390	.395	.394		5-10 cm.	.384	.368		
	0.399	.404	.366			.391	.375		
$\bar{X}$				.391				.379	
20-25 cm	.409	.420	.397		20-25 cm	.387	.388		
	.395	.436	.395			.417	.391		
$\bar{X}$				.408				.395	
CONTROL SOLID					CONTROL LIQUID				
5-10 cm.	.379	.358	.377		5-10 cm.	.397	.398		
	.357	.381	.386			.391	.404		
$\bar{X}$				.373				.397	~~.385~~
20-25 cm.	.390	.404	.403		20-25 cm.	.397	.410		
	.274[1]	.403	.403			.414	.447		
$\bar{X}$				.379				.417	
SUMMARY									
HS					HL				
5-10 cm		.391			5-10		.379		
20-25 cm		.408			20-25		.395		
CS					CL				
5-10		.373			5-10 =		.397		
20-25		.379			20-25		.417		

Appendix 6a.

R J Hill Laboratories
25 Te Aroha Street
Phone (071) 552-266
P O Box 4048
Hamilton, N.Z.

Client :	Soil Science Dept	**Laboratory No :**	35519
Address :	Massey University, Private Bag	**Date Received :**	14/03/91
	PALMERSTON NORTH	**Date Completed :**	21/03/91
Contact :	Lance Currie	**Page Number :**	1 of 1

PLANT TISSUE ANALYSIS

Plant Type: Maize

Sample Name	E 4 L	E 35 L	E 29 L
Lab No	35519/1	35519/2	35519/3
Nitrogen (%)	1.68	2.3	1.90
Phosphorus (%)	.84	.58	.80
Potassium (%)	1.85	2.2	1.68
Magnesium (%)	.44	.24	.38

Methods Used:

Details of methods used are available upon request.

pp R. Hill
D/ Terry Cooney

Appendix 6b.

FERTILIZER & LIME RESEARCH CENTRE

Massey University, Palmerston North, New Zealand.
Telephone (063) 69-099, Datex 30974-Mas Uni.

LABORATORY REPORT

NAME: Angela Olegario

ADDRESS: Massey University

all leaves final harvest

Type of material: Plant

Date analysis completed: 31-8-90

K kg/ha	SAMPLE	N %	P %	K %	S %	Ca %	Mg %	N:P	P input	Mg:K	N:K
		ANALYSIS									
360	M_3 E 4 L	1.99 1.80	1.09	1.85	0.29	0.57	0.42	1.65	~~750~~ 136 kg	NC.	
240	C_2 E 8 L	1.63 1.55	0.70	1.48	0.20	0.47	0.27	2.02	307 kg	C.	1.04
360	C_3 E 13 L	1.97 1.97	1.17	1.73	0.22	0.57	0.26	1.7	461 kg	P.	
240	M_2 E 28 L	1.21 1.35	? 0.57	1.52	0.22	0.45	0.27	2.4	104 kg	Min.	
—	M_0 E 29 L	1.99 1.99	1.07	1.74	0.30	0.65	0.38	1.9	0		
360	L_3 E 33 L	1.58 1.67	0.52	1.49	0.22	0.47	0.24	3.2	156		
240	L_2 E 35 L	2.12 2.22	0.60	2.25	0.23	0.58	0.24	3.7	104		

COMMENT:

[illegible]

P = .207 *

K = 1.48

S = .21

Ca = .47

Mg = .21

SIGNED: [signature] (for Director)

Appendix. 7. Yield Data of Previous Crops.

Trt/Plot	Trt/Rep	Vetch Cover Crop (wt. in g) area=6x15m 22-6-88	Squash (total wt.kg) 88-89	Italian Rye (dm in g) area=30x30cm 27-9-89
Whey	Control-a	6.2	150.2	37.4
	b	6.0	157.8	53.2
	c	6.7	128.4	41.3
	mean	6.3	145.5	43.9
	Low-a	7.8	168.9	60.2
	b	8.5	191.3	32.1
	c	10	186.9	34.9
	mean	8.8	182.4	42.4
	Medium -a	11.2	171.9	62.1
	b	14.4	212.8	49.6
	c	9.2	186.3	64.4
	mean	11.6	190.3	58.7
	High-a	10.3	189.1	62.2
	b	6.7	189.0	62.6
	c	8.7	186.5	55.3
	mean	8.6	188.2	60

Appendix.7. Yield Data of Previous Crops.

