THESIS

submitted in part fulfilment for

the degree of

Doctor of Philisophy of the London University

by

MUNIRUL HUQ, B.Sc.(Agric.), M.Ag.(Soil Science, Dacca)

Department of Agricultural Chemistry,
Imperial College of Science and Technology,
London, S.W.7.

March, 1963.

"STUDIES ON STRAW AND COMPOST DECOMPOSITION AND THEIR EFFECTS UPON NUTRIENT METABOLISM IN SOILS".

ABSTRACT

A review of the literature was made on composting and the effects of non-composted and composted materials on soil properties and plant growth.

A comparison of the effects of three levels of straw and composted straw on the rate of mineralization of carbon from a soil over 311 days was made. In another experiment the rate of carbon mineralization from straw and compost added to a soil adjusted to four different pH levels and maintained at three different moisture levels, including waterlogging, was studied over 118 days.

A comparison was made of the effects of uncomposted straw plus mineral nitrogen, composts prepared from straw with three different accelerators (nitrochalk, sewage sludge and dried blood), a grass compost, and mineral nitrogen alone on the performance of ryegrass and the uptake of nitrogen, phosphorus, potassium, and magnesium in pot tests using a soil of three different pH levels.

The performance of ryegrass and uptake of major nutrients was studied in soil (at three pH levels) treated with three levels each of straw and straw composted with dried blood.

A study was made of the effects of straw and four

different composts on the performance of ryegrass in pot tests with a calcareous soil with either nitrogen or phosphorus as the only limiting nutrient.

The residual effects of straw and four different composts were studied in a pot test by growing two successive crops of wheat.

The availability of nitrogen from four straw composts, prepared with different accelerators, and containing very similar levels of total nitrogen was studied in a sand culture test and compared with the amount of nitrogen mineralized in an incubation test.

Dedication.

To my

late

father, mother and elder brother

in memory of their

love and affection to me.

ACKNOWLEDGEMENT

The author expresses his deep appreciation and gratitude to Dr. A.H. Cornfield, M.Sc., Ph.D., D.I.C., F.R.I.C., under whose supervision and encouragement this investigation was carried out.

The author is particularly indebted to Mr. A.G. Pollard, Mr. N. Gutteridge and Mrs. O. Connell for their timely help. Thanks are also due to Mrs. Reeve and Mrs. Ghosh for typing the thesis.

The writer further expresses his appreciation to the Government of West Pakistan, Ministry of Food and Agriculture, Government of Pakistan, the Colombo plan authorities and the British Council for extending the facilities to carry out this work.

CONTENTS

		Page
CHAPTER I.	Introduction, Literature Review and Objectives of the Present Study.	
	(1) The importance of organic matter in soil.	1
	(2) Decomposition of organic matter, particularly in composts.	7
	(3) Carbon metabolism during decomposition of organic matter added to soil.	15
	(4) N-metabolism in soils treated with organic materials.	18
	(5) Phosphorus metabolism in soils treated with organic materials.	24
	(6) Mobilisation of Potassium and Magnesium due to organic matter.	26
	(7) Field trials comparing straw and composts.	26
	(8) Conclusions from the literature review and objectives of the present investigations.	27
CHAPTER II.	Materials and Methods.	
	(1) Preparation of composts.	30
	(2) Adjusting Silwood soil to different pH values.	33
	(3) General procedure used in the pot experiments.	34.
	(4) Analytical methods.	36.
CHAPTER III.	Experiment A. Mineralisation of C in Silwood soil treated with fresh and composted straw at 3 levels.	
	(1) Experimental.	43

Page

(2) Results.

(a) Straw vs. compost. 44

(b) Varying levels of straw. 46

(c) Varying level of compost. 46

(d) Mixed straw-compost treatments 47

(e) Comparison of the retention of straw and compost on an "economic" basis. 48

(f) Discussion. 49

Experiment B. Effect of soil pH and moisture level on mineralisation of carbon from soil treated with straw and composts.

(1) Experimental 54

(2) Results.

(a) Mineralisation after 20 days incubation. 55

(b) Mineralisation after 47 days incubation. 57

(c) Mineralisation after 118 days incubation. 58

(d) Ultimate carbon retention. 60

(e) General effect of moisture level. 61

(f) General effect of pH level. 61

(3) Discussion. 62

(4) Summary - Experiment A. 68

Experiment B. 69

CHAPTER IV. Effect of treating a soil, at three pH levels, with straw and different composts on nutrient uptake by ryegrass in pot tests.

(1) Introduction. 96

Page

(2) Materials and methods. 96

(3) Results. —

(a) Dry matter yields of tops. 101

(b) Dry matter yields of roots. 103

(c) Top/root total dry matter ratios. 105

(d) Dry matter yield of tops + roots. 106

(e) Uptake of nitrogen. 108

(f) Uptake of phosphorus. 110

(g) Uptake of potassium. 113

(h) Uptake of magnesium. 115

(i) Recovery of applied nitrogen. 118

(j) Recovery of applied phosphorus. 119

(k) Recovery of applied potassium. 121

(l) Recovery of applied magnesium. 122

(m) Discussion. 124

(n) Straw + KNO_3 versus nitrochalk compost. 126

(o) Comparison of the four composts. 133

(p) Top/root dry matter ratios. 138

(q) Summary and Conclusions. 140

CHAPTER V. Effect of level of application of straw and blood compost on yields of and nutrient uptake by ryegrass in pots with a soil of varying pH.

(i) Introduction. 209

(ii) Experimental. 210

(iii) Results. 211

Page

(a) Total top yields of ryegrass. 213

(b) Root yields of ryegrass. 215

(c) Combined tops and root yields. 216

(d) Uptake of nitrogen. 218

(e) Uptake of phosphorus. 221

(f) Uptake of potassium. 224

(g) Uptake of magnesium. 227

(h) Top/root dry matter ratios. 229

(i) Percentage recovery of applied nitrogen. 229

(j) Percentage recovery of applied phosphorus. 230

(k) Percentage recovery of applied potassium. 232

(l) Percentage recovery of applied magnesium. 233

(iv) Discussion. 235

(v) Summary and Conclusion. 247

CHAPTER VI. The effects of straw and compost on the performance of ryegrass in a calcareous soil with: (a) nitrogen as the only limiting nutrient, and (b) phosphorus as the only limiting nutrients.

(1) Introduction. 303

(2) Experimental. 304

(3) Results.

(a) Phosphorus limiting test. 307

(b) Nitrogen limiting test. 309

(4) Discussion. 313

(5) Summary and Conclusion. 318

Page

CHAPTER VII. A study of the effects of straw and composts on the growth of and nutrient uptake by two successive crops of wheat.

(1) Introduction. 332

(2) Experimental. 333

(3) Results. 335

(a) First wheat crop. 336

(b) Second wheat crop. 336

(c) First and second wheat crop. 338

(d) Dry matter top/root ratios in the second crop. 339

(e) Nutrient percentages in the combined tops and roots of the second crop. 339

(4) Discussion. 341

(5) Summary and Conclusion. 344

CHAPTER VIII. The availability of nitrogen from the organic nitrogenous fraction of composts as determined by a sand culture test with ryegrass, and an incubation test.

(1) Introduction. 349

(2) Experimental. 353

(a) Incubation test. 354

(b) Chemical test for available nitrogen. 354

(3) Results. 355

(4) Discussion. 358

(5) Summary and Conclusion. 361

GENERAL DISCUSSION AND CONCLUSION. 363

Bibliography.

Appendix.

CHAPTER 1

Introduction, Literature Review, and Objectives of the Present Study.

The importance of organic matter in maintaining soil fertility is well known. Perhaps the first contribution of organic matter to the main inorganic bulk of the soil body was the protoplasm of the soil microbes and of other lower plant species before the higher plant and animal kingdom established themselves on the soils and rocks of the earth. It is not only an integral part of the soil but it also helps in the formation of soil through its weathering action on parent rocks and minerals.

The function of the organic matter in the soil is manifold. It improves the physical, chemical and biological conditions of the soil. It makes the heavier soil lighter and lighter soil heavier - thus facilitates drainage and increases the water holding power of the soil. It also helps in conservation of heat. In building and maintaining soil structure the need of organic matter is of the greatest importance. Chemically it acts as a reservoir of nutrients - releasing the nutrient elements through mineralisation.

The exchange capacity and buffering power of the soil are increased by organic matter, which is many times more effective than clay in this respect. Organic matter in this way reduces the leaching of nutrients from the soil.

There is evidence also to show that quite small amounts of organic substance affect directly the growth and development of the plant, probably through release of hormone-like substances.

The role of organic matter in the weathering and decomposition of soil minerals.

Organic matter dissolves the phosphates, calcium and magnesium carbonate in the soil through the action of carbonic acid and other metabolic products of roots and soil microbes. Ravich-Shcherbo (1) observed that calcite ($CaCO_3$), aragonite, magnesite ($MgCO_3$), dolomite and siderite ($FeCO_3$) were dissolved in the presence of metabolic products of lactic acid bacteria, butyric acid bacteria, nitrifying bacteria, and anaerobic nitrogen fixers.

Aleksandrov (2) isolated a bacteria which could decompose potassium silicate. Pikovskaya (3) and Gerretsen (4) found that the release of insoluble phosphate from soil minerals occured through microbial

action. Besides dissolving minerals micro-organisms can, as a secondary result of their activity, also decompose various types of minerals and rocks. Organic substances possessing chelating properties have been found to have a pronounced effect on the chemistry of minerals.

From the above references the importance of organic matter in rendering unavailable mineral nutrients into available forms can be assessed.

The action of humic substances.

Humic substances also take part in the decomposition of rocks and minerals. Springel (5) showed that silicates can be decomposed by humic acids with the formation of silicic acid. A decomposing effect of crenic and apocrenic acid was reported by Berzélius (5).

The role of organic matter in soil structure.

The importance of organic matter in building soil structure was studied by early workers like Schloesing, Kostychev and Wollny (5) and it was later developed by Williams (5). Soil with good structure provides the best conditions for the supply of water and nutrients to the plant.

The best water and nutrient regimes are produced

in soil with a fine crumb structure. The formation of crumb structure is dependent on factors like these (5): (I) consolidation of the soil particles under pressure from the highly branched root system of grasses; (II) the formation of active humus of the ulmic and humic acid type; (III) the penetration into the soil crumb of the highly dispersed solutions of ulmic and humic acids; (IV) the conversion of these acids into the state of a cement mainly by means of calcium supplied by the roots of legumes from the lower to the upper soil horizons.

Many workers have attempted to elucidate the role of micro-organisms in the formation of soil structure. They have found the bacterial slimes acting as the cementing agents between the soil particles and thus capable of producing water stable aggregates. Gel'tser (6) isolated some rhizosphere bacteria of the pseudomonas type from the root system of meadow grasses and demonstrated that they were able to produce water-stable aggregates. From the practical point of view good soil structure is obtained by sowing grasses and the application of organic manures.

Soil organic matter as a source of the carbon and mineral nutrients of the plant.

Organic matter from plant or animal sources undergoing decomposition in soil liberates the nutrients in inorganic form which becomes available to plant and soil micro-organisms. Part of the organic matter does not undergo mineralisation and becomes intimately mixed with the mineral fraction of the soil which appears to protect it from microbial attack. This forms the stable humus in soils.

The reserve of organic carbon including all the organic substances of living organisms and their dead residues, totals 6000 billion tons according to Nichiporovich (7) in all the soils on the earth. Considerable reserve of plant nutrients, particularly N and P, are present in organic form in soil humus. In agriculture, the nutrient cycle is complicated by the action of man and domestic animals. The plants take up nutrients from the soil and from the atmosphere; however, only a part of these nutrients is returned to the soil in the form of leaf-fall, stubble and root residues and eventually as farmyard manure. A large part of the nutrients removed by the crops is distributed on the surface of the earth or enters the atmosphere as products of the activity or as wastes of

man and animals.

The effect of organic substances on the growth and development of plants.

Mulder (5) detected the presence of organic acids of low molecular weight in the soil and observed that they promoted plant growth; poor growth occured in soils in which these compounds were absent.

Schrenier (5) isolated some organic substances of non-specific nature from the soil and found that their presence in low concentration in water culture solution inhibited plant growth indicating that harmful as well as beneficial effects may occur.

Bottomley (8) found a beneficial effect of peat inoculated with bacteria on the plant when applied to soil or in water culture. He attributed this effect as due to the presence of a growth-promoting substance such as auxin.

Mockeridge (9) observed that water-soluble humic substances extracted from farmyard manure and from rotted leaves had a positive effect on the growth and development of the plant and on certain biological processes such as nitrification and nitrogen assimilation; the effect of these substances increased as the decomposition of

organic residues increased.

It has also been shown that farmyard manure applications increased the germination capacity and vitamin content of plants; animals given fodder grown on treated fields showed a higher resistance to diseases than did those receiving fodder grown on untreated fields.

Source of soil organic matter.

The main sources of soil organic matter are as follows:-

(1) Crop residues from cash crops.

(2) Green manure crops i.e. crops grown specifically to be ploughed into the soil.

(3) Soils put to "grass" for one season or more.

(4) Organic manures, including stable manures, composted crop residues, peat, sewage sludge and "commercial" organic byproduct fertilizers e.g. dried blood, fish meal, cotton seed meal, etc.

Since the work reported in this thesis is concerned with a comparison of the effects of fresh and composted straw on soil nutrient metabolism and plant growth the literature review will continue with details concerning these aspects.

Decomposition of organic matter, particularly in composts.

Decomposition of organic matter of plant or animal

origin in the soil or in the compost is carried out by a great variety of micro and macro-organisms such as bacteria, fungi, actinomycetes, protozoa, worms, and insect larvae (10). These organisms derive their energy and body material by breaking down the complex organic matter into simpler forms. The carbon of the organic matter which is evolved as CO_2 as a decomposition product is utilized in cell synthesis. Nitrogen, phosphorus and potassium are required for their nutrition, of which the need for N is of paramount importance for protein synthesis. The C/N ratio plays an important role in the extent and type of decomposition. Roughly speaking, for decomposing every 35-40 parts of carbon 1.5-1.7 parts of N (10) is required by the decomposing organisms. If any organic material contains less N than this its rate of decomposition is reduced. The decomposition of cereal straw is delayed due to its wide C/N ratio which is about 80-200:1. To narrow down the C/N ratio and thus to hasten decomposition addition of extra nitrogen becomes necessary. When a material with a wide C/N ratio like cereal straw is incorporated in the soil the microbes will utilize the available N (ammonia and nitrate) in the soil to decompose the straw. Consequently there will be a

deficiency, possibly only temporary, of available nitrogen for the crop.

Through "composting" either in the heap or in the soil the C/N ratio is narrowed down to 15-25 at which ratio plant nutrients are released in available form (11). Some workers suggest the C/N ratio of 20 as the sign of maturity of compost (12). Of course further narrowing down to about 10:1 will be completed in the soil, giving a humus-like material which is a more-or-less stable product.

The source of nitrogen, organic or inorganic, which is applied to bring down the C/N ratio of the composting material is called an activator, starter or accelerator. Materials such as urine, dung, dried blood, sewage-sludge, urea, nitro-chalk, $CaCN_2$, $(NH_4)_2S_4$ and $(NH_4)_2CO_3$ have been used. Organic activators have been reported to be more efficient than inorganic ones in the decomposition process, e.g. Tinsley and Nowakowski (13) found that straw compost made with $(NH_4)_2SO_4$ and $CaCO_3$ in place of poultry droppings had lower N, P and K contents. Hutchinson and Richards (14) also observed that there was less loss of dry matter from the $(NH_4)_2SO_4$ - treated compost than from that treated with manure. Ehner and Springer (15) found

that organic activators acted as a good substrate for the varied micro-flora which carried on efficient decomposition. They also noted poor humification in $(NH_4)_2SO_4$-treated composts even after a lapse of three years. There was development of an unbalanced micro-flora in this treatment.

The decomposition of organic matter is more efficient under aerobic than anaerobic conditions. Hutchinson and Richards (14) and Ghildyal (10) found greater losses of dry matter in straw composted under aerobic than under anaerobic conditions. So it is likely that there will be more loss of organic matter from the loosely built compost heap than from compacted one. Yeh (16) observed a more rapid decomposition in un-compressed compost heaps than in compressed ones. To favour aerobic conditions he stored the material in a wire basket in a cement pit. Cornfield (17) did not get satisfactory decomposition of the straw compost in a wire unit as there was excessive loss of moisture and of N from the materials under these conditions, thus providing unfavourable conditions for microbial decomposition.

Under anaerobic conditions organic acids are produced and the minerals are rendered unavailable (10).

It is a common practice to turn the compost heap before the compost is well rotted.

To prevent reduction of pH due to production of organic acids during composting it is usually necessary to add liming materials such as finely ground chalk, ground lime stone or waste-lime. Hutchinson and Richards (14) advocated a dose of liming material of 1 cwt. calcium carbonate in addition to 3/4 cwt. sulphate of ammonia, per ton of straw.

A high temperature within the heap is helpful for the decomposition of organic matter. Hutchinson and Richards (14) recorded a rise of 65°C (149°F) in the compost heap during the initial stages of decomposition. Tinsley and Nowakowski (13) observed a temperature of 70-80°C in an aerated large compost heap within the first 5 days and then a gradual fall to 20°C after 55 days of composting.

Mattingly (18) found a relationship between soluble-N and total-N in straw-sludge composts. He found that the total-N in the dry matter increased three fold if the initial-N content was increased from 1.2 to 2.2%. The increase in nitrogen in the organic matter was smaller. The amount of soluble N increased from 0.1% to 0.35%. Several well matured composts contained

0.6% nitrifiable-N which represented about 18% of the total-N.

Hoyle and Mattingly (19) noted that the rate of decomposition of straw-sludge composts increased when the initial-N was increased from 1.1 to 1.97%. With more than 1.97% initial N there were heavy losses of N during composting. Soluble nitrogen in the composts was in the form of NO_3. The pH of the mature composts varied inversely with the NO_3 content. Supplementary aeration decreased soluble-N in mature composts and increased losses of N. There was more soluble-N in composts prepared from straw + $(NH_4)_2SO_4$ than composts prepared from straw + sludge with the same initial N content.

Hoyle and Mattingly (20) observed the great effect of source of N applied for composting in producing soluble-N. $(NH_4)_2SO_4$ alone produced 36.4% after 11 months, $(NH_4)_2SO_4$ + sludge produced 17.9% and sludge alone produced 11.4%. NO_3-N as percentage of soluble-N was 92.3, 93.4 and 93.5 respectively after 11 months.

Mattingly (21) studied the changes in the distribution of nitrogen during composting of straw. Investigations of the N fractions in a straw-sludge

compost 0, 9, 44, 114 and 471 days after mixing showed that ammonification of the original soluble-N and deamination of the part of the original protein proceeded simultaneously. Subsequent increase of soluble-N in the mature compost was very slow as was the decrease in soluble N fractions.

Tinsley and Nowakowski (13) devised procedures for the determining of total N, uric acid N and forms of N soluble in cold 0.1N H_2SO_4 in fresh sub-samples. Loss of organic matter and changes in N compounds were followed indirectly from the ratios of ash to loss on ignition and of ash or P or K content to the N content. There was accummulation of NO_3-N up to 1% of the dry matter in composts stored for 2-3 years, the composition of the straw being fairly stable and differing little whether a high or low proportion of droppings was used initially. The optimum ratio of straw to droppings was 1:1.5 by weight.

Tinsley and Nowakowski (22) found that from deep litter compost (poultry-droppings) losses through decomposition totalled 50% of the organic matter and 40% of the N. At the first sampling only a trace of nitrate nitrogen was detected though this eventually increased to 4% of the N; high pH and low moisture

content were presumed to check the activity of nitrifying organisms.

Kaila (23) observed that the rate of decomposition of straw compost was decreased by urea, NH_4 and NO_3 salts applied at rates higher than 0.7% of the weight of straw. According to him the retardation of decomposition appeared to be due to increased acidity caused by nitrification of NH_3-nitrogen and to the high electrolyte concentration in the compost. Incubation of acid peat samples showed intensive nitrification which was followed by a decrease in pH when the concentration of NO_3-N exceeded that of NH_3-nitrogen. The latter results suggest that ammonification, which precedes nitrification, may markedly decrease soil acidity, and this, as well as a greater acid tolerance of microorganisms in organic soils, permits activity of autotrophic nitrifying bacteria in peat soils.

Cornfield (17) found that the N content of composts prepared in small or large cells were very similar. The C/N ratio of the material was 40 at the start and 20 at the end. The sources of added N were nitrochalk, urea and grass. Loss of dry matter was 50-60% and loss of N was 7-14% during the composting period of 4-5 months.

Carbon metabolism during decomposition of organic matter added to soil.

Carbon constitutes about 50% of the dry matter of plant and animal tissues. When organic materials of plant or animal origin are allowed to decompose they are acted upon by various types of micro-organisms. Part of the carbon of organic matter is liberated as CO_2, part of it is utilized by micro-organisms for their cell synthesis and part remains as intermediate product. The total amount of CO_2 liberated depends on the nature of the material, the micro-organisms concerned, and the conditions of decomposition (10).

Materials like cellulose, hemicellulose, sugars and starches lose most of their carbon as CO_2 when decomposed under aerobic conditions. The amount of CO_2 released has been related to the degree of decomposition of organic matter. The decomposition of organic matter increases with increased aeration. Thus Van Suchtelen (10) found greater evolution of CO_2 from a soil placed on pure sand in a jar when an air current was passed through it.

Microbial activity is dependent on nutrient elements such as N in the available form. Waksman (10) found

that much less carbon of rye gtraw was lost as CO_2 in absence of N as when $(NH_4)_2SO_4$ was added. Plant material with wide C/N ratio needs extra nitrogen to be added from an outside source in the form of organic or inorganic nitrogen.

Partial sterilisation of soil by steaming, heat, chloroform or radiation increases the mineralisation of C 2-5 times. Thus Winsor and Pollard (24) found greater mineralisation of C and N after partial sterilization by steaming and after air-drying. They also observed that the C and N mineralized were significantly correlated with the organic C and total N content of soils.

Temperature affects the liberation of CO_2. Thus early workers like Déhérain and Demonssy (10) observed that CO_2 evolution increased with temperature up to 60°C, then decreased and increased again after 90°C. The decomposition of organic matter occurs even below 0°C to a limited extent.

Waksman (10) observed that with varying pH maximum CO_2 evolution occurred under aerobic conditions in neutral and slightly alkaline soils which are supplied with easily assimimmable plant materials. Kick (25) on the other hand found that liming had no effect on the decomposition of straw, peat, manure and sewage-sludge in soil over three years.

Broadbent and his associates (26, 27) found that small additions of grass (having labelled C obtained by being grown in an atmosphere of labelled CO_2) to mineral soils caused overall net losses of native organic matter.

Hallam and Bartholomew (28) found that maize and soyabean residues increased the decomposition of native soil organic matter to similar extents, the extent of increase varying with soil type. They found a net gain in the total organic matter content of the soil with high application (50 tons/acre) but not with low applications (2.5 and 10 tons/acre of residue).

Pinck and Allison (29 and 30) have opposed the view of Broadbent and his associates on the deleterious effect of fresh plant material on native soil humus. They observed that there was no marked oxidation of native soil organic matter following applications of even small amounts of fresh plant material.

Pinck et al (31) found that addition of extra nitrogen with green manure reduced the ultimate losses of total soil organic matter.

Allison et al (30) studied the effect of clay type on retention of C during formation of humus. Bentonite had a marked positive effect on the retention

of C, i.e. on the stabilization of humus, with easily decomposable materials such as sugar, but the effect was much less with sawdust and peat. A montmorillonite type soil and a kaolinitic type soil, however, behaved similarly with respect to C retention, though this may have been due to higher acidity of the kaolinitic soil. Addition of N stimulated decomposition, but the C/N ratio was not as important in determining the quantity of humus formed as were the nature and quantity of soil clays and the nature of the organic material.

Stotzy and Mortensen (32) found that straw-treated soil retained more C than did soils treated with rye or lucerne, probably because the straw, having a high lignin and low N content, was more resistant to the action of micro-organisms. The addition of mineral nitrogen even at 2000 lb. NH_4NO_3/acre had no effect.

N-metabolism in soils treated with organic materials.

The concept that NH_3 is an excretion product of microbial decomposition of organic matter was put forward by Marchal (33) as early as 1893.

Doryland (34) defined ammonification as "an expression of an unbalanced ratio for micro-organisms, in which the nitrogen is in excess of the energy/nitrogen

ratio". When the energy material is equal to or in excess of the energy/N ratio NH_3 production ceases. If the concentration of the energy material is less than the energy/N ratio ammonia will be produced.

Lipman and his associates (10) studied the influence of carbohydrates (sugars) upon the accumulation of NH_3 from nitrogenous materials like rice flour, corn meal, wheat flour, cowpea meal, linseed meal, soybean meal and cotton seed meal, when added to soil. They found that rice flour and corn meal, with a wide C/N ratio, allowed no accumulation of NH_3, with or without addition of carbohydrate. The substances rich in N like linseed meal, soybean meal and cotton seed meal allowed an accumulation of almost 50% of the added nitrogen as NH_3. But this was considerably reduced when available energy in the form of carbohydrates was added as well.

The effect of C/N ratio on mineralisation of nitrogen of organic substances when added to soil was studied by Heck (35) and Norman (36) with fungal and bacterial tissue, by Rubins (37) with organic fertilizers, by Batham (38) and Owen et al (39) with amino acids, by Winsor and Pollard (40) with $(NH_4)_2SO_4$ and sucrose. Winsor and Pollard (41) found a quantitative relationship

between N immobilized and C added to the soil. The relationship was that for every 8.3-10.8 units of C added one unit of N was immobilised.

Dasi (42) studied the comparative decomposition of young and mature mustard plants added to soil. While there was loss of 40% of the N from young plants, there was no loss of N from the mature ones during decomposition. The loss was attributed to the greater amount of N in the young plant.

Barnes (43) studied the metabolism of N-rich and N-poor organic materials over a period of 82 weeks. He found less NO_3 in the straw-treated soil than in the control one throughout the experimental period. The change in N mineralization of mustard (1.49%N) and Tares (3.46%)N was not significant after 11 weeks.

Cornfield (44) studied the metabolism of fresh and rotted organic materials with low N content in soil for a period of 184 days. Straw compost with C/N ratio of 20.6 showed mineralization of nitrogen over practically the whole of the incubation period. Rotted farmyard manure with C/N 15.6 caused a small amount of N fixation, whilst fresh grass with C/N 22.6 caused a fair amount of N fixation in the early stages, but there was a small

overall mineralization of N by the final sampling. A poor straw compost with C/N 42.5 and straw with C/N 147.0 both caused considerable fixation of nitrogen in the early stages. With continuing incubation the bulk of the N fixed by the poor compost, but only a small portion of that fixed by the straw, was released.

Mattingly (45) found no NO_3 formation, when straw-sludge composts were incubated with soil when the total N of the composts was 3% or less. When the total N was 4% or more nitrification occurred.

Garactani and Catani (46) studied the ammonification and nitrification of a number of nitrogen fertilizers in a soil of pH 5.3. Ammonification of the fertilizers was in the decreasing order-$CaCN_2$, urea, castor bean cake, blood meal, hoof and horn meal. Nitrification was in the decreasing order-castor bean cake, urea, hoof and horn meal, blood meal, $(NH_4)_2SO_4$, $CaCN_2$.

Stevens and Withers (47) found that nitrification of organic substances differed more in soil than in artificial media. Wimmer (48) observed that the inhibiting effect of organic matter on the nitrification process was much less in soil than in culture media. Stevens and Withers (49) observed that nitrification of

cotton-seed meal and of ammonium sulphate took place much more rapidly in soil than in solution.

The presence of colloidal substances in the culture solution influences the behaviour of the nitrifying bacteria, (Albrecht and McCalla (50), Conn and Conn (51) and ZoBell (52).) Soils varying in physical and chemical constituents might be expected to show different nitrifying capacities. Pikorvska (53) also found that bacteria isolated from different soils had different nitrifying capacities. Cutler and Mukherjee (54) have isolated four different strains of bacteria from Rothamsted soil, all capable of oxidising ammonium to nitrite.

The effect of pH on nitrification has been studied by Meyerhof (55 and 56) and Winogradsky (57). According to them the optimum pH lies between 7 and 9 with a rapid fall-off on either side. Meek and Lipman (58) found that nitrifiers functioned from pH 5 to 13. Meyerhof (55 and 56) investigated the optimum concentration of ammonium and nitrite for nitrosomonas (the ammonia oxidiser) and for nitro bacter (the nitrite oxidiser). He found the optima at 0.005N-ammonium for nitrosomonas and 0.0072 N-nitrite for nitrobacter respectively. Warington (58 and 59) and Winogradsky

and Omeliansky (60) all showed an inhibiting effect of ammonia on nitrate production. Winogradsky (57) found that organic matter reduces nitrification.

The optimum temperature for nitrifying bacteria has been found by Tandon and Dhar (61) as 25°C for temperate soils.

Goldberg and Gainey (62) studied the role of surface phenomenon in nitrification in culture solution. They observed that the addition to a filtered salts medium of different finely ground soil minerals stimulated or depressed nitrification, depending on the particular mineral or other conditions existing in the medium.

Quastel (63) points out the possible presence in soil of a class of organisms that can convert certain organic nitrogen compounds directly into nitrite and nitrate. He concluded from his investigation that soil contains organisms, presumably heterotrophic, that can speedily oxidise pyruvic oxime to nitrite. According to him the process of nitrification in soil may not be wholly accomplished by the autotrophic organisms and the heterotrophic may intervene in bringing about a direct nitrification of organic nitrogen compounds.

Quastel and Schofield (64) studied the effect of pH and organic substances on nitrification and on the metabolism of amines and the kinetics of NO_2 oxidation in soil following continuous perfusion method and the Warburg manometric technique. The organic matter did not influence the rate of nitrification except that its N encouraged the growth of heterotrophs initially. Addition of Ca increased the nitrification of poorly buffered or acid soils, and the rate of nitrification in slightly acid soils was greater with amino-acids than with NH_4. Many organic substances exercised large but specific effects on the process of nitrification.

Phosphorus metabolism in soils treated with organic materials.

Shapiro (65) studied the effect of organic matter and flooding on availability of soil and synthetic phosphates. He observed a greater amount of P in the soil solution of organically treated soil. The availability to rice of the P occuring naturally in acid soils and of P added as synthetic iron and aluminium phosphates was increased by flooding and by addition of cellulose. This increased availability was due mainly to the reducing conditions produced by the treatments.

Khanna and Roy (66) studied the factors affecting soil fertility in the sugar belt of Bihar. Application of sugar cane filter press cake (free of P) or P-free organic matter (starch, glucose) to calcareous soils increased the H_2CO_3-soluble P in soil by releasing the fixed native P.

Fuller et al (67) studied the factors of availability of P of plant residues incorporated in soil. They found greater release of P from young than from mature residues. The P release also increased with increasing length of time of contact of the residues with the soil. The P/of residues containing less than about 0.2% P was immobilized by micro-organisms.

Kaila (68) observed that mineralization of organic P from easily decomposable material exceeded fixation when the content of orgamic P in the decomposing material exceeded 0.3% of the dry matter. With difficulty decomposable materials the critical value was 0.2% P. With thermophillic organisms and under anaerobic conditions the critical value was still lower. According to Kaila crop residues and manures seldom cause soil-P fixation, but with straw the danger of P fixation is likely.

Mobilisation of Potassium and Magnesium due to organic matter.

The literature appears to contain no work on the effect of organic matter on the mineralization of K and Mg in soils. This is presumably because these elements exist in soils almost entirely in inorganic forms.

Field Trials comparing straw and composts.

Trials at Rothamsted (69) over a number of years showed that better yields of potatoes, sugar beet and barley grain were obtained when straw together with extra N was ploughed directly into the soil than when the straw was composted (using the same amount of N as added to the field-applied straw) before being ploughed in.

Conclusions from the literature review and objectives of the present investigation.

Although the literature review has indicated that much work has been done on various aspects of the decomposition of added organic materials in soil, it would appear that the following aspects have not received much attention:

(1) A comparison of the stability in soil of the fresh organic material and the same organic material composted before being added to the soil. Such a study would indicate whether the fresh or the composted material would be more suitable for maintenance of soil organic matter and improvement of the soil nutrient status. Although a limited amount of work has been reported (43, 44, 45, 46, 65, 66, 67 and 68) for N and P along these lines, little work has been done with the other major nutrients.

(2) A comparison of the effects of different accelerators used for preparing composts on the properties of the finished compost. The properties studied would be such things as the stability of the materials in the soil and their effects on nutrient metabolism. Although a limited amount of work has been reported (13, 14 and 15) on this subject with respect to nitrogen, none has been

reported with respect to the other major nutrients.

The accelerators compared in this study were "chemical" (nitrochalk), or "animal origin" (dried blood), and of "mixed animal and vegetable origin" (sewage sludge).

Since the literature indicated that soil pH had an important bearing on the type of decomposition of added organic materials, most of the experiments carried out in this study were done using a soil adjusted to different pH values.

Wheat straw was selected as the chief material for study for the following reasons:

(1) Wheat is grown in most parts of the world and straw residues are usually available. These residues are usually disposed of as stable litter or by being ploughed into the soil with or without prior composting. Where large amounts of residues are produced they are often burnt. This is undesirable since potential humus is destroyed in this way.

(2) Straw composts well with a range of accelerators, providing these are added in suitable quantity. Straw itself and the compost produced from it are fairly homogeneous materials and are therefore useful for small-scale experimental work, such as pot tests.

In addition and for the sake of comparison a grass compost was also used in this study. The main reason for choosing this was that the material could be composted without addition of any accelerator, since the grass was cut whilst young and was fairly high in nitrogen.

In the studies to be reported mineralization of carbon was studied in incubation tests, whilst metabolism of nutrients in soils was studied in pot tests using rye-grass and wheat as indicator plants.

A sand culture test was also carried out specifically to compare the availability of nitrogen from the organic nitrogenous fraction of different composts.

CHAPTER II.

Materials and Methods.

Preparation of Composts.

The composts were prepared using 2kg. quantities of straw and grass by the method described by Cornfield (70). He had shown that providing the composting was done in a room whose temperature did not fall below 30°C, the final material produced was similar (insofar as C/N ratio was concerned) to composts prepared on a larger scale.

The dry wheat straw and grass were chopped with a chaffing machine into lengths not exceeding 1 inch. 2 kg. portions were weighed into perforated polythene bags and submerged in water in enamelled drums for 48 hr. The bags were then withdrawn from the water and allowed to drain overnight. They were then mixed, where necessary, with the accelerators as indicated in Table 1 (see over).

The blood and nitrochalk composts received sufficient accelerator to give an initial C/N ratio of 40. The sludge compost received sufficient dried sewage sludge to give an initial C/N ratio of 30, since it has been shown (70) that only part of the nitrogen present in sewage sludge is "available" to the micro-organisms concerned

with the composting process. The "poor compost" was included in the study in order to see what would happen when a material which had been composted without addition of sufficient nitrogen was added to soils.

Table 1

Name	Accelerator	Initial C/N ratio (including accelerator).
Poor compost	None	52
Grass "	None	20
Blood "	dried blood, 42.8 g.	40
Nitrochalk "	Nitrochalk, 22.7 g.	40
Sludge "	dried sewage sludge, 212 g.	30

The materials were placed in glazed earthenware cylinders (9 in. internal diameter by 2 ft. high) resting on concrete slabs. The cylinders were kept in a room maintained at 30-35°C and were covered with sacking to reduce evaporation. Water was added when the surface layers of the composts dried. The water was added in small amounts so as to avoid any drainage losses. The materials were "turned" (i.e. removed, mixed and replaced in their containers) 4 weeks after the start of composting and again after another 6 weeks.

20 weeks after the start of composting the materials were removed from the cylinders, and spread in thin layers on brown paper in a greenhouse. After the materials had thoroughly air-dried (4 days) they were ground in a Christie and Norris mill and stored in glass jars. The uncomposted straw was ground in the same way.

The materials were analysed for total carbon, nitrogen, phosphorus, potassium and magnesium and the results, together with pH and C/N ratio are shown in Table 2 below.

Table 2.

Chemical analysis of the composts and fresh straw.

	C/N	Total P_2O_5	Total Mg	Total K	Total N	Total C	pH
Straw	52	0.208	0.138	0.800	0.79	41.25	
Poor compost	32	0.208	0.138	0.400	1.30	41.90	5.53
Grass "	12	0.466	0.181	0.675	2.66	32.5	6.86
Blood "	20	0.250	0.145	0.400	2.03	40.6	5.62
Nitrochalk "	28	0.216	0.133	0.350	1.46	41.20	6.10
sludge "	16	1.383	0.279	0.550	2.33	37.40	7.36

Soils.

In the incubation studies of carbon mineralization a Bagshot sand collected from Silwood Park was used. For the pot tests the Silwood soil, an alluvial loam, and a calcareous sandy loam were used. These samples were collected from the 0-6 in. layer of unmanured plots. The samples were air-dried and broken up to pass a 2 mm. sieve. Mechanical analysis and chemical properties of these soils are shown in Table 3 (at end of chapter).

Adjusting Silwood soil to different pH values.

Batches of Silwood soil were mixed thoroughly with finely ground calcium carbonate or sulphur in amounts shown in Table 4 (on next page). The mixtures were placed in 2 gallon glazed earthenware pots having an outlet at the bottom and the bottoms of which were covered with gravel (to prevent clogging). Distilled water was added in small amounts at a time until drainage water just appeared. A control soil receiving no addition of anything except water was also run at the same time. The pots were kept in a greenhouse and water was added when necessary to keep the soils moist. 30 days from the start 5 in. of water was applied to leach out soluble salts. This was repeated 3 more times at 30-day intervals.

The soils were then spread out to air dry and their pH determined. These results are given in Table 4, below.

Table 4

Treatment	pH of Soils
0.2% $CaCO_3$	7.45
0.1% "	7.30
Control (untreated)	7.73
0.06% S	4.49
0.16% S	2.92

Soils with nominal pH values of 4.5, 5.0, 6.0 and 7.0 were obtained by mixing appropriate amounts of the treated soils. These mixtures were then moistened and kept for 1 month in a greenhouse to allow equilibrium to become established. There were air dried again and their pH determined. These were found to be 4.5, 5.2, 6.2 and 7.2

General procedure used in the pot experiments.

Plastic pots having a capacity of 500g. air-dried soil were used. The bottom of the pot was covered with glass cloth to hold in the soil but to allow free drainage. Each pot rested in a plastic saucer. The air-dried soils were mixed with the organic materials (in amounts to be

given in detail under each experiment) and the mixture placed in the pots. The seed (ryegrass or wheat) was sown in equal weights per pot. Distilled water was applied in measured quantities alternately to the top of the soil and into the saucer. In some cases soluble inorganic nitrogen and phosphate were applied in solution after emergence and after each cutting of ryegrass. The harvested plant material was dried in aluminium dishes in an electric oven with forced air draught at 70°C. The dried plant material was then ground in a Christie and Norris mill and stored in well-stoppered bottles for chemical analysis.

Analytical methods:

Micro-digestion of the plant material.

For the determination of N, P, K and Mg in the plant material, the micro-digestion method of Yuen and Pollard (71) was used. Analar concentrated sulphuric acid containing 3% salicylic acid and sodium thiosulphate with addition of 100 vol. analar hydrogen peroxide were used. Total N was determined by the Nesslerisation method of Yuen and Pollard (72).

Extraction of the soil with Morgan Reagent.

Morgan reagent (73) consisting of sodium acetate tri-hydrate in 3% acetic acid having a pH of 4.8 was used for estimating the "availability" of nutrients under different treatments. Activated charcoal at the rate of 1% of the weight of soil was used to decolourise the extract. The actual extraction was carried out by shaking the soil and the Morgan Reagent in ratio of 1:2 plus the activated charcoal for one minute. After shaking, the mixture was poured on to a dry filter paper (Whatman no. 1) and the filtrate was received in a dry receiver. The nutrients present in this filtrate were determined. The extracts were kept in a refrigerator until analysis.

Carbon Mineralization:-

The CO_2 evolution from the organic matter decomposition in soil was measured by Cornfield's method (74).

Total nitrogen:-

Total N of the soil and composts were determined by the Kjeldahl's method of digestion using selenium oxychloride as the catalyst and distillation in Markham micro distillation still.

Ammoniacal nitrogen in the soil was extracted with Morgan reagents and determined by the method of Bremnar and Shaws (75).

Nitrate nitrogen in the Morgan reagent extract of soil was determined by the method of Bremnar and Shaw (75).

Phosphate in plant material was determined by the molybdenum blue-amino-naphthol sulphonic acid method of Yuen and Pollared (76).

Potassium in plant material was determined by using the flame photometer.

Magnesium in plant material was determined colorimetrically by means of titan

yellow following the method of Cornfield and Pollard (77).

Organic Carbon. Walkley and Black's (78) rapid titration method was used for soil, plant materials and composts.

pH:- The pH of the soil and of composts was determined with the Cambridge pH meter using a calomel-glass electrode system and soil water ratio was made 1:2.5 (79).

Mechanical Analysis.

The revised official method by the Agricultural Education Association (80) was used for the soils.

Determination of the total exchangeable bases and the cation exchange capacity.

Bray and Willhite's (81) method was followed to determine the exchangeable bases from the ammonium acetate extracts. The total cationexchange capacity was determined from the ammonium acetate leached residue by the method described by Piper (79).

Water holding capacity of soils was determined by the Keen-Raczkowski box experiment using the circular shaped boxes as described by Coutts (82).

Table 3.

A. Mechanical analysis of Silwood, Calcareous and Harlington soil. Fractions % in the soils (oven dry basis).

	Silwood Soil	Calcareous Soil	Harlington Soil
Sand	80.2	60.0	53.8
Silt	10.0	30.2	23.0
Clay	5.1	5.6	17.4
Moisture	1.0	1.5	2.0
Loss on ignition	3.9	-	3.0

Table 3.

B. Chemical analysis of Silwood, Calcareous and Harlington soils.

Methods	Determination of pH	Silwood	Calcareous	Harlington
Calomel glass electrode	pH	6.92	8.0	6.25
Ammon. acetate	C.E.C. me/100	10.90	-	12.00
Kjeldahl	Total N %	0.178	0.110	0.157
Boiling HCl	Total P_2O_5 %	0.154	0.320	0.217
Black and Walkley Rapid titration method	Organic Carbon %	2.12	1.20	1.90
Morgan Reagent extract	Total Mg ppm	30.0	37.0	73.0
Morgan Reagent extract	Total K ppm	28.4	25.0	59.6
Ammon. acetate	T.E. Bases me/100	9.3	-	10.12
Collin's Calcimeter	$CaCO_3$ %	nil	0.76	nil
Keen-Raczkowski Box	Water holding capacity %	40.0	49.0	43.0

CHAPTER III

Expt. A. Mineralisation of C in Silwood soil treated with fresh and composted straw at 3 levels.

Expt. B. Mineralisation of C in Silwood soil at various pH and moisture levels treated with fresh straw and composted straw.

Introduction.

Experimental.

Results.

Discussion.

Summary and Conclusion.

Introduction.

A search of the literature has shown that virtually no work has been reported on the comparative rates of decomposition of fresh and composted straw when added to soil. Cornfield (74) in his paper on a method of determining mineralization of carbon in soils also showed that straw decomposed at about three times the rate of compost when these were added to soil and incubated for 90 days. Since this was in the nature of a preliminary experiment the two following more detailed studies were carried out:

Expt. A. Carbon mineralization was determined in a soil of pH 6.1 which had been treated with fresh straw and composted straw each at 0.5%, 1.0% and 2.0% by weight. In addition mixtures of fresh and composted straw were added. This was a long term incubation test lasting for 311 days.

Expt. B. In view of the possible importance of both soil pH and moisture level on the comparative rates of mineralization of the two types of material in soil this experiment was concerned with measuring mineralization rates at four soil pH levels and three moisture levels.

Experiment A.

Effect of three levels of straw and compost in mineralization of carbon.

The soil used was the Silwood soil, the straw was finely ground wheat straw and the compost was the nitrochalk compost. Details of these are given in Chapter II.

Experimental.

10g. portions of the air-dried 2 mm sieved soil were mixed with the finely ground materials in the amounts shown in the table below and placed in 6 in. x $\frac{3}{4}$ in. test tubes. A control soil (i.e. one containing no organic amendment) was also prepared and all treatments were done in duplicate.

Serial no.	Treatments	Abbreviations used
1	Control	
2	soil + 0.5% fresh straw	S_1
3	soil + 1.0% " "	S_2
4	soil + 2.0% " "	S_3
5	soil + 0.5% compost	C_1
6	soil + 1.0% "	C_2
7	soil + 2.0% "	C_3
8	soil + 0.66% compost + 0.33% straw	SC_1
9	soil + 0.33% compost + 0.66% straw	SC_2

Water was added to each tube to bring the moisture content to 50% of the water-holding capacity. This water contained 2 mg. N as potassium nitrate. This was to ensure that nitrogen was not a limiting factor in decomposition, particularly of the straw. The method of determining C mineralization in these tubes during incubation at 28°C then followed that described by Cornfield (74). CO_2 release measurements were made, using Cornfield's apparatus (plate 1), after 3, 6, 10, 15, 20, 28, 38, 48, 58, 69, 83, 103, 125, 147, 175, 235 and 311 days i.e. 17 measurements in all.

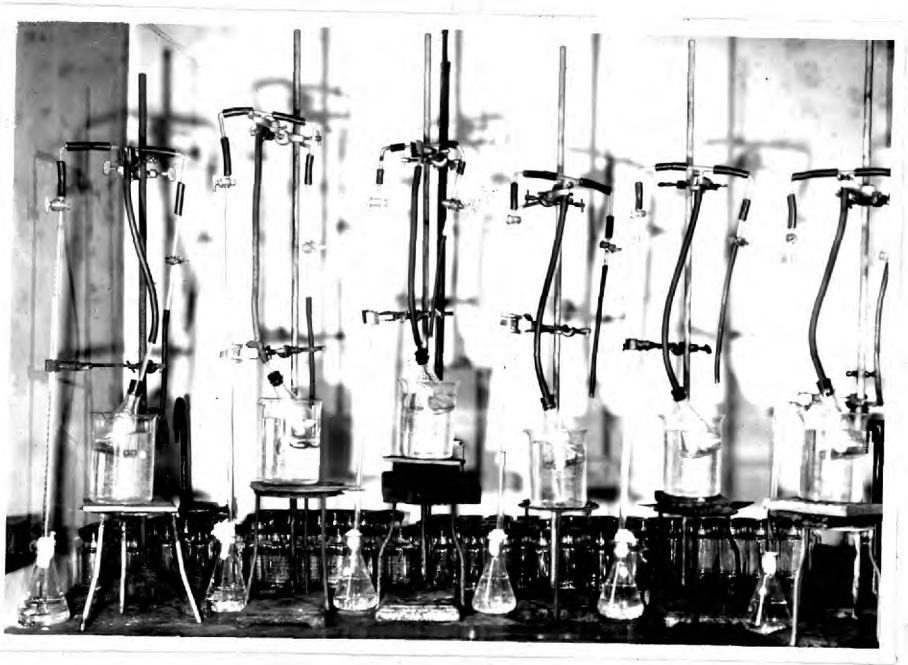
Results.

Results are shown in Table 5 (at the end of chapter) and Fig. 1. Results are presented as cumulative percentage recovery of added carbon (as carbon dioxide) less that given by the control soil.

Straw vs. compost. With each of the three levels of straw there was rapid decomposition of the material during the first 50 days and during this period about half of the original straw was lost. An inflexion point occurred at about this period and thereafter the rate of decomposition with all three levels of straw decreased in comparison with the earlier period. However,

PLATE 1

A battery of six CO_2 measurement apparatus as devised by Cornfield. They were used in the carbon mineralisation experiment as described in this Chapter.



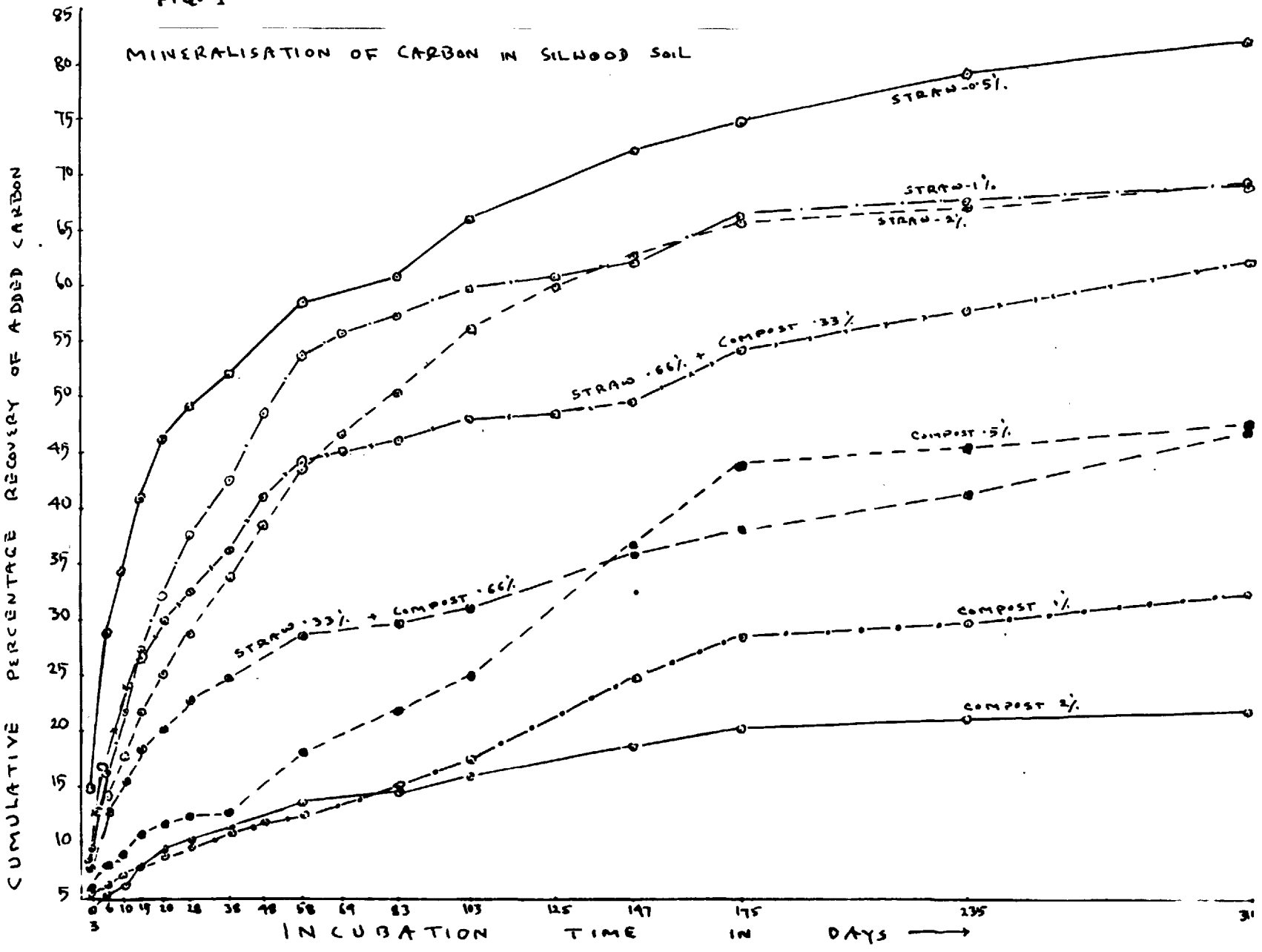
decomposition continued at a more-or-less linear rate.

With the compost there was no relatively rapid release during the earlier period of incubation such as occurred with the straw. The rate of release was more-or-less linear with time right from the start of incubation.

Results were analysed statistically after four periods of sampling, viz., after 20 days, during which period the straw was decomposing relatively rapidly, after 58 days, at which point the rapid rate of decomposition had terminated and the slower rate had started, after 175 days, which is about halfway through the incubation period, and at the end of the incubation period. These results and their statistical interpretation are shown in Table 6 (at end of chapter).

A comparison of straw and compost decomposition at each of the three levels indicated that loss of straw was significantly greater ($P = 0.05$) than that of compost at the same level, at all periods. During the early part of the incubation a much higher proportion of straw was decomposed than was compost compared with the later part of the incubation. Thus after 20 days at the 1% level of addition 32% of the straw and only 9% of the compost

FIG. 1


MINERALISATION OF CARBON IN SILWOOD SOIL
CUMULATIVE PERCENTAGE RECOVERY OF ADDED CARBON
INCUBATION TIME IN DAYS
STRAW-0·5%.
STRAW-1%.
STRAW-2%.
STRAW ·66% + COMPOST ·33%
COMPOST ·5%.
STRAW ·33% + COMPOST ·66%
COMPOST 1%
COMPOST 2%.

had decomposed, whilst at the completion of incubation 69% of the straw and 32% of the compost had decomposed. A similar trend held with the materials at the two other levels of addition.

Varying level of Straw. The lower the level of added straw the greater was the percentage of the added material decomposed after any period. This was particularly the case with the 0.5% level of straw compared with the 1% and 2% levels. With the two latter levels there were significant differences in decomposition during the middle period of incubation, but not during the early and later stages. There was also a trend for differences in decomposition due to level of added material to be greater during the early than during the later stages of incubation.

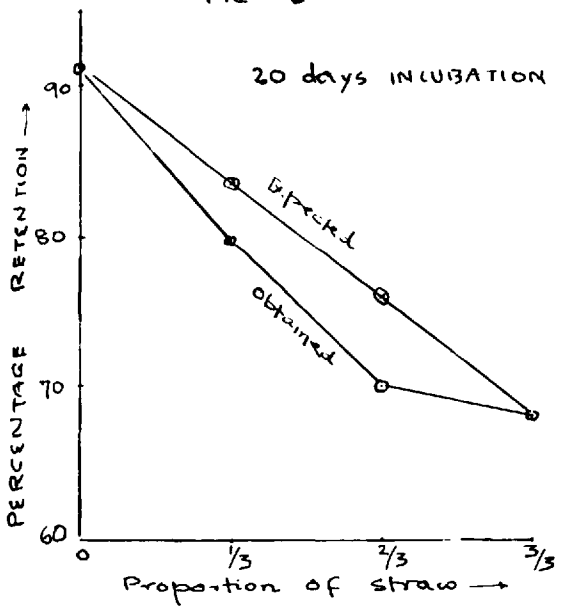
Varying level of Compost. As with straw the lower the level of compost the greater was the percentage of added material decomposed after any period. With up to 58 days incubation there were no significant differences in the percentage decomposition of the 1% and 2% levels of compost, though both of these were significantly less than that of the 0.5% level of compost. By the middle and at the end of incubation there were significant

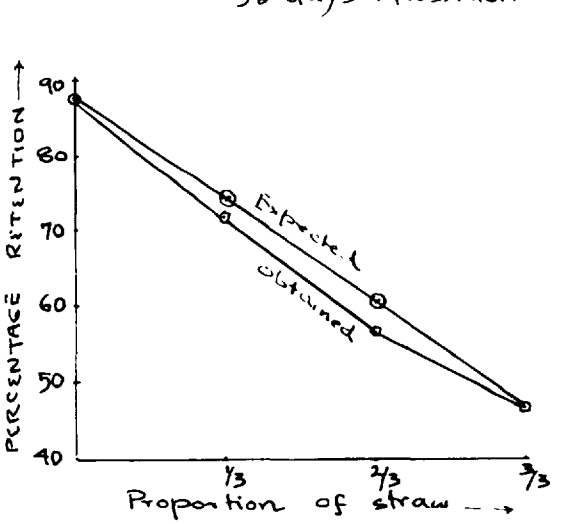
differences in the percentage decomposition at all three rates.

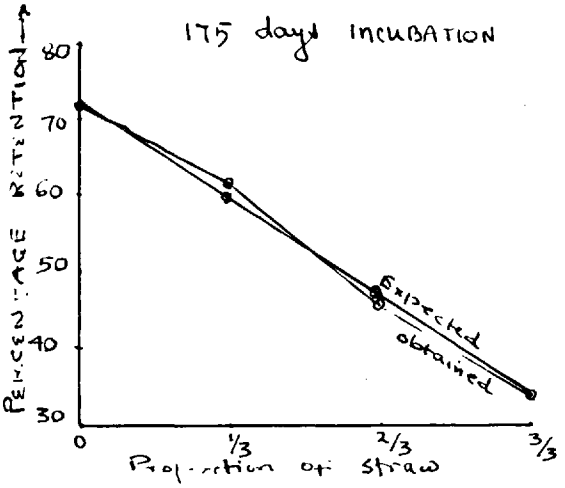
Mixed straw-compost treatments. The mixed straw-compost treatments, given so as to produce a 1% level of total added material, produced results intermediate between those given by straw and compost added separately. The straw 0.66%-compost 0.33% decomposed more rapidly than did the straw 0.33%-compost 0.66% and the differences were significant at all stages of incubation. Replacing one-third of the straw by compost resulted in significantly reduced decomposition, whilst replacing one-third of the compost with straw resulted in significantly increased decomposition. The latter change tended to have a somewhat greater effect than the former, particularly during the early stages of incubation.

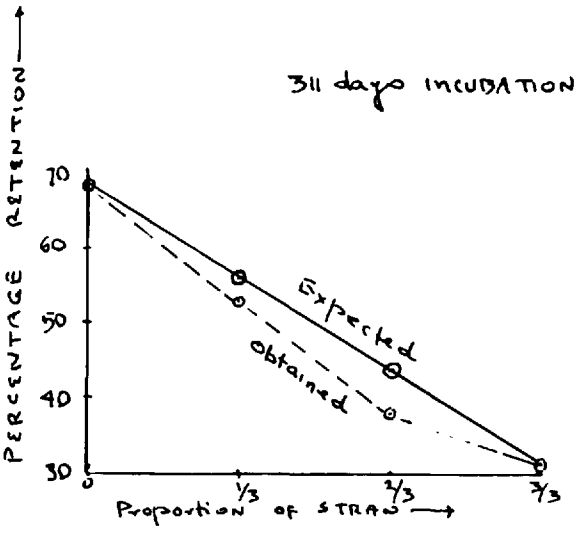
A comparison of expected and obtained values of retention of added material with varying straw-compost ratio at the four sampling dates is shown in Table 7 (at end of chapter). These values were obtained by plotting percentage retention against proportion of straw as shown in Fig. 6. The difference between the expected and obtained value is a measure of the influence of the presence of one material on the decomposition of the other.

FIG – 6


20 days INCUBATION
PERCENTAGE RETENTION →
90
80
70
60
0
1/3
2/3
3/3
Proportion of straw →
Expected
obtained


58 days INCUBATION
PERCENTAGE RITENTION →
90
80
70
60
50
40
1/3
2/3
3/3
Proportion of straw →
Expected
obtained


175 days INCUBATION
PERCENTAGE RETENTION →
80
70
60
50
40
30
0
1/3
2/3
3/3
Proportion of straw
Expected
obtained


311 days INCUBATION
PERCENTAGE RETENTION →
70
60
50
40
30
0
1/3
2/3
3/3
Proportion of STRAW →
Expected
obtained

In all cases, except one, retention was reduced (i.e. decomposition was increased) when the mixed materials were used. There were consistent differences due to varying the proportion of straw to compost from 2:1 to 1:2.

Comparison of the retention of straw and compost on an "economic" basis.

Since during the composting of straw about half the dry matter is lost, a comparison of the retention or stability of the two materials in soil should be made by comparing a given level of added straw with half its level of added compost. This has been done in the table below where the retention of the added materials are presented comparing 1% straw with 0.5% compost and 2% straw with 1% compost.

Incubation period	20 days	58 days	175 days	311 days
Treatments				
Straw 1%	68.0	46.8	33.9	31.1
Compost 0.5%	44.2	41.0	28.0	26.2
Straw 2.0%	75.0	56.5	34.2	30.9
Compost 1%	45.0	43.7	35.7	33.9

With the lower levels of the two added materials retention of straw was always higher than that of

compost, although the retention figures approached each other with time. With the higher levels of the added materials retention values were higher for straw during the early stages of incubation, were similar half way through and were higher for the compost by the end of incubation.

Discussion.

The differences in the rate of decomposition of straw and compost in soil may be accounted for by the differences in the chemical composition of the two materials. The main difference is that straw contains a relatively high proportion of celluloses and hemicelluloses as compared with the compost. These materials are decomposed fairly quickly and this would account for the rapid rate of release of CO_2 during the first few weeks of decomposition. Thereafter the rate of release is lower and the CO_2 released from here to the end of the incubation would come from the relatively slow decomposition of lignin and lignin-like materials (93). In the case of the compost, where cellulose and hemicellulose are virtually absent (95) the general slow rate of release

of CO_2 throughout incubation would come from decomposition of lignin and modified lignin materials formed during the composting process (96). It has been shown that during the composting process (94) lignin tends to accumulate, but becomes modified through association with microbial protein. This association seems to stabilise the lignin to a fair extent, thus its rate of decomposition when added to soil is low. It is interesting to note that after about 175 days of incubation the rate of release of CO_2 for all materials was very similar (the tendency for the curves in Fig. 1 to be more-or-less parallel after this period). This indicates that the less easily decomposable materials in straw have now assumed a composition similar to the materials present in compost. Thus in effect an "in situ" composting of straw has probably occurred during the early stages of decomposition.

When straw was applied at the 0.5% level the amount which was retained (19%) by the end of incubation was much less than that retained (32%) when straw was applied at the 1% and 2% levels. This indicates that if straw is to be used for maintaining soil humus level it would be better to apply large amounts at infrequent intervals

than small amounts at frequent intervals. Broadbent (27) obtained similar results whilst studying the decomposition of oat straw in soils. It is interesting to note that by the end of incubation there was no difference in the extent of retention of the applied 1% and 2% levels of straw. This may be due to the fact that with the heavier dressing (which is equivalent to 20 tons straw per acre-9 in. layer of soil) there results an accumulation of decomposition products which tends to reduce the rate of decomposition of the residual straw. In the case of the different levels of compost there was an increase in the percentage retention (from 53% to 77%) with increasing level of added material. Thus with compost, as with straw, better long-term retention would be obtained with large amount applied infrequently than with small amounts applied frequently.

The decomposition rate of the straw-compost mixtures was usually greater than would be expected from a knowledge of the decomposition rates of the two materials added separately. This interaction effect is perhaps what we might expect if the vigorous microbial population induced through the decomposition of the straw was able also to attack the relatively stable compost. This is

confirmed by the fact that where the proportion of straw to compost was high (2:1) the difference between the obtained and expected decomposition was greater than where the proportion of the straw to compost was low (1:2). This indicates that the stability of compost in soil is due not entirely to inherent chemical stability, but also to the nature of the microbial population present. It also indicates that in practice the application of straw to a soil which in the past has received compost only is likely to accelerate the decomposition of compost. Results along these lines have been obtained by Broadbent (26 and 27) who found that the decomposition of green manure in soil resulted in loss of native organic matter.

When the retention of straw and compost are compared on an "economic" basis (i.e. since it requires a given weight of straw to produce half its weight of compost) it is seen that the ultimate retention of material is slightly better for straw than for compost with the lower rates (i.e. comparing 1% straw with 0.5% compost) whilst the reverse is true with the higher rates (i.e. comparing 2% straw with 1% compost). Thus in practice where waste plant material is available only in limited quantity it

confirms the importance of preserving this material as compost and applying it in large amounts infrequently rather than applying it in small amounts frequently in uncomposted or composted form.

Experiment B.

Effect of soil pH and moisture level on mineralization of carbon from soil treated with straw and compost.

Experimental.

The Silwood soil which had been adjusted to pH levels of 4.5, 5.2, 6.2 and 7.2 (as described in Chapter II) was used in this experiment. For each pH a control, 1% compost addition, and 1% straw addition was made. 10g. samples of soils were used in 6 in. x $\frac{3}{4}$ in. test tubes as described in Experiment A. Three moisture levels were used, viz. 20% of the water-holding capacity (WHC), 50% of the WHC, and water logging (half an inch of water above the soil surface). 2 mg. nitrogen as KNO_3 was added to all tubes. The vial containing barium peroxide was placed in each tube, which was stoppered and incubated at 28°C. Carbon dioxide evolution was determined by analysing the contents of the vial after 3, 8, 14, 20, 28, 37, 47, 64, 86, and 118 days, ten determinations in all.

