A STUDY OF THE 'AVAILABILITY' TO PLANTS OF DIFFERENT FORMS OF PHOSPHATE

by

F.M. El-Reweiny

A thesis presented to the University of Edinburgh
for the Degree of Doctor of Philosophy
in the Faculty of Science

September 1966

15 JAN 1967

EX BIBL. UNIV. EDINBURGH

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. REVIEW OF LITERATURE	4
1. Ca-metaphosphate	4
2. K-metaphosphate	13
3. NH_4^-, Na- and other metaphosphates	17
4. The use of ^{32}P in soil- and fertilizer-P studies	24
III. METHODS and MATERIALS	42
A. Greenhouse and Cage Work	42
1. Experiment I, 1963-64	42
Design and treatments . . .	42
Preparation of pots	43
Sowing	45
Soil sampling pots	45
Subsequent treatments and sampling	45
Soil sampling	47
2. Experiment II, 1964	48
Design and treatments . . .	48
Preparation of pots	49
Sowing	50
Soil sampling pots	51
Subsequent treatments and sampling	52
3. Experiment III, 1964	53
Design and treatments . . .	53
Preparation of pots	54
Sowing	55
Subsequent treatments and sampling	56
B. Analytical Methods	57
1. Plant Analysis	57
Digestion of plant material . .	57
Determination of total P . .	57

Page

2. Soil Analysis 58
Determination of soil reaction . 58
Soil extraction 58
Determination of P in soil extracts 60
Hydrolysis of the metaphosphates. 62
Radioactive analysis . . . 63

IV. RESULTS 66

Definitions 66
Symbols 67

A. Yields and Plant Analysis 69

Experiment I, 1963-64 69
Yield and plant analysis, 1963 . 69
Yield and plant analysis, 1964 . 72

Experiment II, 1964 72
Yields and plant analysis . . 72
"A" Values 77
Labelled-P content 79
Labelled-P uptake 80

Experiment III, 1964 81
Yields and plant analysis . . 82

B. Soil Analysis 85

Experiment I 85

Experiment II 86
(a) Extractable-P 86
(b) Extractable ^{32}P 87
(c) Percentage hydrolysis . . 88

V. DISCUSSION. 89

1. Effects of form of phosphate . . 90

2. Effects of P Rate 105

3. Effects of N Rate 110

4. Effects of Method of Application . 116

5. Important Interactions 118

Page

6. Isotopic Exchange in the Soil . . . 120

7. Hydrolysis of Condensed-P in the Soil . 121

8. The Possibility of Absorption of Polyphosphates by Plants 128

VI. CONCLUSION AND SUMMARY 131

VII. ACKNOWLEDGEMENTS 136

VIII. BIBLIOGRAPHY 137

APPENDICES 154

Appendix I 154

Weather data for 1963-64 154
Analysis of variance for Experiment I . 155
Layout of Experiment I 156
Results of yield and plant analysis, Experiment I 158

Appendix II 204

Layout of Experiment II 204
Analysis of variance for Experiment II . 205
Results of yield and plant analysis, Experiment II 206

Appendix III 248

Layout of Experiment III 248
Analysis of variance for Experiment III . 249
Results of yield and plant analysis, Experiment III 250

Appendix IV 274

Hydrolysis of polyphosphates 274
Results of soil analysis 275

I. INTRODUCTION

Considerable progress has been made, by fertilizer chemists and chemical engineers during recent years, in the development of new fertilizers and of processes for phosphate fertilizer production. Some of the new processes have been expanded to a commercial scale, and there is reason to believe that others will find extensive use in the future.

In 1843 Sir John Lawes of Rothamsted discovered the process of manufacturing superphosphate, by treating rock phosphate with sulphuric acid. That was really the beginning of the phosphate fertilizer industry. Since the discovery of the process, ordinary superphosphate, containing 16-20 per cent P_2O_5, constituted, for many years, the major source of fertilizer phosphorus throughout the world. It proved to be an efficient, easily manufactured, low-cost material with few problems associated with its storage and application. Over the years agronomists have consistently placed superphosphate at the top of the list of phosphorus carriers with regard to plant response, for a wide range of soil, climatic and crop management conditions. However, ordinary superphosphate has the disadvantage of being a product of relatively low P-content, which is an important factor, especially in areas that are located far from the source of supply. High-analysis phosphates have an advantage over superphosphate from the stand point of lower shipping and loading costs per unit of plant nutrient. Also, concentrated materials are preferable for use on steep lands where fertilizer distribution is difficult and frequently done by hand.

Recently, concentrated superphosphate ('double' or 'triple'), 40-50 per cent P_2O_5, has been produced in greatly increased quantities. The tendency has been towards the use of concentrated superphosphate as the standard phosphatic material in experimental work in preference to ordinary superphosphate, since the latter contains large amounts of sulphate introducing an additional plant-growth variable.

Quite a large number of phosphate materials has been produced recently, some of which have been produced on a commercial scale, and others are still produced only on experimental scale. Some of these materials are; mono-, di- and tricalcium phosphates, fused tricalcium phosphate, and calcined phosphates. Ammonium phosphates, nitric phosphates, and ammoniated superphosphates are P-N fertilizers. Other materials are used, like basic slag which is a by-product in steel manufacturing, different rock phosphates, silico-phosphates, liquid phosphoric acid and a wide variety of organic phosphates.

Metaphosphates have been produced during the last 30 years. Calcium metaphosphate was first produced by the Tennessee Valley Authority in 1935. The high P-content of this compound (60-63 per cent P_2O_5) has made it of particular interest in certain areas. Since that time, several thousands of tons have been produced for experimental tests. Other metaphosphates such as potassium-, ammonium-, and sodium metaphosphates have also been produced.

Extensive field and pot experiments, and laboratory work have been done on the evaluation of fertilizers of different

forms, or sources, or solubility.

Metaphosphate fertilizers, particularly calcium metaphosphate, have been extensively tested for many years in pot and field experiments. Crop response to metaphosphates has been, generally, similar to the response to orthophosphates on acid to neutral soils. On alkaline soils, conflicting results have been obtained. In some tests crop responses to meta-, as compared with orthophosphates, were satisfactory, but not in others.

There are few cases in which sodium meta- or polyphosphates have been tested as a source of P for plants in comparison with orthophosphates.

It was the aim of this investigation to study the "availability" to plants of some of water-soluble meta- or polyphosphates in terms of growth response and phosphorus uptake. The materials are all sodium meta- or polyphosphates and have been compared with sodium orthophosphate. For this, a series of three pot experiments was conducted, both in the greenhouse and under natural atmospheric conditions, with perennial ryegrass as the test plant. Five different soils have been used.

II. REVIEW OF LITERATURE

This review covers some of the previous investigations that have been done to evaluate metaphosphates, also the use of radiophosphorus ^{32}P in the soil- and fertilizer-phosphorus studies, and it will be under the following headings.

1. Ca-metaphosphate
2. K-metaphosphate
3. NH_4-, Na-, and other metaphosphates
4. The use of ^{32}P in soil- and fertilizer-phosphorus studies.

1. Ca-metaphosphate

Curtis et al. (1938) reported that Ca-metaphosphate was first produced in 1935 by the Tennessee Valley Authority, and that it contained 60-63 per cent P_2O_5. The chemical composition and properties of that compound were studied by MacIntire et al. (1937).

In a large number of pot experiments using a wide range of soils, all over the U.S.A., tests were conducted by Ross and Jacob (1937) to evaluate 16 samples of phosphate fertilizers of different forms, granule size, or solubility. On acid to neutral soils Ca-metaphosphate was as effective as mono-calcium phosphate, in promoting growth of Sudan grass, sweet clover, wheat, tomato, millett, German millett and tobacco. On calcareous soils it was, apparently, inferior to mono-calcium phosphate. Jacob and Ross (1940), from pot experiments with soils in the pH range 5.2-7.1, reported that calcium metaphosphate gave a relative value of 98 when the value of superphosphate was considered 100, in terms of dry matter yields of Sudan grass and German millett. Considering

the P-content of plants, they found that Ca-metaphosphate gave a value of 120 relative to a value of 100 for superphosphate. On a calcareous soil of pH 9.5, with tomato as the test plant, Ca-metaphosphate was much poorer than superphosphate in terms of yield and P-content.

From field experiments, with cereals and alfalfa grown on alkaline soils, Green (1938) obtained similar results. Toevs and Baker (1939) also found that Ca-metaphosphate produced much poorer yields of alfalfa than did conc. superphosphate, in field experiments on calcareous soils in Idaho. McGeorge (1939) reported that Ca-metaphosphate was equivalent to conc. superphosphate, in a pot experiment on similar soils, while values of 62-87 per cent of that of conc. superphosphate were shown by the Neubauer test. In a greenhouse pot experiment with a calcareous soil of pH 8.2, Baker (1942) found that the yield of barley, as the first crop, was smaller with Ca-metaphosphate than with conc. superphosphate, but the total yield of the three successive crops was only slightly smaller with Ca-metaphosphate. A similar trend was found in the percentage recovery of added P. Hinkle (1942) conducted a field- and a pot-experiment on an irrigated calcareous soil in Southwest Arizona. In the field, Ca-metaphosphate produced smaller yields of alfalfa than did conc. superphosphate. In the pot experiment the yield and P-uptake of annual yellow clover with Ca-metaphosphate was also smaller than with conc. superphosphate.

Brown and Clark (1943) obtained higher yields from the application of Ca-metaphosphate than from superphosphate in seven

out of 12 pot tests with millett, oats, and wheat grown on four acid soils. O'Brien (1944) reported that commercial- and conc. superphosphates were only slightly better than Ca-metaphosphate for a wide variety of crops grown in rotation on eight different locations on the major soil types of Virginia. Chandler and Musgrave (1944) did not find any significant differences between Ca-metaphosphate and superphosphate in two field experiments carried out over a 3-year period with mixed hay, corn, and wheat in two locations in N.Y.State. Using alfalfa as the test crop, Alway and Nesom (1944) compared Ca-metaphosphate with superphosphate in Southwestern Minnesota on a clay loam with a slightly acid surface soil. They found that calcium metaphosphate, well incorporated with the soil in advance of or at the time of seeding, increased the yield virtually as much as did superphosphate for the succeeding three crop seasons. But it was far inferior to superphosphate only in the first season, where top-dressed in the spring for an established stand. On a permanent pasture, Woodhouse (1945) found that Ca-meta-phosphate was as satisfactory as conc. superphosphate.

A summary report of several hundred field- and pot-experiments was published by T.V.A. (1946) and reported by Jones and Rogers (1949). The experiments were conducted under a wide variety of soil and climatic conditions with all the major crops in U.S.A., and comparisons were made between superphosphate, Ca-metaphosphate, fused tricalcium phosphate, and conc. superphosphate. The relative value of Ca-metaphosphate, in terms of crop response, was 99 per cent of that of superphosphate. On Scottish soils of various origins, Williams and Reith (1948) reported that Ca-

metaphosphate, broadcast on the flat for turnips or swedes or over the initial ridges for potatoes, was inferior to superphosphate and that the origin of the soil did not alter the relative values of the different phosphates tested.

Using labelled fertilizers, in a field experiment in New York, Blaser and McAuliffe (1949) found that the percentage of labelled-P in the first harvest of clover was 13.7 from Ca-metaphosphate and 22.5 from superphosphate. Hall et al. (1949) reported, from results of field experiments in N. Carolina, that cotton absorbed more fertilizer-P from Ca-metaphosphate than from superphosphate only on a high-P soil. There was no difference between the two fertilizers in the uptake of labelled-P by corn on either low- or high-P soils. Stanford and Nelson (1949) found that, in field experiments on three acid soils in Iowa, labelled-P uptake by oats and alfalfa was lower from Ca-metaphosphate than from superphosphate, particularly in the early stages of growth, the two fertilizers were broadcast at a rate of 40 lb. P_2O_5 per acre. Olsen and Gardner (1949) found similar results for sugar beet, wheat, and barley grown on calcareous soils in Colorado. Olsen and Gardner attributed the inferiority of Ca-metaphosphate, in the early stages of growth, to the slow hydrolysis of this compound in the soil. Ensminger (1950) reported that Ca-metaphosphate was as effective as ordinary- and conc. superphosphates, in increasing yields of different crops on Alabama soils. Norum and Young (1950) found that drilling phosphate fertilizer produced greater yields of wheat and durum than did broadcasting, on North Dakota soils. However, with both methods of application conc. superphosphate

produced greater yields than did Ca-metaphosphate. Speer et al. (1951) found that, in greenhouse experiments, labelled-P uptake by string beans from Ca-metaphosphate was smaller than that from ordinary- or conc. superphosphate. From results of field experiments on calcareous irrigated soils of Colorado, Olsen et al. (1950) found that the labelled-P uptakes by different crops, from both broadcast and rototilled fertilizers, were about equal from Ca-metaphosphate and superphosphate only in the later stages of growth. Ca-metaphosphate was inferior in the early stages of growth, probably because of its slow hydrolysis during the growing season. In Ohio similar results were obtained, by Bureau et al. (1953), from field experiments with soybeans receiving banded fertilizers on soils of different P-fertility. MacIntire et al. (1953) reported that similar yield responses were obtained with Ca-metaphosphate and conc. superphosphate, incorporated with acid soils in greenhouse experiments with red clover, Sudan grass, and barley. Peterson et al. (1953), in their review of phosphate fertilizer investigations in 15 of the American States, reported that Ca-metaphosphate was inferior to H_3PO_4; ordinary- and conc. superphosphates; or NH_4-phosphates, while it was superior to rock phosphate, di- and tri-calcium phosphates for most crops. Tisdale and Winters (1953), summarised results of crop response to Ca-metaphosphate on alkaline soils of Colorado, Iowa, New Mexico, and Utah. They reported that, in 27 experiments where crop responses were obtained, Ca-metaphosphate was superior to conc. superphosphate in one , inferior in six , and equivalent in 20 cases, in terms

of crop responses. Considering the labelled-P uptake as the criterion of fertilizer effectiveness, there were 38 comparisons between the two sources, from which six showed no difference, and in 32 cases conc. superphosphate was superior. They also reported that, in the early stages of growth of sugar beet and alfalfa, Ca-metaphosphate was inferior to conc. superphosphate, in terms of labelled-P uptake. Although this difference had largely disappeared during the later part of the season, if the materials applied were ex-40 mesh or ex-100 mesh, it was only reduced for the ex-10 mesh materials. From the last observation they suggested that the time of contact between the soil and Ca-metaphosphate as well as the particle size of the material are important factors in its hydrolysis. Schmehl et al. (1955) conducted field experiments in which fertilizers were mixed with calcareous soils of Colorado. Results of those experiments indicated that Ca-metaphosphate was equivalent to superphosphate in terms of yields and P-uptake by sugar beet, barley, lucerne, and potatoes.

In different parts of Great Britain, Ca-metaphosphate was reported, Cooke (1956), to be decidedly inferior to superphosphate in yield production of swedes. On the basis of P-uptake, however, it was only slightly inferior, probably because Ca-metaphosphate hydrolyses slowly in the soil and extra P is taken up by plants late in the season when the crop cannot produce a corresponding increase in the yield of dry matter. Olson et al. (1956) carried out greenhouse and field experiments in Nebraska to test the availability of phosphate carriers to small grains.

They reported that Ca-metaphosphate was as effective as conc. superphosphate on acid soils, but was inferior to conc. superphosphate on calcareous soils, in increasing yields of small grain crops. Placement application of Ca-metaphosphate was more effective than mixing or broadcasting. Odland et al. (1956) reported that, in field experiments on acid soils of Rhode Island, Ca-metaphosphate was almost as effective as ordinary or conc. superphosphate in increasing yields of corn both for grain or for silage, but it produced significantly smaller yields of potatoes. Caldwell et al. (1956) reported that ordinary-, conc. superphosphate, and H_3PO_4 produced greater and more consistent yields, of mixed legume hay, than did Ca-metaphosphate, where they were broadcast annually for six years, in a long term experiment in Minnesota, at a rate of 40 lb. P_2O_5 per acre. In that experiment grain yields of wheat and corn were not affected by P-treatments. Measuring the increases in P-uptake of two samplings of hay, wheat, and corn, the above authors found that ordinary-, conc. superphosphate and Ca-metaphosphate, were more alike, and H_3PO_4 was slightly superior. Robertson and Hutton (1958) found that Ca-metaphosphate produced smaller responses than ordinary and conc. superphosphates, in field experiments in Florida with four field crops. The results of 16 field experiments on acid to neutral soils of Iowa were reported by Webb and Pesek (1959). They found no significant difference between Ca-metaphosphate and conc. superphosphate in increasing the yield of grain or P-content of corn leaves. They also stated that although Ca-metaphosphate is water insoluble, it reacts with water to form soluble orthophosphate. Similar results were reported by

Terman et al. (1960) for grazed legume-grass mixtures in Kentucky, and for alfalfa or legume-grass mixture for hay in Kentucky, N. Carolina, Tennessee, and Virginia. Webb et al. (1961[b]) compared the effectiveness of different fertilizers broadcast on calcareous soils of Iowa in five field experiments with corn. They found that the effectiveness of the ex-12 mesh Ca-metaphosphate was about 70-80 per cent of that of conc. superphosphate, in increasing the yield of grain and P-content of corn leaves, while a value of 60 per cent was obtained for the granular Ca-metaphosphate. In another series of field experiments on acid soils, Webb et al. (1961[a]) found that Ca-metaphosphate was equivalent to conc. superphosphate in increasing yields of oats. Almaras and Black (1962) reported that the "availability coefficient ratios" of Ca-metaphosphate on different soils, relative to superphosphate, were found to range from 0.61 to 1.25 where 1.0 indicates equivalence. The lower values were found on calcareous soils. Beaton and Gough (1962) found that, in greenhouse experiments, Ca-metaphosphate, mixed with 2 calcareous soils, produced slightly higher yields of alfalfa than did mono-calcium phosphate, but there was no difference in P-uptake. However, the percentage-P in the dry matter with mono-calcium phosphate was slightly higher than that with Ca-metaphosphate. Beaton et al. (1962) using similar soils in greenhouse experiments, found that the P-uptake, in both roots and tops of alfalfa, was significantly lower from Ca-metaphosphate than from mono-calcium phosphate. In field experiments in Colorado, Schmehl and Romsdal (1963) found no significant

difference between Ca-metaphosphate and conc. superphosphate as regards yield or P-uptake of alfalfa.

Terman and DeMent (1962) compared the availability of Ca-metaphosphate, granulated partially-hydrolysed Ca-metaphosphate (14-18 per cent of its P water-soluble), and conc. superphosphate, in greenhouse experiments with calcareous-, acid- and limed acid soils. Ca-pyrophosphate, which was formed during the hydrolysis of Ca-metaphosphate, was also included in the tests. The initial crop responses to Ca-metaphosphate and pyrophosphate, especially as coarse granules, were generally poorer than for conc. superphosphate. Later-responses became more alike especially with fine materials. The granular partially-hydrolysed material was similar in effectiveness to ammoniated conc. superphosphate (57 per cent of its P water-soluble). They also reported that these results indicate that the availability of P in Ca-metaphosphate or its degradation products is controlled by the rate of hydrolysis and dissolution.

From the results of this large number of experiments one may extract some useful information. There is a general trend that Ca-metaphosphate is as effective a source of P as conc. superphosphate for most crops, at least on acid to neutral soils. On alkaline soils, the results are rather conflicting and are not, generally, in favour of this fertilizer particularly in the early stages of growth, which may make it an unsuitable P-source for quick-growing crops like vegetables, or as a starter fertilizer, or topdressing. The particle size of the material is also of considerable importance since the finer materials gave better

results than the coarse ones, probably because the latter hydrolyse more slowly in the soil. Method and time of application are also important factors that may influence the effectiveness of Ca-metaphosphate.

Comprehensive reviews, of investigations in which Ca-metaphosphates were tested as fertilizers, have been made by Alway and Nesom (1944), Jones and Rogers (1949), Rogers et al. (1953), Tisdale and Winters (1953), Thorne and Seatz (1955), Cooke (1956) and Terman and Seatz (1956).

2. Potassium metaphosphate

Potassium metaphosphate contains about 55 per cent P_2O_5 and 35 per cent K_2O. Like Ca-metaphosphate, it is practically insoluble in water, and has the same advantage of being a high-analysis material. Harris (1963) considered K-metaphosphate a desirable fertilizer for its important properties; (a) high concentration of P and K, (b) non-hygroscopic and non-caking without any treatment, (c) compatible with other fertilizer raw materials for manufacturing compound fertilizers, and (d) considering its high analysis, the "salt damage" to plants is minimised.

The potassium of K-metaphosphate was balanced up in the investigations reviewed here, unless otherwise stated.

As early as 1933 Bartholomew and Jacob (1933) tested K-metaphosphate as a fertilizer in a pot experiment with Sudan grass using a soil of pH 5.7. They found that K-metaphosphate produced a greater yield of dry matter than did mono-calcium phosphate. The relative value of the increase in P-uptake was about 136 in comparison with mono-calcium phosphate as 100.

Baker (1942) compared K-metaphosphate with conc. superphosphate, as sources of P, for barley and three successive crops grown in the greenhouse on a soil of pH 8.2. K-metaphosphate produced greater yields than did conc. superphosphate, only for the first crop, and the two materials produced similar total yields of the three successive crops. In the same experiment, K-metaphosphate produced percentage recoveries of 40 and 83, as compared with 35 and 67 per cent produced by conc. superphosphate, for the first crop and total of all crops respectively. Hougland et al. (1942) also reported that yields from crops receiving K-metaphosphate either equalled or exceeded those receiving superphosphate. Brown and Clark (1943) reported that K-metaphosphate outyielded superphosphate in 6 out of 12 tests, carried out in the greenhouse on acid soils, with millett, oats and wheat. From the results of two field experiments carried out, in New York, over a period of 3 years, with legume-grass hay, corn, and wheat; Chandler and Musgrave (1944) found that there was a tendency for K-metaphosphate to outyield superphosphate, although the differences were not statistically significant. Woodhouse (1945) reported that, where lime was applied for permanent pasture in N. Carolina, K-metaphosphate was equivalent to 20 per cent superphosphate + K as a source of P and K. On unlimed soils superphosphate + K had only a slight advantage. Ensminger (1950) also reported that K-metaphosphate was as effective as ordinary or conc. superphosphates for most crops in Alabama, in terms of crop responses. On two acid soils, MacIntire et al. (1953) found that, in the greenhouse, K-metaphosphate produced similar

responses to those of conc. superphosphate, on a soil of pH 5.0, and better responses on a soil of pH 5.6; the crops were red clover, Sudan grass, and barley. Thorne and Seatz (1955) reported, in a review on the agronomic value and production of T.V.A. fertilizers, that an average of 46 field tests on acid soils, gave a relative yield value of 101 for P in K-metaphosphate compared with 100 for superphosphate. They also reported that tests in Idaho and Utah calcareous soils showed that K-metaphosphate produced as great responses as did superphosphate. In field trials on acid soils of Rhode Island, Odland et al. (1956) found no difference between K-metaphosphate and ordinary or conc. superphosphate in their effectiveness for corn and mixed hay. DeMent et al. (1963) reported that the total yield of dry matter for three successive crops (corn, oats, and oats) grown in pot experiments and fertilized with 4 particle sizes of K-metaphosphate, was either similar to or greater than that for conc. superphosphate. They also reported that the residual value of the coarse K-metaphosphate, for crops, was relatively greater than that of conc. superphosphate, which indicates a gradual hydrolysis of K-metaphosphate over time. Results of field trials in England and Scotland were reported by Harris (1963). In most cases there was no difference between super. + KCl and K-metaphosphate, in producing yields of red clover, grass, cereals, early- and main crop potatoes. Mondrzak-Rosenberg and Hagin (1964) conducted a greenhouse experiment to evaluate some phosphatic fertilizers including K-metaphosphate, on three alkaline soils. Yields of lettuce, corn, and lettuce grown successively, with K-

metaphosphate, were similar to, and in some cases better than those of mono-calcium phosphate.

In all these investigations K-metaphosphate proved to be at least as effective a source of P as ordinary or conc. superphosphate for most crops. There are few cases, for crops such as potatoes, in which K-metaphosphate was found to be inferior to ordinary- or conc. superphosphate. Although K-metaphosphate was reported to be as effective as superphosphate by Harris (1963) for early and maincrop potatoes, Odland et al. (1956) found that it produced lower yields of potatoes than did ordinary- or conc. superphosphate, on acid soils of Rhode Island. Hagin (1962) found that, in a greenhouse experiment, K-metaphosphate was at least as effective as superphosphate on two out of 4 calcareous soils, but was inferior to superphosphate on the other two soils. In greenhouse experiments at Rothamsted, Cooke (1963) reported that there was no difference in yields of kale or oats receiving K-metaphosphate or conc. superphosphate. Only in the first cut of ryegrass K-metaphosphate produced significantly smaller yields than conc. superphosphate. Granular K-metaphosphate produced greater P-uptake than did granular conc. superphosphate in all cases except for the first cut of ryegrass. Mattingly (1963) summarised evidence from field experiments in G.B. during the preceding 10 years on the agricultural value of a number of phosphatic fertilizers. A single sample of K-metaphosphate was included in some experiments, and it was not, generally, as effective as superphosphate. Munk (1963) found that, in pot experiments carried out for two years with oats, maize and spring

barley, K-metaphosphate was inferior to mono-calcium phosphate over the two years, on a soil of pH 5.0. On a soil of pH 6.7 the two fertilizers produced similar yields. He also reported that the crystalline K-metaphosphate was inferior to the vitreous product.

Extensive reviews have been made by Jones and Rogers (1949), Rogers et al. (1953) and Terman and Seatz (1956).

From this review, it can be concluded that K-metaphosphate is an efficient fertilizer as a source of P for most crops on most soils. However, there is some evidence that it may be inferior to superphosphate for crops such as potatoes. Also on very acid soils, due to its content of Ca, superphosphate may have an advantage over K-metaphosphate.

3. NH_4-, Na- and other metaphosphates

Metaphosphates like $NaPO_3$, NH_4PO_3, HPO_3 and $KCa(PO_3)_3$ have also been tested as phosphorus fertilizers.

McGeorge (1939), carried out a Neubauer test on four calcareous soils (for 15 days with rye seedlings). He found that P-uptake from Na-hexametaphosphate, a glassy water-soluble material, was 80-90 per cent of that from conc. superphosphate, and that the crystalline $NaPO_3$ gave a value of only 63-71 per cent. In a pot experiment with Sudan grass, the same author found that the Na-hexametaphosphate was superior to conc. superphosphate, and that the residual effect was equal for the two materials. Using culture-solutions, McGeorge (1939) also found that rye plants absorbed a greater amount of 'P' from Na-hexa-

metaphosphate than from mon-calcium phosphate. Allison et al. (1941), using the Neubauer technique, found that $NaPO_3$ was equivalent to mon•calcium phosphate on quartz sand, but was inferior on two acid soils of pH 4.8 and 5.1. This superiority of mono-calcium phosphate on acid soils may be due to its Ca-content, since the percentage recoveries for $NaPO_3$, mono-calcium phosphate, calcined phosphate, and tricalcium phosphate, on the soil of pH 4.8, were 7, 20, 32, and 30 per cent respectively. Honya et al. (1961) in field experiments, with paddy rice on a volcanic ash soil in Japan, found that ammoniated Na-tripoly-phosphate and Na-polymetaphosphate, compared with superphosphate as a control, produced poorer growth in the early stages, but increased the growth at the elongation stages. The yield was increased by 5 and 9 per cent, by Na-tripolyphosphate and Na-polymetaphosphate respectively as a result of increased number of ears and number of grains per ear. P-content of the plants was at first lower than that of the control (with superphosphate) but later exceeded it and appeared to promote time of maturity.

Ammonium metaphosphate has also proved to be as effective a fertilizer as NH_4- orthophosphate, ordinary- and conc. super-phosphates. Godfrey et al. (1959) carried out field experiments on an acid and a calcareous soil, in Texas, with Sudan grass and cowpeas. The results of these experiments indicated that there was no difference between NH_4PO_3, $NH_4H_2PO_4$ or superphosphate, in terms of yield and P-uptake of the two crops on the two soils. In 16 field experiments, on representative soils of Iowa, with different phosphates broadcast for corn, Webb and Pesek (1959)

found that there was no evidence to indicate that NH_4PO_3 performed differently from superphosphate, on soils in the pH range 5.5-7.1. Lathwell et al. (1960) found that liquid and solid NH_4PO_3 were as satisfactory as conc. superphosphate, in field experiments for wheat, corn and cotton in Southeastern States, corn and oats in Iowa, and wheat and oats in New York. Schmehl and Romsdal (1963) also reported that NH_4PO_3 and conc. superphosphate, produced similar yield and P-contents of alfalfa on Colorado soils.

Metaphosphoric acid (HPO_3) was found to be equivalent to H_3PO_4 by Doerell (1941), only if it was applied initially, but it was inferior to H_3PO_4 as topdressing for plants grown in the greenhouse. MacIntire et al. (1950), in pot experiments, and Lathwell et al. (1960), in field experiments, found that HPO_3 produced similar results to those obtained by superphosphate.

Potassium-calcium-metaphosphate was tested in a single pot experiment by Baker (1942), and was found to be slightly more efficient than conc. superphosphate, in terms of recovery of applied-P.

Although not much work has been done with these metaphosphates, there is some evidence that $NaPO_3$, and HPO_3 are as effective P-fertilizers as comparable orthophosphates or superphosphate.

The reactions of metaphosphates in solutions or in soils, have been investigated by quite a few workers. The solubility of $Ca(PO_3)_2$ in aqueous solutions was found to vary from 8.0 to 61.6 per cent of its total P-content. MacIntire et al. (1937) attributed these wide variations to the varied amount of solid-

phase PO_3 in excess of the proportion $CaO:P_2O_5$ in relation to silico-phosphates which dissolve and hydrolyse to give HPO_3 and soluble silica. KPO_3 was reported, by Madorsky and Clark (1940), to be practically insoluble in water. Volkerding and Bradfield (1943) reported that the solubility of $Ca(PO_3)_2$ in aqueous solutions was greatly decreased in the presence of $CaCO_3$ while the solubility of KPO_3 was increased. The presence of dilute acids also greatly increased the solubility of KPO_3 and $Ca(PO_3)_2$ showed a marked increase in solubility in aqueous solutions on standing, but KPO_3 solubility was only slightly increased over a considerable length of time.

The hydrolysis of $Ca(PO_3)_2$ to orthophosphate, was reported by MacIntire et al. (1937), to be very slow in aqueous and dilute acid solutions, at room temperature, was slightly increased with salt additions, and greatly increased with increase in temperature or concentration of acid other than H_3PO_4. Studying the changes in the amount of ortho- and metaphosphates in culture-solutions, McGeorge (1939) found that there was a surprisingly rapid hydrolysis of the meta- to orthophosphate when growing roots were present in the culture solution, and concluded that the absorption by plants takes place as ortho-phosphate. Volkerding and Bradfield (1943) found that the rate or amount of hydrolysis of K- or Ca-metaphosphate to ortho-phosphate was not affected by salt concentrations up to 0.02 N, but considerable hydrolysis took place with standing in HNO_3 or H_2SO_4 solutions where the pH was below 4. The presence of $CaCO_3$ in the metaphosphate solutions greatly increased the hydrolysis

of $Ca(PO_3)_2$, KPO_3 and $NaPO_3$. They also reported that, in the presence of 2.0g. $CaCO_3$ per litre of 0.02 N solution of KPO_3 or $NaPO_3$, about 15 per cent of the metaphosphates was hydrolysed after standing at room temperature for 100 days with frequent shaking.

Enzymatic hydrolysis of poly- and metaphosphates, in the presence of micro-organisms in the solution, was reported by Ingelman and Malmgren (1947, 1949), Malmgren (1949), Mattenheimer (1956[a,b]), and Karl-Kroupa et al. (1957). The last measured the hydrolysis under resting conditions of different bacteria and fungi and found that an acceleration in rate of hydrolysis as high as thousandfold was observed in some cases. They also suggested that, under growing conditions, an even more rapid breakdown and utilization might be expected to occur. Ross and Ely (1951) also demonstrated the ability of both plant and animal cells to hydrolyse pyro-, meta- and many organic phosphates.

In soils almost free of $CaCO_3$, Rotini (1951) found that the PO_3^- ion was rapidly fixed particularly in soils rich in organic matter or in hydroxides of Fe or Al. He also reported that PO_3 was subsequently converted to PO_4 presumably by inorganic catalysts in the soil (hydrated MnO_2 and hydrates of Co, Ni, Fe or Al) or under the influence of microbial action. In soils, the hydrolysis of PO_3 to PO_4 was further studied by Rotini and Carloni (1952), and it varied according to the nature of the soil. They found that the mid-period of hydrolysis ranged between 30 days in a heath soil and 43 and 82 days in an acid organic soil and a clay soil respectively. From the results of toluene or

heat treatments of the soil, they also reported that the depolymerization of metaphosphoric acid is of a catalytic nature aided by microbial activity and rendering P available to crops. When the metaphosphates were mixed with silt-loam soils (pH 4.2 and 6.2), maintained at 25 per cent moisture, kept at room temperature for 6 and 15 weeks, and extracted with 0.1 N NH_4Cl and two successive treatments with 0.5 N NH_4F, Donso-Torres (1959) found that an appreciable hydrolysis of $NaPO_3$ and $Ca(PO_3)_2$ had taken place. When the metaphosphates were placed in bands at a depth of 3.5 cm. in the soil and maintained in a vapour-saturated chamber at 25°C for 17-52 days, and extracted in the same manner at 0°C, the mobility of P from $NaPO_3$ was greater than that from $Ca(PO_3)_2$, as shown by the distance of P penetration. The same author also reported that, after 46 days, 50 per cent of the P moved out from the $Ca(PO_3)_2$ band, and only 25 per cent of that from $NaPO_3$ band, were present in condensed form.

Concerning the fixation of PO_3 from suspensions of soil and subsoil (both acid), Fe_2O_3 and Al_2O_3, in both aqueous and ammonium citrate solutions, MacIntire et al. (1937), reported that 'fixation' of PO_3 was decidedly greater than that of PO_4 for the two P concentrations and two pH values of the initial solutions used. These results were confirmed by McGeorge (1939) who used natural and sterilized soil, and who added that micro-organisms and enzymes are not involved in the fixation of PO_3, since the fixation was greater in the sterilized than in the natural soil.

Rotini (1951) reported that the fixation of PO_3 was very rapid particularly in soils of higher content of dry matter, Fe

or Al. In subsequent experiments, Rotini et al. (1952) found that very little more P was absorbed by soil after 7 hours than after one min. of contact between the soil and $NaPO_3$ solution. Thorup and Mehlich (1961) also studied the retention of KPO_3 and KH_2PO_4 by soils and minerals. They found that bentonite and soils containing predominantly 2:1 lattice minerals retained somewhat more P from KH_2PO_4, and that halloysite and soils containing predominantly 1:1 lattice minerals retained somewhat more P from KPO_3. Higher temperature increased the amount of P retained by both soils and minerals, but did not alter the order of fixation of the different forms. Shaking period of 24 hours coincided with the maximum retention of P from the two sources.

From the results of these investigations it is still very difficult to define, exactly, the factors that affect the hydrolysis of metaphosphates in the soil since there is not enough information to do so. In the light of the present information, it can be concluded that factors such as soil pH, temperature, moisture content, and biological activities of the soil, affect the rate of hydrolysis of metaphosphates in the soil.

From the point of view of PO_3 fixation in the soil, there is evidence that soils fix more P from PO_3 than from PO_4. If this is true, it can be explained by the fact that PO_3 is monovalent as compared with trivalent PO_4. There is also evidence that the fixation by soil takes place in the form of PO_3, according to Rotini (1951) and Rotini et al. (1952), which is subsequently converted to orthophosphate.

Arnon (1953) stated that P is absorbed by plants chiefly

in the form of the orthophosphate ion. From the previous review, although it is not certain, there is evidence that metaphosphates are hydrolysed in the soil before their absorption by plants, since it was noticed, in many of the investigations, that plant growth with metaphosphates was slower than that with orthophosphates during the early stages of growth.

4. The use of ^{32}P in soil- and fertilizer-P studies

The isotope ^{32}P was first used by Hevesy et al. (1936) in studying the mobility of P in plants. It was not until ^{32}P was obtained by neutron irradiation in atomic piles that sufficient quantities were available for large-scale greenhouse and field experiments (Mattingly, 1957). In the last 15 years ^{32}P has been extensively used in plant-, soil-, and fertilizer-P studies, such as:- P-uptake from soil and fertilizer, fertilizer evaluation, method of application and fertilizer efficiency, the fate of fertilizer-P in the soil, factors affecting soil- and fertilizer-P uptake, translocation of P in the plant, P-accumulation in different parts of the plant, relationships of P and other plant nutrients, and many other fields of research.

This review will concentrate on the following points:-

(a) P-uptake from soil and fertilizer, and fertilizer-evaluation.

(b) Determination of 'labile-P' in soils.

(c) Factors that affect uptake of P.

(a) P-uptake from soil and fertilizer, and fertilizer evaluation.

Theoretically, the use of ^{32}P should offer an excellent measure of the amount of plant-P derived from the fertilizer and

that from the soil. Practically, there are many factors which may affect the accuracy of the results; (i) radiation may cause some damage to the plants, (ii) isotopic exchange between applied ^{32}P and soil-P may take a long time to reach equilibrium, therefore, the ratio of ^{31}P:^{32}P in the labile pool may be altered before reaching that equilibrium, and (iii) it is difficult to obtain a homogeneous mixture of soil and labelled-fertilizer, especially in field experiments.

(i) Effect of radiation on plants and P-uptake;

Although some radiation effects on plants have been reported by a number of workers, there is no general agreement about the extent or the nature of the damage produced, even at much higher levels of activity than those usually used in fertilizer experiments, and it is not possible to define levels of activity at which no radiation effects on plant growth can be detected.

Russell (1949), Russell et al. (1949, 1950) and Martin and Russell (1954) studied the effects of radiation on wheat- and barley-plants in a number of pot- and water-culture experiments. Significant increases and decreases occurred in the fertilizer-P uptake and in the ratio of fertilizer-P/soil-P. The increased fertilizer-P uptake, and the ratio of fertilizer-P/soil-P, for a slow-growing winter wheat was explained by assuming that the roots, damaged by radiation, regenerated in the top layer of the soil which contained the fertilizer-P. By contrast in the summer sown barley, root development in the lower soil layers was considerably more rapid, resulting in increased uptake of soil-P and decrease in the ratio of fertilizer-P/soil-P. These decreases and

increases in fertilizer-P uptake occurred at levels of activity of 2.0 and 20.0 μ C/pot as compared with 0.2 μ C/pot-level. In water-culture the most consistent symptoms of radiation damage were an increase in the amount of P translocated to the shoots and a reduction in root weight of young barley plants at activity as low as 10 μ C/l. The same authors reported that the damage was apparently due to the accumulation of ^{32}P in the root tips rather than the level of activity in the solution, since they found that the radioactivity in the root-tips, which were significantly damaged, was several hundred times greater than that of the culture solution.

Penner (1954[a]) conducted a series of greenhouse experiments with wheat, barley, oats, and rye. Labelled $NH_4H_2PO_4$ was applied at seed level with a range of activity levels up to 4000 μ C/g.P. Radiation effects on wheat were observed at levels as low as 12 μ C/g.P, but these effects were neither consistent nor systematically affected by the level of activity. Granular fertilizer slightly decreased the soil-P uptake by oats and barley at levels of 8.0 and 80 μ C/g.P respectively, but none of the levels of activity significantly affected the ratio of soil-P/fertilizer-P in any of the four cereals. In another series of field experiments with wheat on three locations in Canada, Penner (1954[b]) applied $NH_4H_2PO_4$ with levels of activity up to 3600 μ C/g.P. In four out of ten separate harvests, significant differences, attributable to ^{32}P, were found in two or more of the criteria studied (plant weight, total-, soil-, and fertilizer-P-uptake, and the ratio soil-P/fertilizer-P), but only in two harvests on

one site were the deviations of sufficient magnitude to cause any concern. Because of the irregularity of the injurious or stimulating effects of ^{32}P, it was not possible to set a range of specific activities where the absence of radiation effects can be guaranteed. Kasal and Kinugawa (1956) found no significant effect on the growth of various organs of kidney bean seedlings, although at high concentrations of ^{32}P, the roots of kidney bean became knotted and crooked and the meristems swelled. Dion and Pond (1949), Bould et al. (1951), (1952), (1953) and (1954), Strzemienski (1952), Armitage (1957) and Larsen and Cooke (1961) reported that ^{32}P has no effect on the fresh- or dry-yields or P-uptake by plants. In a few cases ^{32}P had only slight effects which were not considered to invalidate the use of ^{32}P, even if very high specific activities (in some cases 12.5 m C/g.P) were used. Larsen (1956[a]) reported that the percentage of P taken up from labelled hydroxy-apatite by barley was much smaller when the specific activity was 0.1 m C/g. of P than when it was one tenth of this value. There were no differences, however, in the fertilizer uptake from mono- or dicalcium phosphate in the same experiment that could be attributed to radiation. Larsen suggested that the labelled phosphate dissolving from hydroxy apatite remains more localized in soil than phosphate diffusing from mono- and dicalcium phosphates.

(ii) Effect of isotopic exchange on soil- and fertilizer-P uptake.

Spinks and Barber (1947) stated that "the use of ^{32}P as a quantitative tracer for fertilizer-P is independent of any reaction,

exchange or otherwise, which the P may subsequently undergo". Other workers have taken the view that isotopic exchange could lead to erroneous estimates of the uptake of fertilizer-P. McAuliffe et al. (1949) suggested that isotopic exchange, chemical fixation, and microbial conversion of labelled-P, may decrease the specific activity of plant-P and affect the interpretation of the results. This was the explanation for the decreased percentage-labelled-P in Italian ryegrass in the successive cuts. They also reported that appreciable isotopic exchange took place in the soil even if kept at the moisture equivalent, when the fertilizer was thoroughly mixed with the soil. Strzemienski (1953) suggested that isotopic exchange could account for the increased uptake by barley of soil-P in the presence of labelled-P, but he added that other factors, particularly the distribution of fertilizer-P in the soil would also affect the fertilizer-P-uptake and, therefore, the soil-P uptake. From the results of similar greenhouse experiments, Spinks and Barber (1948) also reported that, in the early stages of wheat growth, practically all P taken up was derived from fertilizer, and that the soil-P uptake was greater from the fertilized pots than from the control. Increase of soil-P uptake, as a result of phosphate-application, was also reported by many workers; Woltz et al. (1949), Dolson and Ketcheson (1953), Mattingly (1957[a]), Pleshkov and Mukhina (1957), Mattingly and Widdowson (1958), Bouldin and Black (1960), Anderson et al. (1961) and Jenkins (1962). In general, this increase in the uptake of soil-P, as a result of application of labelled-

fertilizers, was explained by the slow isotopic exchange of ^{32}P with the soil-P and/or by the increase in root-growth brought about by fertilization. The last explanation is in agreement with suggestions of McConaghy and Stewart (1963) and Smierzcholska (1963), but Simpson (1962) suggested that this may occur only on very low-P soils.

On the other hand, depressions in the uptake of soil-P, as a result of P-applications, were reported by Spinks et al. (1948), Spinks and Dion (1949), Dean (1954), McLean and Hoelscher (1954), Mattingly and Widdowson (1958), Dainty et al. (1959), Verma et al. (1959), Simpson (1960[a,b]) and Simpson (1962). The decrease in soil-P-uptake with P-application, can be explained by a greater ability of applied-P, relative to that of soil-P, to maintain P-concentration in the soil-solution following P-absorption by plant-roots.

Barbier et al. (1954) suggested that the equilibrium of distribution of PO_4 ions between the solid and liquid phase occurs rather slowly. Anderson et al. (1961) also suggested that the rapid stage of reaction between ^{32}P and soil-P which, in the laboratory, is completed in a matter of hours, may last for weeks or even months under comparatively dry conditions in pot experiments. Similarly, Lamm (1961) reported that isotopic exchange and chemical conversions between soil- and fertilizer-P are very slow.

The specific-^{32}P-sorption by soil was studied by Yuan and Robertson (1958), by shaking soil with ^{32}P solution. In the absence of ^{31}P, ^{32}P underwent a two-stage reaction; sorption

took place rapidly and dominated the reaction for 25 hours, followed by a period in which desorption dominated for the remaining 51 hours of shaking. They believed that the desorption resulted from isotopic exchange between sorbed ^{32}P and water-soluble soil-^{31}P in solution. If the carrier ^{32}P was present, ^{32}P underwent a three stage reaction. Following the sorption and desorption as in the absence of ^{31}P, there was a third stage in which sorption dominated again for about 100 hours of shaking. In the latter case, the first two stages took shorter time, which was believed to be because of the more easily established equilibrium brought about by the presence of ^{31}P. Surprisingly, they noticed that the reaction of ^{31}P was different from that of ^{32}P since ^{31}P was sorbed all the time. They concluded that ^{32}P behaved differently from ^{31}P at least in the first 25 hours of shaking with soil, but after 25 hours the rate of sorption was similar for the two isotopes. In contrast with these results, Olsen and Watanabe (1959), found that addition of ^{31}P and ^{32}P, in the orthophosphate form, to calcite showed that the two isotopes display the same reactions, and they suggested that the unusual behaviour of ^{32}P noted by Yuan and Robertson (above) may be due to differences in the ionic form of the ^{32}P sample.

(iii) Homogeneity of mixing labelled-P with the soil:

Gunary (1963) studied the process of isotopic equilibration in perfused crumbs of five soils, by following the changes of the specific-activity of the perfusate. Gunary found that the time required to reach equilibrium was 41 to more than 84 days according to the soil. He also suggested that the rate of

isotopic equilibration in pot experiments will be slow and may be restricted in certain soils by a slow rate of redistribution on a micro-scale of unevenly applied ^{32}P.

(b) Determination of the labile-P in soils:-

Larsen (1952); Fried and Dean (1952); Gunnarsson and Fredriksson (1952); and Barbier et al. (1954), have calculated the quantity of labile phosphate in the soil using the following, or a similar relationship:

$$\text{labile phosphorus} = b\left(\frac{1 - y}{y}\right),$$

where "b" is the amount of labelled fertilizer-P added to the soil and "y" is the fraction of P in the crop derived from the fertilizer. The value obtained by the use of this expression is called 'A'-value or 'L'-value. The term "labile-P" will be used in this investigation. Gunnarsson and Fredriksson (1952), found that the "labile-P" in the soil can be determined, with good precision, by shaking 10 g. soil once daily for 14 days with 100 ml. distilled water containing a known amount of labelled-P, and applying a formula, similar to the above, to P in the water extract. Lesaint et al. (1955), and Russell (1957) suggested similar methods.

Larsen (1952), pointed out that this technique is used for estimation of the "labile-P" in soils on the assumption that; when the added labelled-phosphate and the exchangeable soil-phosphates reach a state of equilibrium, the soil- and fertilizer-P is taken up by plants at constant ratio. For this reason, the fertilizer must be mixed intimately with the soil. Larsen (1956^a) also emphasised that seed-content of P should be accounted for by

alteration in the equation or, better, by continuing the experiment until the P-uptake by plants is so great that the seed-P could be neglected.

From the results of pot experiments with oats, Larsen (1952) showed that the value obtained was independent of the rate of application only when soluble mono-calcium phosphate was used. When hydroxy apatite was used, the "labile-P" values obtained were much greater than those with mono-calcium phosphate, that was apparently due to the very low solubility of hydroxy apatite, and very slow equilibration with the soil phosphates. The results of Fried and Dean (1952) and Dean (1954), were in complete agreement with those of Larsen. Fried and Dean (1952), found that different species of plants produced different values of "labile-P", in field experiments where mixing the fertilizer with the soil is impossible. However, Fried (1953) found that seven species of plants, grown in pots in which mono-calcium phosphate and soil were intimately mixed, produced very similar values for the soil-"labile-P". Dean (1954) found that millet and buckwheat, grown on the same soil in pots, produced similar values for the "labile-P" although buckwheat absorbed greater total-P than did millet . The above authors pointed out that the "labile-P" determined by this technique is independent of the type or size of plant, since it depends on the ratio of the soil- to fertilizer-P in the plant, rather than the quantity. The increasing value of "labile-P" obtained from successive cuts of alfalfa, was explained, by Fried and Dean (1952), by fixation of applied-P and the increasing volume of the

root-zone, but Andersen et al. (1961) and Lamm (1961) reported that slow isotopic exchange is responsible for the increasing "labile-P" value during the growing season.

Although Fried and Dean (1952), Larsen (1952), Mattingly (1957[a]), Nye and Foster (1958), and Andersen et al. (1961) reported that the "labile-P" is independent of the rate of application, Jenkins (1962), McConaghy and Stewart (1963), and Volk and McLean (1963), reported that "labile-P" values were increased with the rate of fertilizer application. This increase may be due to factors such as isotopic exchange, or enhanced root-growth.

Placing the fertilizer near the plant roots, as reported by Fried and Dean (1952) and Jenkins (1962), produced lower "labile-P" values as compared with mixing the fertilizer throughout the soil. This was explained by the concentration of the roots where the fertilizer was placed.

Larsen (1956[b]) reported that liming acid soils increased the total P-uptake but had no effect on the "labile-P" value. Olson et al. (1956) also found that liming had no effect on the "labile-P" values where superphosphate was used, but the values were reduced by liming where rock phosphate was the fertilizer. On the other hand, Prince (1953), and Volk and McLean (1963) reported that liming increased the "labile-P" values probably through increasing the availability of soil-P.

The effect of nitrate-N, on the "labile-P" value, was studied by Larsen (1956[c]). He found that the application of $NaNO_3$, in a pot experiment, increased both yield and total P-

uptake of barley, but the "labile-P" value was not affected. Olson et al. (1956) found that the "labile-P" value was greater when superphosphate and ammonium nitrate were placed near the seed, for small grains, than when broadcast. They also reported that application of sulphur to calcareous soils did not alter the "labile-P" values.

Other factors such as isotopic exchange and radiation damage, may also affect the estimation of the "labile-P" values through the alteration of the soil-P/fertilizer-P ratio in the plant, as discussed before.

The correlations between the "labile-P" values and the crop yields or yields of P, have been found to be highly significant, as reported by Dean (1954), Grunes et al. (1955), Russell et al. (1957), Stanberry et al. (1960), Golden (1961), Grunes et al. (1963) and many other workers. However, Dean (1954) has given the most complete discussion about the relationship between "labile-P" and P-uptake by crops. He analysed results for the growth of millet in pot experiments in the U.S.A. during 1951 and 1952, in which 102 different soils were tested, and labelled mono-calcium phosphate was mixed in the soil. The value "a", obtained by extrapolation of the "yield-of-P" curves, agreed very closely with the "labile-P" values using the formula above. Both values, however, were about twice as great as the Mitscherlich "b" values obtained by extrapolating the yield curves to the same axis. The three values, "labile-P", "a" and "b", were all correlated very highly with yields and P-uptakes in the absence of applied phosphate.

For fertilizer evaluation, Fried (1954) used the increase in the "labile-P" value of the soil, due to application of labelled mineral phosphate, to assess the value of this fertilizer relative to ^{32}P-labelled mono-calcium phosphate. He also suggested this method as a means of quantitatively evaluating the effects of factors such as soil and plant species on the availability of plant nutrients from fertilizers.

(c) Factors that affect P uptake:-

Isotopic exchange, radiation damage, rate of application of phosphate, and other factors which have some effect on the "labile-P" estimation and labelled-P uptake by plants have been discussed above. In this section an attempt will be made to review some of the previous work in which the labelling technique has been employed to study the factors that, generally, affect plant growth and P-uptake by plants with special consideration to nitrogen.

Fried (1954) suggested the use of increases in the "labile-P" values as a means of quantitatively evaluating the effects of factors such as differences in soil on the availability of fertilizer-phosphorus to plants. However, labelled P-fertilizers were used, for a few years earlier, in studies of phosphate utilization by crops under different soil-fertility conditions. Dean et al. (1947) found that the utilization of superphosphate by ryegrass, lettuce, Sudan grass and potatoes, in greenhouse experiments, was decreased with increased P-fertility of the soil, and that placement of the

fertilizer in a band increased the percentage fertilizer-P in the plant more than if it was mixed with all the soil, except for Sudan grass. Other workers, Woltz et al. (1949), Hendriks and Dean (1950), and Bureau et al. (1953), have also reported that the percentage fertilizer-P in the crop is inversely related to the level of soil-P, with different crops under different conditions in the U.S.A. Dainty et al. (1959), Verma et al. (1959), and Simpson (1960[b], 1961) have reported results of field and pot experiments in which low- and high-P soils were included, with oats and potatoes as test crops for studying the factors affecting P-uptake in Southeast Scotland. The results obtained showed that the level of soil-P is inversely correlated to the percentage fertilizer-P of the total uptake, although the actual fertilizer-P uptake was, in some cases, higher from the high-P soils.

Different plants and species have different requirements of phosphorus and different rates of P-absorption due to the rate or habit of growth. Olsen et al. (1950), Fried (1953), Lawton and Davis (1956), Nye and Foster (1956, 1958), Hende et al. (1958) and many others have reported that different species vary greatly in the amount of total P-uptake. Plants may also differ in their ability to absorb phosphorus from the soil at a given P-potential, although the ratio of fertilizer-P/soil-P in the different plant species may be similar, as reported by Fried (1953), Lawton and Davis (1956), and Nye and Foster (1956, 1958).

Drake and Steckel (1955) reported that plants with high

root-cation-exchange-capacity absorbed greater amounts of P, from soils treated with rock phosphate, than did plants with roots having low cation-exchange-capacity. The mechanisms of P-release are believed to be a bonding of Ca by the root colloid to dissolve the insoluble Ca-phosphate, and complexing of Al and Fe by organic anions to render soluble Al- and Fe-phosphates.

The effects of soil moisture tension on the growth, total-, fertilizer- and soil-P uptake by crops have been studied using labelled-fertilizers. From results of field experiments with potatoes in Southeast Scotland, Simpson (1960[a]) reported that total-, and fertilizer P-uptake, as well as the final yield of tubers, were greatly increased by irrigation. Irrigation had only a slight positive effect on the uptake of soil-P in the shoots. At the 6-week stage of growth soil-P in the root was consistently higher on irrigated than on dry plots. The tuber- and total-uptake of soil-P were both increased by irrigation at the 12-week stage. Simpson (1960[b]) also reported that lowering the soil moisture tension, by keeping at field capacity, greatly increased the uptake of fertilizer-P by oats grown in pots on both low- and high-P soils, but there were indications that slower P-fixation took place in the soil under high moisture tension as the crops grown under these conditions continued to absorb P at higher rate in the later part of the season. The uptake of soil-P was not considerably affected by moisture tension. Simpson (1961, 1962[a,b]) reported similar results on the effect of lowering moisture tension on the uptake of

fertilizer-P. He also found that the uptake of soil-P was increased, in some cases, where the fertilizer was placed in a band for potatoes. These considerable increases in P-uptake were attributed to the increase of root development. Yang (1964) found that the upward movement of ^{32}P in sugar cane plants, grown in nutrient solutions for a short period, was greatly increased under high- as compared with low-transpiration conditions. However, under soil conditions lowering moisture tension may increase both water absorption and root development, which in turn will increase P-uptake by plants.

Soil temperature was found to have greater effect on the uptake of soil- than on that of fertilizer-P. Simpson (1960[b], 1961, 1962[b]) reported that increasing soil temperature by 5°C over the growing period produced consistent large increases in the soil-P uptake, but did not greatly affect the fertilizer P-uptake in most of the cases.

Many workers have recorded that the application of nitrogen has considerable effects on the uptake of soil- and fertilizer-P by plants. The magnitude and nature of such effects have been studied by various workers using ^{32}P.

Larsen (1956[c]) has reported a marked effect of nitrogen, in the form of $NaNO_3$, on the yield and P-uptake of barley grown in pots. Both soil- and fertilizer-P uptake were increased at the same ratio. Olson and Dreier (1956) and Olson et al. (1956) conducted a series of field and pot experiments in Nebraska, with wheat, oats, and small grains to study the effect of nitrogen and other factors on P-efficiency of fertilizers.

They found that N increased the uptake of P from banded superphosphate, and that the NH_4 ion was more effective than NO_3 ion, particularly in the early stages of growth. The maximum influence of either ion occurred with intimate mixing of nitrogen fertilizer and superphosphate. Ammonium nitrate, in contact with both super- and metaphosphate carriers, enhanced the uptake of P from the two forms. This effect of associated N-P fertilizers is thought to be the cause of the greater early uptake of P from ammonium phosphates than from other fertilizers. They also reported that N appears to stimulate the absorption by roots and concentrates the roots in the N P bands. On an acid soil (pH 4.9), Yuen and Pollard (1957) found that the uptake of both native and fertilizer-P, by ryegrass grown in pots, was more effectively increased by the physiologically basic N-forms ($NaNO_3$ and KNO_3) than by physiologically acid N-forms, $(NH_4)_3SO_4$ and NH_4Cl. On a slightly acid soil (pH 6.4) the uptake of P was favoured by the physiologically acid compounds. They explained these effects by the results of solution culture studies with oat seedlings, which showed that the maximum P-uptake occurred at pH of 5.8-6.0 and decreased sharply beyond pH range 4.0-6.2. Caldwell (1960) compared the influence of various nitrogen carriers on the uptake of labelled-P by corn. He found that physiologically acid N-carriers greatly increased the P-uptake from superphosphate, but only where N and P sources were mixed together. Physiologically basic N-carriers mixed with superphosphate did not increase P-uptake. He suggested that effects of N on P absorption were brought about by chemical

interactions between the two salts rather than physiological effects of N on the plant.

From results of field experiments with potatoes, Simpson (1960[a]) reported that there is some evidence that physiologically acid $(NH_4)_2SO_4$ reduced the rate of fixation of applied-P. Both soil- and fertilizer-P uptake were increased, in that experiment, at all stages of growth by application of N. The increase of P-uptake brought about by N-application, was attributed to effects on root development. Bennett et al. (1962), growing corn in nutrient solutions, sand cultures, and soil, suggested that the increase in N-uptake as a result of N-application will increase the amounts of N-compounds formed in the plant, and some of these compounds, particularly nucleuproteins contain P, and that others require P for their formation. As a result, additional P would be used and absorbed if available. Zuev and Golubeva (1959) reported that N-deficiency decreased P-content of all the P-fractions in the plant, and that the decrease was greatest in the nucleuproteids. Tueva (1960) found that plants grown in P-deficient solution contained greater amounts of non-protein-N than those grown in complete medium. Cole et al. (1963) conducted a short-term P-uptake experiment with one-month-old corn plants pre-treated to have differential contents of N and P; these plants were placed in different phosphate solutions for two hours. They found that supplemental N-pretreatments, producing increased growth rates and higher levels of N in the plants, stimulated the rate of P-uptake per unit dry weight of root more than did a tenfold increase in P-concentration in the

external solution. N-pretreatments also caused five- to ten-fold increases in the rate of P-translocation to the tops during the uptake period. P-uptake rates were highly correlated to the total N-levels in the roots. The presence of NO_3 or NH_4 ions in the test solutions during the uptake period had negligible effect on the P-uptake rates. They concluded that the stimulation of P-uptake rates with high levels of N in the plants suggests a connection between N-metabolism and P-uptake processes. Grunes (1959) made an excellent review of the effect of nitrogen on the availability of soil- and fertilizer-phosphorus to plants, in which he classified these effects into; (a) biological effects such as root area and absorption capacity, root efficiency, form of N, stage of plant growth and plant metabolism; and (b) chemical effects such as salt- and pH-effects.

III. METHODS and MATERIALS

The experimental work conducted in the seasons 1963-64 included the following experiments:-

Experiment I (1963-64):

A factorial pot experiment with perennial ryegrass grown under natural atmospheric conditions on two soils of pH 5.8 and 6.8. The treatments included different forms and rates of P, and two levels of N.

Experiment II (1964):

A factorial pot experiment with perennial ryegrass grown on a sandy loam soil (pH 6.6) under greenhouse conditions. The treatments consisted of different forms and rates of ^{32}P-labelled phosphates, and 5 rates of N.

Experiment III (1964):

A factorial pot experiment with perennial ryegrass grown under normal atmospheric conditions on an acid soil (pH 5.4) and on a calcareous soil (pH 7.4). The fertilizer-treatments included different forms, rates and methods of P-application, with two levels of N.

A. Greenhouse and Cage Work.

1. Experiment I, 1963-64:

A factorial pot experiment was carried out including 6 P-compounds (A, B, C, D, E, and F) applied at three rates of P_2O_5 (P_1, P_2, P_3) plus two controls (6 x 3 + 2). An acid peaty loam (soil X) of pH 5.8, and a neutral sandy clay loam (soil Y) of pH 6.8 were used. Two levels of nitrogen, N_1 and N_2, were also

included, i.e. each replicate consisted of (6 x 3 + 2) x 2 x 2 = 80 pots. Three replicates used to total 240 pots. The test plant was perennial ryegrass (var. S.24). The pots were arranged in a wire cage open to the atmospheric conditions.

The phosphates used were:-

A: Na-tripolyphosphate ($Na_5P_3O_{10}$)..... 57.5 per cent P_2O_5

B: Na-polyphosphate glass, Na_2O/P_2O_5 = 1.19 .....63.9 " " "

C: Na-trimetaphosphate $(NaPO_3)_3$ ..... 68.5 " " "

D: Na-ultraphosphate, Na_2O/P_2O_5 = 0.735 ..... 76.4 " " "

E: a 1:4 mixture of F and B ..... 62.7 " " "

F: anhydrous NaH_2PO_4 ..... 59.1 " " "

Each compound was applied at rates equivalent to 60, 120, and 180 lb. P_2O_5 per acre. The full P-rates were mixed with the soil during the preparation of the pots. The following rates of N, K and Mg were also applied;

(a) 40 and 80 lb. N/acre as NH_4NO_3 per cut, to N_1 and N_2 pots respectively.

(b) 90 lb. K_2O/acre as K_2SO_4, to all pots.

(c) 80 lb. Mg/acre as $MgSO_4.7H_2O$, to all pots.

Preparation of the pots:

Soil 'X' was taken from "Stonehead Farm, Fauldhouse, West Lothian". The soil is a peaty loam developed on till of clay texture derived from mainly carboniferous rocks. The field-drainage is impeded and the field is drained artificially. Without artificial drainage the soil would revert rapidly to peat. The field has been under rotation 5-6 years grass and 2-3 years cropping.

Soil 'Y' was taken from "Langhill Farm, Roslin, Midlothian". The soil is sandy clay loam derived from fluvio-glacial material consisting mainly of carboniferous shales and sandstones. The field drainage is imperfect owing to an underlying layer of till, 3-4 feet below the surface. The field had been under a rotation, of 3 years grass-cereal-roots-cereal undersown, for many years.

About 30 cwt. of soil were taken, on the 5th April, 1963, from each site to a depth of about 8 in. The soils were spread to dry until ready for riddling, with enough moisture in them to avoid the problem of rewetting and to maintain the microbial population. The soils were passed through a $\frac{1}{4}$ in. riddle to exclude the large stones and plant roots.

The pots used in this experiment were made of fireclay (8 in. diameter, 8 in. deep) coated on the inside with waterproof bituminous paint.

On the 30th April and 1st May, 1963, soils were intimately mixed with equal weights of coarse sand to facilitate drainage and aeration in the pots. The soil for each 3 pots receiving the same treatment was prepared simultaneously by mixing 24 lb. of soil with 24 lb. of coarse sand. The mixture was spread out on a polyethylene sheet and the appropriate amount of fertilizers (combined in 200 ml. aqueous solution) was sprinkled over the mixture, in 3 equal portions with intimate mixing after adding each portion. The quantities of fertilizers applied were calculated, for the weight of soil/sand mixture, on the basis of 2×10^6 lb. soil/acre. $13\frac{1}{2}$ lb. from "soil X-sand" mixture or 15 lb. of "soil Y-sand" mixture were weighed into each pot, and the soil was packed by gently "dumping" the pots. The pots were

randomised, within each replicate, in a wire cage open to the atmospheric conditions at Dryden. The layout of the experiment is shown in appendix I (table 7). The initial analysis of the soil-sand mixtures is given in table 1.

Table 1. Expt. I. Initial analysis of the soil/sand mixtures.

	pH	Loss in ignition %	"Available" P mg P/100 g. soil		
			citric acid	Olsen	Morgan
Soil X	5.6	7.5	2.91	0.84	0.13
Soil Y	6.8	3.8	2.53	0.54	0.19

Sowing:

On the 2nd May 1963, 0.238 g (about 100 seeds) of ryegrass seed were weighed and sown on each pot. The seed was covered with about 250 cc coarse sand (about 0.3 in. depth). By the 15th May there was a good even germination on all pots.

Soil sampling pots:

Forty pots, including only the P-treatments (6 x 3 + 2) and the two soils, were prepared in the same manner and kept under the same conditions.

Subsequent treatments and sampling:

The following fertilizer treatments were applied to the soil surface in 50 ml. nutrient solution per pot, containing the appropriate treatments. After the application the nutrient solution was watered in to avoid any salt damage to the plants. On the 14th June, the equivalent of 40 lb. N/acre was applied to

all the "N_1Y" pots, and 80 lb. N/acre to all "N_2Y" pots, as NH_4NO_3. No nitrogen was applied, at this time, to any of soil "X" pots.

The 1st cut of grass was taken, from all pots, on the 8th July 1963, by cutting the grass to the height of about 1 in. above the surface of the soil. On the same day the equivalent of 40 lb. N/acre was applied to all N_1 pots, and 80 lb. N/acre to all N_2 pots.

The 2nd cut of the grass was taken, in same way, on the 16th and 18th of August 1963. On the 18th August, 1963, the equivalent of 40 lb. N- and 90 lb. K_2O/acre was applied to all N_1 pots, and 80 lb. N- and 90 lb. K_2O/acre were applied to all N_2 pots. That was the last application of fertilizers in 1963. The 3rd cut (and last in 1963) was taken on the 20th September, 1963.