Trt/Plot	Trt/Reps	Vetch Cover Crop (wt. in g) area=6x15m 22-6-88	Squash (total wt. kg) crop yr.88/89 harvest 5/4/89	Italian Rye (dm in g) area=30x30cm 27-9-89
Compost	Control-a	6.1	151.1	29.7
	b	6.0	122.1	39.7
	c	9.1	155.9	42.3
	mean	7.0	143	37.2
	Low-a	9.6	163.9	55.7
	b	9.1	155.2	37.1
	c	11.4	187.1	60.1
	mean	10.0	169	50.9
	Medium-a	9.0	190.6	49.7
	b	11.0	177.5	61.4
	c	10.6	205.5	51.9
	mean	10.2	191.2	54.3
	High-a	10.6	215.2	67.7
	b	8.3	170.2	60.9
	c	13.0	174	66.9
	mean	10.6	186.5	65.2

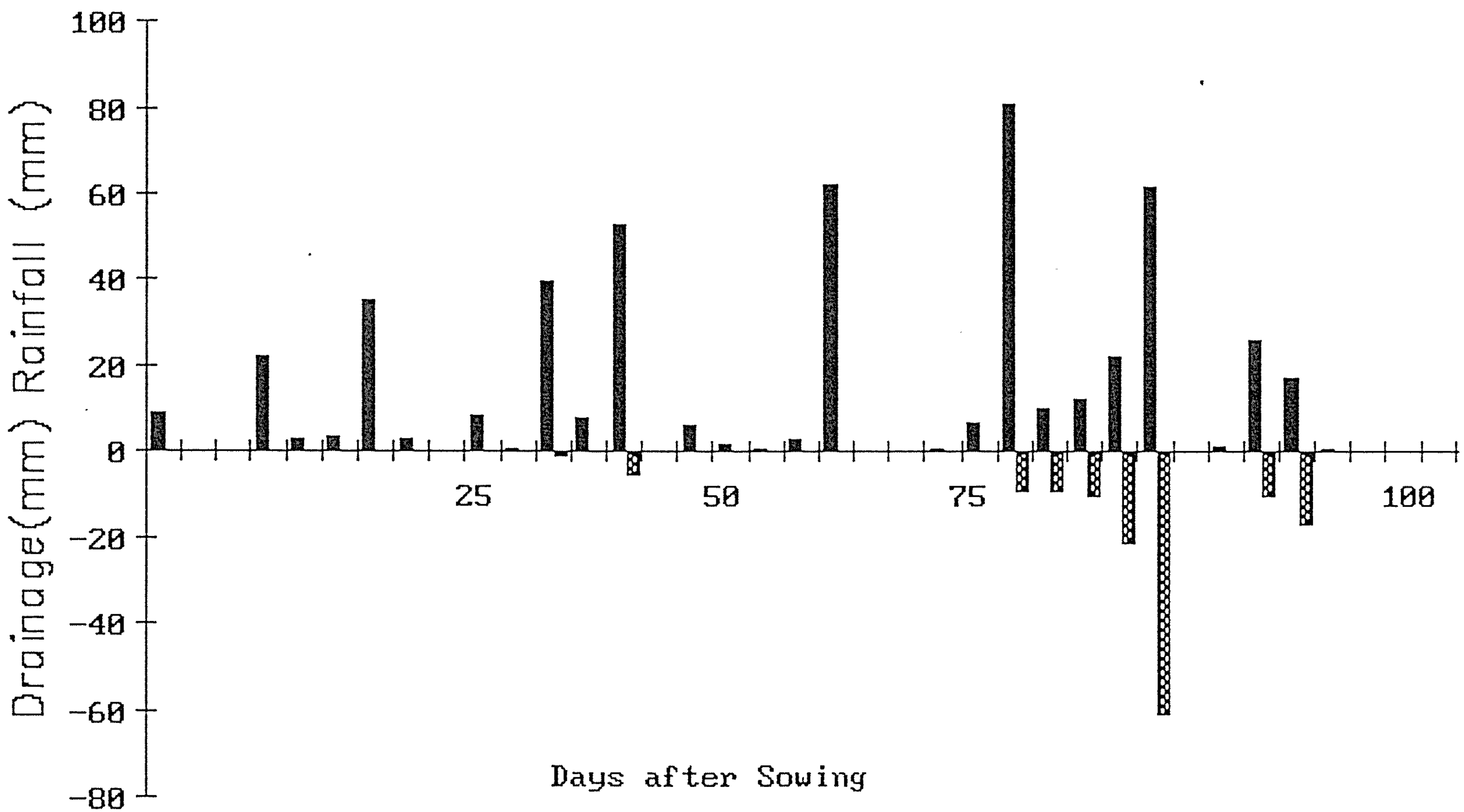
Appendix.7. Yield Data of Previous Crops.