All treatments were done in duplicate.

Results.

Results for the cumulative percentage of added carbon less that from controls are shown in:
Fig. 2 and Table 8 (end of chapter) for the pH 7.2 soil
Fig. 3 and Table 9 (end of chapter) for the pH 6.2 soil
Fig. 4 and Table 10 (end of chapter) for the pH 5.2 soil
Fig. 5 and Table 11 (end of chapter) for the pH 4.5 soil.

Statistical treatment of the results were done for 20 days and 47 days from the start and also for the final sampling (118 days from the start), and are shown in Tables 12, 13 and 14 (at end of chapter).

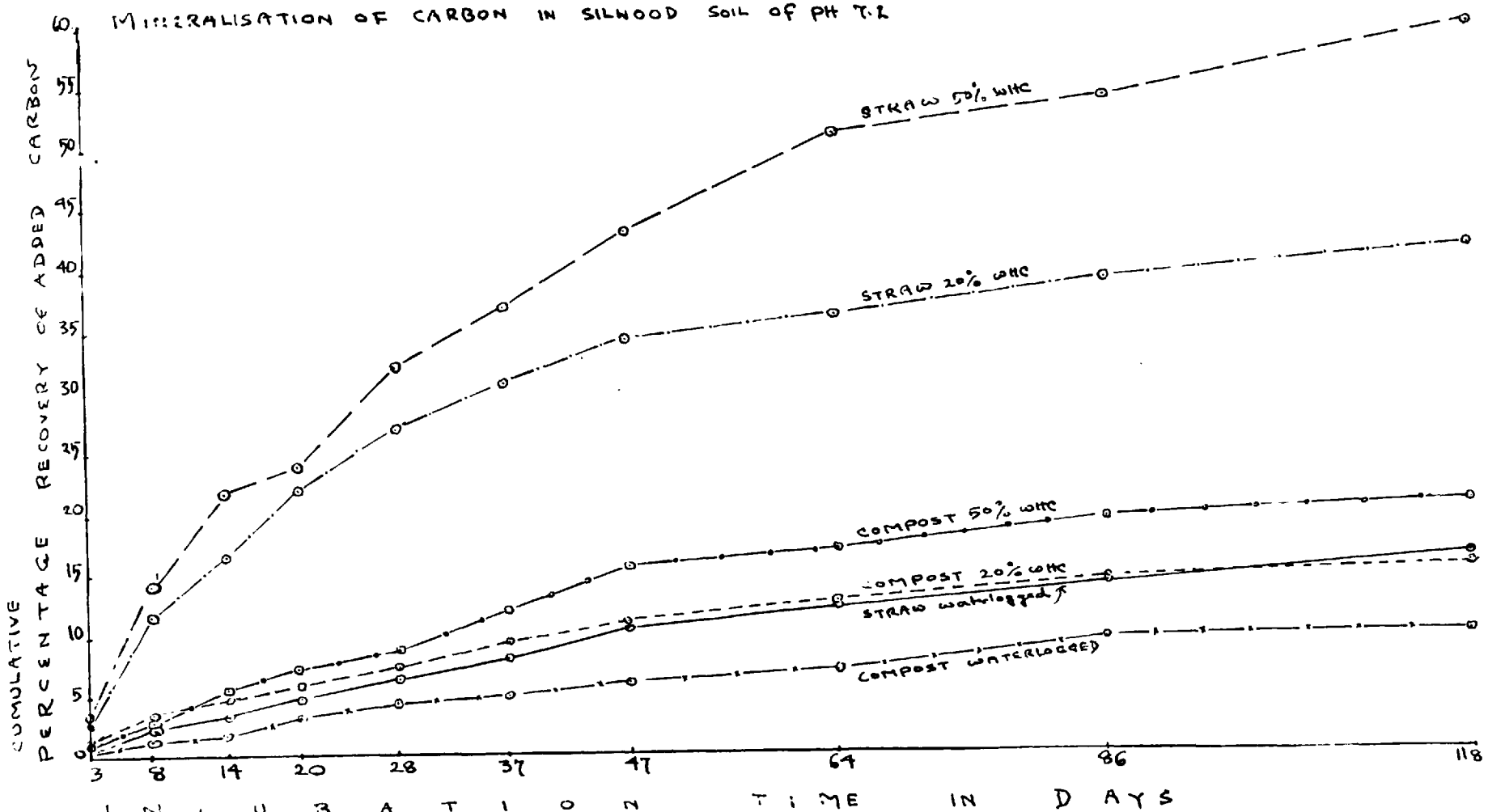
The abbreviations to be used from now on are as follows:

S = straw
C = compost
20% = 20% of the water-holding capacity
50% = 50% of the water-holding capacity
WL = waterlogged.

After 20 days incubation.

The mean CO_2 release from both straw and compost treatments at the three moisture and four pH levels are shown on the next page.

FIG- 2


MINERALISATION OF CARBON IN SILWOOD SOIL of PH 7.2
CUMULATIVE PERCENTAGE RECOVERY OF ADDED CARBON
0
5
10
15
20
25
30
35
40
45
50
55
60
STRAW 50% WHC
STRAW 20% WHC
COMPOST 50% WHC
COMPOST 20% WHC
STRAW waterlogged
COMPOST WATERLOGGED
3
8
14
20
28
37
47
64
86
118
INCUBATION TIME IN DAYS

Straw

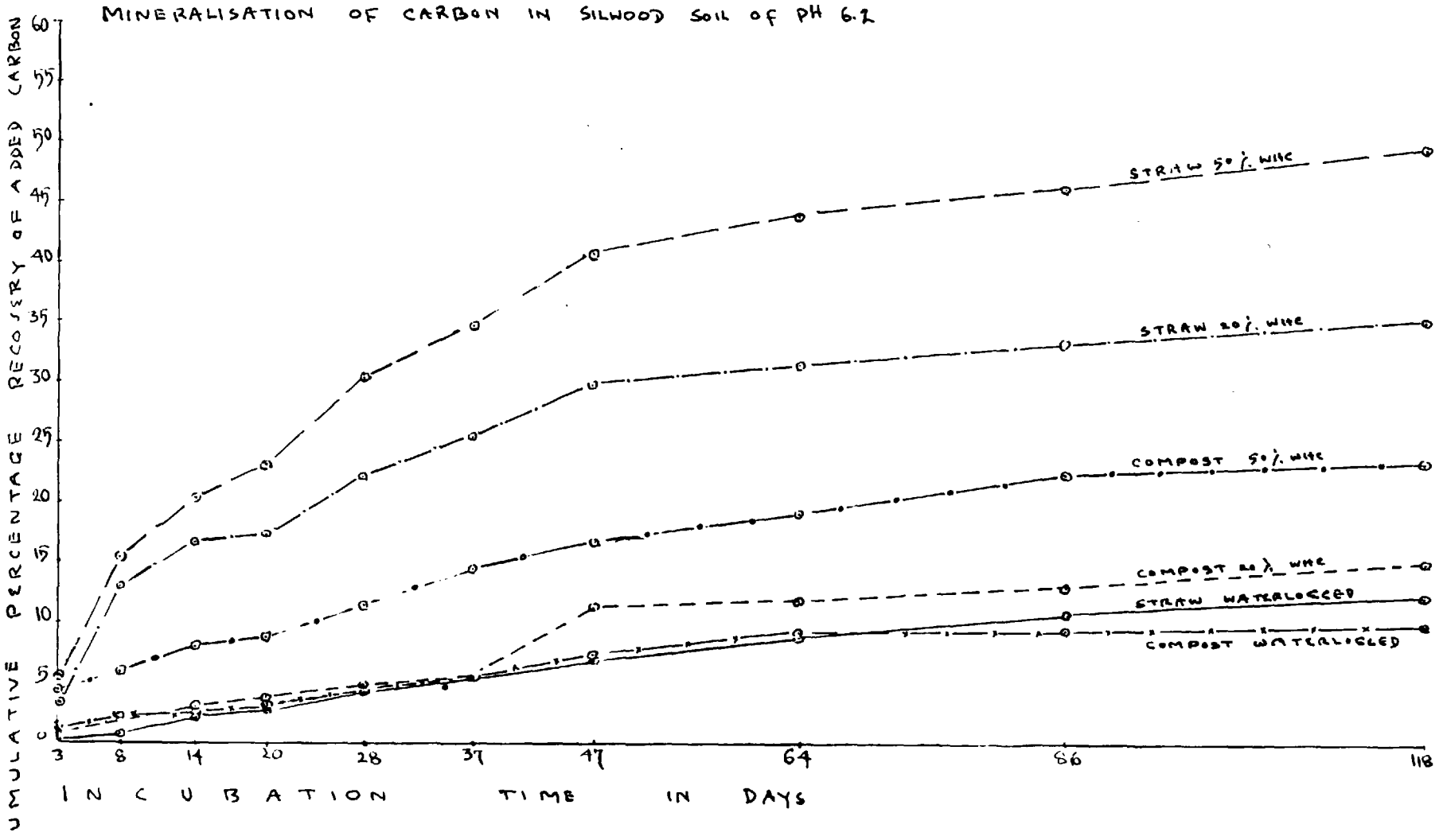
		pH			
		4.5	5.2	6.2	7.2
	WL	3.1	3.0	2.8	4.9
Moisture	50%	15.0	27.2	23.1	23.9
	20%	11.3	18.6	17.3	21.4
		Compost			
	WL	2.8	2.8	3.8	3.8
Moisture	50%	5.6	7.0	8.7	7.1
	20%	4.4	3.5	3.7	6.1

C.D. at P = 0.05 is 0.80

With the straw treatment C mineralization was much less at all pH levels under waterlogging that at 50% or 20%. C mineralization at pH 7.2 was significantly greater than at lower pH levels. With decreasing moisture level C mineralization was at a maximum at 50% and decreased at 20%. Differences due to moisture level were significant at all pH levels.

Under waterlogging C mineralization from the compost treatment was little different from that at straw at all pH levels. C mineralization at 20% was not much higher than that at waterlogging at all pH levels, although the differences were usually significant. As with straw the

FIG- 3


MINERALISATION OF CARBON IN SILWOOD SOIL OF PH 6.2
CUMULATIVE PERCENTAGE RECOVERY OF ADDED CARBON
0
5
10
15
20
25
30
35
40
45
50
55
60
3
8
14
20
28
37
47
64
86
118
INCUBATION TIME IN DAYS
STRAW 50% WHC
STRAW 20% WHC
COMPOST 50% WHC
COMPOST 20% WHC
STRAW WATERLOGGED
COMPOST WATERLOGGED

maximum C mineralization occurred at 50% at all pH levels, though the extent of mineralization was much less (about one-third) than that from straw.

With increasing pH maximum C mineralization occurred under waterlogging and at 20% at pH 6.2 or 7.2 whilst at 50% it occurred at pH 5.2 or 6.2.

After 47 days incubation.

C mineralization from the straw and compost treatments at the three moisture and four pH levels are shown below.

Straw

		pH			
		4.5	5.2	6.2	7.2
	WL	6.9	7.2	6.8	10.3
Moisture	50%	22.2	41.6	40.6	42.9
	20%	17.9	27.7	29.2	39.0

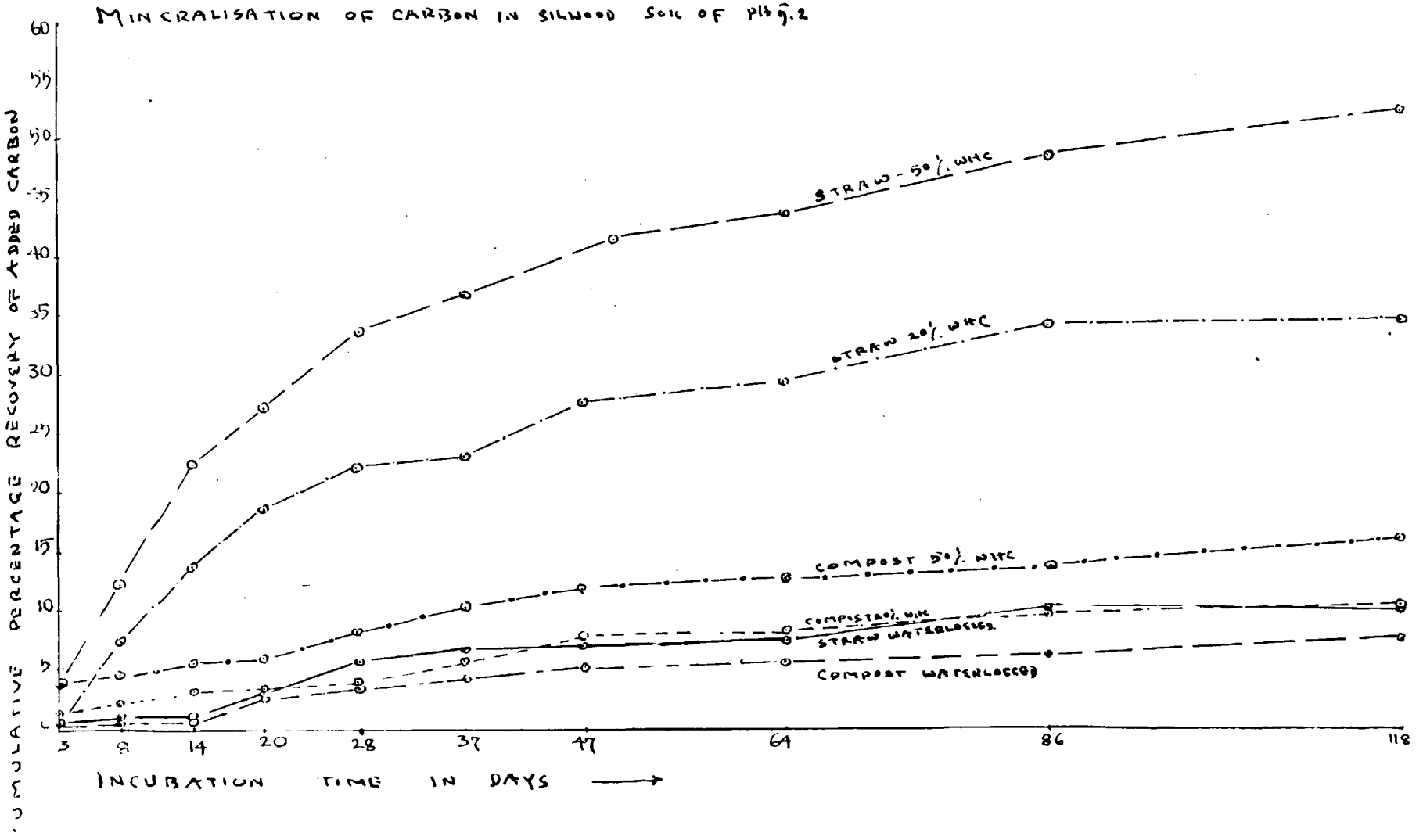
Compost

	WL	4.8	5.4	7.4	5.8
Moisture	50%	7.8	12.0	17.6	15.2
	20%	7.6	8.0	11.1	10.8

C.D. at $p = 0.05$ is 1.2.

Under waterlogging with the straw treatment C

FIG. 4


MINERALISATION OF CARBON IN SILWOOD SOIL OF PLOT 2
CUMULATIVE PERCENTAGE RECOVERY OF ADDED CARBON
60
55
50
45
40
35
30
25
20
15
10
5
0
STRAW - 50% WHC
STRAW 20% WHC
COMPOST 50% WHC
COMPOST 20% WHC
STRAW WATERLOGGED
COMPOST WATERLOGGED
3
8
14
20
28
37
47
64
86
118
INCUBATION TIME IN DAYS

mineralization was greater at pH 7.2 than at the other pH levels. It was much less at all pH levels at water-logging that at 50% or 20%. As with 20 days incubation C mineralization was at a maximum at 50% and decreased again at 20%. Differences due to moisture level were significant at all pH levels.

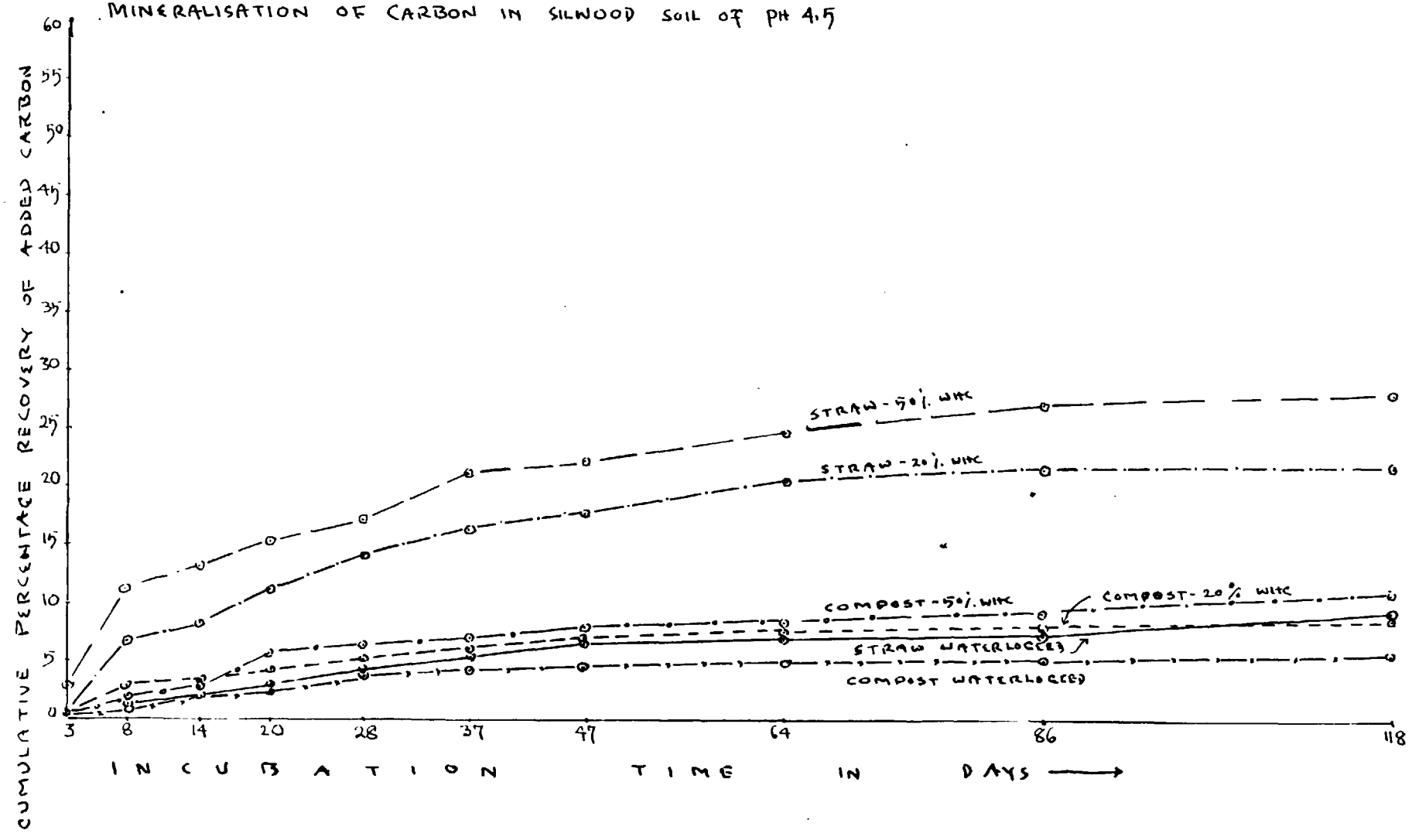
Under water logging C mineralization from compost was usually less than that from straw. It was significantly higher with compost at 20% than at waterlogging, with the difference increasing with pH. As with the straw maximum C mineralization occurred at 50%.

With increasing pH maximum C mineralization occurred at pH 7.2 with straw at all moisture levels and at pH 6.2 with compost at all moisture levels.

<u>After 118 days incubation</u>.

C mineralization from the straw and compost treatments for the three moisture and 4 pH levels are shown on the next page.

FIG-5


MINERALISATION OF CARBON IN SILWOOD SOIL OF PH 4.5
CUMULATIVE PERCENTAGE RECOVERY OF ADDED CARBON
0
5
10
15
20
25
30
35
40
45
50
55
60
STRAW - 50% WHC
STRAW - 20% WHC
COMPOST - 50% WHC
COMPOST - 20% WHC
STRAW WATERLOGGED
COMPOST WATERLOGGED
3
8
14
20
28
37
47
64
86
118
INCUBATION TIME IN DAYS

Straw

		pH			
		4.5	5.2	6.2	7.2
Moisture	WL	8.8	10.3	12.4	16.1
	50%	28.5	52.5	49.9	59.6
	20%	21.9	39.9	35.3	41.5

Compost

Moisture	WL	5.8	7.7	9.9	9.9
	50%	10.9	17.3	23.5	20.5
	20%	8.8	10.6	15.0	15.1

C.D. at p = 0.05 is 1.7

Here again C mineralization from straw was much lower at all pH levels under water logging that at 50% and 20%. Except for the fact that higher values were obtained the trend of differences was similar to those occurring with 47 days incubation.

With increasing time of incubation the main changes to be noted were (a) with both straw and compost under waterlogging an increase in the magnitude of C mineralization due to increasing pH (b) with compost at 50% an increase in the difference in C mineralization due to pH level (c) with straw at 50% an increase in the pH for maximum C mineralization from 5.2 after 20 days to 7.2

after 118 days (d) with compost a tendency for C mineralization to increase with time between 50% and 20%. and (e) with straw at 50% and 20% the rate of C mineralization during the early stages (up to 8-14 days) was much more rapid than at the later stages. At water-logging straw behaved rather like compost in that C mineralisation was almost linear in relation to time.

Ultimate carbon retention.

From the practical point of view the extent of retention of straw and compost at the end of the 118 days incubation period is of interest. These figures are given below.

Straw

		pH				
		4.5	5.2	6.2	7.2	Mean
Moisture	WL	91.2	89.7	87.6	83.9	87.8
	50%	71.6	47.5	50.1	40.4	52.4
	20%	78.1	65.1	64.7	58.5	66.6
	Mean	80.4	67.5	67.4	60.9	68.9

Compost

Moisture	WL	94.2	92.3	90.1	90.2	91.6
	50%	89.0	83.7	76.5	79.5	82.1
	20%	91.2	89.5	85.0	84.9	87.8
	Mean	91.4	88.5	83.8	84.8	87.1

The main trends to be noticed are (a) under water-logging most of the C of both straw and compost remained at the end of the incubation period (b) at 50% about three-quarters of the straw remained at pH 4.5 and about half remained at the three higher pH levels (c) at 50% nine-tenths of the compost remained at pH 4.5 and about four-fifths at the higher pH levels (d) at 20% four-fifths of the straw remained at pH 4.5 and about two-thirds at the higher pH levels; with compost at 20% about nine-tenths remained at all pH levels.

General effect of moisture level.

The average results obtained at all pH levels and the average of the straw and compost treatments showed that C mineralization decreased in the order:

50% 20% WL

These were significantly different from each other and results were similar at 20, 47 and 118 days.

General effect of pH level.

The average results obtained at all moisture levels and the average of the straw and compost treatments decreased in the order given over the page.

20 days	7.2	5.2	6.2	4.5
47 days	7.2	6.2	5.2	4.5
118 days	7.2	6.2	5.2	4.5

Figures over the same line were not significantly different from each other, but were signigicantly different from figures over other lines. Thus it is seen that there is a difference due to date of sampling; after 20 days incubation there was no significant difference at pH 5.2 and 6.2, whilst at the later stages all differences due to pH were significant.

Discussion.

The 20% water-holding capacity moisture level was used in this study because it represented a pF value of 4.1, which is very near the wilting-point pF. The 50% water-holding capacity moisture level was used since it represented a pF of 2.6, which is approximately the field capacity of the soil and gives ideal conditions for plant growth.

The greater losses of C at both 20% and 50% WHC compared with those at water-logging is presumably due to the much more favourable physical and biological conditions prevailing under the former conditions. At 20%

and 50% WHC conditions are suitable for most forms of micro-organisms (aerobic bacteria, fungi, and actinomycetes) which are able to decompose carbonaceous material. Under water-logging, conditions are not suitable for any of these forms, and decomposition is carried out mainly by anaerobic bacteria. Since there is only a limited number of these species, this would explain why C mineralization is poorer under water-logging than under aerobic conditions, where a large variety of species is active. The greater mineralization at 50% than at 20% WHC indicates that the conditions for the functioning of the aerobic organisms are more suitable at the former moisture level. Thus mineralization of added carbonaceous material is at a maximum under those moisture conditions which are also conducive for optimum plant growth. Since C mineralization is usually accompanied by mineralization of essential plant nutrients (nitrogen, phosphorus, sulphur, etc.) it is perhaps fortunate that at the moisture content which is most conducive to optimum plant growth and the highest requirements of the plant for mineral elements maximum mineralization of carbon and also presumably of these nutrients takes place.

From the point of view of retention of added carbonaceous material water-logging conditions are superior to aerobic conditions, and retention also decreases as moisture content increases from the wilting point to field capacity. Thus the ideal conditions for C retention would be under water-logging, preferably, or under dry conditions. Unfortunately under dry conditions plant growth is poor, whilst under water-logged conditions only a limited number of plant species can be grown. These latter are however represented by some very important tropical crops, viz., rice, jute, sugarcane, and bamboo. It is interesting to note that very often where such crops are grown the soil is usually subjected to water-logging during the growing season, but is allowed to dry out almost completely in the off-season. Since both these conditions are conducive to maintenance of organic matter this may explain in part why such soils have remained fairly productive even after many centuries of cropping without addition of inorganic fertilizers.

The general trend for C mineralization of both straw (particularly) and compost to increase with pH is probably due to the fact that at the higher pH levels the cellulose-decomposing bacteria, especially the cytophaga group,

function most efficiently, and are poorly active at pH levels less than 6 (10). At pH 5.2 fungi and actinomycetes are probably mainly responsible for decomposing carbonaceous material, but their activity may be quite considerable, since it is seen that C mineralization at pH 5.2 is not much less than at the higher pH levels, especially under aerobic conditions. At pH 4.5, where C mineralization is much lower than at the other pH levels, only specialized fungi such as the Trichorderma can function, and then only under aerobic conditions.

At pH levels of 5.2, 6.2 and 7.2 the differences in C mineralization rates from straw due to varying moisture levels were not greatly different and the somewhat higher levels of mineralization occurring at a particular moisture level at pH 7.2 compared with the two lower pH levels was statistically significant, but not of much practical significance. A similar trend of results occurred with compost, but here the proportion of compost mineralized was somewhat greater at the highest pH level than at the two lower levels than in the case of straw. At pH 4.5 straw mineralization was reduced to a greater extent at 50% than at 20% WHC compared with the higher pH levels. This is probably because since conditions for mineralization are most favourable at 50% WHC, changes

in pH would have more effect under these conditions than at the lower moisture level, where conditions of mineralization are not so satisfactory.

The most pronounced effect of water-logging at all pH levels was to greatly reduce the mineralization of straw. In fact under these conditions straw mineralization was only slightly greater than compost mineralization.

Of practical significance are the ultimate retention values for the different treatments. The overall retention of straw (i.e. the mean of all treatments at all pH levels) at the end of the 118 days incubation was 68.9% and of compost 87.1%. There were however important differences due to both pH and moisture levels. The effect of greatest magnitude was the much higher retention of straw under water-logging than under aerobic conditions, and also of fair magnitude, the greater retention of straw at pH 4.5 than at higher pH levels. Although results for compost showed similar trends to those for straw, the mggnitude of the differences were not as great, which is what might be expected, since even under the best conditions of moisture and pH compost retention was greater than that of straw. From the

point of view of maintaining soil organic matter it would appear that in general compost is more effective than straw, except under water-logged conditions where there is little to choose between the two materials.

Summary.

Experiment A.

Carbon mineralization was determined over 311 incubation days at 28°C from a soil of pH 6.1 treated with 0.5%, 1.0% and 2.0% of fresh straw and composted straw and also with mixtures of fresh and composted straw.

With all levels of straw there was a rapid decomposition during the first 50 days, during which about half the original straw was decomposed, thereafter decomposition rate was slower. The lower the level of added straw the greater was the percentage of added material decomposed after any period. With the 1% and 2% levels of straw there was little difference in the percentage decomposed by the end of incubation.

The decomposition rate of the composts was more-or-less linear with respect to time of incubation. The lower the level of added compost the greater was the percentage of added material decomposed after any period.

The decomposition rate of mixed straw-compost additions was intermediate between those of straw and compost added separately. However, the decomposition rate of the mixed materials was usually greater than

would be expected from a knowledge of the rates of decomposition of the separate materials.

A comparison of the extent of retention of straw and compost on an "economic basis", i.e. allowing for dry matter lost during the composting process, showed that with low levels of added materials (1% straw, 0.5% compost) retention of straw was always higher than that of compost, although the retention figures approached each other with time. With the higher levels (2% straw, 1% compost) retention values were higher for straw during the early period of incubation, but were higher for compost by the end.

Experiment B.

The decomposition rates during incubation at 28°C over 118 days of 1% fresh straw and 1% composted straw added to a soil which had been adjusted to pH values of 4.5, 5.2, 6.2 and 7.2 and at moisture levels of 20% and 50% of the maximum water-holding capacity (max. W.H.C.) and also at water-logging were determined.

At pH 5.2, 6.2 and 7.2 straw decomposition rate at 50% max. W.H.C. was somewhat greater than that at 20% max. W.H.C., and there were no great differences due to pH.

At pH 4.5 straw decomposition was also somewhat greater at 50% max. W.H.C. than at 20% max. W.H.C., but decomposition at both moisture levels was much less at this pH that at higher pH levels.

Compost decomposition showed trends of differences due to moisture level and pH similar to those for straw, except that the extent of decomposition and the magnitude of the differences were less than for straw.

Under water-logging at all pH levels straw decomposition, in particular, and compost decomposition were less than at the two other moisture levels. Under water-logging the rate of straw decomposition was not much different from that of compost decomposition.

TABLE-5

Table 5. Cumulative percentage recovery (as CO_2) during Silwood soil.

Treatment	Incubation 3	6	10	15	20	28	38
Straw 0.5%	15.0	28.9	34.4	41.0	46.4	48.9	52.4
Straw 1.0%	9.4	16.4	21.6	27.2	32.0	37.5	42.5
Straw 2.0%	10.4	14.3	17.6	21.6	25.0	28.8	33.6
Compost 0.5%	5.9	8.0	9.0	10.8	11.5	12.2	12.5
Compost 1.0%	5.5	6.4	7.0	7.8	8.9	9.5	10.7
Compost 2.0%	4.0	5.2	6.3	7.8	9.3	10.4	11.4
Straw 0.33% + Compost 0.66%	7.6	12.6	15.4	18.1	20.1	22.7	24.8
Straw 0.66% + Compost 0.33%	8.1	16.9	22.1	26.8	30.0	32.5	36.1

Incubation at 28°C from straw and compost added to

in days									
48	58	69	83	103	125	147	175	235	311
-	58.5	-	60.7	65.9	-	72.1	74.6	79.0	82.0
48.5	53.2	55.6	57.1	59.6	60.7	62.0	66.1	67.5	68.9
38.8	43.5	46.5	50.4	56.1	60.0	62.5	65.8	67.2	69.1
-	18.0	-	21.7	24.7	-	36.7	43.9	45.4	47.5
11.9	12.5	-	15.0	17.7	-	24.9	28.5	29.9	32.2
-	13.9	-	14.9	16.1	-	18.6	20.4	21.3	21.9
-	28.4	-	29.6	30.9	-	35.9	38.2	41.4	47.3
41.0	43.9	45.3	46.1	48.1	48.9	49.8	54.3	57.7	62.2

Table 6.

Table 6. The cumulative percentage recovery and retention Silwood soil at 20 days, 58 days, 175 days and 311 days incubation of added carbon are also shown.

Treatments	20 days		58 days	
	Recovered	Retained	Recovered	Retained
S_1	46.4	53.6	58.5	41.5
S_2	32.0	68.0	53.3	46.7
S_3	25.0	75.0	43.5	56.5
C_1	11.5	88.5	18.0	82.0
C_2	8.9	91.1	12.5	87.5
C_3	9.3	90.7	13.9	86.1
SC_1	20.1	79.9	28.4	71.6
SC_2	30.0	70.0	43.9	56.1

General mean (recovery) 22.9

S.E. of treatment mean =0.846

C.D. at 5% = 2.000

Statistical interpretation of recovery percentage at 5%

$\underline{S_1}\ \underline{S_2}\ \underline{S_3}\ \underline{SC_1}\ \underline{SC_2}\ \underline{C_1}\ \underline{C_2}\ \underline{C_3}$

General mean (recovery percentage) 34.8

S.E. of treatment mean (recovery percentage) = 0.6557

C.D. at 5% = 1.55

Statistical interpretation of recovery percentage at 5%

$\underline{S_1}\ \underline{S_2}\ \underline{SC_2}\ \underline{S_3}\ \underline{SC_1}\ \underline{C_1}\ \underline{C_3}\ \underline{C_2}$

of the added straw + compost and their mixture in period are shown. Statistical analyses of the recovery

175 days		311 days	
Recovered	Retained	Recovered	Retained
74.6	25.4	82.0	18.0
66.1	33.9	69.0	31.0
65.8	34.2	69.1	30.9
43.9	56.1	47.6	52.4
28.4	71.6	32.2	67.8
20.5	79.5	21.9	78.1
38.2	61.8	47.3	52.7
54.3	45.7	62.2	37.8

General mean (recovery) 48.98

S.E. of treatment mean (recovery percentage) = 1.5

C.D. at 5% = 3.55

Statistical interpretation at 5% level

$\underline{S_1}\ \underline{S_2}\ \underline{S_3}\ \underline{SC_2}\ \underline{C_1}\ \underline{SC_1}\ \underline{C_2}\ \underline{C_3}$

General mean (recovery) 53.91

S.E. of treatment mean (recovery percentage) = 1.71

C.D. at 5% level = 4.04

Statistical interpretation (recovery percentage) at 5%

$\underline{S_1}\ \underline{S_3\ S_2}\ \underline{SC_2\ C_1}\ \underline{SC_1}\ \underline{C_2}\ \underline{C_3}$

Table 7. Comparison of expected and obtained values of retention of added organic matter with varying straw-compost mixtures.

Incubation time	Treatment	Expected	Obtained	Diff.
20	straw 0.33% + compost 0.66%	83.5	79.9	4.6
	straw 0.66% + compost 0.33%	75.5	70.0	5.5
58	straw 0.33% + compost 0.66	74	71.6	2.4
	straw 0.66% + compost 0.33%	60.5	56.9	3.6
175	straw 0.33% + compost 0.66%	46.5	45.7	0.8
	straw 0.66% + compost 0.33%	59.5	61.8	-2.3
311	straw 0.33% + compost 0.66%	56	52.7	3.3
	straw 0.66% + compost 0.33%	43.5	37.8	5.7

TABLE 8 + 9

Table 8. Cumulative percentage recovery of added C (as added to Silwood soil of pH 7.2.

	3 days	8 days	14 days	20 days	28 days	37 days
STW	0.5	2.3	3.4	4.9	6.2	7.8
ST 50% WHC	3.40	14.00	21.6	23.8	31.9	36.6
ST 20% WHC	2.8	11.5	16.3	21.8	26.7	30.5
CTW	0.6	1.3	1.8	3.7	4.3	4.8
CT 50% WHC	0.9	2.9	5.3	7.0	8.5	11.9
CT 20% WHC	1.3	3.4	4.8	6.0	7.3	9.2

Table 9. Cumulative percentage recovery of C (as CO_2) added to Silwood soil of pH 6.2.

	3 days	8 days	14 days	20 days	28 days	37 days
STW	0.50	0.75	2.1	2.8	4.4	5.5
ST 50% WHC	5.4	15.4	20.3	23.1	30.2	34.6
ST 20% WHC	3.4	13.0	16.8	17.3	22.11	25.5
CTW	1.2	2.4	3.0	3.8	4.7	5.7
CT 50% WHC	4.3	5.9	8.0	8.7	11.5	14.5
CT 20% WHC	0.8	1.9	3.0	3.7	4.7	5.8

CO_2) during incubation at 28°C from straw and composts

47 days	64 days	86 days	118 days	Retention percentage
10.3	12.00	14.08	16.1	83.9
42.88	50.76	53.8	59.6	40.4
34.0	35.7	38.9	41.5	58.5
5.8	6.7	9.4	9.8	90.2
15.1	16.6	19.1	20.5	79.5
10.8	12.1	14.1	15.1	84.9

during incubation at 28°C from straw and composts

47 days	64 days	86 days	118 days	Percentage retention
6.9	8.8	10.8	12.4	87.6
40.7	43.8	46.1	49.9	50.1
29.1	31.5	33.3	35.3	64.7
7.4	8.3	9.5	9.9	90.1
16.6	19.0	22.3	23.5	76.5
11.2	11.9	13.0	15.0	85.0

TABLE 10 & 11

Table 10. Cumulative percentage recovery of C (as CO_2) added to Silwood soil of pH 5.2.

	3 days	8 days	14 days	20 days	28 days	37 days
STW	0.61	1.01	1.22	3.1	5.8	6.7
ST 50% WHC	3.8	12.2	22.5	27.18	33.7	36.8
ST 20% WHC	0.5	7.5	13.8	18.7	22.20	23.10
CTW	0.34	0.80	1.00	2.7	3.45	4.4
CT 50% WHC	3.9	4.8	5.8	6.0	8.2	10.1
CT 20% WHC	1.2	2.3	3.1	3.5	4.0	5.7

Table 11. Cumulative percentage recovery of added C (as added to Silwood soil of pH 4.5.

	3 days	8 days	14 days	20 days	28 days	37 days
STW	1.5	1.9	2.6	3.1	4.4	5.5
ST 50% WHC	2.6	11.2	13.1	15.1	17.2	21.13
ST 20% WHC	0.80	6.57	8.2	11.32	14.1	16.3
CTW	0.6	1.4	2.3	2.7	3.7	4.1
CT 50% WHC	0.5	2.0	2.9	5.8	6.3	7.0
CT 20% WHC	0.70	2.7	3.3	4.4	5.20	6.3

during incubation at 28°C from straw and composts

47 days	68 days	86 days	118 days	Percentage retention
7.2	7.5	10.11	10.3	89.7
41.5	43.7	48.6	52.5	47.5
27.7	29.4	34.10	34.9	65.1
5.4	5.9	6.4	7.7	92.3
12.0	12.8	13.8	16.3	83.7
8.0	8.4	9.7	10.5	89.5

CO_2) during incubation at 28°C from straw and composts

47 days	64 days	86 days	118 days	Percentage retention
6.9	7.5	8.0	8.8	91.2
22.20	24.8	27.4	28.44	71.6
17.9	20.6	21.8	21.91	78.1
4.8	5.0	5.3	5.8	94.2
7.8	8.5	9.3	11.0	89.0
7.6	7.9	8.3	8.8	9.12

Table 12. Statistical analysis of 20 days incubation.

12A.

Treatments

Average percentage recovery	
straw	14.30
compost	4.94
General mean	9.62
S.E. =	0.671
C.D. at 5%	1.39

Statistical interpretation at 5% level of significance.

straw compost

12B

Moisture

Average percentage recovery	
waterlogged	3.36
50% WHC	14.72
20% WHC	10.79
General mean	14.44
S.E. = 0.629	
C.D. at 5% = 1.30	

Statistical interpretation at 5% level of significance

50% WHC 20% WHC waterlogged

12C

Soil pH

Average percentage recovery under different pH

pH 4.5	7.08
" 5.2	10.35
" 6.2	9.91
" 7.2	11.16
General mean	9.63
S.E. of difference of pH menas	0.300
C.D. at 5%	0.621

Statistical interpretation at 5% level

pH 7.2 pH 5.2 pH 6.2 pH 4.5

12D

Interactions of treatment and moisture.

Treatment → / Moisture ↓	Straw	Compost	Average
Waterlogged	3.4	3.2638	3.3632
50% WHC	22.2875	7.1500	14.7198
20% WHC	17.1625	4.4125	10.7875
Average	14.3042	4.9421	9.6235

S.E. = 0.3674 C.D. at 5% = 0.7602

Statistical interpretation at 5% level

S-50% S-20% C-50% C-20% S-WL C-WL

12E

Interactions between treatment and soil pH

Soil pH → / Treatment ↓	4.5	5.2	6.2	7.2	Average
Straw	9.8333	16.2833	14.4000	16.7000	14.3042
Compost	4.3166	4.4167	5.4166	5.6167	4.9417
Average	7.0750	10.3500	9.9083	11.1584	9.6229

S.E. = 0.4243

C.D. at 5% = 0.8779

Statistical interpretation at 5% level

S-7.2 S-5.2 S-6.2 S-4.5 C-7.2 C-5.2 C-6.2 C-4.5

12F

Interactions between soil pH and moisture

Soil pH → / Moisture ↓	4.5	5.2	6.2	7.2	Average
Waterlogged	2.95	2.90	3.3	4.3	3.3625
50% WHC	10.425	17.75	15.925	15.45	14.7225
20% WHC	7.85	11.075	10.500	13.725	10.7875
Average	7.075	10.35	9.91	11.16	9.625

S.E. = 0.5197 C.D. at 5% = 1.0753

Statistical interpretation at 5% level

P5-M50 p6-M50 p7-M50 p4-M50 p7-M20 p5-M20 p6-M20 p4-M20 p7-MWL p6-MWL p4-MWL p5-MWL

Table 12-Part II

Table 12-Part II. Percentage recovery of added days at 28°C in Silwood soil of different pH.

		Soil pH 4.5			Soil pH 5.2		
		R_I	R_{II}	Total	R_I	R_{II}	Total
STRAW	Moisture Waterlogged	3.1	3.2	6.3	3.2	2.9	6.1
	Moisture 50% WHC	15.3	14.8	30.1	26.6	27.7	54.3
	Moisture 20% WHC	12.4	10.2	22.6	18.4	18.9	37.3
	Total	30.8	28.2	59.0	48.2	49.5	97.7
COMPOST	Moisture Waterlogged	3.1	2.4	5.5	3.4	2.1	5.5
	Moisture 50% WHC	6.3	5.3	11.6	6.6	7.4	14.0
	Moisture 20% WHC	4.4	4.4	8.8	3.6	3.4	7.0
	Total	13.8	12.1	25.9	13.6	12.9	26.5
TOTAL	Moisture Waterlogged	6.2	5.6	11.8	6.6	5.0	11.6
	Moisture 50% WHC	21.6	20.1	41.7	33.2	35.1	68.3
	Moisture 20% WHC	16.8	14.6	31.4	22.0	22.3	44.3
	Total	44.6	40.3	84.9	61.8	62.4	124.2

carbon as straw and compost during incubation of 20

Soil pH 6.2			Soil pH 7.2			Total		
R_I	R_{II}	Total	R_I	R_{II}	Total	R_I	R_{II}	Total
2.4	3.2	5.6	5.1	4.6	9.7	13.80	13.9	27.7
23.4	22.8	46.2	23.4	24.3	47.7	88.7	89.6	178.3
17.0	17.6	34.6	21.2	21.6	42.8	69.0	68.3	137.3
42.8	43.6	86.4	49.7	50.5	100.2	171.5	171.8	343.3
3.4	4.2	7.6	3.8	3.7	7.5	13.7	12.4	26.1
9.8	7.7	17.5	7.1	7.0	14.1	29.8	27.4	57.2
4.4	3.0	7.4	7.4	4.7	12.1	19.8	15.5	35.3
17.6	14.9	32.5	18.3	15.4	33.7	63.3	55.3	118.6
5.8	7.4	13.2	8.9	8.3	17.2	27.5	26.3	53.8
33.2	30.5	63.7	30.5	31.3	61.8	118.5	117.0	235.5
21.4	20.6	42.0	28.6	26.3	54.9	88.8	83.8	172.6
60.4	58.5	118.9	68.0	65.9	133.9	234.8	227.1	461.9

Table 13. Statistical analysis of 47 days incubation.

13A

Treatments

	Average percentage recovery
Straw	23.93
Compost	9.37
General mean	16.65

S.E. = 0.3175

C.D. at 5% = 0.6569

Statistical interpretation at 5% level

straw compost

13B

Moisture

	Average percentage recovery
Waterlogged	6.81
50% WHC	24.86
20% WHC	18.28
General mean	16.65

S.E. = 0.3890

C.D. at 5% = 0.8048

Statistical interpretation at 5% level

50% WHC 20% WHC waterlogged

13C

Soil pH

Average percentage recovery under different pH

pH 4.5	11.18
" 5.2	16.98
" 6.2	18.63
" 7.2	19.82
General mean	16.65

S.E. = 0.4491

C.D. at 5% = 0.9292

Statistical interpretation at 5% level

pH 7.2 pH 6.2 pH 5.2 pH 4.5

13D

Interactions of treatment and mositure.

Treatment → / Moisture ↓	Straw	Compost	Average
Waterlogged	7.7750	5.8375	6.8063
50% WHC	36.8300	12.9000	24.8650
20% WHC	27.1900	9.3625	18.2763
Average	23.9317	9.3667	16.6492

S.E. = 0.5500 C.D. at 5% = 1.1380

Statistical interpretation at 5% level

S-50% S-20% C-50% C-20% S-WL C-WL

13E

Interaction between Treatment and Soil pH

Treatment ↓ / Soil pH →	4.5	5.2	6.2	7.2	Average
Straw	15.6500	25.4800	25.5333	29.0500	23.9283
Compost	6.7000	8.4667	11.7200	10.5833	9.3675
Average	11.1750	11.9734	18.6267	19.8167	16.6480

S.E. = 0.6351

C.D. at 5% = 1.3140

Statistical interpretation at 5% level

S-7 S-6 S-5 S-4 C-6 C-7 C-5 C-4

13F

Interaction between soil pH and moisture

Moisture ↓ / Soil pH →	4.5	5.2	6.2	7.2	Average
Waterlogged	5.8000	6.3000	7.1000	8.0250	6.8063
50% WHC	15.0000	26.7750	28.6500	29.0250	24.8625
20% WHC	12.7250	17.8500	20.1250	22.4000	18.2750
Average	11.1750	16.9750	18.6250	19.8167	16.6479

S.E. = 0.7778 C.D. at 5% = 1.6093

Statistical interpretation at 5% level

p7-50% p6-50% p5-50% p7-20% p6-20% p5-20% p4-50%

p4-20% p7-WL p6-WL p5-WL p4-WL

Table 13-Part II.

Table 13- Part II. Percentage recovery of added carbon 28°C in Silwood soil of different pH.

		Soil pH 4.5			Soil pH 5.2		
		R_I	R_{II}	Total	R_I	R_{II}	Total
STRAW	Moisture Waterlogged	6.2	7.5	13.7	7.1	7.3	14.4
	Moisture 50% WHC	23.7	20.7	44.4	41.3	41.8	83.1
	Moisture 20% WHC	18.4	17.4	35.8	28.6	26.8	55.4
	Total	48.3	45.6	93.9	77.0	75.9	152.9
COMPOST	Moisture Waterlogged	5.3	4.2	9.5	4.8	6.0	10.8
	Moisture 50% WHC	8.1	7.5	15.6	10.5	13.5	24.0
	Moisture 20% WHC	7.6	7.5	15.1	8.4	7.6	16.0
	Total	21.0	19.2	40.2	23.7	27.1	50.8
TOTAL	Moisture Waterlogged	11.5	11.7	23.2	11.9	13.3	25.2
	Moisture 50% WHC	31.8	28.2	60.0	51.8	55.3	107.1
	Moisture 20% WHC	26.0	24.9	50.9	37.0	34.4	71.4
	Total	69.3	64.8	134.1	100.7	103.0	203.7

as straw and compost during incubation of 47 days at

Soil pH 6.2			Soil pH 8.2			Total		
R_I	R_{II}	Total	R_I	R_{II}	Total	R_I	R_{II}	Total
6.3	7.3	13.6	10.7	9.8	20.5	30.3	31.9	62.2
40.5	40.8	81.3	42.5	43.3	85.8	148.0	146.6	294.6
30.6	27.7	58.3	35.1	32.9	68.0	112.7	104.8	217.5
77.4	75.8	153.2	88.3	86.0	174.3	291.0	283.3	574.3
6.9	7.9	14.8	5.5	6.1	11.6	22.5	24.2	46.7
16.2	17.1	33.3	14.4	15.9	30.3	49.2	54.0	103.2
10.6	11.6	22.2	12.1	9.5	21.6	38.7	36.2	74.9
33.7	36.6	70.3	32.0	31.5	63.5	110.4	114.4	224.8
13.2	15.2	28.4	16.2	15.9	32.1	52.8	56.1	108.9
56.7	57.9	114.6	56.9	59.2	116.1	197.2	200.6	397.8
41.2	39.3	80.5	47.2	42.4	89.6	151.4	141.0	292.4
111.1	112.4	223.5	120.3	117.5	237.8	401.4	397.7	799.1

Table 14. Statistical analysis of 118 days of incubation.

14A

Treatments

Average percentage recovery	
Straw	30.97
Compost	12.91
General mean	21.94

S.E. = 0.4519

C.D. at 5% = 0.9350

Statistical interpretation at 5%

straw compost

14B

Moisture

Average percentage recovery	
Waterlogged	10.10
50% WHC	32.84
20% WHC	22.88
General mean	21.94

S.E. = 0.5535

C.D. at 5% = 1.15

Statistical interpretation at 5% level

50% WHC 20%WHC waterlogged

14C

Soil pH

Average percentage recovery under different pH

pH 4.5	14.11
" 5.2	22.21
" 6.2	24.33
" 7.2	27.11
General mean	29.25

S.E. = 0.6390

C.D. at 5% = 1.3221

Statistical interpretation at 5% level

pH 7.2 pH 6.2 pH 5.2 pH 4.5

14D

Interactions of treatment and moisture.

Treatment → / Moisture ↓	Straw	Compost	Average
Waterlogged	11.8900	8.3125	10.1013
50% WHC	47.6125	18.0625	32.8375
20% WHC	33.4000	12.3500	22.8750
Average	30.9675	12.9083	21.9379

S.E. = 0.7826 C.D. at 5% level = 1.62

Statistical interpretation at 5% level

S-50% S-20% C-50% C-20% S-WL C-WL

14E

Interactions between treatment and soil pH

Soil pH → / Treatment ↓	4.5	5.2	6.2	7.2	Average
Straw	19.7167	32.5667	32.5167	39.0667	30.9667
Compost	8.5000	11.8500	16.1333	15.1500	12.9083
Average	14.1084	22.2084	24.3250	27.1084	21.9375

S.E. = 0.9037

C.D. at 5% = 1.87

Statistical interpretation at 5% level

S-7 S-5 S-6 S-4 C-6 C-7 C-5 C-4

14F

Interactions between soil pH and moisture

Soil pH → / Moisture ↓	4.5	5.2	6.2	7.2	Average
Waterlogged	7.3000	9.0000	11.1250	12.9750	10.1000
50% WHC	19.7000	34.9000	36.7000	40.0500	32.8375
20% WHC	15.3250	22.7250	25.1500	28.3000	22.8750
Average	14.1083	22.2083	24.3250	27.1083	21.9375

S.E. = 1.11 C.D. at 5% = 2.29

Statistical interpretation at 5% level

p7-50% p6-50% p5-50% p7-20% p6-20% p5-20% p4-50%
p4-20% p7-WL p6-WL p5-WL p4-WL

Table 14-Part II.

Table 14-Part II. Percentage recovery of added carbon 28°C in Silwood soil of different pH.

		Soil pH 4.5			Soil pH 5.2		
		R_1	R_2	Total	R_1	R_2	Total
STRAW	Moisture Waterlogged	8.4	9.2	17.6	11.0	9.6	20.6
	Moisture 50% WHC	29.1	27.8	56.9	51.5	53.5	105.0
	Moisture 20% WHC	21.5	22.3	43.8	35.4	34.4	69.8
	Total	59.0	59.3	118.3	97.9	97.5	195.4
COMPOST	Moisture Waterlogged	6.1	5.5	11.6	7.7	7.7	15.4
	Moisture 50% WHC	11.8	10.1	21.9	13.9	20.7	34.6
	Moisture 20% WHC	9.4	8.1	17.5	11.7	9.4	21.1
	Total	27.3	23.7	51.0	33.3	37.8	71.1
TOTAL	Moisture Waterlogged	14.5	14.7	29.2	18.7	17.3	36.0
	Moisture 50% WHC	40.9	37.9	78.8	65.4	74.2	139.6
	Moisture 20% WHC	30.9	30.4	61.3	47.1	43.8	90.9
	Total	86.3	83.0	169.3	131.2	135.3	266.5

as straw and compost during incubation of 118 days at

Soil pH 6.2			Soil pH 7.2			Total		
R_1	R_2	Total	R_1	R_2	Total	R_1	R_2	Total
11.9	12.8	24.7	15.8	16.4	32.2	47.1	48.0	95.1
50.2	49.6	99.8	59.0	60.2	119.2	189.8	191.1	380.9
36.3	34.3	70.6	43.4	39.6	83.0	136.6	130.6	267.2
98.4	96.7	195.1	118.2	116.2	234.4	373.5	369.7	743.2
11.3	8.5	19.8	9.6	10.1	19.7	34.7	31.8	66.5
23.3	23.7	47.0	19.6	21.4	41.0	68.6	75.9	144.5
14.1	15.9	30.0	16.7	13.5	30.2	51.9	46.9	98.8
48.7	48.1	96.8	45.9	45.0	90.9	155.2	154.6	309.8
23.2	21.3	44.5	25.4	26.5	51.9	81.8	79.8	161.6
73.5	73.3	146.8	78.6	81.6	160.2	258.4	267.0	525.4
50.4	50.2	100.6	60.1	53.1	113.2	188.5	177.5	366.0
146.1	144.8	291.9	164.1	161.2	325.3	527.7	524.3	1053.0

CHAPTER IV

Effect of treating a soil, at three pH levels, with straw and different composts on nutrient uptake by ryegrass in pot tests.

Introduction

Experimental

Results

Discussion

Summary and Conclusions.

Introduction.

In view of the fact that little critical work appears to have been done comparing the effects of straw and composted straw on nutrient uptake by crops, it was decided to carry out a study along these lines. Because of the importance of soil pH on nutrient metabolism the experiment was started in a soil adjusted to four different pH values. However, because of the very poor germination and growth of ryegrass at the lowest pH value (4.5) these pots were eliminated and the experiment was continued only with the soils of higher pH (5.2, 6.2 and 7.2).

Materials and Methods.

The 2 mm. sieved Silwood soil which had been adjusted to different pH levels as described in Chapter II was used. The straw and composts used have also been described in Chapter II.

The experiment was done in plastic pots having a capacity of 500g. soil. The holes in the bottom of the pots were covered with glass cloth. The finely ground straw and composts (see table on the next page) were mixed with the air-dried soil at the rate of 1% (5g. per

pot) and the mixture placed in the pot and tamped down.

Summary of Treatments

Treatments	Rate	Key
Control	—	C
Fresh straw + KNO_3	1% + 25mgN	FS
Blood Compost	1%	BD
Poor Compost	1%	PC
Nitrochalk Compost	1%	NC
Sludge Compost	1%	SG
Grass Compost	1%	GG
KNO_3	25mgN	KN

For each pH there was an appropriate control and also a pot receiving potassium nitrate with nitrogen in amount equal to that added in the straw. This amount of potassium nitrate was also added to the straw-treated pots. This was done since previous tests had shown that growth of ryegrass in straw-treated soil in the absence of extra nitrogen was so poor that there was hardly any material available for cutting analysis. This treatment appears to be justified since in practice one would not add straw to a soil without adding extra nitrogen to compensate for the initial immobilization which takes place.

All treatments were done in duplicate. The pots were placed on the greenhouse bench in a random fashion.

Each pot was sown with 0.25g perennial ryegrass seed placed about $\frac{1}{4}$ in. below the surface. Watering was done with distilled water alternately from the top and from the bottom through the saucer on which each pot rested. The potassium nitrate treatments were given in solution. Half of the total dose was given after emergence and the other half after the second cutting.

The sowing date was 10th May, 1961. The first cutting was made after 77 days, the second cutting after another 73 days, and the third cutting after another 105 days.

The material from each cutting was dried in a forced-air oven in aluminium trays at 55-60°C, weighed, ground to a fine powder in a Christie and Norris mill, and stored in specimen tubes until analysis.

At the end of the experiment the root ball was placed on a sieve and the soil washed away with running water. The roots were then washed with water + stergene, rinsed with water and dried and ground as with the tops.

The ground plant material was analysed for total nitrogen, phosphorus, potassium and magnesium as

described in Chapter II.

Results.

Tabulated results obtained are summarized below.

The dry matter yields of each cutting and roots are shown:

In Table 15 for soil of pH 5.2

In Table 16 for soil of pH 6.2

In Table 17 for soil of pH 7.2.

For the three pH levels and for the three cuttings and roots the percentage nutrient in the plant material is shown:

In Table 17A for nitrogen

In Table 17B for phosphorus

In Table 17C for potassium

In Table 17D for magnesium.

The total uptake (i.e. dry matter x nutrient percentage) for each of the three cuttings and roots is shown:

In Tables 18, 19 and 20 for nitrogen for pH 5.2, 6.2 and 7.2 respectively.

In Tables 21, 22 and 23 for phosphorus for pH 5.2, 6.2 and 7.2 respectively.

In Tables 24, 25 and 26 for potassium for pH 5.2, 6.2 and 7.2 respectively.

In Tables 27, 28 and 29 for magnesium for pH 5.2,

6.2 and 7.2 respectively.

The dry matter yields at each of the three pH levels is shown:

In Table 47 for the combined tops

In Table 48 for the roots

In Table 49 for the combined tops + roots.

For each of the three pH levels the total nutrient uptake by the combined tops + roots is shown:

In Table 50 for nitrogen

In Table 51 for phosphorus

In Table 52 for potassium

In Table 53 for magnesium.

The cumulative uptake of nutrients at each cutting is shown in Tables 30, 31 and 32 for pH 5.2, 6.2 and 7.2 respectively. Since these results can be followed more easily from a diagram, cumulative uptake values are also shown in Figures 7 to 10.

Dry Matter yields of tops (Table 47).

The combined dry matter yields of tops averaged over the 3 pH levels decreased in the order:

KN GG BD SG NC FS C PC

(Treatments over a common line are not significantly different from each other but are significantly different

PLATE 2.

Perennial ryegrass growing in Silwood soil of pH 5.2, 6.2, 7.2 treated with straw and five composts at 1% level of each.

Photograph was taken before the 1st cutting when the plants were 77 days old from the date of sowing.


CONTROL
pH 5.2
FS
SC
NC
GG
BD
CS


CONTROL
pH 6.2
FS
SC
NC
GG
BD
CS


CONTROL
pH 7.2
FS
SC
NC
GG
BD
CS

at P = 0.05 from treatments over other lines).

The average dry matter yeilds of tops of all treatments was significantly greater at pH 7.2 than at pH 6.2 and 5.2; there was no significant difference between the latter two pH levels.

For the individual treatments differences in top dry matter yields due to pH are as follows:

C	pH 7.2	pH 5.2	pH 6.2
FS	pH 6.2	pH 7.2	pH 5.2
BD	pH 7.2	pH 6.2	pH 5.2
PC	pH 5.2	pH 7.2	pH 6.2
NC	pH 7.2	pH 5.2	pH 6.2
SG	pH 7.2	pH 6.2	pH 5.2
GG	pH 7.2	pH 6.2	pH 5.2
KN	pH 7.2	pH 5.2	pH 6.2

It is seen that there is no significant difference due to pH with the fresh straw + KNO_3, and the grass compost treatments. With the other treatments including the control yields at pH 7.2 were usually higher than those at the lower pH levels.

The decreasing order of yields due to treatment at each pH level is shown on the next page.

PLATE 3A.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments of control (C), straw (FS-1%) and blood compost (BD-1%) is shown.

Photograph was taken before the 1st cutting when the plants were 77 days old.


CONTROL
CONTROL
pH 6.2


FS
1%
pH 5.2
FS
1%
pH 6.2
FS
1%


BD
1%
pH 5.2
BD
1%
BD
1%

pH 5.2	KN	GG	SG	BD	NC	FS	PC	C
pH 6.2	KN	GG	SG	BD	FS	NC	C	PC
pH 7.2	KN	BD	SG	GG	NC	C	FS	PC

Thus KNO_3 gave the highest yields at all pH levels. The grass, sludge and blood composts were next in order of effectiveness. Fresh straw + KNO_3 was more effective than the control at pH 6.2. The poor compost produced lower dry matter yields than did the control at pH 6.2 and 7.2.

Dry matter yields of roots. (Table 48).

The dry matter yields of roots for the different treatments averaged over the three pH levels decreased in the order:

KN	FS	GG	SG	BD	NC	C	PC

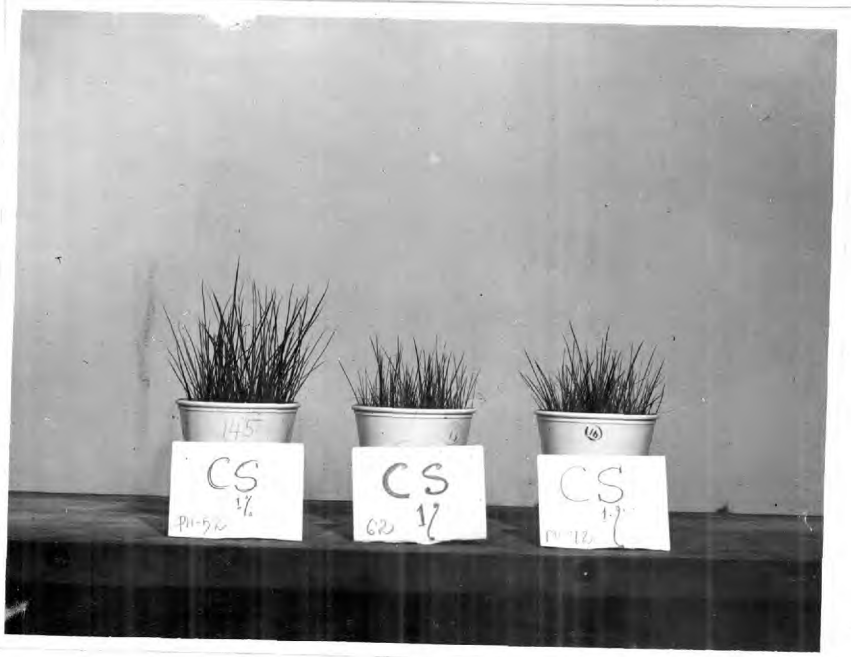
As with the tops, highest root yields were also obtained with the KNO_3 treatment. The main difference from the results with tops was that the fresh straw + KNO_3 treatment produced relatively high root yields compared with most of the other treatments.

For the individual treatments the differences in root dry matter yields due to pH are as follows:

PLATE 3B.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments poor compost (CS-1%) nitrochalk compost (NC-1%) and sludge compost (SG-1%). is shown.

Photograph was taken before the 1st cutting when the plants were 77 days old.


CS
1%
CS
1%
CS
1%


NC
1%
NC
1%
NC


SG
1%
SG
1%
SG
1%

C	pH 7.2	pH 5.2	pH 6.2
FS	pH 5.2	pH 6.2	pH 7.2
BD	pH 7.2	pH 6.2	pH 5.2
PC	pH 5.2	pH 7.2	pH 6.2
NC	pH 7.2	pH 6.2	pH 5.2
SG	pH 7.2	pH 6.2	pH 5.2
GG	pH 7.2	pH 6.2	pH 5.2
KN	pH 6.2	pH 7.2	pH 5.2

Only with the straw + KNO_3 treatment was there no significant difference in root yields due to pH. With the other treatments root yields were usually higher at pH 7.2 than at pH 6.2 and 5.2. The KNO_3 treatment gave the highest yields at pH 5.2. The average dry matter yields of roots of all treatments at pH 7.2 and 6.2 was significantly greater than that at pH 5.2. But there was no significant difference of root yield at the higher two pH levels.