The experiment was continued in 1964 without any further application of phosphate. On the 12th March 1964, all N_1 pots received the equivalent of 20 lb. N + 40 lb. K_2O/acre, N_2 pots received the equivalent of 40 lb. N + 40 lb. K_2O/acre, and this was repeated on the 27th April 1964, in the same manner as the preceding season.

The 4th cut of grass was taken on the 22nd May 1964. On the 25th May all N_1 and N_2 pots received the equivalent of 40 lb. N + 80 lb. K_2O/acre and 80 lb. N + 80 lb. K_2O/acre, respectively. An extra application, equivalent to half of the previous one, was made on the 10th July, since the growth was very poor.

The 5th cut was taken on the 14th August 1964, followed by

an application of the equivalent of 40 lb. N + 40 lb. K_2O/acre to all N_1 pots, and 80 lb. N + 40 lb. K_2O/acre to all N_2 pots, on the 21st August 1964.

The 6th (and final) cut of grass was taken on the 29th and 30th October 1964.

Soil sampling:

The soil-sampling pots were also sampled, during the seasons 1963 and 1964, to a depth of about 2 in. below the soil surface. The sample taken from each pot, every time, was about 250 g. of moist soil. Dates and numbers of samplings are given in table 2.

Table 2. Expt. I. Dates and No. of soil samplings.

1963				1964			
Samp. No.	Date	Samp. No.	Date	Samp. No.	Date	Samp. No.	Date
1st	17th May	4th	3rd Sept.	7th	7th Jan.	10th	19th May
2nd	11th June	5th	3rd Oct.	8th	11th Feb.	11th	14th Aug.
3rd	22nd July	6th	14th Nov.	9th	12th March	12th	31st Oct.

Handling of the grass samples:

After cutting, the grass from each pot was put in a polyethylene bag and weighed, on a "Mettler" electric balance (accuracy of 0.1 g.), and the fresh yield was recorded for each cut. The grass was then transferred to lined paper bags and dried, overnight in an electric oven with extracting fans, at a temperature of 90 to 95°C. The dry matter yield was then recorded by transferring the dry grass from each bag into a small

plastic tray and weighing on the same balance. The dry grass was milled and kept, for the chemical analysis, in plastic pots with air-tight tops.

Handling of the soil samples:

The soil samples were spread, each on a small tray covered with brown paper, for air-drying in a special room at a temperature of about 20°C. When dry, the soil samples were gently rolled, using a wooden roller, to break down the soil crumbs, mixed and kept in the same paper bags for the chemical analysis.

2. Experiment II, 1964:

The experiment was a factorial 3 x 4 x 5, with two replicates (a total of 120 pots). The treatments were:-
(a) Three phosphate compounds: Na-trimetaphosphate (C), Na-dihydrogen phosphate (F), and Na-metaphosphate glass (G). Each applied at rates equivalent to, 0, 60, 120, and 180 lb. P_2O_5/acre.
(b) Five rates of N and K equivalent to 40, 80, 120, 160 and 200 lb. N or K_2O/ acre per cut applied together in the form of NH_4NO_3 or K_2SO_4.
(c) Basal application equivalent to 80 lb. Mg/acre as $MgSO_4.7H_2O$, was applied to all pots.

All P-compounds were labelled with ^{32}P. The specific activity was approximately 40 μ C/pot for all pots. Control pots received only the ^{32}P addition without ^{31}P carrier. The appropriate amounts of P were applied during the preparation of the pots.

N, K and Mg were applied to the surface of the soil in 50 ml. of nutrient solution/pot, containing the appropriate rates, and watered down after each application.

Soil sampling pots: 24 soil sampling pots, including the three P-compounds at the same rates of applications as the grass pots (3 x 4) with two replicates, were prepared in same manner.

Preparation of the pots:

The soil used was a sandy loam (pH 6.6), taken from "House Field, Langhill Farm, Roslin, Midlothian". The soil is derived from fluvioglacial material sorted from carboniferous shales and sandstones. Field drainage was imperfect owing to an underlying layer of till, 3-4 feet below the surface. The general level of management of this soil had been very poor until taken over by the School of Agriculture in 1955. Since this time, regular application of basic slag in addition to compound fertilizers has raised the phosphate status of the soil a little from the original very low level.

The soil was taken, in the 2nd week of April 1964, with a spade to a depth of about 8 in. It was spread for drying until ready for riddling, while visibly moist. The soil was then passed through a $\frac{1}{4}$ in. riddle to remove vegetation and large stones and kept, until used, in polyethylene bags to prevent complete drying.

The radioactive materials were received on the 22nd April 1964. Each compound was dissolved and diluted with distilled

water to contain 10 μ C/ml.

Soil-sand mixture for every five pots receiving the same P-treatment was prepared by mixing 41 lb. of soil and 41 lb. of coarse sand on a polyethylene sheet. After thorough mixing of the soil and the sand, the mixture was spread on the sheet, and 420 ml. of solution containing 200 μ C of ^{32}P plus the appropriate amount and form of ^{31}P, or no ^{31}P in the case of controls, was sprinkled on the mixture in three portions with intimate mixing after each application. The quantities of fertilizers were calculated, for 82 lb. of the soil-sand mixture, on the basis of 2×10^6 lb. soil/acre. 16.3 lb. of the soil-sand mixture were weighed into each pot and gently "dumped" to pack the soil. In the bottom of each pot 1.5 lb. of acid-washed gravel, had been placed, to prevent the soil from passing through the holes of the pot. The polyethylene pots used were 20 cm. high and 22 cm. mean diameter.

The initial analysis of the soil-sand mixture was as follows:

pH	Available P mg./100 g. soil			Loss in ignition %
	Citric Acid	Olsen	Morgan	
6.7	1.27	0.15	0.03	4.3

Sowing:

Mixing the soil, applications of labelled-P-treatments, as well as sowing of the grass seed were all carried out on the 23rd April 1964. About 100 seeds (0.20 g.) of perennial ryegrass (var. S.24) were sown on the surface of the soil in each pot and

covered with about 1 cm. of coarse sand. The pots were arranged, at random within each replicate, in rows of 15 pots in a greenhouse with top windows which were automatically opened or shut according to the temperature. The electric thermostatic control was adjusted to $65 \pm 5^{\circ}F$. At night, however, the temperature was seldom below $55^{\circ}F$, inside the greenhouse, but was very often up to $80^{\circ}F$ or even more on sunny hot days.

The soil, in the pots, was kept moist by daily or more frequent careful spraying of water on the surface of the soil. The germination started about a week after sowing and by the 3rd May there was a regular emergence on all pots. The layout of the experiment is given in appendix II, table 55.

Soil sampling pots:

The soil sampling pots were prepared on the 24th April 1964, in the same manner as the grass pots, including the P-treatments only, with two replicates, i.e. 2 pots each of P_0, P_1, P_2 and P_3 for the three compounds tested in this experiment. Each pot, including the P_0 pots, received about 40 μ C of ^{32}P. The pots were then arranged in two rows in the greenhouse, and the soil in them was kept near field capacity by watering 3-4 times per week. The 1st soil sampling was made on the 29th April 1964 (5 days after preparation), by taking about 500 g. of the moist soil-sand mixture from each pot, to a depth of about 2 in. from the soil surface. The succeeding soil samplings were made in the same manner at the same dates as the grass cuttings. Soil samples were dealt with in same way described in experiment I (see page 48).

KGL. VET. & LANDBOHØJSK. BIBLIOTEKET

Subsequent treatments and sampling:

The first application of N, K, and Mg was made on the 5th May 1964. N and K were applied together at similar rates equivalent to 20, 40, 60, 80 and 100 lb. N or K_2O/acre in the form of NH_4NO_3 and K_2SO_4 respectively for the N_1, N_2, N_3, N_4 and N_5 pots. The equivalent of 40 lb. Mg/acre (as $MgSO_4.7H_2O$) was also applied to all pots. The three nutrients were combined in one solution from which 50 ml., containing the appropriate rates, was applied to the soil surface in each pot. The nutrient solution was watered in after application to avoid any salt hazard to the plants. Application of the same quantities was repeated on the 19th May 1964. By this second application all pots ~~have~~ had received all the Mg that it had been planned to apply (equivalent to 80 lb. Mg/acre).

After the 1st, 2nd and 3rd cuts of grass N and K were applied at equivalent rates of 40, 80, 120, 160 and 200 lb. N or K_2O/acre, in the same manner described above, at the following respective dates; 2nd June, 20th June, and 4th July 1964. Only one half of these rates was applied after the 4th, 6th, and 7th cuts of the grass, on the 18th July, 31st Aug., and 25th September 1964, respectively. No fertilizer was applied after the 5th cut. The number and dates of the grass cuttings are given in table 3.

Table 3. Expt. II. Dates and No. of grass cuts, 1964.

Cut No.	Date	Cut No.	Date
1st	29th May	5th	31st July
2nd	16th June	6th	27th August
3rd	30th June	7th	17th September
4th	14th July	8th	3rd November

On the 22nd June 1964, plastic dishes were placed underneath the pots and filled with water to a level of about 1 in. higher than the bottom of the pots, so that watering was carried out by sub-irrigation. The dishes were removed after each cut and the pots were left to drain till the next morning when the dishes were replaced underneath the pot and filled with water daily as before. Watering was carried on in this system until the 27th July, 4 days before the 5th cut. Salt accumulation on the soil surface was first noticed at that date, and some plants in some of the pots receiving N_4 or N_5 treatments started to die. The dishes were then removed and the pots were given a heavy watering to wash the salts down. Watering was continued from the surface. No fertilizer was applied after that cut and subsequent applications were reduced to one half of the planned rates, thus being 20, 40, 60, 80 and 100 lb. N or K_2O/acre.

Handling of plant and soil samples:

The grass- and soil-samples were dealt with in same manner as in experiment I (see page 47). Extra care was taken in this experiment to avoid contamination with radioactive materials.

3. Experiment III, 1964:

A factorial (3 x 3 + 1) x 2^4 pot experiment with perennial ryegrass grown on 2 soils in a wire cage open to the atmospheric conditions. The treatments were as follows:-

(a) 3-Phosphate compounds; (i) Na-trimetaphosphate.....(C)

(ii) Na-dihydrogen orthophosphate.(F)

(iii) Na-metaphosphate glass .....(G)

(b) 3-Rates of P-application from each compound, equivalent to 60, 120, and 180 lb. P_2O_5/acre.

(c) 1-Control for each soil or method of application.

(d) 2-Methods of P-application.

(i) Liquid (L) - 50 ml. of solution containing the appropriate amount of P per pot (50 ml. distilled water for control pots).

(ii) Solid (S) - the appropriate amount of P was mixed with 10 g. very fine sand per pot (only the sand was used for control pots).

(e) 2-Rates of N; equivalent to 40 and 80 lb. N/acre per cut, as NH_4NO_3.

(f) 2-Soils; (i) Woodhouselee acid soil of pH 5.4 (W).

(ii) Doncaster calcareous soil of pH 7.4 (D).

(g) 2-Replicates of each treatment.

Total = 160 pots.

For both liquid and solid P-applications, the fertilizer was evenly distributed over a portion of the soil-sand mixture (11 lb.) in the pot. The remaining portion was then added to the top of the fertilizer band. Thus giving a fertilizer-band on a depth of about 2½ in. from the surface.

All pots received the equivalent of 180 lb. K_2O/acre as K_2SO_4, and 80 lb. Mg/acre as $MgSO_4.7H_2O$, applied in two equal portions during the early stages of the season. The layout of the experiment is given in appendix III table 141.

Preparation of the pots:

Soil 'W' was collected from the Woodhouselee field, Boghall Farm near Edinburgh. The soil is gravelly loam, derived from

mixed colluvial and glacial material consisting mainly of carboniferous shales and sandstones mixed with local rhyolite and andesite. The field had been in permanent grass within living memory. No fertilizers had been added for many years. The field drainage was imperfect.

Soil 'D' is a calcareous soil with free lime content of about 4.5 per cent. The soil was collected from uncultivated land to the north of Doncaster, Yorkshire. The soil is derived from the permian limestone formation.

The soils were prepared in similar manner to that followed in experiment II, 50 per cent sand and 50 per cent soil, except that P-fertilizers were banded 2½ in. below the surface of the soil.

The weight of the soil-sand mixture per pot was 15½ lb. from the acid soil (W) and 16½ lb. from the calcareous soil (D). The pots used in this experiment were similar to those used in experiment II. The initial soil analysis is given in table 4.

Table 4. Initial soil analysis (soil only).

Soil	pH	Free lime %	Loss in ignition %	"Available" P mg/100 g soil		
				citric acid	Olsen	Morgan
W	5.4	-	6.0	1.27	0.48	0.04
D	7.4	4.5	8.1	2.00	0.60	0.30

Sowing:

The mixing of the soil-sand, application of P-fertilizers, and sowing of the ryegrass seeds (100/pot) were carried out on the 14th May 1964. Similar to the previous experiments the

seeds were covered with about 1 cm. depth of coarse sand. Pots were arranged at random within each replicate in rows of 16 pots. The pots were sprayed with water after seeding and whenever necessary afterwards.

Subsequent treatments and sampling:

By the end of May there was an even emergence on all pots. The first application of N, K, and Mg was made on the 3rd June. Only one half the rates of the 3 nutrients were applied. Similar application was repeated on the 15th June. By the 2nd application (15 June) all pots had received the equivalent of 180 lb. K_2O and 80 lb. Mg/acre. No further dressings of K or Mg were applied in that season. An additional N application equivalent to 20 and 40 lb. N/acre, to N_1 and N_2 pots, was made on the 13th July after a rainy week.

The 1st cut of the grass was taken on the 29th July, in a similar manner to that followed in experiment II. The equivalent of 40 and 80 lb. N/acre was applied to N_1 and N_2 pots, in two equal dressings, on the 1st and 10th August.

The 2nd cut of grass was taken on the 1st September, followed by an application of the equivalent of 40 and 80 lb. N/acre on the 5th September.

The 3rd cut was taken on the 28th and 29th October 1964.

The applications of N, K and Mg were made in similar manner to that in experiment I.

Handling of the grass samples:

The grass samples were treated exactly as in experiment I (see page 47).

B. Analytical Methods

1. Plant Analysis.

Digestion of plant material.

A mixture of HNO_3 and $HClO_4$ was used to prepare extracts for the determination of total P in plant material.

Reagents:-

Conc. HNO_3 (sp.gr. = 1.42)

60% $HClO_4$ (sp.gr. = 1.54)

Procedure:-

Two ml. conc. HNO_3 were added to a 0.5 g. sample of plant material in a 50 ml. graduated Pyrex test tube. The sample was allowed to stand in HNO_3 overnight, and then the tube was gently heated until the material disintegrated. Two ml. 60% $HClO_4$ were added and the heating continued, gently at first, until the liquid was colourless and all the HNO_3 was driven off. After cooling slightly, about 45 ml. hot distilled water were added. When cold, the volume was made up to 50 ml. in the digestion tube, and the digest was filtered through a Whatman No.42 (11 cm.) filter paper.

The micro-digestion apparatus used had been built, by Alston (1964), to enable the simultaneous digestion of 20 samples of plant material.

Determination of Total P.

P was determined by measuring the colour produced on formation of the phosphovanadomolybdate complex (Hanson, 1950).

Reagents:-

KH_2PO_4: range of standard solutions containing 0-50 ppm P

in distilled water.

Mixed Reagent: 25 g. ammonium molybdate, $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$, were dissolved in about 800 ml. distilled water. 1.25 g. ammonium vanadate, NH_4VO_3, were dissolved in about 600 ml. hot distilled water and, after cooling, 175 ml. conc. HNO_3 (sp.gr. = 1.42) were added gradually while stirring. The molybdate solution was then added and, after cooling, the solution was diluted to 2 l.

Procedure:

A calibration curve was prepared; 10 ml. mixed reagent were added to 10 ml. aliquots of the standards in 25 ml. graduated test tubes. The solutions were diluted to 25 ml. with distilled water and thoroughly shaken. The colours developed were measured after about 30 min. in an E.E.L. photoelectric colorimeter using violet filter (426 mμ) and 10 mm. optical length glass cell, setting the instrument to zero with distilled water.

Aliquots of plant digest were treated in the same manner. A 10 ml. aliquot gives the maximum reading if the plant material contains 0.5% P.

2. Soil Analysis.

Determination of soil reaction.

Soil pH was measured in a 1:2.5 suspension of soil and water, using a glass electrode.

Soil Extraction.

Soils were extracted for "available" P with three different extracting solutions.

(i) Citric acid: a 1% citric acid extracting solution (Dyer, 1894), prepared by dissolving 100 g. of citric acid in distilled water and making up to 10 l.

Procedure:

100 ml. extracting solution were added to 10 g. air-dry soil in a 100 ml. shaking bottle. After shaking for 24 hours, on an end-over-end shaker, the extract was filtered through a Whatman No.3 (15 cm.) paper into a 100-ml. bottle.

(ii) 0.5 N $NaHCO_3$: (Olsen et al. 1954), prepared by dissolving 420 g. $NaHCO_3$ in about 9.5 l. distilled water and adjusting the pH to 8.5 by addition of 40% NaOH solution. The volume was then completed to 10 l. with distilled water and the pH was checked again and adjusted if necessary.

Procedure:

100 ml. of the extracting solution were added to 10 g. air-dry soil (only 5 g. is used in the original method) in a 100 ml. shaking bottle and approximately 0.5 g. of activated carbon (Darco-G-60) were added to the suspension. After mechanical shaking for 30 min. the extract was filtered through a Whatman No.3 (15 cm.) paper into a 100-ml. bottle.

(iii) Ammonium acetate-acetic acid:(Hende et al., 1952). The buffered extracting solution (pH 4.5) was prepared by careful addition of 600 ml. glacial acetic acid and 270 ml. NH_4OH solution (sp.gr. = 0.88) to about 5 l. distilled water and diluting to 10 l. when cool.

Procedure:

50 ml. of the extracting solution were added to 10 g. of air-

dry soil in a 100-ml. shaking bottle. About 0.25 g. carbon (Darco-G-60) were added to the suspension. After mechanical shaking for 30 min. the extract was filtered through a Whatman No.3 (15 cm.) paper into a 100-ml. bottle.

Since the carbon, used with the last two methods, was found to release some phosphorus, extracts of the carbon alone, with each method, were used as blanks when developing the colour in the extracts.

Determination of P in the Soil Extracts:

The extracted phosphorus by the three method was determined colorimetrically using the method of "The chlorostannous-reduced molybdophosphoric blue colour" in H_2SO_4 system, according to Jackson (1958).

Reagents:

2N H_2SO_4, 4N Na_2CO_3, 2,4-dinitrophenol indicator (0.25 per cent in water) and the following special reagents:

Sulphomolybdic acid solution (2.5%), was prepared by dissolving 25.0 g. of C.P. ammonium molybdate, $(NH_4)_6\ Mo_7O_{24}.4H_2O$, in about 200 ml. distilled water warmed to about 60°C. 275 ml. P-free, As-free conc. H_2SO_4 were diluted to about 750 ml. with distilled water. After both solutions had been cooled, the molybdate solution was added slowly, while stirring, to the H_2SO_4 solution. After the combined solution had been cooled to room temperature the volume was made up to 1 l. with distilled water, and kept in a dark-brown bottle.

Chlorostannous acid-reductant, was freshly prepared as

required by dissolving 2.5 g. of $SnCl_2.H_2O$ in 100 ml. 1.2 N HCl, giving approximately 0.1 M Sn^{++} solution.

Standard P-solution. a 50 ppm P stock-solution was prepared by dissolving 0.2195 g. of dry pure KH_2PO_4 in about 400 ml. distilled water in a 1000-ml. volumetric flask, 25 ml. of 7 N H_2SO_4 was then added, the solution was made up to 1 l. and mixed. Thus, preserved with H_2SO_4, the solution keeps indefinitely. From this solution 20 ml. were diluted to 250 ml. for the 4 ppm. standard.

Procedure:

A calibration curve was prepared for each method of extraction, by addition of the appropriate aliquot of the extractant to the standard P-solution used for the standard curve. Each of 0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0 and 5.0 ml. aliquots of 4 ppm. P-standard, was pipetted in a 50-ml. test tube, and aliquots of the appropriate extractant were added to every tube of the standards. The pH was adjusted to 3.0 using 2,4-dinitrophenol indicator and 2 N H_2SO_4 or 4 N Na_2CO_3. 2 ml. of the molybdate reagent were then added, and the volume was made up to 50 ml. with distilled water and well mixed. 3 drops (0.15 ml.) of the stannous chloride reagent were added followed by a thorough mixing. The full colour was found to develop in 4-5 min. after the addition of the stannous chloride, and start to fade after about 20 min. The readings were taken 8-10 min. after the addition of the $SnCl_2$.

For P-determination in the soil extracts, aliquots of 2 ml. from the citric acid extracts, or 5 ml. from Olsen's or Morgan's extracts, were used for colour development in the same manner as

the standards. The P-content of the extract was calculated by comparison with the standard curve. The photoelectric colorimeter used was E.E.L. with red filter (684 mμ) and an optical length of 5 mm.

Hydrolysis of the Metaphosphates:

A method was developed for the hydrolysis of the metaphosphate compounds tested in these experiments. The method was also used to hydrolyse soil extracts to measure the amount of hydrolysis that had taken place in the soil.

Reagent:

2 N H_2SO_4

Procedure:

A 5 ml. aliquot of the polyphosphate solution was pipetted into a 50-ml. beaker and an equal volume of 2 N H_2SO_4 was added to bring the acidity of the solution to about 1 N. The beakers were placed on a hot plate and boiled for 15 min., while covered with watch-glasses to avoid any loss of the solution. The hydrolysate was then quantitatively transferred to a 50-ml. test tube for the colorimetric determination of P, using the procedure described above.

Aliquots of soil extracts, of the 3 methods of extraction, were hydrolyzed, using a technique similar to that used with the polyphosphate solutions. The only difference was that the acidity of the Olsen's and Morgan's extracts was first adjusted to pH 3.0 using 2 N H_2SO_4 and 2,4-dinitrophenol indicator. After correcting the acidity of the soil-extract aliquots, the

final volume of the Olsen's-aliquots became 6.3 ml. and that of Morgan's-aliquots became 6.0 ml. Thus the added volume of 2 N H_2SO_4 was 6.3 or 6.0 ml. respectively.

Aliquots of citric acid extracts (2 ml.) were made up to 5 ml. with distilled water and then 5 ml. 2 N H_2SO_4 were added. Thus, the acid concentration was about 1 N, in all solutions to be hydrolyzed, before boiling for 15 min. as described above.

A calibration curve was made for the hydrolyzed extracts and another for the unhydrolyzed extracts of each method of extraction, by addition of all reagents, used in each case, to the standard solutions.

The difference between the amount of P measured in an unhydrolyzed aliquot of soil extract and another aliquot after hydrolysis was considered as the amount of unhydrolyzed extractable polyphosphate.

Radioactive Analysis:

In experiment II, ^{32}P-labelled phosphate compounds were used. Three ^{32}P-compounds; C = Na-trimetaphosphate, F = Na-dihydrogen orthophosphate, and G = Na-metaphosphate glass, were received on the 22nd April 1964 as solid materials. The weight of each compound, its radioactivity, and the dilutions made for the standard solutions were as follows on the 22nd April, 1964:

Compounds	C	F	G
Total activity mC	4.1	2.3	3.1
Weight of material g.	0.203	0.173	0.153
Solution I mC/ml.	0.01	0.01	0.01
Solution II μ 6/l	200	200	200
Solution II mg ^{32}P/l	3.107	3.107	3.107
Solution III μ C/l	8	8	8
Solution III μ g ^{32}P/l	124.3	124.3	124.3
Solution IIIa μ C/l	2	2	2
Solution IIIa μ g ^{32}P/l	3.107	3.107	3.107

Measurements of the radioactivity: 10 ml. aliquots of the standard solution, plant digest, or soil extract, were used for the radioactivity counts using two "PANAX" scalers, at the same time, with liquid counters (English Elect. M.G.). The time of counting was 5-30 min. according to the magnitude of the readings. A background count was measured using 10 ml. water. The radioactivity was expressed in terms of counts per min.

The radioactivity of the standard solution was measured at intervals to give a standard curve for the decomposition of ^{32}P with time for each compound.

Corrections were made for background and dead time and the counts were adjusted to 12 noon G.M.T. before referring to the standard curve of the appropriate compound (C,F or G) to obtain the quantity of ^{32}P in the plant material or in the soil extract. The amounts of labelled fertilizer absorbed by plants, or extracted from the soil, were thus calculated.

Radioactivity measurements were carried out on plant digests

from cuts 1 - 4 and soil extracts of 1st, 2nd and 3rd soil samplings in Experiment II. Radioactivities of soil extracts of later samplings, as well as the Morgan's extracts of the 3rd sampling, were too small to be accurately measured.

IV. RESULTS

All the results are tabulated in the Appendices, but only those having direct relation to major treatments are reported in the text. These results are presented mostly as graphs. Their statistical significance, as determined by analysis of variance (F-test), is shown by means of asterisks as follows:-

* * * Significant, P = 0.001

* * " P = 0.01

* " P = 0.05

N.S. Not significant, P $>$ 0.05

Only those effects and interactions which occurred consistently or occasional effects that were highly significant are discussed in detail, although most other significant effects are mentioned.

The results are presented separately for each experiment, and a discussion of all the results follows in Section V.

Some of the Definitions used:-

1. Labelled P-uptake: or fertilizer P-uptake denotes the quantity of P, found in aerial parts of grass, which had been taken up from the applied fertilizer, according to the ^{32}P measurements.

2. Percentage Recovery of Labelled-P: is the labelled P-uptake calculated as a percentage of the quantity of applied-P.

3. Apparent Recovery of P: is the increase in P-uptake by plant as a result of P-application, i.e. (P-uptake from P-treated soil) - (P-uptake from untreated soil).

4. Percentage Apparent Recovery of P: is the apparent recovery of P calculated as a percentage of the quantity of applied-P.

5. Available Soil-P: soil phosphates which are in a form (or forms) that can be easily utilized by plants. Chemical soil-extraction, may only give a rough idea about the status of the "available" P in a soil on a relative basis for each method of extraction, since different methods extract different quantities of P from a given soil.

6. Labile P in the soil: ('A' or 'L' value) is the quantity of P, in the soil, which is assumed to be in the same order of "availability" to plants as applied fertilizer-P. It is calculated from the ratio of soil-P/fertilizer-P in plants receiving a labelled-fertilizer, according to the following formula (Larsen, 1952):

$$\text{Labile P} = b\left(\frac{1-y}{y}\right),$$

where 'b' is the amount of labelled fertilizer-P added to the soil and 'y' is the fraction of P in the crop derived from the fertilizer.

7. P-Fixation by soil: This term is used here only to indicate the conversion of applied-P, in a water-soluble form, to insoluble or less soluble forms. It does not necessarily mean decreasing the 'availability', to plant, of applied-P.

Symbols:

1. In all 3 experiments P_0, P_1, P_2 and P_3 denote rates of P-application equivalent to 0, 60, 120 and 180 lb. P_2O_5/acre respectively.

2. N_1, N_2, N_3, N_4 or N_5 denote rates of N-application equivalent

to 40, 80, 120, 160 or 200 lb. N/acre per cut.

3. Form of P:

A = Na-tripolyphosphate.

B = Na-polyphosphate glass.

C = Na-trimetaphosphate.

D = Na-ultraphosphate.

E = 1:4 mixture of F and B.

F = Na-dihydrogen orthophosphate (as the standard)

G = Na-metaphosphate glass (not included in experiment I)

Compounds A, B, D and E were included only in experiment I.

4. Soils used:

X = an acid soil of pH 5.8 (Experiment I)

Y = a neutral soil of pH 6.8 (Experiment I)

D = Doncaster calcareous soil of pH 7.4 (Experiment III)

W = Woodhouselee acid soil of pH 5.4 (Experiment III)

In experiment II, only one soil of pH 6.6 was used.

5. Method of application: (Experiment III only).

L = P-fertilizers were applied in solution in a band 2½ in. below seed-level.

S = P-fertilizers were applied in solid form in a band 2½ in. below seed-level.

6. D.M. = yield of oven-dry grass.

FIG.1 EFFECT OF P ON YIELD
(Expt. I, 1963)

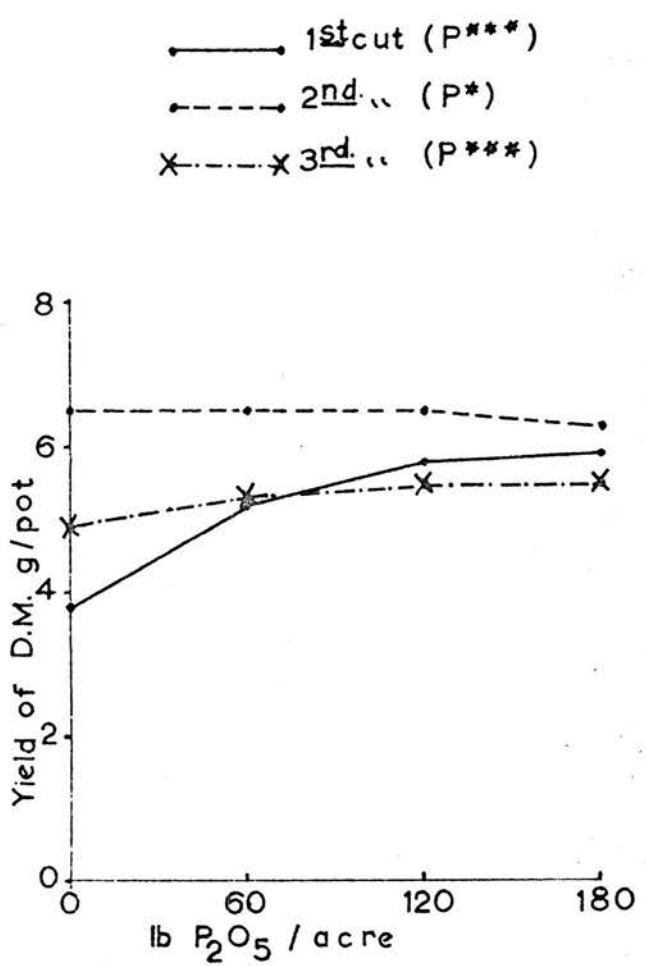
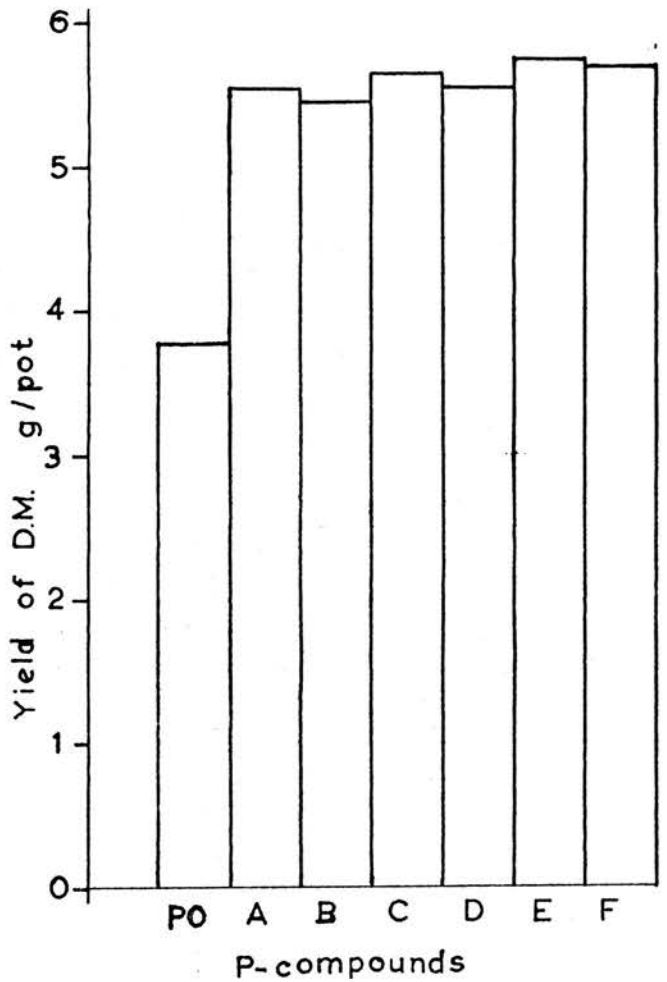


FIG.2 EFFECT of P-FORM, EXPT. I,
1st cut, 1963. (P-Form, N.S.)



A. Yields and Plant-Analyses

EXPERIMENT I (1963-64):

(See pages 42-48 for details of experimental design and fertilizer treatments). All results of this experiment are tabulated in appendix I.

Yields of D.M. (1963):

The first cut of grass showed great yield responses to applied-P and increasing rate of P or N (* * *) on both soils. P_2 and P_3 produced equal yields, both greater than P_1 (fig. 1). The acid soil (X) produced greater (* * *) yields than did the neutral soil (Y). Response to N was very highly significant on both soils, although more pronounced on soil Y.

The form of P had no significant effect on yields, with the mixture of ortho- and polyphosphate (E) producing slightly higher yields than most of the compounds (fig. 2).

The N x P interaction was very pronounced (* * *); increasing the rate of either nutrient greatly increased the response to the other (fig. 3).

In the second cut, the effect of N in increasing yields was very great (* * *), while the highest rate of P (P_3) produced smaller (*) yields than either P_1 or P_2 (fig. 1). The form of P had no significant effect on yields. Soil 'Y' produced slightly greater (*) yields than soil X.

Yields of the third cut showed very similar effects to those of the first cut, except that the effect of applied-P was less pronounced in the 3rd cut although very highly significant (fig.1).

EFFECTS OF N×P INTERACTION & P-FORM

FIG. 3 (1st cut, 1963)

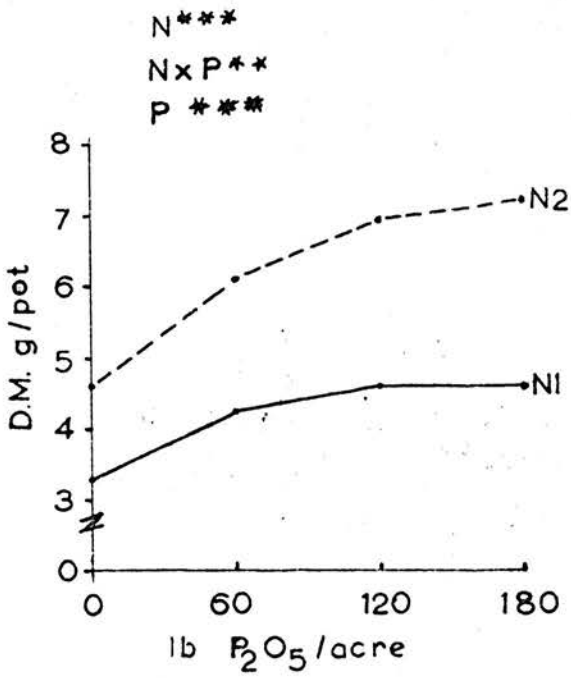


FIG. 4

(Average of 3 cuts, 1963)

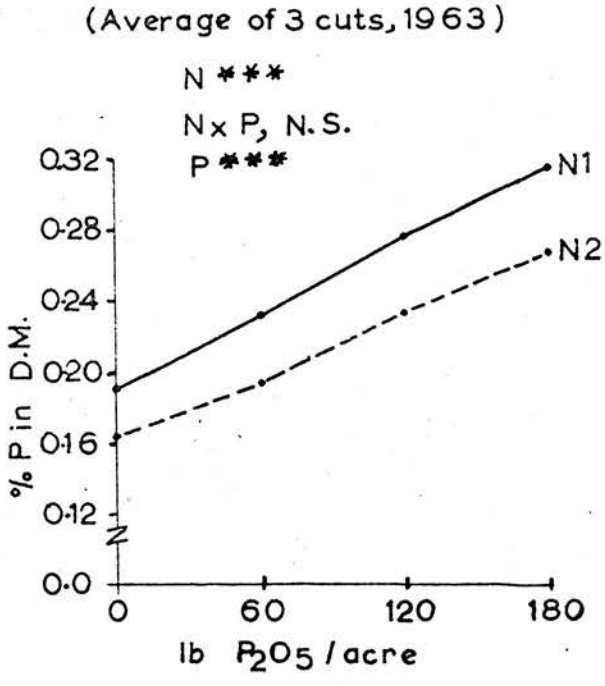


FIG. 5

(Total of 3 cuts, 1963)

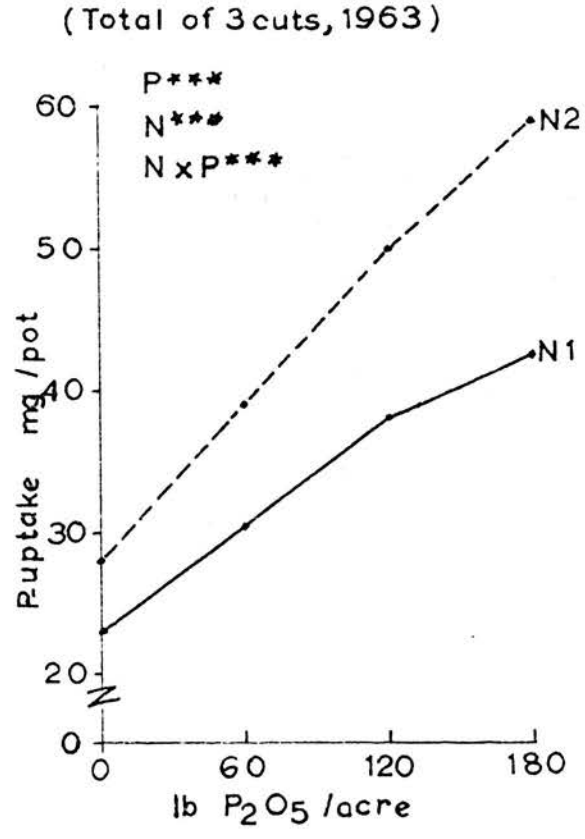
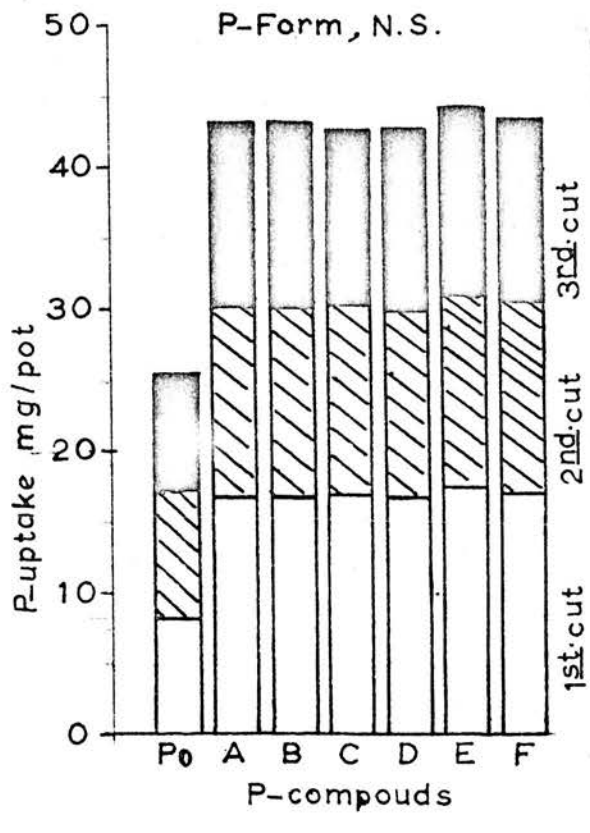


FIG. 6 (EXPT-I, 1963)



The total yields of the three cuts showed no significant difference between the 6 forms of P. The responses to increasing rate of P or N were very highly significant. There was also a positive N x P interaction (*).

Percentage P in D.M. (1963):

In all 3 cuts of grass, increasing rate of P greatly increased (* * *) the P-content of D.M. (fig. 4) with different forms of P being very similar on both soils and with the two rates of N. The high rate of N produced smaller (* * *) P-contents of D.M. than the low rate in all cases (fig. 4). Soil Y produced greater (* * *) P-contents of D.M. than did soil X in the first two cuts of grass, but the two soils produced similar results in the 3rd cut.

Soil x P interaction was very highly significant in the first two cuts of grass, with greater responses to increasing rate of P on the neutral soil (Y). Negative response to N was also greater on soil Y than on soil X.

There was a negative N x P interaction (* * *) only in the 3rd cut of grass; increasing rate of P increased P-contents much more with N_1 than with N_2. Only in the 3rd cut there was a highly significant soil x N x P interaction; the response to increasing rate of P was greater on soil Y than on soil X only with N_1.

P-uptake (1963):

In all three cuts of grass P-uptake was greatly increased (* * *) with increasing rate of P or N (fig. 5). There was no

significant effect of the form of P (fig. 6). Soil Y produced greater P-uptakes (* * *) than soil X in the first two cuts and in the total of the three cuts. There was a positive N x P interaction (* * *) in the first two cuts and in the total of the three cuts (fig. 5). Soil x N interaction was very highly significant only in the first cut, with greater response to N on soil Y than on soil X. Responses to increasing rate of P were also more pronounced on soil Y than on soil X particularly in the first cut (* * *) and in the second cut (* *).

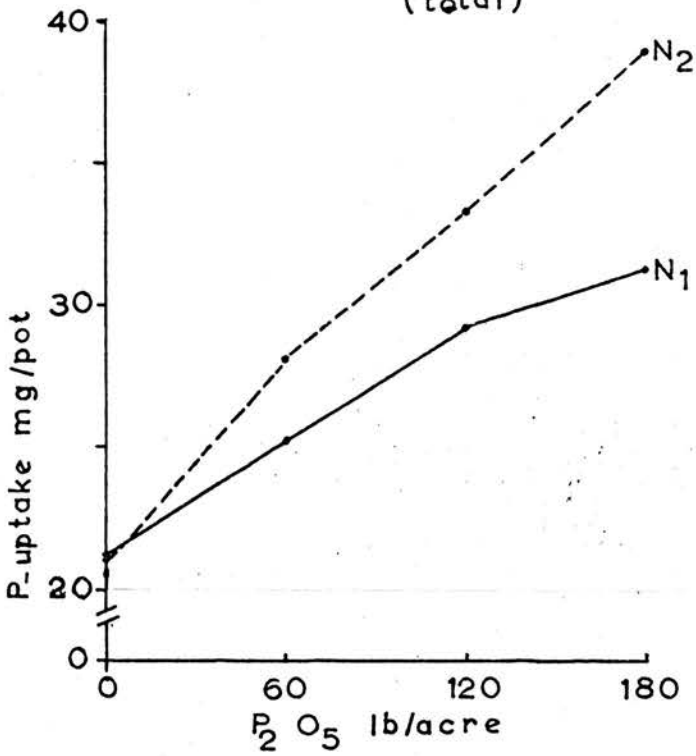
The apparent recovery of applied-P followed exactly the same pattern as the P-uptake.

The percentage apparent recovery of applied-P was greatly increased (* * *) with increasing rate of N in all cuts. Increasing the rate of P decreased the percentage recovery (* *) only in the first and third cut, while increasing the percentage recovery in the second cut (*). The 6 P-compounds were very similar. The percentage recovery on soil Y was greater than that on soil X. The response to N was greater on soil Y (*) only in the first cut, but it was greater (* *) on soil X in the second and third cuts of grass.

The Control (Po):

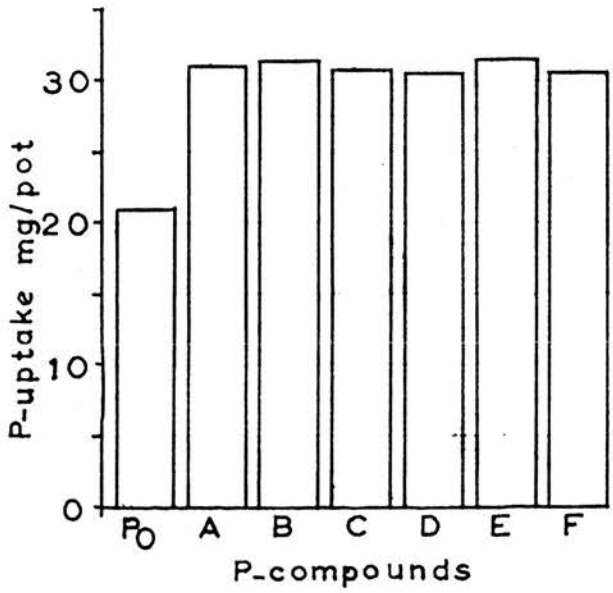
Yields, P-contents and P-uptakes of the control pots were not included in the statistical analyses of these results, since there were only two control-pots in each replicate instead of 6 for the six forms of P. However, it is very obvious from the results (appendix I) and the figures (1-6) that there were great yield responses to applied-P in the first and third cuts, as well

FIG. 7 Effect of N x P on P-uptake, expt. I, 1964. (total)



N***
P***
N x P***

FIG. 8 Effect of P-form on P-uptake, expt. I, 1964. (total of 3 cuts)



P-form, N.S.

FIG. 9 Effect of NxP on %P in D.M., expt.I, 1964.
(average of 3cuts)

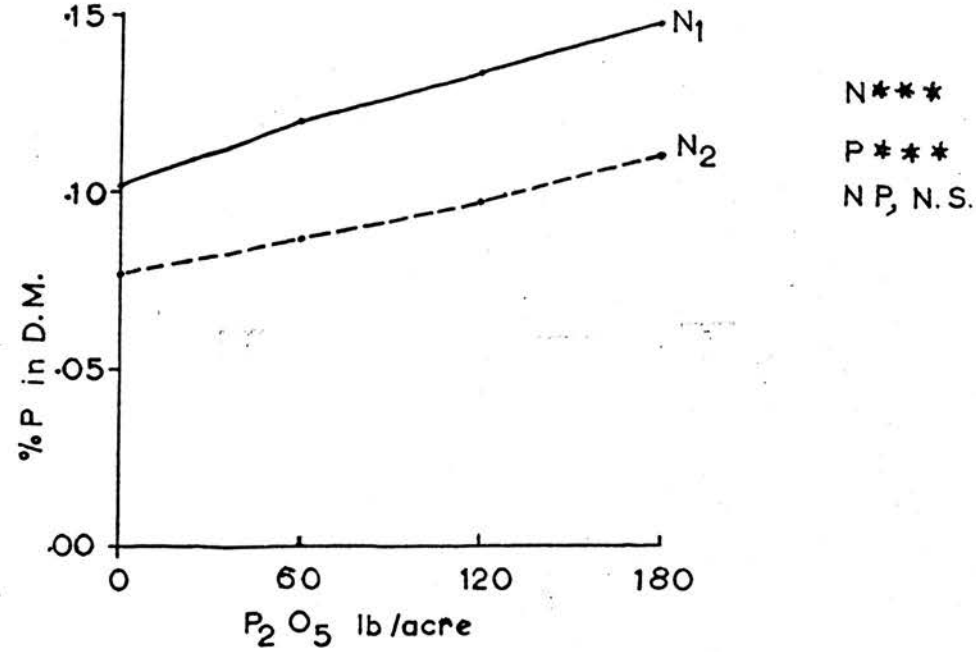


FIG. 10 Effect of NxP on yield of D.M., expt.I, 1964.
(total of 3 cuts)

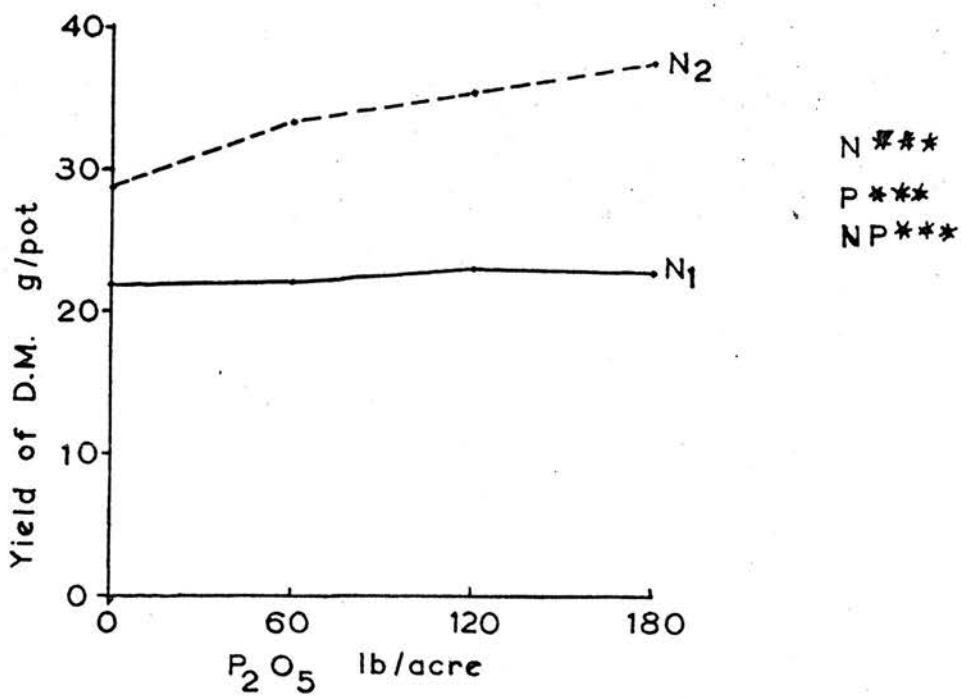


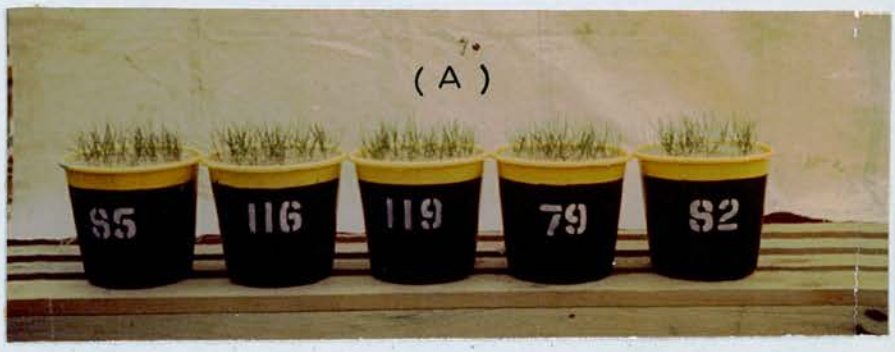
PLATE 1
(Expt.II)

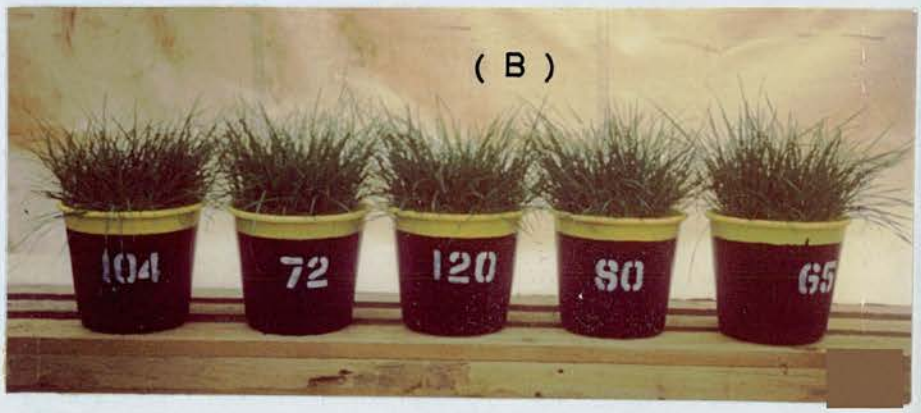
(A) Effect of N on growth where P was not applied.
From left to right:
N_1, N_2, N_3, N_4 & N_5.

(B) Effect of N on growth where P was applied at a rate of 60 lb. P_2O_5/acre.
From left to right:
N_1, N_2, N_3, N_4 & N_5.

(C) Effect of P rate on growth. All pots receiving 200 lb. N/acre.
From left to right:
P_0, P_{60}, P_{120} & P_{180}.

(D) Effect of P-form on early growth. All pots receiving 120 lb. P_2O_5/acre.
From left to right:
C, F & G.





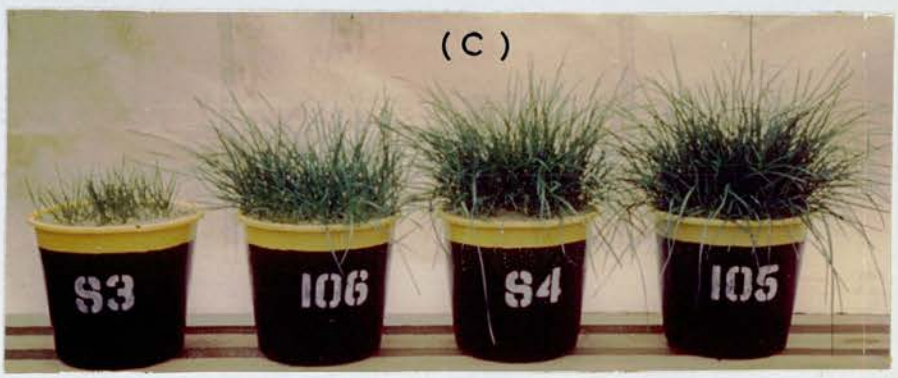


FIG. 11 EFFECT OF N x P ON YIELD OF D.M.,
(1st. CUT, EXPT. II.)

l	= LINEAR
qd	= QUADRATIC
c	= CUBIC
qr	= QUARTIC

N_l ***
N_{qd} ***
P_l ***
P_{qd} ***

$N_l \cdot P_l$ *** $N_{qd} \cdot P_l$ ***

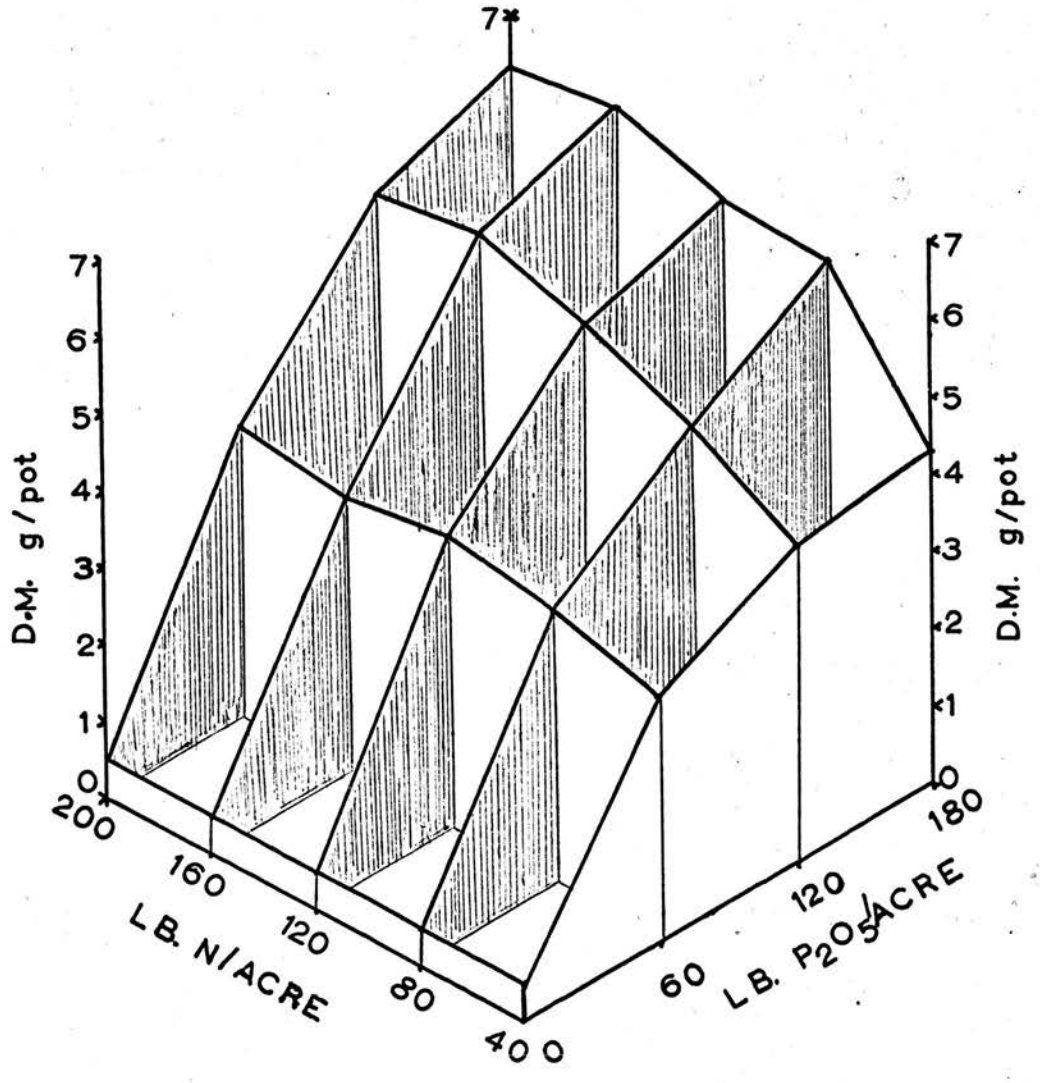


FIG. 12 EFFECT OF N & P ON YIELD OF D.M.

(4th CUT, EXPT. II)

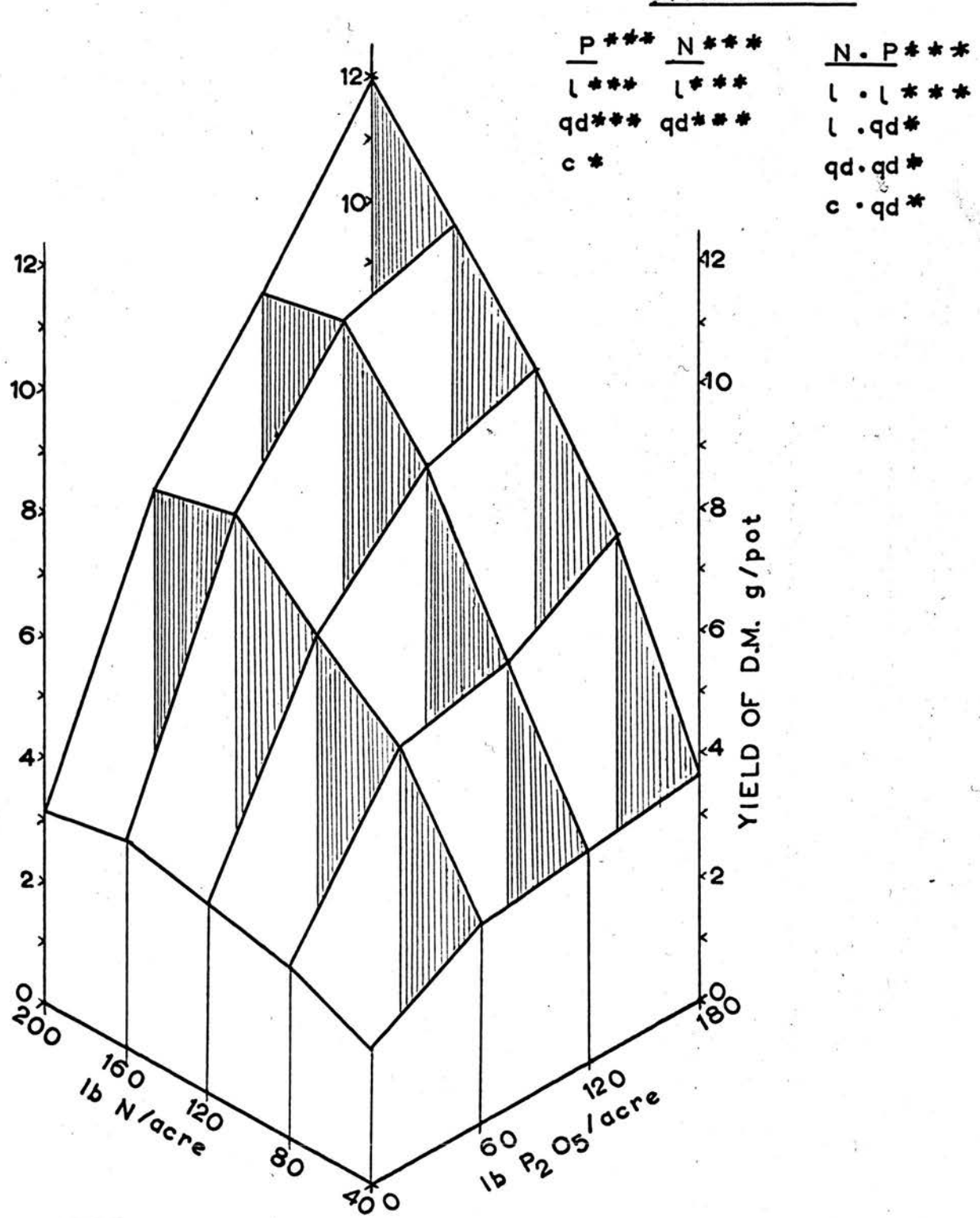
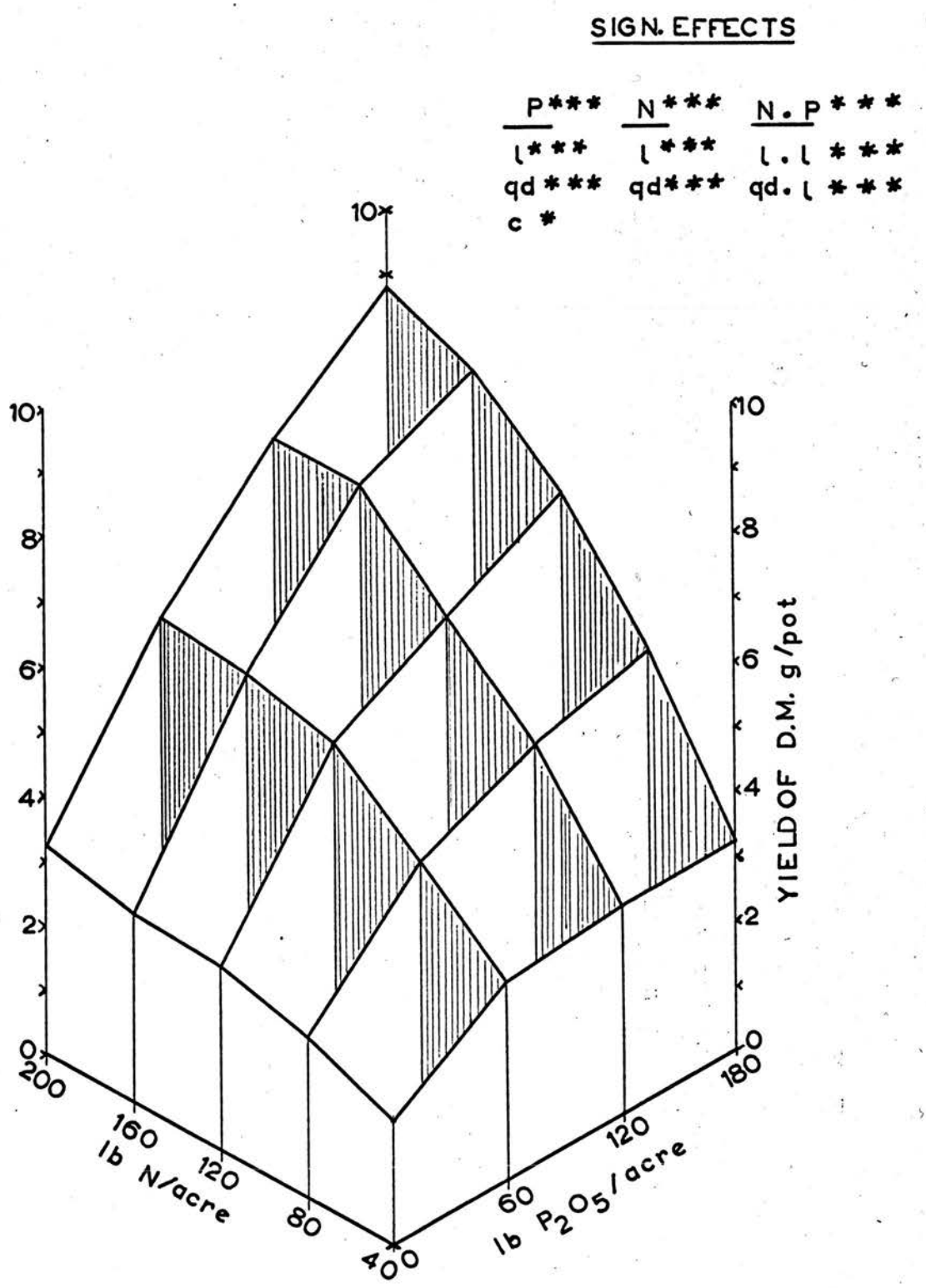


FIG. 13.

EFFECT OF N & P ON YIELD OF D.M.

(AV. OF 8 CUTS, EXPT. II)



as great responses in terms of P-contents and P-uptakes in all cuts of grass.

Results of 1964:

In 1964 three cuts of grass were taken from the same experiment. The results were generally similar to those of the preceding year although the responses were smaller in magnitude particularly in terms of P-contents, P-uptakes or P-recoveries (figs. 7-10).

EXPERIMENT II (1964):

(See pages 48-53 for details of experimental design and fertilizer-treatments). Results of this experiment are tabulated in Appendix II.

Yields of grass:

Yields of fresh grass as well as D.M. were greatly increased (* * *) with P-application or increasing rate of P (figs. 11, 12, 13). Increasing rate of applied-N also greatly (* * *) increased the yields, but only if P was applied (plate 1 and figs. 11, 12, 13). This was most marked in the early cuts of grass (fig. 11). The highest yields were obtained from N_4 or N_5, with no significant difference between them in most cases.

The effects of P-form as well as the Form x P-rate interaction were highly significant in the 1st cut of grass. Fig. 14a shows that both the orthophosphate (F) and the metaphosphate glass (G) were superior (* *) to the trimetaphosphate (C) with P_1, F was also superior to C with P_2 (* *), and at the highest rate of P F was superior to G (* *). In the 4th cut of grass C was also inferior

to F in terms of yield of fresh grass (* *) or yields of D.M. (*).