Trt/Plot	Trt/Reps	Vetch Cover Crop (wt. in g) area=6x15m 22-6-88	Squash (total wt.kg) 88-89	Italian Rye (dm in g) area=30x30c m 27-9-89
Mineral	Control-a	5.5	154.5	36.8
	b	5.8	155.8	47.6
	c	5.7	144.7	52.8
	mean	5.7	151.7	45.7
	Low-a	8.7	172.7	28.1
	b	7.6	164.1	37.4
	c	11.2	160.9	22.0
	mean	9.2	165.9	29.2
	Medium-a	6.5	157.4	65.2
	b	8.1	181.8	65.7
	c	6.8	188	31.2
	mean	7.1	175.7	54
	High-a	8.2	185.3	39
	b	8.9	164.3	43.7
	c	9.8	173.6	36.7
	mean	8.9	174.4	39.8

APPENDIX 8. RESIN P VALUES FOR MINERAL FERTILIZER TREATMENT(SAMPLES TAKEN 20 DAS).

	Control	Low	Medium	High
Rep1	35	39	47	48
Rep2	45	61	51	51
Rep3	37	39	47	54
mean	39	46	48	51

Appendix 9. Water Balance During the Growing Period



Appendix 10.

ORGANIC FERTILISER TRIAL, LEVIN, 1989-90

Table 1 Visual estimates on 21 February 1990

Treat.	corn score /10	weediness /10	% amaranth	% polygon	% docks	% others
Mineral 0	7.5	5.7	52	37	3	8
Mineral 1	6.3	7.2	62	28	2	8
Mineral 2	6.7	6.8	53	35	2	10
Mineral 3	5.8	7.0	62	27	2	9
Solid 0	5.3	7.3	37	50	7	6
Solid 1	6.2	8.7	57	32	7	4
Solid 2	6.7	7.3	60	30	0	10
Solid 3	8.3	7.0	70	18	0	12
Liquid 0	6.7	7.0	37	43	7	13
Liquid 1	7.7	7.0	63	27	0	10
Liquid 2	8.2	6.3	67	23	0	10
Liquid 3	8.5	6.0	70	20	0	10

Appendix 11 APPARENT MINERALIZABLE N

Apparent trt.	Mineralizable-N Plt.Nup	Weedup	SoilN(i)	SoilN(f)	Plt.avilN	Apparent N Plt(alone)	N-min +weeds	TotalN	amtmin%tot pltalone	plusweed
Whey-C	57.4	34.4	36.07	7.6	28.47	28.93	63.33	8215	0.35	0.77
low	77.7	27.2	47.8	9.15	38.65	39.05	66.25	8126	0.48	0.82
medium	105.5	36.9	88.79	8.93	79.86	25.64	62.54	8501	0.30	0.74
high	98.7	46.9	132.08	16.25	115.83	-17.13	29.77	8688	-0.20	0.34
Compost-C	52.7	26.1	31.99	7.75	24.24	28.46	54.56	7783	0.37	0.70
low	81.4	28.5	40.89	8.16	32.73	48.67	77.17	8005	0.61	0.96
medium	66	23.1	48.16	10.44	37.72	28.28	51.38	8303	0.34	0.62
high	91.1	43.4	69.04	13.85	55.19	35.91	79.31	8732	0.41	0.91
Mineral-C	55.2	19.3	35.08	8.45	26.63	28.57	47.87	7740	0.37	0.62
low	67.7	23.7	34.72	9.16	25.56	42.14	65.84	7913	0.53	0.83
medium	87.4	30.6	35.96	8.73	27.23	60.17	90.77	7970	0.75	1.14
high	59.1	29.4	36.19	8.73	27.46	31.64	61.04	7695	0.41	0.79

Actual weed uptake (wc,wh, cc,ch,mh)
others est35%ofuptk