The decreasing order of root yields due to treatment at each pH level is shown over the page.

PLATE 3C.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments - grass compost (GG-1%) and potassium nitrate (KN-100 lbs. N/acre). is shown.

Photograph was taken when the plants were 77 days old from the date of sowing (before 1st cutting).


GG


KN
100 lbs N/A
PH-5.2
KN
KN

pH 5.2	KN	FS	GG	SG	PC	C	NC	BD
pH 6.2	KN	GG	FS	BD	SG	NC	C	PC
pH 7.2	KN	GG	SG	FS	BD	NC	C	PC

As with the tops the KNO_3 treatment again gave the highest root yields at all pH levels. Straw + KNO_3 became less effective with increasing pH. Root yields with the poor compost were not significantly different from the controls.

Top/root total dry matter ratios. (Table 48A).

Total dry matter tops and roots and the ratios of the two for all treatments at each of the three pH levels are shown in Table 48A.

When the results of all treatments are averaged the top/root ratio increased in the order pH 6.2, pH 7.2, pH 5.2. When the individual treatments are considered pH had the greatest effect on top/root ratio with the blood compost treatment, with the lowest ratio occurring at pH 6.2. The control and KNO_3 treatments also showed fair differences in top/root ratio due to pH with the highest ratio occurring at pH 6.2 with the control and the lowest at pH 6.2 with the KNO_3 treatments. Other treatments showed lower variations in top/root ratio due to pH, with the lowest ratio usually occuring at pH 6.2

PLATE 4.

Growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments of straw and composts at 1% level. is shown.

Photograph was taken before the 3rd cutting when the plants were 105 days old after the 2nd cutting.


CONTROL
PH 52
FS
SC
NC
CG
BD
CS


CONTROL
PH 62
FS
SC
NC
CG
BD
CS


CONTROL
PH 72
FS
SC
NC
CG
BD
CS

The effects of treatments averaged over the three pH levels shows that the straw + KNO_3 gave the lowest and the KNO_3 treatments the next lowest top/root ratio. There were no great differences in top/root ratio between the other treatments. When the three pH levels are considered separately the top/root ratio showed a wider range at pH 5.2 than at the two higher pH levels. This was due to the low top/root ratio with the straw + KNO_3 and the high ratio with the blood compost treatment at this pH. The main differences due to treatments and pH were (a) the highest top/root ratio in the control at pH 6.2 and with the blood compost treatment at pH 5.2 and 7.2, and (b) the lowest ratio occurred with the straw + KNO_3 treatment at all pH levels.

Dry matter yields of tops + roots (total dry matter yields). (Table 49).

Total dry matter yields for the different treatments averaged over the three pH levels decreased in the order:

KN GG SG BD FS NC C PC

The order was similar to that for the top yields.

For the individual treatments the differences in total dry matter yields due to pH are as follows:

C	pH 7.2	pH 5.2	pH 6.2
FS	pH 6.2	pH 7.2	pH 5.2
BD	pH 7.2	pH 6.2	pH 5.2
PC	pH 5.2	pH 7.2	pH 6.2
NC	pH 7.2	pH 5.2	pH 6.2
SG	pH 7.2	pH 6.2	pH 5.2
GG	pH 7.2	pH 6.2	pH 5.2
KN	pH 6.2	pH 7.2	pH 5.2

There were no significant differences in total yields due to pH with the KNO_3 and straw + KNO_3 treatments. With the other treatments total yields were usually higher at pH 7.2 than at the two lower pH levels. The average dry matter yield of combined tops and roots of all treatments at pH 7.2 was significantly greater than that at pH 6.2 and 5.2. The combined yields between pH 6.2 and pH 5.2 were not significantly different.

The decreasing order of total dry matter yields due to treatment at each pH level is shown below:

pH 5.2	KN	GG	FS	SG	BD	NC	PC	C
pH 6.2	KN	GG	BD	FS	SG	NC	C	PC
pH 7.2	KN	BD	GG	SG	NC	FS	C	PC

Again KNO_3 gave the highest yields at all pH levels. The blood compost treatment was increasingly more effective and the straw + KNO_3 treatment increasingly less effective with increasing pH. The poor compost produced lower yields than the control at pH 7.2.

Cumulative nitrogen uptake in tops. (Fig. 7).

The main point to note with respect to the different pH levels is that at pH 5.2 the KNO_3 treatment produced the highest cumulative nitrogen uptake at all cuttings, whilst at pH 6.2 and 7.2 although this treatment produced the highest nitrogen uptake at the first and second cuttings, by the third cutting it had been exceeded by the sludge compost at pH 6.2 and by the blood compost at pH 7.2. Another effect due to pH difference was that whereas nitrogen uptake by the tops at pH 5.2 was little different at all cuttings between the control and the poor compost treatment, at the two higher pH levels the poor compost produced less nitrogen uptake at all cuttings than did the control. The other important effect was that the nitrogen uptake due to the fresh straw + KNO_3 treatment paralleled that of the other treatments at pH 5.2 and 7.2, but at pH 6.2 the uptake by the final cutting was much greater compared with those

FIG. 7

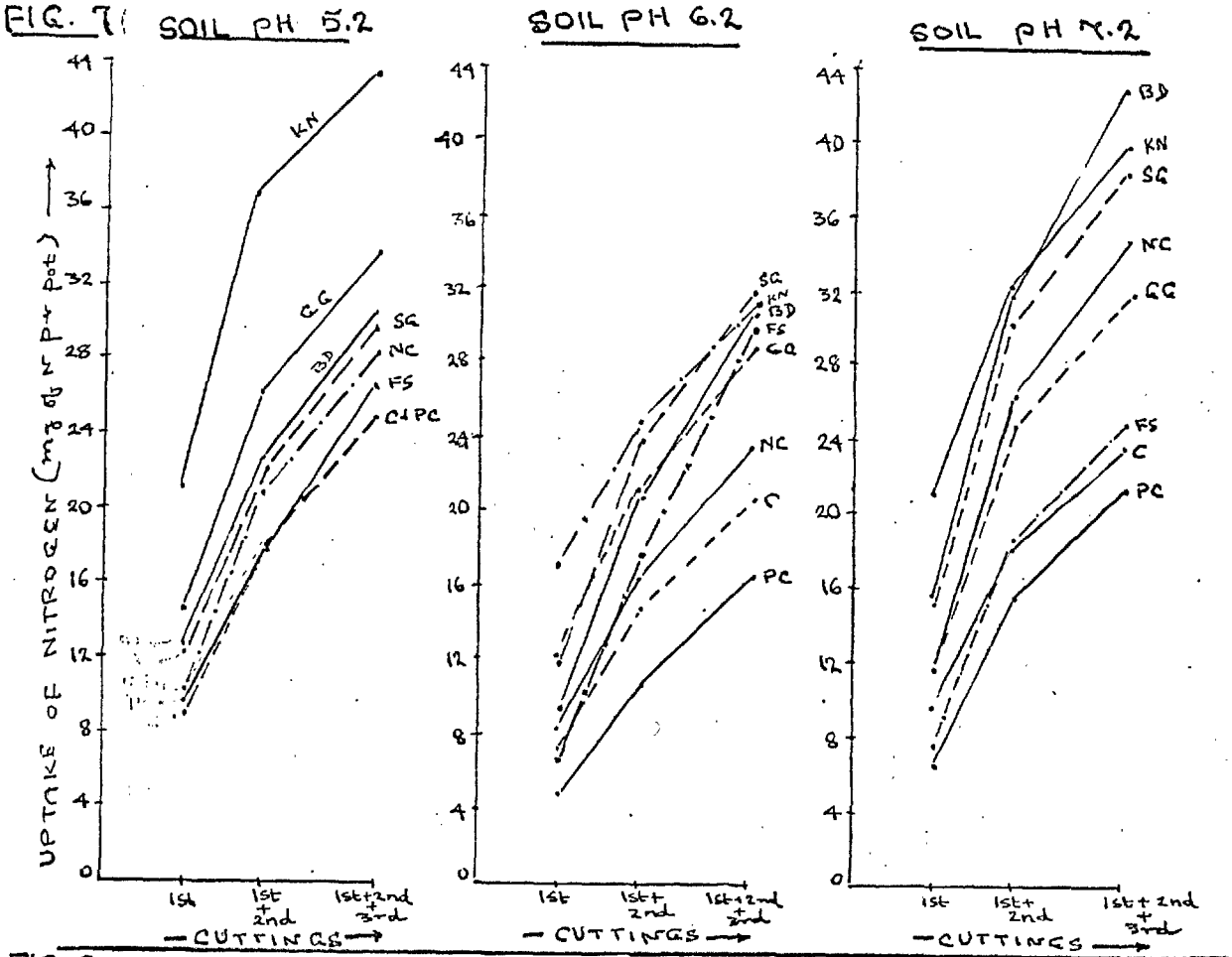
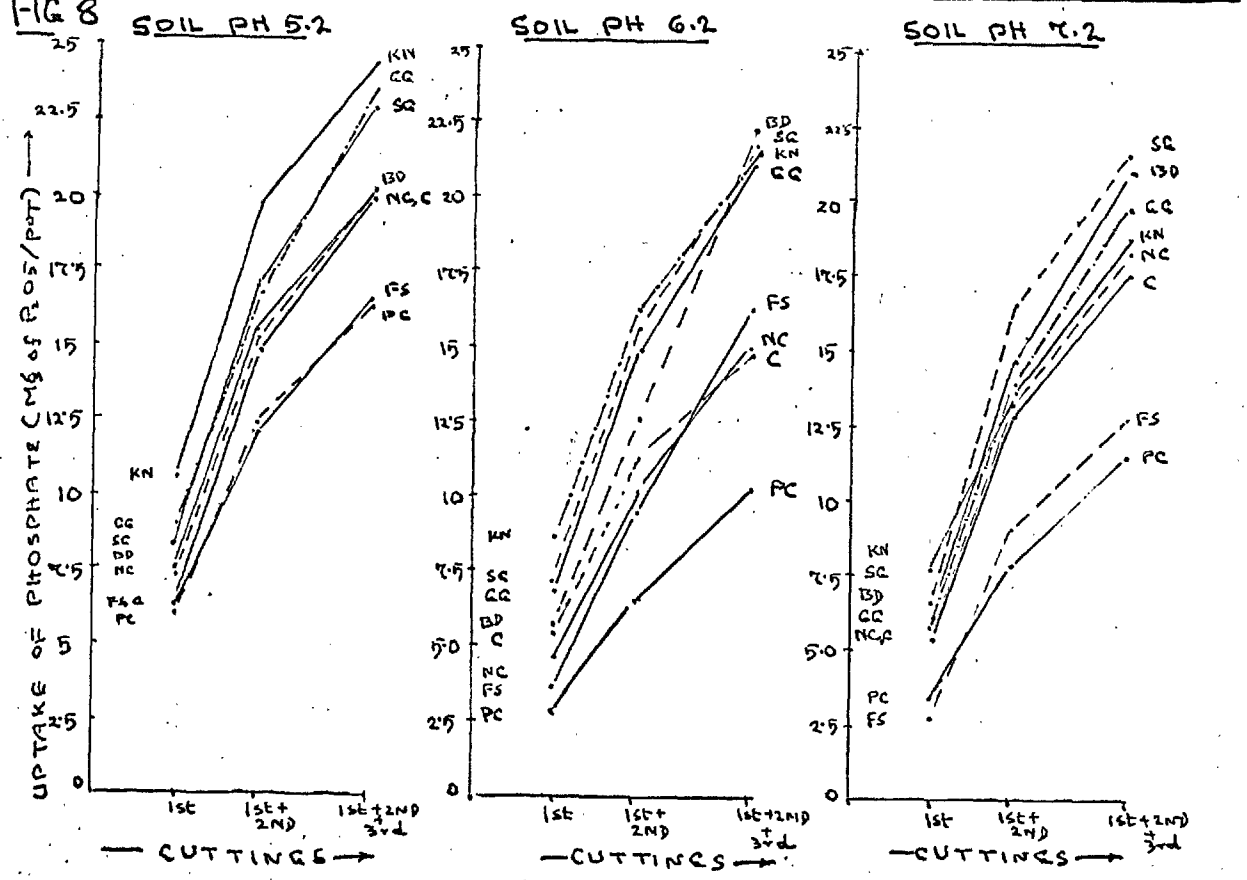

SOIL PH 5.2
SOIL PH 6.2
SOIL PH 7.2
UPTAKE OF NITROGEN (mg of N per Pot)
KN
CC
BD
SG
NC
FS
C & PC
1st
1st + 2nd
1st + 2nd + 3rd
CUTTINGS

FIG 8


SOIL PH 5.2
SOIL PH 6.2
SOIL PH 7.2
UPTAKE OF PHOSPHATE (Mg of P2O5/Pot)
KN
CC
SG
BD
NC, C
FS
PC
1st
1st + 2ND
1st + 2ND + 3rd
CUTTINGS

during earlier cuttings than with the other treatments.

Total uptake of nitrogen.

The total uptake of nitrogen (i.e. by the three cuttings + roots) averaged over the three pH levels decreased in the order:

KN GG BD SG FS NC C PC

For the individual treatments the differences in total nitrogen uptake due to pH are as follows:

C	pH 5.2	pH 7.2	pH 6.2
FS	pH 6.2	pH 5.2	pH 7.2
BD	pH 7.2	pH 6.2	pH 5.2
PC	pH 5.2	pH 7.2	pH 6.2
NC	pH 7.2	pH 6.2	pH 5.2
SG	pH 7.2	pH 6.2	pH 5.2
GG	pH 6.2	pH 7.2	pH 5.2
KN	pH 5.2	pH 7.2	pH 6.2

It is seen that there were no significant differences in total nitrogen uptake due to pH with the control, grass compost and nitrochalk compost treatments. Results with the other treatments were variable in that no one pH value was particularly suitable for optimum nitrogen uptake. Averaging all the treatments showed

that nitrogen uptake was significantly higher at pH 7.2 than at pH 6.2, but was not significantly different from pH 5.2. Also there was no significant difference in uptake between pH 6.2 and pH 5.2.

The decreasing order of total nitrogen uptake due to treatment at each pH level is shown below:

pH 5.2	KN	GG	FS	SG	NC	BD	PC	C
pH 6.2	KN	GG	FS	SG	BD	NC	C	PC
pH 7.2	KN	BD	SG	GG	NC	FS	C	PC

It is seen that KNO_3 was the most effective treatment at all pH levels. Grass compost and straw + KNO_3 were comparatively more effective at pH 5.2 and 6.2 than at pH 7.2. The blood compost increased in comparative effectiveness with increasing pH.

Cumulative phosphorus uptake in tops. (Fig. 8.)

The main points to note with regard to differences due to pH in total phosphorus uptake by the three cuttings are (a) the KNO_3 treatment caused the greatest P uptake in all cuttings only at pH 5.2. At the two higher pH levels it was about as effective as the blood and sludge compost treatments, (b) at pH 5.2 and 7.2 the straw + KNO_3

caused reduced uptake of phosphorus in comparison with the control; this reduction became more apparent with increased number of cuttings, (c) the poor compost caused reduced phosphorus uptake at all pH levels; the extent of this reduction also increased with number of cuttings, (d) there was little tendency for uptakes due to treatment to alter with number of cuttings; the only tendency for any such change was for the blood compost and straw + KNO_3 treatment at pH 6.2 and for grass compost at pH 5.2.

Total uptake of phosphorus.

The total uptake of phosphorus (i.e. by the three cuttings + roots) averaged over the three pH levels decreased in the order:

KN SG GG BD NC C FS PC

The KNO_3 and sludge compost treatments resulted in the greatest uptake of phosphorus, whilst the poor compost treatment reduced phosphorus uptake in comparison with the control.

For the individual treatments the differences in total phosphorus uptake due to pH were as follows:

C	pH 5.2	pH 7.2	pH 6.2
FS	pH 6.2	pH 5.2	pH 7.2
BD	pH 6.2	pH 7.2	pH 5.2
PC	pH 5.2	pH 7.2	pH 6.2
NC	pH 5.2	pH 7.2	pH 6.2
SG	pH 5.2	pH 6.2	pH 7.2
GG	pH 5.2	pH 6.2	pH 7.2
KN	pH 5.2	pH 6.2	pH 7.2

It is seen that there were no significant differences in total phosphorus uptake due to pH with the sludge compost and grass compost treatments. With the other treatments total phosphorus uptake was usually higher at pH 5.2 than at the other two pH levels. When uptake was averaged for all the treatments it was significantly greater at pH 5.2 than at the two other pH levels and there was no significant difference in uptake between pH 6.2 and 7.2.

The decreasing order of total phosphorus uptake due to treatment at each pH level is shown below:

pH 5.2	KN	SG	GG	C	BD	NC	FS	PC
pH 6.2	KN	SG	GG	BD	FS	NC	C	PC
pH 7.2	SG	BD	KN	GG	NC	C	FS	PC

It is seen that at pH 5.2 KNO_3 and the sludge compost treatments caused the greatest uptake of phosphorus. At the two higher pH levels these two treatments were no more effective than the blood compost and grass compost treatments. The poor compost caused reduced uptake of phosphorus, in comparison with the control, at all pH levels.

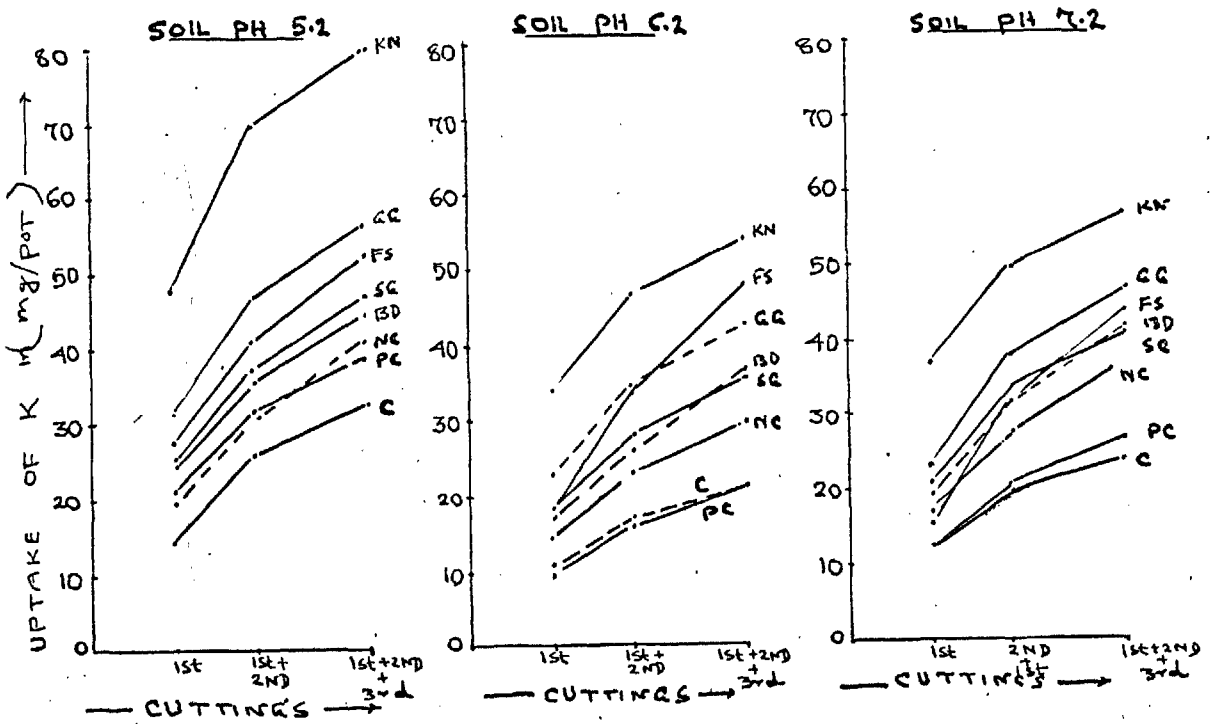
Cumulative potassium uptake in tops. (Fig. 9).

Since potassium was added as nitrate in the KNO_3 and straw + KNO_3 treatments the potassium uptakes due to these treatments cannot strictly be compared with the other treatments. However the relative uptake due to treatment with number of cuttings is of interest, particularly with regard to the straw + KNO_3 treatment; at pH 5.2 uptake paralleled that of the other treatments whilst at pH 6.2 and 7.2 the uptake of potassium due to the straw + KNO_3 treatment resulted in a proportionately greater uptake of potassium with increasing number of cuttings. Unlike nitrogen and phosphorus uptake there was little tendency fof any of the treatments to reduce potassium uptake at any of the cuttings incomparison with the control.

Total uptake of potassium.

The total uptake of potassium (i.e. by the three

FIG-9


SOIL PH 5.2
SOIL PH 6.2
SOIL PH 7.2
UPTAKE OF K (mg/pot)
0
10
20
30
40
50
60
70
80
KN
CC
FS
SC
BD
NC
PC
C
1st
1st + 2ND
1st+2ND + 3rd
CUTTINGS

cuttings + roots) averaged over the three pH levels decreased in the order:

KN FS GG SG BD NC PC C

Ignoring the treatments where KNO_3 was applied it is seen that the grass compost resulted in the highest uptake of potassium.

For the individual treatments the differences in total potassium uptake due to pH are as follows:

C	pH 5.2	pH 7.2	pH 6.2
FS	pH 5.2	pH 6.2	pH 7.2
BD	pH 5.2	pH 7.2	pH 6.2
PC	pH 5.2	pH 7.2	pH 6.2
NC	pH 5.2	pH 7.2	pH 6.2
SG	pH 5.2	pH 7.2	pH 6.2
GG	pH 5.2	pH 7.2	pH 6.2
KN	pH 5.2	pH 6.2	pH 7.2

With every treatment, including the control, total potassium uptake was greater at pH 5.2 than at the two other pH levels. There were no significant differences in total uptake with any of the treatments between pH 6.2 and pH 7.2. When uptake was averaged for all treatments that at pH 5.2 was significantly higher than those at pH 6.2 and 7.2, with no significant difference

in uptake between the two latter pH levels.

The decreasing order of total potassium uptake due to treatment at each pH level is shown below:

pH 5.2	KN	FS	GG	SG	BD	NC	PC	C
pH 6.2	KN	FS	GG	SG	BD	NC	PC	C
pH 7.2	KN	GG	FS	BD	SG	NC	PC	C

It is seen that there are no important differences in the order of the treatment effects due to pH.

Cumulative magnesium uptake in the top. (Fig. 10).

The main points to be noted with regard to differences due to pH in total magnesium uptake are (a) the poor compost caused reduced magnesium uptake, in comparison with the control by the 2nd and final cutting at pH 5.2, in all the three cuttings at pH 6.2 and in the 1st cutting only at pH 7.2, (b) the straw + KNO_3 treatment caused reduced magnesium uptake in comparison with the control in the 1st cutting at pH 6.2 and 7.2 but exceeded that of the control by the 2nd and final cutting at pH 6.2 and remained lower than control in all the cuttings at pH 7.2, (c) at pH 5.2 and 7.2 the sludge compost treatment caused a comparatively much greater uptake of magnesium by the final cutting than in earlier cuttings compared with the

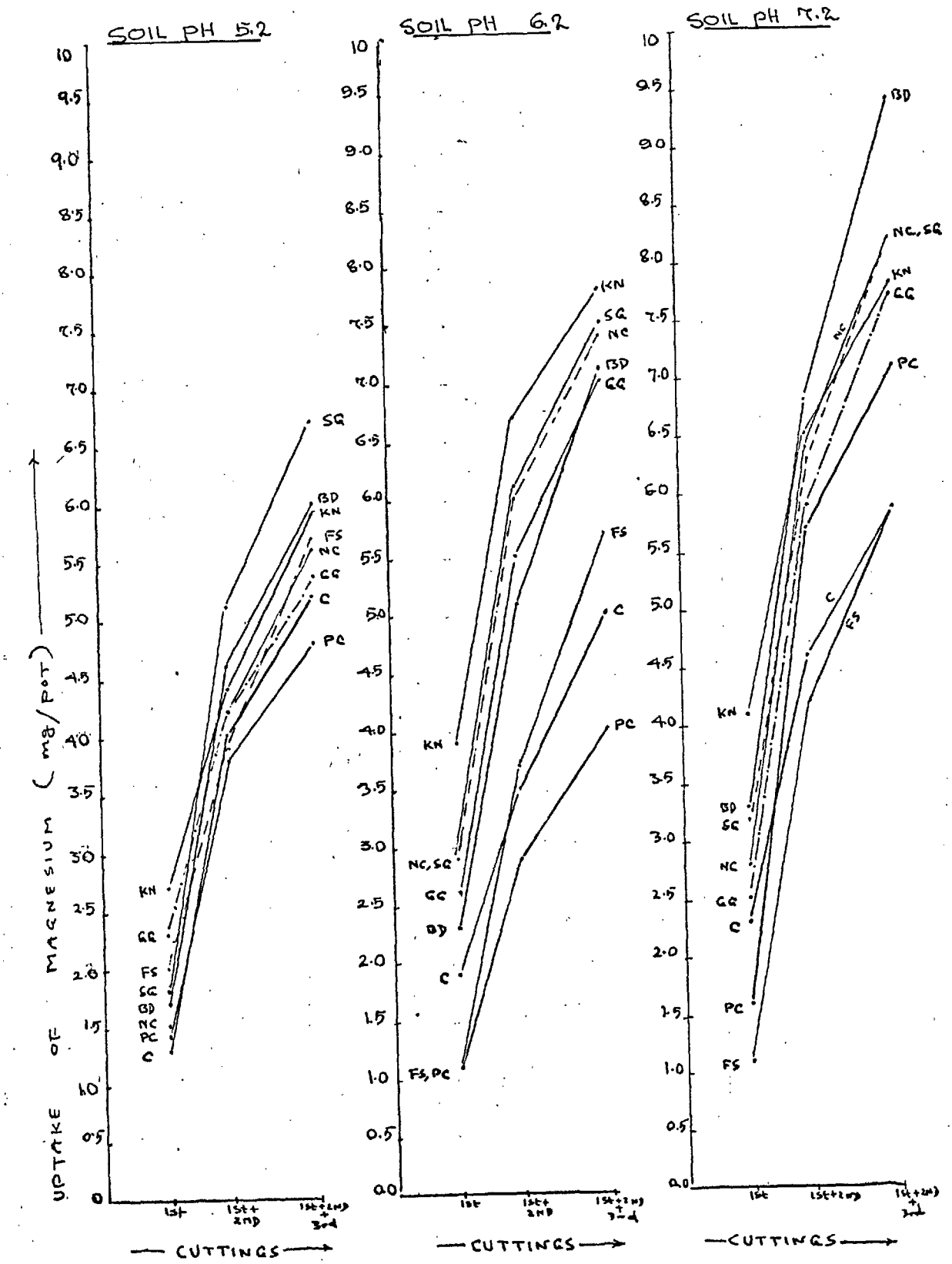

SOIL PH 5.2
SOIL PH 6.2
SOIL PH 7.2
UPTAKE OF MAGNESIUM (mg/POT)
CUTTINGS
1st
1st+2nd
1st+2nd+3rd
KN
GG
FS
SG
BD
NC
PC
C

FIG. 10

other treatments.

Total uptake of magnesium.

The total uptake of magnesium (i.e. by the three cuttings + roots) averaged over the three pH levels decreased in the order:

BD SG NC KN GG FS PC C

For individual treatments the differences in total magnesium uptake due to pH are as follows:

C	pH 7.2	pH 5.2	pH 6.2
FS	pH 7.2	pH 6.2	pH 5.2
BD	pH 7.2	pH 6.2	pH 5.2
PC	pH 7.2	pH 5.2	pH 6.2
NC	pH 7.2	pH 6.2	pH 5.2
SG	pH 7.2	pH 6.2	pH 5.2
GG	pH 7.2	pH 6.2	pH 5.2
KN	pH 6.2	pH 7.2	pH 5.2

The straw + KNO_3 treatment was the only one where total magnesium uptake was not significantly different due to pH. With all the other treatments except KNO_3 uptake was highest at pH 7.2, the differences being significant either from pH 5.2 or 6.2. When magnesium uptake was averaged for all treatments that at pH 7.2 was significantly higher than that at pH 6.2 which in turn was significantly higher than that at pH 5.2

The decreasing order of total magnesium uptake due to treatment at each pH level is shown below:

pH 5.2	SG	BD	FS	NC	GG	KN	C	PC
pH 6.2	KN	SG	NC	BD	GG	FS	C	PC
pH 7.2	BD	SG	NC	KN	GG	PC	FS	C

It is seen that the order of effectiveness of the treatments varied somewhat due to pH; KNO_3 was one of the most effective treatments in increasing magnesium uptake only at pH 6.2; the blood compost was significantly more effective than the other treatments only at pH 7.2; the straw + KNO_3 treatment became less effective, relative to the control, with increasing pH.

Recovery of applied nutrients by ryegrass. (Table (54).

The percentage recovery of nitrogen, phosphorus, potassium and magnesium by the ryegrass tops and roots from the various treatments at the three pH levels is shown in Table 54. These values were obtained by subtracting the total uptake of the particular nutrient from the control from the uptake from the treated soil and expressing this as a percentage of the total amount of nutrient applied. A negative value for a particular treatment indicates that not only was none of the applied

nutrient taken up by the ryegrass, but that the treatment reduced the availability of the nutrient originally present in the soil, or in other words, immobilized some of the native soil nutrient.

Recovery of applied nitrogen.

When the results of all treatments were averaged the recovery of applied nitrogen differed little with pH, ranging from 21.2% to 24.4%. When the individual treatments are considered, however, there were often considerable differences in nitrogen recovery due to pH. The straw + KNO_3 treatment showed maximum recovery at pH 6.2. The blood, nitrochalk, sludge and grass composts all showed increasing recovery of applied nitrogen with pH, particularly from pH 5.2 to pH 6.2. The poor compost showed only slight recovery at pH 5.2 and caused immobilization of native soil nitrogen at the two higher pH levels, as shown by the negative recovery values. The KNO_3 treatment showed the greatest recoveries of applied nitrogen, ranging around 100%. At pH 5.2 and 7.2 the greater than 100% recoveries obtained indicate that the KNO_3 treatment stimulated the uptake of native nitrogen.

The effects of treatments averaged over the three pH levels indicates that the nitrogen in KNO_3 was used

most efficiently, i.e., it was completely used. The nitrogen in poor compost was apparently not utilized at all and this treatment actually resulted in immobilization of some of the soil nitrogen. The nitrogen in the other treatments was utilized to about the same extent, ranging from 10.8% to 14.8%. However, at the different pH levels the nitrogen in the straw + KNO_3 treatment was utilized much more effectively at pH 6.2 and somewhat more effectively at pH 5.2 than was the nitrogen in the composts, whilst the reverse was the case at pH 7.2.

The extent to which the straw immobilized nitrogen during cropping can be determined by subtracting nitrogen recovery with the KNO_3 treatment from that with the straw + KNO_3 treatment. At pH 5.2 and pH 7.2 all the applied nitrate nitrogen was immobilized by the straw, whilst at pH 6.2 only 61% of the applied nitrate nitrogen was immobilized.

Recovery of applied phosphorus.

When the results of all treatments were averaged the recovery of applied phosphorus was 21.4%at pH 6.2, -6.0% at pH 7.2, and -12.2%at pH 5.2, indicating some immobilization of native phosphorus at the two latter pH values. When the individual treatments are considered

there were usually considerable differences in phosphorus recovery due to pH. The greatest difference occurred with the straw + KNO_3 treatment, where there was 38.8% recovery at pH 6.2 and considerable immobilization of native phosphorus at pH 5.2 and 7.2. The blood compost treatment also showed similar differences in magnitude of phosphorus recovery due to pH, with immobilization occurring only at pH 5.2. The sludge and grass composts showed positive recoveries of phosphorus at all pH levels, with the maximum recovery in each case being at pH 6.2. The negative values obtained with the poor compost treatment at all pH levels indicated a fair extent of immobilization of native phosphorus.

The effects of treatments averaged over the three pH levels showed that the phosphorus in the blood and grass composts was most efficiently utilized, followed in decreasing order by that in the sludge and nitrochalk composts. The poor compost caused greater immobilization of native phosphorus than did straw + KNO_3. However, differences due to treatment varied with pH. At pH 5.2 it was only with the sludge and grass composts that there was any recovery of applied phosphorus. At pH 6.2 all treatments except poor compost resulted in phosphorus

recovery, whilst at pH 7.2 all treatments except poor compost and straw +KNO_3 resulted in phosphorus recovery. The greatest differences due to treatment in recovery of applied phosphorus occurred at pH 6.2.

Recovery of applied potassium.

When the results of all treatments were averaged the recovery of applied potassium differed little with pH ranging from 51.2% to 54.1%. However, with individual treatments there were usually fair differences in potassium recovery due to pH. The greatest differences due to pH occurred with the blood compost, where recovery increased with pH from 60% at pH 5.2 to 91% at pH 7.2. Increasing pH also resulted in increasing recovery of potassium from the nitrochalk, sludge and grass composts. pH had comparatively little effect on potassium recovery from the straw + KNO_3 treatment. Recovery of potassium from the KNO_3 treatment decreased with increasing pH, whilst that from the poor compost was at a minimum at pH 6.2.

The effects of the treatments averaged over the three pH levels show that the recovery of applied potassium was highest from the blood compost, followed by the grass compost. The nitrochalk and sludge composts showed the same order of recovery as did the KNO_3 treatment, whilst

the poor compost and straw + KNO_3 treatments showed relatively poor recovery of applied potassium. At each of the three pH levels differences due to treatment were greater at pH 6.2 and 7.2 than at pH 5.2. The main difference due to pH was that recovery of applied potassium from KNO_3 was lower than that from the composts (excluding the poor compost) at pH 7.2, whilst the reverse was true at pH 5.2.

The extent to which the potassium in the straw + KNO_3 treatment was immobilized through decomposition of the straw can be determined by subtracting the recovery values with this treatment from those obtained with the KNO_3 treatment. By doing this it was found that the potassium immobilized by the straw amounted to 46.7%, 27.3% and 26.9% of that applied at pH 5.2, pH 6.2 and pH 7.2 respectively.

Recovery of applied magnesium.

When the results of all treatments are averaged the recovery of applied magnesium was somewhat greater at pH 6.2 and 7.2 than at pH 5.2. When the individual treatments are considered pH variations had the greatest effect on recovery of magnesium from the blood and nitrochalk composts, with maximum recovery occurring at pH 7.2 and 6.2 respectively. Maximum recovery of applied magnesium

also occurred at pH 6.2 from straw + KNO_3, sludge wom-post and grass compost. All the materials except straw + KNO_3 showed lower recovery at pH 5.2 than at pH 7.2. The poor compost was the only material which caused immobilization of applied magnesium and then only to a limited extent at pH 5.2 and 6.2. The effects of treatments averaged over the three pH levels showed that magnesium was most efficiently utilized from the blood and nitrochalk composts and least efficiently from the poor compost and straw + KNO_3. The main differences due to pH were (a) at pH 7.2 recovery of magnesium was much lower from straw + KNO_3 than from the composts, but was of the same order as that from the compost at the two lower pH levels, (b) the poor compost gave the same order of recovery of applied magnesium as the other composts at pH 7.2 whilst at the lower pH levels it was the only material to cause immobilization of magnesium.

Discussion.

Since the main purposes of this study were (a) to compare the effects of fresh straw + N with those of composted straw and (b) to compare the effects of composts prepared with different accelerators on the performance of ryegrass the discussion of the results obtained will be restricted mainly to (1) comparing the effects of the straw + KNO_3 treatment with the nitrochalk compost treatment and (2) comparing the effects of the four composted materials (i.e., the nitrochalk, blood, sludge and grass composts). The nitrochalk compost was selected to be compared with the straw + KNO_3 treatment because in the preparation of this compost less extraneous material was introduced so that the final product could be more reasonably compared with the straw + KNO_3 treatment than in the case of the other composts, where a greater variety and quantity of extraneous material was introduced. This is supported by the fact that the total quantity of the four major elements studied here, except potassium, were added to about the same extent in the nitrochalk compost and straw + KNO_3 treatments, whilst the other composts added greater amounts of two or more of the major nutrients.

Little need be said about the results obtained with the "poor compost" treatment. This material was straw which had been allowed to rot without the addition of any accelerator and it was expected that the addition of this material to soil would give poor results. This was in fact confirmed by the actual results obtained in this study. The material gave the poorest results in nearly every case with respect to dry matter yields of ryegrass and uptake of the four major nutrients. In addition the material caused moderate immobilization of native soil nitrogen (it was in fact the only treatment to do this) and considerable immobilization of native soil phosphorus at all pH levels. Slight immobilization of native magnesium was caused at the two lower pH levels and the recovery of applied potassium from this material was poorer than from any of the others. The poor results obtained from this treatment compared with the other was not due to lower total nutrients added through this treatment (since the total amount of the four major nutrients added through it was little different from those added with the nitrochalk compost treatment) but because the poor compost still contained a fair amount of decomposable cellulosic material (as indicated by the carbon/nitrogen ratio of 32) and decomposition of this

in the soil while the crop was growing resulted in greater immobilization of the major nutrients than in the case of the other treatments.

Straw + KNO_3 versus nitrochalk compost.

The results obtained with these two treatments will be discussed in relation to those obtained with the control and the KNO_3 treatment. A comparison of straw + KNO_3 with the KNO_3 indicates the effect of straw.

The nitrochalk compost supplied about 10% more total nitrogen than did straw + KNO_3; the latter supplied about twice as much total potassium as the former, whilst both materials supplied very similar amounts of total phosphorus and magnesium. There were in general no significant differences* in yields of ryegrass tops and roots between the two treatments and more often than not neither treatment increased yields over the controls. KNO_3 on the other hand significantly increased yields of both tops and roots over all other treatments in nearly every case. Thus as far as dry matter yields are concerned the addition of straw usually nullified the effect of KNO_3. The carbon/nitrogen ratios of the nitrochalk

*For convenience significant differences and the order of results are set out in Table 55 (upper part).

compost and straw + KNO_3 were 28 and 32 respectively, whilst that of the poor compost was also 32. These ratios are of the same order. The fact that the poor compost usually gave lower yields than did the other materials indicates that the carbon/nitrogen ratio in itself, at least in this range, is of little value in indicating the likely effect of the materials on growth. The general conclusion is that if straw is to be composted at all the composting should be done with addition of a suitable amount of accelerator. If this cannot be done it is better to apply the uncomposted straw together with extra nitrogen rather than to apply poorly composted straw without extra nitrogen.

With the straw + KNO_3 treatment the mineral nitrogen and in addition the mineral forms of the other nutrients are being competed for on the one hand by the micro-organisms decomposing the cellulosic material of the straw and on the other hand by the ryegrass roots. During the early stages, where ryegrass root activity is low, we would expect more of the mineral elements to be immobilized by the decomposing straw than taken up by the ryegrass. As growth progresses accompanied by increasing volume and activity of ryegrass roots together with

decreasing activity of immobilzing microorganisms (as the cellulosic materials disappear) the uptake of mineral elements by the roots will exceed that by the immobilising organisms. In addition, and providing the time is long enough part of the mineral elements immobilized initially will mineralize as the body material of the dead microorganisms decompose. The nitrochalk compost, containing little easily decomposable cellulosic material, would not tend to cause any initial immobilization of mineral elements, but would on the other hand tend to give a gradual release of mineral elements with time. Such results have been shown by Cornfield (44) for nitrogen in an incubation test. He found that a nitrochalk compost incubated with soil resulted in a slow release of mineral nitrogen with time (184) days). Straw caused considerable immobilization of native mineral nitrogen up to about 30 days but thereafter the immobilized nitrogen gradually mineralized and by the end of the test 25% of that which had been immobilized initially had again been released.

The comparative ability of the straw + KNO_3 and nitrochalk compost to supply mineral elements to the ryegrass over the whole period of growth is shown in the

cumulative mineral uptake curves (Figs. 7-10). Nitrogen, phosphorus, and potassium uptakes at pH 5.2 and 7.2 over the three cuttings were fairly parallel between the two treatments. On the other hand at pH 6.2 uptake for all three elements was greater with the nitrochalk compost treatment than with the straw + KNO_3 treatment in the first cutting, but by the final cutting total uptake was greater for the straw + KNO_3 treatment. Thus the intermediate pH would seem to be optimum insofar as releasing these initially immobilized mineral elements are concerned. The effect as far as magnesium is concerned is not obvious.

The effect of soil pH is again apparent when the recovery of the applied mineral elements by the ryegrass is considered (Table 54). With all four elements the percentage recovery of the applied element was greater at pH 6.2 than at the lower or higher pH with the straw + KNO_3 treatment. With the nitrochalk compost treatment recoveries were lowest at pH 5.2 and there were little differences in recovery at the two higher pH levels. This indicates that the micro-organisms responsible for immobilization are less active at pH 6.2 than at pH 5.2 and 7.2, whilst those responsible for mineralization are

less active at pH 5.2 than at the two higher pH levels, with little differences between these two higher pH levels. Thus the critical pH above which no further increase in mineralization of organic mineral sources occurs appears to be in the region of 6. This agrees with results obtained by Cornfield (97) for nitrogen, who showed that there was a critical pH in the region of 6 for mineralization of the native organic nitrogen of a wide range of soils. It must be borne in mind that apart from biological immobilization, chemical immobilization or fixation processes will vary depending on soil pH. Chemical fixation is probably not as important as biological immobilization in the case of nitrogen, but is probably as important, if not more so, for the other three elements, particularly for phosphorus. The very great differences in phosphorus recovery due to pH with nearly all the treatments is probably largely due to the chemical processes involved in phosphorus fixation. Thus the greater final recovery of phosphorus at pH 6.2 as compared with the lower and higher pH levels is probably due to the wellknown mechanisms of phosphate fixation by aluminium and iron at the lower pH and phosphate fixation as apatites and hydroxyapatites at the

higher pH.

The availability of the major nutrients, as indicated by their total uptake in the ryegrass tops and roots, was no different between the control, straw + KNO_3, and nitrochalk compost treatments in the soil of pH 5.2. At pH 6.2, straw + KNO_3 supplied more nitrogen but less magnesium than did the nitrochalk compost, with no significant difference in ability to supply phosphorus. At pH 7.2 the nitrochalk compost supplied more nitrogen, phosphorus and magnesium than did straw + KNO_3. Here again the importance of pH in affecting the differential uptake of nutrients from the two materials is obvious.

The effect of straw on the performance of ryegrass is obtained by the difference in results between the KNO_3 and KNO_3 + straw treatments. At pH 5.2 and 7.2 the straw completely prevented the uptake of any of the applied nitrate-nitrogen, whilst at pH 6.2 the straw prevented uptake of 39% of the applied nitrate-nitrogen. Thus the critical effect of the intermediate as compared with the lower and higher pH levels on nitrogen immobilization and mineralization is obvious. In the case of potassium about half of the potassium applied as KNO_3 was prevented by the straw from being taken up by

the ryegrass at pH 5.2, whilst about a quarter was prevented from being taken up by the straw at pH 6.2 and 7.2. Thus the critical pH for potassium is different to that for nitrogen. This is probably because mineral nitrogen is immobilized biologically whilst potassium is immobilized chemically. (It has been reported (98, 99) that potassium is usually fixed chemically, although Waksman (10), Blume and Purvis (100) have suggested that it may be immobilized by micro-organisms in their cell tissue.)

The relatively high recovery of magnesium at the two higher pH levels from nitrochalk compost compared with that from the straw + KNO_3 is of interest. The total amount of magnesium added in both treatments was very similar, hence the differences in recovery of added magnesium may be due to differences in the extent of chemical or biological immobilization. Magnesium uptake over the three cuttings of ryegrass were parallel between the two treatments, indicating no differences in availability at any time due to the mineralization-immobilization effects. However, phosphorus may have been a limiting factor in magnesium uptake, since it is well-known (101, 102, 103) that these two elements are

"carriers" of each other. In this connection, it is interesting to note that the relative recoveries of these two elements over the three pH levels paralleled each other. Another reason for poor recovery of applied magnesium from the straw + KNO_3 treatment compared with that from the nitrochalk compost treatment may be due to the higher level of potassium in the former treatment resulting in reduced magnesium uptake (104, 105, 106, 107). However this does not appear to be an important factor, in view of the fact that potassium recovery was not correlated with magnesium recovery and magnesium uptake was not reduced by the KNO_3 treatment in comparison with the other two treatments.

Comparison of the four composts.

The order of effectiveness of the four composts (nitrochalk, blood, sludge and grass) compared with that of the control and the KNO_3 treatment is shown for dry matter yields and uptake of the four major nutrients in Table 55 (lower part).

The table shows that in nearly every case the KNO_3 treatment was superior to the other treatments with regard to yields and total nutrient uptake. The only exceptions were for total magnesium uptake, at pH 5.2

and 7.2; in addition in some cases values obtained with some treatments were not significantly lower than those obtained with KNO_3.

The nitrochalk compost in general produced significantly lower dry matter yields of roots and tops than did the other composts, particularly at the two lower pH levels. The carbon nitrogen ratio of this compost was 28 and that of the other three composts ranged from 12 to 20. Thus the poorer yields may be ascribed to the general effect of wider carbon/nitrogen ratio resulting in reduced availability of nutrients because of immobilization of these during decomposition of cellulosic material. The grass compost had the lowest carbon/nitrogen ratio, i.e. 12 whilst the sludge and blood composts had ratios of 16 and 20 respectively. There were however usually no differences in dry matter yields between the grass, sludge and blood composts. Thus carbon/nitrogen ratio, providing it is not greater than about 20, does not affect the general performance of the ryegrass as indicated by dry matter yields.

Although there was a general trend for total nitrogen and phosphorus uptakes by ryegrass to increase with nitrogen and phosphorus contents, respectively, of the applied composts, the differences due to treatment

were usually not significant. Thus at pH 5.2 there were no significant differences in nitrogen uptake due to treatment, at pH 6.2 grass compost was significantly better than the other three, whilst at pH 7.2 nitrochalk compost was significantly poorer than the other three. The order of effectiveness of the different composts in supplying nitrogen and phosphorus varied with pH. Thus the blood compost became increasingly more effective in supplying nitrogen and phosphorus in comparison with the other composts with increasing pH. This is shown not only in total nitrogen uptake but also in the way in which the relative uptake with successive cuttings of ryegrass show a comparatively greater nitrogen and phosphorus uptake at the two higher pH levels. This indicates that the mineralization of both organic nitrogen and organic phosphorus in the blood compost increased more rapidly with pH than did those in the other composts. These findings are further confirmed when the recoveries of applied nutrients are considered; recoveries increased to a greater extent with increasing pH in the case of the blood compost than with the other composts. However, in the case of phosphorus recoveries tended to decrease as pH increased from 6.2 to 7.2. The poor phosphorus recoveries at the low pH is presumably due to

immobilization of much or all of the applied phosphate in the iron- and aluminium-bound forms, whilst the poor recoveries at pH 7.2 may be due to fixation as apatites and hydroxyapatites.

The recovery of applied nitrogen from the four composts ranged from 3% to 21%, whilst that from KNO_3 was virtually complete. This is not surprising in view of the ready availability of the nitrate-nitrogen from KNO_3, whilst most of the nitrogen supplied by the composts would have to be mineralized before it became available. However, to offset this relatively poor recovery of nitrogen from the composts, their residual effects must be considered. This problem was studied in another experiment to be reported in another chapter. Apart from this composts would normally be applied to soils in much larger quantities than inorganic nitrogen fertilizers would be applied and thus would be able to supply as much nitrogen as would the inorganic fertilizers.

Potassium uptake by ryegrass was correlated with total potassium content of the four composts, at all pH levels, the grass compost, having the highest potassium content, giving the greatest total uptake of potassium. Although there were no important differences due to pH, recoveries of applied potassium tended to increase with

pH. It is interesting to note that about half to three-quarters of potassium applied in the composts was available to the ryegrass; this was little different from the availability of the potassium applied as KNO_3, which ranged from 49% to 71%. The tendency for recovery of applied potassium from the composts to increase with pH, particularly from pH 5.2 to pH 6.2, whilst that from KNO_3 decreased with pH is of interest. There is a certain amount of controversy (108, 109, 110, 111) as to whether potassium fixation is affected by pH. The results obtained in this study indicate that whereas on the one hand potassium fixation appears to increase with pH when inorganic potassium (i.e. KNO_3) is applied, on the other hand it appears to decrease with increasing pH when potassium is supplied in the form of composts. Thus extent of fixation and hence availability to the plant is affected by the presence of the compost humus and its effect, at least at the two higher pH levels, is to prevent potassium fixation by the mineral fraction of the soil presumably by competing with the mineral exchange complex for some of the potassium.

The most interesting point to note with respect to recovery of applied magnesium by the successive cuttings

of ryegrass is that the recovery of magnesium from the blood compost in relation to that from the other composts increased with cuttings at all pH levels. The total magnesium uptake from the blood compost was as good as or better (depending on pH) than that from the sludge and grass composts, in spite of the fact that the two latter materials contained more total magnesium. This, combined with the fact that recovery of applied magnesium from the blood compost was greater, particularly at the two higher pH levels, than that from the other two materials indicates that the blood compost is superior to the other two materials in either preventing immobilization of magnesium and/or causing immobilized magnesium to become available. There was a rough correlation between recovery of magnesium and recovery of phosphorus over the three pH levels, indicating that the carrier effect between these two nutrients appears to be operative.

Top/root dry matter ratios.

Although the KNO_3 treatment resulted in a greater production of both tops and roots than did any other treatment the top/root ratio obtained with this treatment was little different to that obtained with the composts. This indicates that the effects of all these materials

on dry matter production are different in quantity but not in quality. The only treatment which consistently gave low top/root ratios was straw + KNO_3. This was due more to high root weight than to low top weight compared with the other treatments, particularly at the two lower pH levels. It appears therefore that the vigorous biological reactions occurring as a result of straw decomposition have stimulated root growth to a greater extent than top growth.

Summary and Conclusions.

Pot tests in the greenhouse were carried out on Silwood soil (sandy loam) adjusted to pH 5.2, 6.2 and 7.2 beforethe start and treated with 1% by weight of straw (+ KNO_3 to give 100 lb. N per acre), poor compost, blood compost, nitrochalk compost, sludge compost, and grass compost. At each pH level a control as well as a KNO_3 treatment (in amount equal to that given with the straw) was included. Perennial ryegrass was the test crop and three cuttings were taken over 255 days. The cuttings and roots were analysed for nitrogen, phosphorus, potassium and magnesium.

The results will be summarized so as to compare (a) the KNO_3, straw + KNO_3 and nitrochalk compost treatment and (b) the KNO_3, blood, nitrochalk, sludge and grass compost treatments. The poor compost (prepared by allowing straw to rot without addition of any accelerator) resulted in a poorer performance of ryegrass (with respect to yields and nutrient uptake) even compared with the controls at all pH levels.

Comparison of KNO_3, straw + KNO_3, and nitrochalk compost treatments.

KNO_3 produced higher top and root dry matter yields than did the other treatments at all pH levels, except

for root yields at pH 5.2, where straw + KNO_3 was as effective. In general, straw + KNO_3 and nitrochalk compost were only slightly more effective than the controls as far as dry matter yields of tops and roots were concerned, and there was on the whole no difference in performance between straw + KNO_3 and nitrochalk compost.

Total nitrogen uptake was greatest with KNO_3 at all pH levels, except that at pH 6.2 straw + KNO_3 was as effective. At pH 5.2 total nitrogen uptake was no better with straw + KNO_3 and nitrochalk compost than from the control. At pH 6.2 straw + KNO_3 was more effective than nitrochalk compost in increasing total nitrogen uptake, whilst at pH 7.2 the reverse was true. Recovery of applied nitrogen was complete from KNO_3, increased from about 7% to 15% with increasing pH from nitrochalk compost, and from straw + KNO_3 was higher (31% of that applied) at pH 6.2 than at the two other pH levels. Straw "permanently" immobilized all the KNO_3-nitrogen at pH 5.2 and 7.2 and 60% of the KNO_3-nitrogen at pH 6.2.

Total phosphorus uptake was highest with the KNO_3 treatment, except for nitrochalk compost at pH 7.2. At pH 5.2 total phosphorus uptake was no different between the control, straw + KNO_3, and nitrochalk compost; at

pH 6.2 only straw + KNO_3 increased total phosphorus uptake over the control, whilst at pH 7.2 this treatment reduced total phosphorus uptake compared with the control. The recovery of applied phosphorus was higher at pH 6.2 than at the two other pH levels; at pH 5.2 and 7.2 with the straw + KNO_3 and at pH 5.2 with the nitrochalk compost there was permanent immobilization of applied phosphorus.

Total potassium uptake at all pH levels decreased in the order KNO_3, straw + KNO_3, nitrochalk compost, control. Recovery of KNO_3-potassium decreased with pH; recovery of potassium from straw + KNO_3 was lower and hardly affected by pH. Straw "permanently" immobilized about 47% of the KNO_3-potassium at pH 5.2 and about 27% at pH 6.2 and 7.2.

Total uptake of magnesium at pH 5.2 was not affected by any of the treatments, whilst at pH 6.2 and 7.2 it was increased to a greater extent by KNO_3 and nitrochalk compost than by straw + KNO_3. Recovery of applied magnesium was greater from nitrochalk compost than from straw + KNO_3 at pH 6.2 and 7.2 only. Recovery from both materials was better at pH 6.2 than at the two other pH levels.

The general overall conclusion is that at low pH the performance of ryegrass was affected to about the same extent by composted straw and uncomposted straw applied with extra nitrogen whilst at the higher pH levels the composted straw resulted in better performance of ryegrass than did uncomposted straw with extra nitrogen.

Comparison of KNO_3 and nitrochalk, blood, sludge and grass composts.

KNO_3 produced the highest dry matter yields of tops and roots at all pH levels. At pH 7.2 the four composts produced similar total yields, all of which were greater than the control. At pH 6.2 grass and blood composts produced higher yields than sludge or nitrochalk compost. At pH 5.2 only sludge and grass compost produced higher yields than did the control.

At pH 5.2 only grass compost produced higher total nitrogen uptake than did the control; at pH 6.2 grass compost was again the best but the other composts also caused increased nitrogen uptake compared with the control; at pH 7.2 grass, sludge and blood composts were better than nitrochalk in increasing total nitrogen uptake. The recovery of applied nitrogen increased with pH, particularly from 5.2 to 6.2, with all composts.

Recovery of nitrogen from the blood compost was better than that from the others at high pH and worse than that from the others at low pH. The recovery of nitrogen from the composts varied from 4% to 21%, whilst that from KNO_3 was essentially complete.

At pH 5.2 total phosphorus uptake was greatest with KNO_3 and sludge compost, whilst the other materials did not affect total phosphorus uptake; at pH 6.2 and 7.2 all materials except nitrochalk compost increased total phosphorus uptake. Recovery of applied phosphorus was greater, and usually to a considerable extent, at pH 6.2 than at pH 5.2 and 7.2. "Permanent" immobilization of phosphorus from the blood and nitrochalk composts occurred at pH 5.2. At pH 6.2 and 7.2 recovery of applied phosphorus was greater from the blood and grass than from the other composts.

The order of total potassium uptake due to treatments was little affected by pH. KNO_3 gave the greatest uptake, followed by grass compost and then by the other three composts, all of which caused greater uptake of potassium than did the control. The recovery of applied potassium from the composts increased with pH, particularly from pH 5.2 to 6.2. The greatest recovery of applied

potassium occurred from the grass compost at pH 5.2 and from the blood compost at pH 6.2 and 7.2. The recovery of potassium from KNO_3 was of the same order as that from the composts.

At pH 5.2 total magnesium uptake was greatest with the sludge compost and no different between all other treatments, including the control; at pH 6.2 all treatments caused similar increases in total magnesium uptake over the control; at pH 7.2 the blood compost caused the greatest magnesium uptake, whilst the other treatments caused similar increases of magnesium uptake over the control. Recovery of applied magnesium was of the same order from all composts at pH 5.2, but at pH 6.2 and 7.2 recovery washigher from the blood and nitrochalk composts than from the other composts. With all the composts recovery of applied magnesium was greater at pH 6.2 or 7.2 than at pH 5.2.

The general overall conclusions with respect to the effects of the four composts on ryegrass performance are (a) at pH 5.2 and 7.2 sludge and grass composts were more effective than blood and nitrochalk composts, (b) at pH 6.2 grass, sludge and blood composts were more effective than nitrochalk compost and (c) the extent of responses of all composts was greater at pH 7.2 than at the two lower pH values.

Table 15.

Table 15. Dry matter yield (in gms) of ryegrass (tops

Treatments	1st Cutting			2nd Cutting		
	R_1	R_2	Total	R_1	R_2	Total
C	0.690	0.756	1.446	0.747	0.800	1.547
FS	0.844	0.796	1.640	0.737	0.698	1.435
BD	0.897	1.204	2.101	0.784	0.921	1.705
PC	0.906	0.943	1.849	0.751	0.729	1.480
NC	0.958	0.908	1.866	0.874	0.791	1.665
SG	0.883	1.085	1.968	0.980	0.930	1.910
GG	1.098	1.279	2.377	0.936	1.031	1.967
KN	1.643	1.599	3.242	1.227	1.152	2.379

+ roots) grown in Silwood soil of pH 5.2.

3rd Cutting			Root		
R_1	R_2	Total	R_1	R_2	Total
0.597	0.571	1.168	1.180	1.220	2.400
0.693	0.703	1.396	1.676	1.629	3.305
0.569	0.586	1.155	1.101	1.090	2.191
0.589	0.469	1.058	1.326	1.198	2.524
0.578	0.630	1.208	1.163	1.128	2.291
0.638	0.574	1.212	1.292	1.262	2.554
0.630	0.610	1.240	1.358	1.381	2.739
0.686	0.550	1.236	1.908	1.636	3.544

Table 16.

Table 16. Dry matter yield (in gms) of ryegrass

Treatments	1st Cutting			2nd Cutting		
	R_1	R_2	Total	R_1	R_2	Total
C	0.782	0.911	1.693	0.621	0.666	1.287
FS	0.617	0.659	1.276	0.970	0.903	1.873
BD	0.927	0.881	1.808	0.844	0.749	1.593
PC	0.453	0.512	0.965	0.651	0.489	1.140
NC	0.840	0.772	1.612	0.732	0.670	1.402
SG	1.000	1.057	2.057	0.947	0.930	1.887
GG	1.193	1.184	2.377	0.921	0.988	1.909
KN	1.625	1.735	3.360	1.066	0.967	2.033

(tops + roots) grown in Silwood soil of pH 6.2.

3rd Cutting			Root		
R_1	R_2	Total	R_1	R_2	Total
0.557	0.437	0.994	0.953	0.918	1.871
0.854	0.847	1.701	1.594	1.620	3.214
0.869	0.826	1.695	1.610	1.415	3.025
0.532	0.493	1.025	0.949	0.877	1.826
0.700	0.623	1.323	1.146	1.276	2.422
0.621	0.695	1.316	1.328	1.469	2.797
0.734	0.763	1.497	1.599	1.691	3.290
0.754	0.702	1.456	2.214	2.429	4.643

Table 17.

Table 17. Dry matter yield (in gms) of ryegrass (tops

Treatments	1st Cutting			2nd Cutting		
	R_1	R_2	Total	R_1	R_2	Total
C	0.953	1.101	2.054	0.815	0.747	1.562
FS	0.637	0.637	1.274	0.979	0.983	1.962
BD	1.107	1.169	2.276	1.171	0.908	2.079
PC	0.739	0.574	1.313	0.698	0.775	1.473
NC	1.009	1.149	2.158	1.020	1.043	2.063
SG	1.312	1.070	2.382	1.050	1.060	2.110
GG	1.315	0.859	2.174	1.259	0.884	2.143
KN	1.989	1.697	3.686	1.024	0.777	1.801

+ roots) grown in Silwood Soil of pH 7.2.

3rd Cutting			Root		
R_1	R_2	Total	R_1	R_2	Total
0.680	0.492	1.172	1.428	1.183	2.611
0.731	0.728	1.459	1.685	1.407	3.092
1.124	0.911	2.035	1.383	1.641	3.024
0.617	0.630	1.247	1.079	1.024	2.103
0.757	0.725	1.482	1.579	1.370	2.949
0.825	0.769	1.594	1.425	1.745	3.170
0.786	0.829	1.616	1.877	1.588	3.465
0.736	0.765	1.501	2.148	1.883	4.031

Table 17A.

Table 17A. Percentage nitrogen in perennial ryegrass grown in treatments.

Treatments	Soil pH 5.2								Soil pH 6.2			
	1st Cutting		2nd Cutting		3rd Cutting		Root		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	1.25	1.20	1.20	1.20	1.20	1.20	1.39	1.38	0.81	0.86	1.13	1.20
FS(1%)	1.11	1.26	1.10	1.15	1.28	1.28	1.20	1.36	1.10	0.93	1.13	1.20
BD(1%)	1.23	1.18	1.20	1.20	1.30	1.40	1.55	1.20	1.08	1.00	1.30	1.48
PC	1.08	1.08	1.05	1.28	1.13	1.28	1.08	1.93	0.99	0.91	0.95	1.10
NC	1.18	1.12	1.05	1.40	1.23	1.28	1.80	1.50	1.00	1.03	1.13	1.15
SG	1.26	1.20	1.13	0.98	1.23	1.20	1.58	1.25	1.12	1.14	1.35	1.20
GG	1.24	1.20	1.20	1.20	1.20	1.20	1.34	1.53	1.00	1.01	1.13	0.75
KN	1.40	1.45	1.13	1.20	1.00	1.08	1.50	1.43	0.93	1.09	0.75	0.75

Silwood soil of different pH treated with different

Soil pH 7.2

3rd Cutting		Root		1st Cutting		2nd Cutting		3rd Cutting		Root	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
1.28	1.08	1.85	1.66	0.78	1.08	0.95	1.20	0.90	1.00	1.35	1.43
1.30	1.55	1.63	1.80	1,18	1.20	1.10	1.13	0.93	0.80	1.13	1.38
1.20	1.20	1.28	1.35	1.30	1.45	1.55	1.55	1.15	1.00	1.39	1.35
1.15	1.20	1.43	1.63	0.93	1.11	1.13	1.20	0.95	1.00	1.28	1.25
1.08	1.08	2.00	2.08	1.01	1.15	1.40	1.40	1.10	1.15	1.10	1.43
1.20	1.23	1.43	1.35	1.29	1.29	1.35	1.43	1.00	1.08	1.13	1.48
1.13	1.00	1.75	1.95	1.13	1.03	1.35	0.95	0.85	0.95	1.39	1.33
0.85	0.95	1.25	1.65	1.19	1.18	1.13	1.20	0.95	0.85	1.43	1.43

Table 17B.

Table 17B. Percentage phosphate in perennial ryegrass grown in

Treatments	Soil pH 5.2								Soil			
	1st Cutting		2nd Cutting		3rd Cutting		Root		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	0.97	0.78	1.14	1.06	0.80	0.78	0.58	0.41	0.63	0.62	0.94	0.89
FS	0.73	0.79	0.88	0.85	0.71	0.55	0.39	0.36	0.58	0.52	0.60	0.65
BD	0.74	0.69	0.97	0.85	0.88	0.83	0.36	0.41	0.61	0.61	0.85	0.92
PC	0.61	0.69	0.85	0.85	0.68	0.83	0.36	0.36	0.52	0.54	0.70	0.65
NC	0.79	0.79	0.85	0.94	0.73	0.78	0.46	0.36	0.54	0.61	0.83	0.73
SG	0.88	0.80	0.92	0.89	0.95	1.01	0.41	0.46	0.66	0.69	0.92	0.89
GG	0.76	0.72	0.87	0.75	1.16	0.85	0.36	0.36	0.53	0.61	0.85	0.83
KN	0.65	0.65	0.75	0.78	0.75	0.80	0.36	0.39	0.53	0.52	0.85	0.68

Silwood soil of different pH.

pH 6.2						Soil pH 7.2					
3rd Cutting		Root		1st Cutting		2nd Cutting		3rd Cutting		Root	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
0.73	0.73	0.43	0.40	0.49	0.52	1.14	1.01	0.58	0.70	0.36	0.31
0.92	0.71	0.41	0.39	0.43	0.43	0.63	0.63	0.53	0.48	0.31	0.30
1.14	1.18	0.36	0.36	0.48	0.56	0.83	0.81	0.59	0.65	0.36	0.36
0.73	0.68	0.36	0.35	0.43	0.52	0.65	0.60	0.55	0.63	0.36	0.33
0.66	0.78	0.46	0.46	0.48	0.49	0.78	0.75	0.65	0.69	0.33	0.36
1.06	0.83	0.43	0.48	0.53	0.54	0.84	0.84	0.68	0.58	0.31	0.40
0.73	1.01	0.39	0.40	0.52	0.52	0.75	0.75	0.69	0.68	0.31	0.36
0.68	0.88	0.39	0.39	0.43	0.38	0.68	0.65	0.68	0.63	0.36	0.36

Table 17C.