Considering the total of 8 cuts of grass, yields produced by C were smaller (* * *) than those produced by either F or G with the last two being equivalent. These very highly significant differences, between forms of P, were generally small. Even in the 1st cut of grass, in which the greatest effects of P-form were obtained, the differences in yields produced by the different forms of P were not more than 10 per cent of the overall mean-yield.

The N x P interaction was very pronounced (* * *); increasing rate of either nutrient greatly increased the response to the other (figs. 11, 12, 13). The magnitude of the N x P interactions was increasing in the successive cuts of grass.

After the 5th cut of grass accumulated salt-damage was observed on some pots particularly those receiving high rates of N. This was probably due to the "sub-irrigation" system, used after the 2nd cut, in which the pots were irrigated through a basin underlying each pot. For that reason the basins were removed and, following the fifth cut, the normal N-application was withheld for one cut only. The pots were given a heavy overhead-watering once a day for about a week to leach out the salts. After the 6th and 7th cuts of grass the rates of applied-N were reduced to only one-half of the original. Hence, yield responses were greatly reduced in the last 3 cuts of grass (fig.14).

Percentage D.M.:

The D.M.-content of the grass was affected only by N- or P-rates or N x P-interaction. In most cuts of grass, P-applications

FIG. 14. EFFECT OF P-FORM AND RATE ON YIELD OF D.M., EXPERIMENT II.

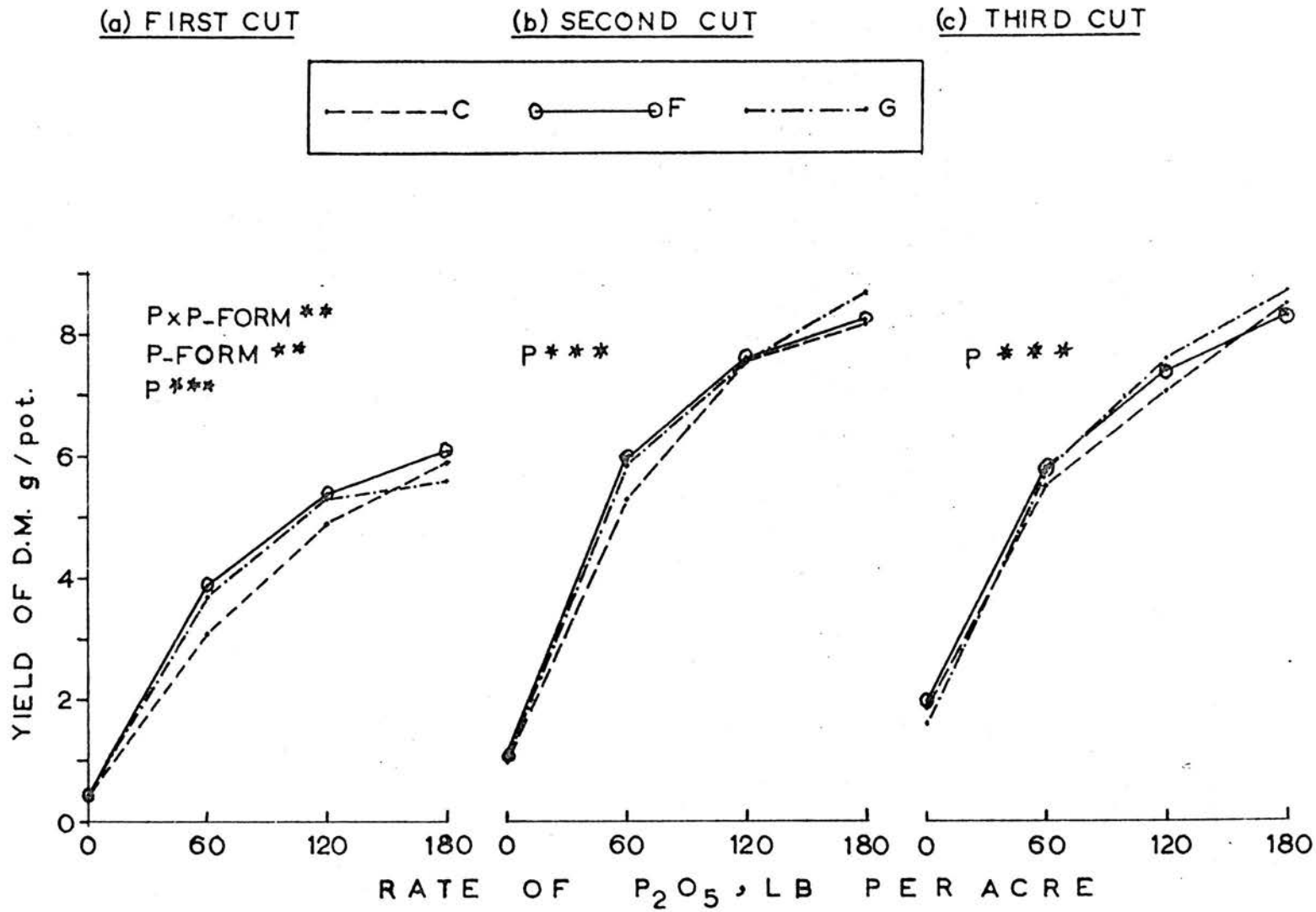


FIG. 14. (contd.)

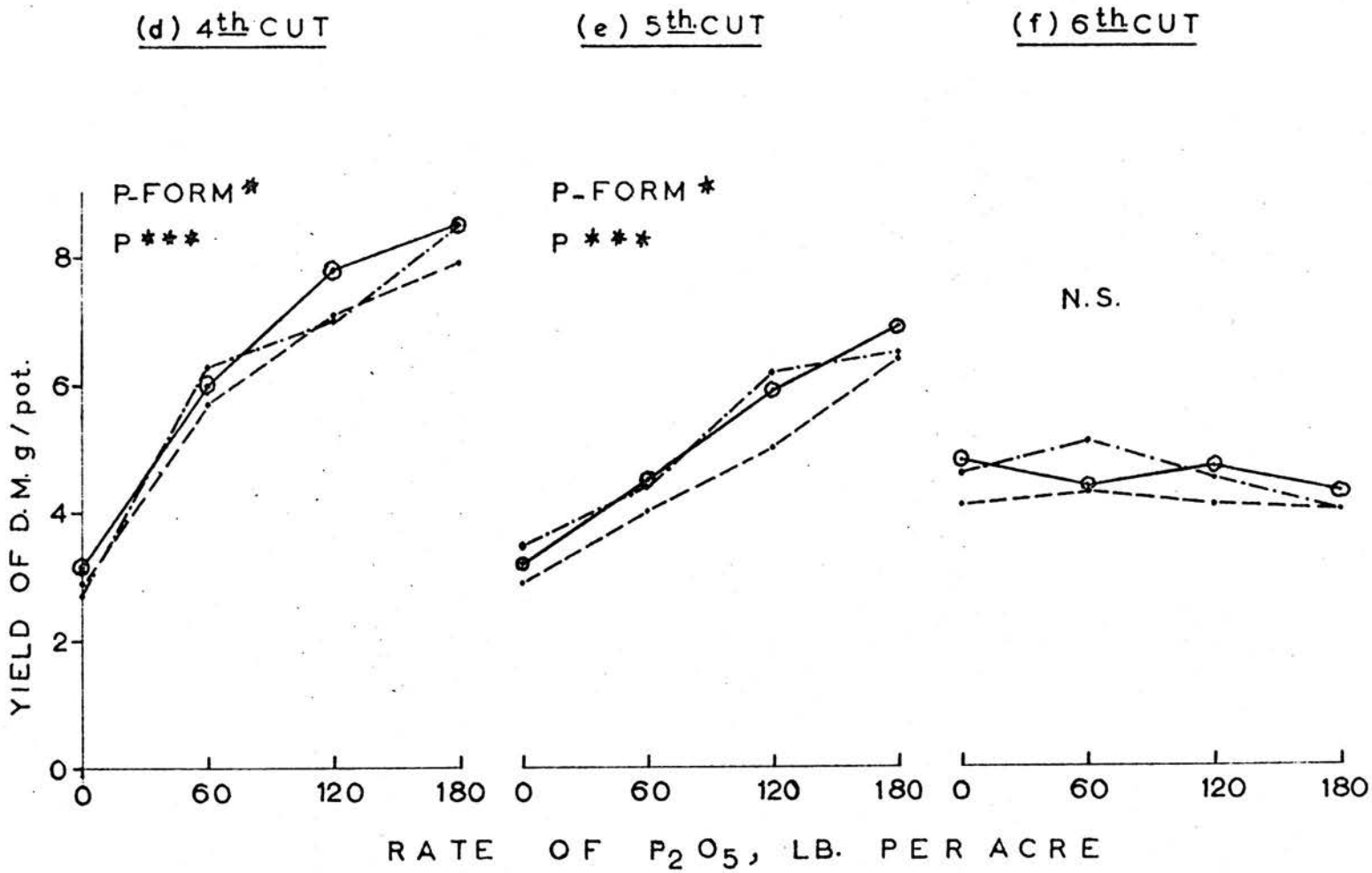

(d) 4th CUT
(e) 5th CUT
(f) 6th CUT
P-FORM *
P ***
P-FORM *
P ***
N.S.
YIELD OF D.M. g / pot.
0
2
4
6
8
0
60
120
180
RATE OF P_2O_5, LB. PER ACRE

FIG. 14. (contd.)

(g) 7th CUT

P-FORM *

P, N.S.

(h) 8th CUT

P-FORM, N.S.

P***

(i) AVERAGE OF 8 CUTS

P-Form ***

P***

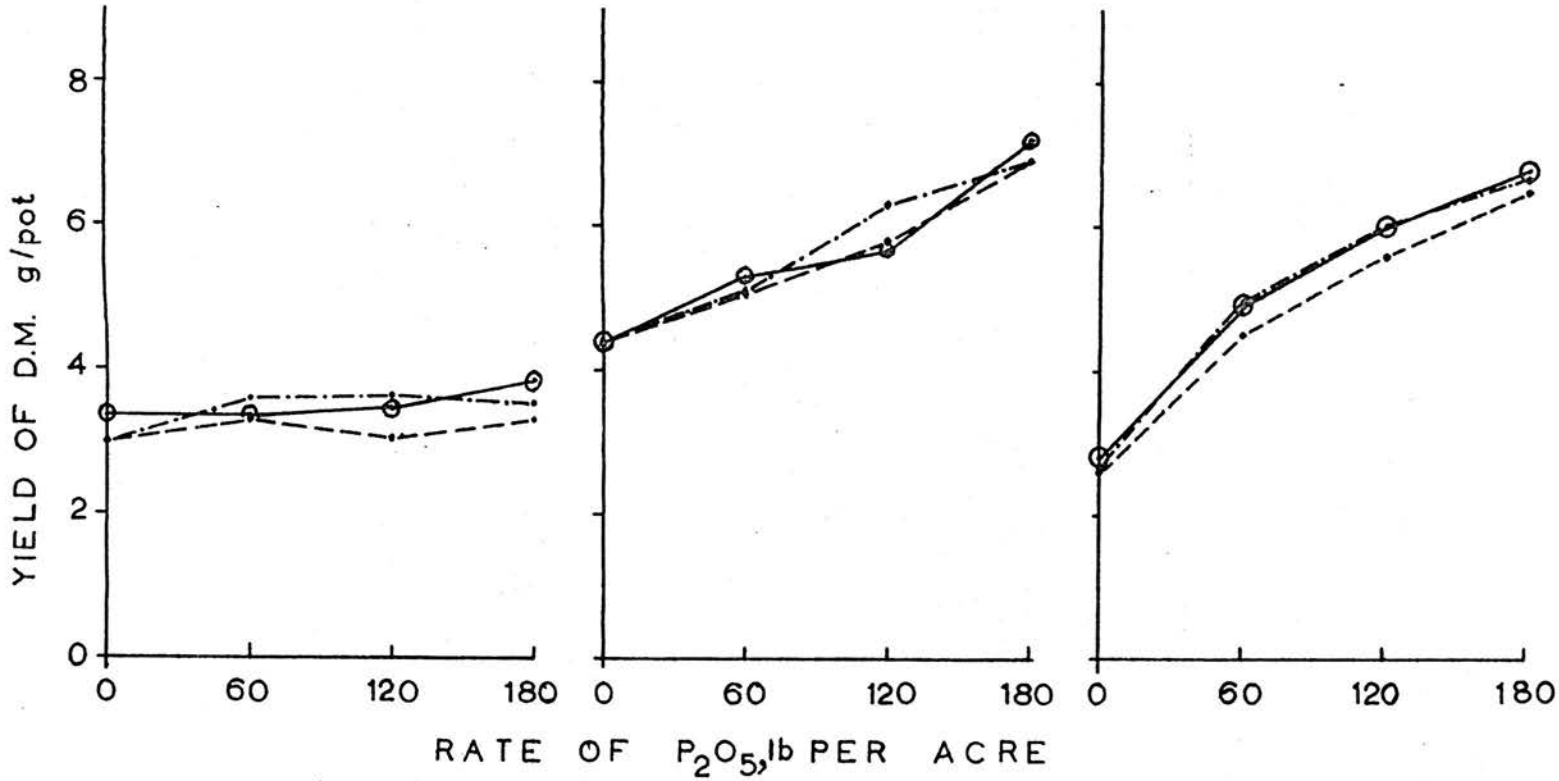


FIG. 15. EFFECTS OF N & P ON D.M. PERCENT OF GRASS (AV. OF 8 CUTS, EXPT. II)

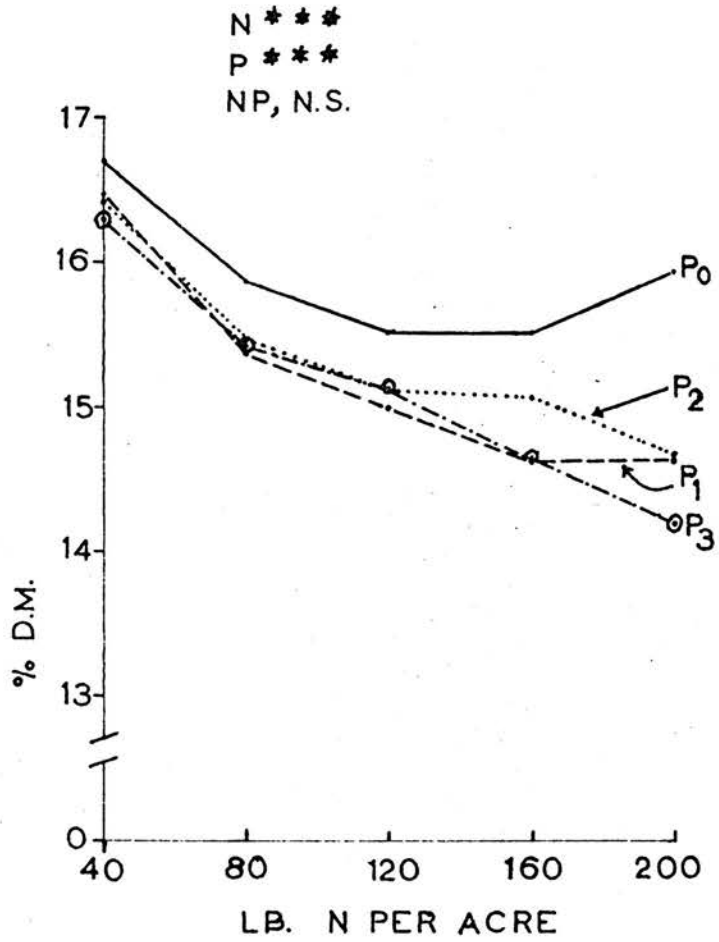
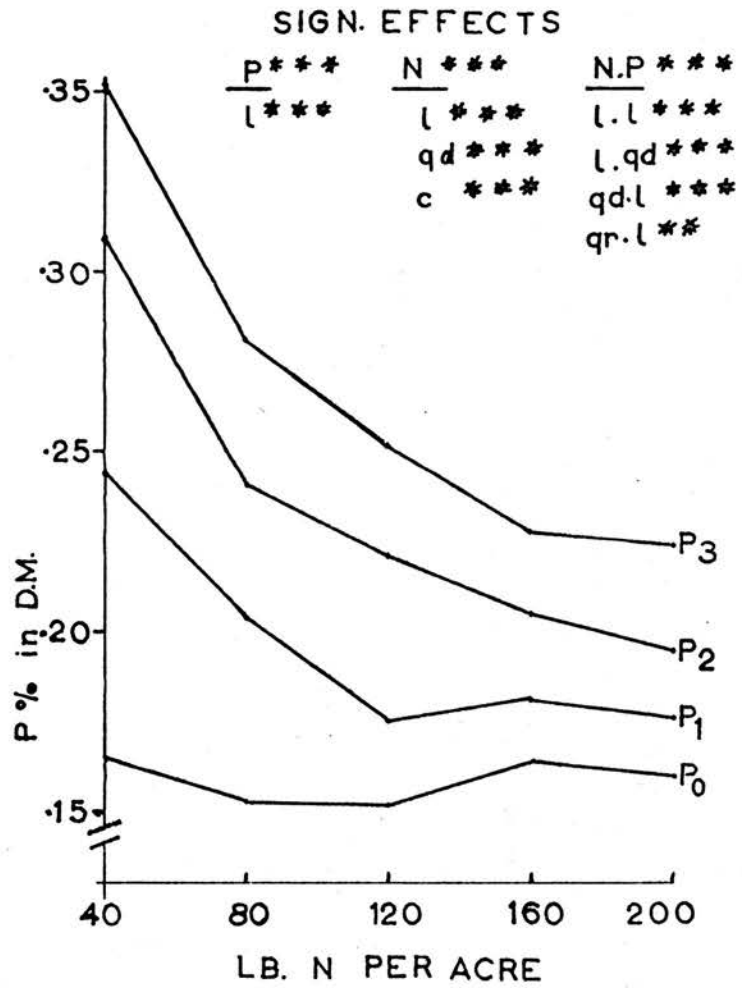


FIG. 16. EFFECT OF N & P ON %P OF D.M. (AV. OF 8 CUTS EXPT. II)



or increasing rate of N decreased (* * *) the D.M. content of the grass, but there was no significant difference between the three rates of P-application. This effect of P was mostly with the high rates of N, while with the low rates of N P-applications either increased the D.M. content or did not affect it. The effect of N in decreasing D.M. content was also more marked if P was applied but with little or no effect of increasing the rate of P (fig. 15).

Percentage P of D.M.:

P-application as well as increasing rate of P greatly increased (* * *) the P-content of D.M. in all cuts of grass. Fig. 16 presents this effect as well as the effects of N and N x P interaction, using the "average" P-contents of the 8 cuts of grass. It may not be valid to average P-contents of grass, but this was done only to demonstrate the general pattern for the effects of P- or N-rates which were consistent in all cuts of grass.

Increasing rate of applied-N greatly depressed (* * *) the P-content of D.M. (fig. 16) only if P was applied. This was consistent in all cuts of grass. At the low rates of N the effect of increasing rate of P was much more pronounced than with the high rates of N (N x P * * *) particularly after the 1st cut of grass in which the yield response to N was smaller compared with all subsequent cuts.

There were only occasional significant differences between forms of P in some cuts; G $>$ C* in the first cut, in the 4th cut

C or G > F* * only with N_5 and C > G * * only with N_1. In the fifth cut the trimetaphosphate (C) produced greater (* *) P-contents than did the orthophosphate (F) or the metaphosphate glass (G). These differences, although they reached the level of significance, were neither great enough nor consistent enough to be of practical importance. In the 5th cut, however, where the effect of P-form was greatest, the differences between forms of P did exceed 6 per cent of the overall-mean of the P-contents of D.M.

P-uptake:

In all 8 cuts of grass, P-uptake was greatly enhanced (* * *) by P-application and it was linearly increasing with increased rate of P (figs. 17, 18, 19).

The 3 forms of P produced similar P-uptakes except in the 1st cut of grass, in which C was inferior to either F * * * or G * *, and in the total of 8 cuts in which both F and G were superior (*) to C (fig. 20). The superiority of F to C in the first cut was most marked with the highest two rates of N-application (N_4 and N_5). F was also superior (*) to G in this cut only with N_5.

In the early cuts of grass N had no significant effect on P-uptake except where P was applied (fig. 17), and in the later cuts the response to N was greatly increased with increasing rate of P (figs. 18, 19). On the other hand the response to increasing rate of applied-P was very great with all rates of N in the early cuts (fig. 17), while in the later cuts of grass it was greatly increasing with rate of N (figs. 18,19). The N x P interaction

FIG. 17

EFFECT OF N×P ON P-UPTAKE, EXPT. II.

(1st. CUT)

SIGN. EFFECTS

P ***	N ***	N . P ***
l ***	l ***	l . l ***
qd ***	qd **	qd . l **

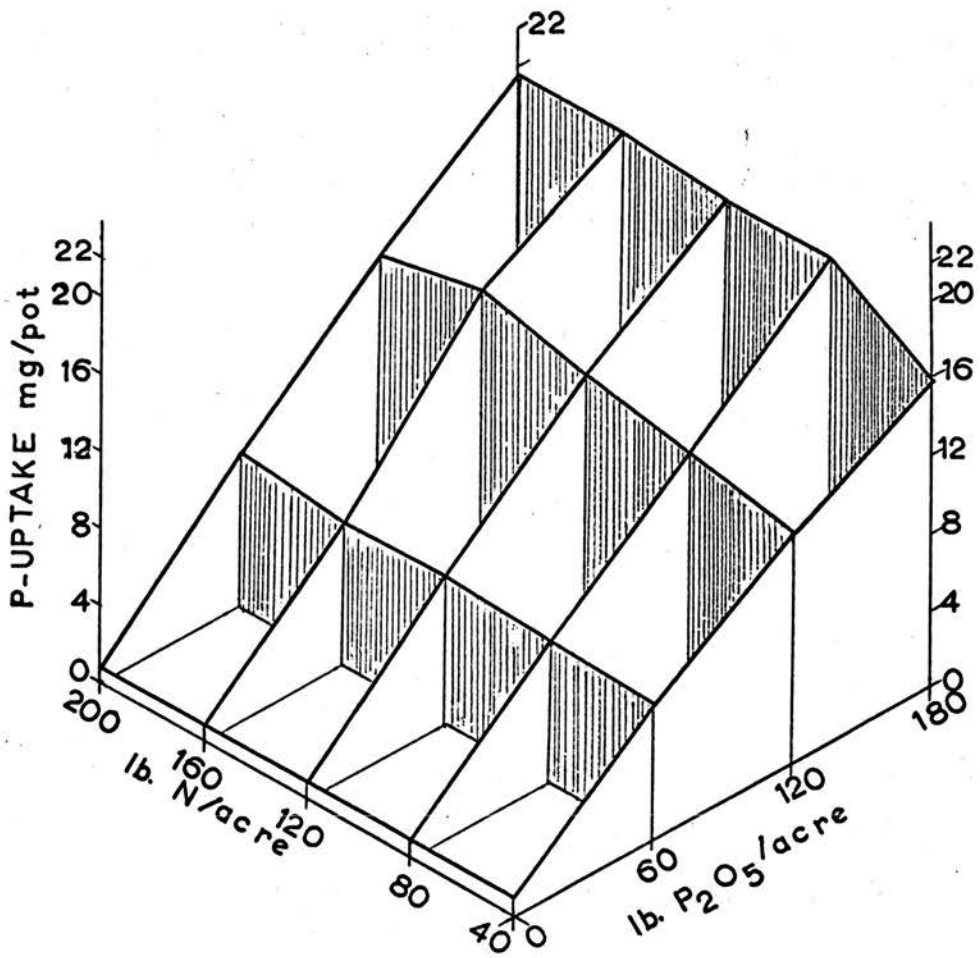


FIG. 18

EFFECT OF N×P ON P-UPTAKE, EXPT. II.

(4th. CUT)

SIGN. EFFECTS

P***	N***	N . P ***
l ***	l***	l . l ***
qd ***	qd***	l . qd *
		qd. l *
		c . qd *

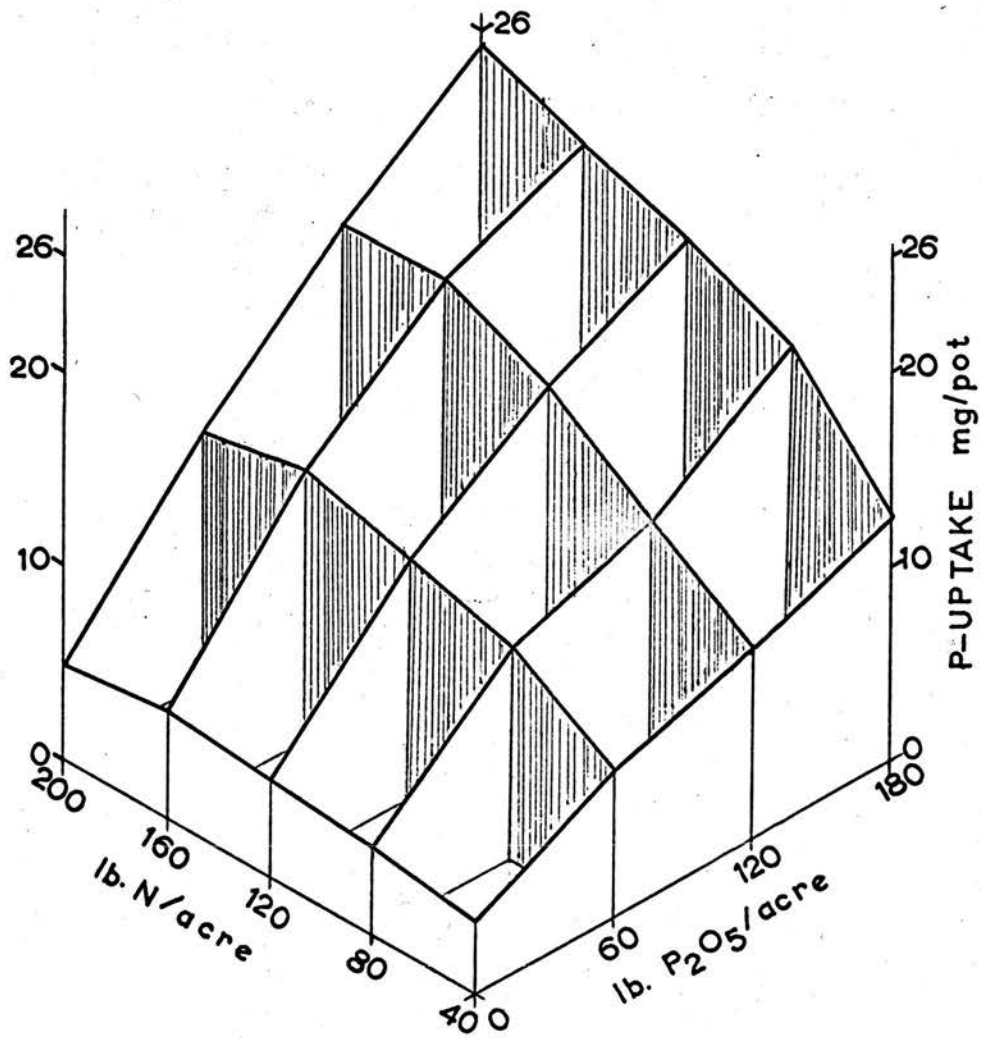


FIG. 19

EFFECT OF N×P ON P-UPTAKE, EXPT. II.
(AVERAGE OF 8 CUTS.)

SIGN. EFFECTS

P***	N***	N . P***
l***	l***	l . l ***
qd***	qd***	qd . l **

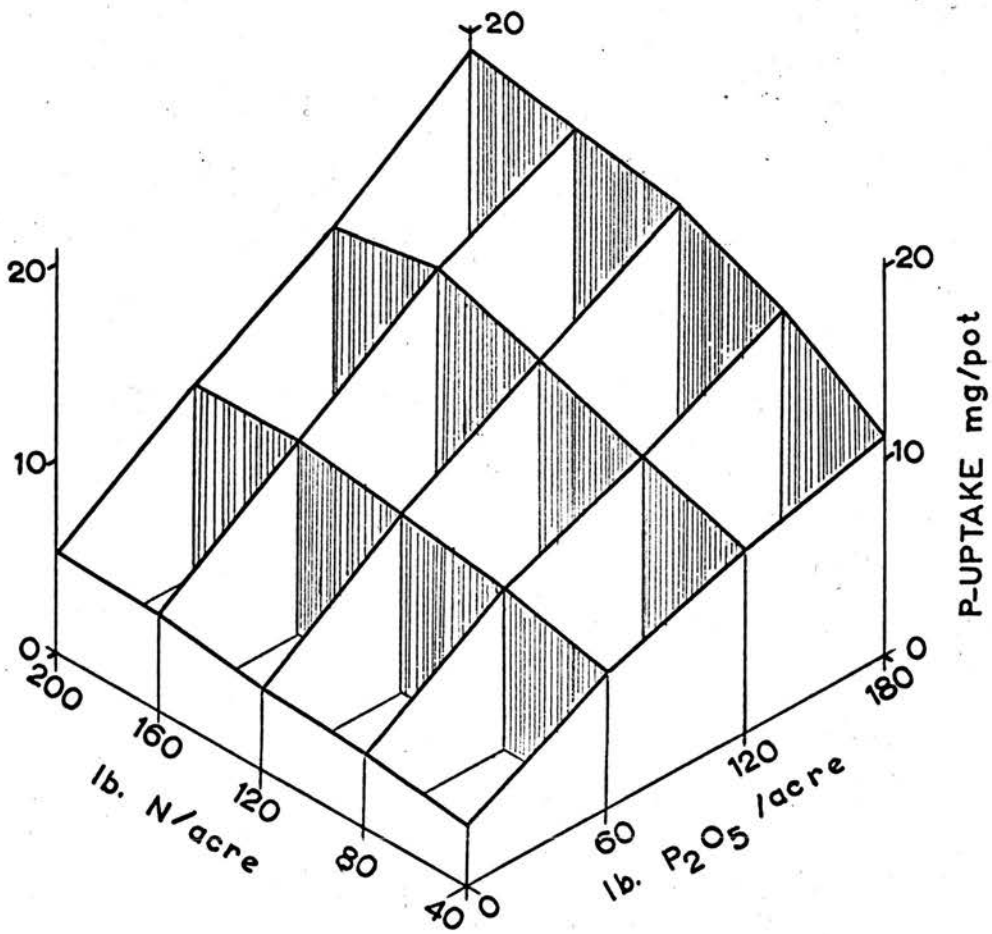


FIG. 20. EFFECTS OF RATE AND FORM OF P ON P-UPTAKE (EXPT. II).

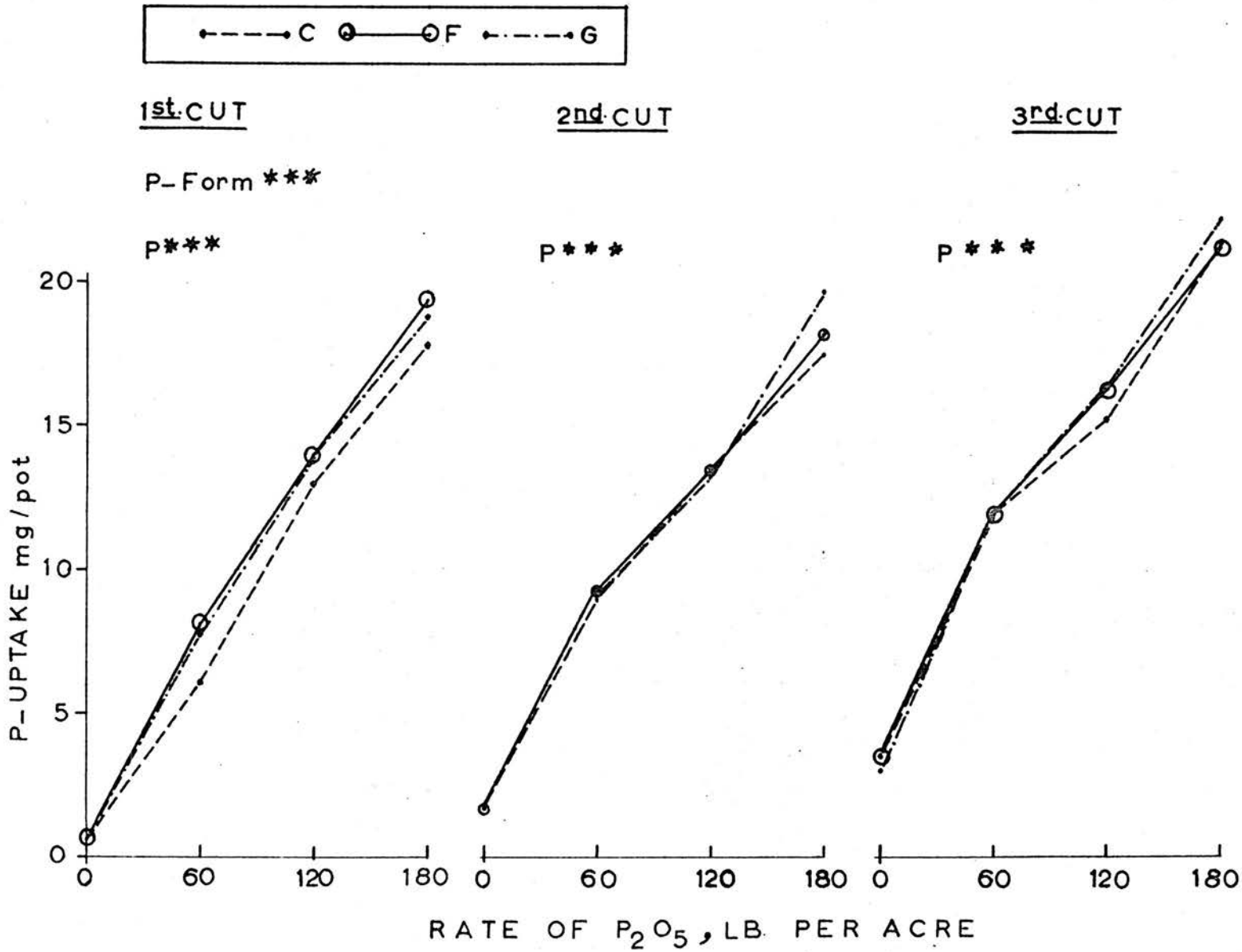


FIG. 20 (contd.)

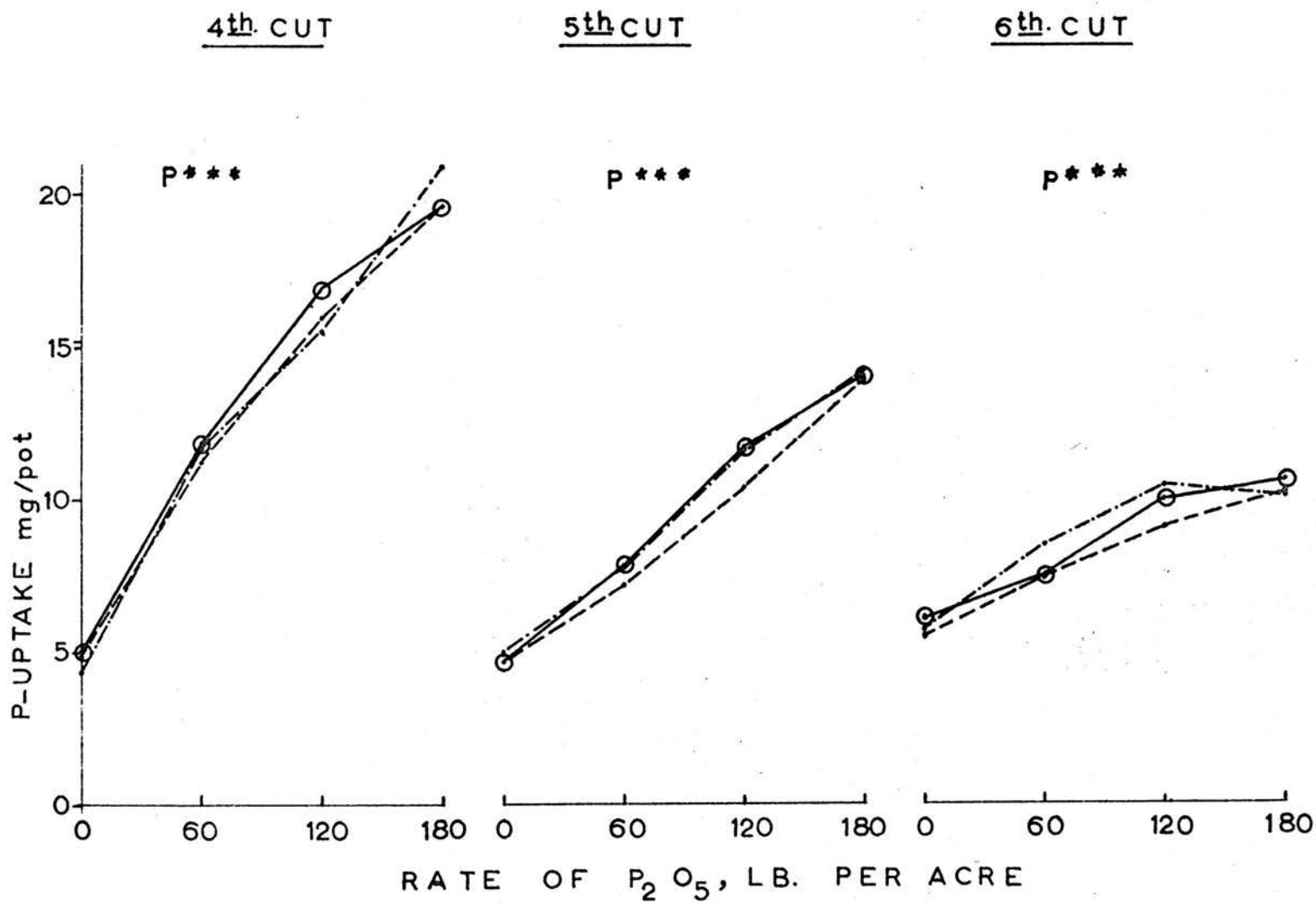

4th. CUT
5th CUT
6th. CUT
P***
P***
P***
20
15
10
5
0
P-UPTAKE mg/pot
0
60
120
180
RATE OF P_2O_5, LB. PER ACRE

FIG. 20 (contd.)

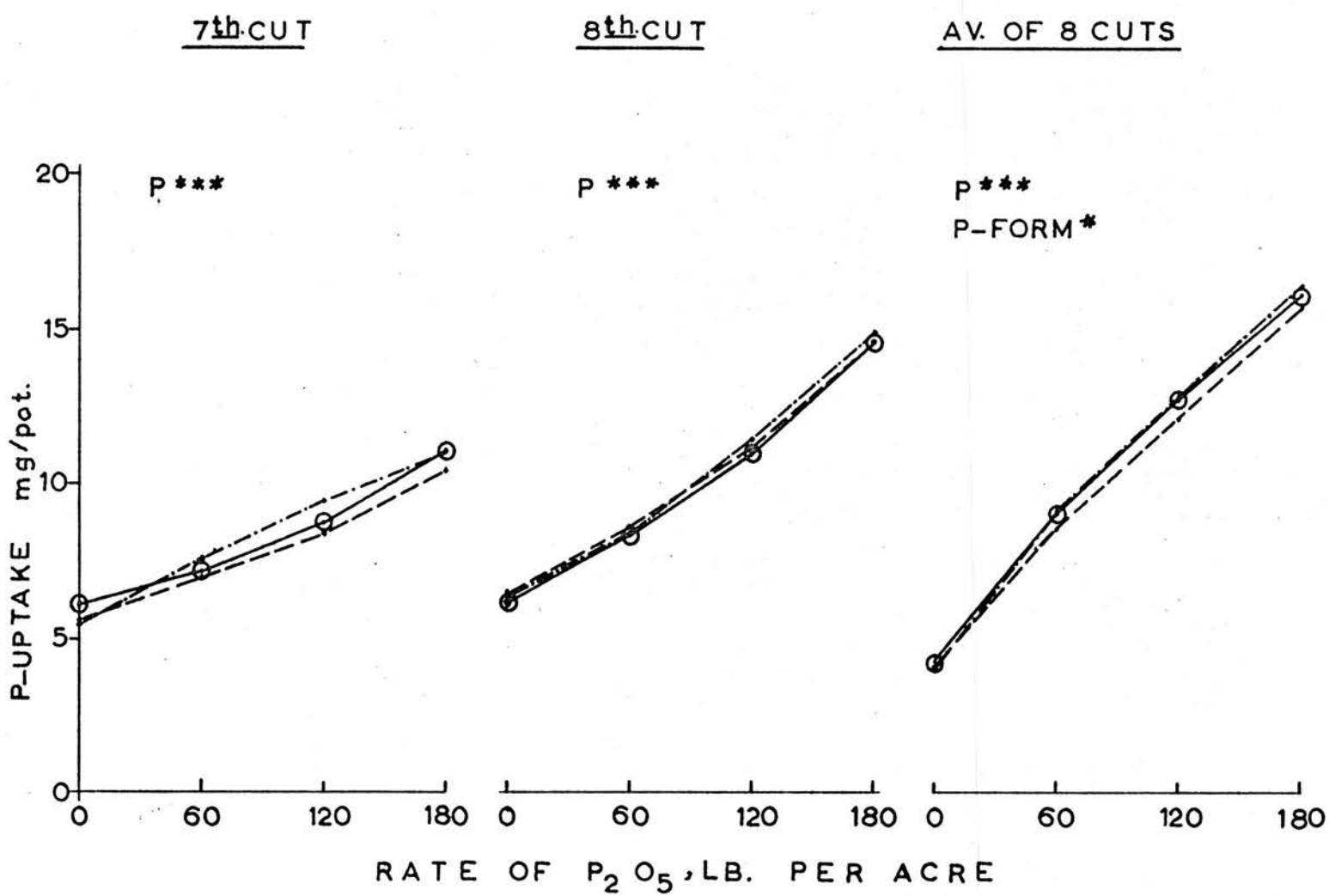

7th CUT
8th CUT
AV. OF 8 CUTS
P ***
P ***
P ***
P-FORM *
P-UPTAKE mg/pot.
20
15
10
5
0
0
60
120
180
RATE OF P_2O_5, LB. PER ACRE

FIG. 21.

EFFECT OF P-RATE ON SOIL-P UPTAKE, EXPT. II.

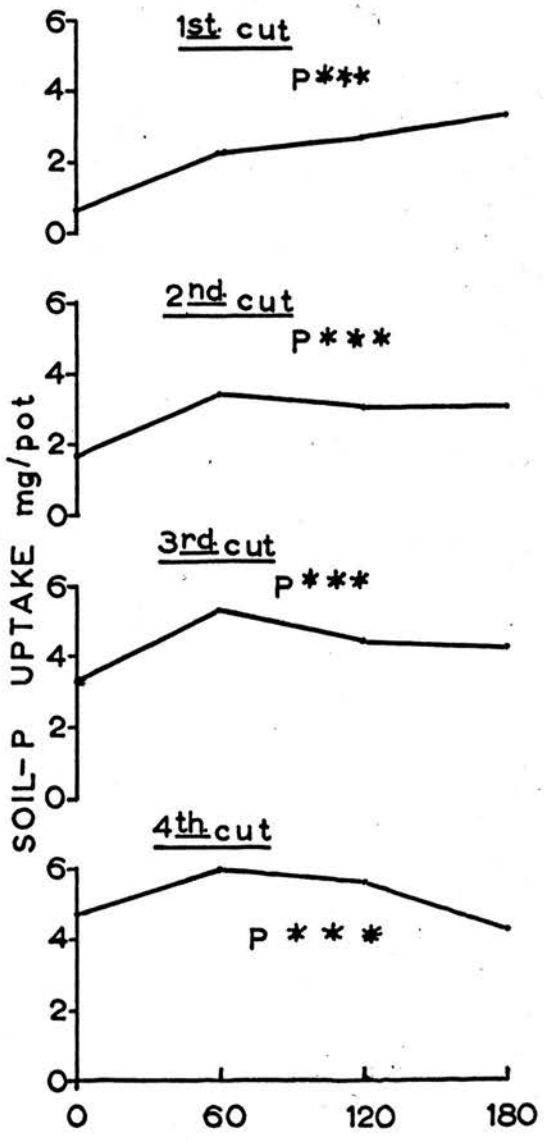


FIG. 22.

EFFECT OF N-RATE ON SOIL-P UPTAKE, EXPT. II.

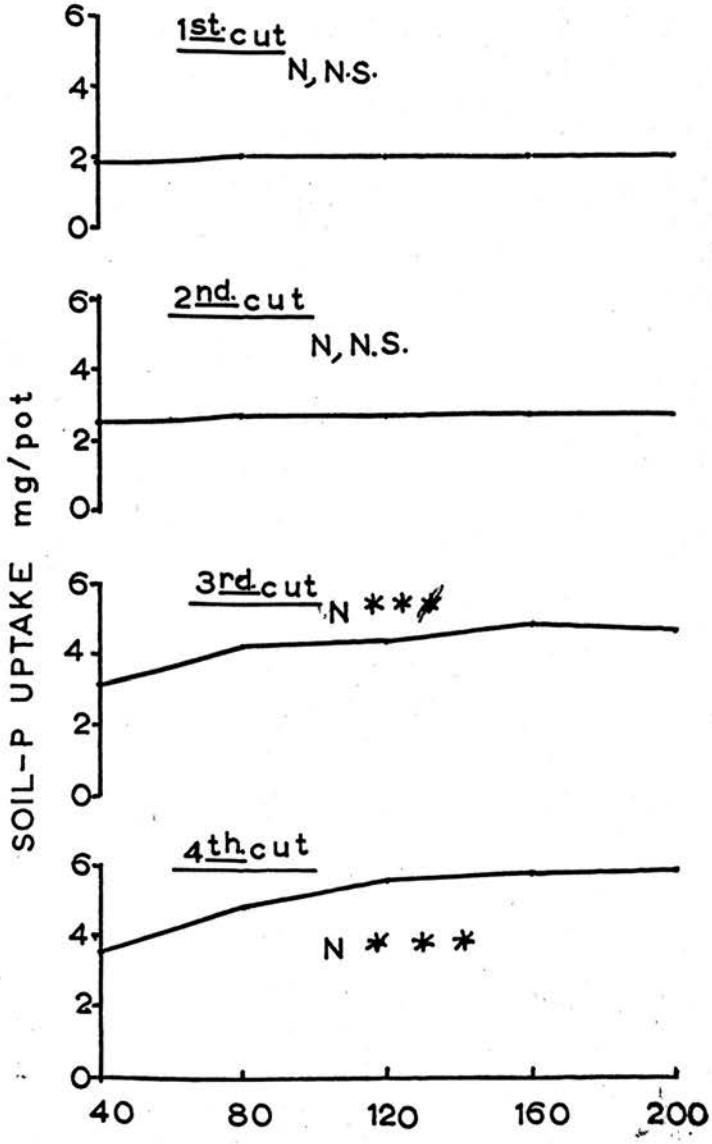


FIG. 23

EFFECTS OF RATE & FORM OF P ON SOIL-P UPTAKE (2nd. EXPT. II)

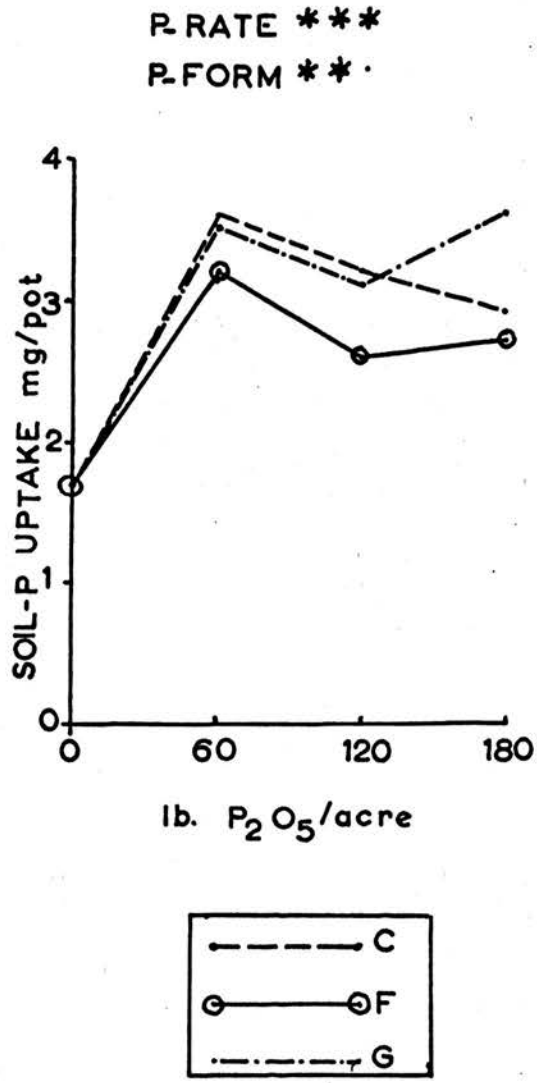
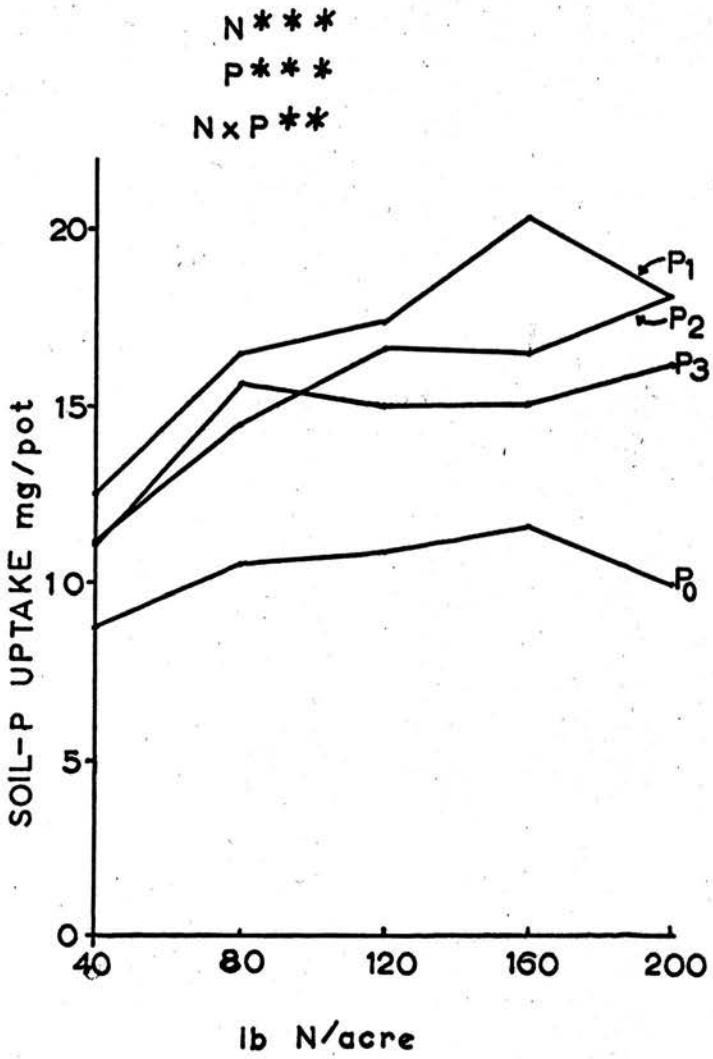


FIG. 24

EFFECT OF N x P ON SOIL-P UPTAKE (TOTAL OF 4 CUTS, EXPT. II)



was very highly significant in 6 out of the 8 cuts of grass and highly significant in the other two (2nd and 7th).

The interaction between the rate and form of P was significant only in the 4th cut of grass, in which G was inferior (*) to F with P_2 and superior to (*) both F and C with P_3.

Soil-P uptake:

Using the ^{32}P-labelling technique, it was possible to differentiate between the fertilizer-P and soil-P taken up by the plant. Fig. 21 shows that P-applications increased the soil-P uptake (* * *), which was increasing with increased rate of P only in the first cut of grass. In the succeeding 3 cuts all rates of applied-P increased the soil-P uptake (* * *), but the magnitude of the increase was decreased with P-rate, and with time in the successive cuts of grass. (There was only 4 cuts of grass in which the radioactivity was measured).

Increasing rate of applied-N considerably increased the soil-P uptake only in the 3rd (* *) and 4th (* * *) cuts of grass (fig.22).

The form of P also had a significant effect (* *) on soil-P uptake only in the 2nd cut of grass (fig. 23), in which both C and G produced greater soil-P uptakes than F.

Considering the total of 4 cuts, the effects of N or P (fig. 24) in increasing soil-P uptake were very pronounced (* * *). N_1 produced smaller (* * *) soil-P uptakes than all higher N-rates, but there were only small differences between these higher rates. The effects of P_1, P_2 and P_3 were very pronounced compared with P_0 (* * *), but within these three rates the soil-P uptake was

decreasing with increased rate of applied-P (fig. 24). N x P interaction (* *) showed that the effect of N in increasing soil-P uptake was more pronounced with P_1 and P_2 as compared with P_0 and P_3 (fig. 24). The trimetaphosphate (C) produced greater (*) soil-P uptake than did the orthophosphate (F) only with P_2, and the metaphosphate glass (G) produced greater values than F only with P_3 (P x Form *).

"A" values:

'A' values, calculated from the proportion of the labelled-P in total P taken-up by plants, showed no significant difference between the forms of P in the first cut of grass. The only significant effect, on the 'A' values in this cut, was that of the rate of P (* *) in which P_3 produced greater values than either P_1 or P_2 (fig. 25a). In the 2nd cut (fig. 25b), the only significant effect was that of the form of P (* * *); compound F produced smaller 'A' values than either C or G.

In the 3rd cut (fig. 25c) compound C produced the highest 'A' values while F produced the lowest (* *), and G was intermediate but not significantly different from the other two. Again in the 4th cut C produced greater values than F (*) and G was intermediate (fig. 25d). Only in the 4th cut increasing rate of P decreased (* * *) the 'A' values (fig. 25d).

The effect of N was significant (*) only in the 4th cut in which N_4 produced smaller values than the 3 lower rates (fig. 26). The N x form interaction was highly significant in the 4th cut in which F produced smaller values than G only with N_5. N x P

FIG. 25 EFFECTS OF RATE & FORM OF P ON A VALUES (EXPT. II).

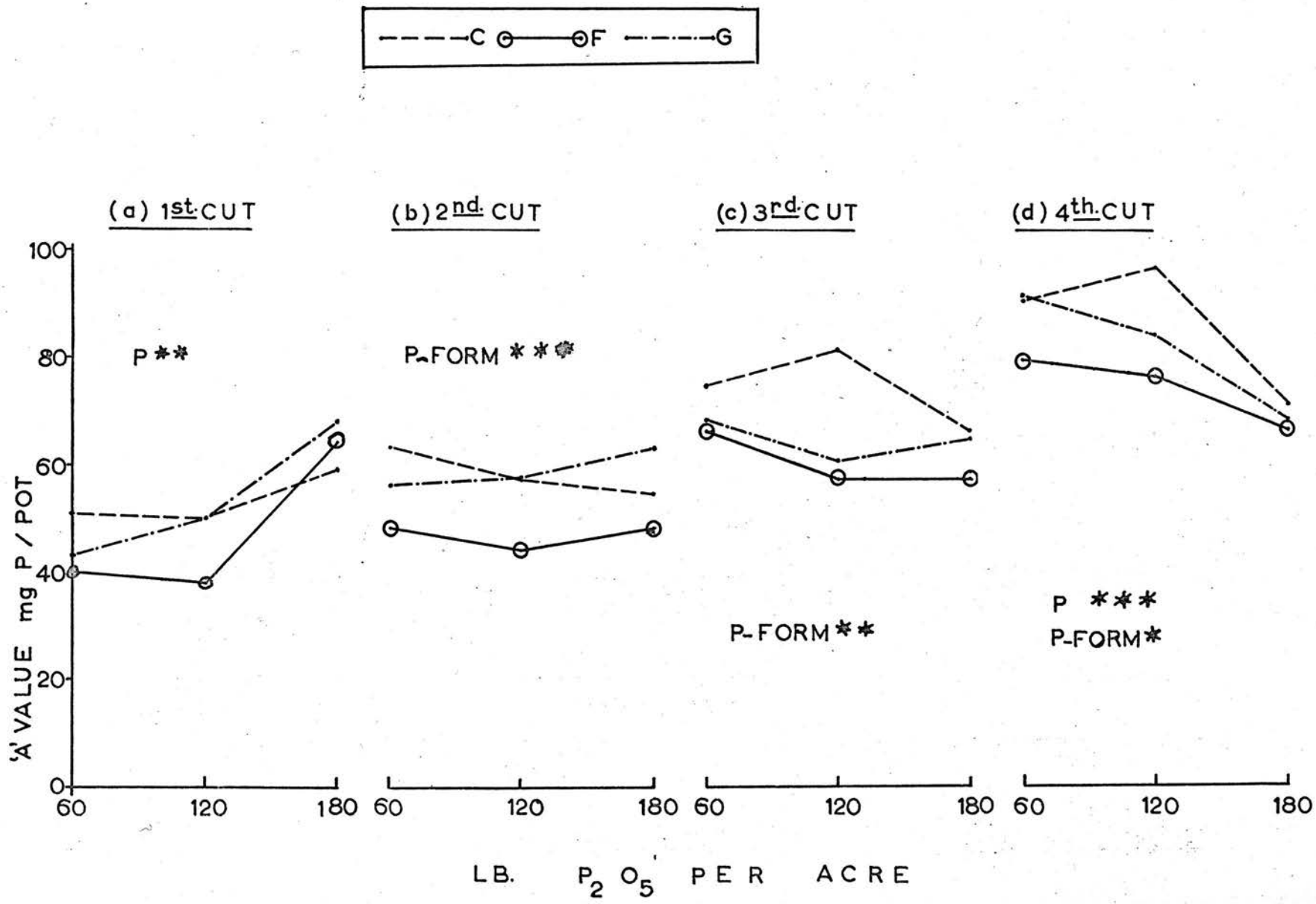


FIG. 26

EFFECT OF N-RATE ON 'A' VALUES
(EXPT. II).

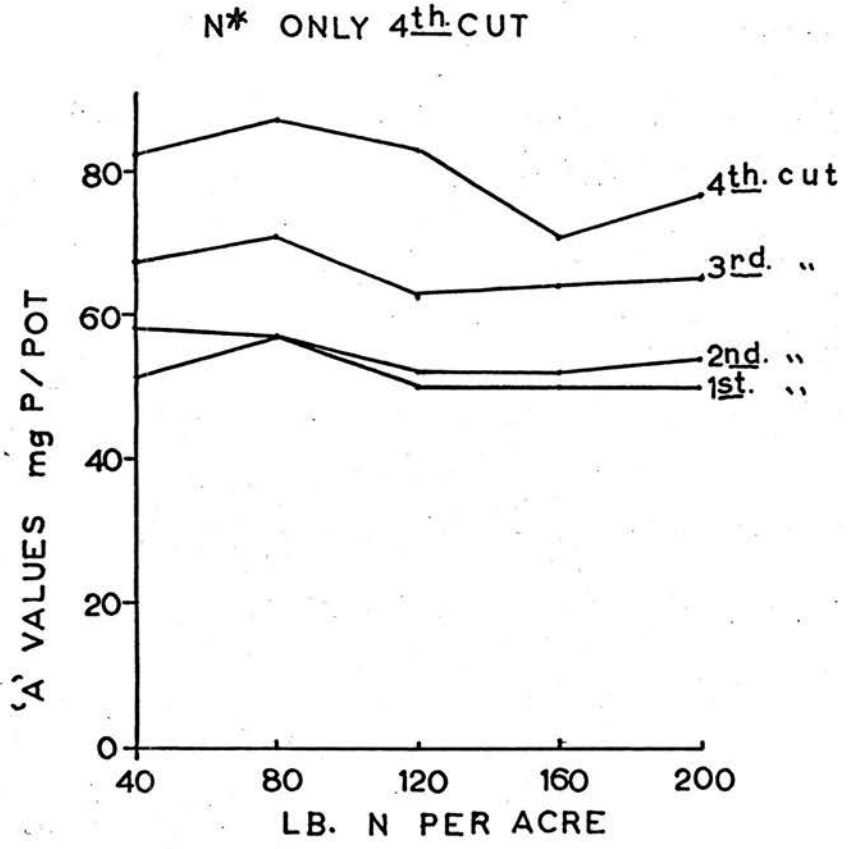


FIG. 27

EFFECT OF N×P ON 'A' VALUES
(4th CUT, EXPT. II)

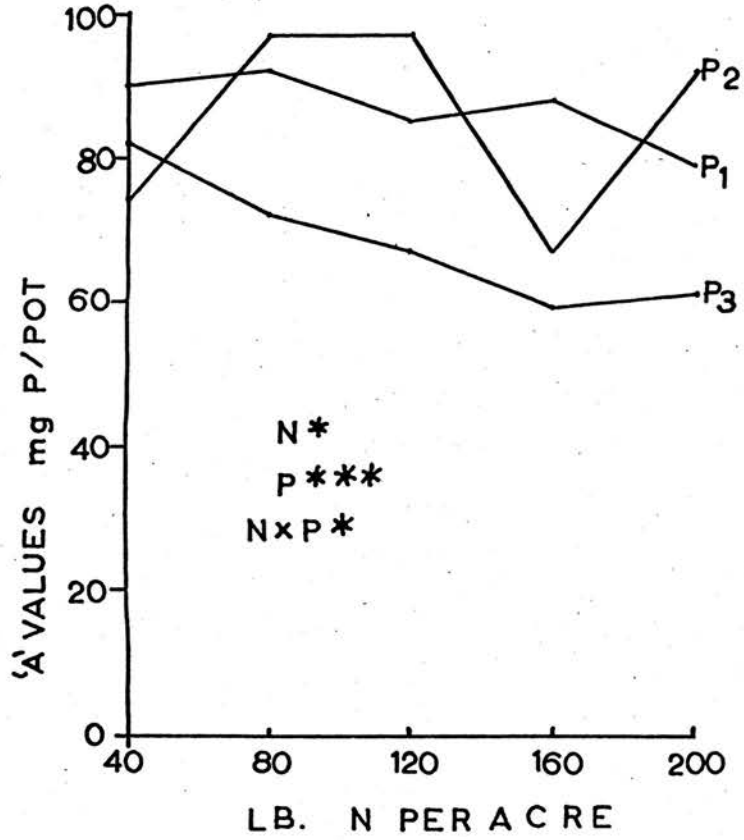


FIG. 28. EFFECT OF RATE & FORM OF P ON 'A' VALUES (EXPT. II).