Table 17C. Percentage K in perennial ryegrass grown in Silwood

Treatments	Soil pH 5.2								Soil			
	1st Cutting		2nd Cutting		3rd Cutting		Root		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	2.25	1.70	1.58	1.40	1.25	1.15	0.45	0.45	1.30	1.25	0.93	1.00
FS(1%)	3.08	3.60	1.85	1.90	1.70	1.65	0.71	0.78	2.58	2.98	1.68	1.63
BD (2%)	2.43	2.18	1.48	1.30	1.60	1.55	0.45	0.50	1.90	1.85	1.15	1.03
PC	2.25	2.28	1.48	1.30	1.33	1.55	0.48	0.41	2.00	1.93	1.10	1.20
NC	2.13	2.13	1.40	1.40	1.50	1.55	0.54	0.48	1.78	1.78	1.25	1.10
SG	2.68	2.33	1.40	1.35	1.55	1.55	0.48	0.48	1.78	1.78	1.03	1.00
GG	2.68	2.68	1.45	1.45	1.65	1.60	0.35	0.35	1.93	1.93	1.10	1.20
KN	2.93	2.98	1.85	1.73	1.60	1.65	0.43	0.48	2.03	2.00	1.40	1.30

soil of different pH.

pH 6.2						Soil pH 7.2					
3rd Cutting		Root		1st Cutting		2nd Cutting		3rd Cutting		Root	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
0.75	0.83	0.30	0.20	1.40	1.00	1.03	0.93	0.70	0.65	0.25	0.13
1.60	1.70	0.50	0.56	2.33	2.43	1.58	1.73	1.78	1.55	0.48	0.43
1.25	1.20	0.30	0.20	1.75	1.75	1.10	1.13	1.05	0.95	0.19	0.19
1.25	0.83	0.30	0.30	1.75	2.00	1.25	1.03	1.00	1.00	0.19	0.21
1.00	1.05	0.39	0.41	1.55	1.60	1.00	1.00	1.10	1.00	0.15	0.25
1.20	1.20	0.30	0.39	1.75	1.78	1.25	1.13	0.83	0.95	0.15	0.28
1.15	1.15	0.35	0.30	2.10	2.13	1.25	1.45	1.00	1.25	0.21	0.33
1.10	1.05	0.30	0.33	2.03	1.93	1.40	1.50	0.95	0.95	0.15	0.21

Table 17D.

Table 17D. Percentage magnesium in perennial ryegrass grown in

Treatments	Soil pH 5.2								Soil			
	1st Cutting		2nd Cutting		3rd Cutting		Root*		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	0.17	0.18	0.36	0.34	0.20	0.20			0.24	0.22	0.32	0.30
FS(1%)	0.25	0.23	0.30	0.23	0.27	0.24			0.18	0.15	0.31	0.30
BD(1%)	0.17	0.16	0.35	0.33	0.24	0.24			0.26	0.24	0.35	0.37
PC	0.15	0.16	0.32	0.31	0.19	0.20			0.22	0.22	0.33	0.32
NC	0.15	0.18	0.31	0.33	0.24	0.21			0.24	0.22	0.33	0.34
SG	0.22	0.15	0.36	0.34	0.26	0.24			0.30	0.27	0.35	0.33
GG	0.20	0.19	0.30	0.30	0.19	0.19			0.22	0.21	0.31	0.30
KN	0.18	0.15	0.29	0.25	0.15	0.17			0.20	0.26	0.26	0.29

* negligible amounts found in roots

Silwood soil of different pH.

pH 6.2				Soil pH 7.2							
3rd Cutting		Root*		1st Cutting		2nd Cutting		3rd Cutting		Root*	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
0.20	0.19			0.22	0.22	0.29	0.30	0.21	0.24		
0.25	0.24			0.18	0.15	0.32	0.31	0.24	0.24		
0.22	0.24			0.27	0.30	0.32	0.36	0.25	0.26		
0.23	0.19			0.24	0.23	0.32	0.38	0.22	0.24		
0.21	0.21			0.27	0.24	0.35	0.36	0.23	0.24		
0.21	0.22			0.24	0.31	0.31	0.26	0.24	0.24		
0.20	0.20			0.24	0.22	0.33	0.34	0.21	0.22		
0.15	0.17			0.24	0.20	0.26	0.27	0.18	0.17		

Table 18.

Table 18. Total uptake of nitrogen (inmgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	8.63	9.07	17.70	8.85	8.96	9.60	18.56	9.28
FS	9.37	10.03	19.40	9.70	8.11	8.03	16.14	8.07
BD	11.03	14.21	25.24	12.62	9.41	11.05	20.46	10.23
PC	9.78	10.18	19.96	9.98	7.89	9.33	17.22	8.61
NC	11.30	10.17	21.47	10.74	9.18	11.07	20.25	10.13
SG	11.13	13.02	24.15	12.08	11.07	9.11	20.18	10.09
GG	13.62	15.35	28.97	14.49	11.23	12.37	23.60	11.80
KN	23.00	23.19	46.19	23.10	13.87	13.82	27.69	13.85

ryegrass (tops and roots) grown in Silwood soil of pH 5.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
7.16	6.85	14.01	7.01	16.40	16.84	33.24	16.62
8.87	9.00	17.87	8.94	20.11	22.15	42.26	21.13
7.40	8.20	15.60	7.80	17.07	13.08	30.15	15.08
6.66	6.00	12.66	6.33	14.32	23.12	37.44	18.72
7.11	8.06	15.17	7.59	20.93	16.92	37.85	18.93
7.85	6.89	14.74	7.37	20.41	15.78	36.19	18.10
7.56	7.32	14.88	7.44	18.20	21.13	39.33	19.67
6.86	5.94	12.80	6.40	28.62	23.39	52.01	26.01

Table 19.

Table 19. Total uptake of nitrogen (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	6.33	7.83	14.16	7.08	7.02	7.99	15.01	7.51
FS	6.79	6.13	12.92	6.46	10.96	10.84	21.80	10.90
BD	10.01	8.88	18.89	9.45	10.97	11.09	22.06	11.03
PC	4.48	4.66	9.14	4.57	6.18	5.38	11.56	5.78
NC	8.40	7.95	16.35	8.18	8.27	7.71	15.98	7.99
SG	11.20	12.05	23.25	11.63	12.78	11.16	23.94	11.97
GG	11.93	11.96	23.89	11.95	10.41	7.41	17.82	8.91
KN	15.11	18.91	34.02	17.01	8.00	7.25	15.25	7.63

ryegrass (tops + roots) grown in Silwood soil of pH 6.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
7.13	4.72	11.85	5.93	17.63	15.24	32.87	16.44
11.10	13.13	24.23	12.12	25.98	29.16	55.14	27.57
10.43	9.91	20.34	10.17	20.61	19.10	39.71	19.86
6.12	5.92	12.04	6.02	13.57	14.30	27.87	13.94
7.56	6.73	14.29	7.15	22.92	26.54	49.46	24.73
7.45	8.55	16.00	8.00	18.99	19.83	38.82	19.41
8.29	7.63	15.92	7.96	27.98	32.97	60.95	30.48
6.41	6.67	13.08	6.54	27.68	30.08	57.76	28.88

Table 20.

Table 20. Total uptake of nitrogen (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	7.43	11.89	19.32	9.66	7.74	8.96	16.70	8.35
FS	7.52	7.64	15.16	7.58	10.77	11.11	21.88	10.94
BD	14.39	16.95	31.34	15.67	18.15	14.07	32.22	16.11
PC	6.87	6.37	13.24	6.62	7.89	9.30	17.19	8.60
NC	10.19	13.21	23.40	11.70	14.28	14.60	28.88	14.44
SG	16.92	13.80	30.72	15.36	14.18	15.16	29.34	14.67
GG	14.86	8.85	23.71	11.86	17.00	8.40	25.40	12.70
KN	23.67	20.02	43.69	21.85	11.57	9.32	20.89	10.45

ryegrass (tops and roots) grown in Silwood soil of pH 7.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
6.12	4.92	11.04	5.52	19.28	16.92	36.20	18.10
6.80	5.82	12.62	6.31	19.04	19.42	38.46	18.23
12.93	9.11	22.04	11.02	19.22	22.15	41.37	20.69
5.86	6.30	12.16	6.08	13.81	12.80	26.61	13.31
8.33	8.34	16.67	8.34	17.37	19.59	36.96	18.48
8.25	8.31	16.56	8.28	16.10	25.83	41.93	20.97
6.68	7.88	14.56	7.28	26.09	21.12	47.21	23.61
6.99	6.50	13.49	6.75	30.72	26.93	57.65	28.83

Table 21.

Table 21. Total phosphate uptake (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	6.69	5.90	12.59	6.30	8.52	8.48	17.00	8.50
FS	6.16	6.29	12.45	6.23	5.75	5.93	11.68	5.84
BD	6.64	8.31	14.95	7.48	7.60	7.83	15.43	7.72
PC	5.53	6.51	12.04	6.02	6.38	6.20	12.58	6.29
NC	7.57	7.17	14.74	7.37	7.43	7.44	14.87	7.44
SG	7.77	8.68	16.45	8.23	9.02	8.28	17.30	8.65
GG	8.34	9.21	17.55	8.78	8.14	7.73	15.87	7.94
KN	10.68	10.39	21.07	10.54	9.20	8.99	18.19	9.09

ryegrass (tops and roots) grown in Silwood soil of pH 5.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
4.78	4.45	9.23	4.62	6.84	5.00	11.84	5.92
4.92	3.87	8.79	4.40	6.54	5.86	12.40	6.20
5.01	4.86	9.87	4.94	3.96	4.47	8.43	4.22
4.01	3.89	7.90	3.95	4.77	4.31	9.08	4.54
4.22	4.91	9.13	4.57	5.35	4.06	9.41	4.71
6.06	5.80	11.86	5.93	5.30	5.81	11.11	5.56
7.31	5.19	12.50	6.25	4.89	4.97	9.86	4.93
5.15	4.40	9.55	4.78	6.87	6.38	13.25	6.63

Table 22.

Table 22. Total uptake of phosphate (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	4.93	5.65	10.58	5.29	5.84	5.93	11.77	5.89
FS	3.58	3.43	7.01	3.51	5.82	5.87	11.69	5.85
BD	5.65	5.37	11.02	5.51	7.17	6.89	14.06	7.03
PC	2.36	2.76	5.12	2.56	4.56	3.18	7.74	7.37
NC	4.54	4.71	9.25	4.63	6.08	4.89	10.97	5.49
SG	6.60	7.29	13.89	6.99	8.71	8.28	16.99	8.49
GG	6.32	7.22	13.54	6.77	7.83	8.20	16.03	8.01
KN	8.61	9.02	17.63	8.82	7.46	6.58	14.04	7.02

ryegrass (tops and roots) grown in Silwood soil of pH 6.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
4.07	3.19	7.26	3.63	4.10	3.67	7.77	3.89
7.86	6.01	13.87	6.94	6.54	6.32	12.86	6.43
9.91	9.75	19.66	9.83	5.80	5.09	10.89	5.45
3.88	3.35	7.23	3.62	3.43	3.07	6.49	3.25
4.62	4.86	9.48	4.74	5.27	5.87	11.14	5.52
6.58	5.77	12.35	6.18	5.71	7.05	12.76	6.38
5.36	7.71	13.07	6.54	6.24	6.76	13.00	6.50
5.13	6.18	11.31	5.66	8.63	9.47	18.10	9.05

Table 23.

Table 23. Total uptake of phosphate (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	4.67	5.73	10.40	5.20	9.29	7.54	16.83	8.42
FS	2.74	2.74	5.48	2.74	6.17	6.19	12.36	6.18
BD	5.31	6.55	11.86	5.93	9.72	7.35	17.07	8.54
PC	3.18	2.98	6.16	3.08	4.54	4.65	9.19	4.59
NC	4.84	5.63	10.47	5.24	7.96	7.82	15.78	7.89
SG	6.95	5.78	12.73	6.37	9.87	9.96	19.83	9.91
GG	6.84	4.47	11.31	5.66	9.44	6.63	16.07	8.04
KN	8.55	6.45	15.00	7.50	6.96	5.05	12.01	6.01

ryegrass (tops and roots) grown in Silwood soil of pH 7.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
3.94	3.44	7.38	3.69	5.14	3.67	8.81	4.41
3.87	3.49	7.36	3.68	5.22	4.22	9.44	4.72
6.63	5.92	12.55	6.28	4.98	5.91	10.89	5.45
3.39	3.97	7.36	3.68	3.88	3.38	7.26	3.63
4.92	5.00	9.92	4.96	5.21	4.93	10.14	5.07
5.61	4.46	10.07	5.04	4.42	6.98	11.40	5.70
5.42	5.64	11.06	5.53	5.82	5.72	11.54	5.77
5.00	4.82	9.83	4.91	7.73	6.78	14.51	7.26

Table 24.

Table 24. Total uptake of potassium (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	15.53	12.85	28.38	14.19	11.80	11.20	23.00	11.50
FS	26.00	28.66	54.66	27.33	13.63	13.26	26.89	13.45
BD	21.80	26.25	48.05	24.03	11.60	11.97	23.57	11.79
PC	20.39	21.50	41.89	20.95	11.11	9.48	20.59	10.30
NC	20.41	19.34	39.75	19.88	12.24	11.07	23.31	11.66
SG	23.66	25.28	48.94	24.47	13.72	12.56	26.28	13.14
GG	29.43	34.28	63.71	31.86	13.57	14.95	28.52	14.26
KN	48.14	47.65	95.79	47.90	22.70	19.93	42.63	21.32

ryegrass grown in Silwood soil of pH 5.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
7.46	6.57	14.03	7.02	5.31	5.49	10.80	5.40
11.78	11.60	23.38	11.69	11.90	12.71	24.61	12.31
9.10	9.08	18.18	9.09	4.95	5.45	10.40	5.20
7.83	7.27	15.10	7.55	6.36	4.91	11.27	5.64
8.67	9.77	18.44	9.22	6.28	5.41	11.69	5.90
9.89	8.90	18.79	9.40	6.20	6.06	12.26	6.13
10.40	9.76	20.16	10.08	4.75	4.83	9.58	4.79
10.98	9.08	20.06	10.03	8.20	7.85	16.05	8.03

Table25.

Table 25. Total uptake of potasium (in mgms) by soil of pH 6.2.

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	10.17	11.39	21.56	10.78	5.78	6.66	12.44	6.22
FS	15.92	19.64	35.66	17.78	16.30	14.72	31.02	15.51
BD	17.61	16.30	33.91	16.96	9.71	7.71	17.42	8.71
PC	9.06	9.88	18.94	9.47	7.16	5.87	13.03	6.52
NC	14.95	13.74	28.69	14.35	9.15	7.37	16.52	8.26
SG	17.80	18.81	36.61	18.31	9.75	9.30	19.05	9.53
GG	23.02	22.85	45.87	22.94	10.13	11.86	21.99	11.00
KN	33.99	34.70	67.69	33.85	14.92	12.57	27.49	12.75

perennial ryegrass (tops and roots) grown in Silwood

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
4.18	3.63	7.81	3.96	2.86	1.84	4.70	2.35
13.66	14.40	28.06	14.03	7.97	9.07	17.04	8.52
10.86	9.91	20.77	10.39	4.83	2.83	7.66	3.83
6.65	4.09	10.74	5.37	2.85	2.63	5.48	2.79
7.00	6.54	13.54	6.77	4.47	5.23	9.70	4.90
7.45	8.34	15.79	7.90	3.98	5.73	9.71	4.86
8.44	8.77	17.21	8.61	5.60	5.07	10.67	5.39
8.29	7.37	15.66	7.83	6.64	8.02	14.66	7.33

Table 26.

Table 26. Total uptake of potassium (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	13.34	11.01	24.35	12.18	8.39	6.95	15.34	7.67
FS	14.84	15.48	30.32	15.16	15.47	17.01	32.48	16.24
BD	12.37	20.46	39.83	19.92	12.88	10.26	23.14	11.57
PC	12.93	11.48	24.41	12.21	8.73	7.98	16.71	8.36
NC	15.64	18.38	34.02	17.01	10.20	10.43	20.63	10.32
SG	22.96	19.05	42.01	21.01	13.13	11.98	25.11	12.56
GG	27.62	18.30	45.92	22.96	15.74	12.82	28.56	14.28
KN	40.38	32.75	73.13	36.57	14.34	11.66	26.00	13.00

ryegrass (tops and roots) grown in Silwood soil of pH 7.2.

3rd Cutting				Root			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
4.76	3.20	7.96	3.98	3.57	1.54	5.11	2.56
13.01	11.28	24.29	12.15	8.09	6.05	14.14	7.07
11.80	8.65	20.45	10.23	2.63	3.12	5.75	2.88
6.17	6.30	12.47	6.24	2.05	2.15	4.20	2.10
8.33	7.25	15.58	7.79	2.37	3.43	5.80	2.90
6.85	7.31	14.16	7.08	2.14	4.89	7.03	3.52
7.86	10.36	18.22	9.11	3.24	5.24	9.48	4.59
6.99	7.27	14.26	7.13	3.22	3.95	7.17	3.59

Table 27.

Table 27. Total uptake of magnesium (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	1.17	1.36	2.53	1.27	2.69	2.72	5.41	2.71
FS	2.11	1.83	3.94	1.97	2.21	1.61	3.82	1.91
BD	1.52	1.93	3.45	1.73	2.74	3.04	5.78	2.89
PC	1.36	1.51	2.87	1.44	2.40	2.26	4.66	2.33
NC	1.44	1.63	3.07	1.54	2.71	2.61	5.32	2.66
SG	1.94	1.63	3.57	1.79	3.53	3.16	6.69	3.35
GG	2.20	2.43	4.63	2.32	1.95	1.83	3.78	1.89
KN	2.96	2.40	5.36	2.68	1.99	1.38	3.37	1.69

ryegrass (tops only) grown in Silwood soil of pH 5.2.

3rd Cutting				Root*			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
1.19	1.14	2.33	1.17				
1.87	1.69	3.56	1.78				
1.37	1.41	2.78	1.39				
1.12	0.94	2.06	1.03				
1.39	1.32	2.71	1.36				
1.66	1.38	3.04	1.52				
1.20	1.16	2.36	1.18				
1.03	0.94	1.97	1.49				

* negligible amounts found in roots.

Table 28.

Table 28. Total uptake of magnesium (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	1.88	2.00	3.88	1.94	1.78	1.31	3.09	1.55
FS	1.11	0.99	2.10	1.05	2.65	2.54	5.19	2.59
BD	2.41	2.11	4.52	2.26	2.95	2.77	5.72	2.86
PC	1.00	1.13	2.13	1.07	2.15	1.56	3.71	1.86
NC	2.02	3.71	5.73	2.87	3.98	2.28	6.26	3.13
SG	3.00	2.85	5.85	2.93	3.31	3.07	6.38	3.19
GG	2.62	2.49	5.11	2.56	2.86	2.96	5.82	2.91
KN	3.25	4.51	7.76	3.88	2.77	2.80	5.57	2.79

ryegrass (tops only) grown in Silwood soil of pH 6.2.

3rd Cutting				Root*			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
1.11	0.83	1.94	0.97				
2.14	2.03	4.17	2.09				
1.91	1.98	3.89	1.95				
1.22	0.94	2.16	1.08				
1.47	1.31	2.78	1.39				
1.30	1.53	2.83	1.42				
1.47	1.53	3.00	1.50				
1.13	1.19	2.32	1.16				

* negligible amounts found in root.

Table 29.

Table 29. Total uptake of magnesium (in mgms) by perennial

	1st Cutting				2nd Cutting			
	R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
Control	2.10	2.42	4.52	2.26	2.36	2.24	4.60	2.30
FS	1.15	0.96	2.11	1.06	3.13	3.05	6.18	3.09
BD	2.99	3.51	6.50	3.25	3.75	3.27	7.02	3.51
PC	1.77	1.32	3.09	1.55	4.39	3.83	8.22	4.11
NC	2.72	2.78	5.5o	2.75	3.57	3.75	7.32	3.66
SG	3.15	3.32	6.47	3.24	3.26	2.76	6.02	3.01
GG	3.16	1.89	5.05	2.53	4.15	2.65	6.80	3.40
KN	4.77	3.39	8.16	4.08	2.66	2.10	4.76	2.38

ryegrass (tops only) grown in Silwood soil of pH 7.2.

3rd Cutting				Root*			
R_I	R_{II}	Total	Mean	R_I	R_{II}	Total	Mean
1.43	1.18	2.61	1.31				
1.75	1.75	3.50	1.75				
2.81	2.37	5.18	2.59				
1.36	1.51	2.87	1.44				
1.74	1.74	3.48	1.74				
1.98	1.85	3.83	1.92				
1.65	1.82	3.47	1.74				
1.32	1.30	2.62	1.31				

*negligible amounts found in roots.

Table 30.

Table 30. Cumulative total uptake of N, P, Mg, K by

	Nitrogen			Phosphate		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	8.85	18.13	25.14	6.30	14.80	19.42
FS	9.70	17.77	26.71	6.25	12.09	16.49
BD	12.60	22.80	30.60	7.48	15.20	20.14
PC	9.98	18.59	24.92	6.02	12.31	16.26
NC	10.70	20.80	28.39	7.37	14.81	19.38
SG	12.20	22.30	29.67	8.23	16.88	22.81
GG	14.50	26.30	33.74	8.78	16.72	22.97
KN	23.20	37.10	43.50	10.50	19.60	24.38

perennial ryegrass grown in Silwood soil of pH 5.2. (in mgms).

Magnesium			Potassium		
1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
1.27	3.98	5.15	14.2	25.7	32.7
1.97	3.88	5.66	27.3	40.8	52.5
1.73	4.62	6.01	24.0	35.8	44.89
1.44	3.77	4.80	21.00	31.30	38.85
1.54	4.20	5.56	19.90	31.60	40.82
1.79	5.14	6.66	24.50	37.60	47.00
2.32	4.21	5.39	31.9	46.2	5.63
2.68	4.37	5.85	47.9	69.2	79.2

Table 31.

Table 31. Cumulative total uptake of N, P, Mg and K by

	Nitrogen			Phosphate		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	7.08	14.59	20.53	5.29	11.18	14.81
FS	6.46	17.36	29.46	3.51	9.36	16.30
BD	9.45	20.45	30.65	5.51	12.54	22.37
PC	4.57	10.35	16.37	2.56	6.43	10.05
NC	8.18	16.17	23.32	4.63	10.12	14.86
SG	11.60	23.60	31.60	6.95	15.45	21.63
GG	11.95	20.86	28.82	6.77	14.79	21.33
KN	17.00	24.63	31.17	8.82	15.84	21.50

perennial ryegrass grown in Silwood soil of pH 6.2

Magnesium			Potassium		
1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
1.94	3.49	4.96	10.80	17.00	20.96
1.05	3.65	5.74	17.80	33.30	47.30
2.26	5.12	7.07	17.00	25.71	36.11
1.07	2.93	4.01	9.50	16.02	21.39
2.87	6.00	7.39	14.40	22.66	29.43
2.93	6.12	7.54	18.30	27.83	35.73
2.56	5.47	6.97	22.90	33.90	42.51
3.88	6.67	7.83	33.90	46.20	54.03

Table 32.

Table 32. Cumulative total uptake of N, P, Mg and K by

	Nitrogen			Phosphate		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	9.66	18.01	23.53	5.20	13.61	17.30
FS	7.58	18.48	24.79	2.74	8.92	12.60
BD	15.7	31.8	42.8	5.93	14.47	20.75
PC	6.62	15.22	21.30	3.08	7.63	11.31
NC	11.70	26.14	34.48	5.24	13.13	18.09
SG	15.40	30.10	38.38	6.37	16.29	21.33
GG	11.90	24.60	31.88	5.66	13.70	19.23
KN	21.90	32.30	39.05	7.50	±13.51	18.42

perennial ryegrass (tops only) grown in Silwood soil of pH 7.2.

Magnesium			Potassium		
1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
2.26	4.56	5.87	12.20	19.87	23.85
1.06	4.15	5.90	15.20	31.44	43.64
3.25	6.76	9.35	19.90	31.50	41.70
1.55	5.66	7.10	12.20	20.56	26.80
2.75	6.41	8.15	17.00	27.30	35.09
3.24	6.25	8.17	21.00	33.60	40.68
2.53	5.93	7.67	23.00	37.30	46.41
4.08	6.46	7.77	36.60	49.60	56.73

Table 47.

Table 47. Total dry matter (tops only) yield (in gms) of

	pH 5.2			pH 6.2	
	R_I	R_{II}	Total	R_I	R_{II}
Control	2.034	2.127	4.161	1.960	2.014
FS + KN	2.274	2.197	4.471	2.441	2.409
BD	2.250	2.711	4.961	2.640	2.456
PC	2.246	2.141	4.387	1.636	1.494
NC	2.410	2.329	4.739	2.272	2.065
SG	2.501	2.589	5.090	2.568	2.682
GG	2.664	2.920	5.584	2.848	2.935
KN	3.556	3.301	6.857	3.445	3.404
Total	19.935	20.315	40.250	19.810	19.459

perennial ryegrass grown in Silwood soil of different pH.

		pH 7.2			Total	
Total	R_I	R_{II}	Total	R_I	R_{II}	Total
3.974	2.448	2.340	4.788	6.442	6.481	12.923
4.850	2.347	2.348	4.695	7.062	6.954	14.016
5.096	3.402	2.988	6.390	8.292	8.155	16.447
3.130	2.054	1.979	4.033	5.936	5.614	11.550
4.337	2.786	2.917	5.703	7.468	7.311	14.779
5.250	3.187	2.899	6.086	8.256	8.170	16.426
5.783	3.360	2.572	5.932	8.872	8.427	17.299
6.849	3.749	3.239	6.988	10.750	9.944	20.694
39.269	23.333	21.282	44.615	63.078	61.056	124.134

Tabel 48.

Table 48. Total dry matter yield (in gms) of roots of

	pH 5.2			pH 6.2	
	R_I	R_{II}	Total	R_I	R_{II}
Control	1.180	1.220	2.400	0.953	0.918
FS	1.676	1.629	3.305	1.594	1.620
BD	1.101	1.090	2.191	1.610	1.415
PC	1.326	1.198	2.524	0.949	0.877
NC	1.163	1.128	2.291	1.146	1.276
SG	1.292	1.262	2.554	1.328	1.469
GG	1.358	1.381	2.739	1.599	1.691
KN	1.908	1.636	3.544	2.214	2.429
Total	11.004	10.544	21.548	11.393	11.695

perennial ryegrass grown in Silwood soil of different pH.

		pH 7.2			Total	
Total	R_I	R_{II}	Total	R_I	R_{II}	Total
1.871	1.428	1.183	2.611	3.561	3.321	6.882
3.214	1.685	1.407	3.092	4.955	4.656	9.611
3.025	1.383	1.641	3.024	4.094	4.146	8.240
1.826	1.079	1.024	2.103	3.354	3.099	6.453
2.422	1.579	1.370	2.949	3.888	3.774	7.662
2.797	1.425	1.745	3.170	4.045	4.476	8.521
3.290	1.877	1.588	3.465	4.834	4.660	9.494
4.643	2.148	1.883	4.031	6.270	5.948	12.218
23.088	12.604	11.841	24.445	35.001	34.080	69.081

Table 48A.

Table 48A. Proportion of dry matter yield of top different pH, treated with fresh straw + KNO_3 and

Treat-ments	Soil pH 5.2			
	Top	Root	Ratio	Top
C	2.081	1.200	1.7	1.972
FS+KN	2.236	1.653	1.4	2.425
BD	2.481	1.100	2.3	2.548
PC	2.194	1.262	1.7	1.565
NC	2.370	1.146	2.1	2.169
SG	2.545	1.277	2.0	2.625
GG	2.792	1.370	2.0	2.892
KN	3.429	1.772	1.9	3.425
Mean			1.9	

and root of perennial ryegrass grown in Silwood soil of composts.

Soil pH 6.2		Soil pH 7.2			
Root	Ratio	Top	Root	Ratio	Average
0.936	2.1	2.394	1.306	1.8	1.9
1.607	1.5	2.348	1.546	1.5	1.5
1.513	1.7	3.195	1.512	2.1	2.0
0.913	1.7	2.017	1.052	1.9	1.8
1.211	1.8	2.852	1.475	1.9	1.9
1.399	1.9	3.043	1.585	1.9	1.9
1.645	1.8	2.966	1.733	1.7	1.8
2.322	1.5	3.494	2.016	1.7	1.7
	1.7			1.8	

Table 49.

Table 49. Total dry matter (tops and roots) yield of

	pH 5.2			pH 6.2	
	R_I	R_{II}	Total	R_I	R_{II}
Control	3.214	3.347	6.561	2.913	2.932
FS	3.950	3.826	7.776	4.035	4.029
BD	3.351	3.801	7.152	4.250	3.871
PC	3.572	3.339	6.911	2.585	2.371
NC	3.573	3.457	7.030	3.418	3.341
SG	3.793	3.851	7.644	3.896	4.151
GG	4.022	4.301	8.323	4.447	4.626
KN	5.464	4.937	10.401	5.659	5.833
Total	30.939	30.859	61.798	31.203	31.154

perennial ryegrass grown in Silwood soil of different pH.

		pH 7.2				Total
Total	R_I	R_{II}	Total	R_I	R_{II}	Total
5.845	3.876	3.523	7.399	10.003	9.802	19.805
8.064	4.032	3.755	7.787	12.017	11.610	23.627
8.121	4.785	4.629	9.414	12.386	12.301	24.687
4.956	3.133	3.003	6.136	9.290	8.713	18.003
6.759	4.365	4.287	8.652	11.356	11.085	22.441
8.047	4.612	4.644	9.256	12.301	12.646	24.947
9.073	5.237	4.160	9.397	13.706	13.087	26.793
11.492	5.897	5.122	11.019	17.020	15.892	32.912
62.367	35.937	33.123	69.060	98.079	95.136	193.215

Table 50.

Table 50. Total uptake of nitrogen (in mgms) by perennial with straw and different composts.

Treatments	Soil pH 5.2			Soil pH 6.2	
	R_1	R_2	Total	R_1	R_2
C	41.15	42.36	83.51	38.11	35.78
FS+KNO_3	46.46	49.21	95.67	54.83	59.26
BD	44.91	46.54	91.45	52.02	48.98
PC	38.65	48.63	87.28	30.35	30.26
NC	48.52	46.22	94.74	47.15	48.93
SG	50.46	44.80	95.26	50.42	51.59
GG	50.61	56.17	106.78	58.61	59.97
KN	72.35	66.34	138.69	57.20	62.91
Total	393.11	400.27	793.38	388.69	397.68

ryegrass grown in Silwood soil of different pH treated

Soil pH 7.2				Total		
Total	R_1	R_2	Total	R_1	R_2	Total
73.89	40.57	42.69	83.26	119.83	120.83	240.66
114.09	44.13	43.99	88.12	145.42	152.46	297.88
101.00	64.69	62.28	126.79	161.62	157.80	319.42
60.61	34.43	34.77	69.20	103.43	113.66	217.09
96.08	50.17	55.74	105.91	145.84	150.89	296.73
102.01	55.45	63.10	118.55	156.33	159.49	315.82
118.58	64.63	46.25	110.88	173.85	162.39	336.24
120.11	72.95	62.77	135.72	202.50	192.02	394.52
786.37	427.02	411.59	838.61	1208.82	1209.54	2418.36

Table 51.

Table 51. Total uptake of phosphate (in mgm) by perennial with straw and different composts.

Treatments	Soil pH 5.2			Soil pH 6.2	
	R_1	R_2	Total	R_1	R_2
C	26.83	23.83	50.66	18.94	18.44
FS + KN	23.37	21.95	45.32	23.80	21.63
BD	23.21	25.47	48.68	28.53	27.10
PC	20.69	20.91	41.60	14.22	12.36
NC	24.57	23.58	48.15	20.51	20.33
SG	28.15	28.57	56.72	27.60	28.39
GG	28.68	27.10	55.78	25.75	29.89
KN	31.90	30.16	62.06	29.83	31.25
Total	207.40	201.57	408.97	189.18	189.39

ryegrass grown in Silwood soil of different pH treated

Soil pH 7.2				Total		
Total	R_1	R_2	Total	R_1	R_2	Total
37.38	23.04	20.38	43.42	68.81	62.65	131.46
45.43	18.00	16.64	34.64	65.17	60.22	125.39
55.63	26.64	25.73	52.37	78.38	78.30	156.68
26.58	14.99	14.98	29.97	49.90	48.25	98.15
40.84	22.93	23.38	46.31	68.01	67.29	135.30
55.99	26.85	27.18	54.03	82.60	84.14	166.74
55.64	27.52	22.46	49.98	81.95	79.45	161.40
61.08	28.24	23.10	51.34	89.97	84.51	174.48
378.57	188.21	173.85	362.06	584.79	564.81	1149.60

Table 52.

Table 52. Total uptake of potassium (in mgms) by perennial different pH.

	pH 5.2			pH 6.2	
	R_I	R_{II}	Total	R_I	R_{II}
Control	40.1	36.1	76.2	23.0	23.5
FS	63.3	66.2	129.5	53.9	57.8
BD	47.5	52.8	100.2	43.0	36.8
PC	45.7	43.2	88.9	25.7	22.5
NC	47.6	45.6	93.2	35.6	32.9
SG	53.5	52.8	106.3	39.0	42.2
GG	58.2	63.8	122.0	47.2	48.6
KN	90.0	84.5	174.5	62.8	62.7
Total	445.8	445.0	890.8	330.2	326.8

ryegrass (tops and roots) grown in Silwood soil of

	pH 7.2			Total		
Total	R_I	R_{II}	Total	R_I	R_{II}	Total
46.5	30.1	22.7	52.8	93.2	82.3	175.5
111.7	51.4	49.8	101.2	168.6	173.9	342.5
79.8	46.7	42.5	89.2	137.1	132.0	269.1
48.2	30.0	27.9	57.8	101.3	93.5	194.8
68.5	36.5	39.5	76.0	119.7	118.0	237.7
81.2	45.1	43.2	88.3	137.5	138.2	275.7
95.7	55.2	46.7	101.9	160.5	159.1	319.6
125.5	64.9	55.6	120.6	217.8	202.8	420.6
657.0	359.7	328.0	687.7	1135.7	1099.8	2235.5

Table 53.

Table 53. Total uptake of magnesium (in mgm) by perennial different pH.

	pH 5.2			pH 6.2	
	R_I	R_{II}	Total	R_I	R_{II}
Control	5.05	5.22	10.27	4.77	4.14
FS	6.19	5.13	11.32	5.90	5.56
BD	5.63	6.38	12.01	7.27	6.86
PC	4.88	4.71	9.59	4.37	3.63
NC	5.54	5.56	11.10	7.47	7.30
SG	7.13	6.17	13.30	7.61	7.45
GG	5.35	5.42	10.77	6.95	6.98
KN	5.98	4.72	10.70	7.15	8.50
Total	45.75	43.31	89.06	51.49	50.42

ryegrass (tops and roots) grown in Silwood soil of

			pH 7.2			Total
Total	R_I	R_{II}	Total	R_I	R_{II}	Total
8.91	5.89	5.84	11.73	15.71	15.20	30.91
11.46	6.03	5.76	11.79	18.12	16.45	34.57
14.13	9.55	9.15	18.70	22.45	22.39	44.84
8.00	7.52	6.66	14.18	16.77	15.00	31.77
14.77	8.03	8.27	16.30	21.04	21.13	42.17
15.06	8.39	7.93	16.32	23.13	21.55	44.68
13.93	8.96	6.36	15.32	21.26	18.76	40.02
15.65	8.75	6.79	15.54	21.88	20.01	41.89
101.91	63.12	56.76	119.88	160.36	150.49	310.85

Table 54.

Table 54. Percentage recovery of N, P, K, Mg from fresh different pH.

Treatments	Percentage Recovery of applied Nitrogen (N)				Percentage Recovery of applied phosphate (P_2O_5)		
	pH 5.2	pH 6.2	pH 7.2	Mean	pH 5.2	pH 6.2	pH 7.2
FS+KN	9.4	31.2	3.8	14.8	-25.7	38.8	-42.2
BD	33.9	13.4	21.5	12.9	-7.9	73.0	35.8
PC	2.9	-10.7	-10.8	-6.2	-43.6	-51.9	-64.7
NC	7.7	15.2	15.5	12.8	-11.6	16.0	13.4
SG	5.0	12.1	15.2	10.8	4.4	13.5	7.7
GG	8.8	16.8	10.4	12.0	11.0	39.2	14.1
KN	110.4	92.5	104.9	102.6			
Mean	21.2	24.4	22.9		-12.2	21.4	-6.0

straw + KNO_3 and composts added to Silwood soil of

	Percentage Recovery of applied Potassium (K)				Percentage recovery of applied Magnesium (Mg)			
Mean	pH 5.2	pH 6.2	pH 7.2	Mean	pH 5.2	pH 6.2	pH 7.2	Mean
-9.7	24.5	29.9	22.2	25.5	7.5	18.4	0.43	8.8
33.6	60.0	83.2	91.1	78.1	11.9	35.9	48.0	31.9
-53.4	31.6	4.3	12.6	16.2	-4.9	-6.7	17.7	2.0
5.9	48.6	62.7	66.5	59.3	6.2	43.9	34.3	28.1
8.5	54.6	63.0	64.7	60.8	10.8	22.0	16.4	16.4
21.4	67.8	72.9	72.8	71.2	2.7	27.6	19.8	16.7
	71.2	57.2	49.1	59.2				
	51.2	53.3	54.1		5.7	23.5	22.8	

Table 55.

Table

	Total dry matter yield (tops)			Dry matter yield(roots)			Dry matter yield (tops + roots)		
	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2
Control	2	3	3	2	4	2	3	3	3
KNO_3	1	1	1	1	1	1	1	1	1
Straw + KNO_3	2	2	3	1	2	2	2	2	23
Nitrochalk compost	2	23	2	2	3	2	23	3	2
Control	4	4	3	23	4	4	4	4	3
Nitrochalk compost	34	4	2	23	3	34	34	4	2
Blood compost	23	23	12	3	2	234	34	23	2
Sludge compost	23	23	2	23	23	23	23	3	2
Grass compost	2	2	2	2	2	2	2	2	2
KNO_3	1	1	1	1	1	1	1	1	1

Explanation. Treatmats with common numbers are not significantly different. The magnitude of the treatment effect decreases with number.

52.

Total N uptake (tops + roots)			Total P uptake (Tops + roots)			Total K uptake (Tops + roots)			Total Mg uptake (tops + roots)		
Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2
2	3	3	2	3	2	4	4	4	1	3	2
1	1	1	1	1	1	1	1	1	1	1	1
2	1	3	2	2	23	2	2	2	1	2	2
2	2	2	2	23	12	3	3	3	1	1	1
3	3	4	23	2	3	5	5	5	23	2	3
23	2	3	3	2	23	4	4	4	123	1	2
23	2	12	3	1	12	34	34	3	12	1	1
23	2	123	1	1	1	3	3	34	1	1	2
2	1	23	2	1	12	2	2	2	23	1	2
1	1	1	1	1	12	1	1	1	23	1	2

CHAPTER V.

Effect of level of application of straw and blood compost on yields of and nutrient uptake by ryegrass in pot tests with a soil of varying pH.

(i) Introduction

(ii) Experimental

(iii) Results

(iv) Discussion

(v) Summary and Conclusions.

Introduction.

A study of the effect of varying levels of straw (plus extra nitrogen) and compost on the performance of ryegrass was considered worthwhile (a) to see whether high levels of these materials might be toxic to the plant, (b) to find the optimum level of application of these materials with regard both to plant performance and recovery of applied nutrients and (c) in the case of straw to determine the optimum ratio of straw to added extra inorganic nitrogen.

This study was started at the same time and run concurrently with that described in the previous chapter. In fact, the intermediate level of application of both materials was the same as that used in the work described in the previous chapter. This was done mainly to reduce the amount of work involved, but is useful in that results obtained in both studies may be compared.

Experimental.

This was as described in the previous chapter using the Silwood soil which had been adjusted to three pH levels. The straw and blood compost were each applied at the 0.5%, 1.0% and 2.0% levels. The inorganic nitrogen application was made as KNO_3 at the rate of 100 lb. nitrogen per acre to all three levels of straw. It was decided to do this rather than to apply the same ratio of straw to KNO_3 since it was considered that the latter type of treatmant would not be so helpful in indicating the optimum ratio of straw to added inorganic nitrogen for best plant performance. The treatments used were compared with a control and a KNO_3 (100 lb. N per acre) treatment at each pH level.

The treatments given are summarized below:

Treatment	Dose	Actual quantity applied per pot containing 500g soil.	Key
Control	-	-	C
Straw + KNO_3	0.5%	2.5g. straw + 25mg N	FS_I
Straw + KNO_3	1.0%	5g. straw + 25 " "	FS_{II}
Straw + KNO_3	2.0%	10g. straw + 25 " "	FS_{III}
Blood Compost	0.5%	2.5g.	BD_I
Blood Compost	1.0%	5.0g.	BD_{II}
Blood Compost	2.0%	10.0g.	BD_{III}
Potassium Nitrate	100 lbs. N/acre	25mg N	KN

Results.

The results obtained are presented in tables and diagrams a description of which is summarized below:

Dry matter yields of each of the three cuttings and roots are shown in:

Table 56 for pH 5.2

Table 57 for pH 6.2

Table 58 for pH 7.2

The nutrient percent in each cutting and roots at the three pH levels is shown in:

Table 59 for nitrogen

Table 60 for phosphorus

Table 61 for potassium

Table 62 for magnesium

The total uptake of nutrients in each cutting and roots at each pH level is shown in:

Table 63-65 for nitrogen

Table 66-68 for phosphorus

Table 69-71 for potassium

Table 72-74 for magnesium

The cumulative uptake of nutrients in the tops (i.e. in the 1st, 1st + 2nd and 1st + 2nd + 3rd cuttings) is shown in:

Table 75 for pH 5.2

Table 76 for pH 6.2

Table 77 for pH 7.2

These values were used to construct Figures 11, 12, 13 and 14 for nitrogen, phosphorus, potassium and magnesium respectively.

Figures 15-21 show, for each level of straw and for the controls and KNO_3 treatments, the comparative effects of pH on total top yields, root yields, top + root yields, and total uptake of nitrogen, phosphorus, potassium and magnesium. Figures 22-28 show the results for each level of blood compost treatment. All these values were derived from Table 78.

The percentage recovery of added nutrients by ryegrass for the four nutrients at each pH level is shown in Table 79.

In what follows it must be understood that when a "straw" treatment is mentioned, this refers in fact to straw + KNO_3.

Statistical significance of total dry matter yield and total uptake of N, P_2O_5, K, Mg for the different treatments included in this experiment has been summarised in Table 80.

Table 81 to 101 which contain statistical analysis are in the appendix.

Total top yields of ryegrass. (Table 78 and Figs. 15 and 22).

When results for the treatments were averaged over the three pH levels total top dry matter yields of ryegrass were in the order:

KN FS_I BD_{III} BD_{II} BD_I FS_{II} C FS_{III}

(As in the previous chapter the results are in decreasing order and treatments over a common line did not give significantly different results).

When individual pH levels are considered the order of yields was:

pH 5.2 KN BD_{II} FS_I BD_{III} BD_I FS_{II} C FS_{III}

pH 6.2 KN FS_I BD_{III} BD_{II} BD_I FS_{II} C FS_{III}

pH 7.2 BD_{III} FS_I KN BD_{II} BD_I C FS_{II} FS_{III}

The main differences due to pH are (a) KNO_3 gave significantly higher top yield than did all other treatments only at pH 5.2. At pH 6.2 and 7.2 the 2% blood compost and the 0.5% straw + KNO_3 treatments gave as high yields as did KNO_3 and (b) the 2% straw + KNO_3 treatment gave significantly lower yields than did the control only at pH 5.2.

When all treatments were averaged differences due to pH were:

pH 7.2 pH 6.2 pH 5.2

FIG. 15

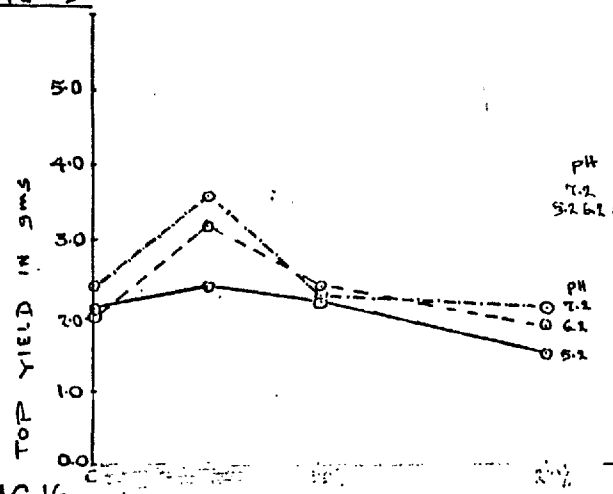


FIG. 22

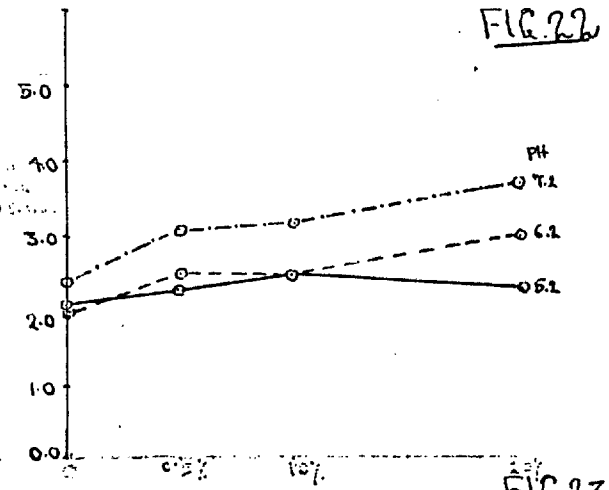


FIG. 16

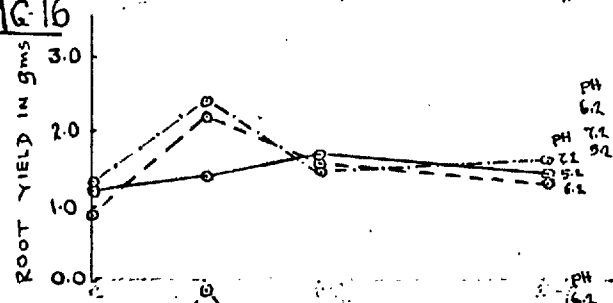


FIG. 23

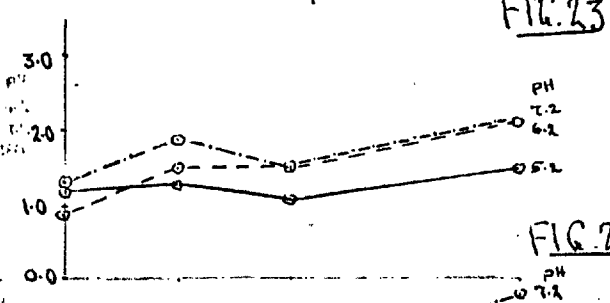


FIG. 17

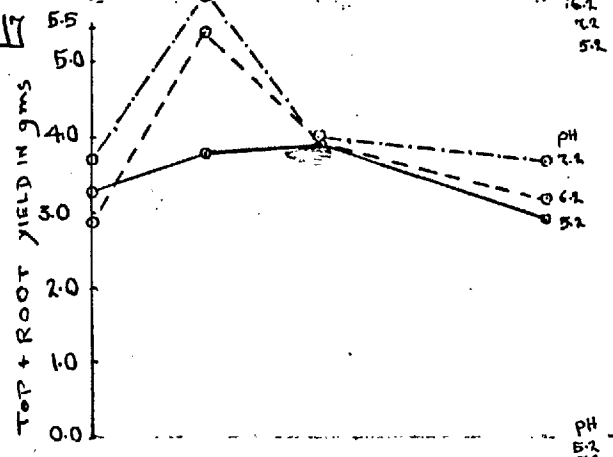


FIG. 2

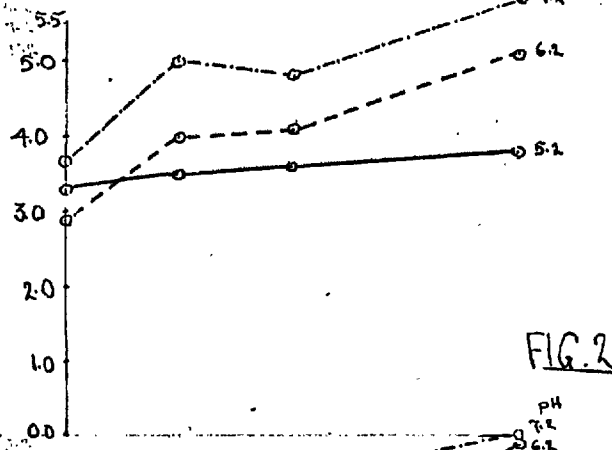


FIG. 18

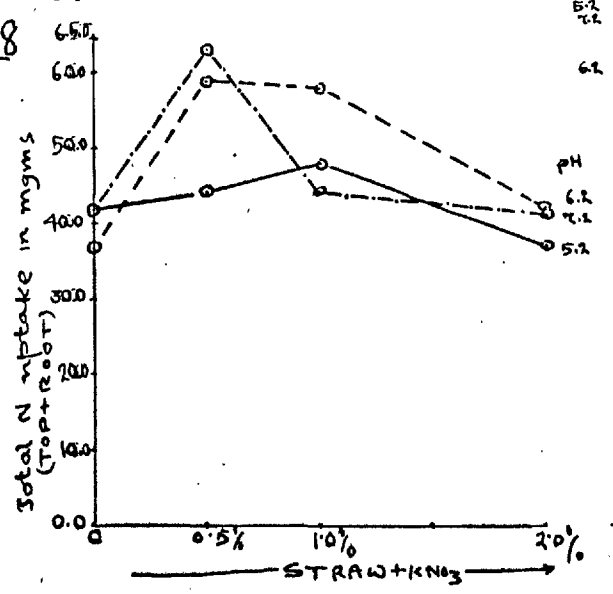
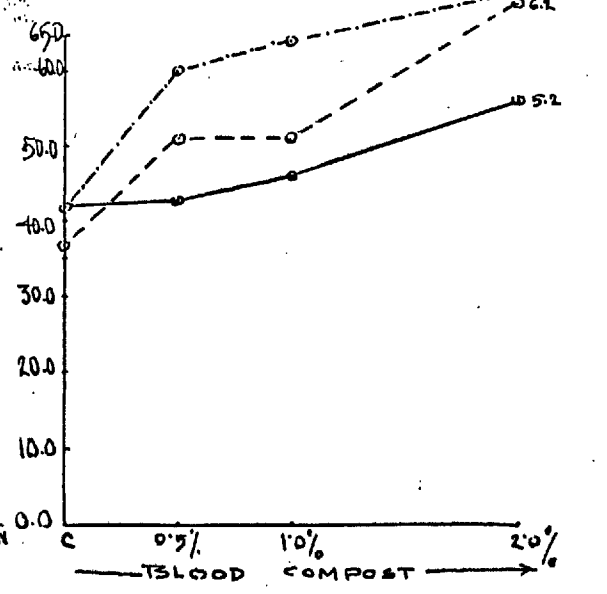


FIG. 25



Results due to individual treatments at each pH were:

C	pH 7.2	pH 5.2	pH 6.2
FS_I	pH 7.2	pH 6.2	pH 5.2
FS_{II}	pH 6.2	pH 7.2	pH 5.2
FS_{III}	pH 7.2	pH 6.2	pH 5.2
BD_I	pH 7.2	pH 6.2	pH 5.2
BD_{II}	pH 7.2	pH 6.2	pH 5.2
BD_{III}	pH 7.2	pH 6.2	pH 5.2
KN	pH 7.2	pH 5.2	pH 6.2

It is seen that with the straw treatments there were no significant differences in top yields between pH 7.2 and 6.2, whilst yields at pH 5.2 were usually lower than at pH 7.2; with the blood compost treatments top yield at pH 7.2 were always greater than at the two lower pH levels, with usually no significant differences between the two lower pH levels.

From Fig. 15 it is seen that the 0.5% straw level increased top yields in comparison with the control only at pH 6.2 and 7.2; the higher levels of straw either had no effect on or in the case of 2% straw at pH 5.2, reduced top yields. Increasing levels of blood compost had no effect on top yields (Fig. 22) at pH 5.2, whilst at the two higher pH levels yields increased with level of blood compost.

PLATE 5A.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments control (C) and potassium nitrate (KN-100 lbs. N/acre). is shown. Photograph was taken before the 1st cutting when the plants were 77 days old.


CONTROL
CONTROL
pH 6.2
CONTROL


KN
100 lbs N/A
pH-5.2
KN
pH 6.2
KN
100 lbs

Root yields of ryegrass. (Table 78 and Figs 16 and 23).

When results for the treatments were averaged over the three pH levels root dry matter yields were in the order:

KN FS_I BD_{III} FS_{II} BD_I FS_{III} BD_{II} C

At each pH level the order of root yields due to treatments were:

pH 5.2 KN FS_{II} BD_{III} FS_{III} FS_I BD_I C BD_{II}

pH 6.2 KN FS_I BD_{III} FS_{II} BD_I BD_{II} FS_{III} C

pH 7.2 FS_I BD_{III} KN BD_I FS_{III} FS_{II} BD_{II} C

The main differences due to pH were (a) the 0.5% straw level gave highest root yields only at pH 7.2; at pH 6.2 this treatment gave higher root yields than did the higher straw levels, whilst at pH 5.2 there were no differences in root yields due to level of straw and (b) the 2% blood compost gave higher root yields than did the lower levels of blood compost only at pH 6.2.

Differences due to pH when all treatments were averaged were:

pH 7.2 pH 6.2 pH 5.2

Differences due to pH with individual treatments are given on the next page.

PLATE 5B.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments - straw (FS-0.5%) and blood compost (BD-0.5%). is shown. Photograph was taken before the 1st cutting when the plants were 77 days old.


FS
pH 5.2 .5%
FS
pH 6.2 .5%
FS
pH 7.2 .5%


BD
pH 5.2 .5%
BD
pH 6.2 .5%
BD
pH 7.2 .5%

C	pH 7.2	pH 5.2	pH 6.2
FS_I	pH 7.2	pH 6.2	pH 5.2
FS_{II}	pH 5.2	pH 6.2	pH 7.2
FS_{III}	pH 7.2	pH 5.2	pH 6.2
BD_I	pH 7.2	pH 6.2	pH 5.2
BD_{II}	pH 7.2	pH 6.2	pH 6.2
BD_{III}	pH 7.2	pH 6.2	pH 5.2
KN	pH 6.2	pH 7.2	pH 5.2

The main differences due to treatment were (a) there were little differences in root yields due to pH with the straw treatments and (b) with the blood compost treatments yields were always lower at pH 5.2 than at the two higher pH levels.

The general pattern of response of root yields to increasing level of straw (Fig. 16) was similar to that of top yields, the main effect being that root yields were increased only with the 0.5% straw treatments, and then only at the two higher pH levels. With regard to level of blood compost (Fig. 23) only at pH 5.2 did root yields increase with level of this material. At the other two pH levels the 0.5% and 2% blood compost levels gave the highest yields.

Combined tops and root yields. (Table 78 and Figs. 17 and 24)

When treatment effects were averaged over the three pH

PLATE 5C.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments - straw (FS-1%) and blood compost (BD-1%). is shown.
Photograph was taken before 1st cutting when the plants were 77 days old.


FS
1%
FS
1%
FS
1%


BD
1%
BD
1%
BD
1%

levels the order of top + root yields was:

KN FS_I BD_{III} BD_I BD_{II} FS_{II} C FS_{III}

When the individual pH levels are considered the order was:

pH 5.2 KN FS_{II} FS_I BD_{III} BD_{II} BD_I C FS_{III}

pH 6.2 KN FS_I BD_{III} BD_{II} FS_{II} BD_I FS_{III} C

pH 7.2 FS_I BD_{III} KN BD_I BD_{II} FS_{II} FS_{III} C

The main differences due to pH were (a) KNO_3 gave the highest yields only at pH 5.2 and 6.2; at pH 7.2 0.5% straw gave higher yields than did KNO_3 and (b) 2% straw gave lower yields than did the control at pH 5.2, higher yields than the control at pH 6.2 and comparable yields at pH 7.2.

When the results of the treatments were averaged the differences due to pH were:

pH 7.2 pH 6.2 pH 5.2

When the individual treatments were compared at each pH level the order was:

C	pH 7.2	pH 5.2	pH 6.2
FS_I	pH 7.2	pH 6.2	pH 5.2
FS_{II}	pH 6.2	pH 7.2	pH 5.2
FS_{III}	pH 7.2	pH 6.2	pH 5.2
BD_I	pH 7.2	pH 6.2	pH 5.2
BD_{II}	pH 7.2	pH 6.2	pH 5.2
BD_{III}	PH 7.2	pH 6.2	pH 5.2
KN	pH 6.2	pH 7.2	pH 5.2

PLATE 5D.

Comparative growth of perennial ryegrass grown in Silwood soil of 3 pH levels in the treatments - straw (FS-2%) and blood compost (BD-2%). is shown.


FS
2%
PH 5.2
FS
2%
PH 6.2
FS
2%
PH 7.2


BD
2%
PH 5.2
BD
2%
PH 6.2
BD
2%
PH 7.2

The highest yields of tops + roots in nearly every case occurred at pH 7.2, although with the 1% straw and KNO_3 treatment yields were not significantly poorer at pH 6.2 than at pH 7.2. With the blood compost treatments yields were always lowest at pH 5.2.

The general pattern of response of top + root yields to increasing level of straw application (Fig. 17) was similar to that for top yields, viz. increased yields in comparison with the controls only with the 0.5% straw level and then only at pH 6.2 and 7.2; also, reduced yield in comparison with the control at pH 5.2 with the 2% straw treatment. With regard to increasing levels of blood compost (Fig. 24) yields were barely increased at pH 5.2, but at pH 6.2 and 7.2 yields increased with level of application, although there was little differences in yields between the 0.5% and 1.0% levels.

Uptake of nitrogen. (Figs. 11, 18 and 25).

The cumulative uptake of nitrogen in the three cuttings of ryegrass is shown in Fig. 11 for the three pH levels. At pH 5.2 most of the cumulative uptake curves tended to be more or less parallel to each other. The exceptions were the 1% and 2% straw treatments which resulted in an almost linear relationship between nitrogen uptake and cuttings whereas the other treatments, including the control

FIG-1

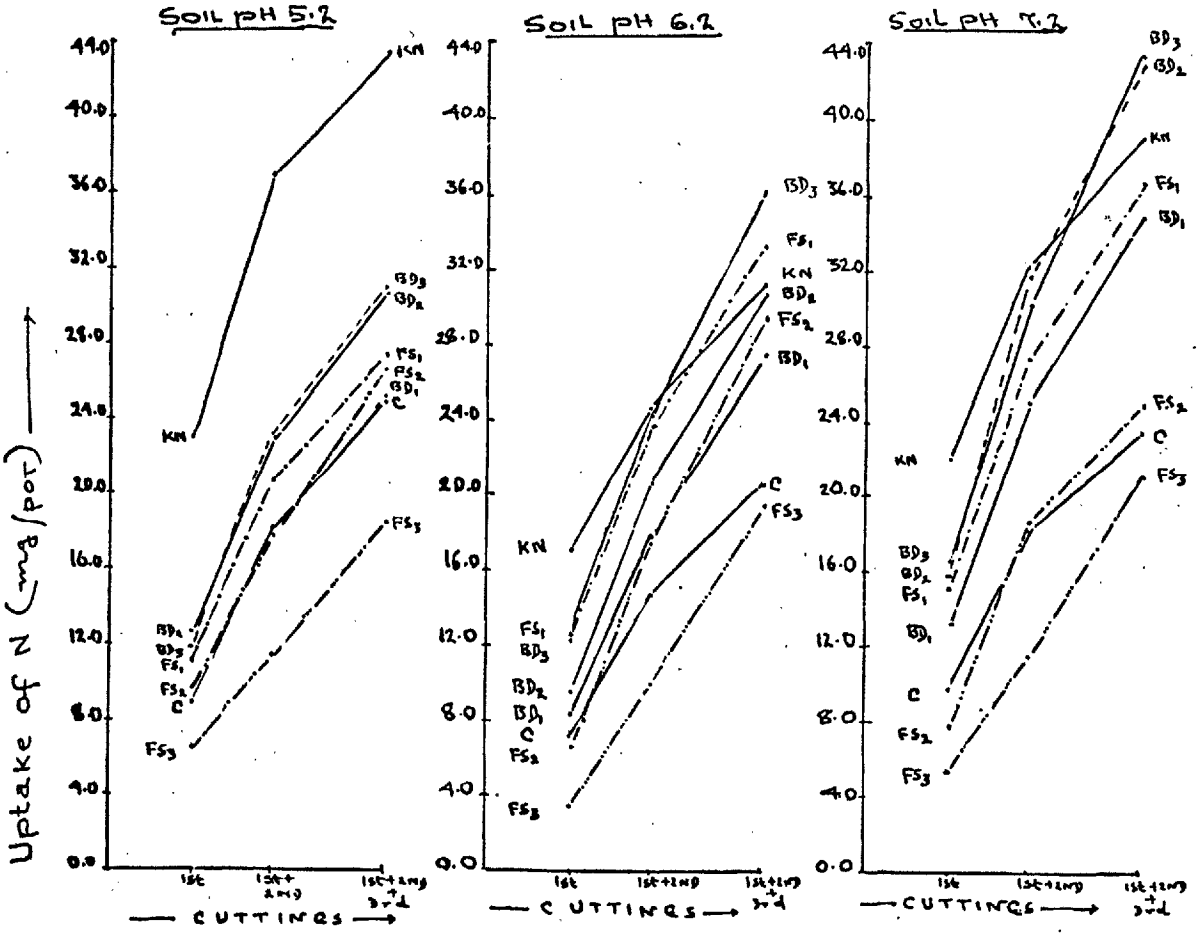
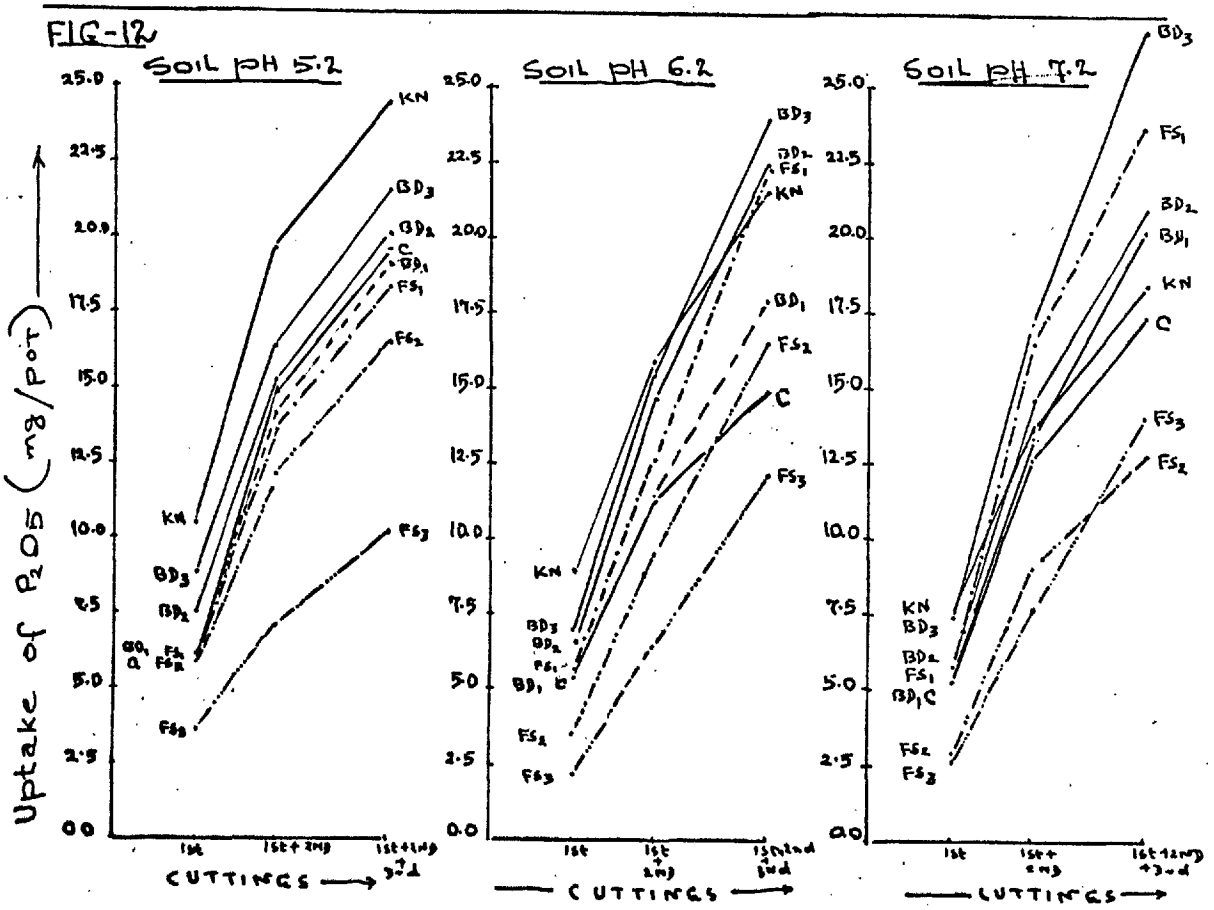

Soil pH 5.2
Soil pH 6.2
Soil pH 7.2
Uptake of N (mg/pot)
CUTTINGS
1st
1st+2nd
1st+2nd+3rd
KN
BD3
BD2
BD1
FS1
FS2
FS3
C

FIG-12


Soil pH 5.2
Soil pH 6.2
Soil pH 7.2
Uptake of P2O5 (mg/pot)
CUTTINGS
1st
1st+2nd
1st+2nd+3rd
KN
BD3
BD2
BD1
FS1
FS2
FS3
C

resulted in proportionately less nitrogen uptake with successive cuttings. At pH 6.2 all the straw and blood compost levels resulted in an almost linear uptake of nitrogen with successive cuttings, in contrast with the control and KNO_3 treatment, where uptake fell off with successive cuttings. At pH 6.2 there was also a very definite tendency for the two higher straw levels to cause an initial lag in nitrogen uptake, so that proportionate uptake was greater after the first cutting. At pH 7.2 only the 2% straw and 2% blood compost treatments tended to show a linear uptake of nitrogen with successive treatments.

The decreasing order of total nitrogen uptake (by combined tops and roots) due to treatments is shown below when the results were averaged over the three pH levels:

KN BD_{III} FS_I BD_{II} BD_I FS_{II} C FS_{III}

At the individual pH levels total nitrogen uptake decreased in the order:

pH 5.2 KN BD_{III} FS_{II} BD_{II} FS_I BD_I C FS_{III}

pH 6.2 BD_{III} KN FS_I FS_{II} BD_I BD_{II} FS_{III} C

pH 7.2 BD_{III} KN BD_{II} FS_I BD_I FS_{II} C FS_{III}

The main differences due to pH were (a) KNO_3 gave highest nitrogen uptake only at pH 5.2 (b) at pH 6.2 2%

PLATE 6.

Growth of perennial ryegrass in Silwood soil of 3 pH levels in the treatments - control (C), straw (FS) and blood compost (BD) at 0.5%, 1% and 2% level. is shown. Photograph was taken beforethe 3rd cutting when the plants were 105. days old after 2nd cutting.


CONTROL
pH 5?
FS
BD
FS
BD
FS
BD


CONTROL
pH 6?
FS
BD
FS
BD
FS
BD


CONTROL
pH 7?
FS
BD
FS
BD
FS
BD

blood compost was as effective as KNO_3, whilst all treatments except 2% straw were as effective as KNO_3 and (c) at pH 7.2 all treatments except the two higher straw levels were equally effective in increasing total nitrogen uptake.

The effect of pH when all treatments were averaged was:

pH 7.2 pH 6.2 pH 5.2

The effect of pH for the individual treatments were:

C	pH 5.2	pH 7.2	pH 6.2
FS_I	pH 7.2	pH 6.2	pH 5.2
FS_{II}	pH 6.2	pH 5.2	pH 7.2
FS_{III}	pH 6.2	pH 7.2	pH 5.2
BD_I	pH 7.2	pH 6.2	pH 5.2
BD_{II}	pH 7.2	pH 6.2	pH 5.2
BD_{III}	pH 6.2	pH 7.2	pH 5.2
KN	pH 5.2	pH 7.2	pH 6.2

The main differences due to treatment were (a) there were no significant differences due to pH in total nitrogen uptake with the control, 2% straw and KNO_3 treatments, (b) the 0.5% straw and 2% blood compost treatments resulted in the lowest nitrogen uptake at pH 5.2 and (c) the 0.5 and 2% blood compost treatments resulted in reduced total nitrogen uptake with decreasing pH, although differences

were not always significant.

The general pattern of response of total nitrogen uptake to increasing level of application of straw (Fig. 18) was similar to that obtained with total dry matter yields (cf. Fig. 17), except that at pH 6.2 total nitrogen uptake was similar between the 0.5% and the 1% straw treatments whereas dry matter yields were lower with the latter treatment. The pattern of response in total nitrogen uptake to increasing level of application of blood compost (Fig. 25) was also similar to that for total dry matter yields (cf. Fig. 24); nitrogen uptake increased with level of application of blood compost and it was only at pH 6.2 that nitrogen uptake at the 2% level of compost was significantly greater than at the lower levels of compost.

Uptake of phosphorus. (Figs. 12, 19 and 26)

The cumulative uptake of phosphorus in successive cuttings of ryegrass at each of the three pH levels is shown in Fig. 12. At pH 5.2 the phosphorus uptake curves tended to be parallel, except for the two higher levels of straw, where phosphorus uptake with successive cuttings decreased proportionately at a greater rate than did those with the other treatments. At pH 6.2 the control and KNO_3 treatment showed decreasing phosphorus uptake with successive cuttings; except for the two higher levels of

all other treatments showed linear uptake with successive cuttings, except for the two higher levels of straw which showed relatively poor uptake of phosphorus in the first cutting. At pH 7.2 the two higher levels of straw again caused relatively poor phosphorus uptake in the first compared with the later cuttings. The 2% blood compost treatment showed linear uptake of phosphorus with successive cuttings, whilst the other treatments showed relatively poor phosphorus uptake in the final cutting compared with that in the previous cutting.

The total phosphorus uptake (combined cuttings and roots) due to treatments averaged over the three pH levels decreased in the order:

BD_{III} KN FS_I BD_{II} BD_I C FS_{II} FS_{III}

Phosphorus uptake at each pH level decreased in the order:

pH 5.2 KN BD_{III} C BD_{II} BD_I FS_I FS_{II} FS_{III}

pH 6.2 BD_{III} KN FS_I BD_{II} BD_I FS_{II} FS_{III} C

pH 7.2 BD_{III} FS_I BD_I BD_{III} KN C FS_{III} FS_{II}

The main differences due to pH were (a) the significantly lower total phosphorus uptake with the 2% straw treatment than from the control which occurred only at pH 5.2,

(b) the 0.5% straw treatment was one of the most effective in increasing total phosphorus at pH 6.2 and 7.2 but not at pH 5.2 and (c) the KNO_3 treatment was more effective than 2% blood compost at pH 5.2, but the reverse was true at pH 7.2.

Differences in total phosphorus uptake due to pH averaged for all treatments were:

pH 6.2 pH 7.2 pH 5.2

For the individual treatments differences due to pH were:

C	pH 5.2	pH 7.2	pH 6.2
FS_I	pH 7.2	pH 6.2	pH 5.2
FS_{II}	pH 5.2	pH 6.2	pH 7.2
FS_{III}	pH 6.2	pH 7.2	pH 5.2
BD_I	pH 7.2	pH 6.2	pH 5.2
BD_{II}	pH 6.2	pH 7.2	pH 5.2
BD_{III}	pH 7.2	pH 6.2	pH 5.2
KN	pH 5.2	pH 6.2	pH 7.2

The main differences due to treatment were (a) with 1% straw the lowest phosphorus uptake occurred at pH 7.2, whilst with the two other levels of straw lowest phosphorus uptake occurred at pH 5.2 and (b) the blood compost treatment usually showed the lowest phosphorus uptake at pH 5.2, although differences due to pH were not always significant.

The general effect of increasing level of straw

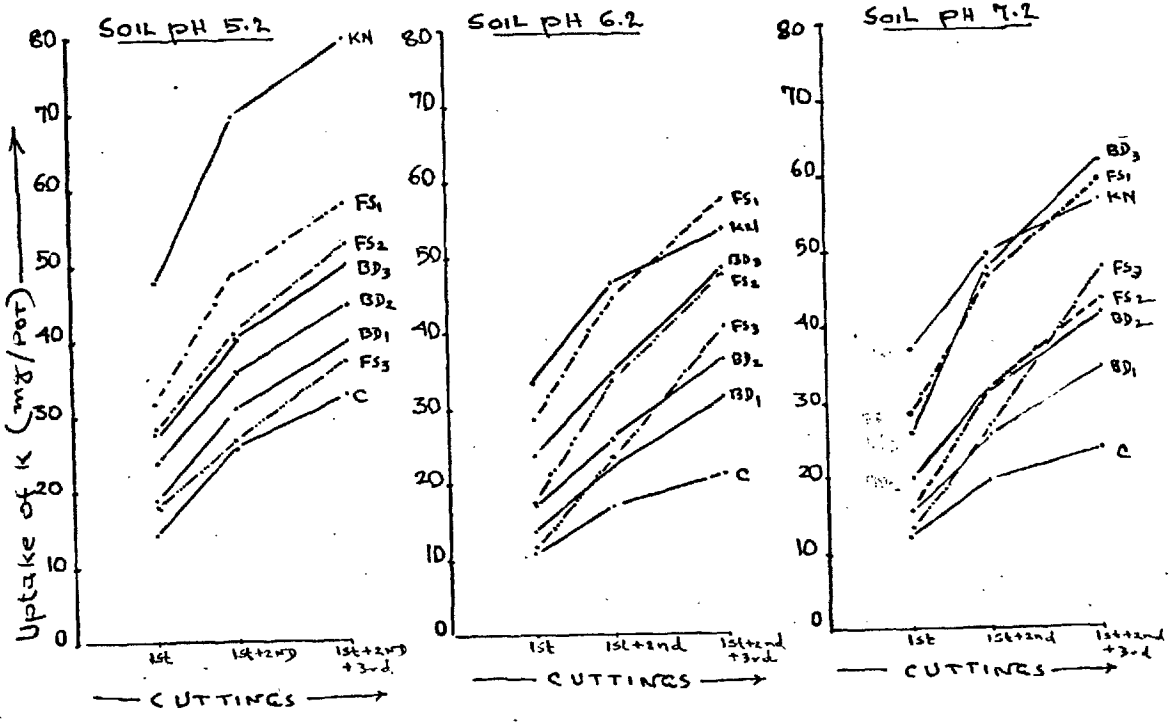
application on total phosphorus uptake (Fig. 19) was similar to that on total dry matter yields (cf. Fig. 17) in that maximum uptake occurred with the 0.5% straw level and then only at pH 6.2 and 7.2. However the magnitude of the differences in phosphorus uptake due to level of added straw was much less than in dry matter yields. Increasing the level of added blood compost had no significant effect on total phosphorus uptake at pH 5.2 (Fig. 26) but resulted in slightly increased uptake at the two higher pH levels; however, there were no significant differences between the 0.5% and 1.0% blood compost levels.

Uptake of potassium. (Figs. 13, 20 and 27)

It must be borne in mind that all "straw treatments" included application of potassium as KNO_3.

The cumulative uptake of potassium in the three cuttings of ryegrass at the three pH levels is shown in Fig. 13. At pH 5.2 after the first cutting all the uptake curves tended to parallel each other. At pH 6.2 the proportionate uptake of potassium in the final cutting due to the blood compost treatments was greater than for the control or KNO_3 treatment. The straw treatments, particularly the highest level showed proportionately the greatest uptake of potassium in the second cutting, but maintained this difference into the final cutting. At pH 7.2 results were

FIG 13


Soil pH 5.2
Soil pH 6.2
Soil pH 7.2
Uptake of K (mg/pot)
0
10
20
30
40
50
60
70
80
KN
FS1
FS2
BD3
BD2
BD1
FS3
C
1st
1st+2nd
1st+2nd +3rd
CUTTINGS

similar to those at pH 6.2, except that with the 2% straw treatmant the uptake of potassium was proportionately even greater in the final cutting.

The total potassium uptake (combined cuttings and roots) due to treatments averaged over the three pH levels decreased in the order:

KN FS_I BD_{III} FS_{II} FS_{III} BD_{II} BD_I C

At the individual pH levels the orders were:

pH 5.2 KN FS_I FS_{II} BD_{III} BD_{II} FS_{III} BD_I C

pH 6.2 FS_I KN FS_{II} BD_{III} FS_{III} BD_{II} BD_I C

pH 7.2 FS_I BD_{III} KN FS_{III} FS_{II} BD_{II} BD_I C

The main differences due to pH were (a) at pH 5.2 total potassium uptake was significantly lower with 0.5% straw than with KNO_3, but this was not so at the two higher pH levels and (b) potassium uptake with 2% blood compost was comparable with that with 0.5% straw only at pH 5.2 and 7.2.

The order of total potassium uptake due to pH averaged over all the treatments was:

pH 5.2 pH 7.2 pH 6.2

With the individual treatments the orders were: (see next page)

FIG. 19

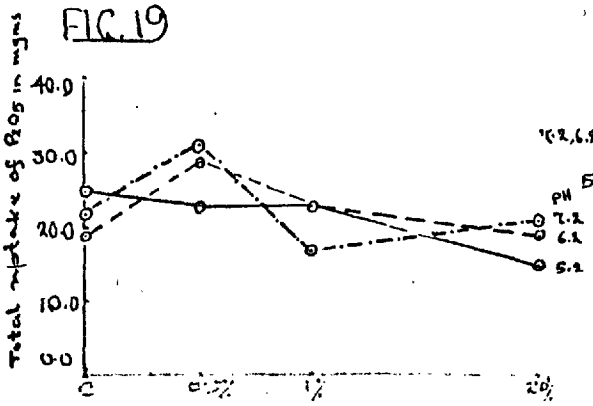
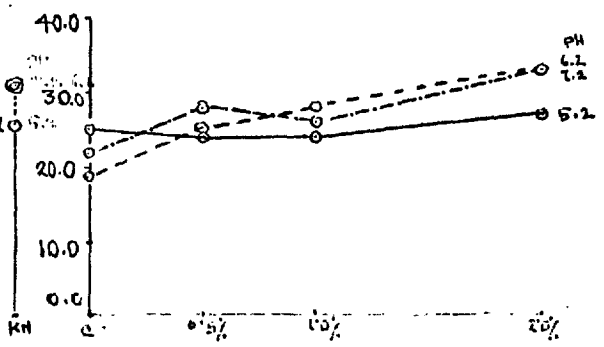


FIG. 26



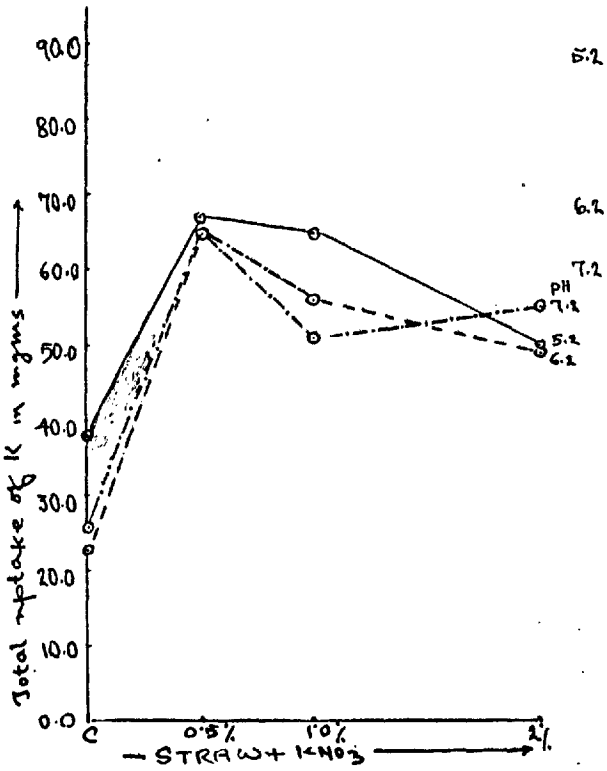


FIG. 20

FIG. 27

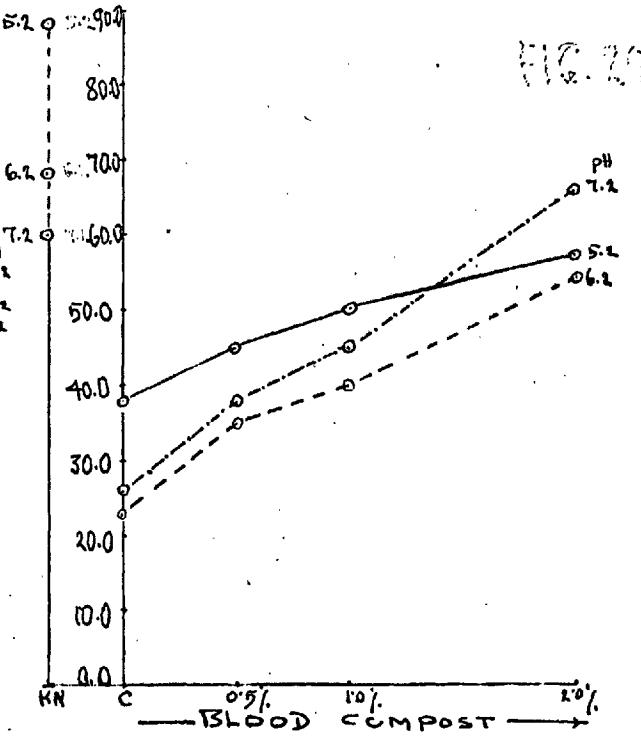


FIG. 27

C	pH 5.2	pH 7.2	pH 6.2
FS_I	pH 5.2	pH 7.2	pH 6.2
FS_{II}	pH 5.2	pH 6.2	pH 7.2
FS_{III}	pH 7.2	pH 6.2	pH 5.2
BD_I	pH 5.2	pH 7.2	pH 6.2
BD_{II}	pH 5.2	pH 7.2	pH 6.2
BD_{III}	pH 7.2	pH 5.2	pH 6.2
KN	pH 5.2	pH 6.2	pH 7.2

The main differences due to treatment were (a) with the lowest level of both organic materials there were no differences in total potassium uptake due to pH; this applied also with the 2% straw application and (b) the 1% and 2% blood compost treatments resulted in the lowest total potassium uptake at pH 6.2.

Increasing the level of straw application resulted in optimum uptake of total potassium with the 0.5% straw level at all pH values (Fig. 20). Potassium uptake decreased with further increasing level of straw, but even with the 2% straw level uptake was still greater than with the control. Increasing the level of application of blood compost (Fig. 27) resulted in almost linear increase in uptake of total potassium at all pH levels. The extent of increase was, however, less at pH 5.2 than at the two other pH levels.

Uptake of magnesium. (Figs. 14, 21 and 28)

The cumulative uptake of magnesium in the three cuttings at the three pH levels is shown in Fig. 14. At pH 5.2 the main effect due to treatment was that all treatments except the 2% straw level showed reduced uptake of magnesium with successive cuttings after the first. At pH 6.2 the control and KNO_3 treatment showed proportionately greater reduction in magnesium uptake in the final cutting than did the other treatments. At pH 7.2 all the straw treatments showed proportionately reduced magnesium uptake in the final cutting compared with the other treatments.

The total magnesium uptake (combined cuttings and roots) averaged over the three pH levels decreased in the order:

BD_{III} BD_{II} FS_I KN BD_I FS_{II} C FS_{III}

At the individual pH levels the orders were:

pH 5.2 BD_{III} BD_{II} FS_{II} BD_I FS_I KN C FS_{III}

pH 6.2 BD_{III} KN BD_{II} FS_I BD_I FS_{II} C FS_{III}

pH 7.2 BD_{III} FS_I BD_{II} KN BD_I FS_{II} C FS_{III}

The main differences due to pH were (a) at pH 5.2 there were no significant differences in total magnesium uptake between any of the treatments with the exception of 2% straw where magnesium uptake was lower than with the other treatments and (b) magnesium uptake due to 2% blood compost was

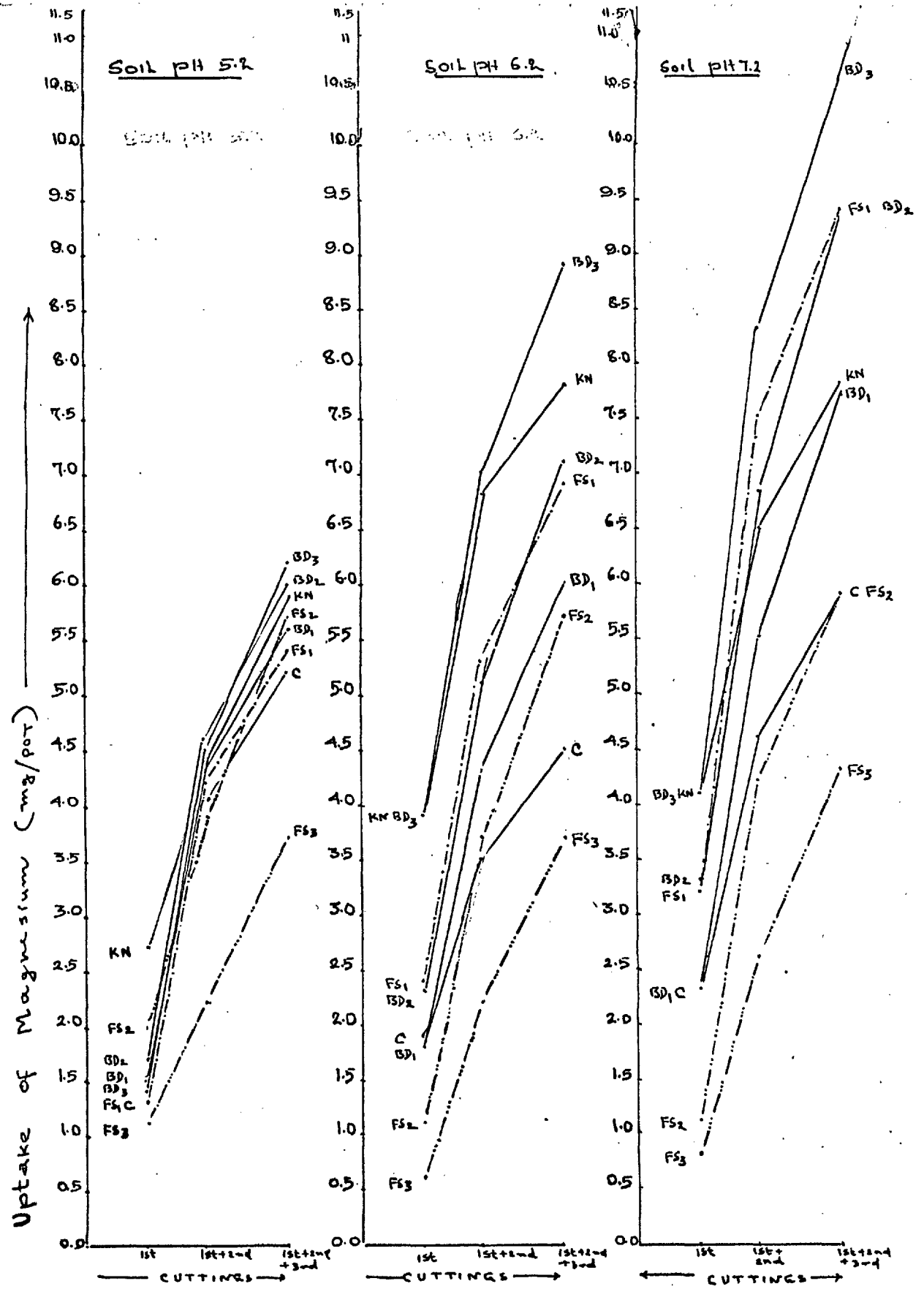

Soil pH 5.2
Soil pH 6.2
Soil pH 7.2
Uptake of Magnesium (mg/pot)
CUTTINGS
1st
1st+2nd
1st+2nd+3rd
KN
FS2
BD2
BD1
BD3
FS1 C
FS3
BD3
BD2
KN
FS2
BD1
FS1
C
FS3
KN BD3
FS1 BD2
C BD1
FS2
FS3
BD3
FS1 BD2
KN
BD1
C FS2
FS3
BD3 KN
BD2 FS1
BD1 C
FS2
FS3

FIG 14

significantly higher than that due to all other treatments only at pH 7;2.

The order of magnesium uptake due to pH averaged over all treatments was:

pH 7.2 pH 6.2 pH 5.2

For the individual treatments the orders were:

C	pH 7.2	pH 5.2	pH 6.2
FS_I	pH 7.2	pH 6.2	pH 5.2
FS_{II}	pH 7.2	pH 6.2	pH 5.2
FS_{III}	pH 7.2	pH 6.2	pH 5.2
BD_I	pH 7.2	pH 6.2	pH 5.2
BD_{II}	pH 7.2	pH 6.2	pH 5.2
BD_{III}	pH 7.2	pH 6.2	pH 5.2
KN	pH 6.2	pH 7.2	pH 5.2

The main differences due to treatment were (a) total magnesium uptake was significantly higher at pH 7.2 than at the two lower pH levels with all levels of blood compost and (b) with the straw treatments magnesium uptake was significantly higher at pH 7.2 than at the two lower pH levels only with the lowest level of straw.

With increasing level of application of straw optimum uptake of magnesium occurred at the 0.5% level at pH 6.2 and 7.2 (Fig. 21). The higher levels of application resulted in reduced uptake. Uptake of magnesium was not

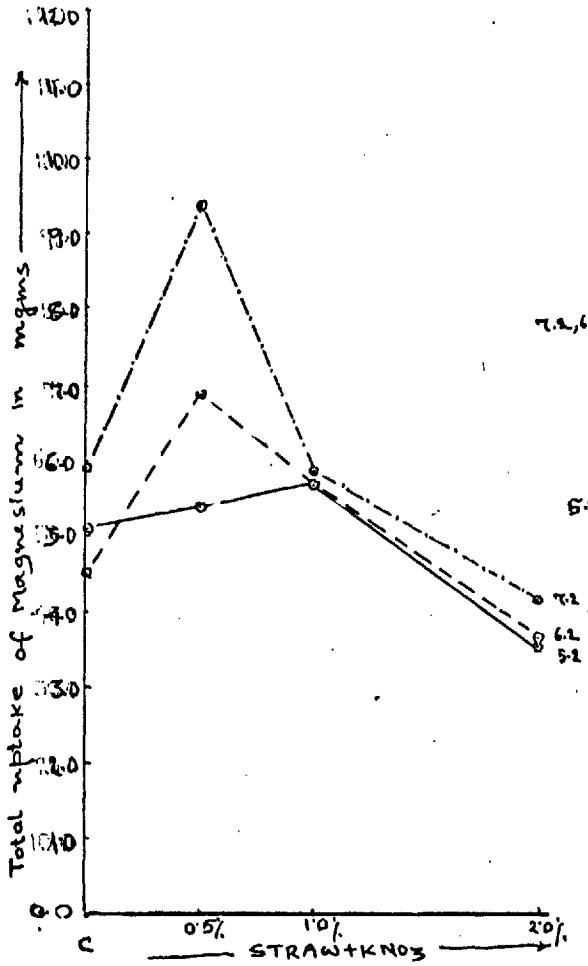

Total uptake of Magnesium in mgms
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
7.2
6.2
5.2
C
0.5%
1.0%
2.0%
STRAW+KNO3

FIG. 21

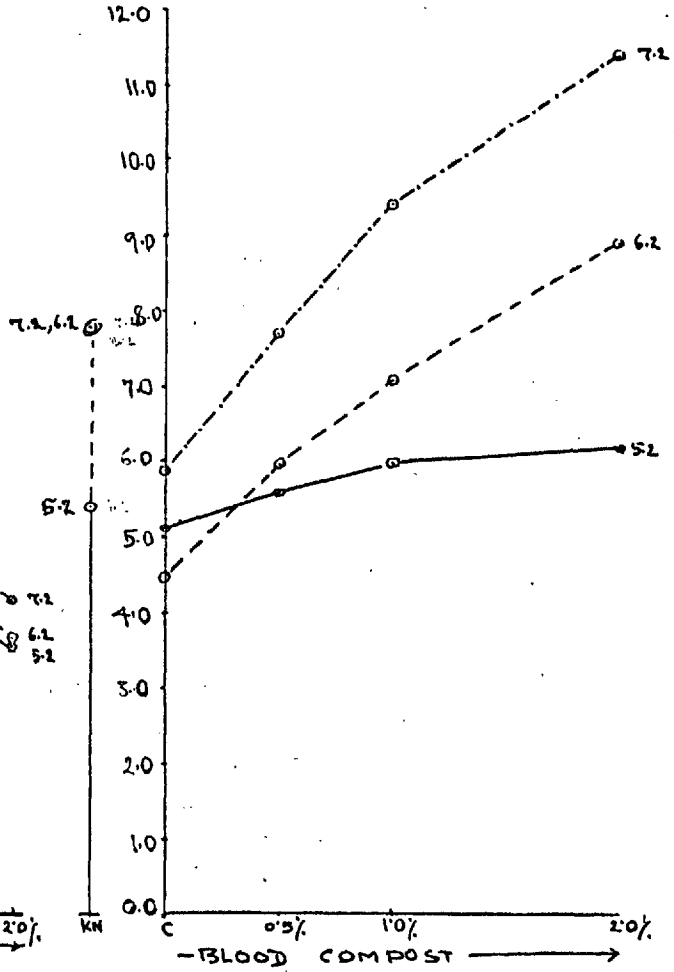

12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
7.2
6.2
5.2
7.2, 6.2
5.2
KN
C
0.5%
1.0%
2.0%
BLOOD COMPOST

FIG. 28

significantly affected by increasing level of application of blood compost (Fig. 28) at pH 5.2, but at pH 6.2 and 7.2 there was an almost linear increase with rate of application of blood compost.

Top/root dry matter ratios. (Table 78)

The most consistent effect to be noted with regard to top/root dry matter ratios was that the lowest ratio was obtained with the 2% straw treatment at all three pH levels. The highest top/root ratio was obtained with 1% blood compost treatment at pH 5.2 and 7.2 and with the control at pH 6.2. There were no great differences in top/root ratio among the other treatments at any pH.

Percentage recovery of applied nitrogen. (Table 79)

The percentage recovery of applied nitrogen from the various treatments (obtained by subtracting the total nitrogen taken up in control pots from that taken up in treated pots and expressing the result as a percentage of the nitrogen applied) is shown in the first three columns of Table 79 for soils of pH 5.2, 6.2 and 7.2. Negative values indicate that not only was none of the applied nitrogen recovered, but that the treatment resulted in immobilization of some of the native soil nitrogen.

With the straw treatments recovery of applied nitrogen at pH 5.2 was low with all levels of straw and was in fact

negative at the highest level. At pH 6.2 about half the applied nitrogen was recovered with the 0.5% straw level, about one-third with the 1% straw level and a negligible amount with the 2% straw level. At pH 7.2 again about half the applied nitrogen was recovered with the 0.5% straw level, but negligible amounts were recovered with the two higher levels.

The differences in recovery of applied nitrogen between the KNO_3 treatments and the straw + KNO_3 treatments indicates the extent to which the applied nitrate-nitrogen has been immobilized by the straw. Thus at pH 5.2 all the applied nitrate-nitrogen was immobilized by the 0.5% and 1.0% straw levels, whilst with the 2% straw level all the applied nitrate-nitrogen and in addition some of the native soil nitrogen was immobilized.

With the blood compost treatments at pH 5.2 there was only slight recovery of applied nitrogen with all three levels of compost. At pH 6.2 about one-third of the applied nitrogen was recovered from the 0.5% compost level, about one-seventh from the 1% and about one-sixth from the 2% compost level. At pH 7.2 results were similar to those at pH 6.2 except that recovery of nitrogen was somewhat higher with the 1% compost level.

Percentage recovery of applied phosphorus. (Table 79)

With the straw treatments there were great differences

in recovery of applied phosphorus due to both pH and level of straw. The general effect due to pH was that recovery was higher at pH 6.2 than at pH 5.2 and 7.2. The differences due to pH were particularly great with the 0.5% straw level; at pH 5.2 there was a fair amount of phosphorus immobilization, at pH 6.2 all the applied phosphorus was recovered and in addition an amount of native soil phosphorus equal to that applied, whilst at pH 7.2 all the applied phosphorus and an amount of native phosphorus almost equal to that applied was recovered. With increasing straw level there was still immobilization of native phosphorus at the two higher straw levels at pH 5.2; at pH 6.2 phosphorus recovery decreased rapidly with increasing level of straw and was negligible with the 2% straw treatment; at pH 7.2 phosphorus recovery also decreased rapidly with increasing level of straw with a fair amount of immobilization occurring with the 1% and a slight amount with the 2% straw level.

Withe the blood compost treatments there were not such great differences in phosphorus recovery due to pH and compost level as with the straw treatments. The effects of the treatments were usually similar to those of straw, viz. with higher phosphorus recovery occurring at pH 6.2 than at pH 5.2 or 7.2 and with phosphorus recovery except at pH 5.2

usually decreasing with increasing level of compost. At pH 5.2 there was more immobilization due to the 0.5% than the 1% compost level, whilst there was some recovery of applied phosphorus with the 2% compost level. At pH 6.2 recovery of applied phosphorus was almost complete from the 0.5% compost level and decreased with increasing level of compost so that about half the applied phosphorus was recovered with the 2% compost treatment. At pH 7.2 recovery was complete from the 0.5% compost level and about half complete at the two higher levels.

Percentage recovery of applied potassium. (Table 79)

The recovery of applied potassium was not affected to such a great extent by pH or level of applied organic material as was recovery of applied phosphorus. The general effect of pH was for recovery to be higher at pH 6.2 and 7.2 than at pH 5.2 and the general effect of level of added organic material was for recovery of potassium to decrease with increasing level.

With the straw treatments at pH 5.2 about half the applied potassium was recovered from the 0.5 straw level, about a quarter from the 1% level and a small amount from the 2% level. At both pH 6.2 and 7.2 about three-quarters of the applied potassium was recovered from the 0.5% straw level, about a quarter from the 1% and about an eighth from

the 2% straw level.

The differences in recovery of potassium between the KNO_3 treatments and the straw + KNO_3 treatments indicates the extent to which the straw has immobilized the applied KNO_3-potassium. With the 0.5% straw level at pH 6.2 and 7.2 it is noted that the recovery of KNO_3-potassium was higher than when KNO_3 was applied by itself. At the other levels of pH and straw KNO_3-potassium was immobilized. The extent of immobilization was greatest with the highest level of straw, amounting to about two-thirds of that applied at pH 5.2, about half of that applied at pH 6.2 and about one-third of that applied at pH 7.2.

With the blood compost treatments recovery of applied potassium was complete or nearly complete with all levels of compost at pH 7.2; with the 0.5% level some of the native potassium was taken up in addition. At pH 6.2 all the applied and some of the native potassium was recovered with the 0.5% compost treatment, whilst with the two higher levels of compost about three quarters of the applied potassium was recovered. At pH 5.2 about two-thirds of the applied potassium was recovered from the 0.5% and 1% compost levels and about half from the 2% level.

Percentage recovery of applied magnesium. (Table 79)

The general effect of pH on the recovery of applied magnesium was for recovery usually to increase with pH,

whilst the general effect of applied organic material was for recovery of applied magnesium to decrease with increasing level of material.

With the straw treatments at pH 5.2 recovery of applied magnesium was low at all straw levels; in fact there was some immobilization of native soil magnesium with the 2% straw treatment. At pH 6.2 about three-quarters of the magnesium was recovered from the 0.5% straw treatment, about one-fifth from the 1% straw treatment, whilst there was slight immobilization of native soil magnesium with the 2% straw treatment. At pH 7.2 all the applied magnesium was recovered from the 0.5% straw level and only small amounts from the two higher levels.

With the blood compost treatments at pH 5.2 recovery of applied magnesium decreased with level from about one-eighth of that applied in the 0.5% level of about one-fourteenth of that applied in the 2% level. At pH 6.2 there was a small decline in recovery of applied magnesium due to level of compost; with all treatments about one-third of the applied magnesium was recovered from the 0.5% and 1% levels and about one-third from the 2% level of compost.

Discussion.

The results obtained in the previous section will be discussed (a) with respect to the effects of increasing level of straw + KNO_3 in relation to the control (untreated) soil as well as to the KNO_3-treated soil at each pH and (b) with respect to the effect of increasing level of blood compost in relation to the control soil at each pH.

The general effect of the straw (+ KNO_3) treatments were similar at pH 6.2 and 7.2, but were different at these two pH levels than at pH 5.2. At the two higher pH levels root and top yields and uptake of all nutrients except potassium increased with the 0.5% straw level, then decreased with the 1% straw level and decreased further, though not to such a great extent, with the 2% straw level. At pH 5.2 on the other hand the general effect was for yields and nutrient uptake to be hardly affected by the 0.5% and 1% straw levels and usually to be reduced slightly by the 2% straw level. Also, with the 1% straw treatment the effects on yields and nutrient uptake were similar at all pH levels; with the 2% straw level there were small, though not always significant differences, due to pH, the general decreasing order being pH 7.2, pH 6.2 and pH 5.2.

The actual effect of straw, irrespective of the KNO_3 added with all straw levels, is obtained by comparing the three straw levels + KNO_3 with the KNO_3 treatment. The

order of yields and nutrient uptake together with indications of significant differences or otherwise are shown for these four treatments in the upper portion of Table 180. This table shows that at pH 5.2 the 0.5% straw level had a deleterious effect on yields and nutrient uptake; at pH 6.2 there was no such deleterious effect, whilst at pH 7.2 the straw either had no effect on or improved the performance of the ryegrass. This is rather surprising in view of the fact that since microbial activity tends to increase with pH (as shown by increased carbon mineralization with increasing pH in Chapter III) we would expect greater immobilization of KNO_3-nitrogen and other mineral nutrients at the higher than at the lower pH levels, thus resulting in poorer performance of the ryegrass at the higher pH levels. The explanation for this anomaly probably lies in the fact that with this low level of added straw the ryegrass roots were able to compete effectively for nutrients with the micro-organisms decomposing the straw at pH 6.2 and 7.2 but not at pH 5.2. This is confirmed by a study of the cumulative uptake curves of the four nutrients at the three pH levels with the 0.5% straw treatment. It is noted with all nutrients, but with nitrogen in particular, that their cumulative uptake tended to parallel that of the KNO_3 treatment at pH 5.2, whilst at pH 6.2 and 7.2 the

cumulative uptake increased to a greater extent with successive cuttings where 0.5% straw + KNO_3 than where only KNO_3 was applied.

The carbon/nitrogen ratios of the straw treatments + KNO_3 were 23, 32 and 40 for 0.5%, 1% and 2% straw respectively. The ratio of 23 for the 0.5% straw + KNO_3 treatment is similar to that for a good compost, thus it is not surprising that, at least at the two higher pH levels where conditions for growth are generally satisfactory, uptake of nitrogen and other nutrients should be good. In fact, it is interesting to note that the performance of the ryegrass, both with respect to yields and nutrient uptake, was as good with 0.5% straw + KNO_3 as with the 2% blood compost treatment and was usually better than with the 0.5% and 1% blood compost treatments.

When the level of straw was increased from 0.5% to 1% or 2% the performance of ryegrass was poorer at all pH levels. At pH 7.2 performance was equally poor between the 1% and 2% straw levels, whilst at pH 5.2 and 6.2 performance was usually poorer with the 2% than with the 1% straw level. With the 2% straw treatment all the KNO_3-nitrogen was permanently immobilized (at least insofar as this crop of ryegrass was concerned) at all pH levels. With the 1% straw level virtually all the KNO_3-nitrogen was immobilized at pH

5.2 and 7.2 whilst at pH 6.2 about 40% of the KNO_3-nitrogen was available to the grass. The possible reasons for this have been discussed in the previous chapter, the general conclusion being that a pH in the region of 6.5 was optimum for nitrogen mineralization but not for nitrogen immobilization by micro-organisms.

It might well be that if extra inorganic nitrogen had been supplied with the higher levels of straw (so as to maintain the carbon/nitrogen ratio of the added materials around 20) then the performance of ryegrass might have been as good as or better than with the 0.5% straw + KNO_3 treatment. Under field conditions however the possible toxic effects of heavy dressings of inorganic nitrogen fertilizers on seed germination and seedling growth must be considered. In addition, if rainfall is heavy or if irrigation is practised the loss of a high proportion of the applied inorganic fertilizers by leaching may occur. Furthermore, the presence in the soil of a high proportion of undecomposed or partially decomposed organic material may make for difficulties of cultivation, especially for seedbed preparation, and would also supply a very suitable medium for the development of plant pathogenic organisms. All these points lead to the conclusion that it would be undesirable and uneconomic to apply heavy dressings of undecomposed plant

material such as straw to the soil. Small dressings, e.g. in the case of straw an 0.5% level (equivalent to 5 tons per acre-7 in. of soil) together with sufficient extra inorganic nitrogen to give the added material a carbon/nitrogen ratio of about 20 should be helpful providing soil pH is not too low. Under these conditions growth stimulation may be comparable with that obtained with the application of inorganic nitrogen alone. The presence of straw would be particularly helpful in light-textured soils by helping to improve their water- and nutrient-holding capacity and in heavy soils by helping to improve structure and drainage. In addition, the residual effects of the straw would be helpful to a following crop.

The general effect of increasing level of blood compost was that both yields and nutrient uptake increased with increasing level of application more at pH 6.2 and 7.2 than at pH 5.2. For any given level of compost response usually decreased in the order pH 7.2, pH 6.2, pH 5.2. Thus it would appear that nutrient availability from the compost is related to microbiological activity, which in turn usually tends to increase with pH.

There were considerable differences in the extent of increases in yields and nutrient uptake with increasing level of compost. Thus, at pH 6.2 and 7.2, potassium and magnesium

uptake were increased to agreater extent than were nitrogen and phosphorus uptake or top or toot yields. At pH 5.2 on the other hand increasing level of compost usually had no significant effect on yields or nutrient uptake (see Table 80 lower portion); it was in fact only with potassium that uptake increased with level of compost, whilst for nitrogen it was only the 2% compost level which increased uptake. This confirms the fact that if heavy applications of compost are made the nutrients in it can be utilized to a reasonable extent only if soil pH is not too low.

A comparison of straw and blood compost at pH 5.2 shows that there was little difference in performance of ryegrass between these two materials when they were applied at 0.5% or 1%. When they were applied at the 2% levelscompost gave better results than did straw, but the differences were greater with respect to yields than to nutrient uptake. At this 2% level whereas nutrient uptake in successive cuttings of ryegrass tended to decrease where compost was applied, in the case of straw nutrient uptake was low, compared with the other treatments, in the first cutting but in later cuttings increased proportionately to a greater extent than with the other treatments. This is a fairly clear indication that nutrients which were immobilized initially by the micro-organisms decomposing the straw again became available later on. In the case of the compost

which contained no easily decomposable material, no immobilization of nutrients occurred so that nutrient availability to ryegrass was determined mainly by the rate of mineralization of nutrients.

The fact that there was no tendency for yields or nutrient uptake to decrease with the 2% level of blood compost as compared with lower levels indicates that no toxic effects were apparent from this heavy dressing, representing 20 tons of dry matter per acre (or approximately 80 tons per acre of a moist compost containing 75% water). This was the case even with the first cutting of ryegrass since it was found that uptake of nutrients with the 2% blood compost treatment paralleled that of the KNO_3 treatment.

At pH 6.2 and 7.2 yields and nutrient uptake were usually similar between the 2% compost treatment and the KNO_3 treatment. In view of the expense involved in preparing (particularly if an expensive accelerator such as dried blood is used) and applying such a heavy dressing of compost under field conditions as compared with the cost of KNO_3 it would hardly seem justifiable to do this in view of the fact that no better results were obtained. However other factors must be considered. There is the residual value of the compost for succeeding crops. There is the ability of the compost for improving the water- and

nutrient-holding capacity of light soils and the structure of heavy soils. There is the possibility that compost can supply trace elements and growth-promoting substances which KNO_3 is not able to do.

Of particular interest with respect to recovery of applied untrients from both straw and compost treatments were the very great differences in recovery of phosphorus due to pH. These differences were greater at the low than at the high level of application of both materials. The negative recovery values obtained indicate that not only was none of the applied phosphorus absorbed by the plant but also that the treatment induced immobilization of some of the available native phosphorus. At pH 5.2 negative recoveries occurred with every treatment except 2% compost. This indicates that at this pH the general effect of the treatments was to encourage the fixation of available phosphate in the unavailable iron- and aluminium-bound forms; it was only the highest level of blood compost with its high buffering capacity tending to exert a protective action against fixation, as well as its high level of organic phosphorus (which would tend to mineralize to inorganic phosphate) where no fixation occurred.

At pH 6.2 and 7.2 high recoveries of applied phosphorus were obtained, particularly with the 0.5% levels of straw

and compost. With the 0.5% straw level at both pH values not only was all the applied phosphorus recovered but an approximately equal amount of native phosphorus was also absorbed by the plant. This indicates that at these pH levels not only is there no fixation of applied phosphate but also that added organic phosphorus is very readily mineralized and rendered available to the plant. In addition the extra activity of phosphorus-mineralizing microbes induced by the presence of the decomposing straw has probably resulted in attack and mineralization of native organic phosphorus; also, or alternatively, these conditions may have been the most suitable ones for releasing phosphorus from the fixed native forms. The very great reduction in phosphorus recovery with increasing straw level at pH 6.2 and 7.2 is probably due to the fact that the higher levels of straw caused greater competition for available phosphate during their microbial decomposition, or alternatively and especially at pH 7.2 where negative recoveries were obtained, these high levels of straw produced conditions which were not suitable for mineralization of native organic phosphorus or for conversion of native fixed phosphorus to available forms.

Recoveries of applied nitrogen were poor with all organic materials at pH 5.2, but was complete with the KNO_3

treatment. This indicates poor nitrogen mineralization from the blood compost and also very effective nitrate-nitrogen immobilization by the decomposing straw, with no tendency for this immobilized nitrogen to be mineralized again even with the lowest level of straw, where one might expect this to occur. This confirms that whereas nitrogen-immobilizing processes may be active at low pH, nitrogen-mobilizing processes are very slow. At pH 6.2 and 7.2 about half the applied nitrogen was recovered from the 0.5% straw + KNO_3 treatment, whilst about half of nitrate-nitrogen was immobilized. With the higher levels of straw recovery of applied nitrogen was decreased, particularly at pH 7.2. This indicates that nitrogen-immobilizing processes, although high at low pH, become even greater with increasing pH, whilst nitrogen-mobilizing processes are somewhat greater at pH 6.2 than at 7.2.

The results obtained with respect to recovery of applied potassium are particularly interesting with regard to the blood compost treatments. With all levels of compost at pH 6.2 and 7.2 the recovery of potassium was greater than from KNO_3, whilst with the 0.5% compost level all the applied potassium and in addition some of the native potassium was absorbed by the plant. This indicates a stimulative effect of the organic material and also indicates that potassium adsorbed on organic material is more easily

available to plants than is that adsorbed on the soil mineral complex, since much of the potassium from the applied KNO_3 would be adsorbed in this way. Of interest also is the considerable reduction in recovery of applied potassium with increasing level of straw at all pH values. This implies that biological immobilization of potassium is occurring. This is confirmed by the fact that with the 2% straw level about one-third to two-thirds of the KNO_3-potassium was immobilized. This is rather surprising in view of the fact that the literature (112) has in general indicated that biological fixation of potassium is of no importance. This discrepancy may arise from the fact that most of the work on potassium fixation has been done with chemical extractants (usually cation-extracting reagents such as ammonium acetate) and it might well be that these are able to extract forms of potassium from organic matter which are not available to plants.

The main effects to be noted with respect to the recovery of applied magnesium are the generally fairly good recovery from all levels of blood compost at pH 6.2 and 7.2, but not at pH 5.2, and the very poor recovery from the 2% straw treatment. The latter indicates that biological fixation of magnesium is operative, the extent of fixation increasing with decreasing pH. The most important effect however is the very good recovery of magnesium from the 0.5%

straw treatment at pH 6.2 and 7.2. This indicates that, even though magnesium may have been immobilized initially by the decomposing straw (although the cumulative uptake curves show little evidence of this) it was eventually in such a condition as to be readily available to the ryegrass.

Summary and Conclusions.

Ryegrass was grown in pot tests in Silwood soil, which had been adjusted to pH 5.2, 6.2 and 7.2, treated with 0.5%, 1% and 2% each of straw and blood compost; the straw-treated pots also received 100 lb. N per acre as KNO_3. KNO_3-treated and control pots were included for each pH level.

Straw (+ KNO_3) treatments versus KNO_3 treatments.

At pH 5.2 top and root yields were less with the straw than with the KNO_3 treatment. At pH 6.2 and 7.2 yields were usually the same with 0.5% straw and KNO_3 and were lower with the higher levels of straw.

At pH 5.2 total nitrogen uptake was greatest from KNO_3, with usually no difference between the three straw levels. At pH 6.2 and 7.2 there were no differences in total nitrogen uptake between KNO_3 and 0.5% straw, whilst the two higher levels of straw usually resulted in reduced nitrogen uptake. Recovery of applied nitrogen was complete from KNO_3 at all pH levels; at pH 5.2 it was low from all straw levels; at pH 6.2 and 7.2 about half the applied nitrogen was recovered from 0.5% straw, whilst recovery decreased with increasing straw level.

At pH 5.2 total phosphorus uptake was greatest from KNO_3, at pH 6.2 from KNO_3 and 0.5% straw, and at pH 7.2 from

0.5% straw. Phosphorus uptake decreased with increasing level of straw at all pH levels. Recovery of applied phosphorus was complete at pH 6.2 and 7.2 from 0.5% straw but declind considerably with increasing level of straw. There was negative recovery of phosphurus from all straw treatments at pH 5.2.

Total uptake of potassium at pH 5.2 was greatest from KNO_3, but was similar from KNO_3 and 0.5% straw at pH 6.2 and 7.2. Potassium uptake was somewhat lowere with the higher levels of straw. Recovery of applied potassium was high from 0.5% straw at all pH levels and decreased with increasing level of straw.

Total uptake of magnesium was similar with KNO_3 and 0.5% straw at all pH levels and usually decreased with increasing level of straw. Recovery of applied magnesium was low from all straw treatments at pH 5.2. At pH 6.2 and 7.2 recovery was high from 0.5% straw, but decreased rapidly with increasing level of straw.

Blood compost treatments versus controls.

At pH 5.2 top yields were similar with all treatments, including the control. At pH 6.2 and 7.2 2% compost gave the highest and the controls the lowest yields. Root yields were highest with 2% compost, with usually little difference between the other treatments at all pH levels.

Total nitrogen uptake at pH 5.2 and 6.2 was higher with 2% compost than with the other treatments, whilst at pH 7.2 all levels of compost produced greater nitrogen uptake than did the control. Recovery of applied nitrogen was low from all levels of compost at pH 5.2; at pH 6.2 and 7.2 about one-third of the applied nitrogen was recovered from 0.5% compost and recovery decreased with increasing level of compost.

Total uptake of phosphorus at pH 5.2 was similar with all treatments. At pH 6.2 and 7.2 uptake of phosphorus was greatest with 2% compost, but the two lower levels of compost also increased phosphorus uptake over controls. The recovery of applied phosphorus at 5.2 was low or negative from the compost treatments. At pH 6.2 and 7.2 recovery was complete from 0.5% compost and usually decreased with increasing level of compost.

Total uptake of potassium at all pH levels was highest with 2% compost, whilst the two lower compost levels also increased potassium uptake over the controls. Recovery of applied potassium was virtually complete from all compost treatments at pH 7.2. At pH 6.2 it was complete from 0.5% compost, but declined somewhat with increasing level of compost. At pH 5.2 about two-thirds of the applied potassium was recovered from 0.5% and 1% compost and about half from 2% compost.

Total uptake of magnesium was similar with all treatments at pH 5.2. At pH 6.2 and 7.2 uptake was greatest with 2% compost, but was usually also higher with the two lower levels of compost than with the controls. Recovery of applied magnesium was poor from all treatments at pH 5.2; at pH 6.2 and 7.2 about half the applied magnesium was recovered from 0.5% compost and recovery decreased slightly with increasing level of compost.

General conclusions.

At pH 5.2 the performance of ryegrass (with respect to yields and uptake of the four nutrients) was best with KNO_3, followed by 2% blood compost, then by 0.5% and 1% compost and straw levels, with the poorest performance being obtained with the 2% straw treatment.

At pH 6.2 and 7.2 the best performance of ryegrass was obtained with the KNO_3, 0.5% straw + KNO_3 and 2% compost treatments. The 0.5% and 1% compost treatments gave the next best performance, whilst the 1% and 2% straw treatments gave the poorest performance.

Thus providing soil pH is not below about 6 the application of a low level of straw (5 tons per acre) plus sufficient extra nitrogen to give a carbon/nitrogen ratio around 20 should give results as satisfactory as with inorganic nitrogen alone, with the added advantage that the

straw will help maintain water status and soil structure and reduce leaching of exchangeable cations as well as having some residual effect on the following crop. In order to achieve similar results with compost a much heavier level (of 20 tons dry matter per acre) would have to be applied and though this may not be economic the significance of this high level of compost in maintaining or even improving soil structure may be important; in addition there would be a considerable residual value for following crops. In soil with pH near 5 KNO_3 is more satisfactory than any level of straw (+ KNO_3) or compost.

Table 56. Dry matter yield (in gms) of ryegrass (tops + fresh straw + KNO_3 and blood compost at three levels of

Treatments	1st Cutting			2nd Cutting		
	R_1	R_2	Total	R_1	R_2	Total
C	0.690	0.756	1.446	0.747	0.800	1.547
FS_I+KN	0.887	0.952	1.839	0.885	0.943	1.828
FS_{II}+KN	0.844	0.796	1.640	0.737	0.698	1.435
FS_{III}+KN	0.509	0.460	0.969	0.425	0.487	0.912
BD_I	0.859	0.882	1.741	0.833	0.875	1.708
BD_{II}	0.897	1.204	2.101	0.784	0.921	1.705
BD_{III}	0.733	0.797	1.530	0.865	1.009	1.874
KN	1.643	1.599	3.242	1.227	1.152	2.379

roots) grown in Silwood soil of pH 5.2 treated with each treatment.

3rd Cutting			Root		
R_1	R_2	Total	R_1	R_2	Total
0.597	0.571	1.168	1.180	1.220	2.400
0.615	0.545	1.160	1.489	1.327	2.816
0.693	0.703	1.396	1.676	1.629	3.305
0.607	0.528	1.135	1.497	1.324	2.821
0.572	0.538	1.110	1.224	1.279	2.503
0.569	0.586	1.155	1.101	1.090	2.191
0.580	0.644	1.224	1.428	1.533	2.961
0.686	0.550	1.236	1.908	1.636	3.544

Table 57.

Table 57. Dry matter yield (in gms) of ryegrass (tops + fresh straw + KNO_3 and blood compost at three levels of

Treatments	1st Cutting			2nd Cutting		
	R_1	R_2	Total	R_1	R_2	Total
C	0.782	0.911	1.693	0.621	0.666	1.287
FS_I+KN	1.273	1.179	2.451	1.124	1.011	2.135
FS_{II}+KN	0.617	0.659	1.276	0.970	0.903	1.873
FS_{III}+KN	0.529	0.307	0.836	0.708	0.648	1.356
BD_I	0.909	0.895	1.804	0.732	0.764	1.496
BD_{II}	0.227	0.881	1.808	0.844	0.749	1.593
BD_{III}	1.255	1.021	2.276	0.949	0.858	1.807
KN	1.625	1.735	3.360	1.066	0.967	2.033

roots) grown in Silwood soil of pH 6.2 treated with each treatment.

3rd Cutting			Root		
R_1	R_2	Total	R_1	R_2	Total
0.537	0.437	0.994	0.953	0.918	1.871
0.855	0.904	1.759	2.255	2.231	4.486
0.854	0.847	1.701	1.594	1.620	3.214
0.793	0.790	1.583	1.418	1.271	2.689
0.832	0.822	1.654	1.438	1.618	3.056
0.869	0.826	1.695	1.610	1.415	3.025
1.123	0.833	1.956	2.172	1.928	4.100
0.754	0.702	1.456	2.214	2.429	4.643

Table 58. Dry matter yield (in gms) of ryegrass (tops + fresh straw + KNO_3 and blood compost at three levels of

Treatments	1st Cutting			2nd Cutting		
	R_1	R_2	Total	R_1	R_2	Total
C	0.953	1.101	2.054	0.815	0.747	1.562
FS_I+KN	1.380	1.186	2.566	1.413	1.225	2.638
FS_{II}+KN	0.637	0.637	1.274	0.979	0.983	1.962
FS_{III}+KN	0.402	0.627	1.029	0.603	0.856	1.459
BD_I	1.196	1.011	2.207	0.997	0.956	1.953
BD_{II}	1.107	1.169	2.276	1.171	0.908	2.079
BD_{III}	1.510	1.297	2.807	1.373	1.007	2.380
KN	1.989	1.697	3.686	1.024	0.777	1.801

roots) grown in Silwood soil of pH 7.2 treated with each treatment.

3rd Cutting			Root		
R_1	R_2	Total	R_1	R_2	Total
0.680	0.492	1.172	1.428	1.183	2.611
0.933	0.964	1.897	2.464	2.274	4.738
0.731	0.728	1.459	1.685	1.407	3.092
0.782	0.990	1.772	1.428	1.773	3.201
1.102	0.888	1.990	2.001	1.766	3.767
1.124	0.911	2.035	1.383	1.641	3.024
1.181	1.017	2.198	2.219	1.914	4.133
0.736	0.765	1.501	2.148	1.883	4.031

Table 59.

Table 59. Percentage uptake of nitrogen by perenial ryegrass

Treatments	Soil pH 5.2								Soil			
	1st Cutting		2nd Cutting		3rd Cutting		Root		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	1.25	1.20	1.20	1.20	1.20	1.20	1.39	1.38	0.81	0.86	1.13	1.20
FS_I	1.34	1.09	1.05	1.05	1.15	1.15	1.25	1.08	0.94	1.08	1.13	0.98
FS_{II}	1.11	1.26	1.10	1.15	1.28	1.28	1.20	1.36	1.10	0.93	1.13	1.20
FS_{III}	1.44	1.20	1.20	0.98	1.23	1.23	1.43	1.15	0.80	0.85	0.98	0.85
BD_I	1.10	1.10	1.05	0.90	1.30	1.30	1.25	1.65	0.90	0.93	1.20	1.30
BD_{II}	1.23	1.18	1.20	1.20	1.30	1.40	1.55	1.20	1.08	1.00	1.30	1.48
BD_{III}	1.35	1.73	1.28	1.13	1.30	1.28	1.42	1.90	1.08	1.08	1.35	1.25
KN	1.40	1.45	1.13	1.20	1.00	1.08	1.50	1.43	0.93	1.09	0.75	0.75

grown in Silwood soil of different pH.

pH 6.2				Soil pH 7.2							
3rd Cutting		Root		1st Cutting		2nd Cutting		3rd Cutting		Root	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
1.28	1.08	1.85	1.66	0.78	1.08	0.95	1.20	0.90	1.00	1.35	1.43
1.08	1.08	1.15	1.15	1.18	1.17	0.90	0.95	0.90	1.05	1.10	1.10
1.30	1.55	1.63	1.80	1.18	1.20	1.10	1.13	0.93	0.80	1.13	1.28
1.15	1.30	1.50	1.85	0.93	1.13	0.85	0.80	1.00	1.15	1.15	1.30
1.15	1.23	1.58	1.53	1.14	1.24	1.13	1.30	1.00	1.00	1.28	1.35
1.20	1.20	1.28	1.35	1.30	1.45	1.55	1.55	1.15	1.00	1.39	1.35
1.20	1.28	1.70	1.63	1.10	1.25	1.20	1.10	1.30	1.13	1.33	1.15
0.85	0.95	1.25	1.65	1.19	1.18	1.13	1.20	0.95	0.85	1.43	1.43

Table 60.

Table 60. Percentage uptake of phosphate by perennial

Treatments	Soil pH 5.2								Soil			
	1st Cutting		2nd Cutting		3rd Cutting		Root		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	0.97	0.78	1.14	1.06	0.80	0.78	0.58	0.41	0.63	0.62	0.94	0.89
FS_I	0.75	0.71	0.75	0.75	0.78	0.83	0.38	0.29	0.52	0.52	0.70	0.85
FS_{II}	0.73	0.79	0.78	0.85	0.71	0.55	0.39	0.36	0.58	0.52	0.60	0.65
FS_{III}	0.71	0.77	0.75	0.78	0.54	0.54	0.36	0.31	0.52	0.52	0.58	0.65
BD_I	0.73	0.79	0.89	0.87	0.90	0.92	0.36	0.36	0.56	0.61	0.80	0.80
BD_{II}	0.74	0.69	0.97	0.85	0.88	0.83	0.36	0.41	0.61	0.61	0.85	0.92
BD_{III}	1.14	1.16	0.87	0.73	0.90	0.83	0.41	0.36	0.63	0.61	0.89	0.94
KN	0.65	0.65	0.75	0.78	0.75	0.80	0.36	0.39	0.53	0.52	0.70	0.68

ryegrass grown in Silwood soil of different pH.

pH 6.2				Soil pH 7.2							
3rd Cutting		Root		1st Cutting		2nd Cutting		3rd Cutting		Root	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
0.73	0.73	0.43	0.40	0.49	0.52	1.14	1.01	0.58	0.70	0.36	0.31
0.92	0.80	0.31	0.33	0.45	0.43	0.78	0.85	0.75	0.79	0.26	0.35
0.92	0.71	0.41	0.39	0.43	0.43	0.63	0.63	0.53	0.48	0.31	0.30
0.71	0.73	0.48	0.56	0.52	0.52	0.68	0.65	0.63	0.64	0.44	0.41
0.75	0.83	0.46	0.46	0.45	0.49	0.85	0.81	0.68	0.68	0.41	0.46
1.14	1.18	0.36	0.36	0.48	0.56	0.83	0.81	0.59	0.65	0.36	0.36
0.83	0.94	0.41	0.45	0.52	0.52	0.81	0.85	0.82	0.94	0.30	0.31
0.68	0.88	0.39	0.39	0.43	0.38	0.68	0.65	0.68	0.63	0.36	0.36

Table 61.

Table 61. Percentage uptake of K by perennial ryegrass straw and composted straw at three levels of each.