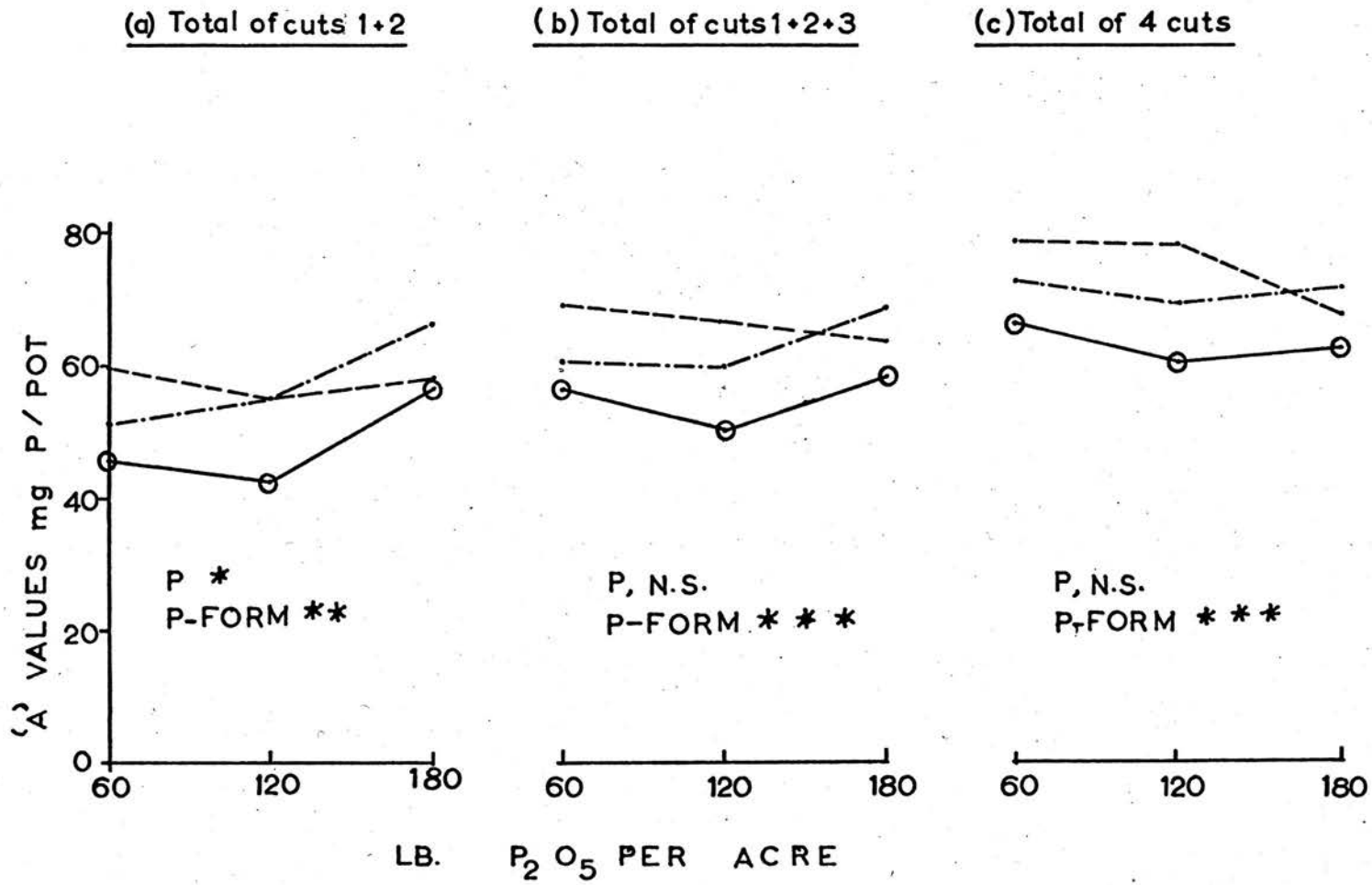


FIG. 29

EFFECT OF N-RATE ON A VALUES
(EXPT. II)

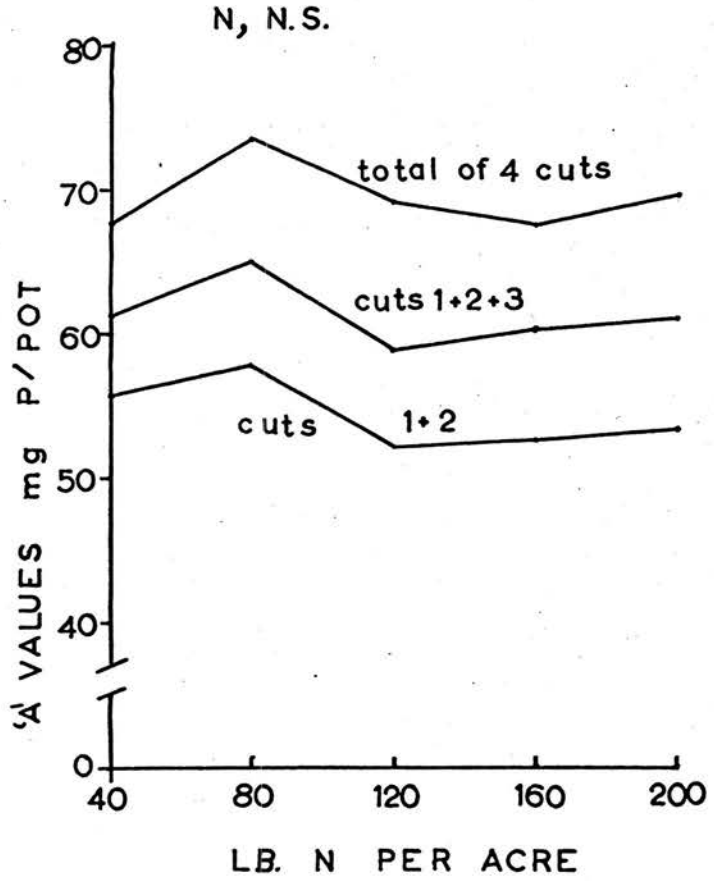
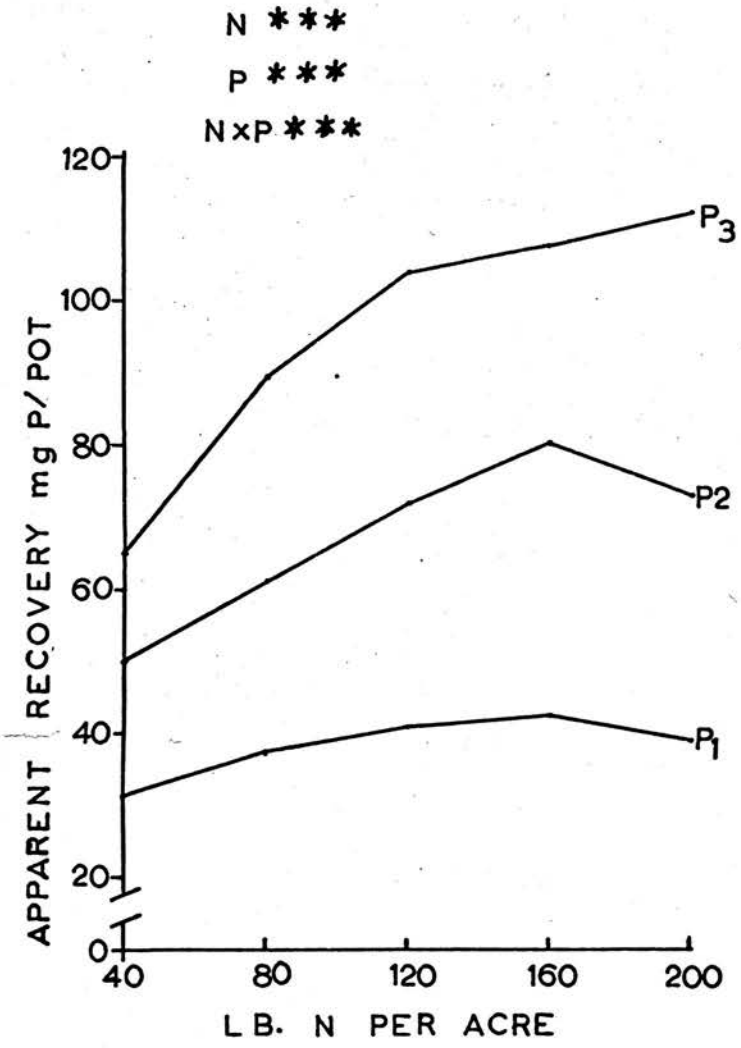


FIG. 30. EFFECT OF N×P ON
APPARENT RECOVERY OF APPLIED-P
(TOTAL OF 8 CUTS EXPT. II)



interaction was just significant (*) in the 4th cut and showed that increasing rate of P decreased the 'A' values with all rates of N except N_1 (fig. 27). On the other hand, 'A' values (of the 4th cut) were not significantly affected by N-rate with P_1, while being increased with increasing N at P_2 and decreased with increased N at P_3.

If the labelled-P uptake results were accumulated for the successive cuts, the only consistent significant effect on the calculated 'A' values was that of the form of P. The total of the first two cuts showed that F produced smaller (* *) values than C or G. In the total of the first 3 or all 4 cuts, both C and G produced greater (* * *) values than 'F' (fig. 28 b,c). The effect of P-rate was significant only in the total of the first 2 cuts (*) which showed that P_3 produced greater values than P_1 or P_2 (fig. 28a). The rate of N had no significant effect on the 'A' values in any of the totals (fig. 29). The time factor was also very important since 'A' values were greatly increased in the successive cuts particularly with P_1 and P_2 (fig. 25).

Apparent Recovery of Applied-P:

Increasing rate of N or P greatly increased the P-recovery in a pattern very similar to that of their effects on the P-uptake (fig. 30).

The effect of P-form showed that C was inferior to F* * * or G** only in the first cut (fig. 31). The total P-recovery (8 cuts) showed that C was inferior to G* *, while F produced intermediate results which were not significantly different from the

other two forms (fig. 32). In general, the results for P-recovery, as compared with the P-uptake, are slightly in favour of compound G, since the P-uptakes by the controls of G (GO) were slightly smaller than those of C or F.

Apparent Percentage Recovery of Applied-P:

The effects of N and of P-form on the percentage recovery of applied-P were very similar to their effects on the P-recovery.

Increasing rate of P decreased the percentage recovery in the first cut (* *) and in cuts 2 to 5 (* * *), while in the 6th and 7th cut the rate of P had no significant effect. In the 8th cut, increasing rate of P increased (*) the percentage recovery. This was due to the N x P interaction (* *) which showed that increasing rate of N considerably decreased the percentage P-recovery from P_1 and P_2 but not from P_3. The total of 8 cuts showed that P_1 produced greater (* * *) percentage recoveries of P than either P_2 or P_3 (fig. 33). The metaphosphate glass produced greater percentage recovery (* *) than the trimetaphosphate while the orthophosphate (F) was intermediate (fig. 34).

Labelled-P Content of D.M.:

From the ^{32}P measurements in the plant material, figure 35 shows that the negative effect of increasing N-rate and the positive effect of increasing rate of P were very pronounced (* * *) in the first 4 cuts of grass, the only cuts in which the radioactivity was measured. The N x P interaction was not significant in the first cut while very highly significant in the other 3 cuts (2nd to 4th). This negative interaction showed

that the effect of P-rate in increasing ^{32}P-content of the D.M. was greatly reduced with increasing rate of N, although very highly significant with all rates of N (fig. 35).

The effect of P-form was significant (*) only in the 2nd cut and in the average of the 4 cuts of grass. In the 2nd cut F produced slightly greater (*) ^{32}P-contents than either C or G, and in the average of 4 cuts F was superior only to C (*). In the 2nd, 3rd and average of the 4 cuts, the interaction between the N-rate and P-form was significant (*). This interaction did not show any consistent differences at the various cuts except that, at the N_4 and/or N_5 levels, the combination with F was slightly superior (*) to either C or G or both (fig. 36).

The interaction between the rate and form of P was significant only in the 4th cut, which showed that both C and G produced slightly greater (*) ^{32}P-contents of the D.M. than F but only with the highest rate of P (fig. 37).

Labelled-P Uptake:

Very great responses to increasing rate of P or N were obtained in all 4 cuts of grass (* * *). The effect of P did not change considerably with time in the successive cuts (fig.38), while that of N increased greatly with time (fig. 39). The N x P interaction was very great only in the 3rd (* *), 4th (* * *), and in the total of 4 cuts (* * *) which showed that the response to N, particularly in the 3rd and 4th cuts, were much greater with P_2 and P_3 than with P_1, while the response to P was

FIG. 31. Effect of P-form & rate on "apparent recovery" of applied-P (1st cut EXPT. II)

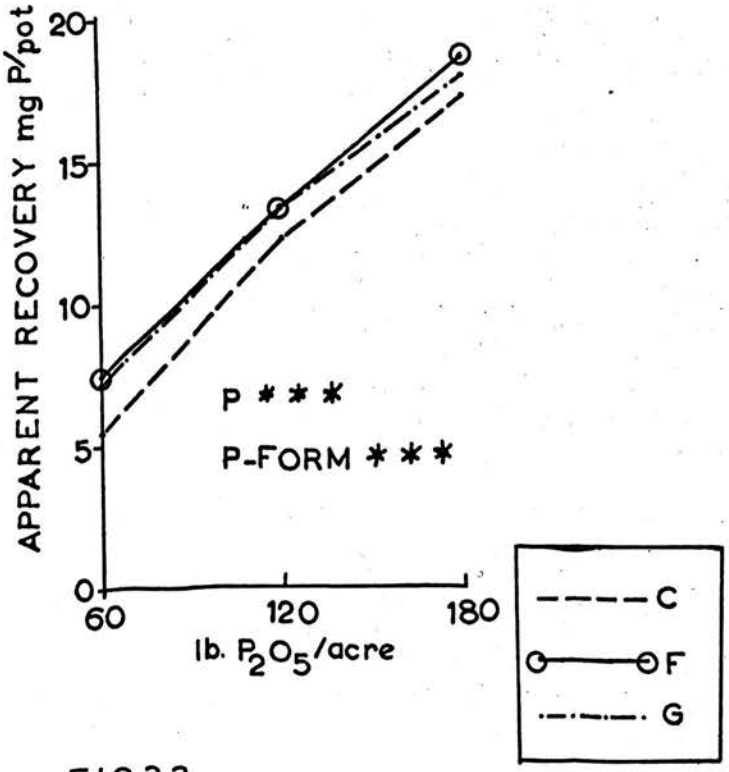


FIG. 32. Effect of P-form & rate on total "apparent recovery" of applied-P (EXPT. II)

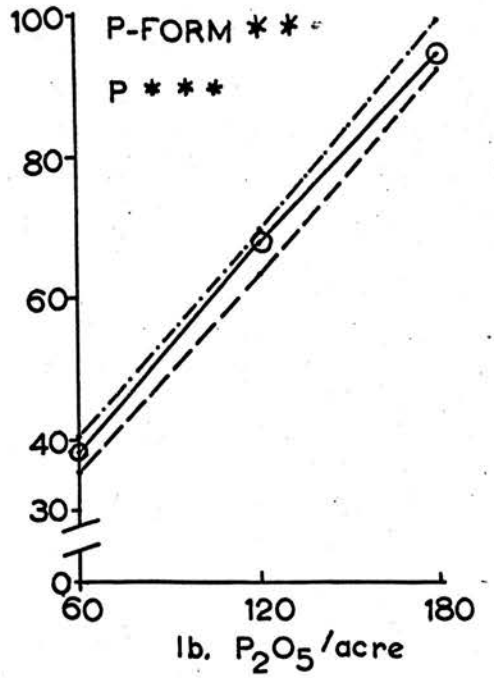


FIG. 33. Effect of P-rate on % "apparent recovery" (total of 8 cuts EXPT. II)

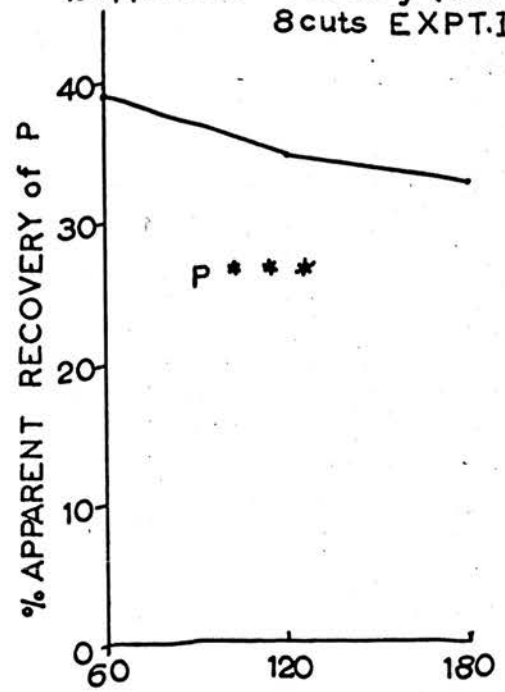
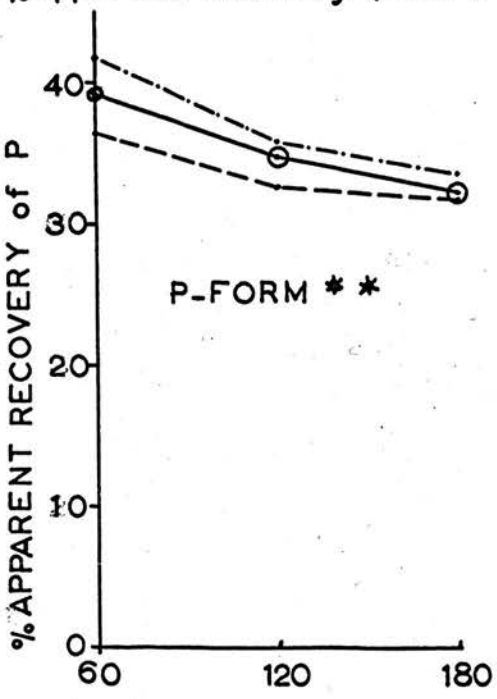


FIG. 34. Effect of P-form on total % "apparent recovery" (EXPT. II)



LB. P_2O_5 PER ACRE

FIG. 35. EFFECT OF N×P ON %^{32}P IN D.M. (AV. OF 4 CUTS, EXPT. II)

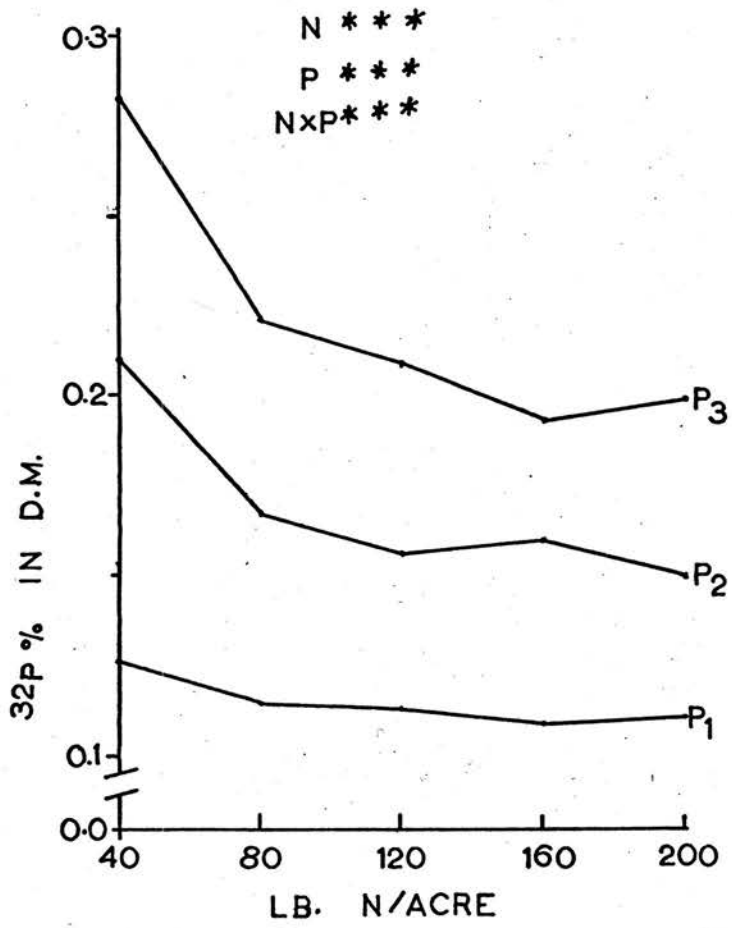


FIG. 36. EFFECT OF N×P-FORM ON %^{32}P IN D.M. (AV. OF 4 CUTS, EXPT. II)

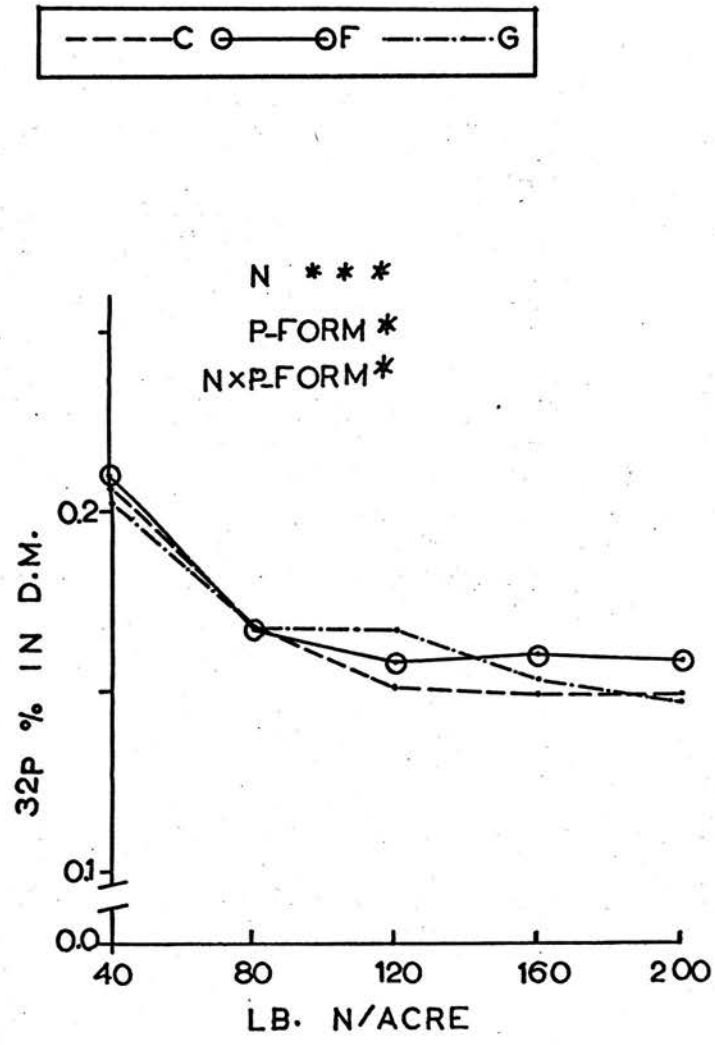


FIG. 37. EFFECT OF P×P-FORM ON ^{32}P % IN D. M. (4th cut, EXPT. II)

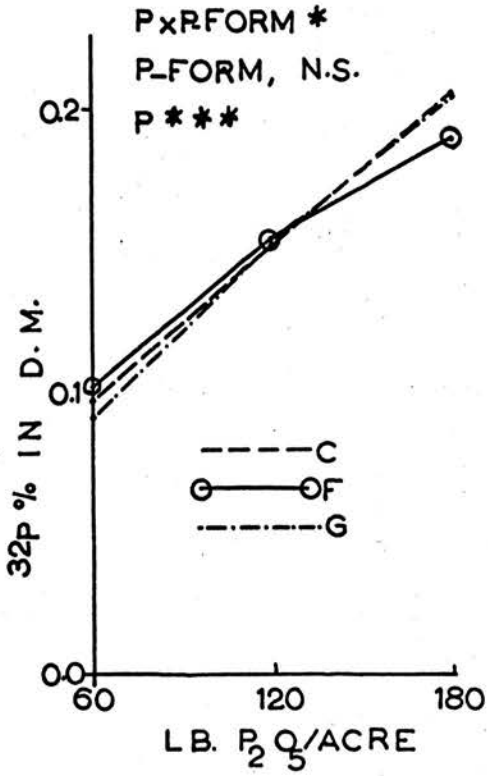


FIG. 38. ^{32}P-UPTAKE IN THE 4 CUTS OF GRASS (EXPT. II)

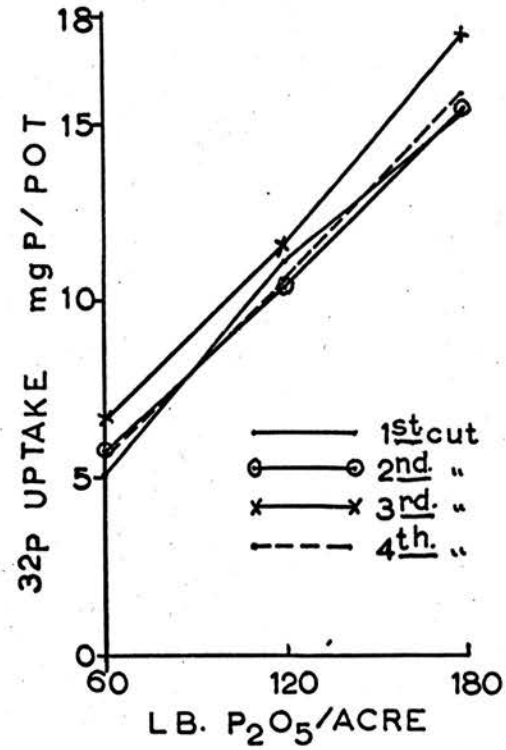


FIG. 39. EFFECT OF N-RATE ON ^{32}P-UPTAKE IN DIFFERENT CUTS OF GRASS (EXPT. II)

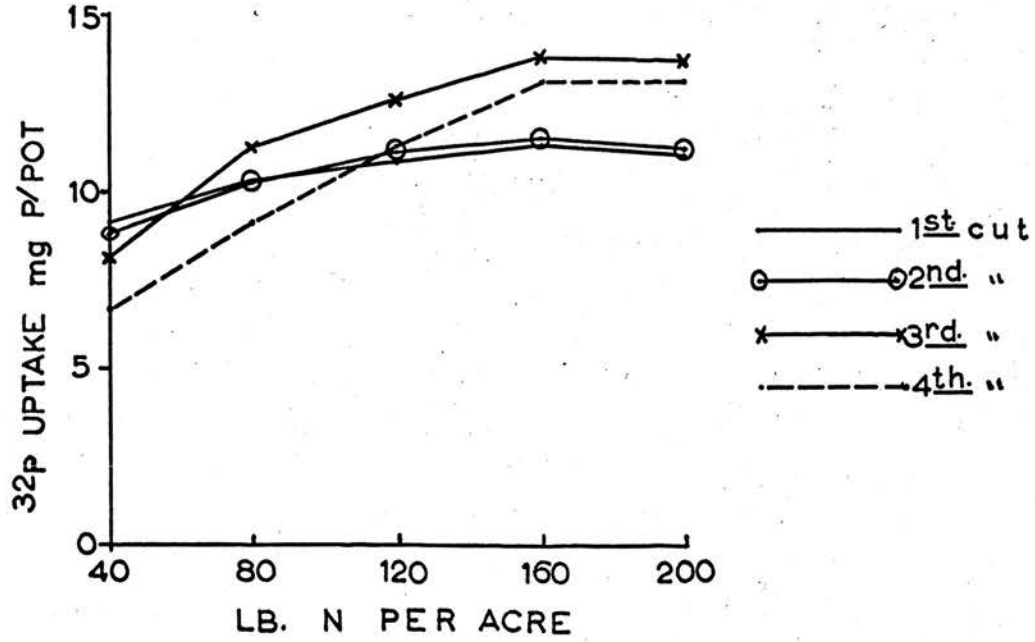


FIG. 40.

EFFECT OF NxP ON LABELLED-P UPTAKE

(TOTAL OF 4 CUTS, EXPT. II)

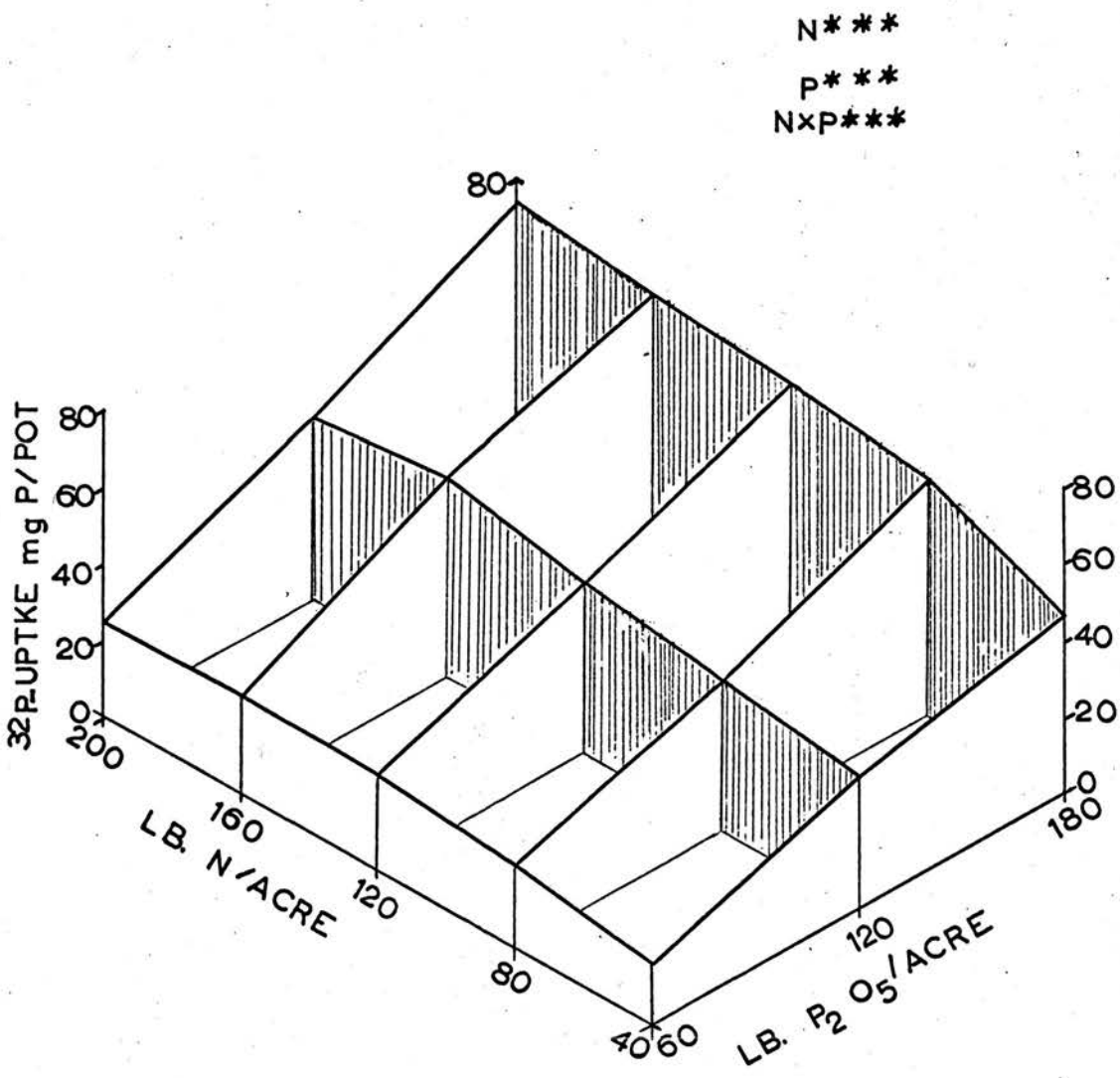
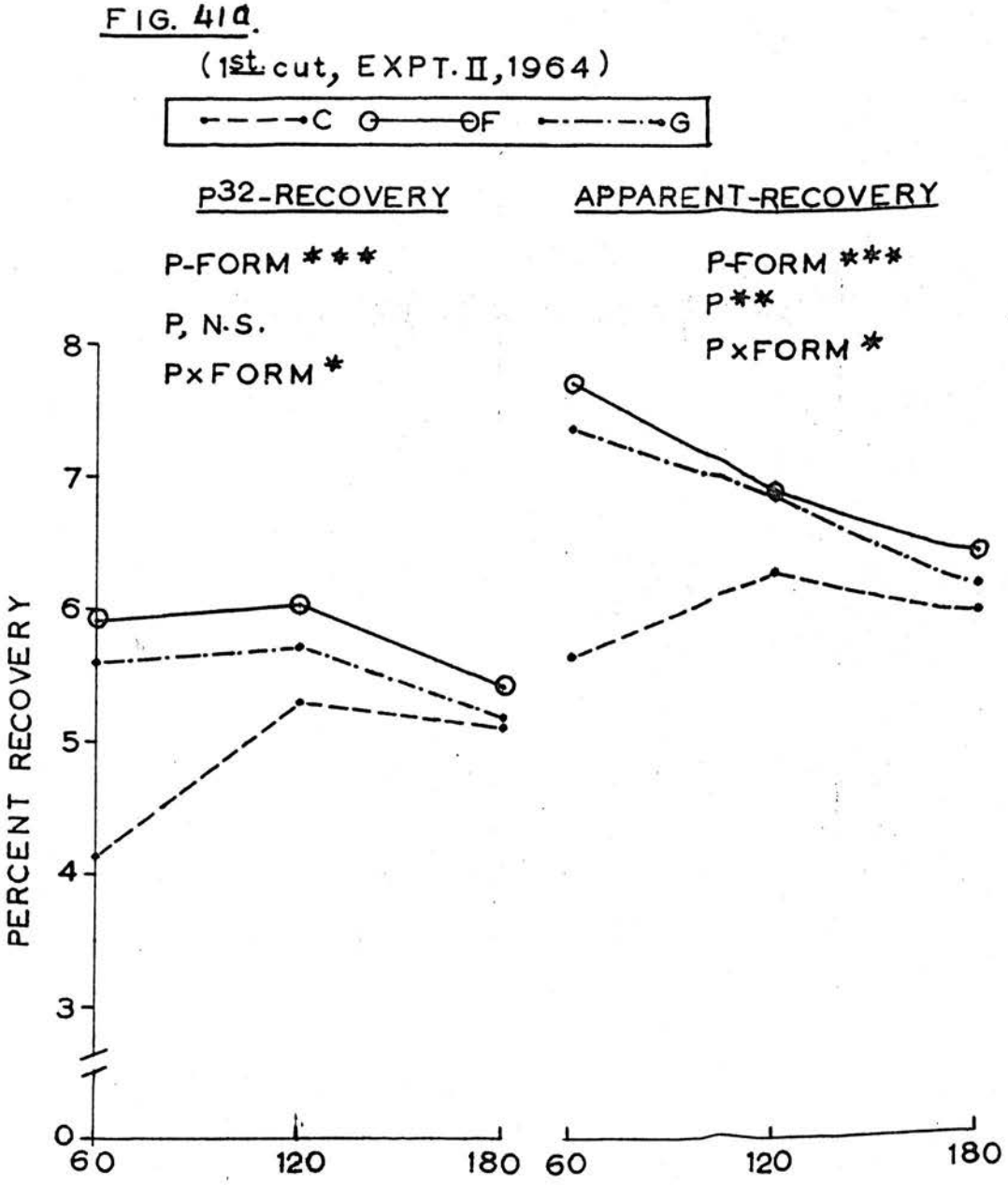


FIG. 41a.

(1st cut, EXPT. II, 1964)



lb. P_2O_5 PER ACRE

FIG. 41. EFFECTS OF P-RATE & FORM ON LABELLED-P UPTAKE

(TOTAL OF 4 CUTS EXPT. II)

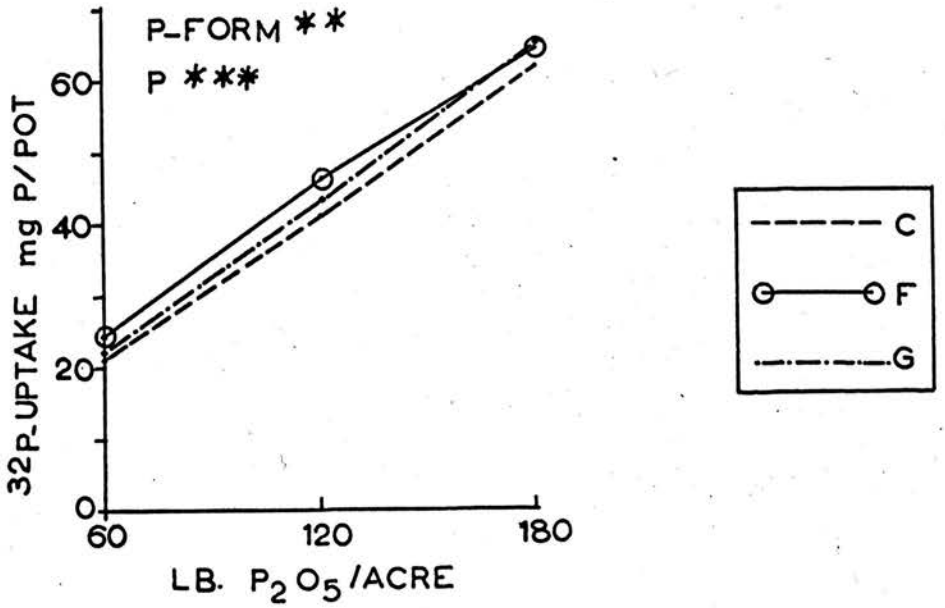
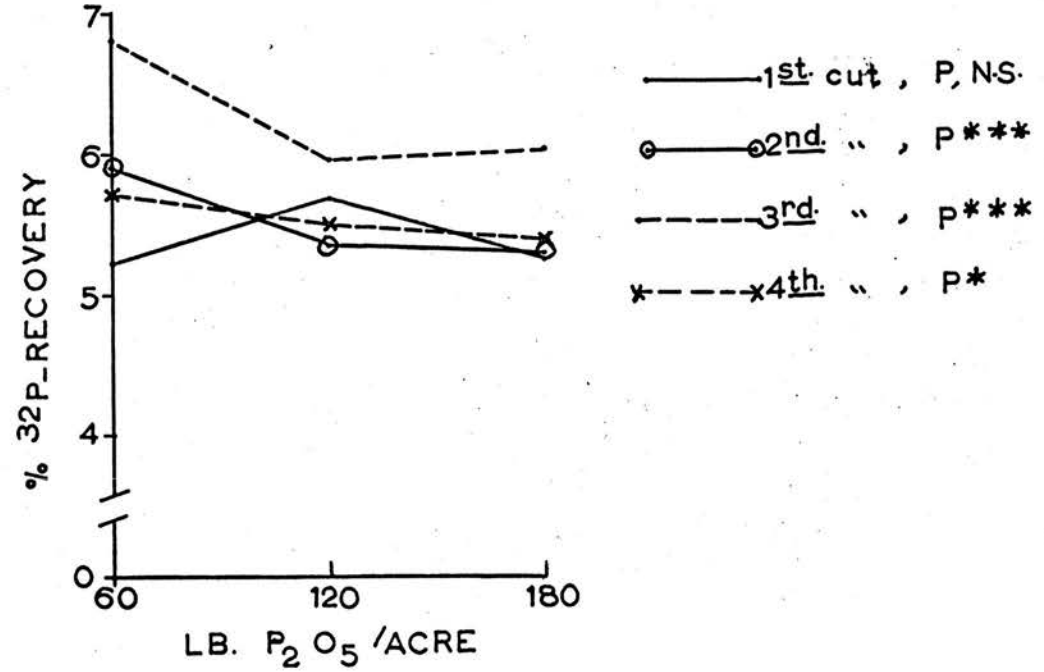


FIG. 42. EFFECT OF P-RATE ON % ^{32}P-RECOVERY IN DIFFERENT CUTS (EXPT. II)



very great with all rates of N (see fig. 40, for the total of 4 cuts).

Neither the rate of N nor the rate of P had any significant interaction with the form of P. But the overall effect of P-form showed that C was inferior to both F (* *) and G (*) in the first cut. In the 2nd cut both F and G were slightly superior (*) to C. In the 4th cut F was slightly superior (*) to either C or G. Considering the total of 4 cuts, C was inferior to F (* *) or G (*), but there was no significant difference between F and G (fig. 41).

The interaction between the rate and form of P was not significant in terms of ^{32}P-uptake, but it reached the level of significance in the percentage recovery of applied-P, calculated from ^{32}P-data, only in the 1st cut of grass (fig.41a), which showed that F was superior to C with P_1 and P_2, while G was superior to C only with P_1, and with P_3 all forms were equal. Effects of rate of N and form of P on the percentage recovery of labelled-P were exactly similar to their effects on the labelled-P-uptake. The effect of P-rate was very small in both the 1st and 4th cuts, while in the 2nd and 3rd cuts, increasing rate of P significantly decreased (* * *) the percentage recovery of applied labelled-P (fig. 42).

EXPERIMENT III (1964):

(See pages 53-56 for details of the experimental design and fertilizer treatments.)

Results of this experiment are tabulated in appendix III.

Yields of grass:

Application of P produced very high yield increases in all three cuts of grass; the greatest responses were obtained in the first cut. Increasing rate of P also increased the yields (* * *) particularly with the high rate of N (N x P* * *)(fig. 43). The yield responses to applied P were much higher on soil D than on soil W (figs. 43, 44).

The form of P had very little effect on yields. The two metaphosphates, with practically no difference between them, produced slightly greater yields than the orthophosphate particularly in the first cut (fig. 45) where these differences were significant (*) only with the yields of fresh grass.

There was great response to increasing rate of N only if P was applied, and this effect was more pronounced on soil D than on soil W.

P-content of D.M.:

In the first cut of grass percentage-P of the D.M. was considerably depressed by P-application (as compared with the control) on the acid soil 'W', but not on the calcareous soil D (fig. 46). However, increasing rate of P greatly increased (* * *) the P-content of the grass on both soils. In the succeeding two cuts, all applications of P as well as increasing rate of P greatly increased the P-content of the grass on both soils and more pronouncedly on soil D (fig. 46).

The metaphosphates produced greater P-contents than the orthophosphate (* * *) in all cuts and particularly with the

FIG. 43. EFFECTS OF N-& P-RATES ON YIELD OF D.M.

(EXPT-III)

——— N_1

- - - - - N_2

SIGN. EFFECTS

1st. cut : N***, P***, N-P** , N-Soil*** P.Soil***

2nd. " : " " , " " , " ***, " " " , " *

3rd. " : " " , " " , " " , " "" , " N.S.

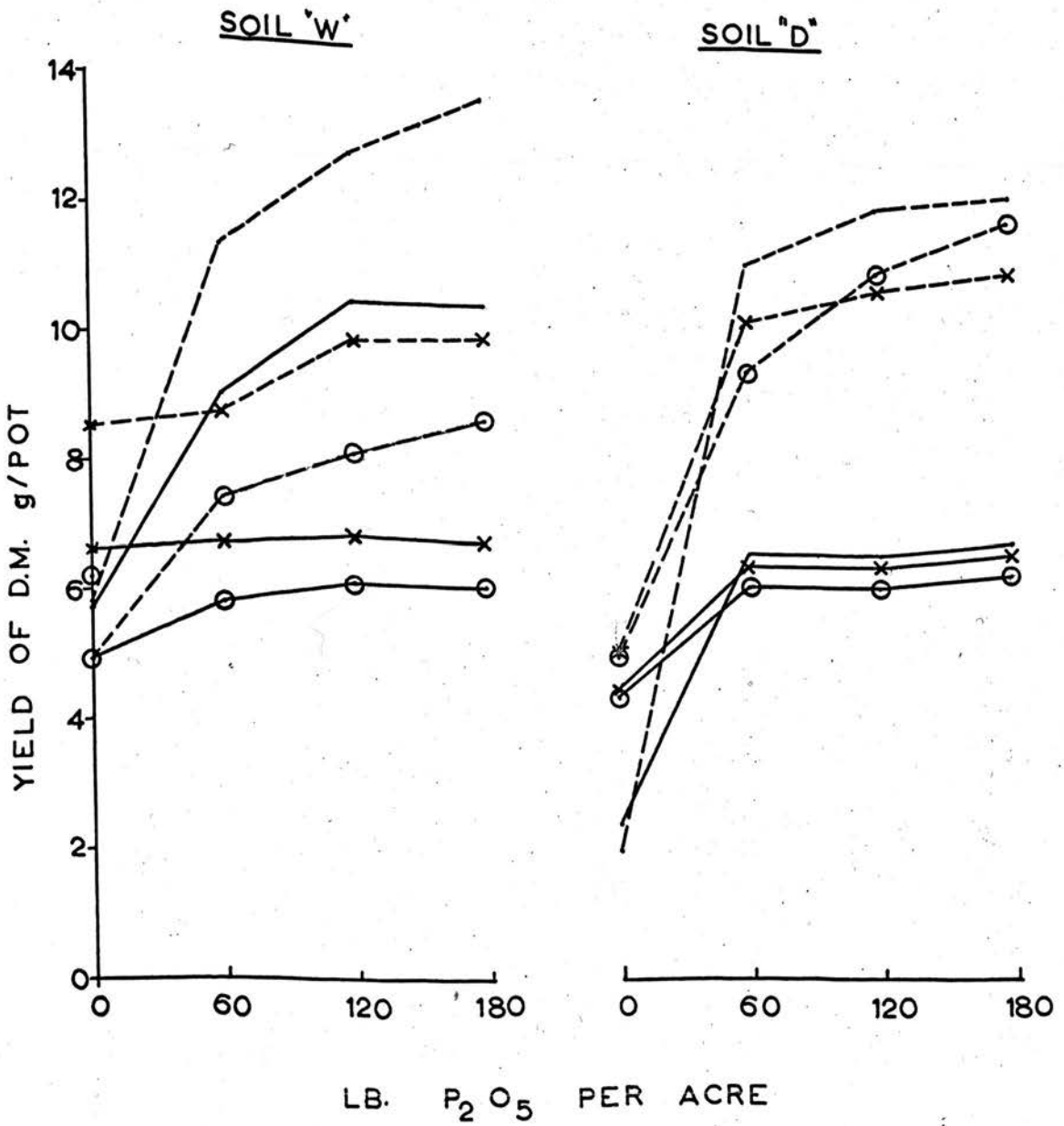
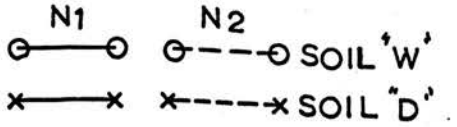


FIG. 44. EFFECTS OF N, P, and SOIL ON YIELDS (TOTAL OF 3 CUTS, EXPT. III)



N ***
N.P***
P ***
N.Soil ***
P.Soil *

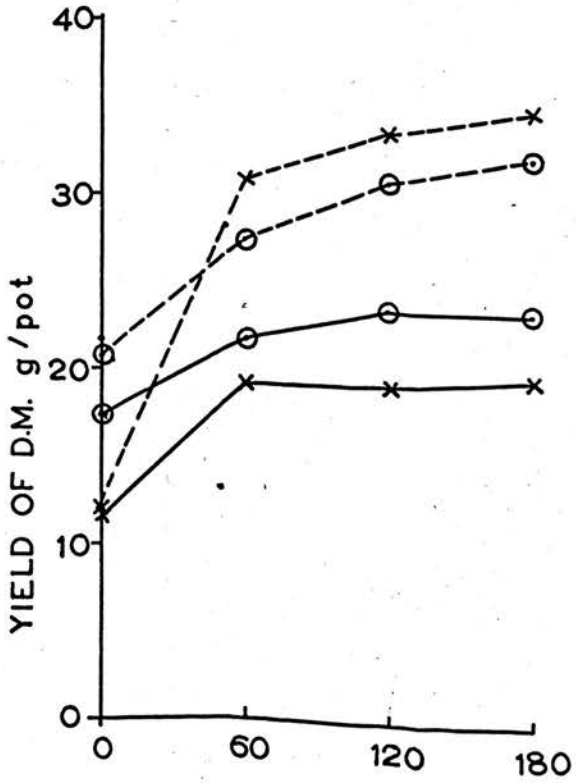
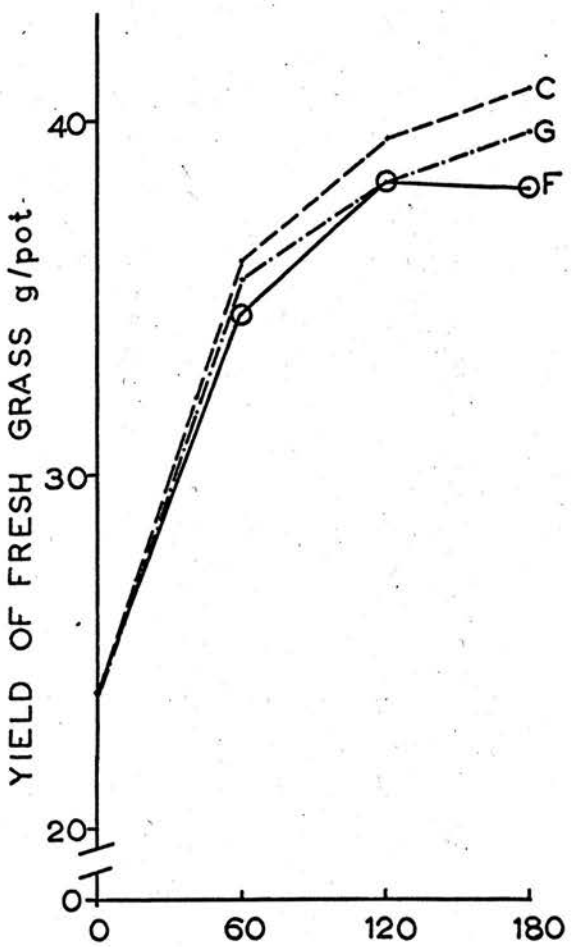


FIG. 45. EFFECTS OF P-RATE & FORM ON YIELDS (1st cut, EXPT. III)

P***

P-FORM*



LB. P_2O_5 PER ACRE

FIG. 46. EFFECTS OF P-RATE & SOIL ON %P IN D.M. (EXPT. III).

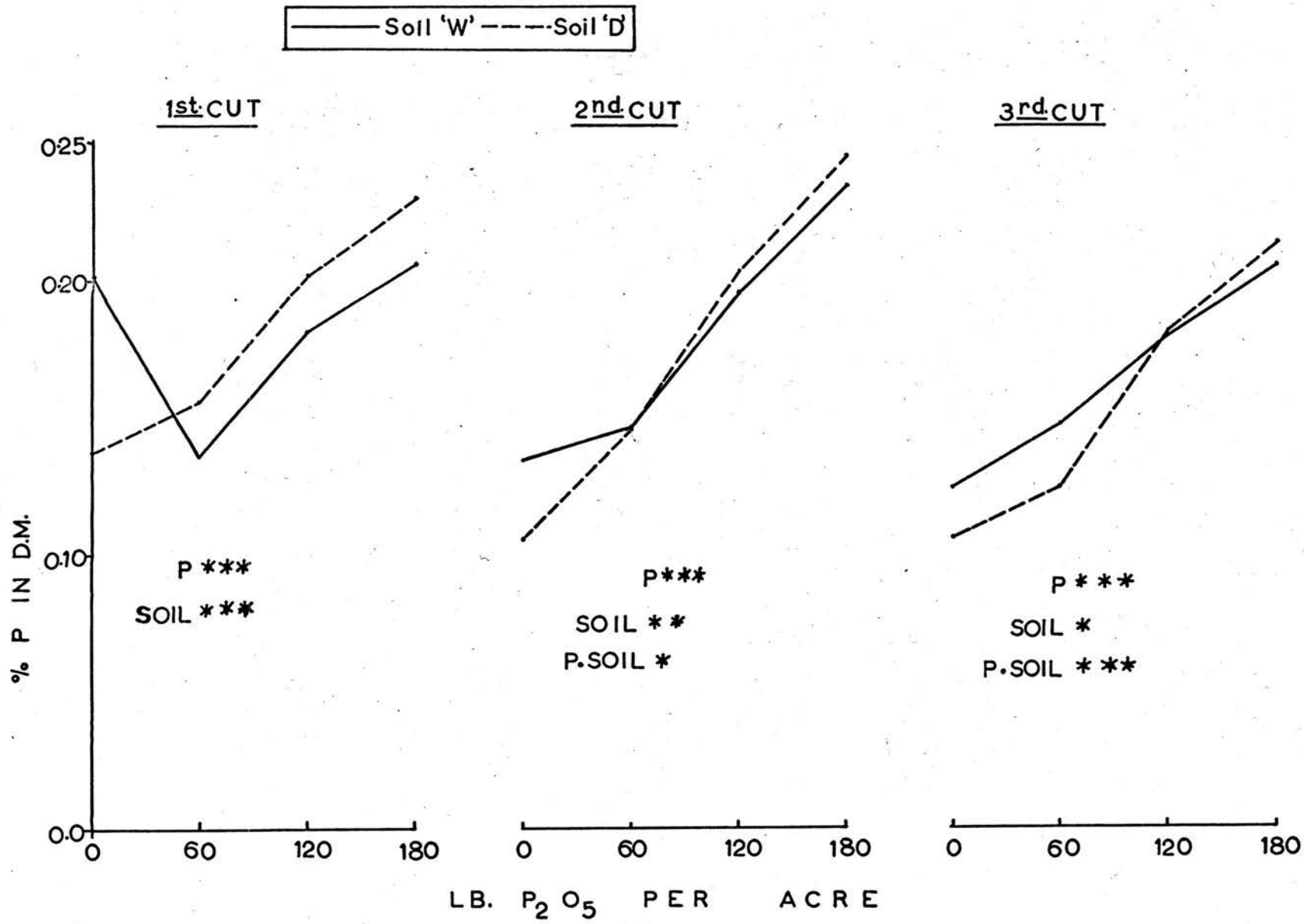


FIG. 47. EFFECT OF P-FORM ON % P IN D.M. (AV. OF 3 CUTS, EXPT. III)

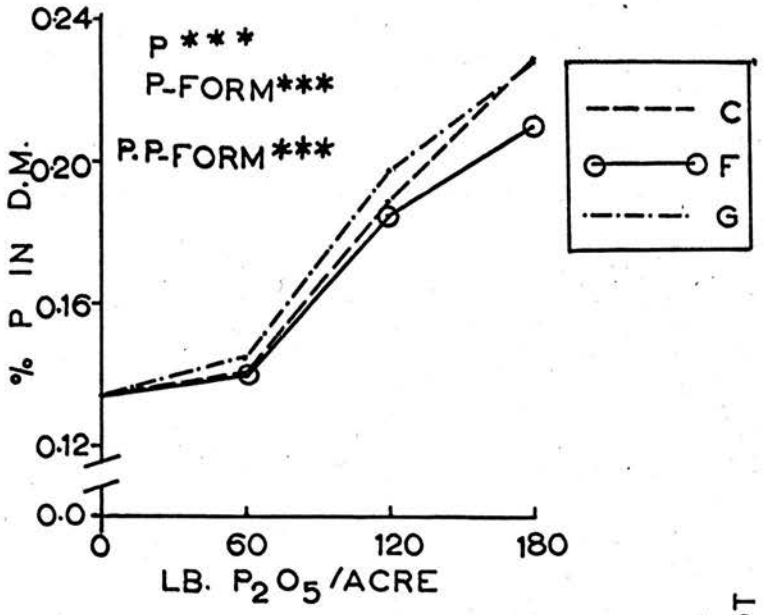


FIG. 48. EFFECT OF N ON % P IN D.M. (AV. OF 3 CUTS EXPT. III)

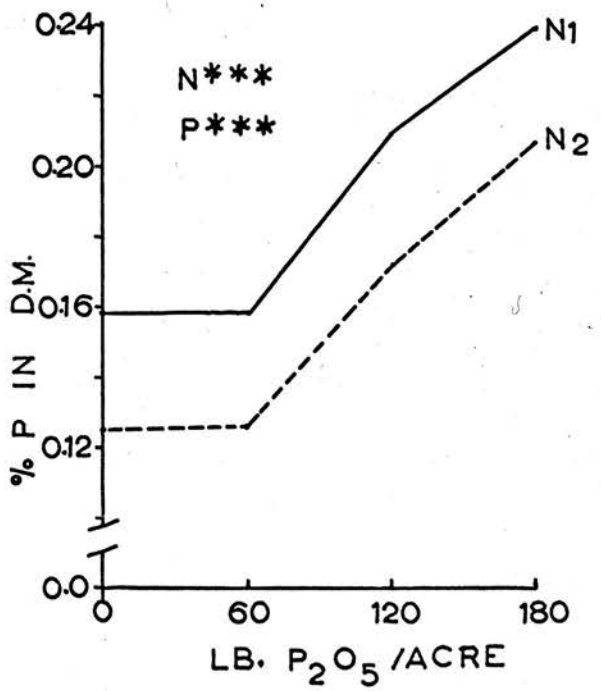


FIG. 49. EFFECTS OF P-FORM AND RATE ON P-UPTAKE (TOTAL OF 3 CUTS EXPT. III)

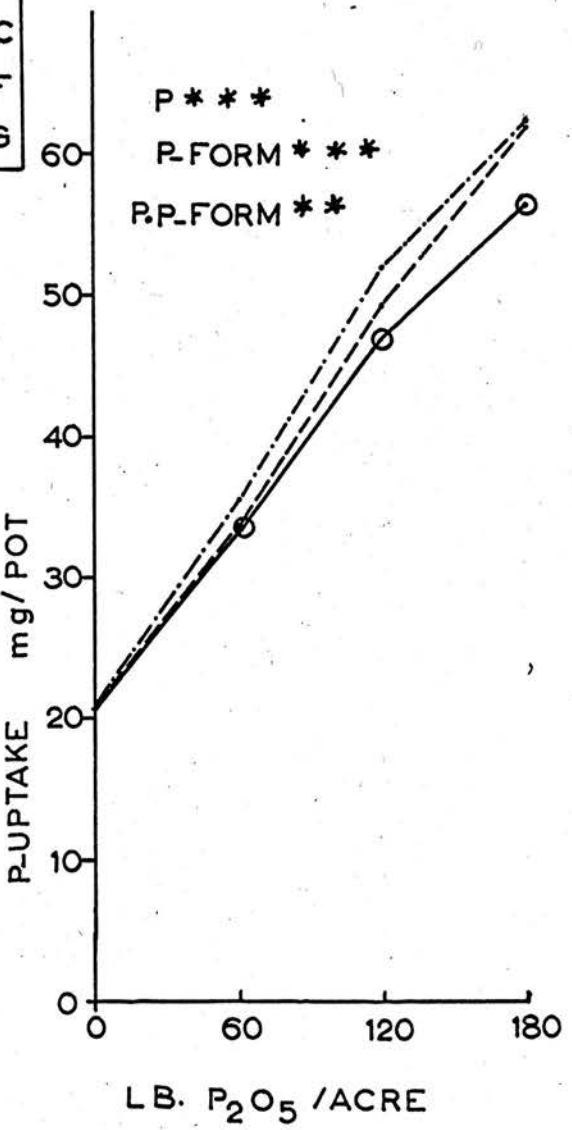
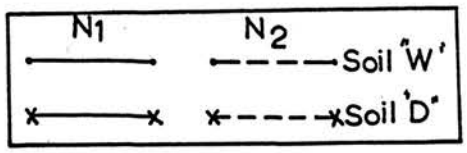


FIG. 50. EFFECT OF N x P x SOIL ON RECOVERY OF APPLIED-P (TOTAL OF 3 CUTS, EXPT. III)



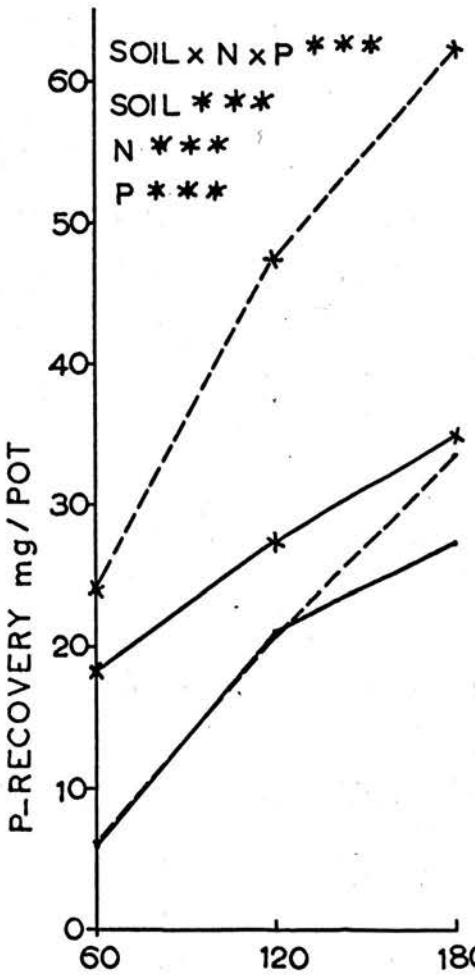
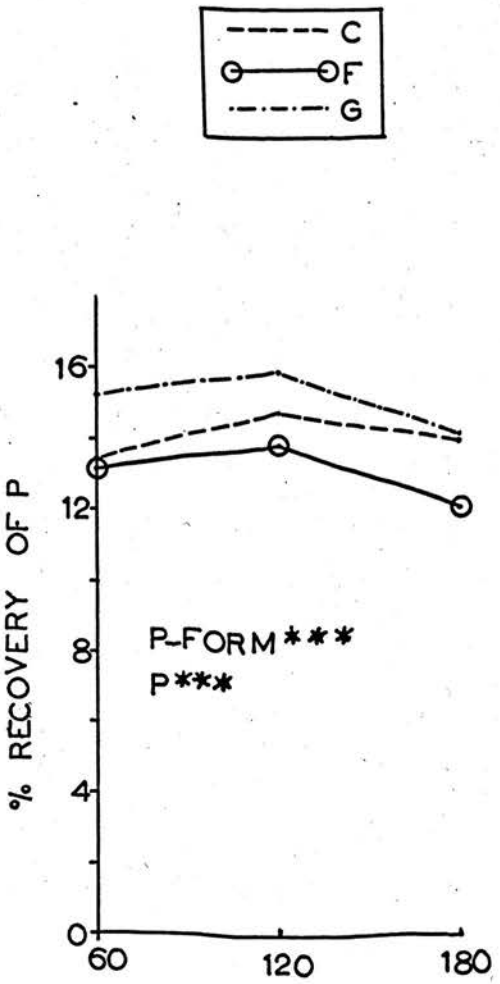


FIG. 51. EFFECTS OF P-RATE & FORM ON % RECOVERY OF APPLIED-P (TOTAL OF 3 CUTS, EXPT. III)



LB. P_2O_5 PER ACRE

highest rate of P-application on both soils (fig. 47). The metaglass was also superior to the trimetaphosphate but only in the last two cuts and at the 120 lb. rate of P_2O_5.

The higher rate of N decidedly produced smaller (* * *) P-contents than the low one on both soils, with all rates of P, and in all cuts of grass (fig. 48). The solid-application of fertilizer was inferior to the liquid-form of application only on the acid soil (W) in the last two cuts, with the highest rate of P.

P-uptake:

Application of P as well as increasing rate of applied-P greatly increased (* * *) P-uptake. This response was more pronounced on soil D than on soil W in all cuts. The effects of P-form on P-uptake were very similar to those on the P-content (figs. 47, 49).

The high rate of N produced greater P-uptakes than those from the low rate, particularly at the higher rates of P and with soil D.

The apparent recovery of applied-P followed the same pattern as the P-uptake except that the recoveries were generally greater on soil D than on soil W (fig. 50). The effects of N, soil or form of P on the "percentage apparent recovery" of applied-P also followed the same pattern as with P-uptake (fig. 51). Increasing rate of P significantly (* * *) decreased the percentage recovery of applied P in the 1st cut of grass. In the 2nd cut, the results were similar to those of the 1st but

only on soil D, while on soil W, increasing rate of P increased the percentage recoveries (fig. 52). In the 3rd cut P_2 produced the highest percentage recoveries on both soils, but this effect was significant (* * *) only on soil D (fig. 52).

Effect of Method of Application:

Method of P-application (liquid v. solid) had very little effects on yields. The liquid-application of P was superior to the solid-application (* *) only in the first cut in terms of yield of D.M., but there was no significant difference between the two methods in terms of fresh yield of grass.

Considering the P-contents of D.M. and P-uptakes by grass, the liquid application was superior in each of the three cuts of grass (* *) but only on the acid soil (W) and particularly with the highest rate of P (fig. 53). The method of P-application had a significant effect on the relative efficiency of the different forms of P at different rates (Method x Form x P-rate interaction*). This 3-factor interaction was significant only in terms of total P-uptake by the 3 cuts of grass. Fig. 54 shows that, G was superior to F with both methods of application. G was also superior to C but only with solid-application (S) at the two low rates of application (P_1 and P_2). C was superior to F at all P-rates with the liquid application (L), but with the solid application it was superior to F only with P_3.