Treatments	Soil pH 5.2								Soil			
	1st Cutting		2nd Cutting		3rd Cutting		Root		1st Cutting		2nd Cutting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
Control	2.25	1.70	1.58	1.40	1.25	1.15	0.45	0.45	1.30	1.25	0.93	1.00
FS_I	3.60	3.30	1.85	1.80	1.65	1.60	0.78	0.50	2.18	2.53	1.35	1.58
FS_{II}	3.08	3.60	1.85	1.90	1.70	1.65	0.71	0.78	2.58	2.98	1.68	1.63
FS_{III}	3.70	3.60	1.95	1.95	1.70	2.00	0.95	0.75	2.78	2.53	1.73	1.90
BD_I	2.03	2.25	1.48	1.40	1.43	1.65	0.43	0.39	1.50	1.50	1.20	1.15
BD_{II}	2.43	2.18	1.48	1.30	1.60	1.55	0.45	0.50	1.90	1.85	1.15	1.03
BD_{III}	3.70	3.60	1.30	1.35	1.70	1.38	0.48	0.50	2.18	2.00	1.25	1.10
KN	2.93	2.98	1.85	1.73	1.60	1.65	0.43	0.48	2.03	2.00	1.40	1.30

grown in Silwood soil of different pH treated with fresh

pH 6.2				Soil pH 7.2							
3rd Cutting		Root		1st Cutting		2nd Cutting		3rd Cutting		Root	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
0.75	0.83	0.30	0.20	1.40	1.00	1.03	0.93	0.70	0.65	0.25	0.13
1.43	1.55	0.30	0.35	2.13	2.33	1.40	1.35	1.33	1.38	0.25	0.30
1.60	1.70	0.50	0.56	2.33	2.43	1.58	1.73	1.78	1.55	0.48	0.43
2.10	2.25	0.65	0.71	2.63	2.53	2.00	1.75	2.15	2.50	0.48	0.48
1.05	1.10	0.28	0.25	1.35	1.50	1.03	1.03	0.80	0.93	0.21	0.19
1.25	1.20	0.30	0.20	1.75	1.75	1.10	1.13	1.05	0.95	0.19	0.19
1.33	1.38	0.28	0.28	1.90	1.78	1.80	1.80	1.33	1.33	0.21	0.15
1.10	1.05	0.30	0.33	2.03	1.93	1.40	1.30	0.95	0.95	0.15	0.21

Table 62.

Table 62. Percentage uptake of magnesium by perennial with fresh straw.

	Soil pH 5.2							
	1st Cutting		2nd Cutting		3rd Cutting		1st Cutting	
Treatments	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
C	0.17	0.18	0.36	0.34	0.20	0.20	0.24	0.22
FS_I	0.14	0.15	0.31	0.31	0.21	0.20	0.18	0.22
FS_{II}	0.25	0.23	0.30	0.23	0.27	0.24	0.18	0.15
FS_{III}	0.24	0.22	0.24	0.23	0.27	0.23	0.13	0.18
BD_I	0.18	0.16	0.33	0.33	0.24	0.24	0.20	0.19
BD_{II}	0.17	0.16	0.35	0.33	0.24	0.24	0.26	0.24
BD_{III}	0.18	0.18	0.33	0.34	0.28	0.28	0.36	0.31
KN	0.18	0.15	0.29	0.25	0.15	0.17	0.20	0.26

ryegrass grown in Silwood soil of different pH treated

Soil pH 6.2				Soil pH 7.2					
2nd Cutting		3rd Cutting		1st Cutting		2nd Cutting		3rd Cutting	
R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
0.32	0.30	0.20	0.19	0.22	0.22	0.29	0.30	0.21	0.24
0.32	0.32	0.19	0.19	0.20	0.30	0.34	0.32	0.19	0.20
0.31	0.30	0.25	0.24	0.18	0.15	0.32	0.31	0.24	0.24
0.23	0.18	0.19	0.18	0.13	0.16	0.24	0.25	0.19	0.19
0.32	0.35	0.20	0.21	0.22	0.24	0.32	0.34	0.22	0.23
0.35	0.37	0.22	0.24	0.27	0.30	0.32	0.36	0.25	0.26
0.36	0.33	0.20	0.19	0.25	0.24	0.36	0.36	0.25	0.26
0.26	0.29	0.15	0.17	0.24	0.20	0.26	0.27	0.18	0.17

Table 63.

Table 63. Uptake of N by perennial ryegrass grown in blood composts at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	8.63	9.07	17.70	8.85	8.96	9.60	18.56	9.28
FS_I+KN	11.89	10.38	22.27	11.14	9.29	9.90	19.19	9.60
FS_{II}+KN	9.37	10.03	19.40	9.70	8.11	8.03	16.14	8.07
FS_{III}+KN	7.33	5.52	12.85	6.43	5.10	4.77	9.87	4.94
BD_I	9.45	9.70	19.15	9.58	8.75	7.88	16.53	8.32
BD_{II}	11.03	14.21	25.24	12.62	9.41	11.05	20.46	10.23
BD_{III}	9.90	13.79	23.69	11.85	11.07	11.40	22.47	11.24
KN	23.00	23.19	46.19	23.10	13.87	13.82	27.69	13.85

Silwood soil of pH 5.2 treated with straw + KNO_3 and

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
7.16	6.85	14.01	7.00	16.40	16.84	33.24	16.62
7.07	6.27	13.34	6.67	18.61	14.33	32.94	16.47
8.87	9.00	17.87	8.94	20.11	22.15	42.26	21.13
7.47	6.49	13.96	6.98	21.41	15.23	36.64	18.32
7.44	6.99	14.43	7.22	15.20	21.10	36.40	18.20
7.40	8.20	15.60	7.80	17.07	13.08	30.15	15.08
7.54	8.24	15.78	7.89	20.28	29.13	49.41	24.71
6.86	5.94	12.80	6.40	28.62	23.39	52.01	26.00

Table 64.

Table 64. Uptake of nitrogen (mgm) by perennial ryegrass and blood composts at three levels of each treatment.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	6.33	7.83	14.16	7.08	7.02	7.99	15.01	7.50
FS_I+KN	11.97	12.72	24.69	12.35	12.70	9.91	22.61	11.31
FS_{II}+KN	6.79	6.13	12.92	6.46	10.96	10.84	21.80	10.90
FS_{III}+KN	4.23	2.61	6.84	3.42	6.94	5.51	12.45	6.23
BD_I	8.18	8.32	16.50	8.25	8.78	9.93	18.71	9.36
BD_{II}	10.01	8.88	18.89	9.45	10.97	11.09	22.06	11.03
BD_{III}	13.55	11.03	24.58	12.29	12.81	10.73	23.54	11.77
KN	15.11	18.91	34.02	17.01	8.00	7.25	15.25	7.63

grown in Silwood soil of pH 6.2 treated with straw + KNO_3

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
7.13	4.72	11.85	5.93	17.63	15.24	32.87	16.44
9.23	9.76	18.99	9.50	25.93	25.66	51.59	25.80
11.10	13.13	24.23	12.12	25.98	29.16	55.14	27.57
9.12	10.27	19.39	9.70	21.27	23.51	44.78	22.39
9.57	10.11	19.68	9.84	22.72	24.76	47.48	23.74
10.43	9.91	20.34	10.17	20.61	19.10	39.71	19.86
13.48	10.66	24.14	12.07	36.92	31.43	68.35	34.18
6.41	6.67	13.08	6.54	27.68	30.08	57.76	28.88

Table 65.

Table 65. Uptake of N (mgm) by perennial ryegrass grown blood compost at three levels of each treatment.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	7.43	11.89	19.32	9.66	7.74	8.96	16.70	8.35
FS_I+KN	16.28	13.88	30.16	15.08	12.72	11.64	24.36	12.18
FS_{II}+KN	7.52	7.64	15.16	7.58	10.77	11.11	21.88	10.94
FS_{III}+KN	3.74	7.09	10.83	5.42	5.13	6.85	11.98	5.99
BD_I	13.63	12.54	26.17	13.09	11.27	12.43	23.70	11.85
BD_{II}	14.39	16.95	31.34	15.67	18.15	14.07	32.22	16.11
BD_{III}	16.61	16.21	32.82	16.41	16.48	11.08	27.56	13.78
KN	23.67	20.02	43.69	21.85	11.57	9.32	20.89	10.45

in Silwood soil of pH 7.2 treated with straw + KNO_3 and

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
6.12	4.92	11.04	5.52	19.28	16.92	36.20	18.10
8.40	10.12	18.52	9.26	27.10	25.01	52.11	26.06
6.80	5.83	12.62	6.31	19.04	19.42	38.46	19.23
7.82	11.39	19.21	9.61	16.42	23.05	39.47	19.74
11.02	8.88	19.90	9.95	25.61	23.84	49.45	24.73
12.93	9.11	22.04	11.02	19.22	22.15	41.31	20.66
15.35	11.49	26.84	13.42	29.51	22.01	51.52	25.76
6.99	6.50	13.49	6.75	30.72	26.93	57.65	28.83

Table 66.

Table 66. Uptake of phosphate (in mgm) by perennial straw + KNO_3 and blood compost at three levels of each

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	6.69	5.90	12.59	6.30	8.52	8.48	17.00	8.50
FS_I+KN	6.65	6.76	13.41	6.71	6.64	7.07	13.71	6.86
FS_{II}+KN	6.16	6.29	12.45	6.23	5.75	5.93	11.68	5.84
FS_{III}+KN	3.61	3.54	7.15	3.58	3.19	3.80	6.99	3.50
BD_I	6.27	6.97	13.24	6.62	7.41	7.61	15.02	7.51
BD_{II}	6.64	8.31	14.95	7.48	7.60	7.83	15.43	7.72
BD_{III}	8.36	9.25	17.61	8.81	7.53	7.37	14.90	7.45
KN	10.68	10.39	21.07	10.54	9.20	8.99	18.19	9.10

ryegrass grown in Silwood soil of pH 5.2 treated with treatment.

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
4.78	4.45	9.23	4.62	6.84	5.00	11.84	5.92
4.80	4.52	9.32	4.66	5.66	3.85	9.51	4.76
4.92	3.87	8.79	4.40	6.54	5.86	12.40	6.20
3.28	2.85	6.13	3.07	5.39	4.10	9.49	4.75
5.15	4.95	10.10	5.05	4.41	4.60	9.01	4.50
5.01	4.86	9.87	4.94	3.96	4.47	8.43	4.22
5.22	5.35	10.57	5.28	5.85	5.52	11.37	5.69
5.15	4.40	9.55	4.78	6.87	6.38	13.25	6.63

Table 67.

Table 67. Uptake of phosphate (in mgm) by perennial straw + KNO_3 and blood compost at three levels of each

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	4.93	5.65	10.58	5.29	5.84	5.93	11.77	5.89
FS_I+KN	6.62	6.13	12.75	6.38	7.87	8.59	16.46	8.23
FS_{II}+KN	3.58	3.43	7.01	3.51	5.82	5.87	11.69	5.85
FS_{III}+KN	2.75	1.60	4.35	2.18	4.11	4.21	8.32	4.16
BD_I	5.09	5.46	10.55	5.28	5.86	6.11	11.97	5.99
BD_{II}	5.65	5.37	11.02	5.51	7.17	6.89	14.06	7.03
BD_{III}	7.91	6.23	14.14	7.07	8.45	8.07	16.52	8.26
KN	8.61	9.02	17.63	8.82	7.46	6.58	14.04	7.02

ryegrass grown in Wilwood soil of pH 6.2 treated with treatment.

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
4.07	3.19	7.26	3.63	4.10	3.67	7.77	3.89
7.87	7.23	15.10	7.55	6.99	7.36	14.35	7.18
7.86	6.01	13.87	6.94	6.54	6.32	12.86	6.43
5.63	5.77	11.40	5.70	6.81	7.12	13.93	6.97
6.24	6.82	13.06	6.53	6.61	7.44	14.05	7.03
9.91	9.75	19.66	9.83	5.80	5.09	10.89	5.45
9.32	7.83	17.15	8.58	8.91	8.68	17.59	8.80
5.13	6.18	11.31	5.66	8.63	9.47	18.10	9.05

Table 68.

Table 68. Uptake of phosphate (in mgm) by perennial straw + KNO_3 and blood compost at three levels of each

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	4.67	5.73	10.40	5.20	9.29	7.54	16.83	8.42
FS_I+KN	6.21	5.10	11.31	5.66	11.02	10.41	21.43	10.72
FS_{II}+KN	2.74	2.74	5.48	2.74	6.17	6.19	12.36	6.18
FS_{III}+KN	2.09	3.26	5.35	2.68	4.10	5.56	9.66	4.83
BD_I	5.38	4.95	10.33	5.17	8.47	7.74	16.21	8.11
BD_{II}	5.31	6.55	11.86	5.93	9.72	7.35	17.07	8.54
BD_{III}	7.85	6.74	14.59	7.30	11.12	8.56	19.68	9.84
KN	8.55	6.45	15.00	7.50	6.96	5.05	12.01	6.01

ryegrass grown in Silwood soil of pH 7.2 treated with treatment.

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
3.94	3.44	7.38	3.69	5.14	3.67	8.81	4.41
7.00	7.62	14.62	7.31	6.41	7.96	14.37	7.19
3.87	3.49	7.36	3.68	5.22	4.22	9.44	4.72
4.93	8.12	13.05	6.53	6.28	7.27	13.55	6.78
7.49	6.04	13.53	6.77	8.20	8.12	16.32	8.16
6.63	5.92	12.55	6.28	4.98	5.91	10.89	5.45
9.68	9.56	19.24	9.62	6.66	5.93	12.59	6.30
5.00	4.82	9.82	4.91	7.73	6.78	14.51	7.26

Table 69.

Table 69. Uptake of Potassium (in mgm) by perennial straw + KNO_3 and blood compost at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	15.52	12.85	28.38	14.19	11.80	11.20	23.00	11.50
FS_I+KN	31.93	31.42	63.35	31.68	16.37	16.97	33.34	16.67
FS_{II}+KN	26.00	28.66	54.66	27.33	13.63	13.26	26.89	13.45
FS_{III}+KN	18.83	16.56	35.39	17.70	8.29	9.50	17.79	8.90
BD_I	17.44	19.85	37.29	18.65	12.33	12.25	24.58	12.29
BD_{II}	21.80	26.25	48.05	24.03	11.60	11.97	23.57	11.79
BD_{III}	27.12	28.69	55.81	27.91	11.25	13.62	24.87	12.44
KN	48.14	47.65	95.79	47.90	22.70	19.93	42.63	21.32

ryegrass grown in Silwood soil of pH 5.2 treated with

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
7.46	6.57	14.03	7.02	5.31	5.49	10.80	5.40
10.15	8.72	18.87	9.44	11.61	6.64	18.25	9.13
11.78	11.60	23.38	11.69	11.90	12.71	24.61	12.31
10.32	10.56	20.88	10.44	14.22	9.93	24.15	12.08
8.18	8.88	17.06	8.53	5.26	4.99	10.25	5.13
9.10	9.08	18.18	9.09	4.95	5.45	10.40	5.20
9.86	8.89	18.75	9.40	6.85	7.67	14.52	7.26
10.98	9.08	20.06	10.03	8.20	7.85	16.05	8.03

Table 70.

Table 70. Uptake of K (in mgm) by perennial ryegrass and blood compost at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	10.17	11.39	21.56	10.78	5.78	6.66	12.44	6.22
FS_I+KN	27.75	29.80	57.55	28.78	15.17	15.97	31.14	15.57
FS_{II}+KN	15.92	19.64	35.56	17.78	16.30	14.72	31.02	15.51
FS_{III}+KN	14.71	7.77	22.48	11.24	12.25	12.31	24.56	12.28
BD_I	13.64	13.43	27.07	13.54	8.78	8.79	17.57	8.79
BD_{II}	17.61	16.30	33.91	16.96	9.71	7.71	17.42	8.71
BD_{III}	27.36	20.42	47.78	23.89	11.86	9.44	21.30	10.65
KN	32.99	34.70	67.69	33.85	14.92	12.57	27.49	12.25

grown in Silwood soil of pH 6.2 treated with straw + KNO_3

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
4.18	3.63	7.81	3.96	2.86	1.84	4.70	2.35
12.23	14.01	26.24	13.13	6.77	7.81	14.58	7.29
13.66	14.40	28.06	14.03	7.97	9.07	17.04	8.52
16.65	17.78	34.43	17.22	9.22	9.02	18.24	9.12
8.74	9.04	17.78	8.89	4.03	4.05	8.08	4.04
10.86	9.91	20.77	10.39	4.83	2.83	7.66	3.83
14.94	11.50	26.44	13.22	6.08	5.40	11.48	5.74
8.29	7.37	15.66	7.83	6.64	8.02	14.66	7.33

Table 71

Table 71. Uptake of K (in mgms) by perennial ryegrass and blood compost at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	13.34	11.01	24.35	12.18	8.39	6.95	15.34	7.67
FS_I+KN	29.39	27.63	57.02	28.51	19.78	16.54	36.32	18.16
FS_{II}+KN	14.84	15.48	30.32	15.16	15.47	17.01	32.48	16.24
FS_{III}+KN	10.57	15.86	26.43	13.22	12.06	14.98	27.04	13.52
BD_I	16.15	15.17	31.32	15.66	10.27	9.85	20.12	10.06
BD_{II}	19.37	20.46	39.83	19.92	12.88	10.26	23.14	11.57
BD_{III}	28.69	23.09	51.78	25.89	24.71	18.13	42.84	21.42
KN	40.38	32.75	73.13	36.57	14.34	11.66	26.00	13.00

grown in Silwood soil of pH 7.2 treated with straw + KNO_3

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
4.76	3.20	7.96	3.98	3.57	1.54	5.11	2.56
12.41	13.30	25.71	12.86	6.16	6.82	12.98	6.49
13.01	11.28	24.29	12.15	8.09	6.05	14.14	7.07
16.81	24.75	41.56	20.78	6.85	8.51	15.36	7.68
8.82	8.26	17.08	8.54	4.20	3.36	7.56	3.78
11.80	8.65	20.45	10.23	2.63	3.12	5.75	2.88
15.71	13.53	29.24	14.62	4.66	2.87	7.53	3.77
6·99	7·27	14·26	7·13	3·22	3·95	7·17	3·59

Table 72.

Table 72. Uptake of Mg (in mgms) by perennial ryegrass and blood compost at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	1.17	1.36	2.53	1.27	2.69	2.72	5.41	2.71
FS_I+KN	1.24	1.43	2.67	1.34	2.74	2.92	5.66	2.83
FS_{II}+KN	2.11	1.83	3.94	1.97	2.21	1.61	3.82	1.91
FS_{III}+KN	1.22	1.01	2.23	1.12	1.02	1.13	2.14	1.07
BD_I	1.55	1.41	2.96	1.48	2.75	2.89	5.64	2.82
BD_{II}	1.52	1.93	3.45	1.73	2.74	3.04	5.78	2.89
BD_{III}	1.32	1.43	2.75	1.38	2.85	3.43	6.28	3.14
KN	2.96	2.40	5.36	2.68	1.99	1.38	3.37	1.69

grown in Silwood soil of pH 5.2 treated with straw + KNO_3

3rd Cutting				Root *			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
1.19	1.14	2.33	1.17				
1.29	1.09	2.38	1.19				
1.87	1.69	3.56	1.78				
1.64	1.21	2.85	1.48				
1.37	1.29	2.66	1.33				
1.37	1.41	2.78	1.39				
1.62	1.80	3.42	1.71				
1.03	0.94	1.97	1.48				

* Negligible amounts in roots.

Table 73.

Table 73. Uptake of Mg (in mgm) by perennial ryegrass and blood compost at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	1.88	2.00	3.88	1.94	1.78	1.31	3.09	1.55
FS_I+KN	2.29	2.59	4.88	2.44	2.74	2.89	5.63	2.82
FS_{II}+KN	1.11	0.99	2.10	1.05	2.65	2.54	5.19	2.60
FS_{III}+KN	0.69	0.55	1.24	0.62	1.83	1.42	3.24	1.62
BD_I	1.82	1.70	3.52	1.76	2.34	2.67	5.01	2.51
BD_{II}	2.41	2.11	4.52	2.26	2.95	2.77	5.72	2.86
BD_{III}	4.52	3.17	7.69	3.85	3.42	2.83	6.25	3.13
KN	3.25	4.51	7.76	3.88	2.77	2.80	5.57	2.79

grown in Silwood soil of pH 6.2 treated with straw + KNO_3

3rd Cutting				Root *			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
1.11	0.83	1.94	0.97				
1.62	1.72	3.34	1.67				
2.14	2.03	4.17	2.09				
1.51	1.42	2.93	1.47				
1.66	1.73	3.39	1.70				
1.91	1.98	3.89	1.95				
2.25	1.58	3.83	1.92				
1.13	1.19	2.32	1.16				

* Negligible amounts found in roots.

Table 74.

Table 74. Uptake of Mg (in mgm) by perennial ryegrass and blood compost at three levels of each.

Treatments	1st Cutting				2nd Cutting			
	R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
C	2.10	2.42	4.52	2.26	2.36	2.24	4.60	2.30
FS_I+KN	2.76	3.56	6.32	3.16	4.80	3.92	8.72	4.36
FS_{II}+KN	1.15	0.96	2.11	1.06	3.13	3.05	6.18	3.09
FS_{III}+KN	0.52	1.00	1.52	0.76	1.45	2.14	3.59	1.80
BD_I	2.63	1.92	4.55	2.28	3.19	3.25	6.44	3.22
BD_{II}	2.99	3.51	6.50	3.25	3.75	3.27	7.02	3.51
BD_{III}	4.98	3.11	8.09	4.05	4.94	3.63	8.57	4.29
KN	4.77	3.39	8.16	4.08	2.66	2.10	4.76	2.38

grown in Silwood soil of pH 7.2 treated with straw + KNO_3

3rd Cutting				Root			
R_1	R_2	Total	Mean	R_1	R_2	Total	Mean
1.43	1.18	2.61	1.31				
1.77	1.93	3.70	1.85				
1.75	1.75	3.50	1.75				
1.49	1.88	3.37	1.69				
2.42	2.04	4.46	2.23				
2.81	2.37	5.18	2.59				
2.95	2.64	5.59	2.80				
1.32	1.30	2.62	1.31				

Table 75.

Table 75. Cumulative uptake of N, P, K, Mg by perennial treated with straw + KNO_3 and blood compost at three

Treatments	Nitrogen (N) (in mgms)			Phosphate (P_2O_5) (in mgms)		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	8.85	18.13	25.13	6.30	14.80	19.42
FS_I+KN	11.14	20.74	27.41	6.71	13.57	18.23
FS_{II}+KN	9.70	17.77	26.71	6.23	12.07	16.47
FS_{III}+KN	6.43	11.37	18.35	3.58	7.08	10.15
BD_I	9.58	17.90	25.12	6.62	14.13	19.18
BD_{II}	12.62	22.85	30.65	7.48	15.20	20.14
BD_{III}	11.85	23.09	30.98	8.81	16.26	21.54
KN	23.10	36.95	43.35	10.54	19.64	24.42

ryegrass (tops only) grown in Silwood soil of pH 5.2 levels of each.

Potassium (K) (in mgms)			Magnesium (Mg) (in mgms)		
1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
14.19	25.69	32.71	1.27	3.98	5.15
31.68	48.35	57.79	1.34	4.17	5.36
27.33	40.78	52.47	1.97	3.88	5.66
17.70	26.60	37.04	1.12	2.19	3.67
18.65	30.94	39.47	1.48	4.30	5.63
24.03	35.82	44.91	1.73	4.62	6.01
27.91	40.35	49.75	1.38	4.52	6.23
47.90	69.22	79.25	2.68	4.37	5.85

Table 76.

Table 76. Cumulative uptake of N, P, K, Mg by perennial treated with straw + KNO_3 and blood compost at three

Treatments	Nitrogen (N) (in mgms)			Phosphate (P_2O_5) (in mgms)		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	7.08	14.58	20.51	5.29	11.18	14.81
FS_I+KN	12.35	23.66	33.16	6.38	14.61	22.16
FS_{II}+KN	6.46	17.36	29.48	3.51	9.36	16.30
FS_{III}+KN	3.42	9.65	19.35	2.18	6.34	12.04
BD_I	8.25	17.61	27.45	5.28	11.27	17.80
BD_{II}	9.45	20.48	30.65	5.51	12.54	22.37
BD_{III}	12.29	24.06	36.13	7.07	15.33	23.91
KN	17.01	24.64	31.18	8.82	15.84	21.50

ryegrass (tops only) grown in Silwood soil of pH 6.2 levels of each.

Potassium (K) (in mgms)			Magnesium (Mg) (in mgms)		
1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
10.78	17.00	20.96	1.94	3.49	4.46
28.78	44.35	57.47	2.44	5.26	6.93
17.78	33.29	47.32	1.05	3.65	5.74
11.24	23.52	40.74	0.62	2.24	3.71
13.54	22.33	31.22	1.76	4.27	5.97
16.96	25.67	36.06	2.26	5.12	7.07
23.89	34.54	47.76	3.85	6.98	8.90
33.85	46.10	53.93	3.88	6.67	7.83

Table 77.

Table 77. Cumulative uptake of N, P, K, Mg by perennial treated with straw + KNO_3 and blood compost at three

Treatments	Nitrogen (N) (in mgms)			Phosphate (P_2O_5) (in mgms)		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	9.66	18.01	23.53	5.20	13.62	17.31
FS_I+KN	15.08	27.26	36.52	5.66	16.38	23.69
FS_{II}+KN	7.58	18.52	24.83	2.79	8.97	12.65
FS_{III}+KN	5.42	11.41	21.02	2.68	7.51	14.04
BD_I	13.09	24.94	34.89	5.17	13.28	20.05
BD_{II}	15.67	31.78	42.80	5.93	14.47	20.75
BD_{III}	16.41	30.19	43.61	7.30	17.14	26.76
KN	21.85	32.30	39.05	7.50	13.51	18.42

ryegrass grown in Silwood soil of pH 7.2 levels of each.

Potassium (K) (in mgms)			Magnesium (Mg) (in mgms)		
1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
12.18	19.85	23.83	2.26	4.56	5.87
28.51	46.67	59.53	3.16	7.52	9.37
15.16	31.40	43.55	1.06	4.15	5.90
13.22	26.74	47.52	0.76	2.56	4.25
15.66	25.72	34.26	2.28	5.50	7.73
19.92	31.49	41.72	3.25	6.76	9.35
25.89	47.31	61.93	4.05	8.34	11.14
36.57	49.57	56.70	4.08	6.46	7.77

Table 78.

Table 78. Total dry matter yield of tops, of roots, of tops + KNO_3 and blood compost at three levels of each.

	Soil pH 5.2							
	Total N (Tops+ roots)	Total P_2O_5 (Tops+ roots)	Total K (Tops+ roots)	Total Mg (Tops+ roots)	Top yield	Root yield	Top+ root yield	Top/ Root ratio
C	41.8	25.3	38.1	5.14	2.081	1.200	3.281	1.7
FS_I+KN	43.9	23.0	67.0	5.36	2.414	1.408	3.822	1.7
FS_{II}+KN	47.9	22.7	64.8	5.66	2.236	1.653	3.888	1.4
FS_{III}+KN	36.7	14.9	49.2	3.61	1.508	1.411	2.919	1.1
BD_I	43.3	23.7	44.6	5.63	2.280	1.252	3.531	1.8
BD_{II}	45.7	24.4	50.2	6.01	2.481	1.096	3.576	2.3
BD_{III}	55.7	27.3	57.0	6.23	2.314	1.481	3.795	1.6
KN	69.4	31.1	87.3	5.35	3.429	1.772	5.201	1.9

+ roots of total N, total P_2O_5, total K, total Mg uptake by ryegrass grown in Silwood soil treated with straw

Soil pH 6.2							
Total N (Tops+ roots)	Total P_2O_5 (Tops+ roots)	Total K (Tops+ roots)	Total Mg (Tops+ roots)	Top yield	Root yield	Top + Root yield	Top/ Root Ratio
37.0	18.7	23.3	4.46	1.987	0.936	2.923	2.1
59.0	29.4	64.8	6.93	3.173	2.243	5.416	1.4
57.1	22.7	55.9	6.73	2.425	1.607	4.032	1.5
41.8	19.0	49.9	3.71	1.888	1.345	3.232	1.4
51.2	24.8	35.3	5.96	2.477	1.528	4.005	1.6
50.5	27.8	39.9	7.07	2.548	1.513	4.061	1.7
70.4	32.7	53.5	8.89	3.020	2.050	5.070	1.5
60.1	30.5	67.8	7.83	3.425	2.322	5.746	1.5

Soil pH 7.2							
Total N (Tops+ roots)	Total P_2O_5 (Tops+ roots)	Total K (Tops+ roots)	Total Mg (Tops+ roots)	Top yield	Root yield	Top+ root yield	Top/ Root Ratio
41.7	21.7	26.4	5.87	2.394	1.306	3.700	1.8
62.6	30.9	66.0	9.37	3.551	2.369	5.920	1.5
44.1	17.3	50.6	5.90	2.348	1.546	3.894	1.5
40.8	20.8	55.2	4.24	2.130	1.601	3.731	1.3
59.6	28.2	38.0	7.73	3.075	1.884	4.959	1.6
63.5	26.2	44.6	9.35	3.20	1.512	4.707	2.1
69.4	33.1	65.7	11.13	3.693	2.067	5.759	1.8
67.9	25.7	60.3	7.77	3.494	2.016	5.510	1.7

Table 79.

Table 79. Percentage recovery of added N, P, K, Mg from different pH.

	Percentage recovery of added Nitrogen (N)			Percentage recovery of added Phosphate (P_2O_5)		
	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2.	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2
FS_I+KN	4.7	49.2	46.7	-44.2	205.8	176.9
FS_{II}+KN	9.5	31.2	3.7	-25.0	38.5	-42.3
FS_{III}+KN	-4.9	4.62	0.9	-50.0	1.4	-4.3
BD_I	3.0	28.0	35.3	-25.6	97.6	104.0
BD_{II}	3.8	13.3	21.5	-7.2	72.8	36.0
BD_{III}	6.9	16.5	13.7	8.0	56.0	45.6
KN	110.4	92.4	104.8			

Percentage recovery of added Potassium (K)			Percentage recovery of added Magnesium (Mg)		
Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2
53.0	76.2	72.7	6.4	71.6	101.5
24.5	29.9	22.2	7.5	18.4	0.4
5.1	12.2	13.2	-11.1	-5.4	11.8
65.0	120	116	13.5	41.4	51.3
60.5	83	91	12.0	36.0	48.0
47.3	75.5	98.3	7.52	30.6	36.3
KN 71.3	64.5	49.1			

Table 80.

Table 80. The order of yields due to different treatment treatments. Bottom half of table: blood compost vs.

	Top Yield			Root Yield			Top+Root Yield		
	pH 5.2	pH 6.2	pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2
KN	1	1	1	1	1	1	1	1	1
FS_I+KN	2	1	1	23	1	1	2	2	1
FS_{II}+KN	2	2	2	12	2	3	2	3	3
FS_{III}+KN	3	3	2	23	2	3	3	4	3
C	1	3	3	2	3	2	2	3	3
BD_I	1	2	2	12	2	1	12	2	2
BD_{II}	1	2	2	2	2	2	1	2	2
BD_{III}	1	1	1	1	1	1	1	1	1

Treatments with a common number in the

(1>2>3>4). Top half of table: straw + KNO_3 vs. KNO_3 control treatments.

Total N uptake			Total P_2O_5 uptake			Total K uptake			Total Mg Uptake		
Soil pH			Soil pH			Soil pH			Soil pH		
5.2	6.2	7.2	5.2	6.2	7.2	5.2	6.2	7.2	5.2	6.2	7.2
1	1	1	1	1	2	1	1	12	1	1	1
23	1	1	2	1	1	2	1	1	1	12	1
2	1	2	2	2	3	2	12	2	1	2	2
3	2	2	3	3	3	3	2	2	2	3	2
2	3	2	1	3	3	3	3	3	1	3	3
2	2	1	1	2	2	23	2	2	1	23	2
2	2	1	1	2	2	2	2	2	1	2	2
1	1	1	1	1	1	1	1	1	1	1	1

Column are not significantly different.

CHAPTER VI

The effects of straw and compost on the performance of ryegrass in a calcareous soil with:

(a) Nitrogen as the only limiting nutrient, and

(b) Phosphorus as the only limiting nutrient.

(i) Introduction

(ii) Experimental

(iii) Results

(iv) Discussion

(v) Summary and Conclusion

Introduction.

The pot experiments described in previous chapters were done with a soil adjusted to varying pH levels before treatment. All the pH levels used represented unsaturation or just saturated soil (pH 7.2) and there is a possibility that differences due to treatment may well have been due to differences in pH induced by the varying treatments.

It was decided therefore to carry out an experiment with a calcareous soil, which, by virtue of the buffering effect of the free calcium carbonate present, would eliminate any differences in pH induced by the treatments. Only two nutrients were studied, namely, nitrogen and phosphorus, and the experiment was done in such a way that only nitrogen or only phosphorus was limiting.

Experimental.

Details of the calcareous soil used are given in Chapter II (the soil was obtained from a garden in South London). Texturally it is a sandy loam and contained 0.76% free calcium carbonate. The details ofthe pot experiments were as described in the previous two chapters except that the soil was mixed with an equal weight of acid-washed sand (this mixture will hereinafter be referred to as the soil). The straw and four different composts were added at the 1% level, being mixed with the soil before this was placed in the pots. The ryegrass seed was sown and the soils were moistened. After emergence the following nutrients were applied in solution:

Nitrogen limiting: A basal dose of 50 lb. nitrogen per acre was supplied as potassium nitrate to all pots including the control. This was done to ensure that at least some growth of ryegrass would be obtained, since it was considered that if nitrate was not added ryegrass yields might be so poor, particularly with the straw treatment, that insufficient material would be available for analysis. KH_2PO_4 (100 lb. P_2O_5 per acre) was applied to ensure that phosphorus was not limiting; half of this was applied after emergence and half after the first cutting. The potassium supplied in the KNO_3 and KH_2PO_4 was reckoned as being sufficient to ensure that this element would not be limiting. Previous work with this

soil (113, 114) showed that it was very well supplied with both magnesium and sulphate, so that these major elements were not added. Trace elements were not added since "field" experience of this soil has indicated that these were not limiting.

Phosphorus limiting: Nitrogen was added at the rate of 150 lb. per acre in the form of potassium nitrate (100 lb being added after emergence and 50 lb. after the first cutting) to all pots including the control.

The ryegrass was sown on 10th June, 1961 and the three cuttings were made 64, 125 and 215 days after sowing. Roots were separated from the soil after the final cutting. The cuttings and roots were handled and analysed as described in Chapter IV.

Results.

The tables and figures derived from the results are summarized below:

Dry matter yields of the three cuttings and roots are shown in Table 102 for the phosphorus-limiting and in Table 103 for the nitrogen-limiting test.

P_2O_5 percentage in the three cuttings and roots are shown in Table 104 for the phosphorus-limiting test and N percentage in the three cuttings and roots in Table 105 for the nitrogen-limiting test.

Uptake of P_2O_5 (dry matter yields x P_2O_5 percentage) in the three cuttings and roots are shown in Table 106 for the P-limiting test and corresponding uptake of nitrogen for the nitrogen-limiting test in Table 107.

For the phosphorus-limiting test total dry matter yields of the combined tops and total P_2O_5 uptake by the combined tops are shown in Table 108. This table also shows the percentage recovery of applied nutrients in the three cuttings and roots arranged cumulatively and also shows top/root dry matter ratios.

For the nitrogen-limiting test total dry matter yields of the combined tops and total nitrogen uptake by the combined tops are shown in Table 109. This table also shows percentage recovery of applied nitrogen and top/root dry matter ratios.

The above tables will be found at the end of this chapter. Tables 110-123 relating to statistical treatment of the results, will be found in the appendix.

For the phosphorus-limiting test Fig. 29 shows the cumulative dry matter yields of the three cuttings, Fig. 30 shows P_2O_5 percentage in each cutting, and Fig. 31 shows the cumulative P_2O_5 uptake in the cuttings.

For the nitrogen-limiting test Fig. 32 shows the cumulative dry matter yields of the three cuttings, Fig. 33 shows the nitrogen percentage in each cutting, and Fig. 34 shows the cumulative nitrogen uptake in the cuttings.

The above figures will also be found at the end of this chapter.

Phosphorus-limiting test.

Dry matter yields of the combined tops decreased in the order:

GG SG BD NC FS C

Thus the grass and sludge composts gave the highest yields which were significantly better than all other treatments (including the control), between which there were no significant differences.

Dry matter root yields decreased in the order:

GG FS SG BD NC C

PLATE 7.

Comparative growth of perennial ryegrass grown in Calcareous soil phosphate limiting (-P) and nitrogen limiting (-N), in the treatments - control (C), straw (FS-1%) and nitrochalk compost (NC-1%), blood compost (BD-1%), sludge compost (SG-1%) and grass compost (GG-1%). is shown.

Photograph was taken before the 1st cutting when the plants were 60 days old from the date of sowing.


CONTROL (-P)
FS 1%
SG 1%
NC
GG 1%
BD
KN


CONTROL (-N)
FS 1%
SG 1%
NC 1%
GG 1%
BD 1%
KN

Only the grass and sludge composts and the straw treatment gave significantly higher yields than the control.

Total dry matter yields (combined tops and roots) decreased in the order:

GG SG FS BD NC C

Only the grass and sludge compost treatments increased yields over the control.

Total uptake of phosphorus by the combined tops and roots decreased in the order:

SG GG FS NC BD C

Thus the sludge compost produced the greatest phosphorus uptake followed by the grass compost. The straw and nitrochalk and blood compost also increased total phosphorus significantly.

Fig. 29 shows that with the exception of the straw treatment cumulative dry matter yields of tops tended to be parallel with the control; the straw treatment resulted in proportionately less dry matter yield in the first than in the last cutting. A comparison of Fig. 29 with Fig. 31 (showing cumulative phosphorus uptake in the three cuttings) shows a very similar trend with respect to treatments in both dry matter yields and phosphrus uptake. Fig. 30 shows that P_2O_5 percentage for all treatments except straw and nitrochalk compost was higher in the second than in the first and

FIG. 29

CUMULATIVE TOP YIELD

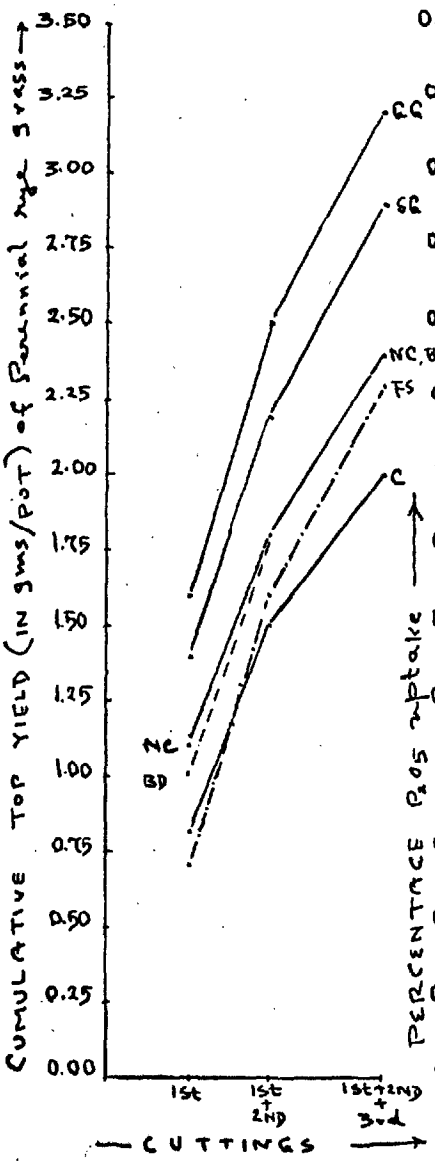


FIG. 30

P_2O_5 Percentage in each cutting

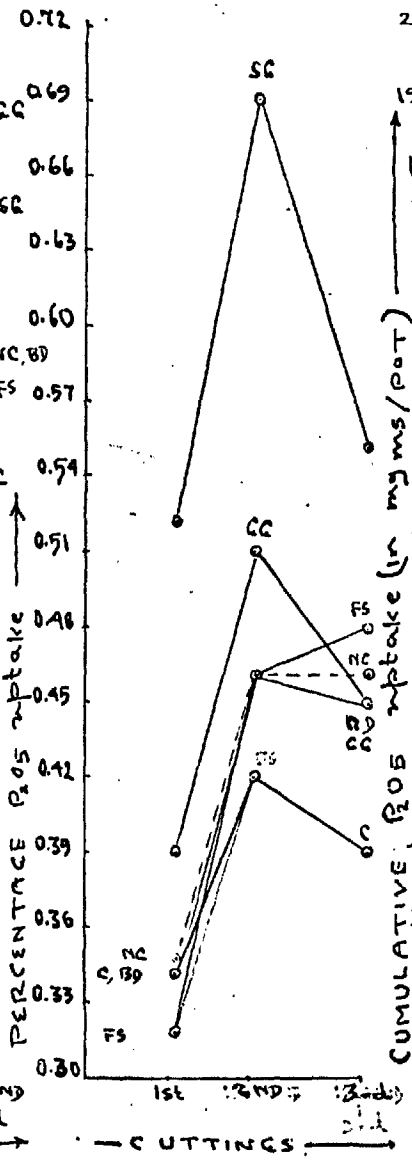
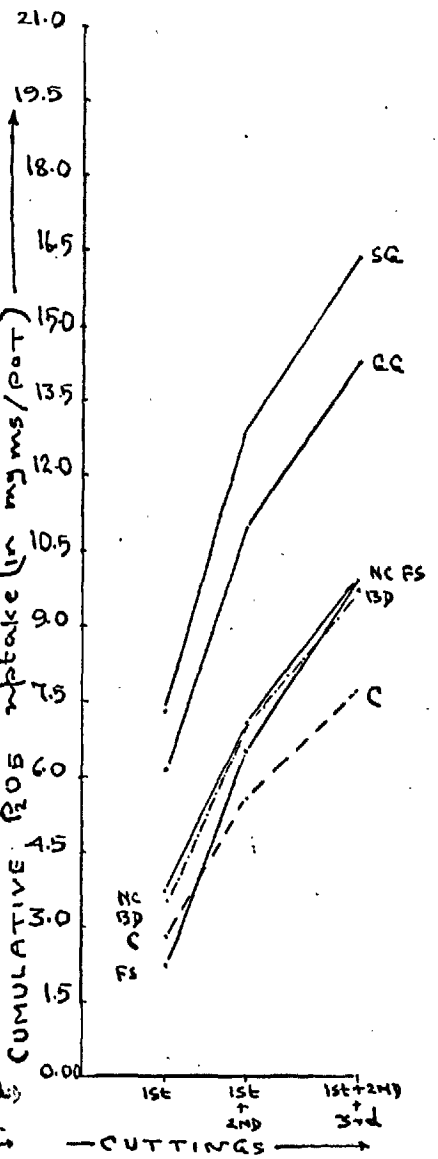


FIG. 31

CUMULATIVE P_2O_5 uptake



PERENNIAL RYE GRASS IN CALCAREOUS SOIL

(P- LIMITING)

third cuts and was also higher in the third than in the first cuts for all treatments.

There were little differences in dry matter top/root ratios (Table 108) between the treatments, including the control, except for the straw treatment, which resulted in a lower top/root ratio than did the others.

The values for percentage recovery of applied phosphorus showed that in the first cutting there was a positive recovery of phosphorus with all treatments except straw, which, during the growth period upto the first cut had caused immobilization of native soil phosphorus. By the second cutting however even the straw resulted in positive recovery of applied phosphorus. Final recoveries were highest from straw and grass compost and then decreased in the order nitrochalk compost, blood compost and sludge compost.

Nitrogen-limiting test.

Dry matter yields of the combined tops decreased in the order:

GG BD SG NC C FS

Thus it is seen that all treatments except straw produced higher yields than did the control; there were no differences in results between the four composts.

Dry matter root yields decreased in the order:

SG GG BD NC FS C

PLATE 8A.

Comparative growth of perennial ryegrass grown in calcareous soil phosphate limiting (-P) and nitrogen limiting (-N) in the treatments - control (C), straw (FS-1%) and blood compost (BD-1%).

Photograph was taken before the 1st cutting when the plants were 60 days old.


CONTROL
+N -P
CONTROL
-N +P


FS
1%
+N -P
FS
1%
-N +P


BD
1%
+N -P
BD
1%
-N +P

There were no significant differences in results between the four composts, all of which exceeded the control; straw did not produce significantly different root yields from the cnntrol.

The combined dry matter yields of top and roots decreased in the order:

GG SG BD NC C FS

Thus the four composts produced the same effect and were significantly greater than the control, whilst straw was not significantly different from the control.

Total uptake of nitrogen (combined tops + roots) decreased in the order:

SG GG BD NC C FS

Thus sludge and grass composts resulted in significantly greater uptake of nitrogen than did nitrochalk compost, whilst blood compost was not significantly different from the other composts. All composts caused significantly greater nitrogen uptake than did straw and the control.

Cumulative dry matter production in the three cuttings (Fig. 32) was approximately parallel for all treatments except grass compost, where proportionately less dry matter was produced, compared with the other treatments, in the final cutting. All treatments, except grass compost caused proportionately greater dry matter production than in the

FIG. 32

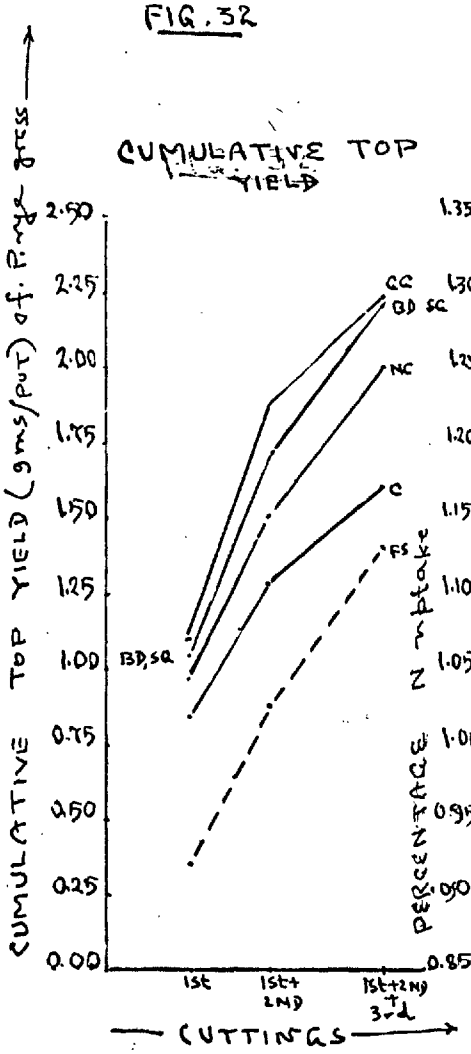


FIG. 33

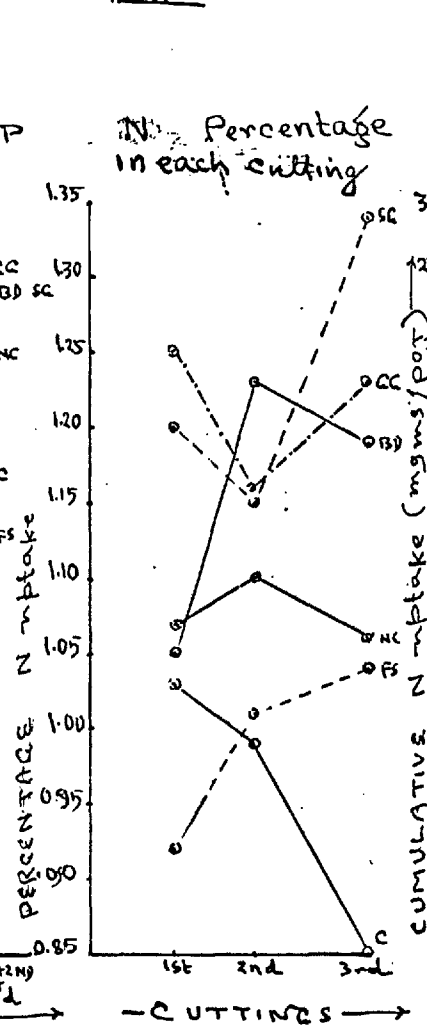
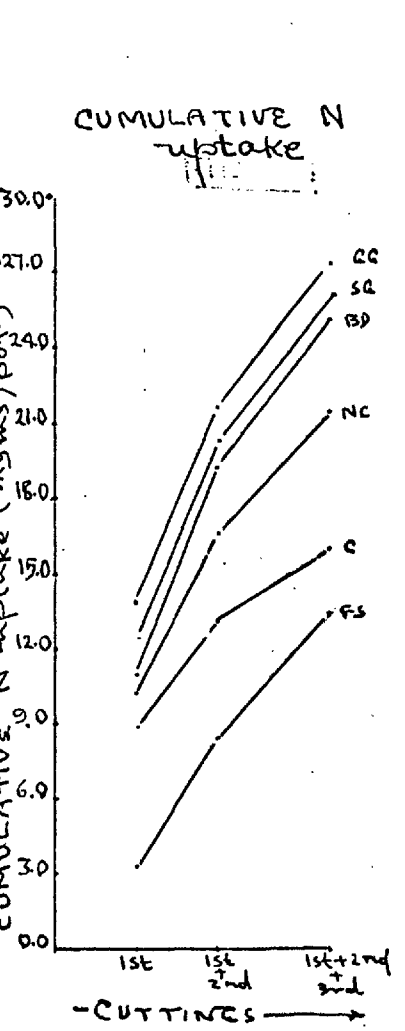


FIG. 34



PERENNIAL RYE GRASS IN CALCAREOUS SOIL

(N LIMITING)

control in the final cutting. The straw treatment resulted in much reduced dry matter production in the first cutting compared with the control, but by the final cutting total dry matter yields were not significantly different from the control.

Nitrogen percentage was less in the second than in the first and third cutting for sludge and grass composts (Fig. 33), but was greatest in the second cutting for the blood and nitrochalk composts. Nitrogen percentage in the control decreased and in the straw treatment increased with successive cuttings.

Cumulative nitrogen uptake (Fig. 34) by the successive cuttings paralleled that of cumulative dry matter yields (Fig. 32). Nitrogen uptake in the first cutting was much less for the straw treatment than with the control, but by the final cutting total nitrogen uptake was similar for both.

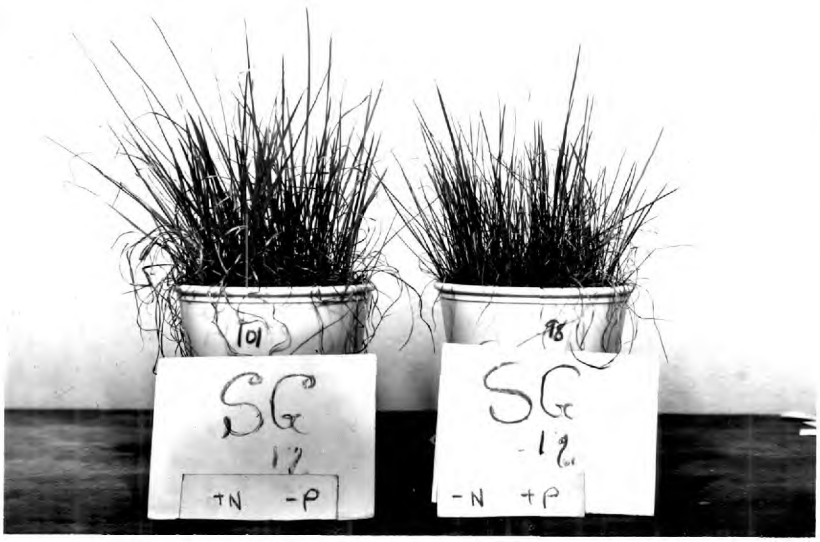
Dry matter top/root ratios (Table 109) were not greatly different between the treatments, including the control, except for the straw treatment where top/root ratio was rather low.

Values for the percentage recovery of applied nitrogen from the added organic materials (Table 109) (and this does not include the nitrate-nitrogen added) were negative for the straw treatment with all cuttings and even by the end

PLATE 8B.

Comparative growth of perennial ryegrass grown in calcareous soil P-limiting (-P) and N-limiting (-N) in the treatments - nitrochalk compost (NC-1%), sludge compost (SG-1%) and grass compost (GG-1%). is shown. Photograph was taken before the 1st cutting when the plants were 60 days old.


NC
+N -P 1%
NC
-N +P 1%


101
SG
1%
+N -P
98
SG
1%
-N +P


106
GG
+N -P 1%
GG
-N +P 1%

of the test. Nitrogen recovery from the four composts was very similar at all stages though there was a tendency for recovery from nitrochalk and blood composts to be somewhat lower than from sludge and grass composts in the first cutting.

PLATE 9.

Comparative growth of perennial ryegrass grown in calcareous soil P-limiting (-P) and N-limiting (-N) in the treatments - control (C), straw (FS-1%), sludge compost (SG-1%) and blood compost (BD-1%), grass compost (GG-1%). is shown.

Photograph was taken before the 3rd cutting when the plants were 90 days old after the 2nd cutting.


CONTROL (-P)
FS
SC
NC
GG
BD
KN


CONTROL (-N)
FS
SC
NC
GG
BD
KN

Discussion.

In the phosphorus-limiting test dry matter yields and total phosphorus uptake were positively related to the P percentage of the materials applied. Thus when all nutrients except phosphorus were applied in adequate amounts the availability of phosphorus was related to the phosphorus content of the materials. Soil treated with all materials showed a rate of organic phosphorus mineralization in excess of that of the control and this applied particularly to the two materials containing the highest P percentage, namely the sludge and grass composts.

The efficiency of utilization of the phosphorus from the various materials, as shown by recovery of the phosphorus from the materials, varied considerably and was not related to the P percentage of the materials. Thus highest recoveries were obtained from grass compost and straw, the former having the second highest and the latter the lowest phosphorus content; the sludge compost, having the highest phosphorus content, showed the lowest recovery of phosphorus. This indicates that much of the phosphorus present in the sludge compost was unavailable to ryegrass. This is probably related to the fact that the sewage sludge used to prepare this compost was high in iron, this iron having been derived from the iron salts added to the digested sludge to aid filtration. The iron had probably locked up much of

the phosphate as ferric phosphate, which is unavailable to plants. However, in spite of the presence of much of the phosphorus in the sludge compost as ferric phosphate, this material still promoted the greatest uptake of phosphorus in the ryegrass, indicating that the organically bound phosphorus in sludge compost was readily mineralized and, having been mineralized, was available to the plant, and was not immobilized by the free chalk present in the soil. This is confirmed by the high P percentage, particularly in the first and second cuttings of ryegrass, where sludge was applied, as compared with results obtained with the other materials.

The high recovery of phosphorus from the straw is rather surprising in that it might have been expected that the wide carbon/nitrogen ratio of the straw should have resulted in permanent immobilization of at least some of the phosphorus applied in this material. In fact, the negative recovery of phosphorus obtained in the first cutting indicated that immobilization did in fact take place early in the test, but much of this immobilized phosphorus became available to the plant at a later stage. This is confirmed by comparing the cumulative uptake of phosphorus curves for the control and straw-treated soil. Alternatively or in addition the high "apparent" recovery of phosphorus from the straw may have been due to the high biological activity induced by this

treatment, resulting in release of much carbon dioxide, which through formation of carbonic acid, resulted in the dissolution and increased availability of native phosphates such as hydroxyapatites (it is interesting to note that a well-known chemical method (115, 116, 117) of assessing the phosphorus status of calcareous soils involves determining the phosphate dissolved by bubbling carbon dioxide through a soil-water suspension). Thus the high recovery of the phosphorus from the straw may not in fact be real, but due to the indirect effect of the decomposing straw in helping to mobilize native phosphates. This effect can be confirmed only by studying the effect of the addition to soil of straw containing labelled phosphorus.

In the nitrogen-limiting test total uptake of nitrogen by ryegrass was positively correlated with the nitrogen percentage in the composts, whilst the straw treatment had no effect on nitrogen uptake. However, nitrogen uptake was not significantly different between the sludge, grass, and blood compost treatments. Conditions for nitrogen mineralization in the calcareous soil would be ideal, so that nitrogen uptake and growth would be determined largely by the rate of mineralization of nitrogen from the organic materials added. This is confirmed by the close parallel between cumulative dry matter yields and cumulative nitrogen uptake for each treatment. The close parallel between the

cumulative nitrogen uptake curves of the sludge, grass, and blood composts indicates that nitrogen was being mineralized at the same rate, at least in the middle and later part of the test, from all these materials. The nitrogen in the nitrochalk compost mineralized somewhat more slowly than did that in the other composts, but still better than did that in the control.

The straw treatment caused considerable immobilization in the early part of the test, as indicated by the poor nitrogen uptake and low yields in the first cutting when the straw treatment was compared with the control. This immobilized nitrogen, however, eventually became available to the further cuttings of ryegrass, as indicated by the fact that final dry matter yields and total nitrogen uptake were not significantly different between the control and straw treatment. None of the straw-nitrogen became available to the ryegrass, as indicated by the slightly negative recovery of applied nitrogen for this treatment. The increasing availability with time of the initially-immobilized nitrogen due to the grass treatment is shown even more clearly in the way in which nitrogen percentage in the successive cuttings of ryegrass increased with the straw treatment and decreased in the control. The shape of the former curve also indicates that with a longer period

of growth some of the straw-nitrogen may have become available to the ryegrass.

The percentage recovery of nitrogen by the ryegrass from all the composts was very similar ranging from 12.0% to 14.5% of that applied. This indicates that, at least in calcareous soils, there is a general similarity in the extent of availability of the nitrogen from all four materials. These results can be compared with those obtained with soils of three different pH levels described in Chapter IV. At pH 7.2 the recovery of nitrogen was better from blood compost than from the others, whilst at pH 5.2 the reverse was true. This indicates the importance of pH on differential nitrogen availability effects.

The recovery of phosphorus from the composts using the calcareous soils in this study may be compared with phosphorus recovery in the soils of different pH in Chapter IV. In the calcareous soil recovery of phosphorus from the composts was greater for all materials except the blood compost than in the soil of pH 7.2. However, at pH 6.2 phosphorus recovery was greater than in the calcareous soil for the blood compost.

A comparison of the results obtained for the calcareous soil and the soils of the three pH levels described in Chapter IV indicates that whereas with the latter soils lack of nitrogen may in general have been limiting phosphorus uptake, except for the blood compost, lack of phosphorus was not limiting nitrogen uptake by the ryegrass for any of the

composts.

Summary and Conclusions.

Pot tests with ryegrass in a 1:1 mixture of sand and a calcareous soil (0.76%) treated with 1% levels of straw and nitrochalk, blood, sludge and grass composts were carried out. Major elements were added so that one series involved phosphorus and another series involved nitrogen as the only limiting nutrient.

Phosphorus-limiting test.

The total uptake of phosphorus by the combined tops and roots was in the order sludge compost > grass compost > straw = nitrochalk compost = blood compost > control.

Phosphorus percentage in the cuttings was greater in the second than in the first and third cuttings for all treatments except straw and nitrochalk.

Only the grass and sludge composts resulted in total dry matter yields in excess of the control.

The recovery of applied phosphorus was in the order grass compost > straw > nitrochalk compost > blood compost > sludge compost.

Nitrogen-limiting test.

The total uptake of nitrogen was in the order sludge

compost = grass compost = blood compost > nitrochalk compost > control = straw.

Nitrogen percentage in the three successive cuttings of ryegrass increased with the straw treatment, was at a maximum in the second cutting with blood and nitrochalk composts and was at a minimum in the second cutting with sludge and grass compost treatments.

The total dry matter yields were similar with the four composts and were greater for these than for the straw treatment or control.

There was no recovery of nitrogen from straw whilst recovery of nitrogen from the four composts was fairly similar, ranging from 12.0% to 14.5%.

The general conclusions from the phosphorus-limiting test were (a) grass and sludge composts resulted in better performance of ryegrass than did the blood and nitrochalk composts, (b) straw was as satisfactory as were blood and nitrochalk composts, and (c) the apparent utilization of applied phosphorus was best from grass compost and straw and worst from sludge compost.

The general conclusions from the nitrogen-limiting test were (a) grass, sludge and blood composts resulted in better

performance of ryegrass than did nitrochalk compost, (b) straw resulted in poorer performance of ryegrass than did all the compost treatments, but was not inferior to the control, and (c) the apparent utilization of applied nitrogen was very similar from all the composts, whilst none of the straw nitrogen was utilized.

Table 102

Table 103.

Table 102. Top and root yield (in gms) of perennial ryegrass

	1st Cutting					2nd Cutting				
	R_1	R_2	R_3	Total	Average	R_1	R_2	R_3	Total	Average
C	0.894	0.731	0.813	2.438	0.813	0.724	0.609	0.682	2.015	0.672
FS	0.959	0.628	0.521	2.108	0.703	1.099	0.895	0.808	2.802	0.934
NC	1.033	1.070	1.054	3.157	1.052	0.670	0.751	0.824	2.245	0.748
BD	1.024	0.844	1.240	3.108	1.036	0.807	0.645	0.848	2.300	0.767
SG	1.163	1.656	1.364	4.183	1.394	0.942	0.713	0.796	2.451	0.817
GG	1.643	1.615	1.450	4.708	1.569	0.912	0.830	1.084	2.826	0.942

Table 103. Top and root yield (in gms) of perennial ryegrass

	1st Cutting					2nd Cutting				
	R_1	R_2	R_3	Total	Average	R_1	R_2	R_3	Total	Average
C	0.952	0.770	0.833	2.555	0.852	0.492	0.402	0.409	1.303	0.434
FS	0.332	0.413	0.296	1.041	0.347	0.469	0.525	0.602	1.596	0.532
NC	0.896	0.942	1.033	2.871	0.957	0.524	0.567	0.607	1.698	0.566
BD	1.069	1.117	0.949	3.135	1.045	00.745	0.701	0.562	2.008	0.669
SG	0.943	1.243	0.943	3.129	1.043	0.715	0.699	0.614	2.028	0.676
GG	1.000	1.209	1.109	3.318	1.106	0.640	0.736	0.657	2.033	0.678

grown in calcareous soil (P-limiting).

3rd Cutting					Root				
R_1	R_2	R_3	Total	Average	R_1	R_2	R_3	Total	Average
0.552	0.502	0.549	1.603	0.534	1.063	0.880	0.977	2.920	0.913
0.753	0.698	0.657	2.098	0.699	1.505	1.460	1.270	4.235	1.412
0.598	0.578	0.597	1.773	0.591	1.058	1.160	1.371	3.589	1.196
0.566	0.535	0.678	1.779	0.593	1.248	0.971	1.413	3.632	1.211
0.730	0.639	0.610	1.979	0.660	1.487	1.268	1.458	4.213	1.404
0.746	0.720	0.731	2.197	0.732	1.945	1.777	1.455	5.177	1.726
				Total	8.306	7.516	7.944	23.766	

grown in calcareous soil (N-limiting).

3rd Cutting					Root				
R_1	R_2	R_3	Total	Average	R_1	R_2	R_3	Total	Average
0.372	0.289	0.307	0.968	0.323	0.937	0.710	0.844	2.491	0.830
0.419	0.444	0.553	1.416	0.472	0.942	0.912	1.221	3.075	1.025
0.439	0.407	0.522	1.368	0.456	1.071	1.132	1.358	3.561	1.187
0.451	0.473	0.468	1.392	0.464	1.211	1.273	1.250	3.734	1.245
0.438	0.472	0.423	1.333	0.444	1.325	1.525	1.069	3.929	1.310
0.392	0.485	0.498	1.375	0.458	1.268	1.384	1.191	3.843	1.281

Table 104.

Table 105.

Table 104. Pecentage phosphate (P_2O_5) in the topand root

	1st Cutting			2nd Cutting		
	R_I	R_{II}	R_{III}	R_I	R_{II}	R_{III}
C	0.344	0.344	0.344	0.369	0.413	0.463
FS	0.344	0.269	0.344	0.413	0.463	0.513
NC	0.369	0.344	0.344	0.463	0.438	0.463
BD	0.344	0.413	0.275	0.463	0.463	0.463
SG	0.581	0.513	0.463	0.650	0.725	0.700
GG	0.344	0.369	0.463	0.513	0.525	0.488

Table 105. Percentage Nitrogen in the top and root of

	1st Cutting			2nd Cutting		
	R_I	R_{II}	R_{III}	R_I	R_{II}	R_{III}
C	1.00	1.05	1.05	0.98	1.05	0.95
FS	0.84	0.80	1.13	0.93	0.98	1.13
NC	1.13	1.03	1.05	1.01	1.20	1.10
BD	1.06	1.04	1.05	1.20	1.20	1.28
SG	1.18	1.11	1.31	1.20	1.08	1.18
GG	1.19	1.20	1.36	1.13	1.20	1.16

of perennial ryegrass grown in calcarous soil P-limiting.

3rd Cutting			Root		
R_I	R_{II}	R_{III}	R_I	R_{II}	R_{III}
0.344	0.388	0.438	0.275	0.275	0.275
0.437	0.506	0.506	0.275	0.319	0.344
0.438	0.438	0.513	0.369	0.344	0.344
0.463	0.438	0.438	0.319	0.344	0.344
0.513	0.513	0.628	0.388	0.388	0.438
0.438	0.438	0.463	0.344	0.344	0.369

ryegrass grown in calcareous soil N-limiting.

3rd Cutting			Root		
R_I	R_{II}	R_{III}	R_I	R_{II}	R_{III}
0.95	0.74	0.86	0.86	0.95	0.80
1.08	1.08	0.95	0.84	0.90	0.98
1.06	1.06	1.05	1.05	0.95	0.90
1.05	1.08	1.43	1.06	1.00	0.99
1.35	1.11	1.55	1.05	1.08	1.03
1.23	1.26	1.21	0.90	0.90	0.95

Table 106.

Table 107.

Table 106. Total uptake of phosphate (P_2O_5 - in mgms) by

	1st Cutting					2nd Cutting				
	R_I	R_{II}	R_{III}	Total	Average	R_I	R_{II}	R_{III}	Total	Average
C	3.08	2.51	2.80	8.39	2.80	2.67	2.52	3.16	8.35	2.78
FS	3.30	1.69	1.79	6.79	2.26	4.54	4.14	4.15	12.83	4.28
NC	3.81	3.68	3.63	11.12	3.71	3.10	3.29	3.82	10.21	3.40
BD	3.52	3.49	3.41	10.42	3.47	3.73	2.98	3.92	10.64	3.55
SG	6.76	8.50	6.31	21.57	7.19	6.12	5.17	5.57	16.86	5.62
GG	5.65	5.96	6.71	18.32	6.11	4.68	4.36	5.29	14.33	4.78

Table 107. Total uptake of Nitrogen (N - in mgms) by perennial

	1st Cutting					2nd Cutting				
	R_I	R_{II}	R_{III}	Total	Average	R_I	R_{II}	R_{III}	Total	Average
C	99.52	8.09	8.75	26.36	8.78	4.82	4.22	3.89	12.93	4.31
FS	2.79	3.33	3.34	9.46	3.15	4.36	5.14	6.87	16.37	5.46
NC	10.12	9.70	10.84	30.66	10.22	5.29	6.80	6.68	18.77	6.26
BD	11.33	11.62	9.96	32.91	10.97	8.93	8.41	7.19	24.53	8.18
SG	11.13	13.80	12.34	37.27	12.42	8.58	7.55	7.24	23.37	7.79
GG	11.84	14.51	15.08	41.43	13.81	7.23	8.54	7.62	23.39	7.80

perennial ryegrass grown in calcareous soil - P-limiting.

3rd Cutting					Root				
R_I	R_{II}	R_{III}	Total	Average	R_I	R_{II}	R_{III}	Total	Average
1.90	1.95	2.40	6.25	2.08	2.92	2.42	2.69	8.03	2.68
3.29	2.53	3.27	10.09	3.36	4.14	4.66	4.37	13.17	4.39
2.62	2.53	3.06	8.21	2.74	3.90	3.99	4.72	12.61	4.21
2.62	2.34	2.97	7.93	2.64	3.98	3.44	4.86	12.28	4.09
3.74	3.28	3.83	10.85	3.62	5.07	4.92	6.39	17.08	5.69
3.26	3.15	3.38	9.79	3.27	6.69	6.11	5.37	18.17	6.06

ryegrass grown in calcareous soil - N-limiting.

3rd Cutting					Root				
R_I	R_{II}	R_{III}	Total	Average	R_I	R_{II}	R_{III}	Total	Average
3.53	2.14	2.64	8.31	2.77	8.06	6.74	6.75	21.55	7.18
4.53	4.80	5.25	14.58	4.86	7.91	8.21	11.97	28.09	9.36
4.65	4.31	5.48	14.44	4.81	11.25	10.75	12.22	34.22	11.41
4.74	5.11	6.69	16.54	5.51	12.83	12.73	12.38	37.94	12.65
5.91	5.24	6.56	17.71	5.90	13.91	16.58	11.01	41.50	13.83
4.82	6.11	6.02	16.95	5.65	11.41	12.46	11.31	35.18	11.73

Table 108.

Table 108. Cumulative top yield (in gms) and uptake of phosphate by perennial ryegrass grown in calcareous soil

	Top Yield			Cumulative total P_2O_5		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	0.813	1.485	2.019	2.80	5.58	7.66
FS	0.703	1.636	2.336	2.26	6.54	9.90
NC	1.052	1.800	2.391	3.71	7.11	9.85
BD	1.036	1.803	2.396	3.47	7.02	9.66
SG	1.394	2.211	2.871	7.19	12.81	16.43
GG	1.569	2.511	3.243	6.11	10.89	14.16

phosphate (in mgms) and percentage recovery of added P-limiting.

Percentage recovery of added P_2O_5				
1st	1st+2nd	1st+ 2nd+3rd	3 Cuttings +Root	Top/ Root Ratio
				2.1
-51.9	9.2	21.5	38.0	1.7
8.4	14.2	20.3	34.4	2.0
5.4	11.5	16.0	27.4	2.0
6.3	10.5	12.7	17.1	2.0
14.2	22.7	27.9	42.3	1.9

Table 109.

Table 109. Cumulative top yield (in gms) and uptake of nitrogen by perennial ryegrass grown in calcareous soil

	Top Yield			Cumulative total N		
	Cuttings			Cuttings		
	1st	1st+2nd	1st+ 2nd+3rd	1st	1st+2nd	1st+ 2nd+3rd
C	0.852	1.286	1.609	8.78	13.09	15.86
FS	0.347	0.879	1.351	3.15	8.61	13.47
NC	0.957	1.523	1.979	10.22	16.48	21.29
BD	1.045	1.714	2.178	10.97	19.15	24.66
SG	1.043	1.719	2.163	12.42	20.21	26.11
GG	1.106	1.784	2.242	13.81	21.61	27.26

nitrogen (in mgms) and percentage recovery of added N-Limiting.

Percentage recovery of added N				
Cuttings + Root				
1st	1st+2nd	1st+ 2nd+3rd	3 Cuttings +Root	Top/ Root Ratio
				1.9
-14.3	-11.3	-6.1	-3.1	1.3
2.0	4.6	7.4	13.2	1.7
2.2	6.0	8.7	14.0	1.7
3.1	6.1	8.8	14.5	1.7
3.8	6.8	8.6	12.0	1.8

CHAPTER VII

A study of the effects of straw and composts on the growth of and nutrient uptake by two successive crops of wheat.

(i) Introduction

(ii) Experimental

(iii) Results

(iv) Discussion

(v) Summary and Conclusion.

Introduction.

The studies which have been reported in this thesis up to now have been done with ryegrass as the test crop. This species is useful in studying the long-term effects of manurial applications, since successive cuttings of ryegrass may be made and the 'residual' effects of a material may be determined by noting the performance of the later cuts of ryegrass. There is a possibility however that the true residual effects of a manure may be obscured by much of the applied nutrient being locked up in the root system of the grass. In view of this it was decided to carry out a pot experiment using two successive crops of wheat, since this this species does not form an extensive root system and would thus indicate more accurately the residual effects of the organic manures.

Experimental.

The soil used in the pot test was a sandy clay loam (the Harlington soil) of pH 6.2, detailed characteristics of which are given in Chapter II. The organic materials were applied at the 1% rate and the straw treatment received in addition 100 lb. nitrogen per acre as KNO_3. A KNO_3 treatment (50 lb. N per acre) and a control were included. (The treatments were in fact identical with those given in the experiment described in Chapter IV except that the poor compost treatment was excluded). Details of the treatments are given below: (all treatments were in triplicate).

Treatments	Abbreviations	Dose	Actual quantity applied for 500gm soil
Control	C	Nil	Nil
Straw + KNO_3	FS	1%+100 lbs. N/acre	5g straw + 25 mgm N
Nitrochalk compost	NC	1%	5 gm
Blood Compost	BD	1%	5 gm
Sludge compost	SG	1%	5 gm
Grass compost	GG	1%	5 gm
Potassium nitrate	KN	50Ø lbs. N/acre	12.5 mgm N

The first sowing of wheat was made on 16th May, 1961 and the crop was harvested on 11th August. The soil block in each pot was removed, air-dried and broken up to separate

the roots. The soils were then returned to the pots and the second sowing of wheat was made on 26th August and harvested on 2nd November. The first crop gave seed, but unfortunately the second did not, presumably because light was a limiting factor even though the pots were kept in a heated greenhouse.

Where it was formed the seed was separated and tops, roots, and seed were analysed separately.

Results.

The results obtained with the first crop of wheat were rather disappointing in that the yields of seed, tops and roots were lower for all treatments than for the control, with the straw treatments having the greatest deleterious effect in this respect. This was probably due to the fact that the soil was already a rich one with respect to nutrients for wheat growth and the application of all materials tended to be toxic with respect to growth. The results obtained for dry matter yields of and total nutrient uptake by the second wheat crop are of more interest, in that many treatments were superior to the control in these respects. This is fortunate in that the main purpose of this study was of the residual effects of the materials applied. Thus the results obtained will be presented and discussed mainly in relation to the performance of the second crop of wheat. Results obtained with the first crop are however presented, since they form part of the total dry matter yields and nutrient uptake for the combined first and second crops.

Table 124 shows the dry matter yields of tops + roots + seed (where formed) of the first crop, second crop and first + second crop. Also given in the table are the total uptake of nitrogen, phosphorus, potassium and magnesium in each crop and in the combined crops. The nutrient

FIG. 35

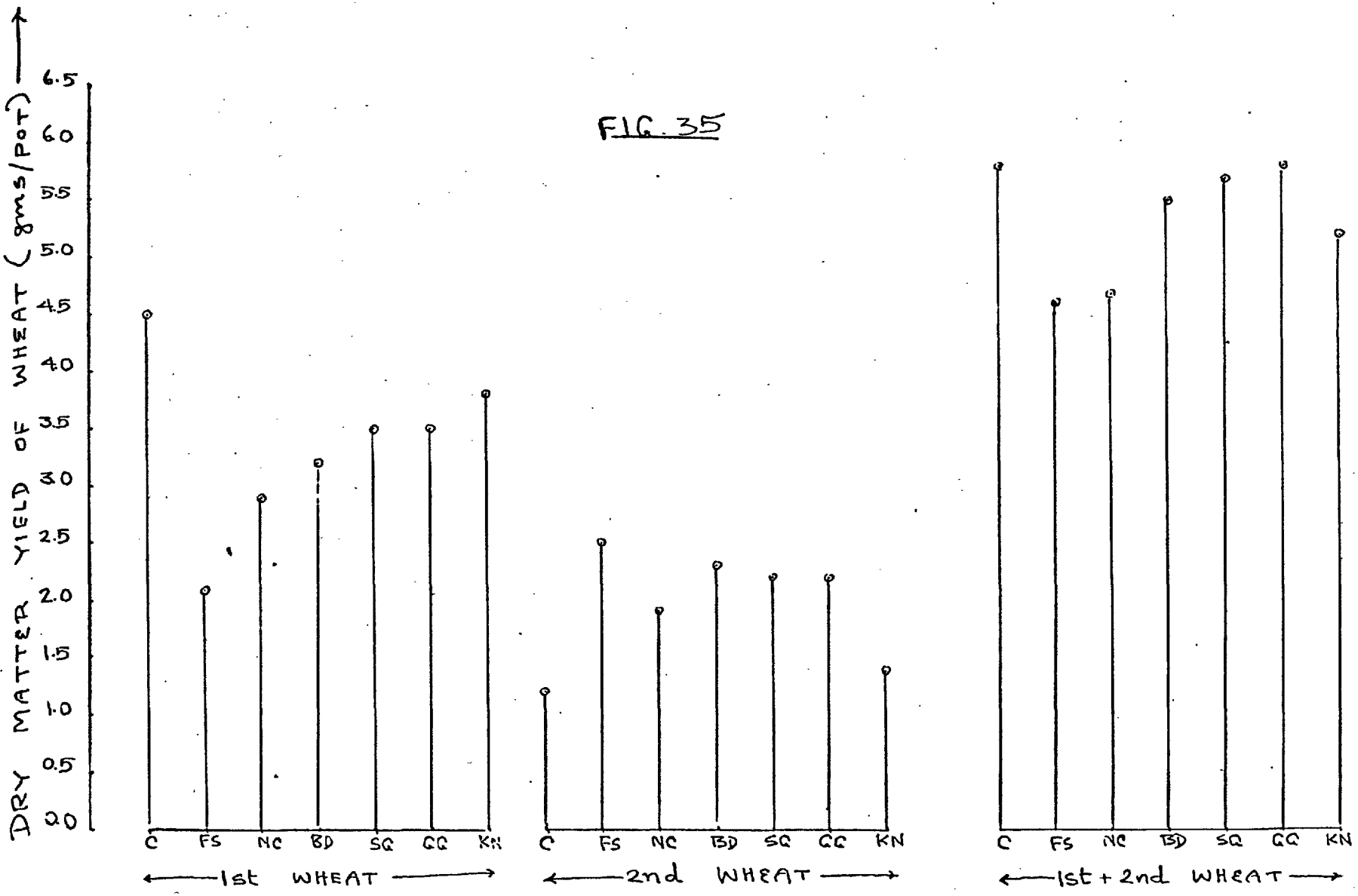

DRY MATTER YIELD OF WHEAT (gms/POT)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
C FS NC BD SQ CC KN
1st WHEAT
C FS NC BD SQ CC KN
2nd WHEAT
C FS NC BD SQ CC KN
1st + 2nd WHEAT

PLATE 10.

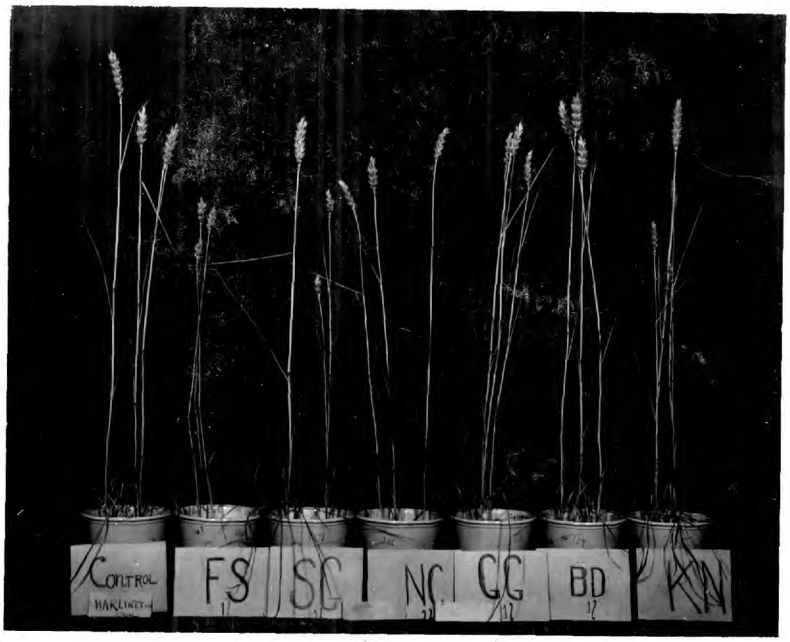
Growth of 1st wheat crop in Harlington soil in the different treatments - control (C), straw (FS-1%), potassium nitrate (KNO_3-50 lbs. N/acre), sludge compost (SG-1%), nitrochalk compost (NC-1%), grass compost (GG-1%), blood compost (BD-1%). is shown.

1st photograph (top to bottom) - was taken when the crop was 42 days old from the date of sowing.

2nd photograph was taken when the crop was 87 days old from the date of sowing.

3rd photograph shows the root growth in different treatments.


CONTROL
FS
KN
SC
NC
GG
BD


CONTROL
FS
SC
NC
GG
BD
KN


CONTROL
FS
NC
BD
SC
KN

percentages in the second crop are also given.

The results are also presented graphically in:

Fig. 35 for dry matter yields

Fig. 36 for total nitrogen uptake

Fig. 37 for total phosphorus uptake

Fig. 38 for total potassium uptake

Fig. 39 for total magnesium uptake

Fig. 40 for the percentage nitrogen, phosphorus, potassium and magnesium in the second crop.

First wheat crop.

As has already been stated all treatments resulted in reduced dry matter yields in comparison with the control. This was due presumably to the presence of excessive available nutrients resulting in a slight toxic effect. It was noted that seedling emergence from all treated pots was slower than that from control pots. In addition, uptake of the four major nutrients was always lower or no better than the control, except for uptake of phosphorus and potassium

---

*Nitrochalk compost produced poorer yields than did the other composts.

Dry matter yields of roots decreased in the order:

BD GG FS SG NC KN C

All treatments except KNO_3 produced greater root yields than did the control.

percentages in the second crop are also given.

The results are also presented graphically in:

Fig. 35 for dry matter yields

Fig. 36 for total nitrogen uptake

Fig. 37 for total phosphorus uptake

Fig. 38 for total potassium uptake

Fig. 39 for total magnesium uptake

Fig. 40 for the percentage nitrogen, phosphorus, potassium and magnesium in the second crop.

First wheat crop.

As has already been stated all treatments resulted in reduced dry matter yields in comparison with the control. This was due presumably to the presence of excessive available nutrients resulting in a slight toxic effect. It was noted that seedling emergence from all treated pots was slower than that from control pots. In addition, uptake of the four major nutrients was always lower or no better than the control, except for uptake of phosphorus and potassium with the KNO_3 treatment.

Second wheat crop.

Dry matter yields of tops decreased in the order:

FS BD SG GG NC KN C

Thus the straw treatment produced the greatest yields, whilst the KNO_3 treatment was no better than the control. *

FIG. 36

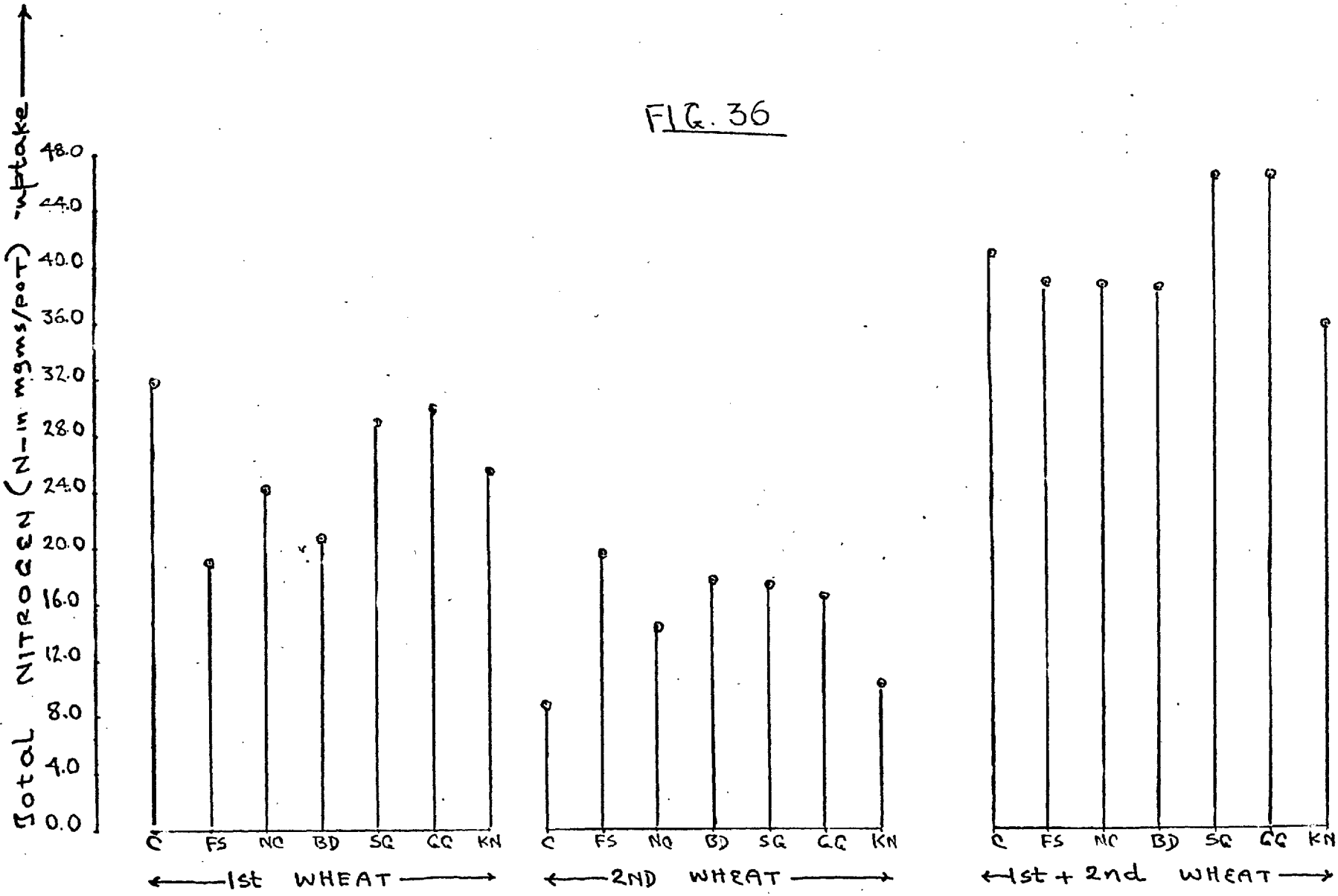

Total NITROGEN (N-in mgms/pot) -uptake
48.0
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
C FS NC BD SC CC KN
1st WHEAT
C FS NC BD SC CC KN
2ND WHEAT
C FS NC BD SC CC KN
1st + 2nd WHEAT

PLATE 11.

Close view of the growth of wheat ears in the treatments - control (C), straw (FS-1%), sludge (SG-1%), nitrochalk (NC), grass (GG), blood (BD) composts and potassium nitrate (KN-50 lbs. N/acre) in Harlington soil when the plants were 87 days old.



C FS SG NC



GG BD KN

Nitrochalk compost and KNO_3 produced poorer root yields than did the other treatments.

Dry matter yields of tops + roots (Fig. 35) decreased in the order:

FS BD GG SG NC KN C

Thus the straw treatment gave higher dry matter yields than all treatments except blood compost. Nitrochalk compost gave the poorest yields of all the composts. KNO_3 was no better than the control.

The total uptake of nitrogen (i.e. in the combined tops and roots) (Fig. 36) decreased in the order:

FS BD SG GG NC KN C

Thus straw resulted in the greatest nitogen uptake, the nitrochalk compost was poorer than the other composts, and KNO_3 was no better than the control.

The total uptake of phosphorus (Fig. 37) decreased in the order:

FS GG BD NC SG KN C

Thus straw and grass and blood compost produced the highest phosphorus uptakes, whilst KNO_3 was no better than the control.

The total uptake of potassium (Fig. 38) decreased in the order:

FS GG BD SG NC KN C

Thus straw resulted in the greatest uptake of potassium, there

FIG. 37

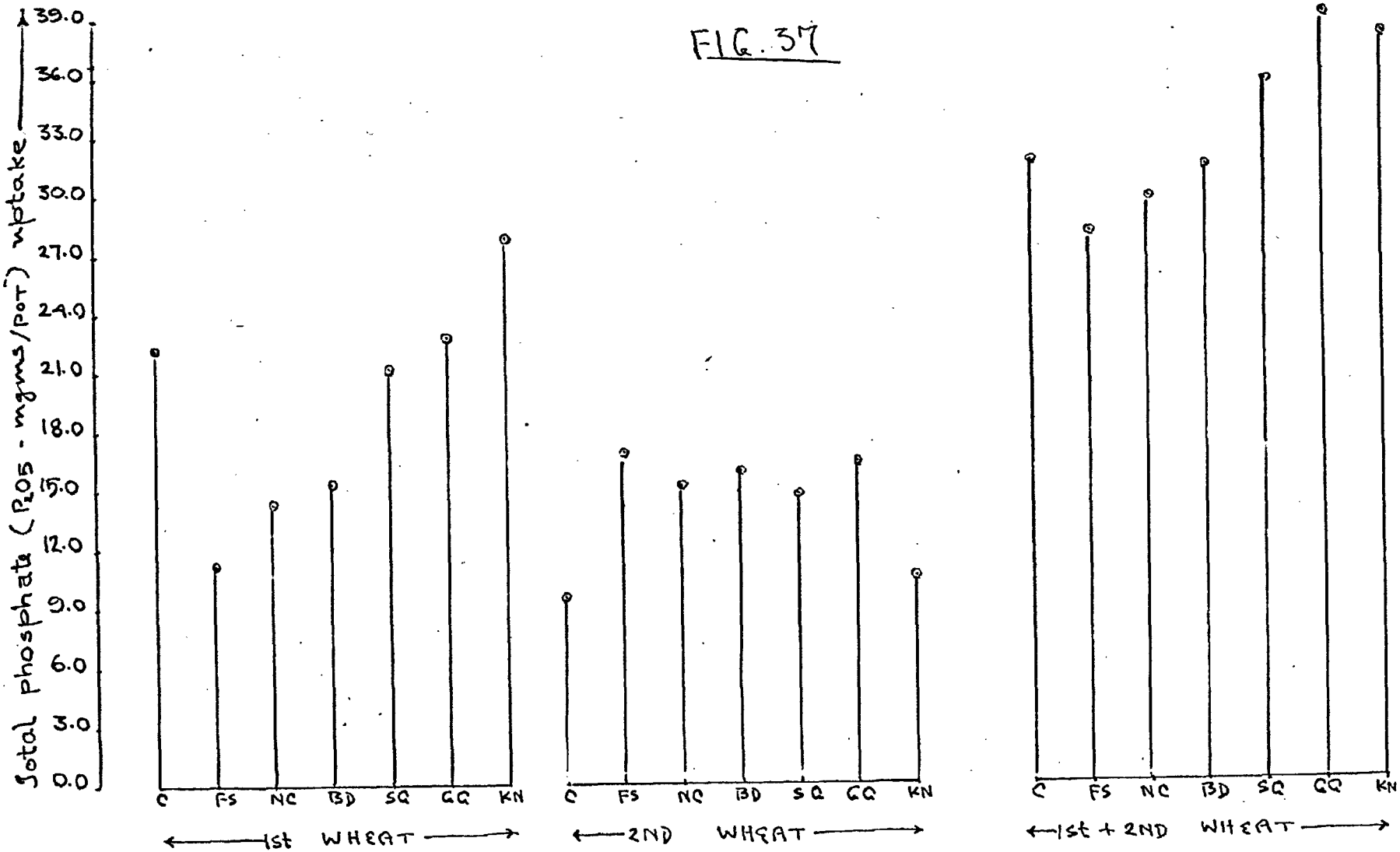

Total phosphate (P_2O_5 - mgms/pot) uptake
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
C FS NC BD SQ GQ KN
1st WHEAT
C FS NC BD SQ GQ KN
2ND WHEAT
C FS NC BD SQ GQ KN
1st + 2ND WHEAT

PLATE 12.

Comparative growth of 2nd wheat crop in Harlington soil in the treatments - control (C), straw (FS-1%), sludge (SG-1%), nitrochalk (NC-1%), grass (GG-1%), blood (BD-1%) and potassium nitrate (IN-50 lbs. N/acre) when the plants were 67 days old from the date of sowing, is shown.


CONTROL
HARLINGEN
FS
SC
NC


GG
HARLINGEN
BD
KN

were no differences between the four composts, and KNO_3 was no better than the control.

The total uptake of magnesium (Fig. 39) decreased in the order:

FS BD SG GG NC C KN

Thus straw and all composts except nitrochalk compost were equally satisfactory in increasing magnesium uptake, whilst nitrochalk compost and KNO_3 were no better than the control.

First plus second crops.

The total dry matter yields in the first + second crops (Fig. 35) decreased in the order:

GG C SG BD KN NC FS

Thus total dry matter yields were no better with the grass and sludge composts than with the control. The other treatments resulted in poorer dry matter yields than did the control.

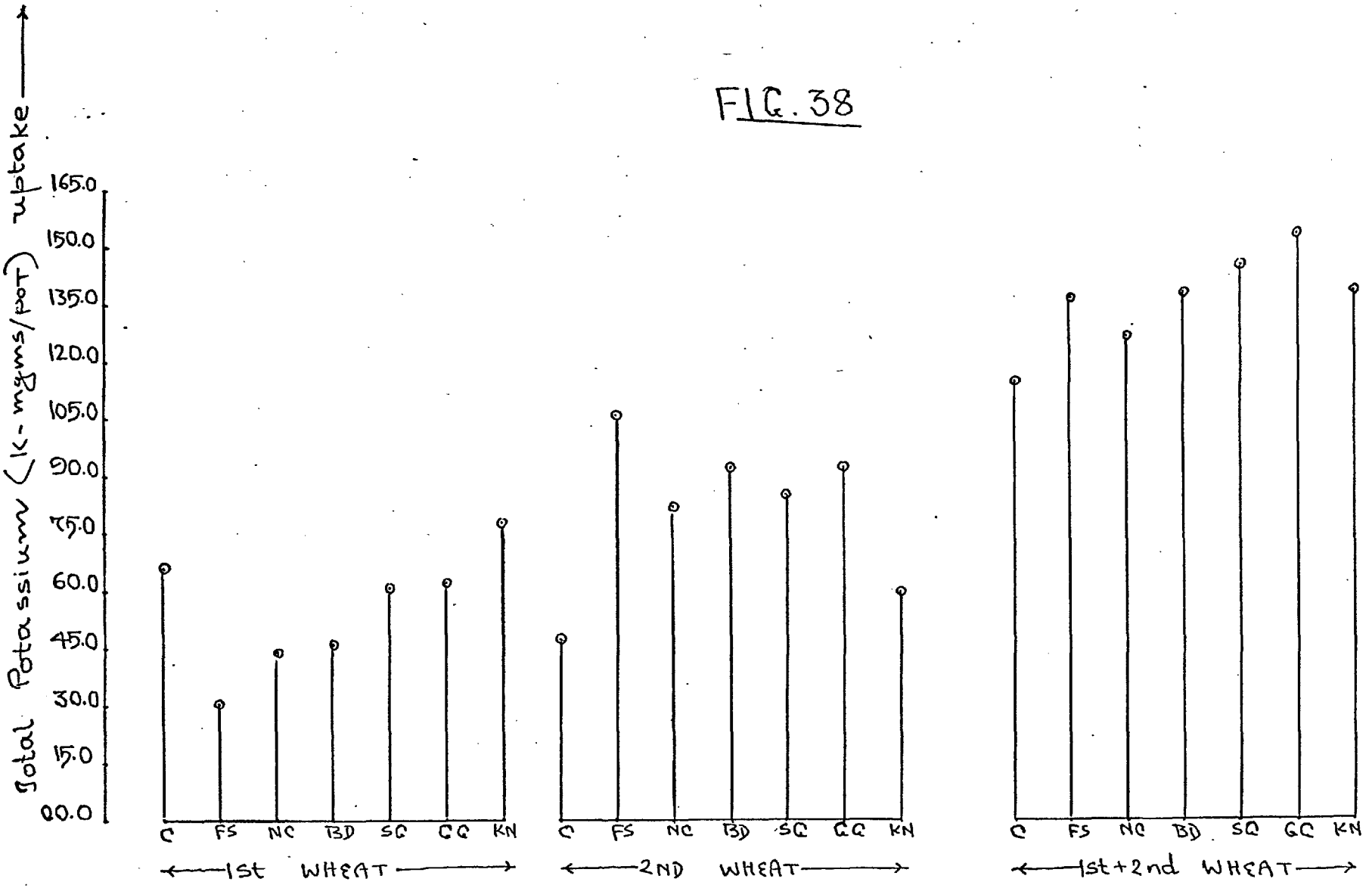
Total nitrogen uptake by the combined crops (Fig. 36) decreased in the order:

GG SG C FS NC BD KN

Thus only the grass and sludge composts resulted in greater nitrogen uptake than did the control, whilst KNO_3 resulted in poorer nitrogen uptake.

Total phosphorus uptake by the combined crops (Fig. 37) decreased in the order: (see next page)

FIG. 38


Total Potassium (K - mgms/pot) uptake
165.0
150.0
135.0
120.0
105.0
90.0
75.0
60.0
45.0
30.0
15.0
00.0
C FS NC BD SQ GQ KN
1st WHEAT
C FS NC BD SQ GQ KN
2ND WHEAT
C FS NC BD SQ GC KN
1st+2nd WHEAT

GG KN SG BD C NC FS

Thus grass compost, KNO_3 and sludge compost were the only treatments which resulted in greater phosphorus uptake than did the control, whilst straw was poorer than the control.

Total potassium uptake by the combined crops (Fig. 38) decreased in the order:

GG SG KN BD FS NC C

Thus all treatments except nitorchalk compost resulted in greater potassium uptake than did the control.

Total magnesium uptake by the combined crops (Fig. 39) decreased in the order:

GG C SG BD KN FS NC

Thus grass and sludge composts resulted in no better magnesium uptake than did the control, whilst all other treatments were poorer than the control.

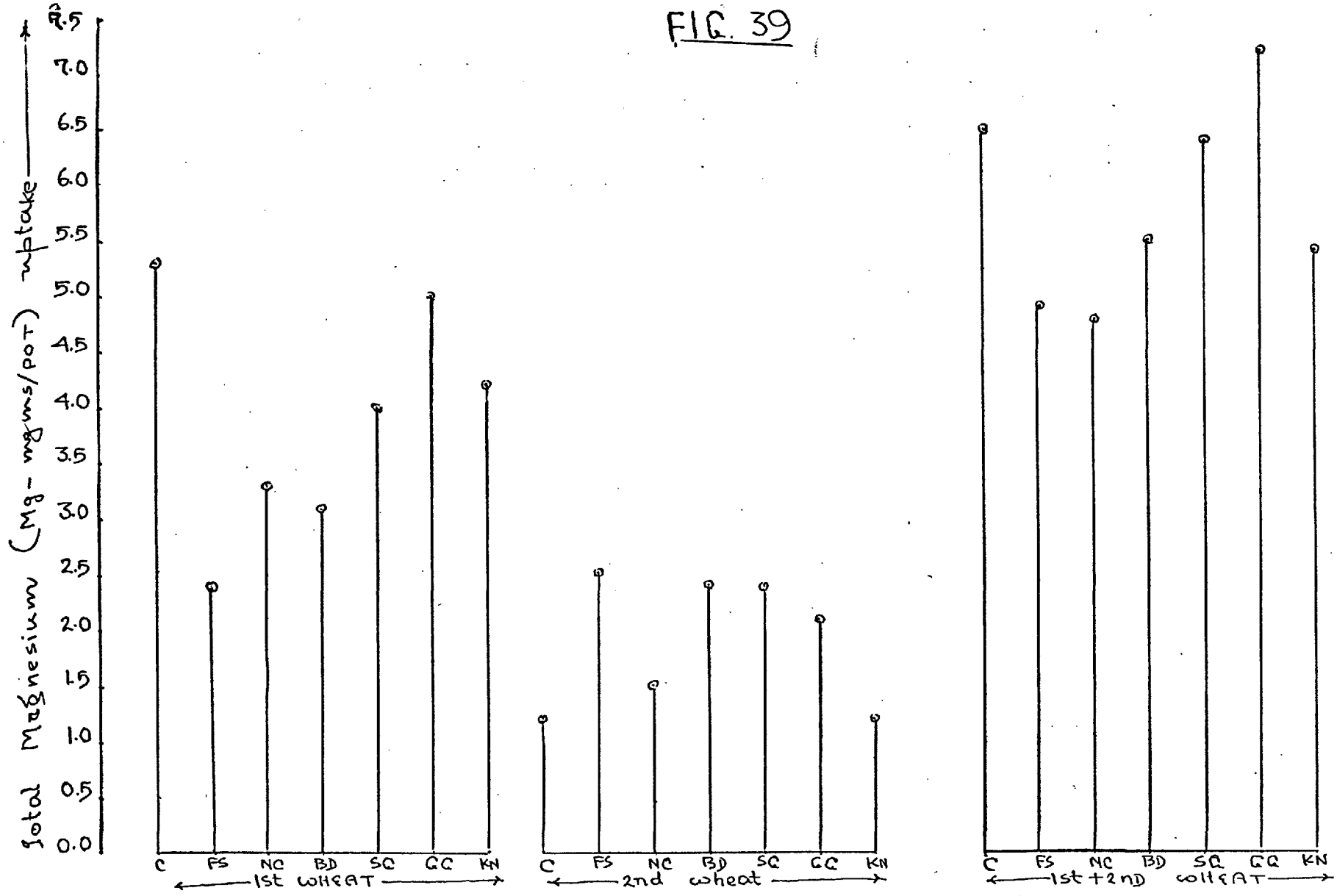
Dry matter top/root ratios in the second crop. (Table 124).

The straw and nitrochalk compost treatments increased the top/root ratio in comparison with the control, the blood and grass composts reduced it, whilst the sludge compost and KNO_3 treatments had little effect.

Nutrient percentages in the combined tops and roots of the second crop.

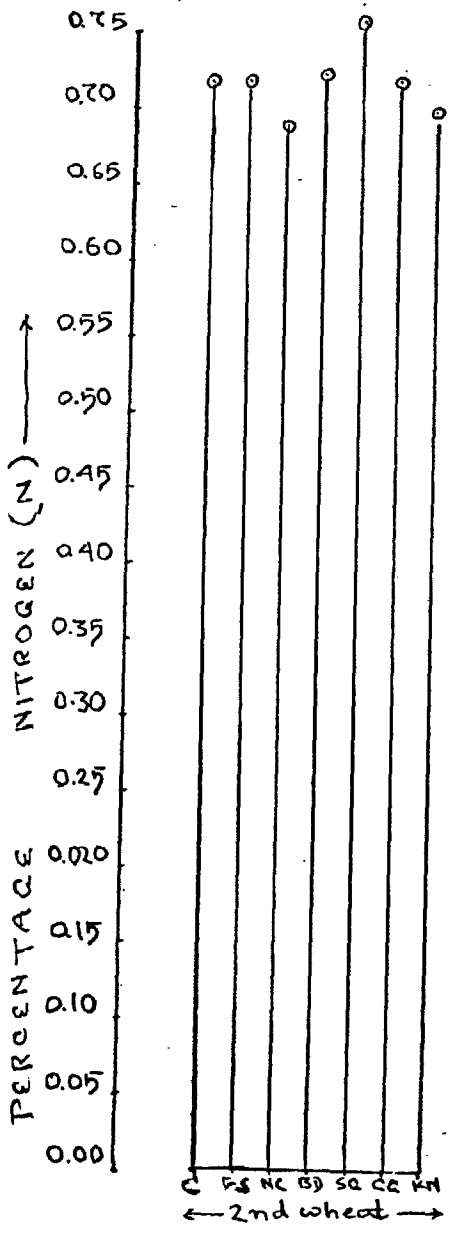
These are illustrated graphically in Fig. 40. There were little differences in nitrogen percentages in the dry

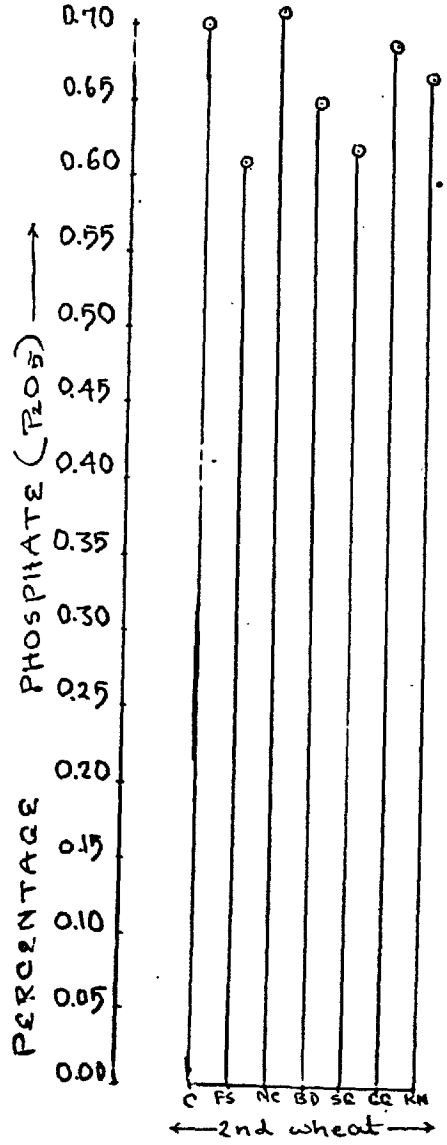
FIG. 39

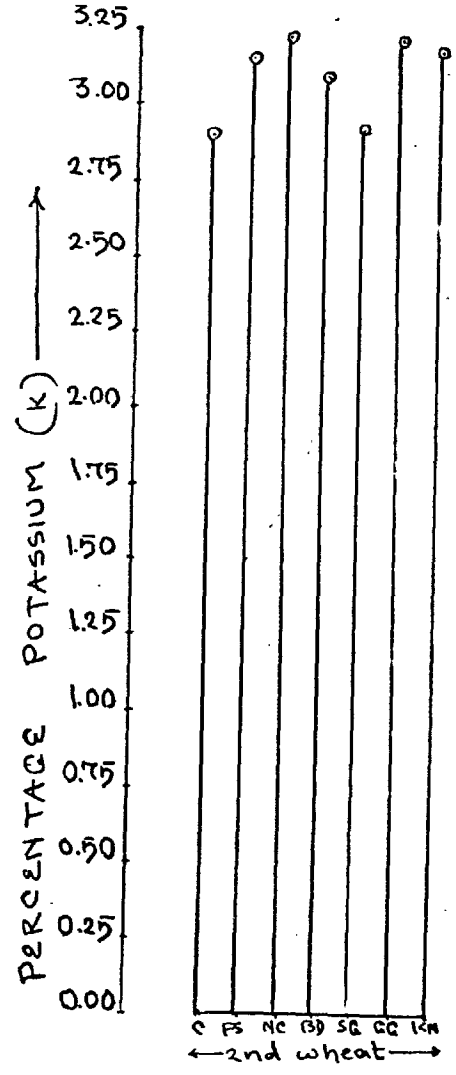

Total Magnesium (Mg - mgms/pot) uptake
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
C FS NC BD SC CC KN
1st wheat
C FS NC BD SC CC KN
2nd wheat
C FS NC BD SC CC KN
1st + 2nd wheat

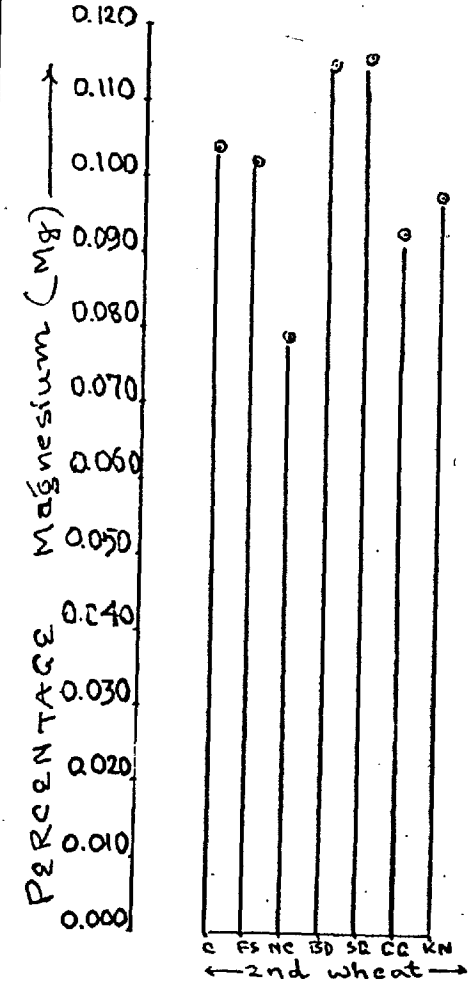
matter due to the treatments. Phosphorus percentage was somewhat lower with the straw and blood and sludge compost than with the other treatments. Potassium percentage was slightly lower with the control and sludge compost treatment than with the other treatments. Magnesium percentage was highest with the blood and sludge composts and lowest with the nitrochalk compost.

FIG- 40


PERCENTAGE NITROGEN (N)
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.020
0.15
0.10
0.05
0.00
C FS NC BD SQ CC KN
←2nd wheat→


PERCENTAGE PHOSPHATE (P_2O_5)
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
C FS NC BD SQ CC KN
←2nd wheat→


PERCENTAGE POTASSIUM (K)
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
C FS NC BD SQ CC KN
←2nd wheat→


PERCENTAGE Magnesium (Mg)
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
C FS NC BD SQ CC KN
←2nd wheat→

Discussion.

The results obtained in this study show clearly the residual effect of the straw (+ KNO_3) treatment as indicated by the response of the second crop of wheat to this treatment. The effect of this treatment in comparison with the control was obvious for dry matter yields as well as for uptake of all four nutrients. The residual effect of this treatment was also greater than that of any of the other treatments, although in some cases the effect of the straw treatment was not significantly different from that of some of the composts.

The poorest residual effect was obtained with the KNO_3 treatment. In fact, this treatment had no residual effect, when compared with results obtained with the control, except for a significant residual effect of potassium. The latter is not surprising in view of the low requirement of wheat for potassium, so that the potassium applied in the KNO_3 was more than adequate for the first crop and thus produced the residual effect.

What was rather surprising was the inability to account for any of the nitrogen in the applied KNO_3; in fact, total nitrogen uptake by the combined crops was significantly less for this treatment than for the control. This indicates that with the KNO_3 treatment the toxic effect evident in the

first crop had persisted, though to a much lesser extent, into the second crop. This seems a more reasonable explanation than that nitrate had been lost by denitrification, since moisture conditions in these soils did not even approach waterlogging.

Whilst the residual effects of the straw treatment were greater than those of all the compost treatments, the overall effect of straw was lower than that of the composts (with the exception of the nitrochalk compost, which gave results rather similar to the straw treatment with respect to overall performance of the two crops). This indicates a net positive immobilization of all nutrients by the straw even though the amount of nitrogen added as KNO_3 with the straw was sufficient to give the added material a carbon/nitrogen ratio of 32 (the only exception to this was for potassium, where the combined uptake from the straw treatment was similar to that from the other composts; this might be expected because of the extra potassium added as KNO_3). The relatively poor residual effects of the nitrochalk compost as well as its poor overall effects, in comparison with the other composts, is most likely due to the high carbon/nitrogen ratio of the nitrochalk compost, i.e. 28, in comparison with the ratios of the other composts, i.e. 12-20.

A comparison of the performance of the grass, sludge and

blood composts showed that although they all had positive residual effects, the extent of these effects were in general similar for all three composts. The overall effects of the materials, however, declined in the order grass compost, sludge compost, blood compost. It is interesting to note that the overall effects of the four composts were correlated with their carbon/nitrogen ratios, i.e. overall performance improved with decreasing carbon/nitrogen ratio.

The similarity in the nitrogen percentage of the dry matter of the second crop due to the different treatments is rather interesting in view of the fair differences in total nitrogen uptake and dry matter yields. This indicates that there should be a close correlation between dry matter yields and total nitrogen uptake and in fact this is the case, as can be seen by comparing Fig. 35 with Fig. 36. Total magnesium uptake was also fairly closely correlated with dry matter yields (cf. Fig. 35 and Fig. 39), whilst magnesium percentage (Fig. 40) was poorly correlated with either factor. Phosphorus percentage was poorly correlated with dry matter yields or total phosphorus uptake (cf. Figs. 35, 37 and 40), although the two latter factors were roughly correlated. Similar results were obtained for potassium (cf. Figs. 35, 38 and 40).

Summary and Conclusions.

Pot tests were carried out with a sandy clay loam (pH 6.2) to study the effects of straw + KNO_3, compost treatments, and KNO_3 on the performance of two successive crops of wheat so as to indicate the residual effects of the materials.

Dry matter yields of and uptake of nutrients by the first crop were less for all treatments than for the control. The straw + KNO_3 had the greatest and the KNO_3 treatment usually the least effect in these respects. This reduced growth was considered to be due to a slightly toxic effect of all materials.

All treatments except KNO_3 showed a residual effect with respect to dry matter yields of and nutrient uptake by the second crop of wheat. The straw treatment was more effective than any of the compost treatments in these respects. Among the composts the residual effects were usually highest for the blood and lowest for the nitrochalk compost, whilst the effects of the grass and sludge composts were intermediate between these two.

The overall effects (i.e. the effects obtained on the first plus second crops) showed that none of the materials increased dry matter yields, whilst only the grass compost increased the total uptake of all nutrients. The sludge

compost was almost as effective as the grass compost, whilst the straw and nitrochalk compost treatment usually reduced nutrient uptake in comparison with the control.

The main general conclusion which may be gained from this study indicates that although straw has a poor effect on the growth of a first crop than have composts or KNO_3, the residual effect of the straw treatment on the succeeding crop is greater than that of any other treatment. However, the overall effect of straw indicates that it has the most deleterious effect of all the treatments. Of the four composts studied the blood compost in general had the greatest and the nitrochalk compost the least residual effect. The greatest overall effect was shown by the grass and sludge composts.

Table 124.

Table

	1st crop (wheat)					2nd crop (wheat)				
	Total yield and uptake					Total yield and uptake				
	Dry matter in gms	N	P_2O_5	K	Mg	Dry matter in gms	N	P_2O_5	K	Mg
			in mgms					in mgms		
C	4.544	31.83	22.17	67.03	5.25	1.207	9.14	9.45	47.21	1.23
FS	2.097	19.14	11.17	30.91	2.40	2.523	19.74	16.81	105.54	2.49
NC	2.873	24.25	14.32	44.08	3.25	1.872	14.41	15.07	82.30	1.51
BD	3.177	20.80	15.32	46.26	3.09	2.318	17.69	15.93	92.04	2.44
SG	3.482	28.92	21.06	61.02	3.99	2.211	17.50	14.77	85.22	2.40
GG	3.542	30.04	22.61	61.80	5.03	2.227	16.57	16.36	92.30	2.13
KNO_3	3.757	25.49	27.66	78.72	4.15	1.430	10.38	10.48	60.00	1.23

124.

1st & 2nd crops (wheat)					Percentage nutrient for 2nd crop (wheat)				Top/Root Ratio 2nd wheat		
Total yield and uptake											
Dry matter in gms	N	P_2O_5	K	Mg	N	P_2O_5	K	Mg	Top	Root	Top/ Root
					in mgms						
5.751	40.97	31.62	114.24	6.48	0.72	0.70	2.99	0.104	0.899	0.308	2.9
4.620	38.88	27.98	136.45	4.89	0.72	0.61	3.16	0.102	1.907	0.616	3.1
4.745	38.66	29.39	126.38	4.76	0.69	0.71	3.24	0.079	1.430	1.430	3.2
5.495	38.49	31.25	138.30	5.53	0.72	0.65	3.10	0.115	1.676	0.642	2.6
5.693	45.42	35.83	146.24	6.39	0.76	0.62	2.93	0.116	1.628	0.583	2.8
5.769	46.61	38.97	154.10	7.16	0.72	0.69	3.21	0.093	1.604	0.623	2.6
5.187	35.87	38.14	138.72	5.38	0.70	0.67	3.19	0.098	1.067	0.363	2.9

CHAPTER VIII

The availability of nitrogen from the organic nitrogenous fraction of composts as determined by a sand culture test with ryegrass, and an incubation test.

(i) Introduction

(ii) Experimental

(iii) Results

(iv) Discussion

(v) Summary anc Conclusion.

Introduction.

The composts used in the experiments so far described in this thesis have contained variable amounts of nitrogen. This is inevitable in view of the differences in the nature of the starting materials as well as the extent to which nitrogen changes occur during composting. In spite of differences in the nitrogen content of different composts a reasonable comparison of the availability of this nitrogen to plants may be obtained from the figures for recovery of applied nitrogen. Thus in Chapter IV it was shown that at least in the soil of pH 7.2 the nitrogen from the blood compost was more available than that from the nitrochalk and sludge compost, whilst that from the grass compost was the least available to ryegrass.

It was considered however that a better comparison of the availability of orgnanic nitrogen from these materials could be obtained if the materials contained initially the same amounts of organic nitrogen. In earlier work in this department when different methods of composting were being studied many types of compost were prepared over some years and these were analysed routinely for nitrogen and carbon. Fortunately it was possible to select from these a sample each of a nitrochalk, blood, sludge and grass compost having very similar values for total, inorganic and organic nitrogen as well as for organic carbon and carbon/nitrogen

ratio. The latter two values were not as similar for the different material as might have been desired, but since their carbon/nitrogen ratios were all well below 20 it was considered that this variable would have little effect. (All these values are given in Table 137). In view of the fair differences in pH between the materials it was decided to carry out the pot experiment in a medium containing free calcium carbonate so as to eliminate these differences. It was also decided to do the experiment in sand culture rather than in soil with all major and trace nutrients supplied except nitrogen. Concurrently with this trial there was carried out an incubation test to asses the extent of mineralization of organic nitrogen. In addition a chemical test (118), based on measuring the amount of ammonia released when the material is treated with N-sodium hydroxide, and which had been shown to be satisfactory for indicating the nitrogen-supplying power of soils, was also used.

It may be mentioned here that an attempt to find composts of different origin containing similar amounts of phosphorus, so that experiments similar to the above could be carried out with respect to phosphorus, was not successful. This is presumable due to the fact that sewage sludges and samples of young grass inevitably contain a relatively high proportion of phosphorus to nitrogen compared with that contained in cereal straws. Thus since composts are normally prepared

by starting off with a certain ratio of carbon to nitrogen, it was inevitable that their phosphorus contents would vary widely.

Table 137.

Table 138.

Table

	1	2	3	4	5	6	7	8
Treat-ments	Total N	% Mineral N	% Org.N	% Org.C	Org. C/N	Soil: water (1:2) pH	Uptake of N (in mgm) by r.grass (top)	Uptake of N in mgm by r.grass (root)
NC	2.902	0.253	2.649	39.4	15.0	6.87	19.0	10.7
BD	3.013	0.270	2.743	40.0	14.6	6.14	31.3	12.0
SG	3.004	0.281	2.723	36.5	13.4	6.06	25.8	11.1
GG	2.940	0.260	2.680	37.8	14.1	6.01	21.2	11.0

Table 138. Total cumulative uptake of N (in mgm) per pot by

Top

Days	10	18	25	31
Treat-ments	Cutting 1	Cuttings 1+2	Cuttings 1+2+3	Cuttings 1+2+3+4
NC	4.35	10.05	15.56	17.28
BD	4.05	16.27	26.92	29.34
SG	4.66	16.44	22.51	24.33
GG	3.71	13.69	18.42	19.89

137.

9	10	11	12	13	14
Uptake of N in mgm by r.grass (top+ root)	Total uptake of N in control pot	Total uptake of N Control N 9-10	Original mineral N in 7g. compost in mgm	organic N taken up (mgm)	% Recovery of organic N
29.7	5.9	23.8	17.7	6.1	3.28
43.3	5.9	37.4	18.9	18.5	9.65
36.9	5.9	31.0	19.7	11.3	5.92
32.2	5.9	26.3	18.2	8.1	4.33
L.S.D. 3 mg					L.S.D. 1.21

ryegrass (top) and also by root.

		Root
38	45	
Cuttings 1+2+3+4+5	Cuttings 1+2+3+4+5+6	
18.41	19.03	10.66
30.63	31.27	12.02
25.30	25.82	11.07
20.70	21.17	11.05

Experimental.

Pot test.

700g. of acid-washed silver sand (which had been shown by Kjeldhal digestion to be free of all forms of nitrogen) was used in each pot. The sand was mixed with 1% by weight of the dried ground composts and 1% by weight of calcium carbonate. The mixtures were placed in plastic pots, each pot was sown with 0.4g. ryegrass seed and the pots moistened with water, containing a mixed inoculum from a field soil and a fresh compost. After emergence all major and trace elements, except nitrogen, were added regularly using the Long Ashton nutrient culture solution (119). All treatments including the control were done in duplicate. The seed was sown on 6th June 1961 and cuttings were made 10, 18, 25, 31, 38 and 45 days from the date of sowing. Yields declined rapidly with successive cuttings and since it was obvious that little further top growth would occur after the last cutting already mentioned the experiment was stopped and the roots removed for analysis. Each cutting and roots were dried and analysed for total nitrogen by Kjeldhal digestion followed by ammonia distillation (the salicylic acid - thiosulphate modification of the Kjeldhal method was used to allow for the presence of nitrate in the plant material). Since the top growth of the controls were so poor no cuttings were taken

from them, and the total uptake of nitrogen by the controls was determined by analysing the combined tops and roots at the end.

Incubation test.

The technique used is described in detail by Cornfield (120) and is briefly as follows: 10g. of a 1:1 mixture of Silwood soil and acid-washed silver sand was treated with 1% of calcium carbonate and 2% of compost. The whole was mixed thoroughly, placed in a test tube and treated with sufficient water (containing an inoculum of soil and compost) to bring the water content to 50% of the water-holding capacity. An appropriate control was also prepared and all treatments were in duplicate. The tubes were plugged with cotton wool and incubated at 28°C for 6 weeks, moisture losses being made up when necessary. The material in the tubes was then extracted with 0.5N-sodium acetate and analysed for ammonia and nitrate (75).

Chemical test for available nitrogen.

This is the method described by Cornfield (118) somewhat modified. 0.1g. of ground compost and 5 ml. N-sodium hydroxide were placed in the outer chamber of the perspex microdiffusion cell and after mixing and incubation for 48 hr. at 28°C the ammonia released was determined by titration of the boric acid in the central chamber.

Results.

The cumulative total nitrogen uptake by the cuttings of ryegrass with the four compost treatments is shown in Fig. 41 and also in Table 138. It is seen that at the first cutting there were no differences due to treatment, but by the second cutting nitrochalk compost resulted in the lowest uptake, grass compost the next lowest, whilst there were no differences in the uptake of nitrogen from the blood and sludge composts. By the third cutting and thereafter, however, blood compost was superior to sludge compost. Total nitrogen uptake by the roots was similar for all treatments, with the blood compost resulting in a slightly higher uptake than the other treatments.

The total nitrogen uptake by the combined cuttings and roots is shown in column 9 of Table 137. Significantly more nitrogen was taken up from the blood than from the sludge compost, which in turn was superior to the grass and nitrochalk composts, between which there was no significant difference with respect to nitrogen availability. If it is assumed that all the mineral nitrogen initially present in the composts was taken up by the ryegrass then it is seen (columns 12 and 13) that in the case of the blood compost about equal amounts of nitrogen were derived by the ryegrass from inorganic and originally organic sources, whilst with the other composts

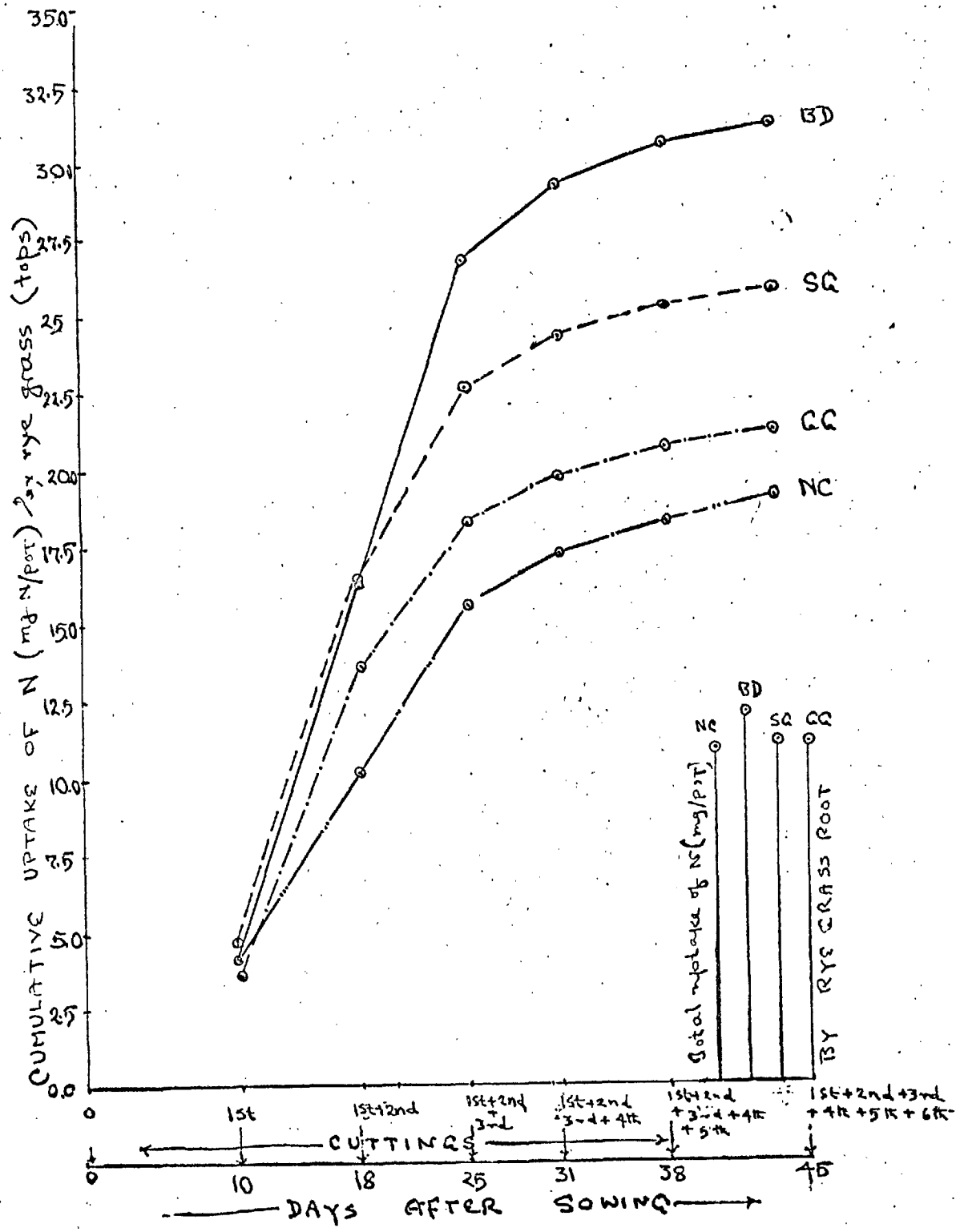

CUMULATIVE UPTAKE OF N (mg N/pot) by rye grass (tops)
350
32.5
30
27.5
25
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
BD
SQ
CC
NC
Total uptake of N (mg/pot) BY RYE GRASS POOT
NC
BD
SQ
CC
0
1st
1st+2nd
1st+2nd +3rd
1st+2nd 3-d+4th
1st+2nd +3-d+4th +5th
1st+2nd+3rd +4th+5th+6th
CUTTING
0
10
18
25
31
38
45
DAYS AFTER SOWING

FIG. 41

about 2-3 times as much of the absorbed nitrogen was derived from the inorganic than from the organic source. The percentage recovery of originally organic nitrogen (column 14) was 9.65 for the blood compost, 5.92 for the sludge compost, 4.33 for the grass compost, and 3.28 for the nitrochalk compost. With the exception of the last two values, these differences were significant.

The mineralization of organic nitrogen during the incubation test expressed as a percentage of the organic nitrogen originally present is shown below, with percentage recovery of organic nitrogen by the ryegrass set alongside for comparison:

	Percentage recovery of organic nitrogen	
	Pot Test	Incubation Test
Nitrochalk compost	3.28	5.7
Blood compost	9.65	15.9
Sludge compost	5.92	7.4
Grass compost	4.33	9.3

It is seen that the same trends are apparent for both tests, except for the sludge and grass composts. Blood compost yielded the highest and nitrochalk compost the lowest amount of their organic nitrogen; in the pot test sludge compost was superior to grass compost whilst in the incubation test the reverse was the case.