FIG. 52. EFFECTS OF SOIL & P-RATE ON %RECOVERY OF APPLIED-P (EXPT. III)

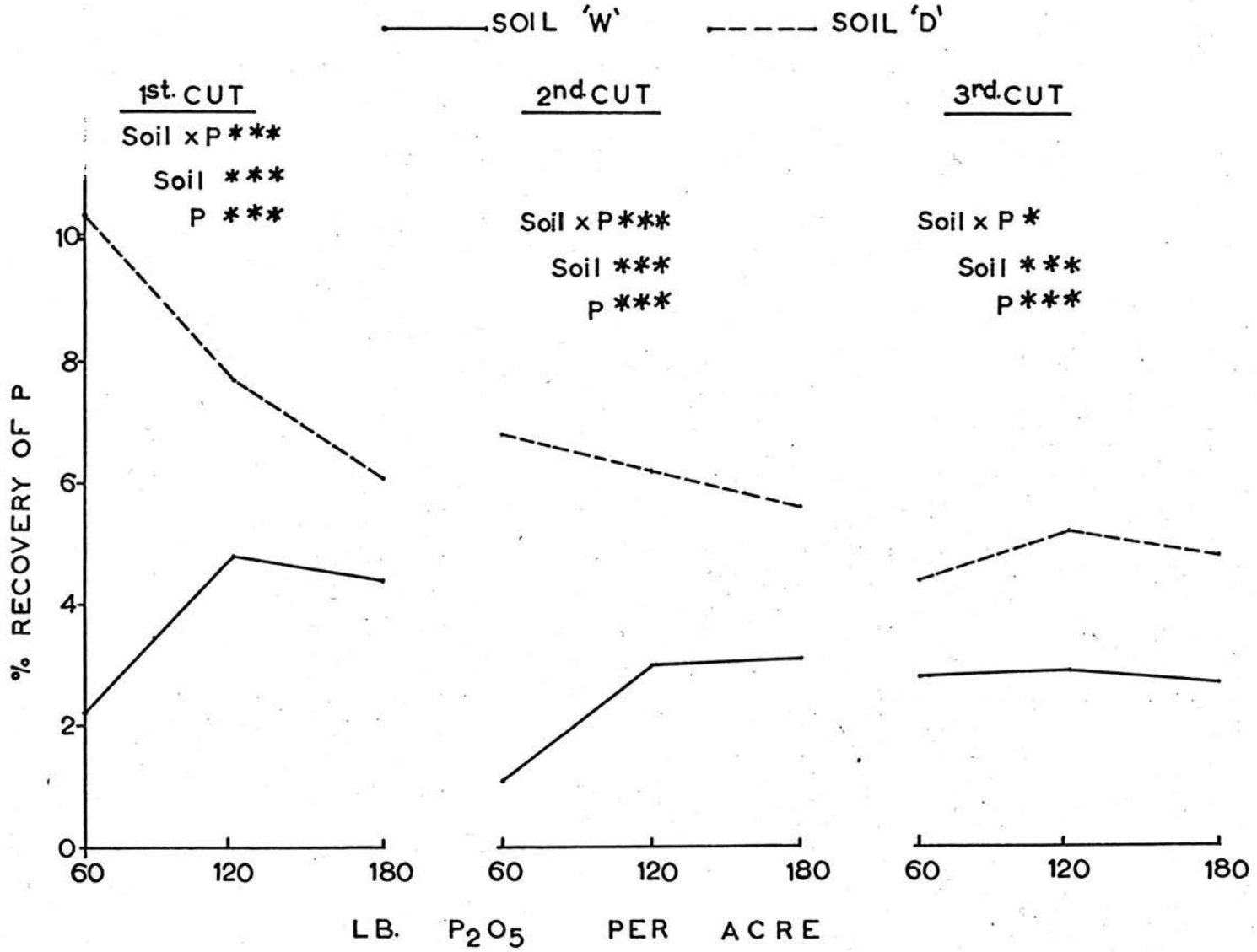


FIG. 53. EFFECT OF METHOD OF P-APPLICATION ON P-UPTAKE (TOTAL OF 3 CUTS, EXPT. III)

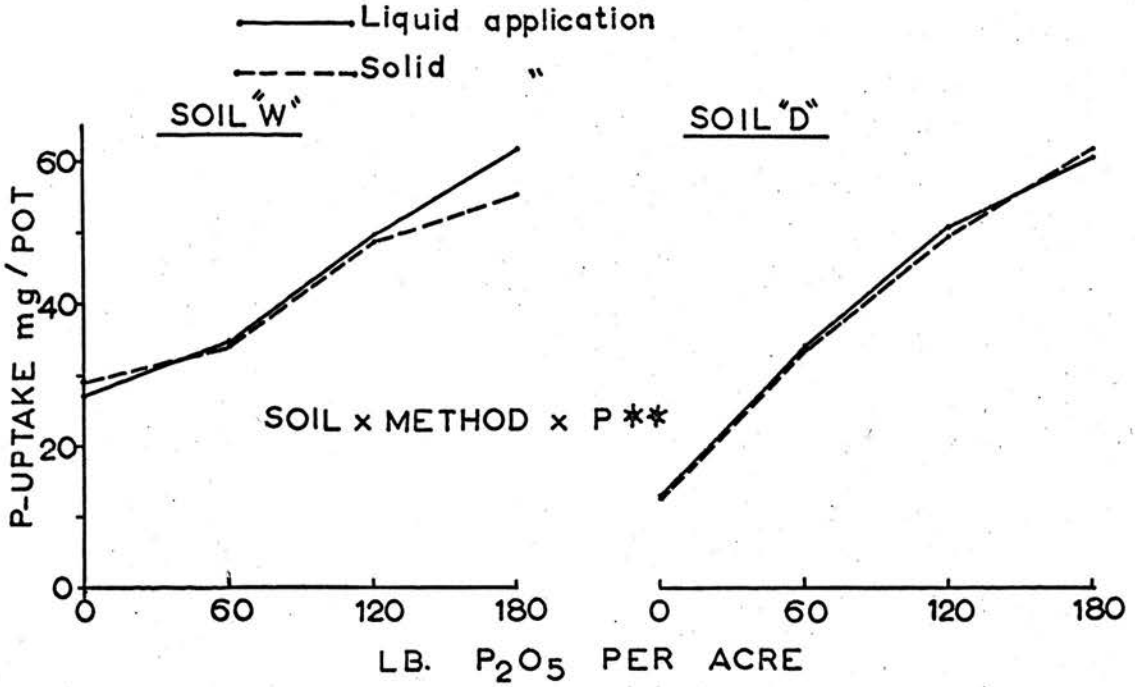
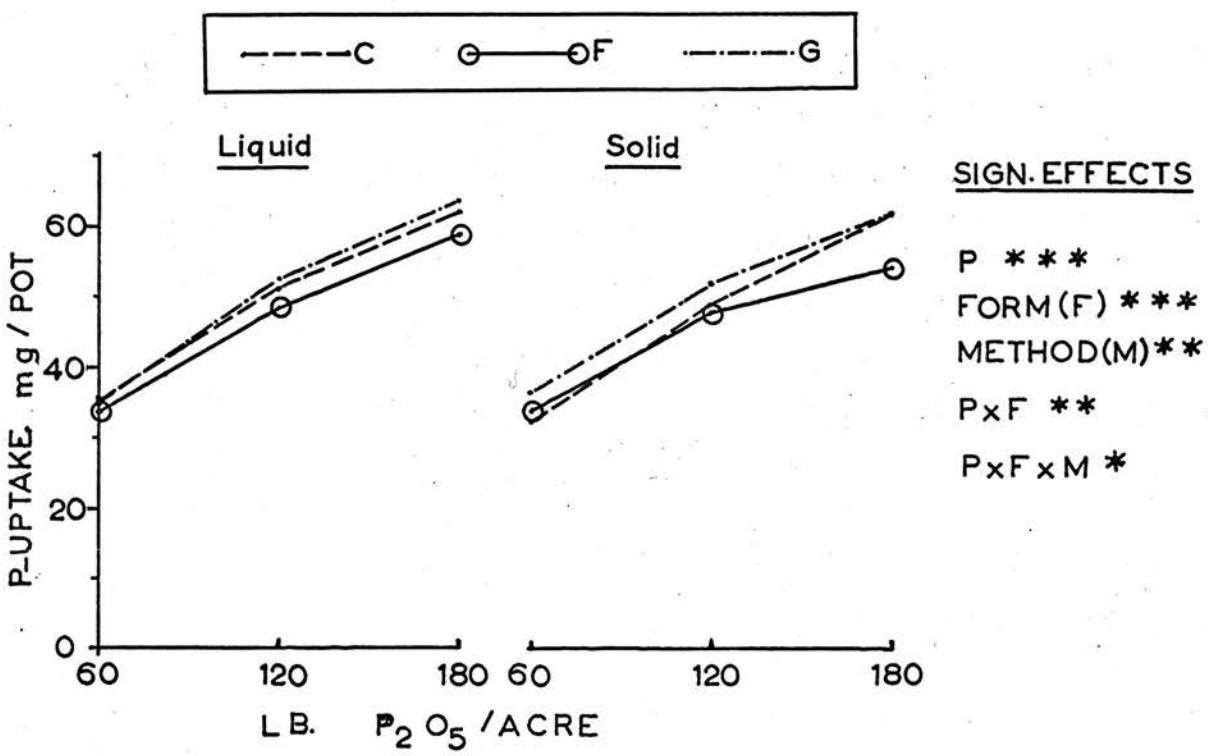


FIG. 54. EFFECTS OF METHOD OF P-APPLICATION, FORM & RATE OF P ON P-UPTAKE (TOTAL OF 3 CUTS, EXPT. III)



B. Soil Analysis

Results of the soil analysis are tabulated in Appendix IV.

EXPERIMENT I:

Samples, from soil sampling pots, were extracted with 3 different solutions (see page 58 for methods) and the P-contents of the extracts are presented in appendix IV and figures 55-62. Differences between the orthophosphate and other forms of P, in terms of extractable PO_4, were considerable only in the first sampling with both citric acid and Olsen's methods (figs. 55,56). On the other hand, hydrolyzable P in the citric acid-soil extracts was greater, in the 2nd- and to a smaller extent in the 3rd sampling, from soils treated with condensed P (fig. 57) than from soils treated with orthophosphate (hydrolysis of extracts was not carried out in the first sampling). In the Olsen- soil extracts, differences in quantity of hydrolyzable P were very small in all samplings (fig.58). The Morgan's method did not show any differences between the forms of P (fig. 59).

Compared with the control (P_0), P-applications, as well as increasing rate of P, greatly increased the extractable PO_4 from the soil with all forms of P as shown by all 3 methods of extraction (figs. 60-62). Even in the first sampling (fig. 60) this increase was very considerable with all forms of P which indicates a very rapid hydrolysis of the condensed-P in the soil. Figures 55, 56 show that the hydrolysis was even greater in the neutral soil (Y) than in the acid soil (X) since the differences between the orthophosphate and other forms were very small in

FIG. 55. EFFECT OF DIFFERENT P-FORMS ON EXTRACTABLE P FROM SOIL 'X'; Av. of 3 P-RATES, EXPT. I.

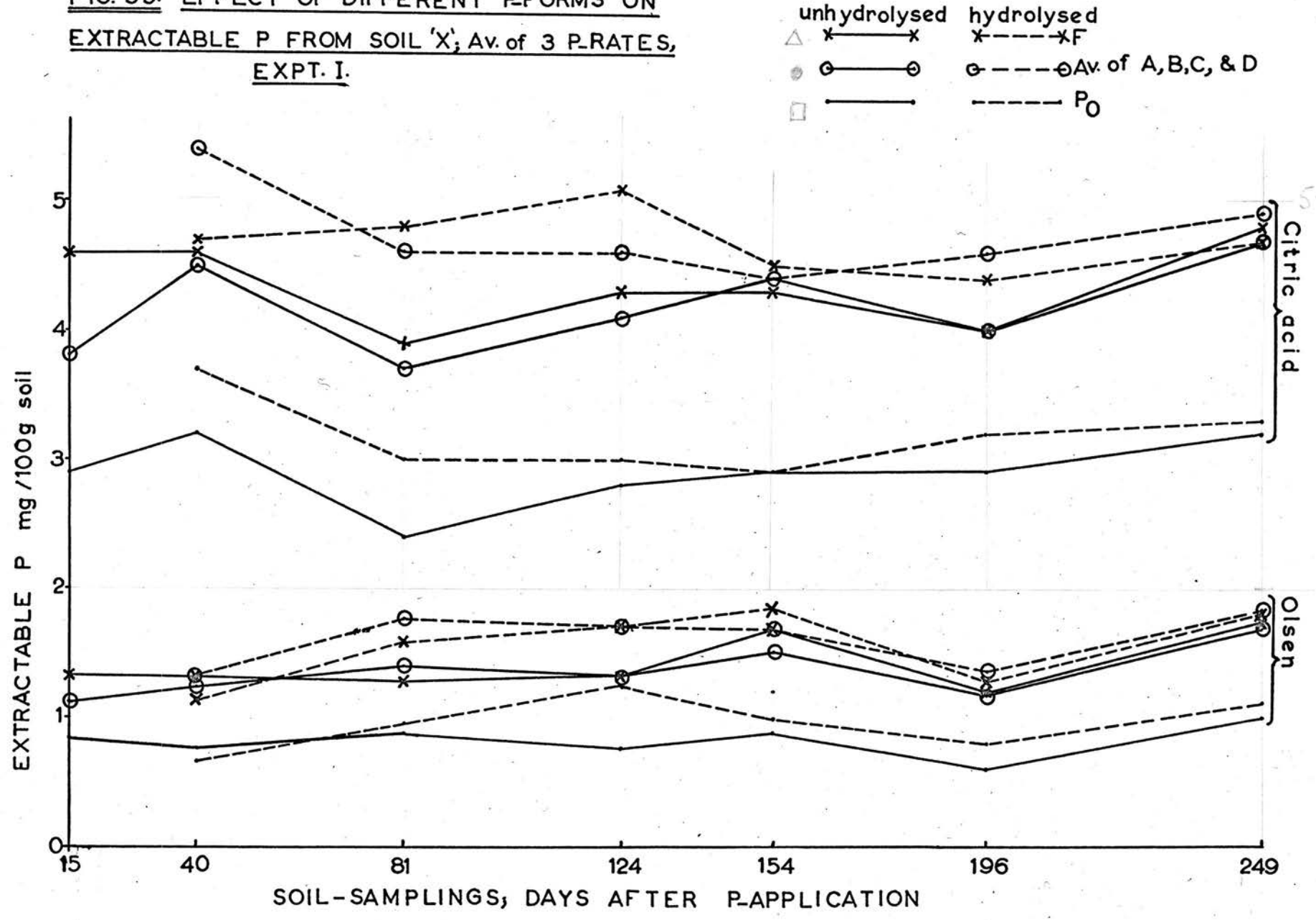
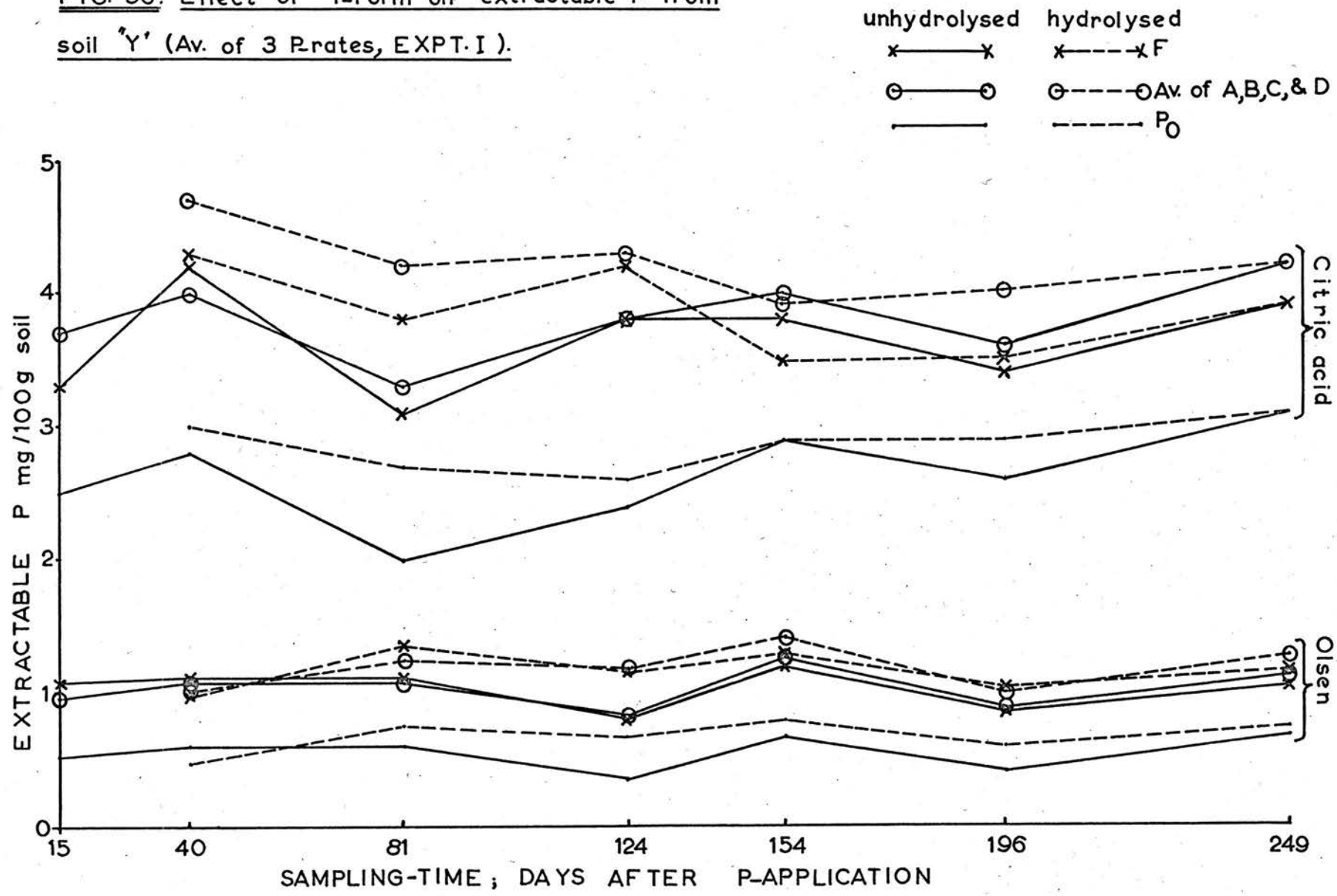


FIG. 56. Effect of P-Form on extractable P from soil 'Y' (Av. of 3 P-rates, EXPT. I).



EFFECT OF P-FORM ON THE QUANTITY OF HYDROLYZABLE P IN SOIL-EXTRACTS

(Av. of 2 soils and 3 P-rates, EXPT. I)

FIG. 57 CITRIC ACID EXTRACTS.

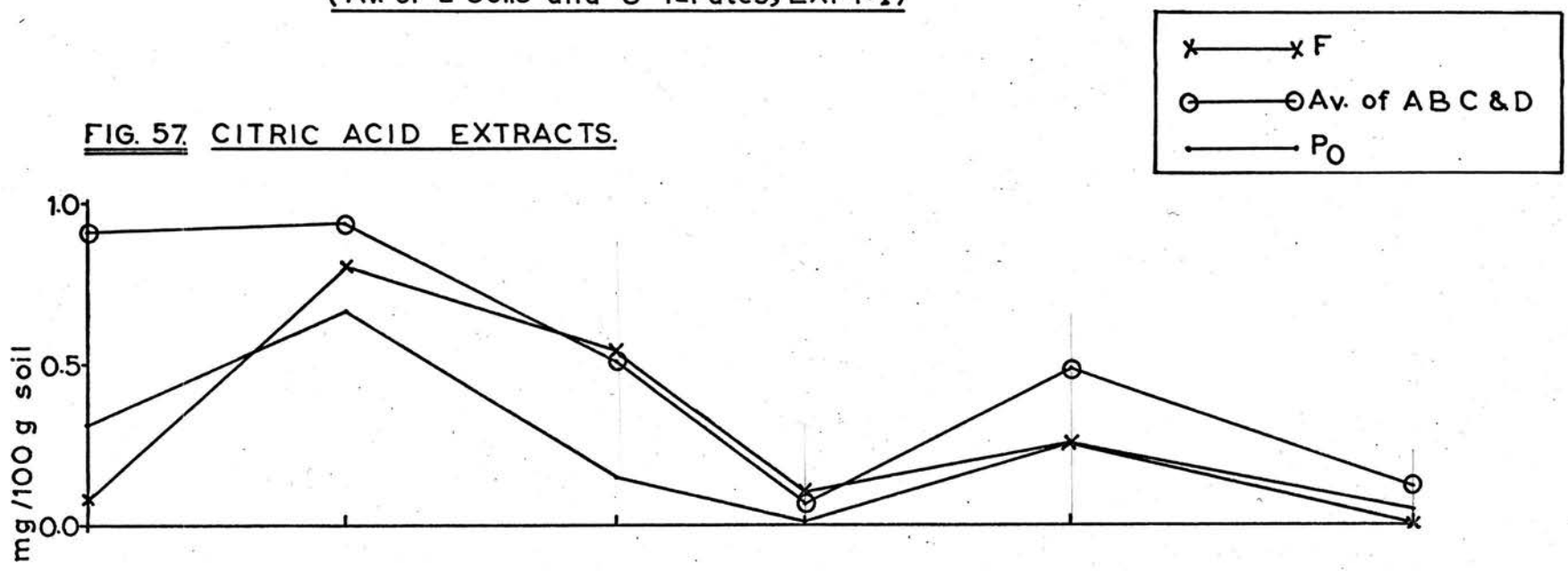


FIG. 58. OLSEN'S EXTRACTS

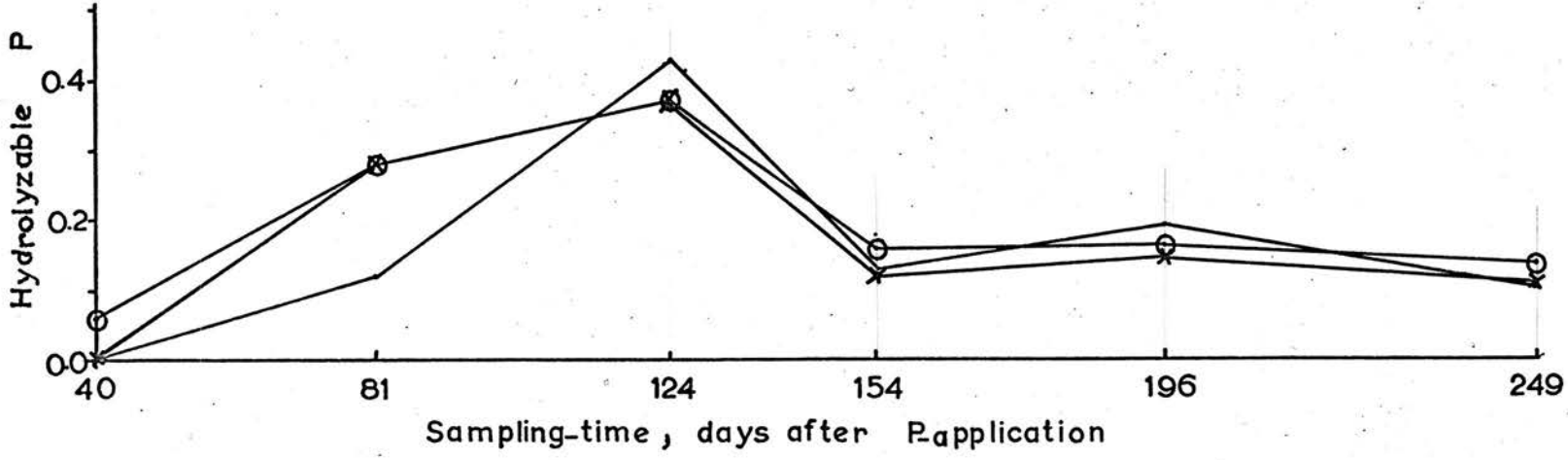


FIG. 59. Effect of P-form on extractable P from the soil (Av. of 2 soils and 3 P-rates, EXPT. I)

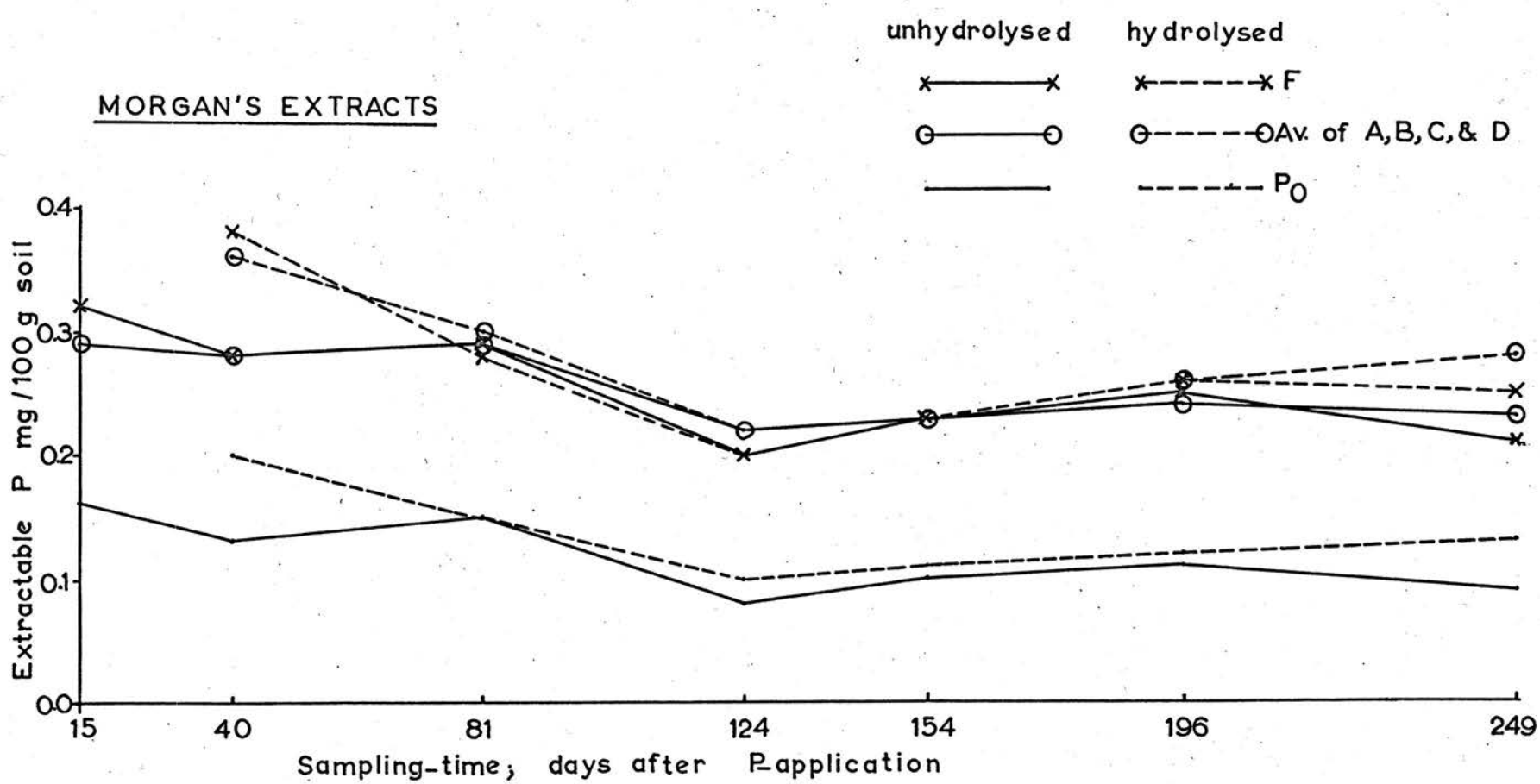


FIG. 60. Effect of P rate and form on extractable PO_4 from soil (Av. of 2 soils, 1st sampling, EXPT. I).

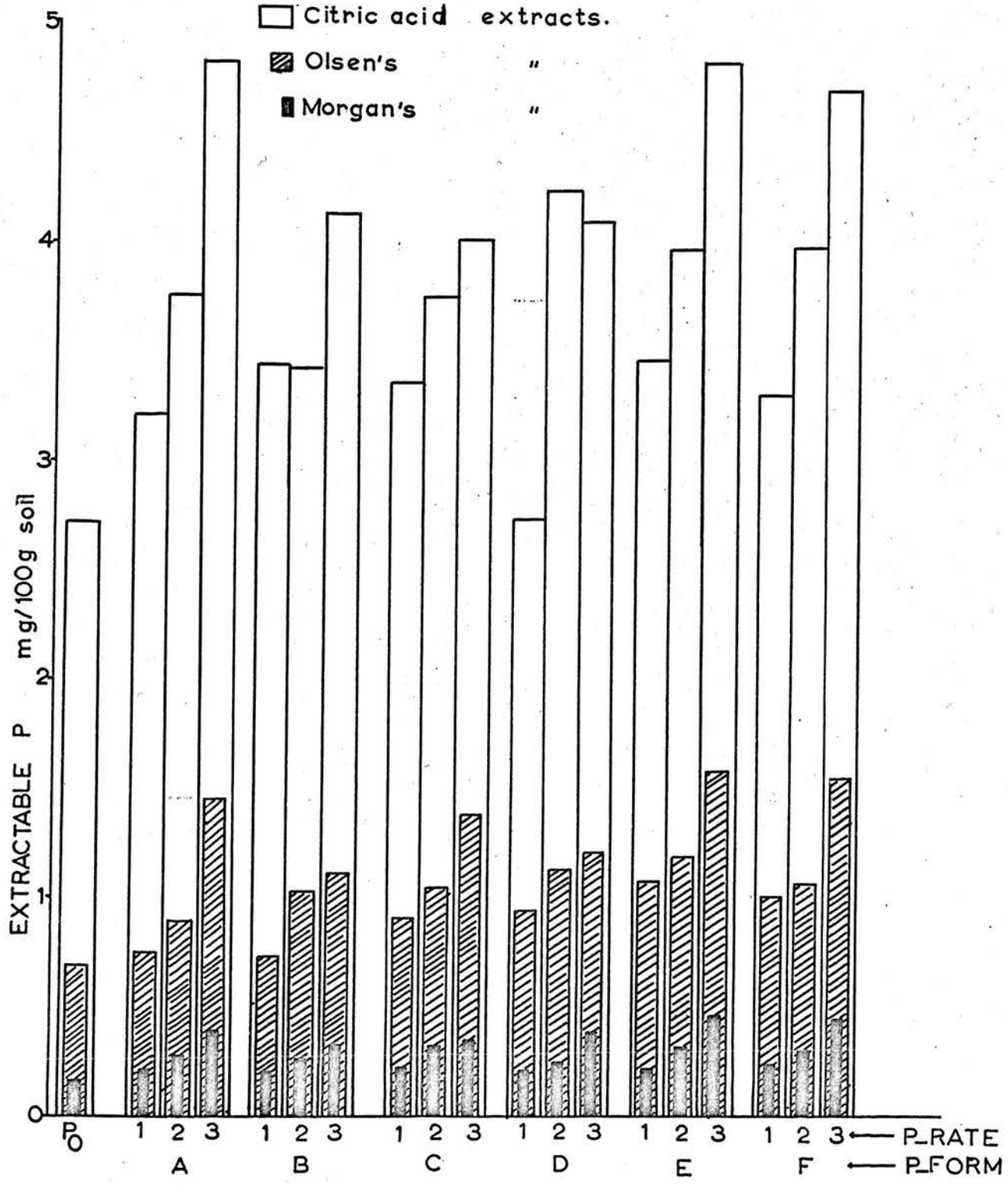


FIG. 61. Effect of P rate and form on extractable PO_4 from the soil (Av. of 2 soils, 3rd sampling, EXPT. I).

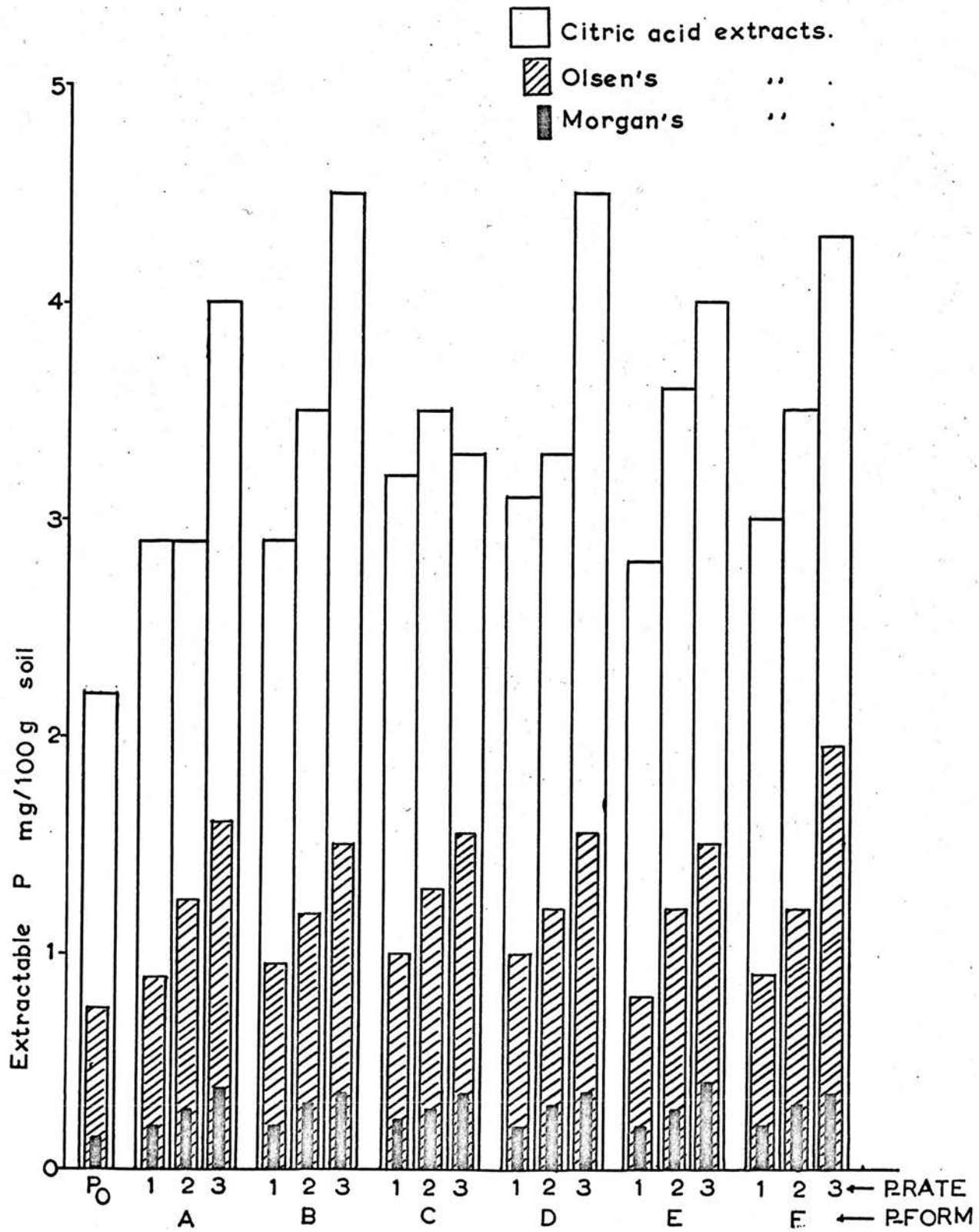
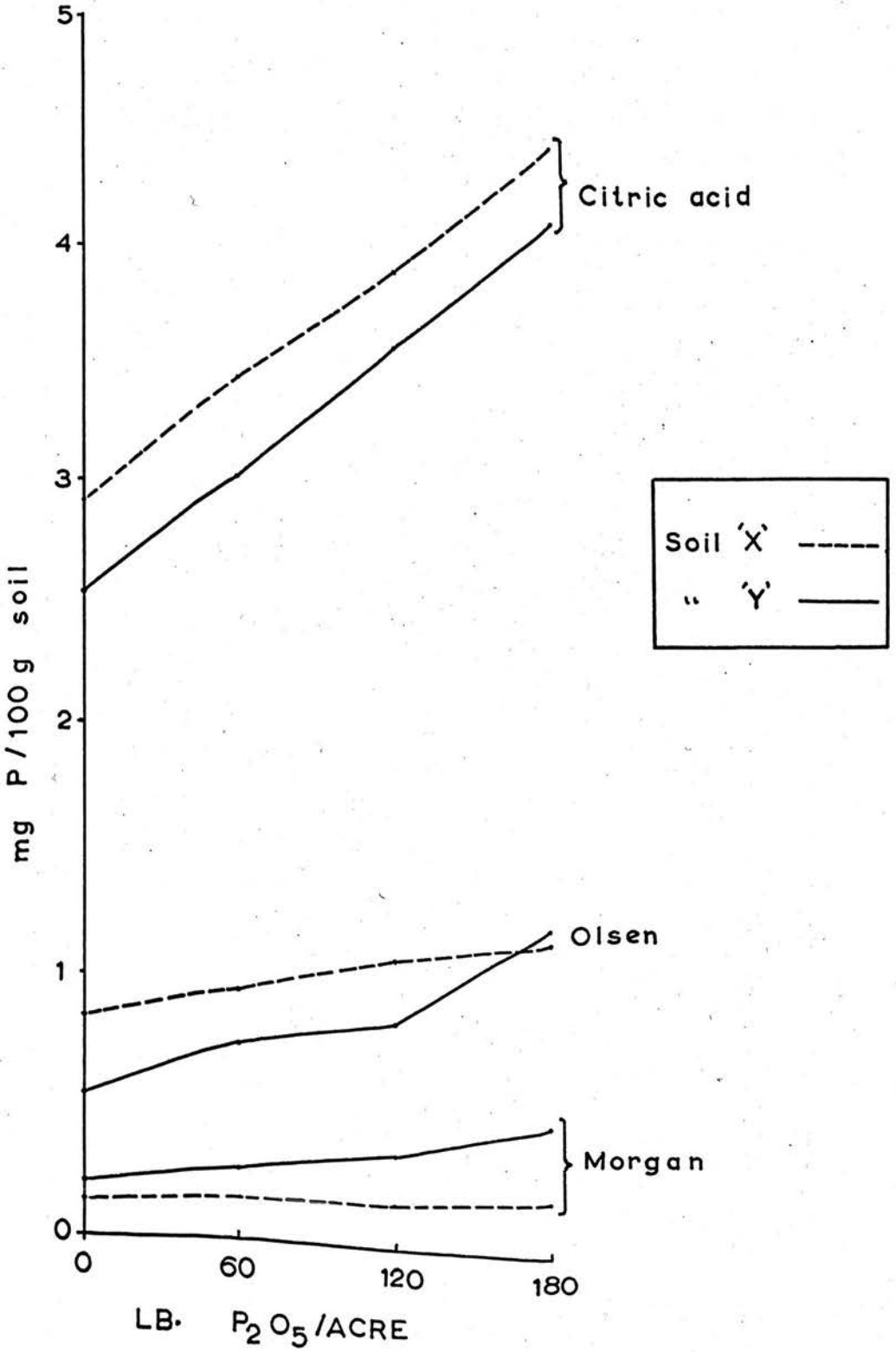


FIG. 6.2. Effects of soil, P-rate, and method of extraction on extractable PO_4 from the soil; 1st. sampling, EXPT. I.
(Mean of all P-forms)



terms of extractable PO_4 in the early samplings as compared with those of soil (X).

EXPERIMENT II:

(a) Extractable P:

Measurements of PO_4 in the soil extracts before and after hydrolysis (figs. 63, 64) showed that the hydrolyzable P, in those extracts from soils treated with metaphosphates, was greatly decreasing with time in the first 3 samplings. At the same time, the quantity of hydrolyzable P from soils treated with orthophosphate was much smaller than those from soils treated with metaphosphates, particularly in the early samplings. These results were obtained by both the citric acid- and the Olsen-methods of extraction. The Morgan's method (which was used only with the first 3 soil samplings) did not show any considerable differences between forms of P except in the first sampling where F was superior to the other two only in terms of extractable PO_4.

It was also demonstrated by the first two methods of extraction (fig. 65) that the quantity of extractable P in the PO_4 form was much greater with 'F' than with either 'C' or 'G' in the early samplings. The greatest differences were in the first sampling and decreased with time until they almost disappeared in the 4th or 5th sampling.

All methods showed that the quantity of extractable P was greatly increased with rate of P-application and with all forms of P (figs. 66-68). The graphs for extractable P from the untreated soil (P_0), in different samplings, were roughly parallel

with those from the P-treated soils, with both the citric acid and Olsen's extracts (fig. 65). Both methods showed that the quantity of extractable P decreased considerably from the 1st to the 2nd sampling, and became more or less steady after that with the Olsen method, while increasing again with the citric acid method to reach a peak in the 5th sampling and gradually decreasing with time in the subsequent samplings (fig. 65). Both methods also showed that the quantity of hydrolyzable P in the extracts, of both untreated and PO_4-treated soils, was decreasing with time to reach a minimum in the 3rd sampling while greatly increased again in the 4th sampling and became nearly steady subsequently (figs.63-64).

(b) Extractable ^{32}P:

Extractable ^{32}P was measured in soil extracts of the first 3 samplings (only in the first two samplings with Morgan-extracts). The citric acid extracted more ^{32}P from C than from F which in turn produced greater values than G, only in the 1st sampling (fig. 69). In the 2nd sampling the same method did not show any considerable differences between the three forms, while in the 3rd sampling F was slightly superior to either C or G only with P_2 and P_3 (figs. 70, 71). Both Olsen and Morgan's solutions extracted more ^{32}P from 'F' than from C or G in the 1st sampling but not in the 2nd (figs. 69,70). In the 3rd sampling the Olsen method extracted more ^{32}P from G than from either of the other two only with P_1 and P_2, while with P_3, F produced greater values than either C or G (fig. 71).

FIG. 63. Hydrolyzable P in the citric acid extracts of the soil as affected by P form.

(Mean of 3 P rates, EXPT. II).

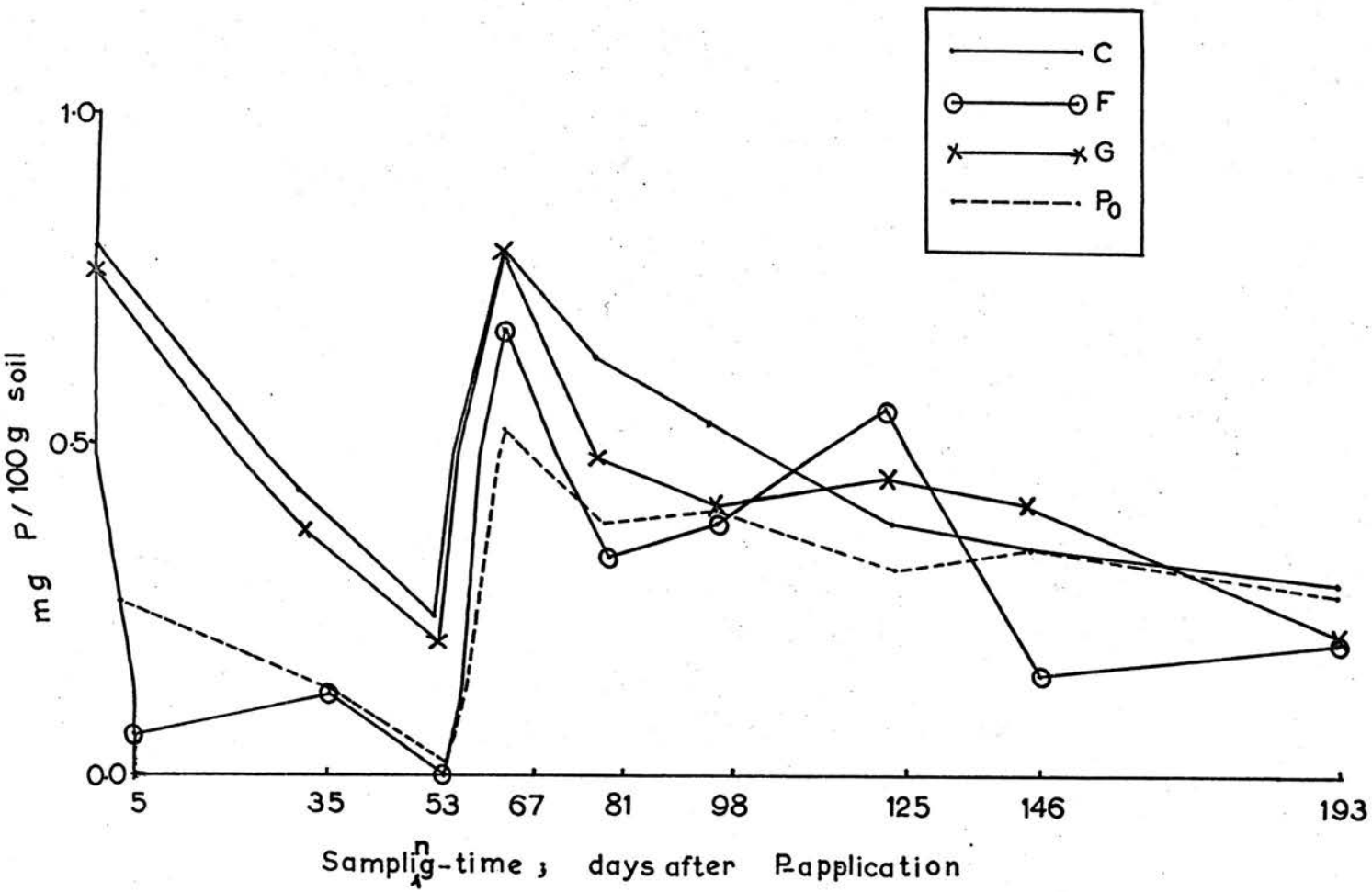


FIG. 64. Hydrolyzable P in Olsen's extracts of the soil as affected by P-form.

(Mean of 3 P-rates, EXPT. II).

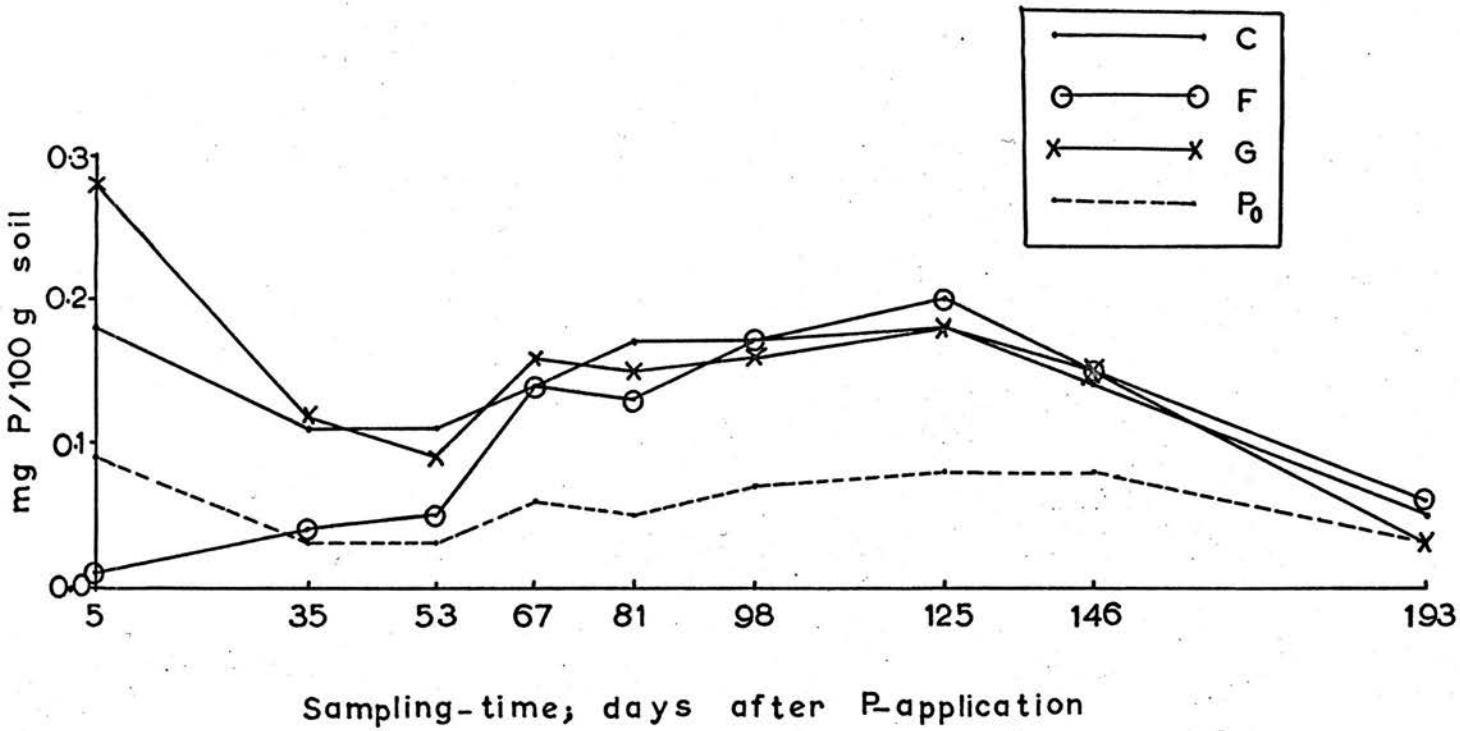
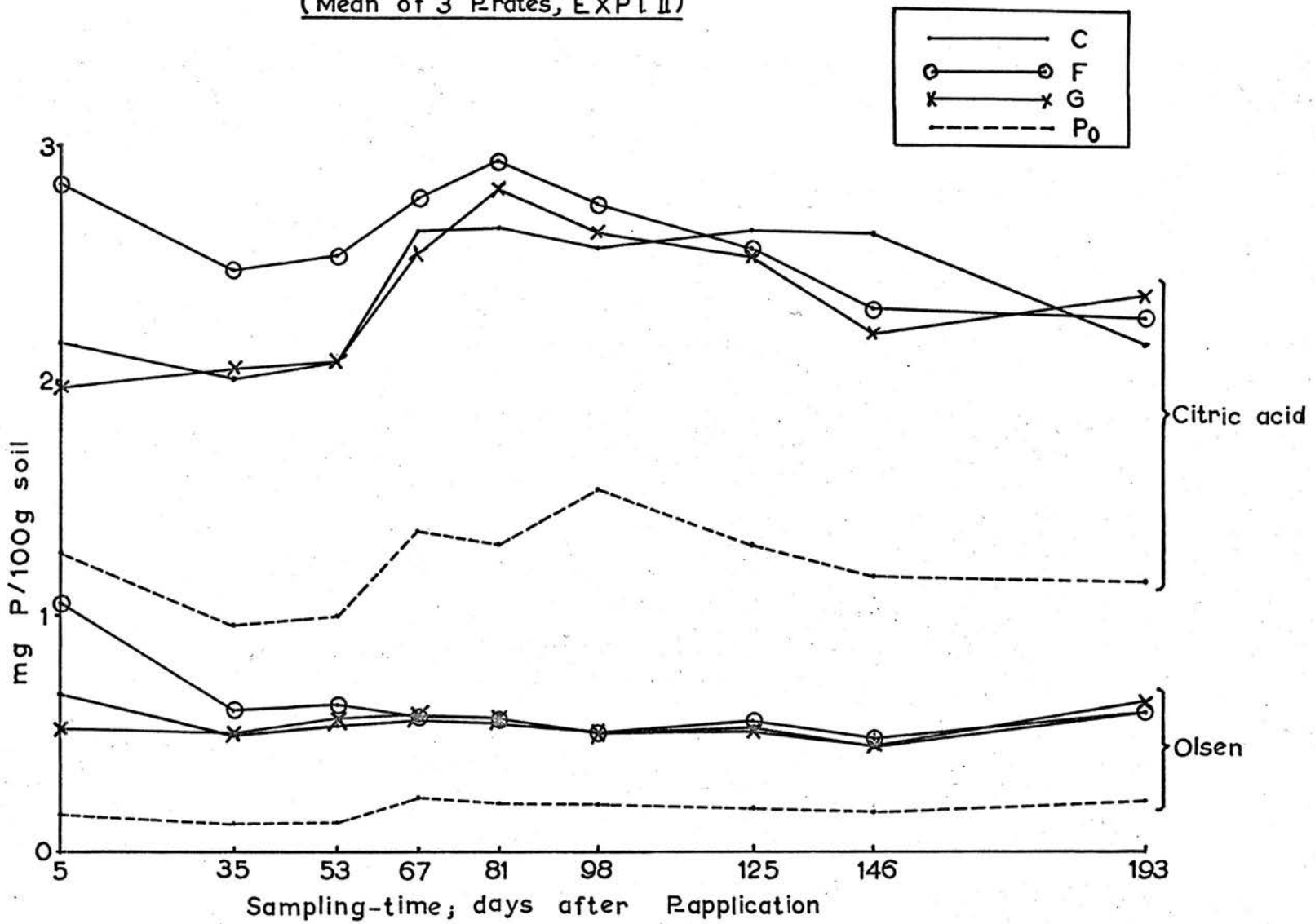


FIG. 65. Extractable PO_4 from the soil as affected by P-form.
(Mean of 3 P-rates, EXPT II)



EXTRACTABLE PO_4 FROM THE SOIL AS AFFECTED BY P-FORM, P-RATE, AND METHOD OF EXTRACTION (EXPT. II)

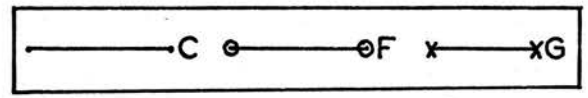
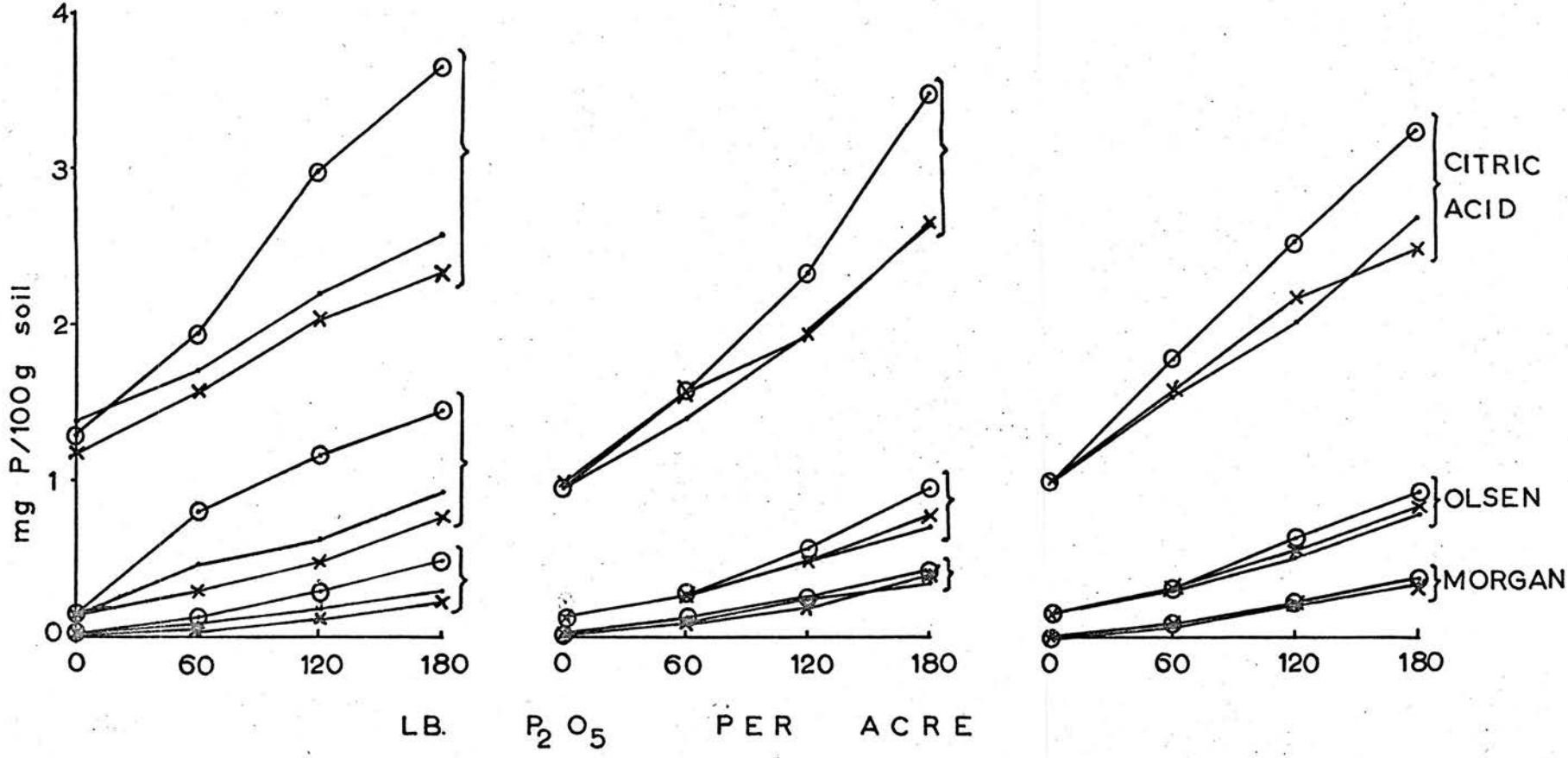


FIG. 66. 1st. sampling.

FIG. 67. 2nd. sampling.

FIG. 68. 3rd. sampling.



EXTRACTABLE ^{32}P FROM THE SOIL AS AFFECTED BY P-FORM & RATE (EXPERIMENT II).

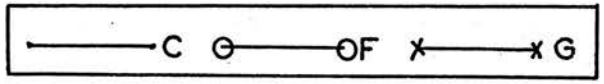


FIG.69. 1st. Sampling

FIG.70. 2nd. Sampling

FIG.71. 3rd. Sampling

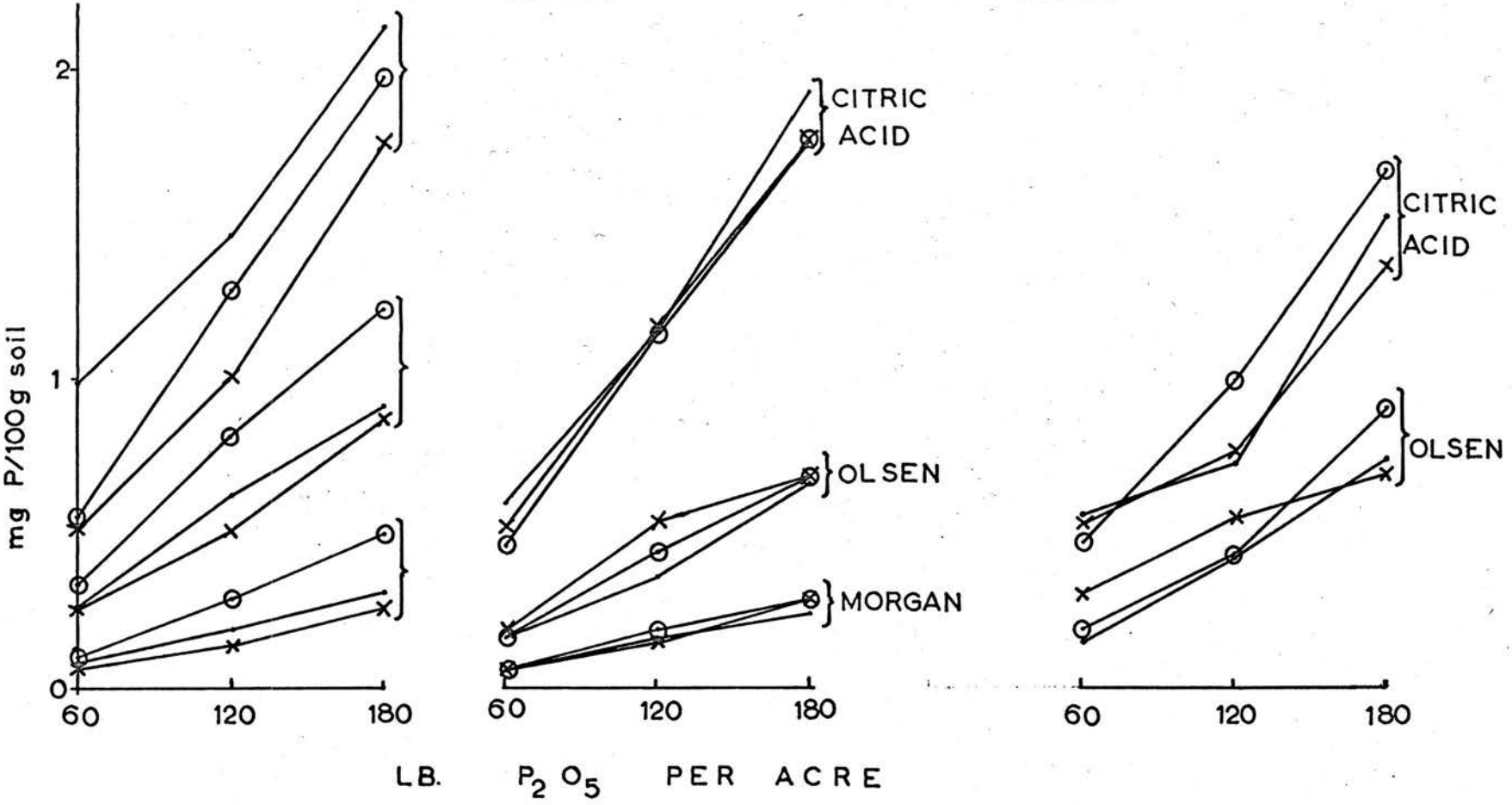
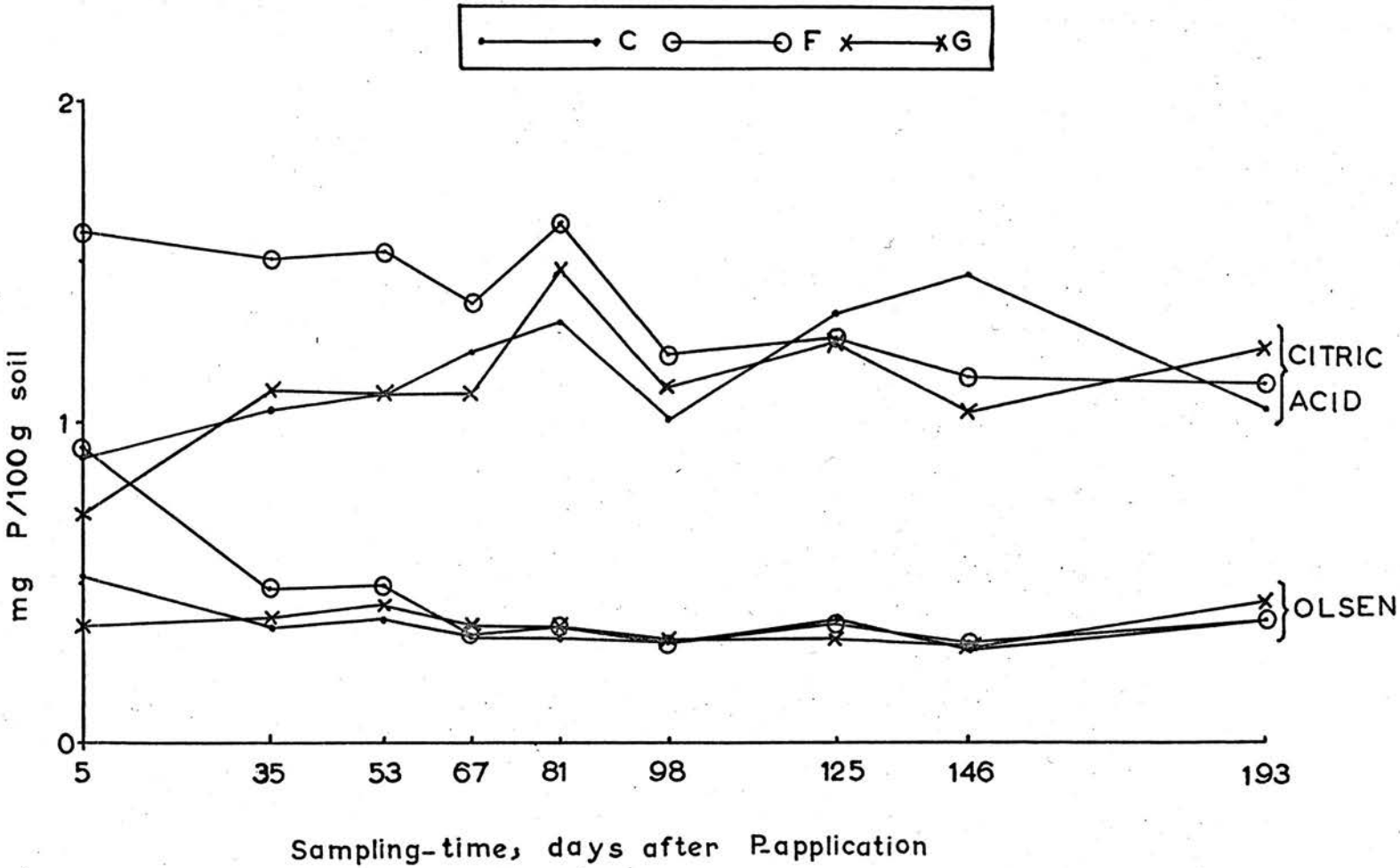


FIG. 72. APPARENT RECOVERY OF P IN SOIL-EXTRACTS AS AFFECTED BY P-FORM.

(MEAN OF 3 P-RATES, EXPT. II)



(c) Percentage hydrolysis:

The recovery of P in the form of extractable PO_4, by the citric acid and Olsen methods, is plotted against time in figure 72 for the three forms of P. If the total extractable-P is considered 100 and the recovery of PO_4-P was calculated as a percentage of it, the percentage hydrolysis could be calculated, assuming that this extractable P represents the fertilizer-P in the soil (which may or may not be the case). Since compound 'F' is orthophosphate, the percentage of its PO_4-P recovery was considered 100 and calculated values of the other two forms were corrected to account for the hydrolyzable P extracted from soils treated with F. Figures 73, 74 present the percentage hydrolysis of the two metaphosphates with time. From these figures it could be concluded that the hydrolysis of both forms was complete by the 4th sampling which was taken 67 days after mixing the fertilizer with the soil. The two metaphosphates were shown to behave very similarly (in the soil) by the citric acid method, while the Olsen method indicated faster hydrolysis of C only in the first sampling.

Figure 75 shows the percentage hydrolysis of the metaphosphates on the basis of extractable ^{32}P, i.e. recovery of PO_4-P was calculated as a percentage of the extractable labelled-P. These values, however, did not differ considerably from those obtained by the above method of calculating the percentage hydrolysis.