The ammonia-nitrogen released in the chemical test expressed as a percentage of the original organic nitrogen is shown below:

Nitrochalk compost	5.26
Blood compost	6.16
Sludge compost	6.78
Grass compost	5.40

The results show only small differences due to type of compost; the sludge compost gave the greatest and the nitrochalk compost the least release of ammonia.

Discussion.

Both the pot and incubation tests have clearly shown wide differences in the "availability" of the organic nitrogen of the different composts, even though these materials contained similar amounts of both total and organic nitrogen (varying by about 3%). It may be argued that differences in results may have been due to differences in carbon/nitrogen ratio which varied by about 10%. However, the blood compost, which had the second highest carbon/nitrogen ratio of the four composts and on this basis might be expected to show a relatively low release of organic nitrogen, in fact showed by far the greatest release. In fact the blood compost released about twice as much of its organic nitrogen as did the sludge and grass composts, and about three times as much as did the nitrochalk compost.

It might be said that the difference between the 3.28% of the organic nitrogen mineralized from the nitrochalk compost and the 9.65% mineralized from the blood compost does not represent a great deal of nitrogen. But it must be borne in mind that organic manures such as compost are supplied at very heavy rates compared with inorganic fertilizers. Thus if 25 tons per acre of compost (25% dry matter) are applied and if field differences are comparable to those obtained in this pot test, the amount of nitrogen supplied from the organic fraction of the blood compost would be 37 lb.

per acre as compared with 12 lb. per acre for the nitrochalk compost. Although this difference is not great when compared with the heavy levels of inorganic nitrogen fertilizers which are frequently applied, it may well be sufficient to make the difference between a good or a mediocre crop, particularly if inorganic nitrogen fertilizer is not applied at the same time as the compost.

The results obtained in the pot test in this chapter may be compared with the recovery of nitrogen from the soil of pH 7.2 in the experiment described in Chapter IV. Both tests indicate that the blood compost is the best of the four composts with regard to ability to yield nitrogen to the growing plant. Both tests also show that the grass compost was a relatively poor supplier of nitrogen and that the sludge compost was intermediate between these two. However the two tests differ in that the sand culture test showed the nitrochalk compost to be a poor supplier of nitrogen whilst the test described in Chapter IV showed it to be as satisfactory as the sludge compost. This difference presumably arises from the fact that the materials used in the test in Chapter IV varied fairly widely in carbon/nitrogen ratio.

The incubation test described in this chapter was a reasonably good indicator of the availability of the organic

nitrogen in the four composts to the ryegrass, being able to distinguish between those materials which were able to supply fairly widely different amounts of their organic nitrogen to ryegrass, but tending to give a somewhat erroneous result in the case of the grass compost; in fact, indicating that the grass compost would yield to ryegrass more of its organic nitrogen than it actually did. This indicates that if the incubation test is to be used as a measure of the availability of the organic nitrogen of composts, results should be treated with caution if the nature of the materials is not known.

The poor correlation obtained between the chemical test and the incubation test is rather surprising in view of the fact that results obtained for these two tests are well correlated when the organic nitrogen of soils are considered (118). This indicates differences in the nature of the organic nitrogen fraction between soils and composts. It might be that if the chemical test is altered in some way (e.g. by altering the concentration of sodium hydroxide used or reducing or increasing the time of contact) it may be made satisfactory for assessing the nitrogen-supplying power of composts.

Summary and Conclusions.

Samples of blood, sludge, grass and nitrochalk composts having very similar nitrogen and carbon contents were selected. Sand culture pot tests (in the presence of excess calcium carbonate) were carried out with these materials to determine the availability to ryegrass of the nitrogen contained in them when all major elements, except nitrogen, and trace elements were supplied in adequate amounts. In addition an incubation test (6 weeks at 28°C) and a chemical test (ammonia released on treating the composts with N-NaOH over 48 hr. at 28°C) were used to determine the nitrogen status of the composts.

In the first cutting of ryegrass there were no differences in nitrogen availability, as measured by total nitrogen uptake by the grass, from the four composts. With further cuttings, however, differences became apparent and at the end of the experiment (45 days from sowing, by which time there was very little top growth) the total nitrogen available from the four composts decreased in the order blood compost, sludge compost, grass compost, and nitrochalk compost. The availability of the original organic nitrogen present the materials decreased in the same order; the blood compost yielded about twice as much of its organic nitrogen as did the sludge compost and about three times as much of its organic nitrogen and did the

nitrochalk and grass composts.

Results obtained with the incubation test were well correlated with those obtained in the pot test except for the respective positions of the sludge and grass composts.

The chemical test was a poor indicator of the availability of nitrogen from the different materials.

The general conclusion from this experiment is that the availability of the nitrogen from the organic fraction of composts is dependent on the nature of the materials used to make the compost, even though the carbon and nitrogen contents of the finished composts may be very similar.

GENERAL DISCUSSION AND CONCLUSIONS.

Organic manures are added to soils with a view to improving soil physical conditions and/or soil nutrient status. The former reason is important for fine-textured soils particularly in that drainage is improved through the ameliorating effect of organic materials on aggregate structure; in coarse-textured soils structure is not of much importance and the main physical function of added organic materials is to improve the water- and nutrient- retaining capacity of the soils. The nutrient-supplying capacity of organic materials is important for soils of all textural grades, but here again there may be differences in nutrient requirements depending on texture; thus coarse-textured soils would usually tend to be more deficient in potassium than would fine-textured soils, whilst the reverse would hold for phosphorus. From these considerations it can be seen therefore that the "ideal" organic material which should be added to a fine-textured soil would be one which could improve aggregate structure and also supply phosphate. For a coarse-textured soil the organic material should be of high water- and nutrient-holding capacity and should be relatively resistant to microbial decomposition in view of the ease with which organic matter is lost by oxidation because of the high aeration of such soils. In addition the organic

material should be able to supply good amounts of potassium.

The work reported in this study has been concerned with only two types of organic material, viz. straw on the one hand and composts on the other and also with only a few effects of the materials mentioned in the above paragraph, viz. carbon retention as affected by pH , soil moisture content and level of added material and the capacity of the materials for supplying four of the major nutrients to ryegrass as affected by pH and level of application.

Although no attempt was made here to study the effects of straw and composts on soil physical properties, the experiments dealing with carbon mineralization and hence of the extent of retention of these materials indicate to what extent the different materials might affect physical properties, since the literature has indicated (5, 6) that physical properties such as aggregation and water-holding properties have improved with soil organic carbon content. In this study compost was retained better than straw whatever the rate of application of the material, providing the soil was not water logged and also providing that pH was not too low, i.e. less than about 6. Greater retention of both materials occurred under waterlogged than under aerobic conditions and also under acid (pH 5.2) than under less acid conditions (pH 6.2 and 7.2). Under waterlogged conditions only small amounts of

both straw and compost were decomposed, indicating high retention of these materials. This is of little practical significance in view of the fact that structure in a water-logged soil is of no importance, and in fact it would appear that aggregate structure is undesirable, since it is common practice to puddle the soil by stamping or ploughing before planting out rice seedlings. However, where such soils are drained after the rice crop and planted to a normal "aerobic" crop, then decomposition of the added organic material will be of particularly great significance in improving structure, particularly in view of the initial puddled nature of the soil.

Where organic materials are available only in limited amounts the question may be asked whether, from the point of view of soil carbon retention, it is better to apply this in small amounts at frequent intervals or in large amounts at less frequent intervals. From the results obtained in this study it appears that for both straw and compost the latter method of application is more desirable. The differences in extent of retention between the application of small and large dressings was greater for straw than for compost.

When the retention of straw and compost are compared on an "economic" basis (i.e. since a given weight of compost requires about twice its weight of straw as a raw material) it is seen that the ultimate retention of the material was

slightly better for straw than for compost with low rates of application (comparing 1% straw with 0.5% compost) whilst the reverse was true for higher rates (2% straw and 1% compost). Thus in practice where waste material is available in limited quantity it should be preserved as compost and applied in large amounts infrequently rather than be applied frequently in small amounts in uncomposted or composted form.

Turning our attention now to the nutrient-supplying power of the organic materials, the deleterious effect of the "ppor compost" (straw allowed to rot without addition of an accelerator) on performance of ryegrass was clearly indicated. This was not due to the lower total nutrient content of this material as compared with some of the other composts, but to the presence of a fair amount of undecomposed cellulosic matter, which presumably resulted in immobilization of some of the major nutrients on addition to the soil. These results indicate clearly the danger of applying to soils improperly prepared composts. If they have to be applied it is important to apply sufficient extra mineral nutrients, especially nitrogen, to ensure that native soil nutrients are not immobilized. If facilities or time are not available for properly composting straw, it would be better to apply uncomposted straw together with extra nitrogen rather than to apply poorly composted straw without extra nitrogen. This

is brought out clearly by a comparison of the results obtained between the poor compost treatment and the straw + KNO_3 treatment. The carbon/nitrogen ratio of the added materials of both these treatments was almost identical, indicating at least in this range that the carbon/nitrogen ratio is of little value in indicating the likely effects of these materials on growth.

Whether straw should be applied fresh or composted is best seen by comparing the straw + KNO_3 treatment with the nitrochalk compost treatment. The general overall conclusion, with respect to ryegrass yields and uptake of nutrients, was that at low pH (pH 5.2) both materials had similar effects, whilst at higher pH levels (6.2 and 7.2) the composted straw was superior to the straw plus nitrogen treatment. The magnitude of the effects of both treatments was however fairly small in comparison with the effects of KNO_3 applied alone. In fact the presence of the decomposing straw immobilized virtually all the applied KNO_3-nitrogen at pH 5.2 and 7.2, whilst at pH 6.2 it immobilized about two-fifths of the applied mineral nitrogen. This was considered to be due to the fact that micro-organisms responsible for nitrogen immobilization were least active at the intermediate pH whilst those responsible for nitrogen mineralization were least active at the lowest pH.

A comparison of the efficiency of the four "good" composts in supplying nutrients to ryegrass and in improving yields showed that the nitrochalk compost was generally inferior to the other materials (blood, grass and sludge composts), particularly at the two lower pH levels. This may have been because the nitrochalk compost had a carbon/nitrogen ratio of 28 whilst the others had ratios of less than 20, thus nutrient availability of the former was reduced by immobilization effects. The variation of carbon/nitrogen ratio below 20 did not however effect ryegrass yields.

The order of effectivenews of the different composts in supplying nitrogen and phosphorus varied with pH, particularly in that the blood compost became increasingly more effective than the other composts with increasing pH. This was shown, particularly in the case of nitrogen, both in increasing total uptake and in increasing recovery of applied nitrogen. The superiority of the blood compost over the other composts at the high pH was further confirmed in the sand culture experiment where the effects of varying nitrogen and carbon content of the materials had been eliminated.

Apart from the direct nutritional effects of the applied organic materials their indirect effect is of importance, particularly with respect to soil pH. This was shown particularly clearly in the case of phosphorus recovery from applied straw plus mineral nitrogen. At pH 5.2 not only was

none of the applied phosphorus recovered but the treatment resulted in immobilization of some of the native soil phosphorus; at pH 6.2 and 7.2, on the other hand, where a low level of straw (0.5%) was applied not only was all the applied phosphorus apparently recovered, but an almost equal amount of native soil phosphorus was also recovered. The results obtained indicate that, at least for phosphorus, the effect of the material on the availability of native phosphorus was of greater importance for the nutrition of ryegrass than was the phosphorus contained in the material. Because of the vigourous microbial activity induced by the decomposing straw it is perhaps hardly surprising that profound chemical changes may also occur. These would affect the phosphorus status of the soil in particular, in view of the well-known effect of pH on phosphorus availability. However it is interesting to note that similar effects were noted with the blood compost treatment, although the magnitude of the differences due to pH were not as great as with the straw treatments. In addition, the magnitude of the differences in phosphorus recovery decreased with increasing level of application of both straw and blood compost. This indicates a buffering effect of the heavier applications.

The experiment on varying the levels of straw and compost showed that, providing that soil pH was not less than about 6 the application of a low level of straw (equivalent to 5 tons

per acre) plus sufficient extra mineral nitrogen to give a carbon/nitrogen ratio of 20 gave results as satisfactory as with mineral nitrogen alone, with the added advantage that the straw had improved the physical characteristics of the soil and probably would have some residual chemical effect. A similar result was obtained only with the heaviest dressing of compost (equivalent to 20 tons per acre) and though this may not seem economic, the siginificance of this high level in improving soil physical conditions could be important. In addition this high level would have a considerable residual effect on following crops. In the acid soil (pH 5.2) on the other hand the mineral nitrogen treatment resulted in better performance of ryegrass than did any of the levels of straw plus nitrogen or compost. This was shown to be due to poor or even negative recoveries of nitrogen, phosphorus, and magnesium from the applied organic materials at the low pH. This indicates the importance of selecting the correct manurial treatment in relation to soil pH.

The greater residual effects of the straw treatments as compared with the compost treatments have been consistently shown not only in the experiment specifically designed to test the effect (Chapter VII) but also in the uptake of nutrients in the successive cuttings of ryegrass in the other experiments. The residual effects were clearly apparent not only for nitrogen, which we would well expect in view of the high

nitrogen requirement of the micro-organisms decomposing the straw, but also for the other nutrients. This fact combined with the relatively poor recovery of nutrients from the straw treatment in the first ryegrass experiment, indicates that ploughing straw into soil could be used to immobilize nutrients temporarily so as to prevent them from being leached out of soils during rainy fallow periods. This could be particularly useful in tropical areas where rainfall is seasonal. In this way nutrients would be conserved and would become available to the crop when this was planted.

The extent of recovery of the four major nutrients from the composts is indicative of the importance of these materials in being able to supply major nutrients. In fact the proportion of the applied potassium recovered from the composts was much greater than the proportion of the applied nitrogen, whilst magnesium recovery was also greater than nitrogen recovery. The blood and grass composts also yielded on average, more of their phosphorus than of their nitrogen.

Further work needs to be done before it can be explained why the blood compost was superior to the other composts in supplying nitrogen to ryegrass. This occurred even when the materials contained similar amounts of mineral and organic nitrogen and all limiting factors except nitrogen supply were eliminated. One hesitates to introduce the "organics" versus "inorganics" controversy, but the blood compost was

from an animal source of nitrogen, namely, dried blood whilst the other materials were of inorganic (nitrochalk compost) or vegetable origin (grass and sludge composts). Sewage sludge is however partly of animal origin and it is perhaps significant to note that the compost prepared from this was the second most effective in supplying its nitrogen to ryegrass. These experiments should be repeated before any definite conclusions could be made.

The choice as to whether fresh straw plus mineral nitrogen or composted straw should be used in any area is dependent on a number of factors apart from those dealt with in this study. Thus the cost of the raw materials may be important. If a cheap material such as sewage sludge is available then it would be economic to compost the straw with this; in fact it would be a very suitable way of disposing of sewage sludge and could be much more hygienic than applying the sludge directly to the soil. Again if conditions are such that grass growth is so great that the production is in excess of animal requirements (including dried grass) then the grass could be cut whilst still green and would probably contain sufficient nitrogen so that no extra nitrogen would be needed for good composting. If the grass was very high in nitrogen it could be mixed with straw before composting. Labour costs involved in preparing composts may be so great as to preclude its

preparation, but this is not likely to be important where suitable machinery is available. Problems of application may decide which material should be used. Thus the relatively dense compost, as compared with straw, can probably be more easily transported and more easily and uniformly applied than can the straw. In addition, in windy areas the light straw may be blown all over the place during application.

BIBLIOGRAPHY

1. Ravich-Scherbo, Yu.A., 1928 Apkhiv-biol.Nauk, 28.3
2. Aleksandranov, 1949, Dokl.Akad. S.Kh.Nauk Lenin, 3.
3. Pikovskaya, R.I., 1948, Mikrobiologiya, 17,5.
4. Gerretsen, F., 1948, Plant and Soil, 1, 51.
5. Kononova, M.M., Soil organic matter 1961.
6. Gel'tser, F.Yu., 1943, Pochvovedene, 9-10.
7. Nichiporovich, A.A., 1955, Izd. Akad. Nauk SSSR
8. Bottomley, W., 1914, Proc. Roy. Soc., 88, 237 (1917) ibid., 89, 102, 481; (1919) ibid., 91, 83, (1920) Ann. Bot., 34, 353.
9. Mockeridge, F., 1924, Biochem. J., 14, 432; 1924 ibid., 18, 550; 1924, Ann. Bot., 38, 723.
10. Waksman, S.A., 1952, Soil microbiology.
11. Acharya, C.N., 1948, Indian Farm 125-126.
12. Bould, C., Ph.D. Thesis 1946 Reading University.
13. Tinsley, J., Nowakowski, T.Z., 1959, J. Sci. Food Agric. 10, 145-167.
14. Hutchinson, H.B. and Richards, E.H, 1921, Jour. Min. Agric. 28.
15. Ehner, A., Springer, V., 1950, Z. Pflbau. Pflschutz. 1, 97-118.
16. Yeh, T.P., 1957, Soils Fert. Taiwan 5, 73-75.
17. Cornfield, A.H., 1958, Plant and Soil 10, 183-193.
18. Mattingly, G.E.G., 1952, Trans. Int. Soc. Soil Sci. Comm. II and IV 2, 68-70.
19. Hoyle, D.A., Mattingly, G.E.G., 1954, J.Sci. Fd. Agric. 5, 54-64.
20. Hoyle, D.A., Mattingly, G.E.G., 1952 Nature (London), 164, 116-117.

21. Mattingly, G.E.G., 1952, Nature (London) 169, 75-76.

22. Tinsley, J., Nowakowski, T.Z., 1959, J. Sci. Food Agric. 16, 224-232.

23. Kaila, A., 1954, Acta Agric. Scand. 4, 17-32.

24. Winsor, G.W., Pollard, A.G., 1956, J.Sci. Food Agric. 7 618-624.

25. Kick, H. 1956, Z. Pflernahr. Dung. 74, 1-10.

26. Broadbent, F.E., 1947, Soil Sci. Soc. Amer. Proc. 12, 246-249.

27. Broadbent, F.E. and Bartholomew, W.V., 1948, Soil Sci. Soc. Amer. Proc. 13, 271-274.

28. Hallam, M., Bartholomew, W.V., 1953, Soil Sci. Soc. Amer. Proc. 17, 365-368.

29. Pinck, L.A., Allison, F.E., 1951, Soil Sci., 71, 67-75.

30. Allison, F.E., Sherman, M.S., Pinck, L.A., Soil Sci. 68, 1949 (463-478).

31. Pinck, L.A., Allison, F.E., Gaddy, V.L., J. Amer. Soc. Agron. 40, 1948.

32. Stotzy, G and Mortensen, J.L., 1957, Soil Sci. 83, 165-174.

33. Marchal, E. 1893, Bull. Acad. Roy. Belg. 25, 727.

34. Doryland, C.J.T., 1916, N. Dakota Agr. Expt. Sta. Bull, 116.

35. Heck, A.F., Soil Sci., 1929, 27, 1.

36. Norman, A.G., Ann. Appl. Biol., 1933, 20, 146.

37. Rubins, E.J. and Bear, F.E., Soil Sci., 1942, 54, 411.

38. Batham, H.N.? Soil Sci., 1927, 24, 187.

39.Owen, O., Winsor, G.W. and Long, M.I.E., Nature London 1950.

40. Winsor, G.W., Pollard, A.G., 1956, J. Sci. Food Agric. 7, 134-141.

41. Winsor, G.W., Pollard, A.G., 1956, J. Sci. Food Agric. 7, 142-149.

42. Daji, J.A., 1934, J. Agric. Sci. 24, 15.

43. Barnes, T.W., 1953, J. Agric. Sci. 43, 365.

44. Cornfield, A.H., 1959, 52, 327-329.

45. Mattingly, G.E.G., 1956, J. Sci. Food Agric. 7, 601-605.

46. Garactani, H., Catani, R.R., 1957 Bragantia 16, 261-268.

47. Stevens, F.L. and Withers, W.A., 1910, Z.bl. Bact. 11, 27, 169.

48. Wimmer, G., Z. Hyg. Infektkr. 48.

49. Stevens, F.L. and Withers, W.A., 1909, Z bl. Bakt 11, 23, 255.

50. Albrecht, W.A. and McCalla, T.M., 1938, Amer. J. Bot 25, 403.

51. Conn, H.J. and Conn, J.E., 1940, J. Bact. 39, 99.

52. ZoBell, C.E., 1943, J. Bact. 46, 39.

53. Pikorvska, R. 1940, Microbiol. Zh. 7, 182 (Biol. Abstr. 16, 12, 981).

54. Cutler, D.W. and Mukherjee, B.K., 1931, Proc. Roy. Soc. B, 108, 384.

55. Meyerhof, O., 1916, Pflng. Arch. ges. Physiol. 164, 253; 165, 229.

56. Meyerhof, O. 1917, Pflug. Arch. ges. Physiol. 166, 240.

57. Winogradsky, S., 1933, Ann. Inst. Pasteur, 50, 350.

58. Meek, C.S. and Lipman, C.B., 1922, J. Gen-Physiol. 5, 195.

59. Warington, R. 1891, J. Chem. Soc. 59, 484.

60. Winogradsky, S. and Omeliansky, W.L., 1902, Arch. Sci. biol., St. Petersb., 7, 3.

61. Tandon, S.P. and Dhar, N.R., 1934, Soil Sci., 38, 183.

62. Goldberg, S.S., Gainey, P.L., 1955 Soil Sci. 80 43-53.

63. Quastel, J.H., 1950 Advancement of Science 7, 16-18.

64. Quastel, J.H., Schofield, P.G., 1951, Bact. Rev., 15, 1-53.

65. Shapiro, R.E., 1958, Soil Sci. 85, 267-272.

66. Khanna, K.L., Roy, P.K., 1956, J. Indian Soc. Soil Sci. 4, 189-192.

67. Fuller, W.H., Neilsen, D.R., Miller, R.W., 1956, Soil Sci. Amer. Proc. 20, 218-224.

68. Kaila, A., 1954, Z. Pflernahr. Dung. 64, 27-35.

69. Russel, E.J. 1950, Soil Conditions and Plant Growth, Eighth Edition.

70. Private Communication with Dr. A.H. Cornfield, Imperial College, London, S.W.7.

71. Yuen, S.H. and Pollard, A.G., 1954, J. Sci. Fodd Agric., 5, 364.

72. Yuen, S.H. and Pollard, A.G., 1951, J.Sci. Food Agric. 2, 36.

73. Morgan, M.F., 1941, Soil Testing Conn Agri. Exp. Sta. Bul., 450, 581.

75. Bremner, J.M. and Shaw, K., 1955. Jour. Ag. Sci. 46, No. 3, 320-328.

74. Cornfield, A.H., 1961, Plant and Soil 14, 90.

76. Yuen, S.H. and Pollard, A.G., 1951, J.Sci. Food Agric. 2, 36.

77. Cornfield, A.H. and Pollard, A.G. 1950, J. Sci. Food Agric. 1, 357-358.

78. Walkley, A. and Black, I.A., Soil Sci., 1934, 37, 29-38.

79. Piper, C.E., 1950, Soil and Plant Analysis. First Ed. The University of Adelaid, Adelaid.

80. Annonymous, 1928, Agricultural Progress, 5, 137-144.

81. Bray, R.H. and Willhite, F.M., 1929 Ind. Eng. Chem. (Anal. Ed.), 1, 144.

82. Coutts, J.R.H., 1930, J. Agric. Sci., 20, 407-413.

93. Tenny, F.G., and Waksman, S.A., 1929, Soil Sci. 28, 55-84.

94. Peevy, W.J. and Norman, A.G., 1948, Soil Sci. 65, 209-226.

95. Waksman, S.A., and Tenny, F.G., 1928, Soil Sci., 26, 155-171.

96. Louis, A. Pick, Franklin E. Allison and Mildred S. Sherman, 1950, Soil Sci., 69, 391-401.

97. Cornfield, A.H., 1959, J. Sci. Food Agric. 1, 27-28.

98. Khan, A.B., Ph.D. Thesis, 1960, London University.

99. Joffe, J.S. and Levine, A.K., 1946, Soil Sci., 62, 411-419.

100. Blume, J.M. and Purvis, E.R., 1939, Jour. Amer. Soc. Agron. 31, 857-868.

101. Loew, O., 1903, U.S. Dept. Agr. Bur. Plant Indus. Bul. 45.

102. Truog, E., et al. 1947 Soil Sci., 63, 19-25.

103. Bartholomew, R.P., 1933, Ark. Agr. Exp. Sta. Bul. 289.

104. Walsh, T., O'Donohue, T.F., 1945, J. Agric. Sci., 35, 254-263.

105. Marel, H.W. Vander, Brock, J.M.L. Vanden, 1959, Z. Pflernahr. Dung, 84, 244-254.

106. Boischot, P., Drouineau, G., 1942, C.R. Acad. Agric. 27, 36-42.

107. Harding, R.B., 1954, Soil Sci. 77, 119-128.

108. Peech and Bradfield 1943, Soil Sci., 55, 37-48.

109. Hofmann, E. and Hunnius, W., Z. Pflernahr, Dung., 1955, 70, 104.

110. Jenny, H., and Shade, E.R., 1934, Jour. Amer. Soc. Agron. 26, 162-170.

111. Dean, H.C., 1936, Iowa Agr. Exp. Sta. Res. Bul. 197.

112. Hoagland, D.R., 1944, Inorganic Plant nutrition. Prather Lectures.

113. Magar, W.Y., 1961, Ph.D. Thesis, Agr. Chem. London Univ.,

114. Ali Massumi, 1962 Ph.D. Thesis, Agri. Chemistry, London University.

115. Mitscherlich, E.A., 1930.

116. McGeorge, W.T., Arizona, Agr. Exp. Sta. Tecl. Bull., 82 295.

117. Brind, W.D., Soils and Fertilizers, 1950, 13, 235-239, 315-320.

118. Cornfield, A.H., 1960, Nature, 16, 260-261.

119. Hewitt, Sand and Water Culture Methods used in the Study of Plant Nutrition.

120. Cornfield, A.H., 1952, J. Sci. Fd. Agric., 3, 343.

APPENDIX

Table 33-46 - In connection with Chapter IV

Table 81-101 - In connection with Chapter V

Table 110-123 - In connection with Chapter VI

Table 125-136 - In connection with Chapter VII

Table 33. Dry matter yield of rye grass (tops) per pot (weight in gms.) at all pH levels.

Treatments	Treatment means (in gms)
Control C	2.154
Fresh straw FS	2.336
Blood compost BD	2.741
Poor compost CS or PC	1.925
Nitrochalk compost NC	2.463
Sludge compost SG	2.738
Green Grass compost GG	2.883
Potassium Nitrate KN	3.449
General mean	2.586

S.E. of treatment difference = 0.104

C.D. at 5% = 0.216

Table 34. Interaction effect of treatment and pH on the yield (tops) of rye grass grown in Silwood soil of different pH.

pH ⟶ / Treatments ↓	5.2	6.2	7.2	Average
C	2.080	1.987	2.394	2.154
FS	2.235	2.425	2.348	2.336
BD	2.480	2.548	3.195	2.741
PC	2.194	1.565	2.016	1.925
NC	2.370	2.168	2.852	2.463
SG	2.545	2.625	3.043	2.738
GG	2.792	2.892	2.966	2.883
KN	3.428	3.424	3.494	3.449
Average	2.516	2.454	2.789	2.586

S.E. of interaction of treatment x pH = 0.181

C.D. at 5% = 0.374

S.E. of pH difference = 0.064

C.D. at 5% = 0.132

Table 35. Dry matter yield of roots (in gms) of rye grass grown in Silwood soil of different pH.

Treatments	Treatment means
C	1.147
FS	1.602
BD	1.373
PC	1.076
NC	1.277
SG	1.420
GG	1.582
KN	2.036
General mean	1.439

S.E. of treatment mean difference = 0.0714

C.D. at 5% = 0.148

Table 36. Interactions of treatment and pH on the root yield (in gms) of rye grass grown in Silwood soil of different pH.

Treatment ↓ / pH →	5.2	6.2	7.2	Average
C	1.200	0.936	1.306	1.147
FS	1.652	1.607	1.546	1.602
BD	1.096	1.512	1.512	1.373
PC	1.262	0.913	1.052	1.076
NC	1.146	1.211	1.474	1.277
SG	1.277	1.399	1.585	1.420
GG	1.370	1.645	1.732	1.582
KN	1.772	2.321	2.016	2.036
Mean	1.347	1.443	1.528	1.439

S.E. of interaction of treatment and pH = 0.124

C.D. at 5% = 0.256

S.E. of pH difference = 0.044

C.D. at 5% = 0.091

Table 37. Total dry matter yield (tops and roots) of rye grass grown in Silwood soil of different pH.

Treatments	Treatment means (in gms)
Control	3.301
FS	3.938
BD	4.114
PC	3.000
NC	3.740
SG	4.158
GG	4.466
KN	5.485
General mean	4.025

S.E. of treatment difference = 0.138

C.D. at 5% = 0.286

Table 38. Interaction effect of treatment and pH on the yield (tops and roots) of rye grass grown in Silwood soil of different pH.

Treatment ↓ pH →	5.2	6.2	7.2	Average
Control	3.280	2.922	3.700	3.301
FS (1%)	3.888	4.032	3.894	3.938
BD	3.576	4.060	4.707	4.114
PC	3.456	2.478	3.068	3.000
NC	3.515	3.380	4.326	3.740
SG	3.822	4.024	4.628	4.158
GG	4.162	4.536	4.698	4.465
KN	5.200	5.746	5.510	5.485
Average	3.862	3.897	4.313	4.025

S.E. of interaction of treatment x pH = 0.239

C.D. at 5% = 0.495

S.E. of pH difference = 0.085

C.D. at 5% = 0.175

Table 39. Mean uptake of nitrogen (in mgms) from different treatments.

Treatment	Treatment means
C	40.11
FS	49.65
BD	53.24
PC	36.18
NC	39.46
SG	52.64
GG	56.04
KN	65.75
General mean	50.38

S.E. of treatment difference = 2.45

C.D. at 5% = 5.08

Table 40. Interaction effect of pH and treatment on the uptake of nitrogen by perennial rye grass grown in Silwood soil of dfferent pH.

Treatment ↓ / pH ⟶	5.2	6.2	7.2	Average
C	41.75	36.94	41.63	40.11
FS	47.84	57.04	44.06	49.65
BD	45.72	50.50	63.48	53.24
PC	43.64	30.30	34.60	36.18
NC	47.37	48.04	52.96	49.46
SG	47.63	51.00	59.28	52.64
GG	53.39	59.29	55.44	56.04
KN	69.34	60.06	67.86	65.75
Average	49.59	49.15	52.41	50.38

S.E. of interaction of pH and treatment = 4.25

C.D. at 5% = 8.79

S.E. of pH difference = 1.50

C.D. at 5% = 3.11

Table 41. Mean uptake of phosphate (in mgms) for different treatments per pot.

Treatments	Treatment means (in mgms)
C	21.91
FS	20.90
BD	26.11
PC	16.36
NC	22.55
SG	27.79
GG	26.90
KN	29.08
General mean	23.95

S.E. of treatment difference = 0.845

C.D. at 5% = 1.75

Table 42. Interaction effect of pH and treatment on the uptake of phosphate by perennial rye grass grown in Silwood soil of different pH.

Treatments ↓ pH →	5.2	6.2	7.2	Average
C	25.33	18.69	21.71	21.91
FS	22.66	22.72	17.32	20.90
BD	24.34	27.82	26.18	26.11
PC	20.80	13.29	14.98	16.36
NC	24.08	20.42	23.16	22.55
SG	28.36	28.00	27.02	27.79
GG	27.89	27.82	24.99	26.90
KN	31.03	30.54	25.67	29.08
General mean	25.56	23.66	22.63	23.95

S.E. of interaction of treatment x pH = 1.46

C.D. at 5% = 3.03

S.E. of pH difference = 0.518

C.D. at 5% = 1.07

Table 43. Mean uptake of potassium.

Treatments	Treatment means
C	29.30
FS	57.1
BD	44.9
PC	32.5
NC	39.6
SG	46.0
GG	53.3
KN	70.1
General Mean	46.6

S.E. of treatment difference = 1.77

C.D. at 5% = 3.7

Table 44. Mean uptake of potash under different treatments at pH 5.2, 6.2, 7.2.

Treatments	pH 5.2	pH 6.2	pH 7.2	Treatment mean
C	38.1	23.3	26.4	29.3
FS	64.8	55.8	50.6	57.1
BD	50.1	39.9	44.6	44.9
PC	44.4	24.1	28.9	32.5
NC	46.6	34.2	38.0	39.6
SG	53.1	40.6	44.2	46.0
GG	61.	47.9	50.9	53.3
KN	87.3	62.8	60.3	70.1
General mean	55.7	41.1	43.0	46.6

S.E. of interaction of treatment x pH = 3.07

C.D. at 5% = 6.3

S.E. of pH difference = 1.08

C.D. at 5% = 2.2

Table 45. Mean uptake of magnesium by perennial rye grass from different treatments.

Treatments	Treatment means
C	5.15
FS	5.76
BD	7.47
PC	5.30
NC	7.03
SG	7.45
GG	6.67
KN	6.98
General mean	6.48

S.E. of treatment difference = 0.3314

C.D. at 5% = 0.69

Table 46. Uptake of Mg by perennial rye grass from different treatments added to Silwood soil of different pH.

Treatments	pH 5.2	pH 6.2	pH 7.2	Average
C	5.14	4.46	5.87	5.15
FS	5.66	5.73	5.90	5.76
BD	6.00	7.06	9.35	7.47
PC	4.80	4.00	7.09	5.30
NC	5.55	7.38	8.15	7.03
SG	6.65	7.53	8.16	7.45
GG	5.38	6.96	7.66	6.67
KN	5.35	7.83	7.77	6.98
Mean	5.57	6.37	7.49	6.48

S.E. of interaction of pH x treatment = 0.5739

C.D. at 5% = 1.19

S.E. Of pH difference = 0.2042

C.D. at 5% = 0.42

TABLE 81

Dry matter yield of rye grass (tops) per pot grown in Silwood soil treated with straw+KNO_3 and Blood Compost at three levels of each treatment.

Treatments	Treatment means (in gms)
Control - C	2.1538
FS_I + KN(0.5%)	3.0455
FS_{II} + KN(1%)	2.3360
FS_{III} + KN(2%)	1.8418
BD_I(0.5%)	2.6105
BD_{II}(1%)	2.7412
BD_{III}(2%)	3.0087
KN	3.4490
General mean	2.6483

C.D. for treatment effect at 5% = 0.2690

TABLE 82

Intraction effect of treatment and pH on the top yield of rye grass (in gms) grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each.

Treatments ↓ pH →	pH 5.2	pH 6.2	pH 7.2	Average
C - Control	2.080	1.987	2.394	2.154
FS_I + KN (0.5%)	2.414	3.172	3.550	3.046
FS_{II}(1%) +KN	2.235	2.425	2.348	2.336
FS_{III}(2%) + KN	1.508	1.838	2.130	1.842
BD_I(0.5%)	2.280	2.477	3.075	2.611
BD_{II}(1%)	2.480	2.548	3.195	2.741
BD_{III}(2%)	2.314	3.020	3.692	3.009
KN	3.428	3.424	3.494	3.449
General mean	2.342	2.618	2.985	2.649

C.D. for pH effect at 5% = 0.1643 = 0.164

C.D. for pH x treatment at 5% =0.4.6532 = 0.465

TABLE 83

Root yield of perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each treatment.

Treatments	Treatment means (in gms)
Control	1.147
FS_I(0.5%) + KN	2.007
FS_{II}(1%) + KN	1.602
FS_{III}(2%) + KN	1.452
BD_I(0.5) + KN	1.554
BD_{II}(1%) + KN	1.373
BD_{III}(2%) + KN	1.866
KN	2.036
General mean	1.630

C.D. for treatment effect at 5% = 0.1589 = 0.159

TABLE 84

Interaction effect on the root yield (in gms) of rye grass grown in Silwood soil of different pH treated with Straw+KNO_3 and Composts at three levels of each.

Treatments ↓ pH →	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Average
C	1.200	0.936	1.306	1.147
FS_I(5%)+KN	1.408	2.243	2.369	2.007
FS_{II}(1%)+KN	1.652	1.607	1.546	1.602
FS_{III}(2%)+KN	1.410	1.344	1.600	1.452
BD_I(0.5%)	1.252	1.528	1.884	1.554
BD_{II}(1.0%)	1.096	1.512	1.512	1.373
BD_{III}(2.0%)	1.480	2.050	2.067	1.866
KN	1.772	2.321	2.016	2.036
General mean	1.409	1.693	1.788	1.630

C.D. for pH effect = 0.0970 = 0.097 at 5%

C.D. for pH x treatment effect at 5% = 0.274 (0.274)

TABLE 85

Dry matter yield (tops + roots) of rye grass (in gms) grown in Silwood soil of different pH treated with straw + KNO_3 and composts at three levels of each.

Treatments	Treatment means (in gms)
C	3.301
FS_I(0.5%) + KN	5.052
FS_{II}(1.0%) + KN	3.938
FS_{III}(2.0%) + KN	3.294
BD_I	4.165
BD_{II}	4.114
BD_{III}	4.874
KN	5.485
General mean	4.278

C.D. for treatment effect at 5% = 0.389

TABLE 36

Interaction effect of (pH x treatment) on the yield (top+ roots) of rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Composts at three levels of each.

Treatments ↓ \ pH →	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Average
C	3.280	2.922	3.700	3.301
FS_I + KN	3.822	5.414	5.920	5.052
FS_{II} + KN	3.888	4.032	3.894	3.938
FS_{III} + KN	2.918	3.232	3.730	3.294
BD_I	3.531	4.005	4.958	4.165
BD_{II}	3.576	4.060	4.707	4.114
BD_{III}	3.794	5.070	5.759	4.874
KN	5.200	5.746	5.510	5.485
Average	3.751	4.310	4.772	4.278

C.D. for pH effect at 5% = 0.075

C.D. for pH x treatment effect at 5% = 0.264

TABLE 87

Total uptake of N (in mgms) from combined (tops+roots) of rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each treatment.

Treatments	Treatment means (in mgms)
C	40.1
FS_I + KN	55.1
FS_{II} + KN	49.7
FS_{III} + KN	39.7
BD_I	51.4
BD_{II}	53.2
BD_{III}	65.1
KN	65.8
General mean	52.5

C.D. for Treatment effect at 5% = 6.4

TABLE 88

Interaction of pH and treatment effect on the uptake (in mgms) of N by rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Composts at three levels of each treatment.

Treatment ↓ / pH →	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Average
C	41.8	36.9	41.6	40.1
FS_I + KN	43.9	58.9	62.6	55.1
FS_{II} + KN	47.8	57.0	44.1	49.7
FS_{III} + KN	36.7	41.7	40.7	39.7
BD_I	43.3	51.2	59.6	51.4
BD_{II}	45.7	50.5	63.5	53.2
BD_{III}	55.7	70.3	69.4	65.1
KN	69.3	60.1	67.9	65.8
General mean	48.0	53.3	56.2	52.5

C.D. for pH effect = 3.9
at 5%.

C.D. for pH x treatment effect at 5% = 11.1

TABLE 89

Mean uptake of phosphate (in mgms) by perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each treatment.

Treatments	Treatment means
C	21.9
FS_I + KN	27.7
FS_{II} + KN	20.9
FS_{III} + KN	18.2
BD_I	25.6
BD_{II}	26.1
BD_{III}	31.0
KN	29.1
General mean	25.0

C.D. for Treatment effect at 5% = 2.11 = 2.1

TABLE 90

Interaction effect of pH and treatment on the uptake (in mgms) of phosphate by perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each treatment.

Treatments	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Average
C	25.3	18.7	21.7	21.9
FS_I + KN	23.0	29.3	30.9	27.7
FS_{II} + KN	22.7	22.7	17.3	20.9
FS_{III} + KN	14.9	19.0	20.8	18.2
BD_I	23.7	24.8	28.2	25.6
BD_{II}	24.3	27.8	26.2	26.1
BD_{III}	27.2	32.7	33.1	31.0
KN	31.0	30.5	25.7	29.1
Average	24.0	25.7	25.5	25.1

C.D. for pH effect at 5% = 1.29 = 1.3

" " pH x treatment effect at 5% = 3.66 = 3.7

TABLE 91

Treatment effect on the uptake of K (in mgms) by perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Composts at three levels of each treatment.

Treatment	Treatment means (in mgms)
C	29.3
FS_I + KN	65.9
FS_{II} + KN	57.1
FS_{III} + KN	51.4
BD_I	39.3
BD_{II}	44.9
BD_{III}	58.7
KN	70.1
Average	51.7

C.D. for Treatment effect at 5% = 5.87 = 5.9

TABLE 92

Interaction effect of pH and treatment on the uptake of potassium (in mgms) by perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost.

Treatment	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Average
C	38.1	23.3	26.4	29.3
FS_I + KN	66.9	64.8	66.0	65.9
FS_{II} + KN	64.8	55.8	50.6	57.1
FS_{III} + KN	49.1	49.9	55.2	51.4
BD_I	44.6	35.3	38.0	39.3
BD_{II}	50.1	39.9	44.6	44.9
BD_{III}	57.0	53.5	65.7	58.7
KN	87.3	62.8	60.3	70.1
Average	57.2	48.2	50.9	52.1

C.D. for pH effect at 5% = 3.59 = 3.6

C.D. for pH x treatment effect at 5% = 10.2

TABLE 93

Treatment effect on the Mg uptake (in mgms) by perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each treatment.

Treatment	Treatment means (in mgms)
C	5.15
FS_I + KN	7.22
FS_{II} + KN	5.76
FS_{III} + KN	3.85
BD_I	6.44
BD_{II}	7.47
BD_{III}	8.74
KN	6.98
General mean	6.45

C.D. for Treatment effect = 0.98 (0.98)
at 5%

TABLE 94

Interaction effect of pH and treatment on the Mg uptake (in mgms) by perennial rye grass grown in Silwood soil of different pH treated with straw+KNO_3 and Blood Compost at three levels of each.

Treatment	Soil pH 5.2	Soil pH 6.2	Soil pH 7.2	Average
C	5.14	4.46	5.87	5.15
FS_I + KN	5.36	6.92	9.37	7.22
FS_{II} + KN	5.66	5.73	5.90	5.76
FS_{III} + KN	3.61	3.70	4.24	3.85
BD_I	5.63	5.96	7.72	6.44
BD_{II}	6.00	7.06	9.35	7.47
BD_{III}	6.22	8.88	11.12	8.74
KN	5.35	7.83	7.77	6.98
Average	5.37	6.32	7.67	6.45

C.D. for pH effect at 5% = 0.60

C.D. for pH x treatment effect at 5% = 1.70

TABLE-95

TABLE 95

Dry matter (tops only) yield (in gms) of rye grass grown in Silwood soil of different pH.

	Soil pH 5.2			Soil pH 6.2		
Treatment	R_1	R_2	Total	R_1	R_2	Total
Control	2.034	2.127	4.161	1.960	2.014	3.974
FS_I(0.5%)	2.387	2.440	4.827	3.252	3.093	6.345
FS_{II}(1%)	2.274	2.197	4.471	2.441	2.409	4.850
FS_{III}(2%)	1.541	1.475	3.016	2.030	1.745	3.775
BD_I	2.264	2.295	4.559	2.473	2.481	4.954
BD_{II}	2.250	2.711	4.961	2.640	2.456	5.096
BD_{III}	2.178	2.450	4.628	3.527	2.712	6.039
KN	3.556	3.301	6.857	3.445	3.404	6.849
Total	18.484	18.996	37.480	21.568	20.314	41.882

TABLE 95

Soil pH 7.2			Total		
R_1	R_2	Total	R_1	R_2	Total
2.448	2.340	4.788	6.442	6.481	12.923
3.726	3.375	7.101	9.365	8.908	18.273
2.347	2.348	4.695	7.062	6.954	14.016
1.787	2.473	4.260	5.358	5.693	11.051
3.295	2.855	6.150	8.032	7.631	15.663
3.402	2.988	6.390	8.292	8.155	16.447
4.064	3.321	7.385	9.569	8.483	18.052
3.749	3.239	6.988	10.750	9.944	20.694
24.818	22.939	47.757	64.870	62.249	127.119

TABLE - 96

TABLE 96

Dry matter (roots only) yield (in gms) of rye grass grown in Silwood soil of different pH.

	Soil pH 5.2			Soil pH 6.2		
Treatments	R_1	R_2	Total	R_1	R_2	Total
Control	1.180	1.220	2.400	0.953	0.9181	1.871
FS_I(.5%)	1.489	1.327	2.816	2.255	2.231	4.486
FS_{II}(1%)	1.676	1.629	3.305	1.594	1.620	3.214
FS_{III}(2%)	1.497	1.324	2.821	1.418	1.271	2.689
BD_I(.5%)	1.224	1.279	2.503	1.438	1.618	3.056
BD_{II}(1%)	1.101	1.090	2.191	1.610	1.415	3.025
BD_{III}(2%)	1.428	1.533	2.961	2.172	1.928	4.100
KN	1.908	1.636	3.544	2.214	2.429	4.643
Total	11.503	11.038	22.541	13.654	13.430	27.084

TABLE 96

Soil pH 7.2			Total		
R_1	R_2	Total	R_1	R_2	Total
1.428	1.183	2.611	3.561	3.321	6.882
2.464	2.274	4.738	6.208	5.832	12.040
1.685	1.407	3.092	4.955	4.656	9.611
1.428	1.773	3.201	4.343	4.368	8.711
2.001	1.766	3.767	4.663	4.663	9.326
1.383	1.641	3.024	4.094	4.146	8.240
2.219	1.914	4.133	5.319	5.375	11.194
2.148	1.883	4.031	6.270	5.948	12.218
14.756	13.841	28.597	39.913	38.309	78.222

TABLE-97

TABLE 97

Dry matter (tops and roots both) yield (in gms) of rye grass grown in Silwood soil of different pH.

	Soil pH 5.2			Soil pH 6.2		
Treatments	R_1	R_2	Total	R_1	R_2	Total
Control	3.214	3.347	6.561	2.913	2.932	5.845
FS_I	3.876	3.767	7.643	5.507	5.324	10.831
FS_{II}	3.950	3.826	7.776	4.035	4.029	8.064
FS_{III}	3.038	2.799	5.837	3.448	3.016	6.464
BD_I	3.488	3.574	7.062	3.911	4.099	8.010
BD_{II}	3.351	3.801	7.152	4.250	3.871	8.121
BD_{III}	3.606	3.983	7.589	5.499	4.640	10.139
KN	5.464	4.937	10.401	5.659	5.833	11.492
Total	29.987	30.034	60.021	35.222	33.744	68.966

TABLE 97

Soil pH 7.2			total		
R_1	R_2	Total	R_1	R_2	Total
3.876	3.523	7.399	10.003	9.802	19.805
6.190	5.649	11.839	15.573	14.740	30.313
4.032	3.755	7.787	12.017	11.610	23.627
3.215	4.246	7.461	9.701	10.061	19.762
5.296	4.621	9.917	12.695	12.294	24.989
4.785	4.629	9.414	12.386	12.301	24.687
6.283	5.235	11.518	15.388	13.858	29.246
5.897	5.122	11.019	17.020	15.892	32.912
39.574	36.780	76.354	104.783	100.558	205.341

TABLE-98

TABLE 98

Total uptake of Nitrogen (in mgms) by perennial rye grass grown in Silwood soil of different pH.

	Soil pH 5.2			Soil pH 6.2		
	R_1	R_2	Total	R_1	R_2	Total
Control	41.2	42.4	83.6	38.1	35.8	73.9
FS_I	46.9	40.9	87.8	59.8	58.1	117.9
FS_{II}	46.5	49.2	95.7	54.8	59.3	114.1
FS_{III}	41.3	32.0	73.3	41.6	41.9	83.5
BD_I	40.9	45.7	86.6	49.3	53.1	102.4
BD_{II}	44.9	46.5	91.4	52.0	49.0	101.0
BD_{III}	48.8	62.6	111.4	76.8	63.9	140.7
KN	72.4	66.3	138.7	57.2	62.9	120.1
Total	382.9	385.6	768.5	429.6	424.0	853.6

TABLE 98

Soil pH 7.2			Total		
R_1	R_2	Total	R_1	R_2	Total
40.6	42.7	83.3	119.8	120.9	240.7
64.5	60.7	125.2	171.2	159.6	330.8
44.1	44.0	88.1	145.4	152.5	297.9
33.1	48.4	81.5	116.0	122.3	238.3
61.5	57.7	119.2	151.7	156.5	308.2
64.7	62.3	127.0	161.6	157.8	319.4
78.0	60.8	138.8	203.6	187.3	390.9
73.0	62.8	135.7	202.5	192.0	394.5
459.5	439.4	853.6	1271.8	1248.9	2520.7

TABLE - 99

TABLE 99

Total uptake of phosphate (in mgms) by perennial rye grass grown in Silwood soil of different pH.

	Soil pH 5.2			Soil pH 6.2		
Treatment	R_1	R_2	Total	R_1	R_2	Total
Control	26.8	23.8	50.6	18.9	18.4	37.3
FS_I(.5%)	23.8	22.2	46.0	29.4	29.3	58.7
FS_{II}(1%)	23.4	22.0	45.4	23.8	21.6	45.4
FS_{III}(2%)	15.5	14.3	29.8	19.3	18.7	38.0
BD_I(.5%)	23.2	24.1	47.3	23.8	25.8	49.6
BD_{II}(1%)	23.2	25.5	48.7	28.5	27.1	55.6
BD_{III}(2%)	27.0	27.5	54.5	34.6	30.8	65.4
KM	31.9	30.1	62.0	29.8	31.3	61.0
Total	194.8	189.6	384.4	208.1	203.0	411.1

TABLE 99

Soil pH 7.2			Total		
R_1	R_2	Total	R_1	R_2	Total
23.0	20.4	43.4	68.7	62.6	131.3
330.6	31.1	61.7	83.8	82.6	166.4
18.0	16.6	34.6	65.2	60.2	125.4
17.4	24.2	41.6	52.2	57.2	109.4
29.5	26.9	56.4	76.5	76.8	153.3
26.6	25.7	52.3	78.3	78.3	156.6
35.3	30.8	66.1	96.9	89.1	186.0
28.2	23.1	51.3	90.0	84.5	174.5
208.6	198.8	407.4	611.6	591.3	1202.9

TABLE - 100

TABLE 100

Total uptake of K(mgms) by perennial rye grass grown in Silwood soil of different pH treated with fresh straw and Compost straw at three levels of each.

	Soil pH 5.2			Soil pH 6.2		
Treatments	R_1	R_2	Total	R_1	R_2	Tota
Control	40.1	36.1	76.2	23.0	23.5	46.5
FS_I(0.5%)	70.1	63.8	133.9	61.9	67.6	129.5
FS_{II}(01%)	63.3	66.2	129.5	53.9	57.8	111.7
FS_{III}(2%)	51.7	46.6	98.3	52.8	46.9	99.7
BD_I(.5%)	43.2	46.0	89.2	35.2	35.3	70.5
BD_{II}(1%)	47.5	52.8	100.3	43.0	36.8	79.8
BD_{III}(2%)	55.1	58.9	114.0	60.2	46.8	107.0
KN	90.0	84.5	174.5	62.8	62.7	125.5
Total	461.0	454.9	915.9	392.8	377.4	770.2

TABLE 100

Soil pH 7.2			Total		
R_1	R_2	Total	R_1	R_2	Total
30.1	22.7	52.8	93.2	82.3	175.5
67.7	64.3	132.0	199.7	195.7	395.4
51.4	49.8	101.2	168.6	173.9	342.5
46.3	64.1	110.4	150.8	157.5	308.3
39.4	36.6	76.0	117.8	117.9	235.7
46.7	42.5	89.2	137.2	132.1	269.3
73.8	57.6	131.4	189.1	163.3	352.4
64.9	55.6	120.6	217.8	202.8	420.6
420.3	393.2	813.6	1274.2	1225.5	2499.7

TABLE - 101

TABLE 101

Total uptake of Magnesium (in mgms) by perennial rye grass grown in Silwood soil of different pH treated with fresh straw and Composted Straw.

	Soil pH 5.2			Soil pH 6.2		
	R_1	R_2	Total	R_1	R_2	Total
Control	5.05	5.22	10.27	4.77	4.14	8.91
FS_I	5.27	5.44	10.71	6.65	7.20	13.85
FS_{II}	6.19	5.13	11.32	5.90	5.56	11.46
FS_{III}	3.88	3.34	7.22	4.02	3.39	7.41
BD_I	5.67	5.59	11.26	5.82	6.10	11.92
BD_{II}	5.63	6.38	12.01	7.27	6.86	14.13
BD_{III}	5.79	6.66	12.45	10.19	7.58	17.77
KN	5.98	4.72	10.70	7.15	8.50	15.65
Total	43.46	42.43	85.94	51.77	49.33	101.10

TABLE 101

Soil pH 6.2			Total		
R_1	R_2	Total	R_1	R_2	Total
5.89	5.84	11.73	15.71	15.20	30.91
9.33	9.41	18.74	21.25	22.05	43.30
6.03	5.76	11.79	18.12	16.45	34.57
3.46	5.02	8.48	11.36	11.75	23.11
8.24	7.21	15.45	19.73	18.90	38.63
9.55	9.15	18.70	22.45	22.39	44.84
12.87	9.38	22.25	28.85	23.62	52.47
8.75	6.79	15.54	21.88	20.01	41.89
64.12	58.56	122.68	159.35	150.37	309.72

TABLE 110

Top yield (in gms) of perennial rye grass grown in Calcareous soil. (P - Limiting)

Treatment	Treatment means (in gms)
Control (C)	2.019
Fresh straw (FS)	2.336
Nitrochalk Compost (NC)	2.392
Blood Compost (BD)	2.396
Sludge Compost (SG)	2.871
Green grass Compost (GS)	3.244
General mean	2.543

S.E. = 0.1985

C.D. at 5% = 0.4423 = 0.442

TABLE 111

Root yield (in gms) of perennial rye grass grown in Calcareous soil. (P - Limiting)

Treatment	Treatment means (in gms)
C	0.973
FS	1.412
NC	1.196
BD	1.211
SG	1.404
GG	1.726
General mean	1.320

S.E. = 0. 1493

C.D. at 5% = 0.333

TABLE 112

Total dry matter yield (top + root) of perennial rye grass grown in Calcareous soil.

Treatment	Treatment means (in gms)
C	2.992
FS	3.748
NC	3.588
BD	3.606
SG	4.275
GG	4.969
General mean	3.863

S.E. = 0.396

C.D. at 5% = 0.884

TABLE 113

Total uptake of phosphate (P_2O_5 - in mgms) by perennial rye grass grown in Calcareous soil. (P - Limiting)

Treatment	Treatment means (in mgms)
C	10.34
FS	14.29
NC	14.05
BD	13.76
SG	22.12
GG	20.20
General mean	15.79

S.E. for treatment = 0.6065

C.D. at 5% = 1.3513 = 1.35

TABLE - 114

TABLE 114

TOP + YIELD

Replication → / Treatment ↓	R_I	R_{II}	R_{III}	Total
C	2.170	1.842	2.044	6.056
FS	2.811	2.221	1.976	7.008
NC	2.301	2.399	2.475	7.175
BD	2.397	2.024	2.766	7.187
SG	2.835	3.008	2.770	8.613
GG	3.301	3.165	3.265	9.731
Total	15.815	14.659	15.296	45.770

TABLE 114

(TOP + ROOT) YIELD

R_I	R_{II}	R_{III}	Total
3.233	2.722	3.021	8.976
4.316	3.681	3.246	11.243
3.359	3.559	3.846	10.764
3.645	2.995	4.179	10.819
4.322	4.276	4.228	12.826
5.246	4.942	4.720	14.908
24.121	22.175	23.240	69.536

TABLE 115

PHOSPHATE

	R_I	R_{II}	R_{III}	Total
C	10.57	9.40	11.05	31.02
FS	15.27	14.02	13.58	42.87
NC	13.43	13.49	15.23	42.15
BD	13.85	12.25	15.17	41.27
SG	22.39	21.87	22.10	66.36
GG	20.28	19.58	20.75	60.61
Total	95.79	90.61	97.88	284.28

TABLE 116

Top yield of perennial rye grass grown in Calcareous soil (N - Limiting).

Treatment		Treatment means (in gms)
C	C	1.609
F/S-1%	FS	1.351
N/C	NC	1.979
B/C-1%	BD	2.178
Sg/C	SG	2.163
Gg/C	GG	2.242
General mean		1.9203 gms

S.E. = 0.1536 gms

C.D. at 5% = 0.34222 gms

TABLE 117

Root yield of perennial rye grass grown in Calcareous soil (N - Limiting).

Treatment	Treatment means (in gms)
C	0.830
FS	1.025
NC	1.187
BD	1.245
SG	1.310
GG	1.281
General mean	1.15

S.E. = 0.1201 gms

C.D. at 5% = 0.2676 = 0.268

TABLE 118

Top + root yield of perennial rye grass grown in Calcareous soil (N - Limiting).

Treatment	Treatment means (in gms)
CC	2.439
FS	2.376
NC	3.116
BD	3.423
SG	3.473
GG	3.523
General mean	3.067

S.E. for treatment means = 0.266 gms

C.D. at 5% = 0.5926 gms = 0.593 gms

TABLE 119

Total uptake of Nitrogen by perennial rye grass grown in Calcereous soil (N - Limiting).

Treatments		Treatment means (in mgms)
C	C	23.05
F/S-1%	FS	22.83
N/C-	NC	32.70
B/C	BD	37.31
Sg/c	SG	39.95
Gg/c	GG	38.98
General mean		32.47

S.E. = 2.4055 mgm

C.D. at 5% = 5.3595 = 5.36 mgm

TABLE 120

Top yield of perennial rye grass grown in Calcareous Soil (N - Limiting).

	R_I	R_{II}	R_{III}	Total
C	1.816	1.461	1.549	4.826
FS	1.220	1.382	1.451	4.053
NC	1.859	1.916	2.162	5.937
BD	2.265	2.291	1.979	6.535
SG	2.096	2.414	1.980	6.490
GG	2.032	2.430	2.264	6.726
Total	11.288	11.894	11.385	34.567

TABLE 121

Root yield (in gms) of perennial rye grass grown in Calcareous soil (N - Limiting).

	R_I	R_{II}	R_{III}	Total
C	0.937	0.710	0.844	2.491
FS	0.942	0.912	1.221	3.075
NC	1.071	1.132	1.358	3.561
BD	1.211	1.273	1.250	3.734
SG	1.325	1.535	1.069	3.929
GC	1.268	1.384	1.191	3.843
Total	6.754	6.946	6.933	20.633

TABLE 122

TOP + ROOT yield of perennial rye grass grown in Calcareous soil (N - Limiting).

	R_I	R_{II}	R_{III}	Total
C	2.753	2.171	2.393	7.317
FS	2.162	2.294	2.672	7.128
NC	2.930	3.048	3.520	9.498
BD	3.476	3.564	3.229	10.269
SG	3.421	3.949	3.049	10.419
GG	3.300	3.814	3.455	10.569
Total	18.042	18.840	18.318	55.200

TABLE 123

NITROGEN

	R_I	R_{II}	R_{III}	Total
C	25.93	21.19	22.03	69.15
FS	19.59	21.48	27.43	68.50
NC	31.31	31.56	35.22	98.09
BD	37.83	37.87	36.22	111.92
SG	39.53	43.17	37.15	119.85
GG	35.30	41.62	40.03	116.95
Total	189.49	196.89	198.08	534.46

Table 125. Straw yield of 2nd wheat (in gms).

Treatment	Treatment means (in gms)
C	0.899
F/S	1.907
N/C	1.430
B/C	1.676
Sg/C	1.628
Gg/C	1.604
K/N	1.067
General mean	1.459

S.E. of treatment means = 0.092315 gm.

C.D. at 5% = 0.198016 gm = 0.198 gm

Statistical interpretation at 5% level of significance

FS BD SG GG NC KN C

Table 126. Root yield of 2nd wheat (in gms).

Treatment	Treatment means (in gms)
C	0.308
F/S	0.616
N/C	0.442
B/C	0.642
Sg/C	0.583
Gg/C	0.623
K/N	0.363
General mean	0.511

S.E. of treatment means = 0.04337 gms.

C.D. at 5% = 0.093029 gms = 0.093 gm.

Statistical interpretation at 5% level of significance

BD GG FS SG NC KN C

Table 127. Straw + Root yield of 2nd wheat.

Treatment	Treatment means (in gms)
C	1.207
FS	2.523
NC	1.872
BD	2.318
SG	2.211
GG	2.227
KN	1.430
General mean	1.970

C.D. at 5% = 0.267

statistical interpretation at 5% level of significance

FS BD GG SG NC KN C

Table 128. Total uptake of nitrogen (in mgms) by 2nd wheat.

Treatment	Treatment means (in mgms)
C	9.14
F/S - 1%	19.74
N/C	14.41
B/C	17.69
Sg/C	17.50
Gg/C	16.57
K/N	10.38
General mean	15.06

S.E. of treatment menas = 0.9332

C.D. at 5% = 2.00171 mgms = 2.00

FS BD SG GG NC KN C

Table 129. Total uptake of phosphate (in mgms) by 2nd wheat.

Treatment	Treatment means (in mgms)
C	9.45
F/S	16.81
N/C	15.07
B/C	15.93
Sg/C	14.77
Gg/C	16.36
K/N	10.48
General mean	14.12

S.E. of treatment means = 0.6978 mgms

C.D. at 5% = 1.49678 mgms = 1.50 mgm

Statistical interpretation at 5% level of significance

FS GG BD NC SG KN C

Table 130. Total uptake of potassium (in mgms) by 2nd wheat.

Treatment	Treatment means (in mgms)
C	47.21
F/S	105.54
N/C	82.30
B/C	92.04
Sg/C	85.22
Gg/C	92.30
K/N	60.00
General mean	80.66

S.E. of treatment means = 5.1725 mgms

C.D. at 5% = 11.095013 mgms = 11.10

FS GG BD SG NC KN C

Table 131. Total uptake of magnesium (in mgms) by 2nd wheat.

Treatment	Treatment means (in mgms)
C	1.231
F/S	2.489
N/C	1.513
B/C	2.442
Sg/C	2.404
Gg/C	2.131
K/N	1.230
General mean	1.920

S.E. of treatment means = 0.210813 mgms

C.D. at 5% = 0.452194 mgm = 0.452 mgm

FS BD SG GG NC C KN

Table 132. Total dry matter yield of 1st + 2nd wheat.

Treatment	Treatment mean (in gms)
C	5.751
FS	4.620
NC	4.745
BD	5.495
SG	5.693
GG	5.769
KN	5.187
General mean	5.323

C.D. at 5% = 0.534 gm

GG C SG BD KN NC FS

Table 133. Total N uptake by 1st and 2nd wheat (combined)

Treatment	Treatment means (in mgms)
C	40.97
FS	38.88
NC	38.66
BD	38.49
SG	46.42
GG	46.61
KN	35.87
General mean	40.84

C.D. at 5% = 4.00 mgm

GG SG C FS NC BD KN

Table 134. Total P_2O_5 uptake by 1st and 2nd Wheat (combined).

T

Treatment	Treatment means (in mgms)
C	31.62
FS	27.98
NC	29.39
BD	31.25
SG	35.83
GG	38.97
KN	38.14
General mean	33.3

C.D. at 5% = 3 mgm.

GG KN SG BD C NC FS

Table 135. Total K uptake by 1st and 2nd wheat (combined)

Treatment	Treatment means (in mgms)
C	114.24
FS	136.45
NC	126.38
BD	138.30
SG	146.24
GG	154.10
KN	138.72
General mean	136.35

C.D. at 5% = 22 mgm.

GG SG KN BD FS NC C

Table 136. Total Mg uptake by 1st and 2nd wheat (combined).

Treatment	Treatment means (in mgms)
C	6.48
FS	4.89
NC	4.76
BD	5.53
SG	6.39
GG	7.16
KN	5.38
General mean	5.80

C.D. at 5% = 0.904 mgm.

GG C SG BD KN FS NC