FIG. 73. PERCENT APPARENT HYDROLYSIS OF METAPHOSPHATES IN THE SOIL (CALCULATED FROM CITRIC ACID-EXTRACTED P; MEAN OF 3 P-RATES, EXPT. II)

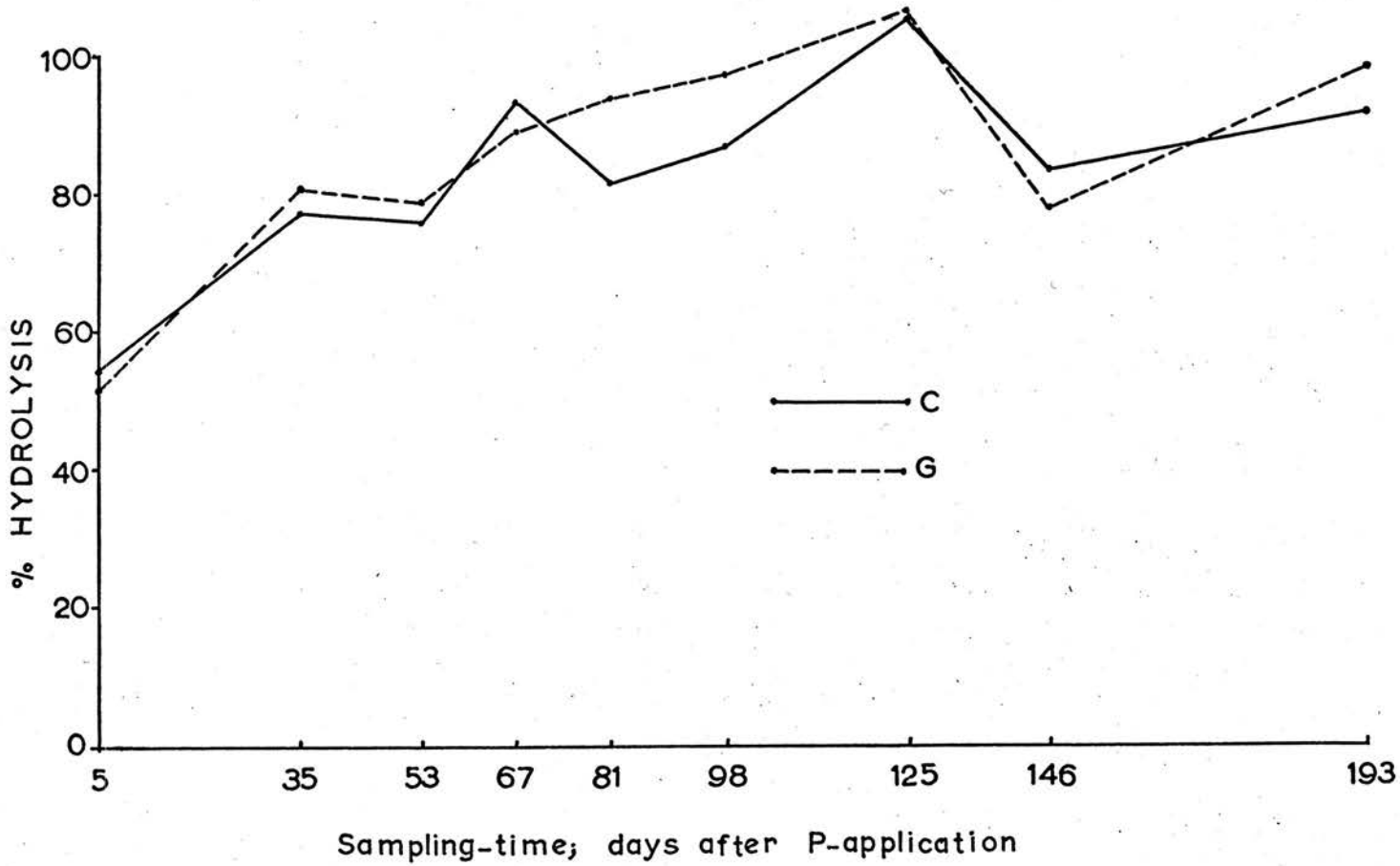


FIG. 74. PERCENT APPARENT HYDROLYSIS OF METAPHOSPHATES IN THE SOIL (CALCULATED FROM OLSEN'S SOIL EXTRACTS; MEAN OF 3 P-RATES, EXPT. II)

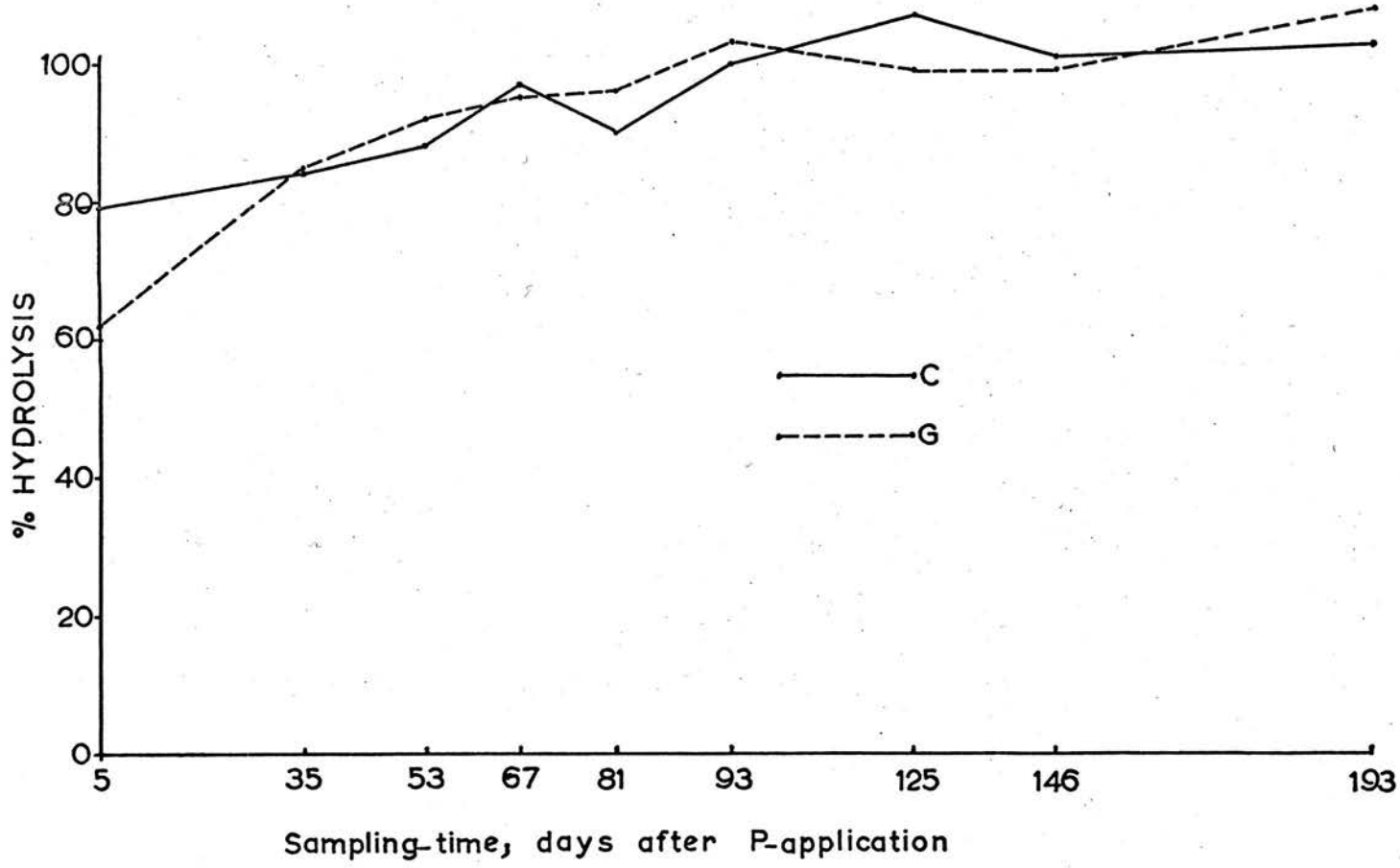
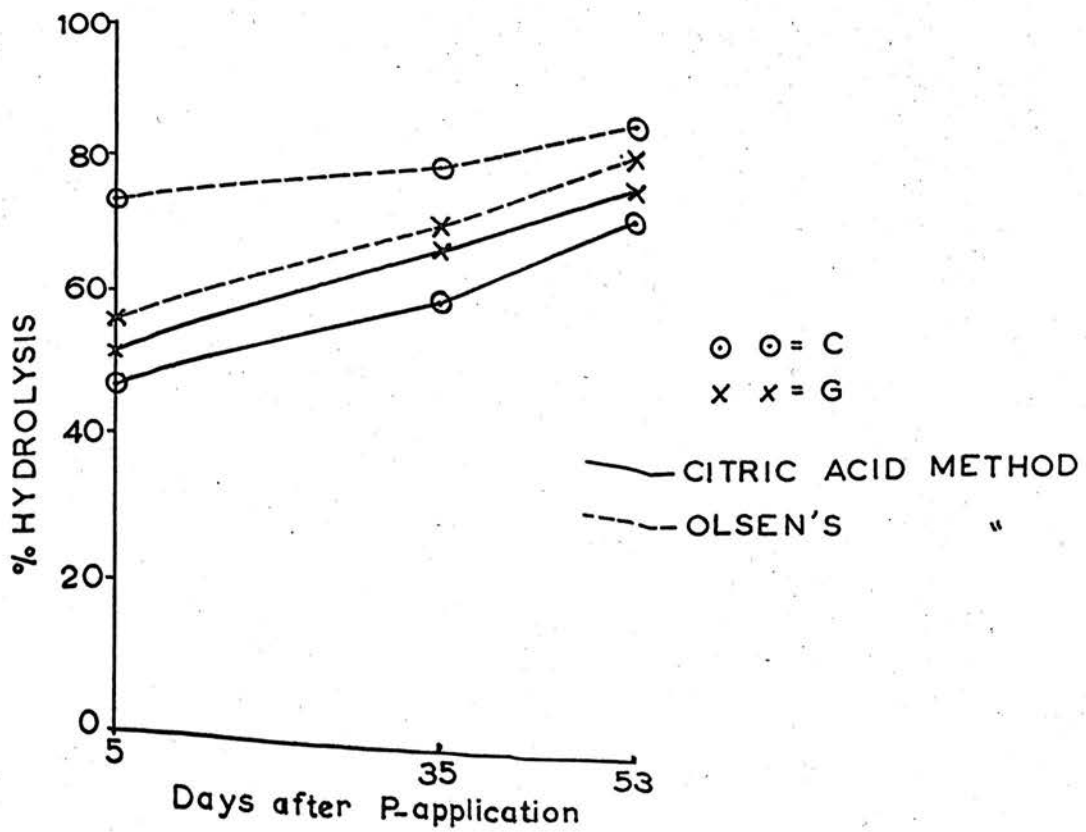


FIG. 75. % HYDROLYSIS OF METAPHOSPHATES IN SOIL, CALCULATED FROM ^{32}P & PO_4 IN THE SOIL-EXTRACTS. (Mean of 3 P-rates, EXPT. II)



V. DISCUSSION

The main object was to study the efficiency of condensed phosphates as a source of P for plants in comparison with orthophosphate as the standard. It was thought that the rate of hydrolysis of these phosphates, in the soil, may govern their availability to plants. Since soil conditions may affect their rate of hydrolysis, different soils were included. The different soils were also used to study other points, which may affect the availability of the phosphates to plants, such as retention and release from the soil in comparison with the orthophosphate.

As a result of the similar effectiveness, of the condensed phosphates and orthophosphates, obtained in the first cage-experiment (1963), a greenhouse experiment was conducted in 1964 with rates of N-application up to 200 lb. N/acre/cut. This was done to enhance the rate of growth and, hence, the demand for P by plants. Thus, the smallest differences in the availability of the phosphates used may be shown. Both the metaphosphates and the orthophosphate were labelled with ^{32}P to compare the quantities of P, taken up by plants, from the different forms.

The third experiment (1964) was carried out firstly to study the behaviour of these phosphates on both acid and calcareous soils, as sources of P for plants. The second purpose, for which P-fertilizers were banded, was to saturate the phosphate-fixing capacity of the soil around the band, thus any differences in the extent of diffusion of the different forms may affect their

relative availability. Banding was also made to retard the rate of hydrolysis of the condensed phosphates, since it was thought that mixing P-fertilizers with all the soil in the pot, in the 1st experiment, had enhanced the rate of hydrolysis of the condensed phosphates.

Soil sampling pots were included in the 1st and 2nd experiments to study the rate of hydrolysis of condensed phosphates, and to compare their effectiveness with that of the orthophosphate in increasing the "available" P in the soil as determined by different extraction techniques.

1. Effects of Form of Phosphate

(a) On yields:

The equality of yields produced by different forms of P in the first experiment, commenced in 1963, could probably be attributed either to fast hydrolysis of the condensed phosphates in the soil, or to direct absorption of these forms by plants. It is also believed that the rate of growth of the grass was not rapid enough to show if there are any initial differences in the "availability" of the different forms of P, since the yield response to increasing rate applied-P was not very great although highly significant in the first cut, 1963. Under such conditions soil-P may contribute to a considerable extent in supplying the plant with its needs of P, and hence masks any small differences between the P-forms in their initial availability. This could also be seen from the relatively high yields produced by the control pots without any applied-P.

The residual effects of the different forms of P in 1964 were also very similar. This, however, was not unexpected, since the condensed phosphates would not persist as such under soil conditions. Thus, after being converted to orthophosphate, they should show similar residual effects.

The second experiment (1964) was conducted in the greenhouse with increased rates of N and K up to 200 lb. N or K_2O per acre per cut. This was done because it was thought that shortage of N-supply, and probably K-supply, restricted the yield-response to increased rate of P in the first experiment (1963). Application of N and K_2O at the same rates was recommended by Reith et al. (1961) and Cooke (1963) particularly if the grass is grown for continuous cutting. Cooke (1963) presented data which showed that the cut grass removes about 1 lb. K_2O for each applied lb. of N. The effect of K on P-uptake, however, is not usually of considerable importance unless K is a limiting factor of growth. Robertson et al. (1954), Olson et al. (1956), Pratt (1961) and Nielsen et al. (1963) reported that K had little or no effect on P-uptake by plants.

In the greenhouse experiment the yield responses to increasing rates of N or P were very great, but the effects of P-form were generally small. It is evident, however, that most of these effects of P-form were in the first cut of grass. Compared with the orthophosphate, the trimetaphosphate was inferior (* * *) particularly at the rates of 60 and 120 lb. P_2O_5/acre, while the metaphosphate glass was only slightly inferior (*) at the 180 lb. level in the first cut of grass. In subsequent cuts the effect

of P-form was only occasionally significant with either the orthophosphate or the metaphosphate glass superior to the trimetaphosphate. The very highly significant effect of P-form in the total of 8 cuts, which showed the trimetaphosphate to be inferior to the other two forms, was actually a result of an accumulation of small differences, which were often not significant, in most cuts throughout the season.

It is quite interesting that the inferiority of the trimetaphosphate was greatest in the first cut of grass and mainly at the lower rates of P. This could be an indication of slow hydrolysis of this compound in the soil that could not cope with the demand for PO_4-P by the rapidly growing grass. The fact that the orthophosphate was superior to the trimetaphosphate only with lower rates of applied-P can then be explained by a proportional hydrolysis of the quantity applied. Thus P_3 would be greater than P_1 and P_2 in orthophosphate-supply.

In agreement with these results, are those reported by McGeorge (1939) who found that the Neubauer test on 4 calcareous soils showed that Na-hexametaphosphate was only slightly inferior to conc. superphosphate and that pure crystalline $NaPO_3$ was inferior to vitreous hexametaphosphate. Honya et al. (1961) also reported that Na-polymetaphosphate and Na-tripolyphosphate gave poorer growth in early stages of growth of paddy rice, as compared with superphosphate as control in a field experiment, while increasing the growth at the elongation stages and producing greater yields of grain. Metaphosphoric acid was found to be equivalent to H_3PO_4 when both were applied before seeding

(Doerell, 1941), but metaphosphoric acid was inferior to orthophosphoric acid as a top dressing to an established stand in a pot experiment. Tsuge and Yashida (1958a,b) reported that in sand cultures Na-polyphosphates were as effective as mono-calcium phosphate, while under water-logged conditions they produced greater yields of rice than did superphosphate, and they also recorded greater residual effect on naked barley.

Results of the cage experiment (III, 1964) were slightly in favour of the metaphosphates which produced slightly greater yields than the orthophosphate. However, the effects of P-form, in this experiment, were greater and more consistent in terms of P-contents and P-uptakes which will be discussed later.

(b) <u>On P-contents of D.M.</u>:

Experiment I (1963-64) did not show any considerable differences between the different forms of P, which was in good agreement with the yield results. This may also indicate that, unless condensed-P was absorbed as such by roots, which is not likely since metaphosphates were inferior to the orthophosphate in the first cut of grass in the greenhouse experiment, the rate of hydrolysis of the condensed phosphates must have been rapid enough to show them equal to the orthophosphate in supplying plants with PO_4. It is also thought that the water-solubility is an important factor in their rate of hydrolysis, since the water-insoluble K- and Ca-metaphosphates were often shown (as mentioned in the 'review of literature') to be inferior in the early stages of growth and often equivalent to orthophosphates in

final yields, while in some cases they produced greater P-contents than the orthophosphates.

The most interesting results are those of experiment III (1964) in which the P-fertilizers were banded 2½" below the seed. In all 3 cuts of grass, the metaphosphate glass (G) produced greater P-contents of the D.M. (* * *) than did the orthophosphate (F). The trimetaphosphate (C) was also superior to F (* *) in the 1st cut of grass and (* * *) in the 2nd and 3rd cuts. It is also remarkable that the interaction between the rate and form of P was significant in all 3 cuts of grass. Very consistently, the superiority of the metaphosphates was mostly at the highest rate of P and to a smaller extent with P_2, which could be a result of more stable fixation of the orthophosphates in the soil and/or gradual hydrolysis of the metaphosphates to orthophosphate.

Both ortho- and metaphosphates are very quickly fixed by the soil. In experiment I, where soil leachates were collected from Mitscherlich pots (with no grass), no P was recovered in leachates at any time. MacIntire et al. (1937) reported that, in suspensions of soil, subsoil, ferric and aluminium oxides in both aqueous and ammonium citrate solutions of meta- and orthophosphates, the adsorption of PO_3 was decidedly greater than that of PO_4 in every parallel system, for each P_2O_5 concentration and pH value of the initial solution. McGeorge (1939) also reported similar results using both natural and sterilized calcareous soils. Donso-Torres (1959) found that more P from $NaPO_3$ was fixed by the soil than from KH_2PO_4. Thorup and Mehlich (1961) reported that bentonite and soils containing predominantly 2:1 lattice minerals

retained somewhat more P from KH_2PO_4 than from KPO_3, and that halloysite, kaolinite, and soils containing predominantly 1:1 lattice minerals retained somewhat more P from KPO_3. Rotini (1951) concluded that PO_3 (from $NaPO_3$) is rapidly fixed by soils almost free of $CaCO_3$ and that the fixation was greater in soils rich in organic matter or hydroxides of Fe or Al. Rotini et al. (1952), measuring the velocity of metaphosphate fixation of organic soils from 0.1 N $NaPO_3$ solution, found that metaphosphate absorption was almost instantaneous, since the absorption after 7 hours was very little more than that after only one min. They also concluded that the fixation process represents all characteristics of colloidal absorption phenomena.

Results reported by these workers leave little or no doubt that metaphosphates are very quickly fixed by the soil colloids. Whether this fixation takes place in the form of PO_3 or after hydrolysis, it is not certain. But if hydrolysis were to take place before fixation there should not be any difference in the amount of fixed-P from either form, which contradicts ~~with~~ the findings, mentioned above, that include evidence that more PO_3-P than PO_4-P is fixed by the soils, probably due to the difference in valency.

Under soil conditions, meta- or polyphosphates are hydrolyzed to the more stable orthophosphate and hence fixed condensed-phosphate is not as stable as the fixed orthophosphate. The gradual hydrolysis and the fixation of the resulting PO_4 will take a longer time than the direct fixation of the orthophosphate, hence "availability" to plants of that freshly-hydrolyzed-fixed

phosphate may be greater than that of the originally-fixed orthophosphate. Williams (1950) reported that freshly fixed PO_4 is "available" to plants and that its inherited "availability" decreases with time. On the other hand, Tsuge and Yoshida (1958[a]) reported that polyphosphate-complexes with Al, Fe and Ca are more readily utilized by plants than those of orthophosphate.

The superiority of the metaphosphates in the cage-experiment (III), particularly with the higher rates of P, may be explained by this theory, since the lower rates of applied-metaphosphate may take a shorter time to hydrolyze, relative to the high rates. Thus, no considerable difference could be detected between the three forms of P at the low rates. Under conditions of experiment III, it seems that by the time the plant roots reached the fertilizer-band sufficient hydrolysis of the metaphosphates might have taken place to meet the plant requirements of orthophosphate. The rate of growth was also relatively slow and hence the demand for P was not particularly great in comparison with that under greenhouse conditions.

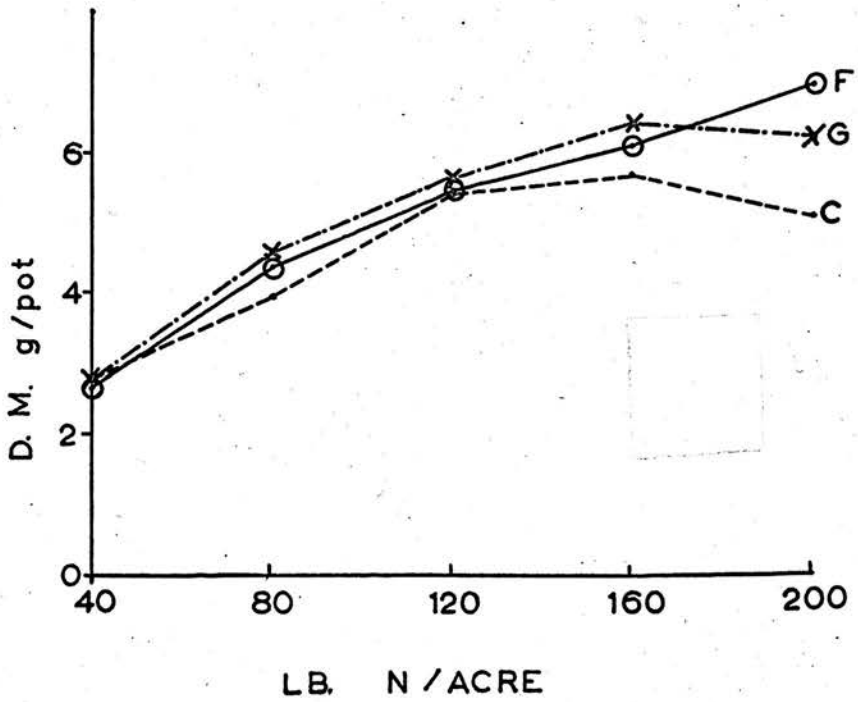
In experiment II (greenhouse, 1964) the greatest effects of P-form on the P-contents were those of the 4th and 5th cuts of grass, with the trimetaphosphate producing greater (* *) P-contents than the other two. The greatest difference, however, did not exceed 6 per cent of the overall mean P-content of the D.M. At the same time the trimetaphosphate produced slightly smaller (*) yields of D.M., in these two cuts, than the other two forms. Cooke (1956), reported that Ca-metaphosphate produced smaller yields of swedes than superphosphate, but it was only

slightly inferior to superphosphate in terms of P-uptake. He explained this by slow hydrolysis of the Ca-metaphosphate, and as a result extra P was taken up late in the growing season when the crop could not produce corresponding increase in yield of D.M.

This explanation, of Cooke (1956), may not be valid in this case since the yields of D.M. as well as P-contents of the D.M. were very similar for the three forms of P in the 2nd and 3rd cuts of grass. Alternatively, the superiority of the trimetaphosphate only in terms of P-content of D.M., could be a result of the salt damage observed in the 5th cut of grass on pots receiving high rates of N. This damage might have occurred, by chance, to a greater extent on the pots treated with the trimetaphosphate (fig. 75[a]), thus reducing the yields produced by these pots. Accordingly these smaller yields are expected to contain greater P-concentration.

The effect of P-form on the ^{32}P-contents of grass was not in full agreement with that on the total P-contents of D.M. in the first 4 cuts of grass of experiment II, 1964. Although the differences between forms were small they were significant in the 2nd, 3rd and 4th cuts of grass. In the 2nd and 3rd cuts, the metaphosphates, particularly the trimetaphosphate, were inferior (*) to the orthophosphate. This was more marked with the high rates of applied-N, i.e. where the rate of growth was fast and hence the demand for P was very great. On the other hand, the two metaphosphates were superior to the orthophosphate only with the highest rate of P in the 4th cut of grass.

FIG. 75a. Effect of salt-damage with high N-rates on yields of D.M. (5th cut, EXPT. II)



The last two observations, together with the equality of the three forms of P in the first cut only in terms of P-contents of D.M., could be explained by the theory of gradual hydrolysis mentioned above (Cooke, 1956). The equality of the orthophosphate to the metaphosphates, in terms of ^{32}P-contents in the 1st cut, and its superiority in the 2nd and 3rd cuts, which was not in agreement with the total P-content data, could be explained by isotopic exchange of the different forms and soil-P. It may be due to slower isotopic exchange of the metaphosphates, or to the time-lapse for their hydrolysis, subsequent to which the orthophosphate produced would presumably exchange with the "soil-labile P". Before reaching equilibrium between soil-P and fertilizer-^{32}P, isotopic exchange tends to decrease the radioactivity in the soil solution.

(c) Form of P and P-uptake:

The equality of the different forms of P, in terms of yield production and P-contents in the 1st cage experiment (1963-64), resulted in equal P-uptakes from all 6 forms of P in both seasons. In the 2nd experiment (greenhouse, 1964) the P-uptakes followed the same trend as the yield of D.M. since there were no considerable differences between the three forms in terms of P-contents.

In experiment III where the yields produced by different forms of P were not considerably different, the superiority of the metaphosphates, in terms of P-uptakes, was mainly due to their superiority in increasing P-contents of the D.M. This occurred with both liquid and solid applications of the fertilizers which

proved that any hydrolysis that may take place during the solution of the metaphosphates had no effect on their availability to plants.

Banding the fertilizers had been done to saturate the phosphate fixing capacity of the soil in that layer around the band, and also to retard fast hydrolysis which, it was thought, had been accelerated, in the first experiment, by mixing the fertilizers with the entire soil in the pot. From results of this experiment, banding the fertilizer seemed to be advantageous to the metaphosphates, since only this experiment showed that the metaphosphates had supplied more P to plants than did the orthophosphate. Another point is that the superiority of the metaphosphates was greater with the high rates of P as shown by the interactions between the rate and form of P. These two points may indicate that less firm fixation of metaphosphates by soil, as mentioned above (see p.95), is more responsible for their superiority to the orthophosphate, since it is likely that banding P will retard the hydrolysis of the metaphosphates. Even if the hydrolysis was enhanced, the orthophosphate should be at least equivalent to the metaphosphates. Besides the references mentioned above in discussing the P-contents (page 94-5) about the fixation of metaphosphates and polyphosphates by soil, Michaels (1958) reported that the adsorption of polyphosphates by Kaolinite occurs on the alumina sheet (gibbsite) to neutralize the vacant co-ordination sites, and that the longer the polyphosphate chain the more fixation (i.e. with orthophosphate only ½ of the vacant sites in any row may be filled, with pyrophosphate 2/3, with

tripoly $\frac{3}{4}$ ... and so on). He also explained the rapid hydrolysis of the polyphosphate in contact with kaolinite and the role of the aluminium in the process as follows: "while the distance between the Si atoms in a planar silica sheet is slightly greater than that between the Al atoms in gibbsite, the distance between P atoms in a polyphosphate is considerably less. Thus, co-ordination of a polyphosphate chain with a gibbsite sheet must produce a rather tensile stress in the P-O-P linkages between the phosphate tetrahedra. In an aqueous environment these stresses would lower the activation energy required for polyphosphate hydrolysis and favour reversion to orthophosphate." This theory is in agreement with Rotini et al. (1952) who suggested that metaphosphate fixation by soils presents all characteristics of colloidal adsorption phenomena. But the findings of Michaels (1958) may also indicate that the adsorption of polyphosphates by kaolinite is not very stable in comparison with that of the orthophosphate. Thus the stable fixation of the metaphosphates is expected to take a longer time than that of the orthophosphate, since hydrolysis may have to take place to form orthophosphate.

Under conditions of great demand for P, however, the rate of hydrolysis may be more responsible for the efficiency of condensed phosphates rather than this theory of fixation. Since, under greenhouse conditions with high rates of N, the metaphosphates and particularly the trimetaphosphate were inferior to the orthophosphate in the first cut of grass. This superiority was only in terms of yields, but was reflected in the total P-uptakes.

Both the ^{32}P- and total P-uptakes in the first cut, as well

as the superiority of both F and G (*) to C in the 2nd cut (in terms of ^{32}P-uptakes), indicate that the rate of hydrolysis of metaphosphates is responsible for these results. It also indicates that the hydrolysis of G is slightly greater than that of C. These results are in agreement with the results of a Neubauer test carried out by McGeorge (1939) on 4 calcareous soils. Honya et al. (1961) also reported similar results with a field experiment with paddy rice, but they reported that the final yields of rice were greater with Na-poly- or polymeta-phosphate than with superphosphate.

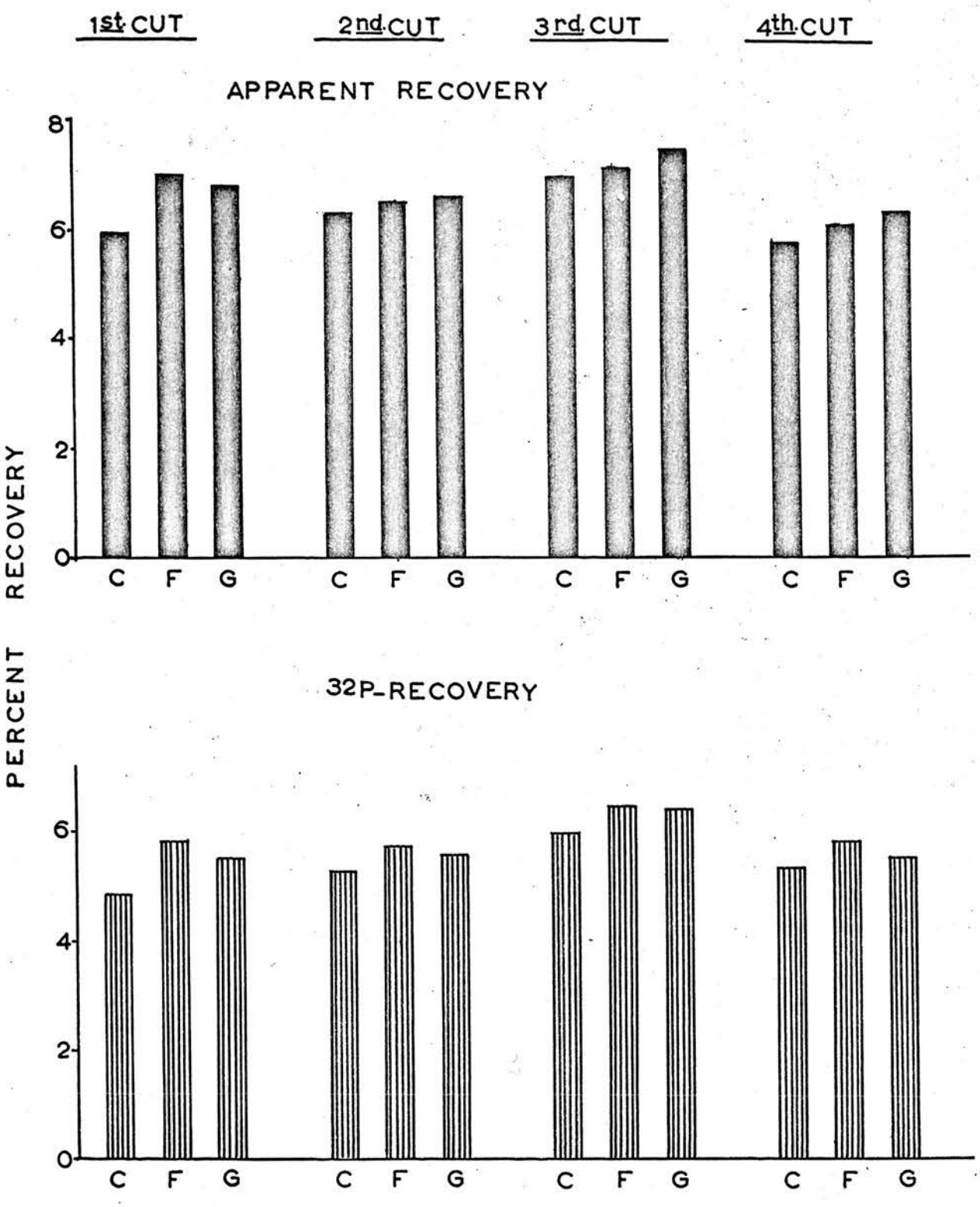
The "labile P-values" of the soil (L-values of Larsen, 1952 or A-values of Fried and Dean, 1952) calculated from the ^{32}P-measurements in the first 4 cuts of grass (experiment II) were greater with the metaphosphates than with the orthophosphate. Since the differences between forms in terms of total P-uptake were much smaller than those of "labile P-values", this may be a result of slower isotopic exchange between soil-P and metaphosphate-P. This is suggested by the decrease in the differences with time in the successive cuts. The effect of P-form was very pronounced in the 2nd cut (* * *) and highly significant in the 3rd, while only significant (*) in the 4th cut. These differences were greater between the orthophosphate (F) and the trimeta-phosphate (C) than between F and the metaphosphate glass (G), the latter difference was significant only in the 2nd cut.

Fried (1954) suggested the use of "A" values as a measure of relative availability of different fertilizers. According to Fried's method the results show that the availability of the

different forms in the greenhouse experiment decreases in the order of F > G > C. However, the fertilizers used by Fried were all in the orthophosphate-form, and it may not be justifiable to use that method in these comparisons since the total P-uptake values showed no considerable differences between the three forms after the first cut of grass. Even if the equality of the total P-uptakes is due to increase in the soil-P-uptake in the case of metaphosphates rather than equality in their availability to plants after the first cut, the metaphosphates are indirectly responsible for this increase in soil-P-uptake. Simpson (1956) suggested that the "apparent recovery" may be regarded as a good index of fertilizer efficiency, since the fertilizer-P is indirectly responsible for the uptake of greater quantities of soil-P.

A comparison between the "apparent recovery" and ^{32}P-uptake, in the first 4 cuts of grass (experiment II), shows that the first parameter generally produced slightly greater values. Fig. 76 shows that the two methods are very similar in the first cut of grass as far as the effect of P-form is concerned. In the succeeding 3 cuts the "apparent recovery" was slightly in favour of the metaphosphate glass (G) and this tendency increased with time until the 4th cut in which the metaphosphate glass was significantly (*) superior to the trimetaphosphate (C), while the orthophosphate (F) produced intermediate values which were not significantly different from the other two forms. On the other hand, the ^{32}P-uptake was slightly in favour of the orthophosphate (F) particularly in the 4th cut (*), while in the 2nd cut, the

FIG. 76. Comparison between apparent and ^{32}P-recovery in relation to the form of P (mean of 3 P rates, EXPT. II)



trimetaphosphate (C) was inferior (*) to the other two.

Although the differences between P-forms are generally small, it is evident that the metaphosphate glass was in most cases very similar to the orthophosphate, while the crystalline trimetaphosphate was inferior. This was observed in terms of yields, P-uptakes, ^{32}P-uptakes and "apparent recoveries". These observations are in general agreement with those of other workers. McGeorge (1939) found that Na-hexametaphosphate glass was superior to crystalline Na-metaphosphate. Hill and Armiger (1955) also reported that the amorphous Ca-metaphosphate and Ca-pyrophosphate were superior to the crystalline ones in terms of yield production of millet in the greenhouse. Similar results with K-metaphosphates were also reported by Munk (1963). Although no explanation was given for the superiority of the vitreous materials, recent work by Almaras and Black (1965) on the hydrolysis of Ca-metaphosphate in the soil, produced evidence that the hydrolysis of the vitreous material was faster than that of the crystalline form which had lower solubility. They reported that the hydrolytic degradation of Ca-metaphosphate in soils involves several steps including the formation of a dense, viscous liquid from the vitreous but not from the crystalline material. The rate-controlling step in the early stages of the transformation of the condensed-P to orthophosphate in soils treated with Ca-metaphosphate was the degradation of the viscous liquid rather than the hydrolysis of condensed-P in the solution derived from the viscous liquid. These findings could be applied only where solid fertilizers are used and particularly if they are slowly soluble in water such as

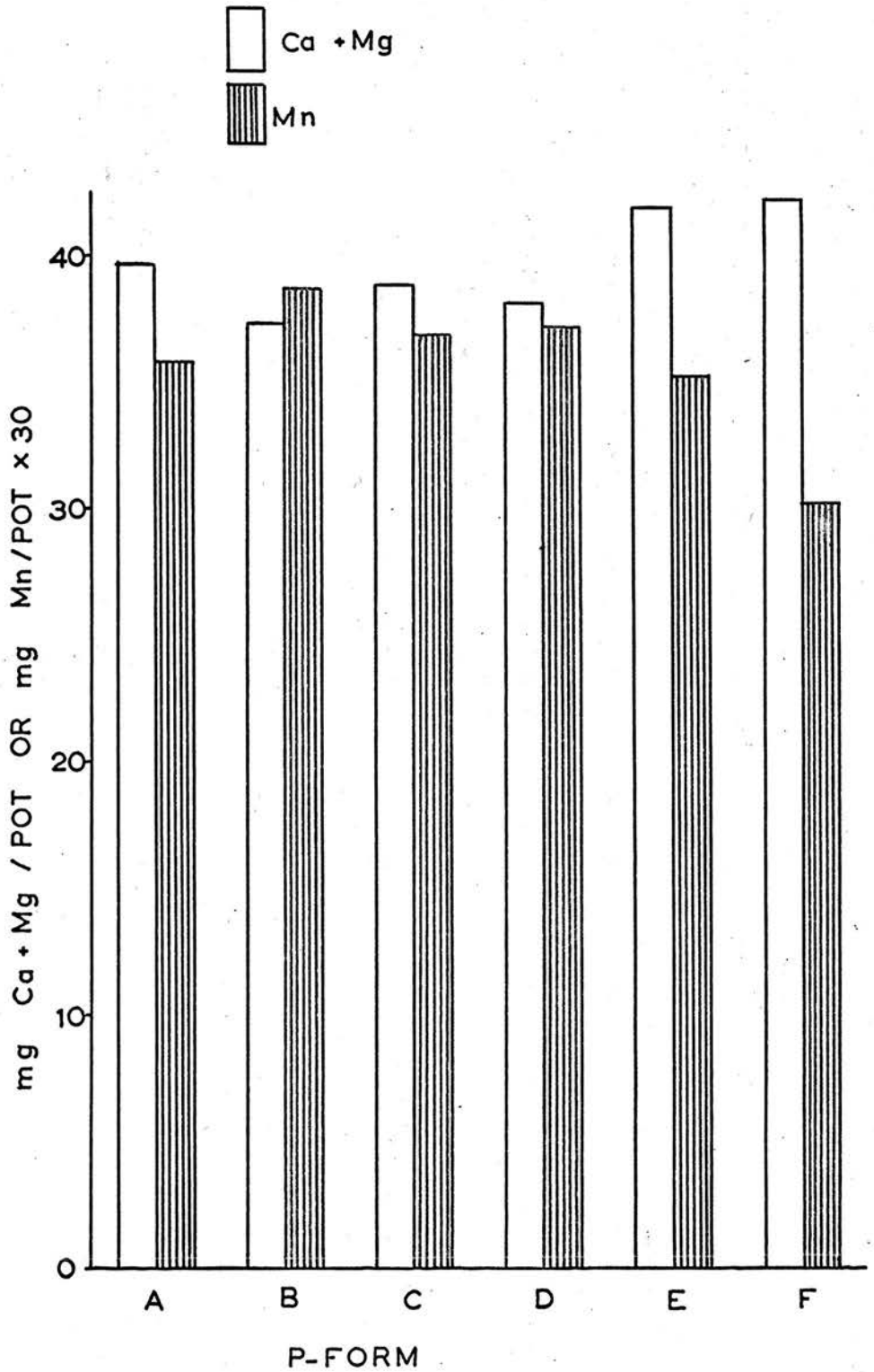
Ca- and K-metaphosphates. Van Wazer (1958) reported that the branching points in a high polymer phosphate undergo quicker scission than the normal P-O-P. linkage in the chain compound. This could be the case with the metaphosphate glass which hence may undergo faster hydrolysis than the trimetaphosphate. The ring structured trimetaphosphate may be degraded first to a straight chain of tripolyphosphate before it is further degraded to orthophosphate (Mattenheimer, 1956). Slack et al. (1965) also reported that the P-O-P band in the highly condensed phosphates seems to hydrolyze more readily than those of the pyrophosphate-form.

(d) Form of P and other nutrients:

Chemical analysis of the first cut of grass (experiment I, 1963) suggests that the uptakes of K, Fe and Cu were not considerably affected by the form of P (appendix I). In the case of Mn the Soil x Form interaction was significant. This interaction showed that, on the acid soil (X), Mn-uptake was smaller with the orthophosphate (F) than with any of the condensed forms of P (fig. 77). The reverse occurred with Ca- and Mg-uptakes. The effect of P-form was very considerable in the case of Ca (* * *) and Mg (* *) particularly on the acid soil (X), with the orthophosphate (F) and the mixture of poly- and orthophosphate (E) producing the highest values in both cases (fig. 77).

This effect may be a result of a temporary chelation of Ca and Mg by the condensed phosphate, before being hydrolyzed, and hence reducing their mobility in the soil solution of the acid

FIG. 77. EFFECT OF P-FORM ON UPTAKE OF Ca + Mg & Mn BY GRASS ; 1st. CUT ; SOIL 'X' ; EXPT. I, 1963.



soil. This chelation had no marked effect on the uptake of Ca and Mg on the neutral soil (Y) probably because of its greater contents of the two nutrients, or due to faster hydrolysis of the polyphosphates in that soil. The non-existence of the effect of chelation on the uptake of other nutrients such as K, Fe, Cu or Mn from both soils is difficult to explain.

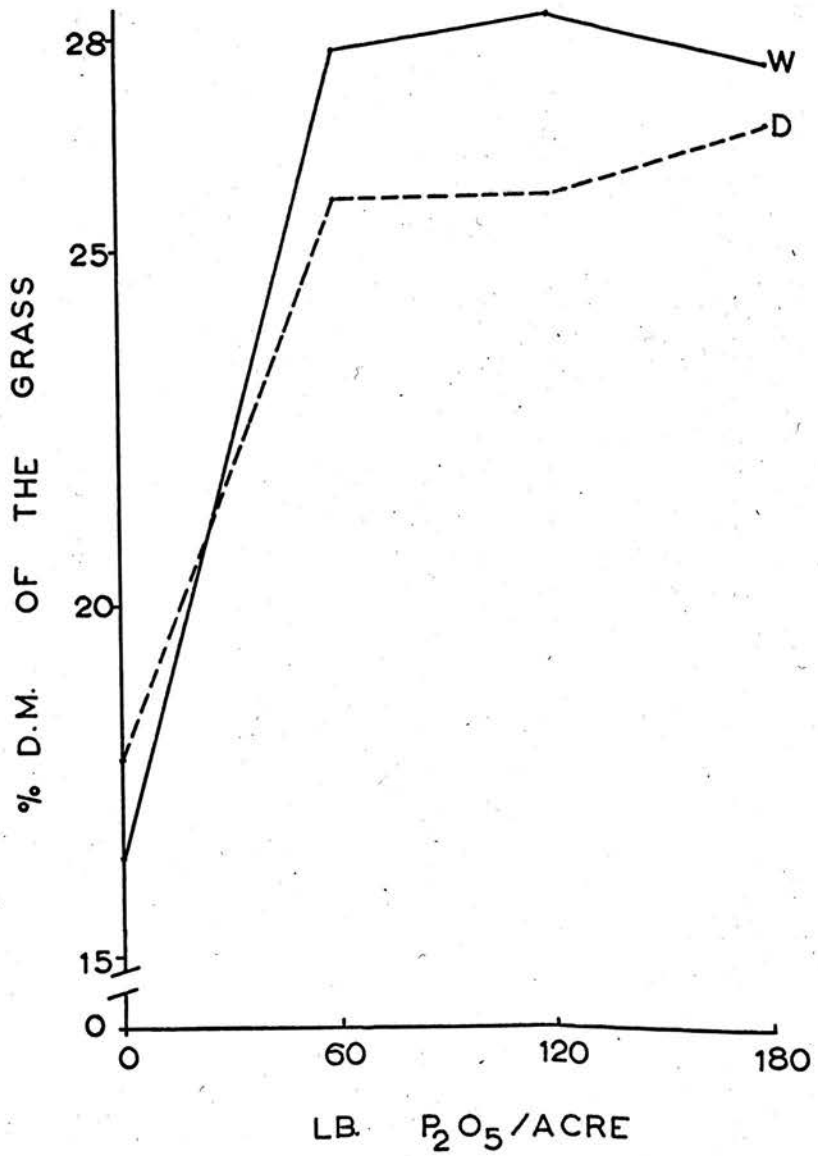
The smaller Mn-uptake with the orthophosphate treatment (F) on the acid soil may be a result of antagonism between Mn and Ca rather than Mg since there was a negative correlation (*) between Mn-uptakes and Ca- or Ca + Mg-uptakes with different forms of P on that soil, while the correlation between Mn-uptakes and Mg-uptakes was not significant. MacIntire et al. (1953) reported that K-metaphosphate treatments of the soil decreased the amount of Ca in the leaching water (in lysimeter studies) much more than did K_2SO_4 both on limed and unlimed soils. They attributed the difference to the orthophosphate, resulting from the hydrolysis of the metaphosphate, which may react with Ca and Mg solutes and with exchangeable Ca and Mg to form dicalcium- and dimagnesium phosphates. It could also have been a combined effect of chelation of Ca by the metaphosphate and precipitation of Ca-phosphate by the orthophosphate resulting from its hydrolysis.

2. Effects of P-rate

In all three experiments and most cuts of grass, P-application as well as increasing rate of P greatly increased the P-uptake. This was a result of increases in both yields and P-contents of

the grass in most cases. In some cases where the grass-yield did not respond to applied-P, i.e. in the 2nd cut of experiment I (1963), the P-contents of the grass were greatly increased with increasing rate of P-application. In such cases, yield response to P was probably restricted by other growth factors such as nitrogen and weather conditions. In the first cut of cage experiment III (1964), the lowest rate of P-application decreased the P-contents of grass, as compared with those of the control (P_0), only on the acid soil (W). In this experiment the growth on the P-treated pots was much faster than that on the control pots (P_0), which brought about very great yield responses to applied-P, and hence diluted the P taken up in the grass. Another factor which had probably contributed to a great extent to this observed decrease in P-contents, was the period of drought that came during the rapid growth-period, about 2 weeks before cutting. During that time the rate of transpiration of the P-treated plants must have been much greater than that of the P-control plants, hence the soil dried much quicker in the P-treated pots compared with control-pots. While the P-treated plants wilted badly, those of controls were still fresh and did not show any signs of wilting. Under such conditions the water uptake per unit dry matter (D.M.) would be much greater from the control-pots and hence P-contents of the dry matter may be greater. This could be demonstrated in fig. 78 which presents the D.M. per cent of the grass at different rates of P-application in that cut. This in fact did not occur to such a great extent on the calcareous soil (D) since the growth on that soil was smaller, in that cut,

FIG. 78. % D.M. OF THE GRASS, 1st CUT, EXPT. III.



than the growth on the acid soil (W), so that when spray irrigation was practiced, during the drought period, the grass grown on the calcareous soil recovered better than that on the acid soil. Mattingly (personal communication) also observed similar results particularly under bad growth-conditions. However, even in that cut the response to applied-P as well as increasing rate of P was very pronounced in terms of P-uptake.

Effect of applied-P on soil-P uptake:

The effect of rate of applied-P on soil P-uptake (in the greenhouse experiment) was very remarkable. All P-applications increased the soil-P-uptake. In the 1st cut of grass this was increasing with rate of P, but not in the 3 succeeding cuts. In the 3rd and 4th cuts of grass the increase in soil P-uptake brought about by the 60 lb. rate of P_2O_5 was greater than that brought about by higher rates.

This effect is obviously a result of increase of the rooting system brought about by applied P, and the resultant greater volume of soil coming in contact with plant roots where P was applied. The increased soil-P uptake with increasing rate of P in the first cut of grass is a good indication of this effect. Another indication of the effect of rooting system is the marked increase of P-uptake from the untreated pots (P_0) in the successive cuts.

The alternative explanation for the marked effect of applied-P on soil P-uptake, is the slow isotopic exchange between labelled-P and soil-P. If equilibrium between the two sources is not

reached, the process of exchange would reduce the radioactivity of the soil solution. That is because the ^{32}P adsorbed by the soil is replaced by ^{31}P from the soil. Under these conditions the soil-P uptake will be apparently greater where labelled-P was applied. This explanation may be accepted for the increase in soil-P uptake brought about by P-application, in general, but it is not a feasible explanation for the effect of increasing rate of P on soil-P uptake in the first cut of grass. It would be expected that increasing the rate of applied-P will decrease the time required for reaching equilibrium between soil- and fertilizer-P in the soil. Thus increasing rate of P would not increase the soil-P uptake through isotopic exchange.

In the succeeding 3 cuts of grass all rates of applied P increased (* * *) the soil-P uptake, but this increase was decreasing with increased rate of P. In this case, the relatively small increases in soil P-uptake brought about by the high rates of P, could be a result of faster equilibrium between soil- and fertilizer-P, and the relatively greater increase brought about by the lowest rate of P is a result of slower isotopic exchange. The effect of applied-P on rooting system could be responsible for the general increase in soil-P uptake. Thus, the increases in soil-P uptake were brought about by the combined effect of applied-P on the rooting system and that of rate of P-application on the rate of isotopic exchange between soil- and fertilizer-P.

Similar increases in soil-P uptake, due to application of labelled-P, were reported by many workers including Spinks and Barber (1948), Woltz *et al.* (1949), Dolson and Ketcheson (1953),

Strzemienski (1953), Mattingly (1957[a]), Pleshkov and Mukhina (1957), Mattingly and Widdowson (1958), Bouldin and Black (1960), Andersen et al. (1961) and Jenkins (1962). They were generally in agreement with the above explanations. McConaghy and Stewart (1963) and Smiercholska (1963) explained the increase in soil-P uptake by increased root-growth brought about by applied-P, while Simpson (1962[a]) added that this may occur only on very low-P soils.

Many other workers (including Spinks et al., 1948; Spinks and Dion, 1949; Dean, 1954; McLean and Hoelscher, 1954; Mattingly and Widdowson, 1958; Dainty et al., 1959; Verma et al., 1959; and Simpson (1960[a,b] and 1962[a]) reported depressions in the uptake of soil-P as a result of P-applications, which contradicts with the results quoted above.

These reported increases and depressions in the uptake of soil-P, brought about by applied-P, may be largely due to the P-status of the soil. In soil of moderate to high-P status, response to applied-P is not usually great, thus the rooting system may not be greatly affected by applied-P and the result would be a depression in the soil-P uptake. That is because the freshly-applied P is more able, relative to the soil-P, to maintain P-concentration in the soil-solution following P-absorption by plant roots. Fig. 79 shows that the ratio of soil-P/fertilizer-P in plant was increasing with time, which supports this theory.

On the other hand, on a soil of low-P status, the response to applied-P is usually very great, as in these experiments, and the root-growth would be expected to increase greatly with P-application. This in turn would lead to increased uptake from soil-P, as well as from fertilizer-P, by plants.

FIG. 79. Effect of P-rate and time on the ratio of soil/labelled-P in grass. (EXPT. II).

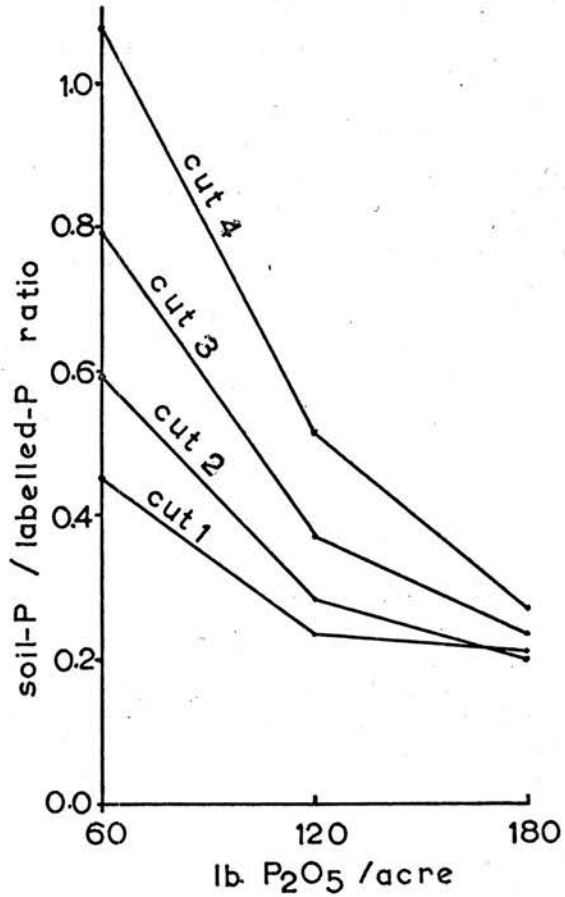
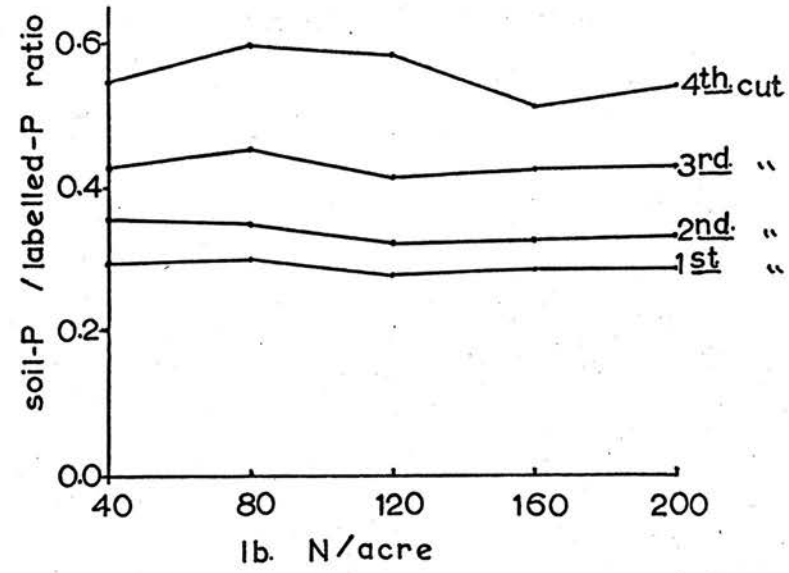


FIG. 80. Effect of N-rate and time on the ratio of soil-P/labelled-P in grass. (EXPT. II)



3. Effects of N Rate

Increasing rate of N-application greatly increased both yields of grass and P-uptakes in all cases where P was applied. In the early cuts of each experiment, increasing rate of N had very little effect unless P was applied (N x P interaction was very pronounced). On the other hand, increasing rate of N greatly decreased P-contents of the grass at least at the 0.01 level of significance in all cuts in all experiments except where N did not affect yields of grass. This decrease in P-content of the grass with increasing rate N is apparently due to great yield increases which brought about a dilution of the phosphorus absorbed by plants.

In the greenhouse experiment (1964), increasing rate of applied-N did not greatly affect the uptake of soil-P in the first two cuts while considerably increased it in the 3rd and 4th cuts of grass. The total P-uptake was increasing with increased rate of N in all cuts of grass but this effect was increasing with time in the successive cuts. The ratio of soil-P to fertilizer-P in the plant was not considerably affected by N rate (fig. 80) although it was increasing with time in the successive cuts of grass.

It is evident that the effect of N on both soil- and fertilizer-P uptake was greatly increasing with time in the successive cuts of grass. This could be due to one or more of the following factors; (1) in the early cuts of grass the low rates of N were sufficient to meet plant requirements of N, so that there was not much benefit from the higher rates of N;

(2) the size of the root-system was increasing so that the volume of soil in contact with plant roots was increasing; (3) the freshly fixed fertilizer-P was more easily "available" in the early cuts of grass and its availability decreased with time, thus becoming nearer to that of soil-P; and (4) in the later cuts of grass, plant roots were able to penetrate into the centre of the soil-crumbs where fertilizer-P may not have been present.

The first two factors may well explain the increasing effect of N on the total P-uptake in successive cuts, since it is well established that increasing the rate of N greatly enhances the growth of plant tops rather than roots. Thus in the early cuts of grass where the rooting system was still relatively small, the high rates of N did not show greater increases in growth than the lower rates. These two factors, however, cannot explain the effect of N-rate on the ratio of soil-P/fertilizer-P in the plant.

Any one of the last three factors may well explain the increase in soil-P/fertilizer-P ratio in the successive cuts, since the increase in rooting system, or the penetration of soil-crumbs by roots, or the decreased relative availability of fertilizer-P with time, tends to increase the relative uptake of soil-P. But only the 3rd factor may explain the differential effect of N-rate on the ratio of soil-P/fertilizer-P in the plant. Grunes (1959) suggested that fertilizer-P has greater ability than soil-P to maintain the P-concentration in the soil solution, by diffusion, following P-absorption by roots. This may well explain why practically all the increase in P-uptake, brought

about by increasing rate of N, came from labelled-P in the first two cuts of grass. In these two cuts the effect of increased rate of N on soil-P uptake was very small.

In the 3rd and, to a greater extent, in the 4th cut of grass the effect of increasing rate of N on the uptake of soil-P was very considerable, which may be a result of decrease in the relative "availability" of applied-P (factor, 3) with time.

The above discussion is more concerned with effect of N-rate on the P-uptake in different cuts of grass and the proportional absorption of soil-P and fertilizer-P by the grass. As to the effect of N and N x P interaction on P-uptake in general, there is not much argument in the literature about its existence. The argument is more concerned with the explanation of this remarkable effect.

Grunes (1959) made a comprehensive review of the effects of N on the soil- and fertilizer-P availability. He classified the effects of N into biological and chemical effects. The biological effects included root area and absorbing capacity, root efficiency, NH_4 ion effect, and effect of N on plant metabolism and ability of roots to absorb P. The chemical effects were salt- and pH effects.

Chemical effects of N-fertilizers on P-fertilizers or soil-P, have been suggested by many workers including Olson and Dreier (1956), Olson et al. (1956[a]), Yuen and Pollard (1957), Caldwell (1960), Simpson (1960[a]), Cooke (1961, 1963[b]) and Dev (1965), as an explanation for the effect of N on P-uptake. However, the effect of N-rate on the fertilizer-P uptake in the greenhouse

experiment was very pronounced compared with the effect of N-rate on the soil-P-uptake. This cannot be satisfactorily explained by chemical effects of N, otherwise the increasing rate of N would have increased the soil-P-uptake at least to the same degree as the fertilizer-P-uptake. It is, thus, more likely that this effect of N is due to increase in the absorbing capacity of the roots or the root area which may increase the uptake of any "available"-P.

Blanchar (1964) studied the mechanisms of the effect of NH_4 ion on the availability of fertilizer-P to plants. He reported that measurements of water-soluble P and other chemical properties around the fertilizer pellets had indicated no difference between $Ca(H_2PO_4)_2 + NH_4Cl$ and $Ca(H_2PO_4)_2 + HCl$. Hence he attributed the increase in P-uptake, due to NH_4, to an increase in the ability of plants to absorb P. Bennett et al. (1962), using water-, sand- and soil-cultures to study the effect of N on P-absorption by corn, concluded that neither the chemical effect of N nor the increase in weight of roots was of considerable importance in increasing P-absorption by corn and that a physiological stimulation of the plant is more likely. They suggested that applied-N generally results in an increased N-uptake as well as per cent N, hence larger amounts of N-compounds would be formed in the plant, and some of these compounds, particularly nucleoproteins, contain P. Other N-compounds require P for their formation, hence additional P would be used and absorbed if available. Barker and Bradfield (1963) reported that higher levels of applied-N increased the content of free amino acids of corn plants.

Cole et al. (1963) conducted a short-term experiment on P-uptake with corn plants pre-treated to establish different contents of N and P. These plants were placed in different phosphate solutions (labelled with ^{32}P) for 2 hours. They found that supplemental N-pre-treatments, producing increased growth rates and higher levels of N in the plants, stimulated the rate of P-uptake per unit dry weight of root more than did a tenfold increase in the P-concentration in the external solution. P-uptake rates were highly correlated to the total N-levels in the roots. The presence of NH_4 or NO_3 ions in the test solutions, during the uptake period, had negligible effect on the P-uptake rates. They also found that N-pre-treatments caused five to ten-fold increases in the rate of ^{32}P-translocation to the tops during the uptake period (2 hours).

On the other hand, Simpson (1962[a]) reported that N increased the uptake of both soil- and fertilizer-P by potatoes and that there was a strong positive correlation between yield of roots and P-uptake. Nielsen et al. (1963) also suggested that N stimulates the proliferation of roots which enables the plant to absorb more P. However, it is not unexpected that N may increase the root growth of plants, but it is also well established that the effect of N is more pronounced on increasing plant tops. Thus, a unit weight of roots would be expected to have a greater ability to absorb P (and probably other nutrients) to cope with the greater increase in vegetative growth. This was proved by the results, quoted above, of Cole et al. (1963) who used the unit weight of roots as a basis in their comparisons.

The question of the mechanism of increasing root absorbing-capacity by N is very difficult to answer. Drake and Stechel (1956) reported that root systems with high cation exchange capacity (C.E.C.) were more effective in obtaining P from soil and rock phosphate, and were two to three times as effective as the root systems of lower C.E.C. in solubilizing soil- and rock-phosphate for the following crop. The mechanism of P-release was believed to be a bonding of Ca by the root colloid to dissolve the rock phosphate, and the complexing of Al and Fe by organic anions to solubilize soil phosphates. At the same time, McLean et al. (1956) reported that additions of N increased the C.E.C. of roots of oat-plants grown in solution-culture. Kickuth (1965) also reported that organic acids, particularly quinic and glutamic, excreted by roots of sweet clover and lucerne liberated large amounts of P from slightly soluble phosphates, and that the effects were due to chelation rather than to pH. These mechanisms, however, may not explain the increase in P-uptake from solutions where P is in soluble form. Hagen and Hopkins (1955) discussed the mechanism of phosphate absorption by the plant in terms of binding sites (or compounds) on plant roots and Grunes (1959, 1960) suggested that N-applications, in some way, may increase the number or the activity of these binding sites or compounds. These results, mentioned above, indicate that N plays a part in the mechanism of the P-absorption by roots. On the other hand, the findings of Zuev and Golubeva (1959), Tueva (1960) and Cole et al. (1963), all using ^{32}P-labelled phosphates in culture solutions, leave no doubt that N plays an important role in the translocation

of P from the roots to the tops of the plant. Zuev and Golubeva (1959) also found that, under N-deficiency conditions, the percentage P of all P-fractions of the plant was greatly decreased. The decrease being most marked in the nucleuproteid fraction. The last observation may indicate that N is important for the metabolism of P in the plant. P was also shown to be necessary for protein formation in the plant, since Tueva (1960) found that the content of organic non-protein N was 0.68 per cent in pumpkin plants grown in complete nutrient solution, and 1.96 per cent in plants grown in P-deficient solution.

Although the exact role is not well defined, it is almost certain that N, or N-compounds in the plant, affects the absorption of P by the roots as well as both translocation and metabolism of the absorbed-P. P also plays an important role in the synthesis of the plant proteins and it is contained in some of them, particularly the nucleuproteins. This may explain the positive N x P interactions as well as the effect of N on P-uptake observed in these experiments.

(4) Effect of Method of Application

In experiment III (1964), the application of the P-fertilizers was in a band either in liquid or solid form. This was done after the results of the first experiment (1963) showed equal effectiveness of the different forms of P. It was then thought that the solution of the condensed phosphates as well as mixing with the entire soil in the pot had helped their hydrolysis. The liquid application was superior to the solid only on the acid soil and particularly with the highest rate of P (180 lb. P_2O_5/acre) which

may be a result of greater fixing capacity of the calcareous soil. This difference did not, in any case, affect the relative efficiency of the different forms of P, which may indicate that the solution of the condensed phosphates did not have any considerable effect on their hydrolysis.

Comparing the results of this experiment with those of the previous one (1963), it seems that banding the fertilizer is slightly in favour of the metaphosphates. The different forms demonstrated similar efficiency when mixed with the soil (experiment I, 1963), and the metaphosphates were slightly superior to the orthophosphate when banded. This may be explained by slightly greater diffusion of the metaphosphates in the soil, thus coming in contact with a greater volume of the roots. Alternatively, by temporarily unstable fixation of the metaphosphates in the form of PO_3 which is to be subsequently hydrolyzed and refixed in the form of PO_4. The latter explanation was discussed in more detail under the "effects of P-form".

The possibility of greater diffusion, in the soil, from the metaphosphates than from orthophosphates may not be of great importance even if it exists. Heslep and Black (1954) reported that the diffusion, in the soil, from a superphosphate band was slightly greater than from Ca-metaphosphate band, Even though, very little P diffused more than 2 cm. from the superphosphate-band a month after the addition. Blanchar and Caldwell (1966) also reported that P did not move more than 4 cm. from monocalcium phosphate pellets into the soil. Unfortunately, there are no available data in the literature, about the extent of diffusion

of water-soluble metaphosphates in the soil in comparison with orthophosphates.

However, since the two experiments were conducted on different soils and seasons, it is not very appropriate to draw too definite a conclusion.

(5) Important Interactions

The most important interactions were those of N x P and rate x form of P which have already been discussed above. Another interesting interaction is that between the rate of N and form of P. This interaction existed only in the greenhouse experiment and only in terms of total P-uptake in the 1st cut, ^{32}P-contents in the 2nd and 3rd cuts. In the three cases, the only consistent observation was that the trimetaphosphate (C) was slightly inferior to the orthophosphate (F) with the high rates of N-application. Differences between the metaphosphate glass and the other two were not consistent. Although the differences are not great, they indicate that only under great demand for P by plants, was the trimetaphosphate not as effective as the orthophosphate, which may be a result of relatively slow hydrolysis of the trimetaphosphate. Under normal atmospheric conditions (experiments I and III) as well as in all other parameters measured in the greenhouse experiment, this interaction was not significant.

In experiments I and III (in the cage), where different soils were used, there was no interaction between the soil and form of P, although there was interaction between the soil and rate of P or N in most cases. In experiment I, the responses, to increased

rate of P or N were greater on the neutral soil (Y) than on the acid soil (X), in terms of both yields and P-uptakes. In experiment III, the calcareous soil (D), similarly, produced greater responses than the acid soil (W). In both experiments the acid soils had greater organic matter-contents and produced greater yields and P-uptakes by the control pots (P_0) than the other two soils. This may explain the relatively smaller responses to increased rate of N or P on the two acid soils used. It is evident that the behaviour of the metaphosphates was very similar on both acid and calcareous soils. It had been thought ~~that~~ that soil acidity would play an important part in the hydrolysis of the metaphosphates. These results, however, are in agreement with those of other workers who tested water-soluble metaphosphates on soils of different pH values (Godfrey et al., 1959; Webb and Pesek, 1959; Lathwell et al., 1960; and Schmehl and Romsdal, 1963). On the other hand, water-insoluble condensed phosphates, particularly Ca-metaphosphate were found to behave differently on different soils, and were often inferior to ortho-phosphates on calcareous soils but not on acid soils (Ross and Jacob, 1937; Green, 1938; Toevs and Baker, 1939; Jacob and Ross, 1940; Hinkle, 1942; Olsen et al., 1956; Webb et al., 1961[a, b]; Almaras and Black, 1962 and Beaton et al., 1962). The inferiority of Ca-metaphosphate on calcareous soils was, in all cases, attributed to slower hydrolysis and dissolution.

From results of these experiments as well as those of other workers, quoted above, it is remarkable that the water-solubility of the meta- or polyphosphates is apparently very important in their availability to plants even under different soil-conditions.

(6) Isotopic Exchange in the Soil

The isotopic exchange between ^{32}P-fertilizers and soil-phosphate has been discussed in detail in the "review of literature" and briefly in different sections of the "discussion". This is further discussed in this section with special reference to the difference between polyphosphates and orthophosphates.

It was found from the results of experiment II, in which ^{32}P was used, that the metaphosphates, particularly the trimeta-phosphate, were inferior to the orthophosphate in terms of total P-uptake only in the first cut of grass. In terms of ^{32}P-uptake the trimetaphosphate was inferior to the orthophosphate in the 1st and 2nd cuts of grass. The difference between these two parameters, total- and ^{32}P-uptake, was explained by slower isotopic exchange between soil-P and the trimetaphosphate-P. Until equilibrium is reached, between soil- and fertilizer-P, the slow isotopic exchange tends to decrease the specific activity of the phosphates of the soil-solution. This may be demonstrated as follows:

$$^{32}P(\text{in solution}) + {}^{31}P\ (\text{on soil}) \rightleftharpoons {}^{31}P(\text{in solution}) + {}^{32}P(\text{on soil})$$

This was reported by many workers including McAuliffe et al. (1949) and Larsen (1952). Thus the longer the time to reach this equilibrium the longer the time during which the specific activity of P in solution may be reduced. This in turn will reduce the specific activity of the plant.

Do different forms of P undergo exchange at different rates?

Although there is no available published work on this subject,

it is well established that, at a given concentration, the ratio "size/valency" of an ion is a very important factor in its ability to replace another. The smaller the ratio the greater is this ability. This fact is obviously in favour of a greater ability of orthophosphate, than metaphosphate, to replace other anions on the solid phase of the soil.

As to the equilibrium between soil-P and applied metaphosphate, or any condensed-P, it could not be reached, with respect to ^{32}P, as long as the metaphosphate persists in the soil. That is because of its gradual hydrolysis which results in PO_4 anion which has a different ability of exchange than the original metaphosphate, thus equilibrium may not be reached. On the other hand, exchange of P atoms or PO_4 groups between metaphosphate, or any condensed-P, and soil-PO_4 or other form of P does not occur (Van Wazer, 1958). Even between orthophosphate and orthophosphate esters, P atoms or PO_4 groups do not exchange.

Thus, there is little doubt that reaching equilibrium between ^{32}P-metaphosphate, or any polyphosphate, and soil-PO_4 would take a longer time than that between ^{32}P-orthophosphate and soil-PO_4.

(7) Hydrolysis of Condensed-P in the Soil

The methods of extraction used are assumed to extract a portion of the phosphate, in soil, which gives a fairly good indication of the "available" phosphate status of the soil. It is not certain that this extractable-P, by any of the methods used, represents proportionally the different forms of phosphates in the

soil, particularly those of applied fertilizer. However, even if this extractable-P does not represent all forms of P in the soil, it represents the easily extractable P which is usually regarded as "available" to plants. The citric acid method of extraction produced a recovery of applied-P of about 50 per cent.

If the orthophosphate treated soil is used as a standard, the extractable PO_4 from soils treated with condensed-P may give a good indication of their behaviour in the soil. Since the quantities of extractable PO_4 were increasing with increased rate of applied-P, from soils treated with PO_4, there is no reason why the increases in extractable PO_4 from soils treated with condensed-P should not be a measure of the hydrolysis of these phosphates in the soil.

The quantities of extractable PO_4 from soils treated with condensed-P were smaller than those from soils treated with orthophosphate only in the first sampling (15 days of contact between soil and fertilizer, experiment I, 1963). This difference was considerable only on the acid soil (X) but not on the neutral soil (Y). The citric acid extractant showed this difference more obviously than did the bicarbonate, or NH_4 acetate-acetic acid extractant. This is an indication of a fairly fast hydrolysis of the condensed phosphates in the acid soil and faster hydrolysis in the neutral soil. By the 2nd sampling of this experiment (25 days after the 1st), applied condensed-P increased the extractable PO_4 (compared with P_0) as much as did the applied orthophosphate. This may indicate that a nearly complete

hydrolysis of the condensed-P had taken place in the soil. All 3 methods of extraction showed similar indications on both soils.

In experiment II, 1964, where ^{32}P-labelled fertilizers were mixed with the soil, the 1st soil sampling was taken only 5 days after mixing the fertilizer with the soil. From this first sampling about 50 per cent of the applied-P was extracted by the citric acid from both ortho- and metaphosphates. About 50 per cent of the extracted-fertilizer P from soils treated with metaphosphates was in the form of PO_4. This means that at least 25 per cent of applied-metaphosphates was hydrolysed in the soil under greenhouse conditions within 5 days. If the extracted-P is considered to represent the fertilizer-P in the soil the percentage hydrolysis will be about 50 per cent. The bicarbonate solution extracted much smaller quantities of P, in general, but showed similar trends to those of the citric acid solution as far as the comparison between forms is concerned.

It will be expected that, if plant roots were present in the soil, the rate of hydrolysis would be greater than that observed in the soil sampling pots without any plants growing in them, as a result of greater microbiological activity in the vicinity of the roots and also as a result of enzymatic hydrolysis by the plant roots. McGeorge (1939), reported that, in water cultures, a surprisingly rapid hydrolysis of metaphosphates to orthophosphate occurred when growing roots were present in the solution. This may indicate that plant roots are able to hydrolyse the condensed-P.

Extractable soil-P:

It was found that the soil extracts, of both citric acid and bicarbonate, contained considerable quantities of P-compounds which were not measured as inorganic orthophosphate. This was found in extracts of soils treated with orthophosphate as well as untreated soils. It is thought that these non-orthophosphates are organic phosphates which were hydrolyzed in boiling NH_2SO_4. Thus, it was difficult to measure with precision the extractable condensed-P from soils treated with condensed phosphates, particularly in experiment I, in all soil samplings, and in experiment II after the radioactivity of the extracts became too small to be measured. However, these quantities of soil non-orthophosphates, which fluctuated in different samplings during the season, were accounted for in calculating the percentage hydrolysis of metaphosphates in the soil.

It was thought that this extractable non-orthophosphate from the soil may be of important value for plants. For this, correlation coefficients were calculated between the extractable-P, from the first 3 soil samplings, 1963, and P-uptakes by plant in the first 3 cuts of grass, 1963. The correlation coefficients were very highly significant in all cases. The extracted non-orthophosphates from the soil seemed to be of slightly smaller value, to plants, than that of extracted PO_4, since the correlation coefficients were slightly smaller if the non-ortho-phosphate-P was included, although very highly significant in both cases.

Factors that affect hydrolysis of polyphosphates:

Hydrolysis of polyphosphates in aqueous solutions was reported (Van Wazer 1958) to be greatly affected by the following factors in decreasing order of their effectiveness: (1) Temperature, (2) pH, (3) Enzymes, (4) Colloidal gel, (5) Complexing cations, (6) Concentration, and (7) Ionic environment in solution.

Under certain conditions of pH, catalysts and other factors, the rate of hydrolysis will be about doubled for every 5°C rise in temperature. In a 1 per cent solution of tripolyphosphate, decreasing the pH from 7 to 4 reduced the time required for 5 per cent hydrolysis from about 2 months to about 10 days at a temperature of 30°C. He also reported that factors 2-7 describe catalytic effects. The hydrolysis of all chain and ring polyphosphates is strongly catalyzed by hydrogen ions.

The enzymatic hydrolysis of chain and ring phosphates can be extremely rapid under the right conditions. It is greatly affected by the presence of small amounts of certain metal ions and by pH and temperature. In general, divalent cations, especially Mg, are essential for the activity of phosphatases. The effect of colloidal gels such as hydrated oxides of Fe, Al, Co, Ni, and rare earths in accelerating the hydrolytic degradation of chain and ring polyphosphates is also very great.

The complexing effect of cations also increases the rate of hydrolysis; Ca ion gives a considerably greater increase than does Na.

As to the effect of concentration, it appears that the

hydrolysis of short-chain polyphosphates is truly a first-order process so that the rate of hydrolysis is exactly proportional to concentration.

The above author also reported that, at 20°C and pH 7, the half-life of the dissolved tripolyphosphate was greater than a year. The half-life was greatly reduced by decreasing pH and increasing temperature. Slack et al.(1965) also reported similar results.

Great effects of enzymes on the breakdown of polyphosphates, in solutions, were reported by Ingelman and Malmgren (1947, 1949), Malmgren (1949), Mattenheimer (1956[a,b]), and Karl-Kroupa et al. (1957).

In soils, the rate of hydrolysis of polyphosphates is much faster compared with that in aqueous solutions. In moist soils, the microbiological activity may play a great role in the hydrolysis of polyphosphates. Soil colloids (Michaels, 1958) also greatly increase the rate of hydrolysis of polyphosphates. Hydrated oxides of Fe, Al, Co, Ni and other minerals also accelerate the hydrolysis of condensed phosphates (Rotini, 1951; Rotini and Carloni, 1952 and Van Wazer, 1958). Other factors, such as complexing effect of cations, were reported to be of great importance (Van Wazer, 1958) in accelerating the hydrolysis of polyphosphates. Such cations, Ca, Mg and others, are existing in soils in great quantities.

Thus, there is every reason to believe that the rate of hydrolysis of polyphosphates should be much faster in soils than in solutions, since nearly all important factors that enhance the rate of hydrolysis, under certain conditions of pH and

temperature, are present in the soil. Rotini and Carloni (1952) reported that the half-life of Na-metaphosphate hydrolysis ranged between 30 days, in a loamy sand organic soil of pH 4.8, and 82 days in a clay soil of pH 5.8. Donso-Torres (1959) found that about 75 per cent of a Na-metaphosphate band was found to be hydrolyzed to orthophosphate after 46 days if the soil was kept in a vapour-saturated chamber at 20°C.

The effect of soil pH seems to be of less importance in the hydrolysis of condensed phosphates, compared with the biological activity effects, since in soils of higher pH values (about neutral), the microbiological activity is usually greater than that in soils of lower pH values. Thus, the great effects of microbiological activity, on hydrolysis of polyphosphates, would mask the effect of the soil pH in that respect.

Sutton and Larsen (1964) reported that the biological hydrolysis (that is, enzymatic) must be the most important factor involved in the hydrolysis of Na-pyrophosphate in soils. They also reported that the rate of hydrolysis was much higher in soils of greater biological activity and higher pH values. The half-life of sodium pyrophosphate ranged between 4 and 100 days in 12 soils tested. In soils of pH 7.0-7.6 (high biological activity) the half-life was between 4 and 10 days.

This remarkable effect of biological activity may well explain the greater hydrolysis observed in the neutral soil (Y) then in the acid soil (X) in the soil sampling pots of experiment I, 1963.

(8) The Possibility of Absorption of Polyphosphates by Plants

The remarkable equality of poly- and orthophosphates in experiment I, even in the 1st cut of grass, in terms of percentage-P as well as yields of D.M., brought up the idea of the possibility of direct absorption, of these forms, by plants, without prior hydrolysis. It was thought that under normal atmospheric conditions, the rate of hydrolysis of these forms would not be very fast. Thus, if P is to be absorbed by plants in the form of PO_4, the polyphosphates may not be as efficient as the orthophosphate in providing the plant with PO_4, at least in the first cut of grass. This was not the case. On the other hand, it was equally thought that the relatively slow rate of growth in this experiment and the remarkably rapid hydrolysis, found in the soil sampling pots, were important factors in demonstrating similar effectiveness of the different forms of P. Thus more information was required to clarify this matter.

The greenhouse experiment was, then, conducted with increased rates of N and K to enhance the rate of growth, and the phosphate-fertilizers were labelled with ^{32}P.

Results of this experiment showed that the metaphosphates were inferior to the orthophosphate, only in the first cut of grass, in terms of yield of D.M., total P-uptake and ^{32}P-uptake. There was no difference between forms in terms of P-content of the D.M., which may indicate that all absorbed-P had been utilized at the same degree of efficiency, with all forms, in increasing the growth.

Since the metaphosphates used are all water-soluble, one would believe that their inferiority to orthophosphate in the first cut of grass is due to their chemical form and the time required for their conversion to orthophosphate. The absorption of ^{32}P from the metaphosphates does not necessarily mean that they had been absorbed, by plants, in the condensed-form, since only 5 days after fertilizer-application to the soil-sampling pots, at least 50 per cent of the fertilizer-P recovered in extracts from soils treated with metaphosphates was in the form of PO_4. Thus, in soils with plants growing on them, at least a similar amount of hydrolysis would take place, which in turn favours the possibility that absorbed-P was in the form of PO_4.

Rogers et al. (1940) reported that excised roots of tomato and corn were not able to hydrolyze phytin or lecithin to a considerable extent, while tomato and corn plants absorbed both phytin and lecithin from solution cultures. The rate of uptake from phytin approached that of KH_2PO_4, but lecithin was absorbed more slowly. Thus, they concluded that phytin and lecithin were directly absorbed by plants. More recently, Kotelev and Nikova (1955) reported that ^{32}P-uptake from labelled lecithin was negligible under sterile conditions, but it was very considerable in the presence of microflora mineralizing organic phosphates. Szember (1960) reported that plant-roots are able to break down both phytin and lecithin under sterile conditions. When the growing medium (sterile sand or soil) was inoculated with soil micro-organisms, the breakdown of these compounds was enhanced. Gerretsen (1948) also demonstrated the considerable ability, of

both plant-roots and micro-organisms, to dissolve water-insoluble phosphates such as bonemeal, different rock phosphates, tricalcium phosphate, and iron phosphate.

Sutton and Larsen (1964) found that the rate of ^{32}P-absorption, by barley seedlings, from $Na_2H_2P_2O_7$-solution was only 40 per cent of that from NaH_2PO_4-solution. They suggested that this difference was due to the difference in valency of the two forms. This explanation may not be very satisfactory since the pyro-phosphate, they used, is similar in valency to the orthophosphate ($H_2P_2O_7^{=}$ and $H_2PO_4^{-}$) per atom of P. Thus it must have been either the size of ion or the rate of hydrolysis, that was responsible for the smaller rate of absorption from the pyrophosphate. In soil-culture, however, they found that both pyro- and orthophosphate were very similar on a soil of high biological activity, but the pyrophosphate was inferior on a sandy acid soil of low biological activity. This was attributed to the rate of hydrolysis of the pyrophosphate.

It is worth remembering that the pyrophosphate, mentioned above, is the simplest form of condensed phosphate. Hence, it would be expected that the absorption of highly polymerized phosphates, by plant-roots, would be even smaller than from the pyrophosphate. Thus, direct absorption of condensed-P could not be responsible for the similarity between the orthophosphate and polyphosphates used in this series of experiments.

VI. CONCLUSIONS AND SUMMARY

Three pot experiments were carried out during the seasons 1963-64 to investigate the "availability" to plants of some Na-condensed phosphates in comparison with Na-orthophosphate. Two of the experiments were carried out in a wire cage open to atmospheric conditions, and the third was conducted in a greenhouse. Ryegrass was the test plant in all the experiments. Different soils, including a calcareous soil, were used. The effect of N on both soil- and fertilizer-P uptake was studied in the greenhouse experiment using ^{32}P-labelled fertilizers. Hydrolysis of condensed-phosphates in the soil was also studied in soil-sampling pots with no grass on them.

Different rates of P (0, 60, 120 and 180 lb. P_2O_5/acre) were used in all experiments. P-fertilizers were thoroughly mixed with the soil-sand mixture in two experiments, and banded $2\frac{1}{2}$ in. below the seed-level in the third experiment. All P-treatments were done just before seeding. Mg was applied as a basal dressing during the early stages of growth in all experiments. K was applied as a basal dressing in the two cage experiments, while in the greenhouse experiment, it was applied at similar rate to N, at the beginning of the experiment and after each cut of grass. Nitrogen was applied as NH_4NO_3 at rates of 40 and 80 lb. N/acre per cut in the two cage experiments, and 40, 80, 120, 160 and 200 lb. N per acre per cut, in the greenhouse experiment.

The results obtained and conclusions reached may be

summarised as follows:-

1. In the first cage experiment (1963) condensed-phosphates were as effective as the orthophosphate in terms of yield-production, percentage P in the dry matter, and P-uptake. This was not affected by the rate of N or by the soil.

2. The residual effect of all forms of P was very similar in the second season (1964) of the first cage-experiment.

3. In the second cage experiment, where P-fertilizers were banded, the metaphosphates were superior to the orthophosphate only in terms of percentage P of the dry matter and P-uptake, but not in terms of dry matter-production.

4. In the greenhouse experiment, the two metaphosphates (trimeta-phosphate and metaphosphate glass) were slightly, but significantly, inferior to the orthophosphate only in the first cut of grass. This was found in terms of yield-production or of P-uptake, but not in terms of percentage P of the dry matter.

5. The metaphosphate glass tended to be slightly more effective than the ring-structured trimetaphosphate. The former probably hydrolyses more rapidly in the soil.

6. The similar effectiveness of both polyphosphates and ortho-phosphates, in increasing yields or P-uptakes by grass, is thought to be a result of fast hydrolysis of the polyphosphates. The rate of hydrolysis seems to be sufficient to meet plant-requirements of PO_4 under normal soil-conditions, in the cage experiments, where the rate of growth is relatively slow. In the greenhouse, where the rate of growth is very rapid, the rate of hydrolysis of

metaphosphates may not be sufficiently fast to cope with plant-requirements of PO_4 particularly in the early stages of growth.

7. The slightly greater P-contents of dry matter produced by the metaphosphates, compared with those produced by the orthophosphate, in the second cage experiment, were explained by gradual hydrolysis of the metaphosphates in the soil, since the three forms produced similar yield-increases. This behaviour was similar on both acid and calcareous soils.

8. In the greenhouse experiment, the metaphosphates were equivalent to the orthophosphate, after the first cut, in terms of yield-production and total P-uptake, but they produced slightly smaller uptakes of labelled-P than the orthophosphate. This was explained by a slower isotopic exchange, in the soil, between applied-metaphosphate and soil-P. It is also suggested that equilibrium between soil-P and applied ^{32}P-metaphosphates may not be attained before their hydrolysis in the soil.

9. The possibility of direct absorption of polyphosphates by plants was discussed, but needs more study.

10. The rate of hydrolysis of the metaphosphates in the soil is extremely rapid. It was also found that the hydrolysis was faster on a neutral soil than on an acid soil. This was probably due to greater microbiological activity, therefore greater enzymic hydrolysis, on the neutral- than on the acid soil.

11. The effects of applied-P, as well as increasing its rate of application, were very pronounced in increasing yields, P-uptakes,

and P-contents of the grass. The responses to applied-P were increasing up to the highest rate, 180 lb. P_2O_5/acre, in most cases. The mean-apparent recoveries as per cent of applied-P were; 10.6 in 3 cuts of the cage experiment I (1963); 9.9 in 3 cuts as the residual effect in the second season of the cage experiment I; 35.4 in 8 cuts of the greenhouse experiment II (1964); and 14.1 in 3 cuts of the cage experiment III (1964). Factors that affected the per cent apparent recovery were; soil, rate of N, rate of P and rate of growth.

12. Where labelled-P was used, P-applications increased the uptake of soil-P. This effect was greatest early in the season and decreased with time. Possible explanations given were increased rooting system, slow isotopic exchange, and decreasing availability of applied-P with time.

13. Increasing rate of applied-N greatly increased yields as well as P-uptakes, particularly where P was applied. N considerably decreased percentage P of the dry matter which was probably a result of a dilution effect brought about by great yield-responses to N. In the greenhouse experiment, there was no considerable difference between yields produced by the highest two rates of N (160 and 200 lb. N/acre/cut).

14. N x P interaction was very pronounced in most cases. The increasing response to applied-P with increased rate of N was explained by effects of N in promoting growth, increasing the quantity of N-compounds in the plant, increasing the root-capacity for P-absorption, and speeding up P-metabolism.

15. 'A'-values, calculated from ^{32}P-measurements, were not considerably affected by rate of applied-N. Increasing rate of applied-P increased the 'A'-values in the 1st cut while decreasing them in the 4th cut of grass. For totals of 2, 3 or all 4 cuts of grass the 'A'-values were not affected by P-rate. The metaphosphates produced greater 'A'-values than did the orthophosphate.

16. In the greenhouse, sub-irrigation can be troublesome, particularly with high rates of fertilizer-application. Surface irrigation may be necessary to avoid salt-accumulation on the soil-surface.

17. If metaphosphates can be produced at $\overset{a}{\lambda}$ cost comparable to that of orthophosphates, they can well be a good substitute as a source of P for plants. Having the advantage, over the orthophosphates, of being of higher P-contents, they can also be more useful than orthophosphates in manufacturing concentrated compound-fertilizers.

VII. ACKNOWLEDGEMENTS

The author acknowledges with deep gratitude the advice and guidance given by Dr. A.M. Smith during the first year, and by Mr. K. Simpson and Mr. P. Crooks throughout the course of this investigation. Thanks are also due to the Research Staff of Scottish Agricultural Industries for supplying the polyphosphates used in this investigation; members of staff in the Soil's Department of the Edinburgh School of Agriculture who assisted with the practical work; Mr. G. Ross and Mr. C.W. Fearne of Rothamsted Experimental Station for their help in programming and computing the results for the statistical analysis; and to Dr. E. Jean MacKenzie of the Spectrochemistry Department for reading the typed copy.

VIII. BIBLIOGRAPHY

Allison, F.E.; Pinck, L.A. and Sherman, M.S. 1941. Comparative availabilities of organic and inorganic phosphates as shown by Neubauer method. J. amer. Soc. Agron., 33, 918-26.

Allmaras, R.R. and Black, C.A. 1962. Relative value of calcium metaphosphate and superphosphate as sources of phosphorus for plants on different soils. Soil Sci. Soc. Amer. Proc., 26, 470-75.

Allmaras, R.R. and Black, C.A. 1965. Hydrolysis of condensed phosphates in soils. Soil Sci. Soc. Amer. Proc., 29, 487-88.

Alston, A.M. 1964. Ph.D. Thesis, Edinburgh University.

Alway, F.J. and Nesom, G.H. 1944. Effectiveness of calcium metaphosphate and fused rock phosphate on alfalfa. J. amer. Soc. Agron., 36, 73-88.

Andersen, A.; Hansen, G.B. and Nielsen, G. 1961. Determination of the phosphate condition of soils by means of radio-active phosphorus in pot experiments. Acta. Agric. Scand., 11, 270-90.

Armitage, E.R. 1957. Measurement of fertilizer phosphorus uptake and radiation damage using radio-phosphorus. Chem. Ind. No.47, 1533-34.

Arnon, D.I. 1953. The physiology and biochemistry of phosphorus in green plants. Agronomy Monograph Series, 4, 1953, 1-42.

Baker, G.O. 1942. Comparative values of various phosphate carriers determined. Idaho agric. expt. Sta. Bull. No. 251, 9-10.

Barbier, G.; Lesaint, L. and Tyszkiewicz, E. 1954. (Investigations, by means of isotopes, of autodiffusion phenomena in soil and of nutrition of plants.) Ann. Agron. Paris, 5, 923-59. Abst. in Soils and Fert., 18, 1446.

Barker, A.V. and Bradfield, R. 1963. Effect of potassium and nitrogen on the free amino acid content of corn plant. Agron. J., 55, 465-70.

Bartholomew, R.P. and Jacob, K.D. 1933. Availability of iron, aluminium, and other phosphates. J. Assoc. Offic. Agric. Chem., 16, 598-611.

Beaton, J.D. and Gough, N.A. 1962. The Influence of soil moisture regime and phosphorus source on response of alfalfa to phosphorus. Soil Sci. Soc. Amer. Proc., 26, 265-70.

Beaton, J.D.; Read, D.W.L. and Hinman, W.C. 1962. Phosphorus uptake by alfalfa as influenced by phosphate source and moisture. Canad. J. Soil Sci., 42, 254-65.

Bennett, W.F.; Pesek, J. and Hanway, J. 1962. Effect of nitrogen on phosphorus absorption by corn. Agron. J., 54, 437-42.

Blanchar, R.W. 1964. A study of mechanisms for the effect of ammonium on the availability of fertilizer phosphorus to plants. Diss. Abstr., 25, 2694.

Blanchar, R.W. and Caldwell, A.C. 1966. Phosphate-ammonium-moisture relationships in soils. I. Ion concentration in static fertilizer zone and effects on plants. Soil Sci. Soc. Amer. Proc., 30, 39-43.

Blaser, R.E. and McAuliffe, C. 1949. Utilization of phosphorus from various fertilizer materials: I. Orchard grass and Ladino clover in New York. Soil Sci., 68, 145-50.

Bould, C.; Nicholas, D.J.D. and Thomas, W.D.E. 1951. Radiation effects in plant nutrition experiments with phosphorus-32. Nature, Lond., 167, 140-42.

Bould, C.; Nicholas, D.J.D. and Thomas, W.D.E. 1952. Radiation effects with phosphorus-32 in barley and tomato grown in soil. Trans. int. Soc. Soil Sci. II and IV 1952, 2, 92-94.

Bould, C.; Nicholas, D.J.D. and Thomas, W.D.E. 1953. Radiation effects with radioactive phosphorus in barley and tomato grown in soil. Plant & Soil, 5, 36-53.

Bould, C.; Thomas, W.D.E. and Tolhurst, J.A.H. 1954. Cover crops in relation to soil fertility and fruit tree nutrition: The effect of grass on the uptake of total and fertilizer phosphate by Malling I rootstocks. J. hort. Sci., 29, 301-9.

Bouldin, D.R. and Black, C.A. 1960. Fertilizer evaluation: IV. Use of P^{32}-labelled fertilizers. Soil Sci. Soc. Amer. Proc., 24, 491-6.

Brown, B.E. and Clark, K.G. 1943. An appraisal to calcium and potassium metaphosphates as sources of phosphorus for crop plants. Amer. Fert., 98, (5), 10-11.

Bureau, M.F.; Mederski, H.J. and Evans, C.E. 1953. The effect of phosphatic fertilizer material and soil phosphorus level on the yield and phosphorus uptake of Soybeans. J. amer. Soc. Agron., 45, 150-54.

Caldwell, A.C. 1960. The influence of various nitrogen carriers on the availability of fertilizer phosphorus to plants. 7th int. Congr. Soil Sci., 1960, 3, 517-25.

Caldwell, A.C.; Hustrulid, A. and Hammers, F.L. 1956. Residual availability in the soil of various sources of phosphate as measured by plant absorption of P^{32} and by soil test. Soil Sci. Soc. Amer. Proc., 20, 25-28.

Chandler, R.F. and Musgrave, R.B. 1944. A comparison of potassium chloride and potassium metaphosphate as sources of potassium for plants. Soil Sci. Soc. Amer. Proc., 9, 151-53.

Cole, C.V.; Grunes, D.L.; Porter, L.K. and Olsen, S.R. 1963. The effect of nitrogen on short-term phosphorus absorption and translocation in corn (Zea Mays). Soil Sci. Soc. Amer. Proc., 27, 671-74.

Cooke, G.W. 1956. Field experiments on phosphate fertilizers. J. agric. Sci., 48, 74-103.

Cooke, G.W. 1961. Effects of ammonium sulphate and sodium nitrate on solubility of soil phosphate. Rothamsted expt. Sta. Report for 1961, 53-54.

Cooke, G.W. 1963. Valuing phosphate fertilizers in glasshouse experiments. Rothamsted expt. Sta. Report for 1963, 51.

Cooke, G.W. 1963[a]. General principles governing the potassium manuring of grassland. "Potassium in relation to grassland production" Proc. 1st. veg. Conf. int. Potash Institute., 71-82.

Cooke, G.W. 1963[b]. The effect of forms of N on growth and P-uptake by ryegrass grown on calcareous soils. Rothamsted expt. Sta. Report for 1963, 58.

Curtis, H.A.; Copson, R.L.; Adams, A.J. and Junkins, J.N. 1938. Reported by Jones, R.J. and Rogers, H.T. 1949.

Dainty, J.; Verma, R.D. and Simpson, K. 1959. Studies on the uptake of phosphorus from ^{32}P-labelled superphosphate by crops. II, Potatoes. J. Sci. Fd Agric., 10, 108-114.

Dean, L.A. 1954. Yield-of-phosphorus curves. Soil Sci. Soc. Amer. Proc., 18, 462-6.

Dean, L.A.; Neilson, W.L.; MacKenzie, A.J.; Armiger, W.H. and Hill, W.L. 1947. Application of radioactive tracer technique to studies of phosphatic fertilizer utilization by crops. I. Greenhouse experiments. Soil Sci. Soc. Amer. Proc., 12, 107-112.

DeMent, J.D.; Terman, G.L. and Bradford, B.N. 1963. Crop response to phosphorus and potassium in potassium phosphates varying widely in particle size. J. Agric. Fd Chem., 11, 207-12.

Dev, G. 1965. Pot experiments to study the effect of nitrogen on the efficiency of fertilizer phosphorus. II. Agrochimica, 9, 242-48.

Dion, G.; Bedford, C.F.; Arnaud, R.T.St. and Spinks, J.W.T. 1949. Plant Injury from phosphorus-32. Nature, Lond., 163, 906-7.

Doerell, E.G. 1941. (Metaphosphate as a phosphoric-acid fertilizer and its testing in pot experiments). Forsch Dienst. Sonderh., 15, 71-82. Abstr. in Soils and Fert., 7, 223.

Dolson, D.D. and Ketcheson, J.W. 1953. A study of soil and fertilizer phosphorus on a calcareous soil by oat plants, using radio-active tracer technique. Canad. J. agric. Sci., 33, 225-30.

Donso-Torres, J. 1959. (Reactions of metaphosphates in soils.) Diss. Abstr., 19, 2732.

Drake, M. and Steckel, J.E. 1955. Solubilization of soil and rock phosphate as related to root cation exchange capacity. Soil Sci. Soc. Amer. Proc., 19, 449-50.

Dyer, B. 1894. Analytical estimation of probably available mineral plant food in soils. Trans. Chem. Soc. T65, 115-67. Reported by Hibbard, P.L. 1931.

Ensminger, L.E. 1950. Response of crops to various phosphate fertilizers. Alab. agric. expt. Sta. Bull. No 270, 39.

Fried, M. 1953. The feeding power of plants for phosphates. Soil Sci. Soc. Amer. Proc., 17, 357-9.

Fried, M. 1954. Quantitative evaluation of processed and natural phosphates. J. Agric. Fd. Chem., 2, 241-4.

Fried, M. and Dean, L.A. 1952. A concept concerning the measurement of available soil nutrient. Soil Sci., 73, 263-71.

Gerretsen, F.C. 1948. The influence of microorganisms on the phosphate intake by plant. Plant & Soil, 1, 51-81.

Godfrey, C.L.; Fisher, F.L. and Norris, M.J. 1959. A comparison of ammonium metaphosphate and ammonium orthophosphate with superphosphate on the yield and chemical composition of crops grown under field conditions. Soil Sci. Soc. Amer. Proc., 23, 43-46.

Golden, L.E. 1961. Availability of native and radioactive fertilizer phosphorus to oats on Lake Charles clay. Soil Sci., 91, 349-55.

Green, J.R. 1938. Phosphate investigations on irrigated crops. Montana agric. expt. Sta. Bull. No. 356.

Grunes, D.L. 1959. Effect of nitrogen on the availability of soil and fertilizer phosphorus to plants. Advanc. Agron. 11, 369-96.

Grunes, D.L. 1960. Nitrogen affects the relative availability of soil and fertilizer phosphorus to plants. 7th int. Congr. Soil Sci., 1960, 3, 307-13.

Grunes, D.L.; Haas, H.J. and Shih, S.H. 1955. Effect of long-time dryland cropping on available phosphorus of Cheyenne fine sandy loam. Soil Sci., 80, 127-38.

Grunes, D.L.; Haise, H.R.; Turner, F and Alessi, J. 1963. Relationship between yield response to applied fertilizers and laboratory measures of nitrogen and phosphorus availability. Soil Sci. Soc. Amer. Proc., 27, 675-79.

Gunary, D. 1963. Behaviour of carrier-free phosphorus-32 in natural soils in relation to the measurement of labile soil phosphorus. J. Sci. Fd Agric., 14, 319-24.

Gunnarsson, O. and Fredriksson, L. 1952. A method for determining the amount of "plant available" phosphorus by means of P^{32}. Bull. Docum. I.S.M.A. No.15,16-20.

Hagen, C.E. and Hopkins, H.T. 1955. Ionic species in orthophosphate absorption by barley roots. Plant Physiology, 30, 193-99.

Hagin, J. 1962. Comparison of the efficiency of some phosphatic fertilizers on various soil types of Israel. Israel J. agric. Res., 12, 1-12. Abstr. in Bull. Docum. I.S.M.A. No. 35, 73-75.

Hall, N.S.; Nelson, W.L.; Krantz, B.A.; Welch, C.D. and Dean, L.A. 1949. Utilization of phosphorus from various fertilizer materials: II. Cotton and corn in North Carolina. Soil Sci., 68, 151-56.

Hanson, W.C. 1950. Photometric determination of phosphorus in fertilizers using phosphovanadomolybdate complex. J. Sci. Fd Agric., 1, 172-73.

Harris, F.J. 1963. Potassium metaphosphate: A novel method of manufacture and a summary of its behaviour as a fertilizer. Proc. Fertil. Soc. No.76.

Hende, A. van den.; Cottenie, A. and Jonghe, P.de. 1952. Trans. int. Soc. Soil Sci., 1952, 2, 307-17.

Hende, A. van den.; Cootenie, A. and Loose, R.De. 1958. Influence of plant type and of quantity of phosphate applied on the degree of utilization of labelled phosphates. Proc. 2nd U.N. int. Conf. Peaceful Uses of Atomic Energy, 142-45.

Hendricks, S.B. and Dean, L.A. 1950. Use of P^{32} in measurement of fertilizer effectiveness under field conditions. Trans. 4th int. Congr. Soil Sci., 1950, 1, 221-23.

Heslop, J.M. and Black, C.A. 1954. Diffusion of fertilizer phosphorus in soils. Soil Sci., 78, 389-401.

Hevesy, G.; Linderstøm-Lang, K. and Olsen, C. 1936. Atomic dynamics of plant growth. Nature, Lond., 137, 66-67.

Hibbard, P.L. 1931. Chemical methods for estimating the availability of soil phosphate. Soil Sci., 31, 437-66.

Hill, W.L. and Armiger, W.H. 1955. Fertilizer value of some non-orthophosphates and anhydrous orthophosphates of calcium under millet in greenhouse culture. J. Ass. Offic. Agric. Chem., 38, 881-88.

Hinkle, D.A. 1942. Efficiency of various phosphate fertilizers on calcareous soils for alfalfa and sweet clover. J. Amer. Soc. Agron., 34, 913-8.

Honya, K.; Ueki, S. and Kakizaki, T. 1961. (The prevention of a decrease in available phosphoric acid. 5. Field experiments on the effects of ammoniated complex fertilizers containing sodium polyphosphates on the yield of paddy rice. 1.) J. Sci. Soil Tokyo, 32, 311-4. Soil Sci. & Plant Nutr., 7, 130-31.

Hougland, G.V.C.; Clark, K.G.; Hawkins, A. and Campbell, J.C. 1942. Nutrient value of some new phosphatic materials used on potatoes. Amer. Fert., 97, (7), 5-8, 24, 26.

Ingelman, B. and Malmgren, H. 1947. Enzymatic Breakdown of polymetaphosphate. Acta. Chem. Scand., 1, 422-32.

Ingelman, B. and Malmgren, H. 1949. Enzymatic Breakdown of polymetaphosphate, III. Acta. Chem. Scand., 3, 157-62.

Jackson, M.L. 1958. "Soil chemical analysis", 1st Ed., 141-144. Constable & Co. LTD. Publ., 10 Orange St., London, W.C.2.

Jacob, K.D. and Ross, W.H. 1940. Nutrient value of the phosphorus in defluorinated phosphates, calcium metaphosphate, and other phosphatic materials, as determined by growth of plants in pot experiments. J. agric. Res., 61, 539-60.

Jenkins, W.L. 1962. The yield and uptake of phosphorus by grasses and clovers. I. The effect of "acetic soluble", "residual" and "placed" phosphorus. J. brit. Grassl. Soc., 17, 17-29.

Jones, R.J. and Rogers, H.T. 1949. New fertilizers and fertilizer practices. Advanc. Agron., 1, 39-76.

Karl-Kroupa, E.; Callis, C.F. and Seifter, E. 1957. Stability of condensed phosphates in very dilute solutions. Ind. Eng. Chem., 49, 2061-2.

Kasal, Z. and Kinugawa, K. 1956. (Effect of P^{32} radiation on the development rice and kidney-bean seedlings). J. Sci. Soil Tokyo, 27, 109. Abstr. in Soils & Fert., 20, 221.

Kickuth, R. 1965. (Phosphorus mobilization in the rhizosphere) Sonderh. Landw. Forsch., 12, 103-109. Abstr. in Soils & Fert., 29, 437.

Kotelev, V.V. and Nikova, V.I.S. 1955. (The influence of bacteria mineralizing organic phosphorus compounds on the uptake of the latter by plants.) Izv. moldav. Fil. Akad. Nauk. No.1, 21, 3-8. Abstr. in Soils & Fert., 20, 228.

Lamm, C.G. 1961. A study of isotopic exchanges and chemical conversions between fertilizer-phosphorus and soil-phosphorus. Acta. Agric. Scand., 11, 95-113.

Larsen, S. 1952. The use of P^{32} in studies on the uptake of phosphorus by plants. Plant & Soil, 4, 1-10.

Larsen, S. 1956[a]. The application of radio-isotopes in the study of soil fertility. Bull. Docum. I.S.M.A., No.20, 22-30.

Larsen, S. 1956[b]. The influence of lime on the "L-value". Trans. 6th. int. Congr. Soil Sci., A, 221-22.

Larsen, S. 1956[c]. The influence of nitrate fertilization on the "L-value" of a soil. Trans. 6th. int. Congr. Soil Sci., A, 221.

Larsen, S. and Cooke, I.J. 1961. The influence of radio-active phosphate level on the absorption of phosphate by plants and on the determination of labile soil phosphate. Plant & Soil, 14, 43-7.

Lathwell, D.J.; Cope, J.T. and Webb, J.R. 1960. Liquid fertilizers as source of phosphorus for field crops. Agron. J., 52, 251-4.

Lawton, K. and Davis, J.F. 1956. The effect of liming on the utilization of soil and fertilizer phosphorus by several crops grown on acid organic soils. Soil Sci. Soc. Amer. Proc., 20, 522-6.

Lesaint, M.; Tyszkiewicz, E. and Barbier, G. 1955. (Validity of physical determination, by isotopic dilution, of available soil phosphate). C.R. Acad. Agric. Paris, 41, 350-53. Abstr. in Soils & Fert., 18, 2421.

McAuliffe, C.; Peech, M. and Bradfield, R. 1949. Utilization by plants of phosphorus in farm manure: II. Availability to plants of organic and inorganic forms of phosphorus in sheep manure. Soil Sci., 68, 185-95.

McConaghy, S. and Stewart, J.W.B. 1963. Availability of soil and fertilizer phosphates to growing crops. J. Sci. Fd Agric., 14, 329.

McGeorge, W.T. 1939. Factors influencing the availability of native soil phosphate and fertilizers in Arizona soils. Ariz. agric. expt. Sta. tech. Bull. No. 82, 295-331.

MacIntire, W.H.; Hardin, L.J. and Oldham, F.D. 1937. Calcium metaphosphate fertilizers, chemical composition and properties. J. Ind. Eng. Chem., 29, 224-34.

MacIntire, W.H.; Shaw, W.M. and Robinson, B. 1953. Differential behaviour of potassium metaphosphate and sulphate incorporation in soils. Soil Sci., 75, 69-80.

MacIntire, W.H.; Winterberg, S.H.; Hardin, L.J.; Sterges and Clements. 1950. Fertilizer evaluation of certain phosphorus, phosphorous and phosphoric materials by means of pot cultures. J. amer. Soc. Agron., 42, 543-9.

McLean, E.O.; Adams, D. and Franklin, R.E. 1956. Cation exchange capacities of plant roots as related to their nitrogen contents. Soil Sci. Soc. Amer. Proc., 20, 345-7.

McLean, E.O. and Hoelscher, J.E. 1954. Factors affecting yields and uptake of phosphorus by different crops: I. Previous applications to the soil of rock phosphate and superphosphate. Soil Sci., 78, 453-62.

Madorsky, S.L. and Clark, K.G. 1940. Potassium metaphosphate a potential high-analysis fertilizer material. J. Ind. Eng. Chem., 32, 244-8.

Malmgren, H. 1949. Enzymatic breakdown of polymetaphosphate. IV. The activation and inhibition of the enzyme. Acta. Chem. Scand., 3, 1331-42.

Martin, R.P. and Russell, R.S. 1954. Studies with radioactive tracers in plant nutrition. 3. The effect of radiation from phosphorus-32 on the growth and phosphate utilization of barley seedlings. J. exp. Botany, 5, 91-109.

Mattenheimer, H. 1956[a]. (Substrate specifity of "inorganic" poly- and metaphosphatases. I. Optimum conditions for the enzymatic degradation of poly- and metaphosphatases). Hoppe-Seyler's Z. physiol. Chem., 303, 107-14. Abstr. in C.A., 50, 11382[i].

Mattenheimer, H. 1956[b]. (Substrate specifity of "inorganic" poly- and metaphosphatases. III. Paperchromatographic analysis during the enzymic degradation of inorganic poly- and metaphosphates). Hoppe-Seyler's Z. physiol. Chem., 303, 125-39. Abstr. in C.A., 50, 11383[e].

Mattingly, G.E.G. 1957. The use of isotope ^{32}P in recent work on soil and fertilizer phosphorus. Soils & Fert., 20, No.2, 59-68.

Mattingly, G.E.G. 1957[a]. Effects of radioactive phosphate fertilizers on yield and phosphorus uptake by ryegrass in pot experiments on calcareous soils from Rothamsted. J. agric. Sci., 49, 160-8.

Mattingly, G.E.G. 1963. The agricultural value of some water and citrate soluble fertilizers: An account of recent work at Rothamsted and elsewhere. Proc. Fertil. Soc., No.75.

Mattingly, G.E.G. 1965. Personal communication, Nov. 1965.

Mattingly, G.E.G. and Widdowson, F.V. 1958. Uptake of phosphorus from P^{32}-labelled superphosphate by field crops. Part II. Comparison of placed and broadcased applications to barley. Plant & Soil, 10, 161-75.

Michaels, A.S. 1958. Deflucculation of kaolinite by alkali polyphosphates. J. Ind. Eng. Chem., 50, 951-58.

Mondrzak-Rosenberg, G. and Hagin, J. 1964. Comparison and evaluation of several phosphatic fertilizers. Israel J. agric. Res., 14, 37. Abstr. in Bull. Docum. I.M.S.A., 1965, No.40, 39.

Munk, S. 1963. (The fertilizing effect of potassium metaphosphate). Zeitschr. Pflanzenern. Dungo Bodenk., 101, No.1, 34-42. Abstr. in Bull. Docum. I.M.S.A. 1963, No.36, 55-6.

Nielsen, K.F.; Carson, R.B. and Hoffman, I. 1963. A study of ion interactions in the uptake of nitrogen, phosphorus, potassium, calcium, chlorine and sulfur by corn. Soil Sci., 95, 315-21.

Norum, E.B. and Young, R.A. 1950. Effect of rate, method of application, and source of phosphate fertilizers on yield of wheat and durum. N. Dak. agric. expt. Sat. Bimo. Bull., 12, 125-8. Abstr. in Soils & Fert., 13, 1960.

Nye, P.H. and Foster, W.N.M. 1956. Do plants vary in their ability to utilize less readily available soil phosphate? Trans. 6th. int. Congr. Soil Sci., D, 257-62.

Nye, P.H. and Foster, W.N.M. 1958. A study of the mechanism of soil-phosphate uptake in relation to plant species. Plant & Soil, 9, 338-52.

O'Brien, R.E. 1944. Field experiments with phosphatic fertilizers. Virginia agric. expt. Sta. Bull., 364, 26.

Odland, T.E.; Bell, R.S. and Salomon, M. 1956. A field comparison of eight phosphate fertilizers. Agron. J., 48, 409-12.

Olsen, S.R. and Gardner, R. 1949. Utilization of phosphorus from various fertilizer materials: IV. Sugar beets, wheat, and barley in Colorado. Soil Sci., 68, 163-9.

Olsen, S.R.; Cole, C.V.; Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Circ. No.939, 19

Olsen, S.R.; Schmehl, W.R.; Watanabe, F.S.; Frank, S.; Scott, C.O.; Fuller, W.H.; Jordan, J.U. and Kunkel,R. 1950. Utilization of phosphorus by various crops as affected by source of material and placement. Colo. agric. expt. Sta. tech. Bull. 42, 43.

Olsen, S.R. and Watanabe, F.S. 1959. Behaviour of P^{32} in tracer studies. Soil Sci., 88, 256-9.

Olson, R.A. and Dreier, A.F. 1956. Nitrogen, a key factor in fertilizer phosphorus efficiency. Soil Sci. Soc. Amer. Proc., 20, 509-14.

Olson, R.A.; Dreier, A.F.; Lowrey, G.W. and Flowerday, A.D. 1956. Availability of phosphate carriers to small grains and subsequent clover in relation to: I. Nature of soil and method of placement. Agron. J., 48, 106-11.

Olson, R.A.; Dreier, A.F.; Lowrey, G.W. and Flowerday, A.D. 1956[a]. Availability of phosphate carriers to small grains and subsequent clover in relation to: II. Concurrent soil amendments. Agron. J., 48, 111-16.

Penner, E. 1954[a]. The effect of P^{32} radiation on crop growth and phosphorus uptake. I. Greenhouse studies. Canad. J. agric. Sci., 34, 41-7.

Penner, E. 1954[b]. The effect of P^{32} radiation on crop growth and phosphorus uptake. II. Field studies. Canad. J. agric. Sci., 34, 214-21.

Peterson, H.B.; Nelson, L.B. and Paschal, J.L. 1953. A review of phosphate fertilizer investigation in 15 Western States through 1949. U.S.D.A. Circ. No.927.

Pleshkov, B.P. and Mukhina, G.P. 1957. (A comparative study of the utilization by maize of phosphorus from various marked phosphorus fertilizers). Izv. timiryazev. s.-kh. Akad. No.3, 178-85. Abstr. in Soils & Fert., 21, 712.

Pratt, J.N. 1961. The effect of phosphorus and potassium on the botanical composition, yield and persistence of alfalfa and certain grasses grown in combination. Diss. Abstr. 22, 18-19.

Prince, A.B. 1953. Residual effects of superphosphate application on soil phosphorus level and growth of Crimson clover as measured by yield and phosphorus uptake. Soil Sci., 75, 51-7.

Reith, J.W.S.; Inkson, R.H.E.; Stewart, A.B.; Holmes, W.; Maclusky, D.S.; Reid, D.; Heddle, R.G.; Clouston, D. and Copeman, G.J.F. 1961. The effects of fertilizers on herbage production. Part I. The effect of nitrogen, phosphate and potash on yield. J. agric. Sci., 56, 17-29.

Robertson, W.K. and Hutton, C.E. 1958. An evaluation of ten phosphorus sources by growth of four field crops. Agron. J., 50, 24-8.

Robertson, W.K.; Smith, P.M.; Ohlrogge, A.J. and Kinch, D.M. 1954. Phosphorus utilization by corn as affected by placement and nitrogen and potassium fertilization. Soil Sci., 77, 219-26.

Rogers, H.T.; Pearson, R.W. and Ensminger, L.E. 1953. Comparative efficiency of various phosphate fertilizers. Agronomy, Monograph Series, IV, 189. Academic Press Inc. Publishers, New York, N.Y.

Rogers, H.T.; Pearson, R.W. and Pierre, W.H. 1940. Absorption of organic phosphorus by corn and tomato plants and mineralizing action of exo-enzymes of growing roots. Soil Sci. Soc. Amer. Proc., 5, 285-91.

Ross, M.H. and Ely, J.D. 1951. Alkaline phosphatases in fixed plant cells. Exptl. Cell Research, 2, 339-48. Abstr. in C.A., 48, 5935^{d}.

Ross, W.H. and Jacob, K.D. 1937. Availability of calcined phosphate and other new phosphatic materials as determined by chemical and vegetative tests. J. Assoc. Offic. Agric. Chem., 20, 231-49.

Rotini, O.T. 1951. (Relations of fertilizers with cultivated soils, with regard to their transformations). Ann. Univ. Pisa, Facolta agrar., 12 (N.S.), 159-78. Abstr. in C.A. 47, 5057^{h}.

Rotini, O.T. and Carloni, L. 1952. (The transformation of the metaphosphates into orthophosphates promoted by the agrarian soils). Anali Della Sperimentazione Agraria, 7, 1789-99. Abstr. in Soils & Fert., 17, 701.

Rotini, O.T.; Del Carratore, A.; Lotti, G. and Carloni, L. 1952. (The absorbent power of agricultural land for metaphosphoric acid). Chim. Industr. Milano, 34, 711-14. Abstr. in C.A., 47, 4533^{e} and in Soils & Fert., 16, 1884.

Russell, R.S. 1949. The problem of radiation damage when radioactive phosphorus is used in fertilizer experiments. J. Chem. Soc. London, Suppl. Issue No.2, (S416).

Russell, R.S. 1957. Ability of plants to absorb phosphate from soil. Agric. Review, 2, No.11, 10-19.

Russell, R.S.; Adams, S.N. and Martin, R.P. 1949. Radiation effects due to phosphorus-32 in fertilizer experiments. Nature, Lond., 164, 993-95.

Russell, R.S.; Martin, R.P. and Adams, S.N. 1950. The problem of radiation damage in fertilizer studies with labelled phosphate. Trans. 4th. int. Congr. Soil Sci., 2, 138-41.

Russell, R.S.; Russell, E.W. and Marais, P.G. 1957. Factors affecting the ability of plants to absorb phosphate from soils. I. The relationship between labile phosphate and absorption. J. Soil Sci., 8, 248-67.

Scheffer, F.; Kloke, A. and Lieberoth, I. 1957. (The phosphorus uptake by young rye plants from P^{32} containing organic matter). Z. PflErnahr. Dung., 77, 223-29. Abstr. in Soils & Fert., 20, 1769.

Schmehl, W.R.; Olsen, S.R.; Gardner, R.; Romsdal, S.D. and Kunkel, R. 1955. Availability of phosphate fertilizer materials in calcareous soils in Colorado. Colo. agric. expt. Sta. tech. Bull. No.58, 44.

Schmehl, W.R. and Romsdal, S.D. 1963. Materials and methods of application of phosphate for alfalfa in Colorado. Colo. agric. expt. Sta. tech. Bull., 74, 24.

Simpson, K. 1956. Factors affecting the uptake of phosphorus by crops in South-East Scotland. J. Sci. Fd Agric., 7, 745-53.

Simpson, K. 1960[a]. Effect of supplementing rainfall on the uptake of phosphorus from superphosphate by potatoes. J. Sci. Fd Agric., 11, 71-79.

Simpson, K. 1960[b]. Effect of soil temperature and soil moisture on the uptake of phosphorus by oats. J. Sci. Fd Agric., 11, 449-56.

Simpson, K. 1961. Factors affecting uptake of phosphorus by crops in South-East Scotland. Soil Sci., 92, 1-14.

Simpson, K. 1962[a]. Effects of soil-moisture tension and fertilizers on the yield, growth and phosphorus uptake of potatoes. J. Sci. Fd Agric., 13, 236-48.

Simpson, K. 1962[b]. The significance of effects of soil moisture and temperature on phosphorus uptake. "Open Conference of NAAS Advisory Soil Chemists on the Availability of Soil Phosphorus", Lancaster House, London, S.W.1., 4th and 5th Oct., 1962.

Slack, A.V.; Potts, J.M. and Shaffer, H.B.Jr. 1965. Effect of polyphosphate content on properties and use of liquid fertilizers. J. Agric. Fd Chem., 13, 165-71.

Smierzcholska, K. 1963. (Investigations with P^{32} on the phosphorus uptake from rock phosphate). Roczn. Naukrol., 87A, 331-56. Abstr. in Soils & Fert., 26, 2575.

Speer, R.J.; Allen, S.E.; Maloney, M. and Roberts, A. 1951. Phosphate fertilizers for the Texas Blacklands: I. Relative availability of various phosphatic fertilizers. Soil Sci., 72, 459-64.

Spinks, J.W.T. and Barber, S.A. 1947. Study of fertilizer uptake using radioactive phosphorus. Sci. Agric., 27, 145-56.

Spinks, J.W.T. and Barber, S.A. 1948. Study of fertilizer uptake using radioactive phosphorus: II. Sci. Agric., 28, 79-87.

Spinks, J.W.T. and Dion, G. 1949. Study of fertilizer uptake using radioactive phosphorus. J. chem. Soc. London, Suppl. Issue No.2, S410-S415.

Spinks, J.W.T.; Dion, H.G.; Reade, M. and Dehm, J.E. 1948. Study of fertilizer uptake using radioactive phosphorus: III. Sci. Agric., 28, 309-14.

Stanberry, C.O.; Fuller, W.H. and Crowford, N.R. 1960. Comparison of phosphate sources for alfalfa on a calcareous soil. Soil Sci. Soc. Amer. Proc., 24, 364-66.

Stanford, G. and Nelson, L.B. 1949. Utilization of phosphorus from various fertilizer materials: III. Oats and alfalfa in Iowa. Soil Sci., 68, 157-61.

Strzemienski, K. 1952. Radiation injury from radioactive phosphorus in tracer experiments with plants. N.Z.J. Sci. Tech., 34A, 313-19.

Strzemienski, K. 1953. Phosphate uptake studies with radioactive phosphorus. N.Z.J. Sci. Tech., 34A, 496-506.

Sutton, C.D. and Larsen, S. 1964. Pyrophosphate as a source of phosphorus for plants. Soil Sci., 97, 196-201.

Szember, A. 1960. Influence on plant growth of the breakdown of organic phosphorus compounds by micro-organisms. Plant & Soil, 13, 147-58.

Terman, G.L. and DeMent, J.D. 1962. Crop response to calcium polyphosphate glass and some of its degradation products. Agron. J., 54, 433-37.

Terman, G.L.; Doll, E.C. and Lutz, J.A. 1960. Rate, source, time and method of applying phosphates for alfalfa and legume-grass hay and pasture. Agron. J., 52, 261-64.

Terman, G.L. and Seatz, L.F. 1956. Crop response to metaphosphate fertilizers. Soil Sci. Soc. Amer. Proc., 20, 375-78.

Thorne, D.W. and Seatz, L.F. 1955. Agronomic value and production of T.V.A. fertilizers. World Crops, 7, 159-62.

Thorup, R.M. and Mehlich, A. 1961. Retention of potassium meta- and orthophosphate by soils and minerals. Soil Sci., 91, 38-41.

Tisdale, S.L. and Winters, E. 1953. Crop Response to calcium metaphosphate on alkaline soils. Agron. J., 45, 228-34.

Toevs, J.L. and Baker, G.O. 1939. Progress report of phosphate and other fertilizer investigations at the Aberdeen Branch Experiment Station, University of Idaho. Univ. Idaho agric. Expt. Sta. Bull. No.230.

Tsuge, T. and Yoshida, T. 1958. (Studies on polyphosphates. I. Evaluation of availability of phosphorus in polyphosphates by plant tests). Soils & Fert., 22, Abstr. No.2914.

Tsuge, T. and Yoshida, T. 1958. (Studies on polyphosphates. II. Evaluation of the availability of phosphorus in polyphosphates by plant tests (Contd.)). Soils & Fert., 22, Abstr. No.2915.

Tueva, O.F. 1960. (A study of the dependence of the phosphorus metabolism and productivity of plants on the nitrogen regime in experiments using P^{32}). Fiziol. Rast., 7, 3-12. Abstr. in Soils & Fert., 23, 1764.

T.V.A. 1946. The approach to agricultural development in Tennessee Valley. Soil Sci. Soc. Amer. Proc., 11, 369-73.

Van Wazer, J.R. 1958. "Phosphorus and its compounds", Vol. I, 1st Ed., Interscience Publishers, New York & London, pp. 445, 453, 458, 542 and 641.

Verma, R.D.; Dainty, J. and Simpson, K. 1959. Studies on the uptake of phosphorus from ^{32}P-labelled superphosphate by crops. I. - Oats. J. Sci. Fd Agric., 10, 100-107.

Volk, V.V. and McLean, E.O. 1963. The fate of applied phosphorus in four Ohio soils. Soil Sci. Soc. Amer. Proc., 27, 53-8.

Volkerding, C.C. and Bradfield, R. 1943. The solubility and reversion of calcium and potassium metaphosphates. Soil Sci. Soc, Amer. Proc., 8, 159-66.

Webb, J.R.; Pesek, J.T. and Eik, K. 1961[a]. An evaluation of phosphorus fertilizers varying in water solubility: III. Oat fertilization. Soil Sci. Soc. Amer. Proc., 25, 222-26.

Webb, J.R.; Eik, K. and Pesek, J.T. 1961[b]. An evaluation of phosphorus fertilizers applied broadcast on calcareous soils for corn. Soil Sci. Soc. Amer. Proc., 25, 232-36.

Webb, J.R. and Pesek, J.T. 1959. An evaluation of phosphorus fertilizers varying in water solubility. II. Broadcast application for corn. Soil Sci. Soc. Amer. Proc., 23, 381-84.

Williams, E.G. 1950. Phosphate fixation and availability. J. Sci. Fd Agric., 1, 244-48.

Williams, E.G. and Reith, J.W.S. 1948. The relative effectiveness of phosphatic fertilizers. Emp. J. expt. Agric., 16, 1-13.

Woltz, W.G.; Hall, N.S. and Colwell, W.E. 1949. Utilization of phosphorus by tobacco. Soil Sci., 68, 121-28.

Woodhouse, W.W.Jr. 1945. Use of T.V.A. phosphates and limestone on permanent pastures. N.C. agric. expt. Sta. Agron. Inform. Circ. No.140, 11.

Yang, T.T. 1964. Effect of water absorption and transpiration on translocation of P^{32} in sugarcane roots. Rep. Taiwan Sug. Expt. Sta. 35, 107. Abstr. in Soils & Fert., 28, 1375.

Yuan, T.L. and Robertson, W.K. 1958. Specific P^{32} sorption by soils. Soil Sci., 86, 220-25.

Yuen, S.H. and Pollard, A.G. 1957. The availability of soil phosphate. IV. The effect of nitrogen on the utilization of phosphate by Italian ryegrass. J. Sci. Fd Agric., 8, 475-82.

Zuev, L.A. and Golubeva, P.F. 1959. (The effect of the condition of nitrogen-phosphate nutrition on the development and phosphorus metabolism of spring-wheat seedlings). Fiziol. Rast., 6, 202-205. Abstr. in Soils & Fert., 22, 2965.

APPENDIX I

Yields and Plant Analysis of Experiment I

(1963 - 64)

Table 5. Monthly weather data for the two seasons 1963-64, according to records of the Meteorological Station at Bush near Edinburgh.

	Rainfall (in.)	Mean Temperatures (°F)		Mean Sunshine hours/day
		Maximum	Minimum	
1963				
April	2.66	49.9	37.5	4.2
May	2.16	54.1	39.8	6.1
June	3.95	60.4	47.5	4.6
July	2.39	62.0	48.1	5.4
August	6.14	60.0	48.0	3.4
September	3.21	58.5	45.6	5.2
October	2.30	55.1	41.5	3.7
1964				
March	2.39	41.2	33.3	1.8
April	2.39	51.5	39.1	4.3
May	2.02	56.6	44.1	5.0
June	2.36	59.9	46.7	6.3
July	1.24	62.6	49.7	5.4
August	3.01	61.9	48.7	4.6
September	2.57	60.7	45.9	4.8
October	3.55	51.9	39.2	2.1

Table 6. The analysis of variance of the results of experiment I was as follows:-

Treatments	Degrees of freedom
Replicates	2
Soils (S)	1
N	1
P-form (F)	5
P-level (P)	2
SN	1
SF	5
SP	2
NF	5
NP	2
FP	10
SNF	5
SNP	2
SFP	10
NFP	10
SNFP	10
Error	142
Total	215

Table 7. Layout of Experiment I, 1963,* at Dryden.

1st digit = N-rate
1st letter = P-compound
2nd digit = P-rate
X = an acid soil
Y = a neutral soil

* In 1964, the pots were moved to another wire-cage near the school at West Mains Road. The pots were arranged as in table 8.

Replicate 1

1C3Y	2D3X	2C1Y	1F3X	2C3Y
2E3Y	1F2X	1E3Y	1C2X	2B2X
2C2X	2F2Y	2F3X	2A1X	1A1X
2B1Y	1E2X	1A2Y	1B1Y	2B1X
2-0Y	2F2X	1-0Y	2D1Y	1D3Y
1F3Y	2C3X	1-0X	2B3Y	2B2Y
1C1Y	2A2Y	1C2Y	1A1Y	1E1X
2A3X	2E3X	1B2Y	1D2X	2-0X
2E2Y	1D1X	1A3X	1D3X	2A2X
1A3Y	2-0X	2C1X	2B3X	1F1Y
1-0Y	1B2X	2F1X	1B3X	2C2Y
2-0Y	2A1Y	1D1Y	2A3Y	1E1Y
2F1Y	1F1X	1C3X	2E1X	2E2X
1B3Y	1-0X	2D1X	2F3Y	2D2X
1E2Y	2D2Y	2E1Y	1A2X	1D2Y
1F2Y	2D3Y	1B1X	1E3X	1C1X

Replicate 2

1D2Y	1C3X	1F2Y	2A2Y	2B1Y
1A1Y	2C2X	2E1X	2E3X	2D3Y
2C3X	2F2Y	2D3X	1C2X	2B1X
1B1X	2E3Y	1-0X	1D1Y	1-0Y
1D1X	1E3Y	2F3X	2B3X	1F1X
1C2Y	1B2X	1B3X	1A2X	1E1X
1C3Y	1E3X	1B1Y	2B2X	1D2X
2B3Y	1E2Y	1F3X	2D1X	2C2Y
2F1X	2D2Y	2A1X	2A2Y	2-0Y
1F2X	1A3Y	1D3X	1E2X	2C3Y
2E2Y	2C1X	1A2Y	1C1Y	1-0Y
2-0X	2E1Y	1A1X	1A3X	2-0Y
2C1Y	1C1X	2D1Y	1B2Y	2B2Y
2F1Y	1B3Y	2E2X	2-0X	1E1Y
2F3Y	2D2X	1D3Y	1F1Y	2A3X
2A3Y	2F2X	1-0X	2A1Y	1F3Y

Replicate 3

2E1Y	2A1Y	1A1Y	1B2Y	1C1X
1A3Y	1A3X	2D3X	1-0Y	2D1X
2-0X	1E1X	1F1X	1F3Y	1E3Y
1F2Y	2A1X	1B2X	2B1X	1-0X
1B3Y	2C1Y	2F2X	1E1Y	2A2Y
1D2X	1E2Y	1-0X	2E3X	1F3X
2E2X	2D2X	2F3Y	1A2Y	1A1X
1B1X	2B2X	1E2X	2D3Y	2-0Y
2-0X	2A3X	2B3Y	2C1X	1D1Y
2C3X	1F1Y	1F2X	2C2X	1C2X
1C3X	1D3Y	2E3Y	2D1Y	2B2Y
2F1X	1D2Y	1E3X	2F1Y	2F2Y
1B1Y	1D3X	2C2Y	1C3Y	2E2Y
1B3X	2F3X	1D1X	1-0Y	2D2Y
2A3Y	2B3X	2E1X	2-0Y	1C1Y
2C3Y	1A2X	2A2X	1C2Y	2B1Y

Table 8. Arrangement of the pots of Experiment I, in 1964, after moving them from Dryden (Table 7) to West Mains Road.

Replicate 1	1C3Y	2E3Y	2C2X	2B1Y	2-0Y	1F3Y	1C1Y	2A3X	2E2Y	1A3Y	1-0Y	2-0Y	2F1Y	1B3Y	1E2Y	1F2Y
	2D3X	1F2X	2F2Y	1E2X	2F2X	2C3X	2A2Y	2E3X	1D1X	2-0X	1B2X	2A1Y	1F1X	1-0X	2D2Y	2D3Y
	2C1Y	1E3Y	2F3X	1A2Y	1-0Y	1-0X	1C2Y	1B2Y	1A3X	2C1X	2F1X	1D1Y	1C3X	2D1X	2E1Y	1B1X
	1F3X	1C2X	2A1X	1B1Y	2D1Y	2B3Y	1A1Y	1D2X	1D3X	2B3X	1B3X	2A3Y	2E1X	2F3Y	1A2X	1E3X
	2C3Y	2B2X	1A1X	2B1X	1D3Y	2B2Y	1E1X	2-0X	2A2X	1F1Y	2C2Y	1E1Y	2E2X	2D2X	1D2Y	1C1X
Replicate 2	2B1Y	2D3Y	2B1X	1-0Y	1F1X	1E1X	1D2X	2C2Y	2-0Y	2C3Y	1-0Y	2-0Y	2B2Y	1E1Y	2A3X	1F3Y
	2A2X	2E3X	1C2X	1D1Y	2B3X	1A2X	2B2X	2D1X	2A2Y	1E2X	1C1Y	1A3X	1B2Y	2-0X	1F1Y	2A1Y
	1F2Y	2E1X	2D3X	1-0X	2F3X	1B3X	1B1Y	1F3X	2A1X	1D3X	1A2Y	1A1X	2D1Y	2E2X	1D3Y	1-0X
	1C3X	2C2X	2F2Y	2E3Y	1E3Y	1B2X	1E3X	1E2Y	2D2Y	1A3Y	2C1X	2E1Y	1C1X	1B3Y	2D2X	2F2X
	1D2Y	1A1Y	2C3X	1B1X	1D1X	1C2Y	1C3Y	2B3Y	2F1X	1F2X	2E2Y	2-0X	2C1Y	2F1Y	2F3Y	2A3Y
Replicate 3	1C1X	2D1X	1E3Y	1-0X	2A2Y	1F3X	1A1X	2-0Y	1D1Y	1C2X	2B2Y	2F2Y	2E2Y	2D2Y	1C1Y	2B1Y
	1B2Y	1-0Y	1F3Y	2B1X	1E1Y	2E3X	1A2Y	2D3Y	2C1X	2C2X	2D1Y	2F1Y	1C3Y	1-0Y	2-0Y	1C2Y
	1A1Y	2D3X	1F1X	1B1X	2F2X	1-0X	2F3Y	1E2X	2B3Y	1F2X	2E3Y	1E3X	2C2Y	1D1X	2E1X	2A2X
	2A1Y	1A3X	1E1X	2A1X	2C1Y	1E2Y	2D2X	2B2X	2A3X	1F1Y	1D3Y	1D2Y	1D3X	2F3X	2B3X	1A2X
	2E1Y	1A3Y	2-0X	1F2Y	1B3Y	1D2X	2E2X	1B1X	2-0X	2C3X	1C3X	2F1X	1B1Y	1B3X	2A3Y	2C3Y

Table 9. Experiment I. 1st cut, 1963. Yield of fresh grass, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	25.4	27.6	23.1	32.5	32.0	24.7	19.0	18.2	17.0	30.2	30.5	29.1
0	25.8	26.9	25.1	27.8	28.9	21.1	14.8	14.8	19.5	28.7	30.8	26.5
A1	30.2	24.0	29.9	36.6	26.4	44.4	28.2	23.9	19.9	43.2	38.8	38.9
A2	25.4	25.7	26.0	33.4	38.7	43.0	31.0	25.6	24.6	44.7	53.6	37.3
A3	33.1	19.3	28.0	42.0	42.7	44.0	25.4	26.7	26.6	39.8	53.4	54.1
B1	26.7	30.8	27.0	32.3	32.8	38.1	23.8	19.2	20.6	42.8	42.3	42.3
B2	29.2	27.1	30.0	36.1	35.5	46.8	25.0	23.8	29.7	49.3	49.0	42.9
B3	25.6	27.2	26.6	38.5	35.6	33.0	29.3	27.6	20.8	41.0	48.4	47.2
C1	26.8	26.8	29.8	28.0	34.1	38.1	20.8	24.3	23.3	36.2	51.0	39.2
C2	29.9	28.4	31.0	43.7	38.2	41.5	21.8	37.7	26.1	44.7	43.8	46.0
C3	27.2	35.0	22.8	45.6	38.7	36.8	29.8	32.7	24.7	55.0	51.1	52.5
D1	27.6	30.2	29.6	37.3	28.4	34.9	25.3	22.4	23.4	40.9	39.4	39.3
D2	23.0	30.7	28.5	36.5	40.4	41.7	23.4	31.7	22.8	39.5	48.6	55.8
D3	26.2	26.7	29.8	39.4	36.1	41.6	24.4	24.8	25.4	45.6	50.4	44.3
E1	23.7	31.6	31.2	25.3	35.7	36.9	31.3	24.3	19.6	43.6	45.7	46.8
E2	26.8	26.0	35.9	47.2	35.4	36.7	28.2	26.1	24.0	45.7	47.4	51.9
E3	24.0	31.9	28.5	41.3	38.1	50.8	25.3	25.1	24.1	44.9	50.2	51.8
F1	27.5	23.9	26.9	37.2	33.1	36.5	26.5	22.7	25.3	46.9	45.3	36.5
F2	28.8	28.8	31.1	37.1	35.6	42.0	27.3	26.1	22.1	55.3	46.5	42.2
F3	25.6	29.8	31.6	39.4	38.8	42.7	22.2	29.6	32.7	52.3	57.7	41.1

* These figures denote the replicates.

Table 10. Experiment I. 2nd cut, 1963; Yield of fresh grass g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	24.4	23.8	24.0	38.4	39.1	33.3	22.5	22.7	24.8	36.9	36.0	41.1
0	26.3	24.5	23.3	33.6	36.7	29.8	21.2	21.0	26.4	39.3	36.5	42.3
A1	21.9	23.1	26.6	35.1	37.3	39.9	24.2	27.2	19.6	40.2	37.3	39.1
A2	20.4	22.5	21.9	35.4	40.7	42.4	24.3	25.4	26.5	38.3	41.3	38.4
A3	21.8	21.8	22.4	34.8	36.5	41.6	19.5	24.2	18.2	35.3	41.8	41.4
B1	20.6	22.7	18.4	34.7	38.4	39.1	21.7	18.6	21.1	40.6	41.0	43.0
B2	24.1	23.5	25.2	32.0	37.6	41.0	21.7	26.7	24.2	35.3	40.2	43.6
B3	18.1	20.2	24.2	35.2	34.0	37.7	23.4	23.6	15.7	38.2	41.0	41.7
C1	19.7	23.2	22.3	33.2	42.0	39.9	20.4	24.5	31.0	34.1	45.6	38.3
C2	21.3	22.8	26.3	33.7	38.2	43.1	21.0	25.8	26.0	34.1	39.0	41.3
C3	23.1	25.1	19.0	37.8	37.5	32.7	19.4	23.1	24.8	32.8	42.1	37.1
D1	18.8	19.7	22.4	36.8	34.1	41.7	22.7	23.1	23.3	35.3	37.3	42.6
D2	17.8	21.0	22.8	30.0	36.6	43.5	18.3	29.4	21.0	40.5	37.5	47.4
D3	18.9	22.9	21.9	34.3	32.0	37.9	18.3	21.7	20.9	37.8	46.4	42.9
E1	17.5	20.8	26.8	35.1	38.3	41.9	19.9	28.7	21.1	38.2	42.1	38.6
E2	21.9	21.3	21.3	36.9	35.3	33.0	21.0	20.5	23.9	38.2	39.5	47.5
E3	19.5	20.9	22.3	37.4	39.9	43.3	21.0	23.1	25.5	37.4	39.3	45.1
F1	22.6	21.5	20.4	35.8	35.1	39.3	21.1	24.0	23.8	38.5	45.2	40.4
F2	22.6	22.4	24.9	36.4	33.0	39.1	22.0	23.8	20.9	42.8	43.3	43.8
F3	17.1	21.5	26.1	35.7	34.3	41.6	20.8	25.0	27.4	38.0	41.0	38.6

*These figures denote the replicates.

Table 11. Experiment I. 3rd cut, 1963; Yield of fresh grass, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	21.1	21.9	18.8	31.0	32.1	28.0	19.8	20.0	15.6	32.6	26.9	29.6
0	21.1	20.4	20.1	34.1	28.2	26.8	17.2	19.7	15.4	27.7	29.8	25.2
A1	21.5	21.5	22.1	35.1	31.2	32.4	23.3	19.5	16.2	33.3	31.3	27.6
A2	23.6	23.9	20.4	33.1	39.5	34.2	21.3	21.7	19.1	32.9	33.3	29.0
A3	21.4	24.4	20.9	34.5	40.0	31.2	20.1	21.0	17.7	38.0	28.4	28.9
B1	20.7	20.9	16.8	31.6	35.9	32.5	21.1	17.8	16.5	32.7	31.1	28.2
B2	22.3	22.2	20.5	33.8	35.8	34.0	20.5	22.5	20.2	33.2	36.6	30.1
B3	20.9	21.5	20.1	35.3	38.3	34.6	23.9	19.8	17.0	38.8	25.5	26.2
C1	19.7	20.7	18.0	36.0	35.5	31.1	19.6	22.3	20.5	27.9	27.9	31.6
C2	22.6	24.4	21.4	35.0	35.5	34.4	20.5	18.9	18.0	32.0	30.8	28.5
C3	22.0	21.6	20.2	36.8	31.2	32.2	18.2	18.1	19.2	31.4	33.1	25.1
D1	20.8	18.6	21.0	36.7	32.1	32.5	21.5	20.6	13.9	33.7	29.9	30.2
D2	20.3	29.6	19.7	30.1	35.0	33.7	19.5	21.3	17.5	34.6	30.6	34.0
D3	21.4	21.9	19.7	30.3	33.4	28.5	18.3	18.9	17.3	35.6	37.3	32.4
E1	22.1	23.9	20.8	37.4	33.1	32.4	21.3	23.5	18.3	32.0	34.4	23.1
E2	22.4	23.3	19.5	35.4	33.4	28.6	20.3	17.9	19.3	30.6	27.9	32.9
E3	22.8	20.8	20.9	37.0	40.2	37.2	19.0	20.7	21.0	34.6	32.5	29.5
F1	22.0	22.9	18.1	36.8	27.1	29.2	19.4	21.8	18.3	35.5	26.6	29.7
F2	19.9	18.7	20.6	31.8	29.8	34.3	20.6	20.4	19.9	37.6	32.6	33.9
F3	20.7	21.1	22.9	36.4	34.6	35.7	21.6	24.4	20.4	38.4	28.4	27.9

*These figures denote the replicates

Table 12. Experiment I, 1st cut, 1963; % Dry matter in grass.

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	15.6	14.7	16.8	15.2	15.9	15.7	13.9	15.0	15.7	14.2	14.5	14.8
0	14.7	16.1	14.8	15.9	14.6	15.8	15.8	15.2	14.6	14.3	15.3	14.7
A1	18.1	19.1	17.5	16.5	18.7	17.1	14.5	14.3	14.9	14.4	15.5	14.7
A2	19.0	19.0	19.3	18.2	17.4	17.8	14.5	15.0	14.4	14.0	15.6	14.6
A3	18.1	19.9	19.1	16.7	16.7	18.6	13.4	14.0	15.6	15.4	14.2	15.2
B1	17.6	18.3	18.6	17.5	17.6	16.2	13.7	14.8	16.0	14.0	13.4	14.2
B2	18.2	19.2	18.9	18.1	18.2	17.9	14.4	15.3	14.0	15.0	15.0	13.9
B3	18.7	18.8	19.7	18.7	18.8	19.7	13.6	14.4	15.9	14.7	14.4	15.0
C1	17.7	18.8	18.2	17.2	18.0	16.2	13.6	15.1	13.1	15.0	15.0	15.6
C2	18.3	18.3	18.0	16.4	17.6	17.9	15.3	14.6	14.4	14.6	14.6	15.2
C3	19.1	18.3	20.0	17.8	18.8	19.8	12.9	13.7	15.0	14.4	13.0	14.3
D1	15.8	17.2	17.9	16.7	17.7	18.8	15.1	15.6	14.9	14.5	15.0	14.4
D2	20.0	17.6	20.3	18.5	18.3	18.5	14.6	14.0	14.8	14.5	15.3	13.7
D3	19.0	19.8	19.5	17.9	18.5	19.3	14.3	15.2	15.0	15.0	14.2	14.6
E1	17.6	17.5	18.3	16.9	17.6	17.0	14.7	14.9	15.6	14.6	15.0	15.3
E2	17.5	18.3	18.5	17.7	17.5	18.8	13.6	15.6	16.0	13.7	15.0	14.7
E3	20.1	19.5	19.6	18.0	18.3	18.3	15.0	14.5	15.5	13.7	15.0	15.1
F1	17.2	18.3	19.2	17.8	18.9	19.1	14.2	15.5	14.7	13.9	14.4	15.0
F2	17.3	19.5	19.5	17.9	18.9	18.6	13.1	14.2	15.4	13.7	14.6	13.8
F3	18.6	18.9	19.4	17.7	18.8	18.2	14.0	13.4	15.1	14.4	14.4	15.6

* These figures denote the replicates

Table 13. Experiment I. 2nd cut, 1963. % Dry matter in grass.

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	22.4	22.0	21.3	22.0	22.5	22.9	20.1	22.1	22.8	20.1	20.3	20.1
0	23.5	22.8	21.5	22.0	20.7	22.8	24.0	22.4	21.8	18.8	21.1	20.4
A1	23.0	22.7	20.4	21.1	21.2	21.1	21.1	20.6	22.4	20.2	21.3	20.7
A2	22.3	22.4	22.4	21.2	19.7	20.6	22.1	22.2	21.7	20.6	20.1	19.4
A3	22.2	22.7	22.7	20.4	21.1	21.1	21.2	22.0	22.1	21.0	19.4	22.0
B1	23.5	21.6	23.4	21.8	20.8	22.2	20.3	23.2	24.2	20.1	19.0	18.4
B2	21.7	23.0	22.1	21.6	21.9	21.8	23.1	22.9	21.1	20.9	19.9	19.4
B3	23.3	22.9	23.7	21.3	20.3	21.2	20.9	21.6	23.0	20.5	20.1	20.3
C1	22.7	22.8	21.2	21.6	21.8	21.5	21.4	22.6	15.2	21.4	20.2	21.1
C2	23.0	23.2	21.6	20.2	20.5	20.1	23.8	21.8	21.3	20.6	20.4	20.4
C3	22.8	21.5	23.0	19.9	20.8	21.9	19.9	19.4	21.4	20.4	19.1	21.3
D1	22.5	22.4	21.5	21.8	22.4	20.6	23.0	23.5	22.3	20.5	21.2	19.9
D2	23.1	21.9	23.3	22.0	20.6	21.3	20.7	20.1	23.3	20.8	21.8	18.5
D3	22.7	22.2	21.9	20.5	20.9	20.8	21.9	20.2	23.2	19.9	19.6	20.4
E1	24.3	22.2	22.8	21.7	21.6	20.7	21.8	21.6	22.7	21.0	21.0	21.3
E2	22.0	22.9	22.6	21.1	21.2	21.9	21.6	22.9	22.3	18.8	20.8	19.0
E3	22.2	22.6	21.4	20.3	20.8	20.3	22.4	21.7	20.6	19.6	20.4	20.2
F1	22.1	22.4	22.9	21.2	20.9	22.4	22.1	22.9	23.0	19.2	20.3	20.4
F2	21.6	22.7	21.5	20.8	21.2	21.0	19.8	21.5	22.9	19.6	20.7	19.0
F3	21.6	22.8	20.7	21.1	20.1	21.5	22.6	20.2	21.9	20.0	20.1	21.1

* These figures denote the replicates

Table 14. Experiment I. 3rd cut, 1963. % Dry matter in grass

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	19.9	19.3	19.6	19.5	19.8	19.9	21.2	20.0	21.3	20.0	21.8	19.7
0	20.3	20.6	19.8	21.5	19.5	20.5	20.9	21.0	21.4	20.5	20.6	20.2
A1	20.3	20.8	19.1	19.1	20.8	19.6	20.2	19.9	21.5	20.6	21.6	22.2
A2	20.4	19.8	21.1	20.9	19.0	20.4	20.2	21.8	20.2	20.3	22.5	20.0
A3	20.6	20.5	20.6	19.8	18.5	21.8	20.4	21.5	21.6	20.6	23.0	22.6
B1	20.9	19.5	21.2	20.2	18.2	20.2	20.9	21.4	22.1	19.6	18.9	21.2
B2	19.7	20.4	20.4	20.1	19.6	20.2	21.5	21.4	20.7	21.6	20.2	20.8
B3	20.4	20.1	21.3	19.6	19.8	19.1	20.8	21.1	21.7	20.8	23.5	23.3
C1	21.3	21.2	19.8	19.4	19.4	21.2	20.5	20.8	18.6	21.4	21.8	20.4
C2	20.4	19.6	19.5	18.8	18.7	19.6	21.2	20.8	21.1	21.8	21.8	21.6
C3	20.6	20.2	20.7	18.8	19.9	20.7	19.9	20.4	20.4	22.6	21.4	23.8
D1	20.8	20.1	20.0	19.6	19.4	19.1	20.5	21.5	21.8	21.5	20.7	20.5
D2	20.8	16.7	20.8	21.4	20.4	19.9	21.5	19.5	21.1	21.1	22.3	19.7
D3	21.0	21.0	20.4	21.4	19.6	21.0	20.7	21.8	22.0	20.6	19.1	20.7
E1	20.9	19.6	20.5	19.2	19.3	19.7	21.3	19.8	21.9	20.8	20.9	23.8
E2	19.6	20.2	20.1	20.6	20.0	20.6	21.0	21.8	21.3	21.9	22.2	20.3
E3	20.7	21.0	20.1	19.1	18.9	19.4	20.5	20.7	20.0	19.7	20.9	22.0
F1	19.6	19.9	20.9	19.0	21.4	20.5	20.7	21.3	21.7	20.8	21.5	20.3
F2	19.6	20.3	20.8	19.0	19.5	19.1	21.4	21.0	21.6	20.5	20.2	20.0
F3	20.9	21.3	19.3	18.7	19.6	19.6	20.2	19.7	20.8	19.3	21.7	21.0

* These figures denote the replicates.

Table 15. Experiment I. 1st cut, 1963; Yield of dry matter, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	3.95	4.06	3.87	4.92	5.08	3.86	2.64	2.72	2.67	4.29	4.42	4.31
0	3.78	4.34	3.71	4.41	4.23	3.33	2.34	2.25	2.85	4.09	4.71	3.89
A1	5.47	4.59	5.22	6.04	4.93	7.60	4.07	3.42	2.96	6.22	6.03	5.72
A2	4.82	4.87	5.01	6.08	6.73	7.65	4.51	3.83	3.54	6.27	8.34	5.45
A3	6.00	3.84	5.34	7.01	7.13	8.19	3.40	3.74	4.14	6.11	7.60	8.20
B1	4.70	5.63	5.01	5.65	5.76	6.18	3.26	2.85	3.29	5.99	5.65	5.98
B2	5.30	5.19	5.63	6.52	6.38	8.38	3.61	3.63	4.16	7.38	7.35	5.96
B3	4.78	5.11	5.22	7.18	6.69	6.50	3.99	3.98	3.31	6.01	6.98	7.07
C1	4.73	5.05	5.41	4.82	6.13	6.19	2.82	3.67	3.04	5.44	7.64	6.11
C2	5.46	5.21	5.59	7.18	5.70	7.43	3.33	5.49	3.75	6.51	6.39	6.99
C3	5.20	6.40	4.54	8.11	7.26	7.29	3.84	4.47	3.70	7.94	6.64	7.49
D1	4.34	5.19	5.28	6.21	5.02	6.55	3.82	3.49	3.49	5.93	5.90	5.64
D2	4.59	5.41	5.78	6.76	7.40	7.70	3.41	4.42	3.38	5.72	7.43	7.65
D3	4.98	5.29	5.82	7.05	6.67	8.02	3.48	3.75	3.81	6.86	7.16	6.46
E1	4.18	5.53	5.72	4.27	6.28	6.29	4.61	3.61	3.05	6.36	6.87	7.16
E2	4.68	4.74	6.64	8.35	6.17	6.91	3.83	4.08	3.83	6.26	7.11	7.61
E3	4.82	6.20	5.58	7.42	6.97	9.31	3.80	3.64	3.74	6.13	7.52	7.80
F1	4.73	4.38	5.15	6.61	6.24	6.97	3.77	3.51	3.70	6.49	6.52	5.50
F2	4.99	5.61	6.06	6.65	6.72	7.83	3.57	3.70	3.41	7.55	6.80	5.81
F3	4.75	5.62	6.14	6.98	7.29	7.77	3.10	3.98	4.93	7.52	8.31	6.42

* These figures denote the replicates

Table 16. Experiment I. 2nd cut, 1963; Yield of dry matter, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	5.47	5.22	5.12	8.43	8.81	7.62	4.53	5.01	5.65	7.41	7.33	8.27
0	6.19	5.58	5.01	7.40	7.58	6.80	5.10	4.70	5.74	7.39	7.69	8.61
A1	5.03	5.26	5.42	7.42	7.91	8.43	5.10	5.62	4.39	8.14	7.93	8.09
A2	4.55	5.04	4.92	7.52	8.02	8.75	5.38	5.66	5.75	7.89	8.31	7.45
A3	4.84	4.96	5.08	7.10	7.72	8.80	4.15	5.32	4.01	7.41	8.12	9.11
B1	4.84	4.91	4.29	7.57	8.01	8.68	4.41	4.31	5.10	8.16	7.78	7.90
B2	5.22	5.41	5.56	6.93	8.23	8.92	5.02	6.09	5.12	7.40	8.00	8.45
B3	4.21	4.63	5.74	7.49	6.91	8.00	4.88	5.10	3.62	7.83	8.25	8.48
C1	4.46	5.29	4.72	7.19	9.14	8.58	4.35	5.55	4.71	7.29	9.23	8.10
C2	4.90	5.28	5.68	6.81	7.83	8.65	4.99	5.61	5.55	7.05	7.97	8.42
C3	5.26	5.40	4.38	7.53	7.81	7.17	3.86	4.49	5.32	6.69	8.03	7.90
D1	4.23	4.40	4.81	8.01	7.65	8.58	5.20	5.43	5.19	7.23	7.92	8.50
D2	4.11	4.60	5.32	6.61	7.55	9.28	3.79	5.91	4.89	8.42	8.17	8.78
D3	4.29	5.09	4.81	7.04	6.68	7.90	4.01	4.39	4.85	7.52	9.12	8.75
E1	4.24	4.61	6.10	7.61	8.25	8.70	4.35	6.22	4.80	8.02	8.86	8.22
E2	4.82	4.88	4.82	7.78	7.48	7.22	4.54	4.68	5.32	7.19	8.22	9.01
E3	4.33	4.74	4.78	7.58	8.31	8.80	4.68	5.01	5.24	7.34	8.02	9.10
F1	5.00	4.82	4.68	7.59	7.34	8.79	4.66	5.50	5.48	7.40	9.19	8.23
F2	4.90	5.09	5.35	7.57	6.99	8.22	4.33	5.12	4.79	8.40	8.95	8.31
F3	3.70	4.90	5.40	7.54	6.90	8.95	4.70	5.03	6.00	7.59	8.23	8.13

* These figures denote the replicates

Table 17. Experiment I. 3rd cut, 1963; Yield of dry matter, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	4.21	4.23	3.68	6.05	6.36	5.57	4.20	3.99	3.32	6.52	5.87	5.82
0	4.28	4.20	3.99	7.31	5.50	5.50	3.60	4.14	3.30	5.66	6.16	5.09
A1	4.36	4.49	4.21	6.69	6.49	6.37	4.70	3.89	3.49	6.85	6.78	6.13
A2	4.80	4.74	4.30	6.93	7.52	6.96	4.31	4.72	3.87	6.67	7.48	5.80
A3	4.40	5.00	4.30	6.81	7.41	6.81	4.10	4.51	3.83	7.84	6.51	6.53
B1	4.34	4.08	3.56	6.40	6.52	6.58	4.41	3.80	3.65	6.41	5.86	5.98
B2	4.39	4.54	4.18	6.78	7.03	6.88	4.40	4.80	4.19	7.18	7.39	6.27
B3	4.28	4.33	4.28	6.93	7.59	6.61	4.95	4.18	3.69	8.09	5.98	6.10
C1	4.19	4.39	3.57	7.00	6.87	6.60	4.02	4.63	3.80	5.95	6.10	6.45
C2	4.61	4.78	4.18	6.59	6.63	6.75	4.35	3.93	3.80	6.96	6.71	6.16
C3	4.52	4.38	4.18	6.90	6.20	6.68	3.61	3.69	3.91	7.10	7.10	5.98
D1	4.31	3.73	4.20	7.21	6.23	6.20	4.41	4.43	3.02	7.25	6.20	6.20
D2	4.22	4.93	4.10	6.43	7.13	6.70	4.20	4.16	3.69	7.30	6.84	6.71
D3	4.50	4.59	4.02	6.50	6.55	5.99	3.79	4.11	3.80	7.32	7.11	6.71
E1	4.60	4.70	4.27	7.19	6.37	6.39	4.54	4.65	4.00	6.65	7.19	5.49
E2	4.38	4.70	3.92	7.31	6.70	5.90	4.26	3.90	4.11	6.70	6.19	6.68
E3	4.73	4.38	4.21	7.05	7.60	7.20	3.89	4.29	4.21	6.82	6.79	6.48
F1	4.31	4.57	3.78	6.99	5.80	6.00	4.01	4.63	3.98	7.38	5.71	6.02
F2	3.90	3.80	4.28	6.04	5.82	6.55	4.42	4.29	4.30	7.73	6.60	6.79
F3	4.32	4.49	4.41	6.82	6.78	7.00	4.35	4.82	4.24	7.42	6.16	5.85

* These figures denote the replicates.

Table 18. Experiment I. 1st cut, 1963; % P in the dry matter

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	0.22	0.22	0.20	0.21	0.19	0.21	0.24	0.24	0.22	0.21	0.23	0.21
0	0.24	0.21	0.24	0.20	0.23	0.21	0.22	0.22	0.25	0.21	0.21	0.21
A1	0.24	0.25	0.26	0.24	0.22	0.20	0.32	0.30	0.26	0.28	0.24	0.24
A2	0.27	0.31	0.26	0.24	0.29	0.27	0.41	0.39	0.36	0.36	0.33	0.31
A3	0.32	0.30	0.31	0.27	0.29	0.26	0.41	0.44	0.44	0.43	0.35	0.35
B1	0.29	0.26	0.24	0.24	0.24	0.24	0.32	0.29	0.26	0.27	0.26	0.23
B2	0.26	0.26	0.27	0.27	0.27	0.25	0.38	0.36	0.37	0.35	0.33	0.33
B3	0.31	0.31	0.31	0.29	0.29	0.30	0.45	0.44	0.43	0.47	0.35	0.37
C1	0.23	0.24	0.23	0.27	0.24	0.25	0.29	0.29	0.29	0.27	0.26	0.22
C2	0.29	0.30	0.31	0.25	0.26	0.26	0.39	0.36	0.35	0.32	0.29	0.34
C3	0.31	0.32	0.30	0.26	0.28	0.25	0.41	0.42	0.44	0.40	0.36	0.34
D1	0.26	0.26	0.25	0.26	0.23	0.23	0.31	0.29	0.25	0.27	0.26	0.23
D2	0.27	0.29	0.27	0.24	0.23	0.27	0.35	0.37	0.39	0.32	0.34	0.32
D3	0.35	0.30	0.31	0.26	0.25	0.27	0.43	0.44	0.47	0.42	0.41	0.39
E1	0.24	0.25	0.25	0.27	0.22	0.26	0.32	0.31	0.28	0.28	0.24	0.22
E2	0.28	0.29	0.29	0.24	0.27	0.24	0.37	0.39	0.36	0.30	0.33	0.34
E3	0.31	0.26	0.30	0.26	0.29	0.29	0.48	0.45	0.43	0.37	0.41	0.45
F1	0.24	0.26	0.20	0.21	0.19	0.21	0.31	0.29	0.32	0.27	0.25	0.26
F2	0.25	0.28	0.28	0.25	0.22	0.25	0.34	0.37	0.37	0.36	0.35	0.34
F3	0.27	0.30	0.32	0.32	0.24	0.31	0.45	0.41	0.44	0.39	0.37	0.39

*These figures denote the replicates

Table 19. Experiment I. 1st cut, 1963; Percent K, Ca and Mg in dry matter. (Plant-analysis for these nutrients was kindly done by the Spectro-chemistry Department).

Treatment	SOIL X						SOIL Y					
	K		Ca		Mg		K		Ca		Mg	
	N1	N2	N1	N2	N1	N2	N1	N2	N1	N2	N1	N2
0	4.2*	4.3	0.52	0.57	0.14	0.16	4.3	4.6	0.65	0.68	0.22	0.23
0	4.4	4.4	0.52	0.51	0.14	0.17	3.8	4.6	0.74	0.71	0.24	0.22
1	3.6	3.4	0.51	0.49	0.15	0.16	3.7	3.8	0.68	0.62	0.23	0.21
A2	3.2	3.4	0.51	0.47	0.14	0.16	3.6	3.4	0.65	0.56	0.21	0.21
3	3.2	3.1	0.48	0.47	0.12	0.16	3.1	3.2	0.59	0.60	0.25	0.21
1	3.5	3.5	0.51	0.50	0.14	0.15	4.5	3.8	0.56	0.78	0.24	0.25
B2	3.2	3.5	0.49	0.48	0.13	0.17	4.2	3.4	0.80	0.65	0.24	0.22
3	3.2	2.9	0.49	0.45	0.14	0.16	4.1	3.3	0.74	0.63	0.24	0.22
1	3.4	3.5	0.54	0.49	0.14	0.16	4.7	3.7	0.85	0.64	0.26	0.24
C2	3.4	3.2	0.51	0.46	0.12	0.16	3.6	3.4	0.62	0.65	0.21	0.23
3	3.2	2.9	0.51	0.45	0.12	0.16	4.2	3.4	0.82	0.67	0.27	0.25
1	3.7	3.2	0.51	0.50	0.15	0.16	4.6	3.8	0.65	0.71	0.24	0.24
D2	3.4	4.0	0.52	0.43	0.14	0.17	4.5	3.7	0.81	0.65	0.27	0.24
3	3.3	4.2	0.50	0.45	0.13	0.18	4.4	3.2	0.82	0.63	0.24	0.23
1	2.9	3.8	0.50	0.48	0.14	0.16	4.4	3.4	0.72	0.82	0.24	0.23
E2	3.5	3.6	0.50	0.64	0.15	0.19	4.2	3.1	0.75	0.97	0.24	0.24
3	3.2	3.5	0.49	0.50	0.16	0.16	4.2	3.1	0.61	0.62	0.22	0.21
1	3.5	3.8	0.52	0.52	0.16	0.16	4.0	3.7	0.55	0.73	0.22	0.25
F2	3.3	3.2	0.54	0.50	0.16	0.18	4.1	3.1	0.65	0.71	0.26	0.26
3	3.2	3.1	0.49	0.57	0.15	0.15	4.6	2.9	0.61	0.64	0.24	0.23

* The analysis was carried out on composite samples of the 3 replicates of each treatment.

Table 20. Experiment I. 1st cut, 1963; The contents of Cu, Mn and Fe as ppm. in the dry matter. (Plant-analysis for these nutrients was kindly done by the Spectro-chemistry Department).

Treatment	SOIL X						SOIL Y					
	Cu		Mn		Fe		Cu		Mn		Fe	
	N1	N2	N1	N2	N1	N2	N1	N2	N1	N2	N1	N2
0	6.7*	7.8	227	212	149	229	9.2	8.7	42	23	205	167
0	8.4	9.0	232	220	157	164	7.1	8.8	57	37	142	165
1	6.4	7.5	235	208	161	149	8.1	8.1	28	21	178	165
A2	6.1	8.1	213	176	144	314	8.7	9.3	26	31	203	182
3	5.8	7.1	211	184	164	265	7.3	8.0	26	32	135	263
1	6.3	7.0	241	281	231	218	9.6	9.5	22	33	249	183
B2	7.3	5.6	205	229	153	216	8.2	8.6	21	33	211	206
3	6.7	7.8	202	164	190	166	7.6	7.3	28	33	181	206
1	6.9	8.0	216	238	180	142	8.4	8.8	27	33	210	194
C2	6.0	6.4	209	157	163	163	8.5	7.7	27	33	241	215
3	6.5	6.3	226	190	238	220	8.0	8.4	26	31	213	215
1	6.6	6.0	233	225	246	141	7.3	7.7	27	33	133	155
D2	6.6	6.6	216	192	211	214	8.1	8.0	27	32	194	147
3	6.5	6.8	241.	153	185	168	8.8	8.0	32	31	172	148
1	6.7	7.0	183	199	171	169	7.4	9.0	26	33	209	154
E2	6.9	7.5	227	186	201	181	7.1	8.3	24	29	181	187
3	5.8	6.8	183	179	193	204	6.8	8.5	28	34	147	157
1	7.2	6.9	180	156	164	133	9.1	9.2	28	34	189	222
F2	6.4	6.6	173	165	210	200	6.6	7.6	24	35	161	144
3	6.1	7.6	180	164	183	201	8.0	8.2	28	33	190	241

* The analysis was carried out on composite samples of the 3 replicates of each treatment.

Table 21. Experiment I. 2nd cut, 1963; % P in the dry matter.

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	0.17	0.17	0.16	0.12	0.12	0.12	0.18	0.17	0.13	0.13	0.14	0.12
0	0.15	0.16	0.16	0.13	0.13	0.12	0.15	0.16	0.15	0.15	0.13	0.12
A1	0.21	0.19	0.21	0.16	0.15	0.14	0.22	0.20	0.18	0.17	0.15	0.13
A2	0.23	0.22	0.22	0.20	0.19	0.22	0.25	0.23	0.21	0.20	0.20	0.18
A3	0.26	0.23	0.24	0.20	0.21	0.21	0.28	0.29	0.31	0.22	0.25	0.25
B1	0.17	0.22	0.21	0.17	0.16	0.15	0.22	0.20	0.20	0.16	0.17	0.16
B2	0.24	0.22	0.23	0.18	0.18	0.19	0.22	0.22	0.27	0.21	0.21	0.19
B3	0.25	0.25	0.25	0.24	0.22	0.24	0.30	0.27	0.28	0.26	0.23	0.23
C1	0.20	0.18	0.21	0.15	0.15	0.15	0.19	0.18	0.25	0.15	0.16	0.14
C2	0.23	0.23	0.23	0.22	0.20	0.20	0.22	0.24	0.23	0.18	0.18	0.20
C3	0.23	0.27	0.26	0.24	0.22	0.23	0.33	0.31	0.26	0.25	0.22	0.24
D1	0.20	0.21	0.22	0.15	0.15	0.16	0.19	0.17	0.18	0.15	0.14	0.15
D2	0.22	0.23	0.23	0.20	0.18	0.19	0.25	0.27	0.24	0.18	0.19	0.22
D3	0.26	0.27	0.28	0.25	0.23	0.23	0.30	0.27	0.28	0.27	0.23	0.22
E1	0.20	0.20	0.18	0.15	0.16	0.17	0.21	0.18	0.17	0.14	0.14	0.15
E2	0.23	0.22	0.25	0.21	0.19	0.22	0.24	0.24	0.21	0.19	0.19	0.23
E3	0.26	0.25	0.27	0.23	0.22	0.24	0.29	0.27	0.28	0.22	0.25	0.28
F1	0.20	0.19	0.17	0.16	0.16	0.16	0.21	0.18	0.19	0.15	0.15	0.14
F2	0.22	0.23	0.24	0.19	0.19	0.18	0.27	0.25	0.25	0.22	0.20	0.20
F3	0.25	0.25	0.26	0.24	0.24	0.23	0.26	0.30	0.27	0.26	0.25	0.22

* These figures denote the replicates.

Table 22. Experiment I. 3rd cut, 1963; % P in the dry matter

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	0.19	0.21	0.20	0.15	0.15	0.16	0.16	0.19	0.18	0.14	0.16	0.16
0	0.18	0.20	0.21	0.14	0.17	0.15	0.18	0.17	0.17	0.15	0.15	0.15
A1	0.24	0.24	0.26	0.19	0.17	0.20	0.22	0.27	0.22	0.18	0.18	0.18
A2	0.24	0.28	0.28	0.19	0.21	0.23	0.29	0.27	0.26	0.20	0.21	0.19
A3	0.29	0.28	0.31	0.22	0.24	0.26	0.29	0.34	0.35	0.22	0.24	0.24
B1	0.22	0.27	0.24	0.17	0.21	0.19	0.23	0.23	0.22	0.18	0.21	0.18
B2	0.26	0.27	0.31	0.19	0.21	0.23	0.24	0.27	0.30	0.19	0.22	0.22
B3	0.29	0.30	0.30	0.24	0.23	0.28	0.31	0.33	0.32	0.23	0.22	0.23
C1	0.21	0.21	0.26	0.16	0.19	0.19	0.20	0.24	0.22	0.18	0.19	0.19
C2	0.26	0.28	0.28	0.22	0.22	0.21	0.25	0.30	0.27	0.17	0.21	0.22
C3	0.27	0.31	0.29	0.23	0.24	0.24	0.33	0.31	0.31	0.23	0.21	0.22
D1	0.22	0.25	0.26	0.16	0.19	0.20	0.24	0.22	0.23	0.17	0.18	0.20
D2	0.27	0.25	0.29	0.19	0.20	0.23	0.22	0.34	0.28	0.18	0.21	0.22
D3	0.28	0.30	0.33	0.23	0.24	0.26	0.29	0.32	0.33	0.24	0.26	0.23
E1	0.21	0.22	0.24	0.17	0.20	0.21	0.22	0.23	0.21	0.17	0.18	0.19
E2	0.26	0.26	0.29	0.21	0.21	0.21	0.24	0.28	0.28	0.17	0.21	0.25
E3	0.27	0.31	0.34	0.23	0.22	0.28	0.32	0.34	0.33	0.21	0.26	0.29
F1	0.22	0.21	0.24	0.18	0.19	0.20	0.21	0.22	0.25	0.17	0.20	0.19
F2	0.26	0.27	0.29	0.22	0.21	0.22	0.24	0.29	0.28	0.22	0.23	0.21
F3	0.26	0.27	0.32	0.24	0.24	0.26	0.28	0.32	0.34	0.24	0.24	0.23

* These figures denote the replicates.

Table 23. Experiment I. 1st cut, 1963; P-uptake by grass, mg P/pot

Treatment	SOIL X							SOIL Y						
	N1				N2			N1				N2		
	i*	ii	iii		i	ii	iii	i	ii	iii		i	ii	iii	
0	8.69	8.93	7.74	8.4	10.33	9.65	8.11	9.4	6.34	6.53	5.87	6.25	9.01	10.17	9.05	9.4
0	9.07	9.11	8.90	9.0	8.82	9.73	6.99	8.5	5.15	4.95	7.13	5.8	8.59	9.89	8.17	8.9
A1	13.13	11.48	13.57	12.7	14.50	10.85	15.20	13.6	13.02	10.26	7.70	10.3	17.42	14.47	13.73	15.2
A2	13.01	15.10	13.03	13.7	14.59	19.52	20.66	18.3	18.49	14.94	12.74	15.4	22.57	27.52	16.90	22.3
A3	19.20	11.52	16.55	15.8	18.93	20.68	21.29	20.0	13.94	16.46	18.22	16.2	26.27	26.20	28.70	27.1
B1	13.63	14.64	12.02	13.0	13.56	13.82	14.83	14.1	10.43	8.27	8.55	9.1	16.17	14.69	13.75	14.8
B2	13.78	13.49	15.20	14.2	17.60	17.23	20.95	18.9	13.72	13.07	15.39	14.1	25.83	24.26	19.67	23.3
B3	14.82	15.84	16.18	15.6	20.82	19.40	19.50	19.9	17.96	17.51	14.23	16.6	28.25	24.43	26.16	26.3
C1	10.88	12.12	12.44	11.8	13.01	14.71	15.48	14.4	8.18	10.64	8.82	9.2	14.69	19.86	13.44	16.0
C2	15.83	15.63	17.33	16.2	17.95	17.42	19.32	18.2	12.99	19.76	13.13	15.4	20.83	18.53	23.77	21.0
C3	16.12	20.48	13.62	16.7	21.09	20.33	18.23	19.9	15.74	18.77	16.28	16.9	31.76	23.90	25.47	27.0
D1	11.28	13.49	13.20	12.7	16.15	11.55	15.07	14.3	11.84	10.12	8.73	10.2	16.01	15.34	12.97	14.8
D2	12.39	15.69	15.61	14.6	16.22	17.02	20.79	18.0	11.94	16.35	13.18	13.8	18.30	25.26	24.48	22.7
D3	17.43	15.87	18.04	17.1	18.33	16.68	21.65	18.9	14.96	16.50	17.91	16.5	28.81	29.36	25.19	27.8
E1	10.03	13.83	14.30	12.7	11.53	13.82	16.35	15.9	14.75	11.19	8.54	11.5	17.81	16.49	15.75	16.7
E2	13.10	13.75	19.26	15.4	20.04	16.66	16.58	17.8	14.17	15.91	13.79	14.6	18.78	23.46	25.87	22.7
E3	14.94	16.12	16.74	16.0	19.29	20.21	27.00	22.2	18.24	16.38	16.08	16.9	22.68	30.83	35.10	29.5
F1	11.35	11.39	10.30	11.0	13.88	11.86	14.64	13.5	11.69	10.18	11.84	11.2	17.52	16.30	14.30	16.0
F2	12.48	15.71	16.97	15.1	16.63	14.78	19.58	17.0	12.14	13.69	12.62	12.8	27.18	23.80	19.75	23.6
F3	12.83	16.86	19.65	16.5	22.34	17.50	24.09	21.3	13.95	16.32	21.69	17.3	29.33	30.75	25.04	28.4

*These figures denote the replicates.

Table 24. Experiment I. 2nd cut, 1963; P-uptake by grass, mg. P/pot

Treatment	SOIL X						SOIL Y						
	N1			N2			N1			N2			
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	
0	9.30	8.87	8.19 8·8	10.12	10.57	9.14 9·9	8.15	8.52	7.35 8·0	9.63	10.26	9.92	9·9
0	9.29	8.93	8.02 8·7	9.62	9.85	8.16 9·2	7.65	7.52	8.61 7·9	11.09	10.00	10.33	10·5
A1	10.56	9.90	11.38 10·6	11.87	11.87	11.80 11·9	11.22	11.24	7.90 10·1	13.84	11.90	10.52	12·1
A2	10.47	11.09	10.82 10·8	15.04	15.24	19.25 16·5	13.45	13.02	12.08 12·8	15.78	18.28	13.41	15·7
A3	12.58	11.41	12.19 12·1	14.20	16.21	18.48 16·3	11.62	14.36	12.43 12·8	16.30	20.30	22.78	19·8
B1	8.23	10.80	9.01 9·3	12.87	12.82	13.02 12·9	9.70	8.62	10.20 9·5	13.06	13.23	12.64	13·0
B2	12.53	11.90	12.79 12·4	12.47	14.81	16.95 14·8	11.04	13.40	13.82 12·4	15.54	16.80	16.06	16·1
B3	10.53	11.58	14.35 12·2	17.98	15.20	19.20 17·5	14.64	13.77	10.14 12·9	20.36	18.98	19.50	19·6
C1	8.92	9.52	9.91 9·4	10.79	13.71	12.87 12·5	8.27	9.99	11.78 10·0	10.94	14.77	11.34	12·4
C2	11.27	12.14	13.06 12·2	14.98	15.66	17.30 16·0	10.98	13.46	12.77 12·4	12.69	14.35	16.84	14·6
C3	12.10	14.58	11.39 12·7	18.07	17.18	16.49 17·3	12.74	13.92	13.83 13·5	16.73	17.67	18.96	17·8
D1	8.46	9.24	10.58 9·4	12.02	11.48	13.73 12·4	9.88	9.23	9.34 9·5	10.85	11.09	12.75	11·6
D2	9.04	10.58	12.24 10·6	13.22	13.59	17.63 14·8	9.48	15.96	11.74 12·4	15.16	15.52	19.32	16·7
D3	11.15	13.74	13.47 12·8	17.60	15.36	18.17 17·1	12.03	11.85	13.58 12·5	20.30	20.98	19.25	20·2
E1	8.48	9.22	10.98 9·6	11.42	13.20	14.79 13·1	9.14	11.20	8.16 9·5	11.23	12.40	12.33	12·0
E2	11.09	10.74	12.05 11·3	16.34	14.21	15.88 15·5	10.90	11.23	11.17 11·1	13.66	15.62	20.72	16·7
E3	11.26	11.85	12.91 12·0	17.43	18.28	21.12 18·9	13.57	13.53	14.67 13·9	16.15	20.05	25.48	20·6
F1	10.00	9.16	7.96 9·1	12.14	11.74	14.06 12·6	9.79	9.90	10.41 10·0	11.10	13.79	11.52	12·1
F2	10.78	11.71	12.84 11·8	14.38	13.28	14.80 14·2	11.69	12.80	11.98 12·2	18.48	17.90	16.62	17·7
F3	9.25	12.25	14.04 11·9	18.10	16.56	20.59 18·4	12.22	15.09	16.20 14·3	19.73	20.58	17.89	19·4

* These figures denote the replicates.

Table 25. Experiment I. 3rd cut, 1963; P-uptake by grass, mg P/pot

Treatment	SOIL X						SOIL Y						
	N1			N2			N1			N2			
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii	
C	8.00	8.88	7.36 8.1	9.08	9.54	8.91 9.2	6.72	7.58	5.98 6.7	9.13	9.39	9.31	9.3
O	7.70	8.40	8.38 8.2	10.23	9.35	8.25 9.3	6.48	7.04	5.61 6.4	8.49	9.24	7.64	8.5
A1	10.46	10.78	10.95 10.8	12.71	11.03	12.74 12.1	10.34	10.50	7.68 9.5	12.33	12.20	11.03	11.9
A2	11.52	13.27	12.04 12.3	13.17	15.79	16.01 15.0	12.50	12.74	10.06 11.8	13.34	15.71	11.02	13.3
A3	12.76	14.00	13.33 13.4	14.98	17.78	17.71 16.8	11.89	15.33	13.41 13.5	17.25	15.62	15.67	16.2
B1	9.55	11.02	8.54 9.7	10.88	13.69	12.50 12.4	10.14	8.74	8.03 9.0	11.54	12.31	10.76	11.5
B2	11.41	12.26	12.96 12.2	12.88	14.76	15.82 14.5	10.56	12.96	12.57 12.0	13.64	16.26	13.79	14.6
B3	12.41	12.99	12.84 12.7	16.63	17.46	18.51 17.5	15.35	13.79	11.81 13.7	18.61	13.16	14.03	15.3
C1	8.80	9.22	9.28 9.1	11.20	13.05	12.54 12.3	8.04	11.11	8.36 9.2	10.71	11.59	12.26	11.5
C2	11.99	13.38	11.70 12.4	14.50	14.59	14.18 14.4	10.88	11.79	10.26 11.0	11.83	14.09	13.55	13.2
C3	12.20	13.58	12.12 12.6	15.87	14.88	16.03 15.6	11.91	11.44	12.12 11.8	16.33	14.91	13.16	14.8
D1	9.48	9.33	10.92 9.9	11.54	11.84	12.40 11.9	10.58	9.75	6.95 9.1	12.33	11.16	12.40	12.0
D2	11.39	12.33	11.89 11.9	12.22	14.26	15.41 14.0	9.24	14.14	10.33 11.2	13.14	14.36	14.76	14.1
D3	12.60	13.77	13.27 13.2	14.95	15.72	15.57 15.4	10.99	13.15	12.54 12.2	17.57	18.49	15.43	17.2
E1	9.66	10.34	10.25 10.1	12.22	12.74	13.42 12.8	9.99	10.70	8.40 9.7	11.31	12.94	10.43	11.6
E2	11.39	12.22	11.37 11.7	15.35	14.07	12.39 14.0	10.22	10.92	11.51 10.9	11.39	13.00	16.70	13.7
E3	12.77	13.58	14.31 13.6	16.22	16.72	20.16 17.7	12.45	14.59	13.89 13.7	14.32	17.65	18.79	16.9
F1	9.48	9.60	9.07 9.4	12.58	11.02	12.00 11.9	8.42	10.19	9.95 9.5	12.55	11.42	11.44	11.8
F2	10.14	10.26	12.41 10.9	13.29	12.22	14.41 13.3	10.61	12.44	12.04 11.7	17.01	15.18	14.26	15.5
F3	11.23	12.12	14.11 12.5	16.37	16.27	18.20 17.0	12.18	15.42	14.42 14.0	17.81	14.78	13.46	15.3

* These figures denote the replicates.

Table 26. Experiment I. 1st cut, 1963; Apparent recovery of applied-P, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	4.39	2.74	4.83	5.58	1.93	6.28	7.02	4.26	1.70	8.27	5.32	4.58
A2	4.27	6.36	4.29	5.67	10.60	11.74	12.49	8.94	6.74	13.42	18.37	7.75
A3	10.46	2.78	7.81	10.01	11.76	12.37	7.94	10.46	12.22	17.12	17.45	19.55
B1	4.89	5.90	3.28	4.64	4.90	5.91	4.43	2.27	2.55	7.02	5.54	4.60
B2	5.04	4.75	6.46	8.68	8.31	12.03	7.72	7.07	9.39	16.68	15.11	10.52
B3	6.08	7.10	7.44	11.90	10.48	10.58	11.96	11.51	8.23	19.10	15.28	17.01
C1	2.14	3.38	3.70	4.09	5.79	6.56	2.18	4.64	2.82	5.54	10.71	4.29
C2	7.09	6.89	8.59	9.03	8.50	10.40	6.99	13.76	7.13	11.68	9.38	14.62
C3	7.38	11.74	4.88	12.17	11.41	9.31	9.74	12.77	10.28	22.61	14.75	16.32
D1	2.54	4.75	4.46	7.23	2.63	6.15	5.84	4.12	2.73	6.86	6.19	3.82
D2	3.65	6.95	6.87	7.30	8.10	11.87	5.94	10.35	7.18	9.15	16.11	15.33
D3	8.69	7.13	9.30	9.41	7.76	12.73	8.96	10.50	11.91	19.66	20.21	16.04
E1	1.29	5.09	5.56	2.61	4.90	7.43	8.75	5.19	2.54	8.66	7.34	6.60
E2	4.36	5.01	10.52	11.12	7.74	7.66	8.17	9.91	7.79	9.63	14.31	16.72
E3	6.20	7.38	8.00	10.37	11.29	18.08	12.24	10.38	10.08	13.53	21.68	25.95
F1	2.61	2.65	1.56	4.96	2.94	5.72	5.69	4.18	5.84	8.37	7.15	5.15
F2	3.74	6.97	8.23	7.71	5.86	10.66	6.14	7.69	6.62	18.03	14.65	10.60
F3	4.09	8.12	10.91	13.42	8.58	15.17	7.95	10.32	15.69	20.18	21.60	15.89

* These figures denote the replicates

Table 27. Experiment I. 2nd cut, 1963; Apparent recovery of applied-P, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	1.79	1.13	2.61	2.29	2.29	2.22	3.59	3.61	0.27	3.63	1.69	0.31
A2	1.70	2.32	2.05	5.46	5.66	9.67	5.82	5.39	4.45	5.57	8.07	3.20
A3	3.81	2.64	3.42	4.62	6.63	8.90	3.99	6.73	4.80	6.09	10.17	12.57
B1	-0.54	2.03	0.24	3.29	3.25	3.44	2.07	0.99	2.57	2.85	3.02	2.43
B2	3.76	3.13	4.02	2.89	5.23	7.37	3.40	5.77	6.19	5.33	6.59	5.85
B3	1.76	2.81	5.58	8.40	5.62	9.62	7.01	6.14	2.51	10.15	8.77	9.29
C1	0.15	0.75	1.14	1.21	4.13	3.29	0.64	2.36	4.15	0.73	4.56	1.13
C2	2.50	3.37	4.29	5.40	6.08	7.72	3.35	5.83	5.14	2.48	4.14	6.63
C3	3.33	5.81	2.62	8.49	7.60	6.91	5.11	6.29	6.20	6.52	7.46	8.75
D1	-0.31	0.47	1.81	2.44	1.90	4.15	2.25	1.60	1.71	0.64	0.88	2.54
D2	0.27	1.81	3.47	3.64	4.01	8.05	1.85	8.33	4.11	4.95	5.31	9.11
D3	2.38	4.97	4.70	8.02	5.78	8.59	4.40	4.22	5.95	10.09	10.77	9.04
E1	-0.29	0.45	2.21	1.84	3.62	5.21	1.51	3.57	0.53	1.02	2.19	2.12
E2	2.32	1.97	4.18	6.76	4.63	6.30	3.27	3.60	3.54	3.45	5.41	10.51
E3	2.49	3.08	4.14	7.85	8.70	11.54	5.94	5.90	7.04	5.94	9.84	15.27
F1	1.23	0.39	-0.81	2.56	2.16	4.48	2.16	2.27	2.78	0.89	3.58	1.31
F2	2.01	2.94	4.07	4.80	3.70	5.22	4.06	5.17	4.35	8.27	7.69	6.41
F3	0.48	3.48	5.27	8.52	6.98	11.01	4.59	7.46	8.57	9.52	10.37	7.68

* These figures denote the replicates.

Table 28. Experiment I. 3rd cut, 1963; Apparent recovery of applied-P, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	2.34	2.66	2.83	3.48	1.80	3.51	3.77	3.93	1.11	3.46	3.33	2.16
A2	3.40	5.15	3.92	3.94	6.56	6.78	5.93	6.17	3.49	4.47	6.84	2.15
A3	4.64	5.88	5.21	5.75	8.55	8.48	5.32	8.76	6.84	8.38	6.75	6.80
B1	1.43	2.90	0.42	1.65	4.46	3.27	3.57	2.17	1.46	2.67	3.44	1.89
B2	3.29	4.14	4.84	3.65	5.53	6.59	3.99	6.39	6.00	4.77	7.39	4.92
B3	4.29	4.87	4.72	7.40	8.23	9.28	8.78	7.22	5.24	9.74	4.29	5.16
C1	0.68	1.10	1.16	1.97	3.82	3.31	1.47	4.54	1.79	1.84	2.72	3.39
C2	3.87	5.26	3.58	5.27	5.36	4.95	4.31	5.22	3.69	2.96	5.22	4.68
C3	4.08	5.46	4.00	6.64	5.65	6.80	5.34	4.87	5.55	7.46	6.04	4.29
D1	1.36	1.21	2.80	2.31	2.61	3.17	4.01	3.18	0.38	3.46	2.29	3.53
D2	3.27	4.21	3.77	2.99	5.03	6.18	2.67	7.57	3.76	4.27	5.49	5.89
D3	4.48	5.65	5.15	5.72	6.49	6.34	4.42	6.58	5.97	8.70	9.62	6.56
E1	1.54	2.22	2.13	2.99	3.51	4.19	3.42	4.13	1.83	2.44	4.07	1.56
E2	3.27	4.10	3.25	6.12	4.84	3.16	3.65	4.35	4.94	2.52	4.13	7.83
E3	4.65	5.46	6.19	6.99	7.49	10.93	5.88	8.02	7.32	5.45	8.78	9.92
F1	1.36	1.48	0.95	3.35	1.79	2.77	1.85	3.62	3.38	3.68	2.55	2.57
F2	2.02	2.14	4.29	4.06	2.99	5.18	4.04	5.87	5.47	8.14	6.31	5.39
F3	3.11	4.00	5.99	7.14	7.04	8.97	5.61	8.85	7.85	8.94	5.91	4.59

*These figures denote the replicates.

Table 29. Experiment I. 1st cut, 1963; % apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	5.5	3.4	6.0	7.0	2.5	7.8	7.9	4.8	1.9	9.3	6.0	5.1
A2	2.7	3.9	2.7	3.5	6.6	7.3	7.0	5.0	3.8	7.5	10.3	4.3
A3	4.4	1.2	3.2	4.2	4.9	5.1	3.0	3.9	4.6	6.4	6.5	7.3
B1	6.1	7.4	4.1	5.8	6.1	7.4	5.0	2.5	2.9	7.9	6.2	5.2
B2	3.1	3.0	4.0	5.4	5.2	7.5	4.3	4.0	5.3	9.4	8.5	5.9
B3	2.5	3.0	3.1	5.0	4.4	4.4	4.5	4.3	3.1	7.1	5.7	6.4
C1	2.7	4.2	4.6	5.1	7.2	8.2	2.4	5.2	3.2	6.2	12.0	4.8
C2	4.4	4.3	5.4	5.6	5.3	6.5	3.9	7.7	4.0	6.6	5.3	8.2
C3	3.1	4.9	2.0	5.1	4.7	3.9	3.6	4.8	3.8	8.5	5.5	6.1
D1	3.2	5.9	5.6	9.0	3.3	7.7	6.6	4.6	3.1	7.7	6.9	4.3
D2	2.3	4.3	4.3	4.5	5.0	7.4	3.3	5.8	4.0	5.1	9.0	8.6
D3	3.6	3.0	3.9	3.9	3.2	5.3	3.4	3.9	4.5	7.4	7.6	6.0
E1	1.6	6.3	6.9	3.3	6.1	9.3	9.8	5.8	2.8	9.7	8.2	7.4
E2	2.7	3.1	6.5	6.9	4.8	4.7	4.6	5.6	4.4	5.4	8.0	9.4
E3	2.6	3.1	3.3	4.3	4.7	7.5	4.6	3.9	3.8	5.1	8.1	9.7
F1	3.3	3.3	1.9	6.2	3.7	7.1	6.4	4.7	6.6	9.4	8.0	5.8
F2	2.3	4.3	5.1	4.8	3.6	6.6	3.4	4.3	3.7	10.1	8.2	5.9
F3	1.7	3.4	4.5	5.6	3.6	6.3	3.0	3.9	5.9	7.5	8.1	5.9

* These figures denote the replicates.

Table 30. Experiment I. 2nd cut, 1963; % apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	2.2	1.4	3.3	2.6	2.9	2.8	4.0	4.1	0.3	4.1	1.9	0.3
A2	1.1	1.4	1.3	3.4	3.5	6.0	3.3	3.0	2.5	3.1	4.5	1.8
A3	1.6	1.1	1.4	1.9	2.8	3.7	1.5	2.5	1.8	2.3	3.8	4.7
B1	-0.7	2.5	0.3	4.1	4.1	4.3	2.3	1.1	2.9	3.2	3.4	2.7
B2	2.3	2.0	2.5	1.8	3.3	4.6	1.9	3.2	3.5	3.0	3.7	3.3
B3	0.7	1.2	2.3	3.5	2.3	4.0	2.6	2.3	0.9	3.8	3.3	3.5
C1	0.2	0.9	1.4	1.5	5.2	4.1	0.7	2.6	4.7	0.8	5.1	1.3
C2	1.6	2.1	2.7	3.4	3.8	4.8	1.9	3.3	2.9	1.4	2.3	3.7
C3	1.4	2.4	1.1	3.5	3.2	2.9	1.9	2.4	2.3	2.4	2.8	3.3
D1	-0.4	0.6	2.3	3.0	2.4	5.2	2.5	1.8	1.9	0.7	1.0	2.8
D2	0.2	1.1	2.2	2.3	2.5	5.0	1.0	4.7	2.3	2.8	3.0	5.1
D3	1.0	2.1	2.0	3.3	2.4	3.6	1.6	1.6	2.2	3.8	4.0	3.4
E1	-0.4	0.6	2.8	2.3	4.5	6.5	1.7	4.0	0.6	1.1	2.5	2.4
E2	1.4	1.2	2.6	4.2	2.9	3.9	1.8	2.0	2.0	1.9	3.0	5.9
E3	1.0	1.3	1.7	3.3	3.6	4.8	2.2	2.2	2.6	2.2	3.7	5.7
F1	1.5	0.5	-1.0	3.2	2.7	5.6	2.4	2.5	3.1	1.0	4.0	1.5
F2	1.3	1.8	2.5	3.0	2.3	3.3	2.3	2.9	2.4	4.6	4.3	3.6
F3	0.2	1.4	2.2	3.5	2.9	4.6	1.7	2.8	3.2	3.6	3.9	2.9

* These figures denote the replicates.

Table 31. Experiment I. 3rd cut, 1963; % Apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	2.9	3.3	3.5	4.3	2.2	4.4	4.2	4.4	1.2	3.9	3.7	2.4
A2	2.1	3.2	2.4	2.5	4.1	4.2	3.3	3.5	2.0	2.5	3.8	1.2
A3	1.9	2.4	2.2	2.4	3.5	3.5	2.0	3.3	2.6	3.1	2.5	2.5
B1	1.8	3.6	0.5	2.1	5.6	4.1	4.0	2.4	1.6	3.0	3.9	2.1
B2	2.0	2.6	3.0	2.3	3.4	4.1	2.2	3.6	3.4	2.7	4.1	2.8
B3	1.8	2.0	2.0	3.1	3.4	3.9	3.3	2.7	2.0	3.6	1.6	1.9
C1	0.8	1.4	1.4	2.5	4.8	4.1	1.6	5.1	2.0	2.1	3.1	3.8
C2	2.4	3.3	2.2	3.3	3.3	3.1	2.4	2.9	2.1	1.7	2.9	2.6
C3	1.7	2.3	1.7	2.8	2.3	2.8	2.0	1.8	2.1	2.8	2.3	1.6
D1	1.7	1.5	3.5	2.9	3.3	4.0	4.5	3.6	0.4	3.9	2.6	4.0
D2	2.0	2.6	2.3	1.9	3.1	3.9	1.5	4.2	2.1	2.4	3.1	3.3
D3	1.9	2.3	2.1	2.4	2.7	2.6	1.7	2.5	2.2	3.3	3.6	2.5
E1	1.9	2.8	2.7	3.7	4.4	5.2	3.8	4.6	2.1	2.7	4.6	1.8
E2	2.0	2.6	2.0	3.8	3.0	2.0	2.0	2.4	2.8	1.4	2.3	4.4
E3	1.9	2.3	2.6	2.9	3.1	4.5	2.2	3.0	2.7	2.0	3.3	3.7
F1	1.7	1.8	1.2	4.2	2.2	3.5	2.1	4.1	3.8	4.1	2.9	2.9
F2	1.3	1.3	2.7	2.5	1.9	3.2	2.3	3.3	3.1	4.6	3.5	3.0
F3	1.3	1.7	2.5	3.0	2.9	3.7	2.1	3.3	2.9	3.3	2.2	1.7

*These figures denote the replicates.

Table 32. Experiment I. Total of 3 cuts, 1963; % apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	10.6	8.1	12.8	13.9	7.6	15.0	16.1	13.3	3.4	17.3	11.6	7.8
A2	5.9	8.5	6.4	9.4	14.2	17.5	13.6	11.5	8.3	13.1	18.6	7.3
A3	7.9	4.7	6.8	8.5	11.2	12.3	6.5	9.7	9.0	11.8	12.8	14.5
B1	7.2	13.5	4.9	12.0	15.8	15.8	11.3	6.0	7.4	14.1	13.5	10.0
B2	7.4	7.6	9.5	9.5	11.9	16.2	8.4	10.8	12.2	15.1	16.3	12.0
B3	5.0	6.2	7.4	11.6	10.1	12.3	10.4	9.3	6.0	14.5	10.6	11.8
C1	3.7	6.5	7.4	9.1	17.2	16.4	4.7	12.9	9.9	9.1	20.2	9.9
C2	8.4	9.7	10.3	12.3	12.4	14.4	8.2	13.9	9.0	9.7	10.5	14.5
C3	6.2	9.6	4.8	11.4	10.2	9.6	7.5	9.0	8.2	13.7	10.6	11.0
D1	4.5	8.0	11.4	14.9	9.0	16.9	13.6	10.0	5.4	12.3	10.5	11.1
D2	4.5	8.0	8.8	8.7	10.6	16.3	5.8	14.7	8.4	10.3	15.1	17.0
D3	6.5	7.4	8.0	9.6	8.3	11.5	6.7	8.0	8.9	14.5	15.2	11.9
E1	3.1	9.7	12.4	9.3	15.0	21.0	15.3	14.4	5.5	13.5	15.3	11.6
E2	6.1	6.9	11.1	14.9	10.7	10.6	8.4	10.0	9.2	8.7	13.3	19.7
E3	5.5	6.7	7.6	10.5	11.4	16.8	9.0	9.1	9.1	9.3	15.1	19.1
F1	6.5	5.6	2.1	13.6	8.6	16.2	10.9	11.3	13.5	14.5	14.9	10.2
F2	4.9	7.4	10.3	10.3	7.8	13.1	8.0	10.5	9.2	19.3	16.0	12.5
F3	3.2	6.5	9.2	12.1	9.4	14.6	6.8	10.0	12.0	14.4	14.2	10.5

* These figures denote the replicates.

Table 33. Experiment I. 1st cut, 1964; Yield of fresh grass, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	30.3	28.0	21.8	40.4	26.8	31.0	23.9	19.9	12.7	32.2	30.4	21.6
0	31.9	16.8	20.4	33.6	30.8	32.2	23.1	14.2	20.5	33.6	33.7	25.5
A1	23.6	21.8	21.9	38.1	32.2	41.2	30.3	19.3	18.5	44.7	27.9	30.7
A2	31.3	22.2	22.4	38.2	43.8	35.8	25.6	25.0	20.7	37.8	31.4	32.9
A3	24.5	9.9	23.2	37.0	39.6	38.3	29.6	19.4	20.0	34.8	27.8	38.0
B1	24.2	25.7	20.4	41.4	38.0	37.6	24.8	20.7	20.3	32.1	34.9	29.1
B2	21.9	27.3	21.4	35.4	36.6	40.4	12.7	14.7	15.3	43.4	36.6	36.1
B3	23.5	22.8	24.8	40.4	38.4	42.2	23.7	17.3	21.5	34.7	38.6	39.9
C1	25.6	20.2	14.8	41.5	32.1	37.8	17.7	19.3	15.5	41.0	34.9	30.9
C2	27.2	23.1	22.6	35.9	30.0	36.3	23.7	20.4	17.1	38.8	35.2	40.9
C3	24.0	25.3	23.2	39.7	35.8	37.8	23.9	22.2	17.7	44.6	32.3	37.3
D1	27.5	20.3	25.8	32.2	25.7	37.9	26.1	15.8	15.2	36.2	35.0	36.5
D2	22.6	26.3	24.9	39.9	41.5	39.3	24.4	22.6	23.6	34.8	35.7	35.5
D3	26.2	24.5	23.9	37.3	34.2	41.3	22.5	18.8	22.7	41.0	38.6	32.6
E1	24.2	23.3	27.9	36.9	34.2	36.9	23.9	25.9	14.5	37.8	33.9	35.1
E2	30.2	22.7	21.6	43.2	36.5	37.0	17.7	18.5	18.8	38.6	33.1	34.1
E3	26.9	26.3	25.5	38.1	40.8	40.8	25.2	18.0	16.0	36.2	34.7	43.2
F1	27.1	21.9	20.8	35.7	31.2	37.8	22.3	15.4	20.5	36.2	33.5	39.4
F2	22.1	24.7	24.4	34.9	31.5	34.6	22.1	19.3	23.7	41.0	32.8	31.4
F3	23.0	24.4	25.7	42.0	35.4	42.9	20.9	19.1	18.4	44.1	31.7	35.5

* These figures denote the replicates.

Table 34. Experiment I. 2nd cut, 1964; Yield of fresh grass, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	21.1	26.9	30.6	34.1	33.2	30.7	29.3	24.9	26.8	34.1	35.4	33.0
0	28.2	31.2	22.5	39.5	32.7	32.5	26.7	22.5	27.3	34.5	24.1	36.9
A1	28.3	28.1	24.6	31.6	29.4	47.0	25.6	25.1	28.4	41.5	40.4	40.1
A2	27.7	26.7	28.2	41.5	35.4	40.3	28.6	28.1	30.3	38.4	42.1	32.7
A3	31.3	25.1	22.8	45.8	41.9	38.6	28.5	19.6	25.6	43.5	45.4	48.2
B1	25.3	28.3	23.5	34.3	37.6	29.3	22.8	26.5	27.3	41.2	37.3	42.9
B2	27.8	30.0	24.3	41.0	41.7	43.2	30.7	26.8	30.4	47.5	42.1	44.6
B3	24.4	26.7	31.9	40.9	45.0	48.4	31.6	22.7	25.8	43.9	36.3	44.5
C1	25.1	19.4	26.8	42.2	24.4	38.6	24.4	23.5	29.2	38.6	38.4	36.6
C2	24.8	25.8	24.7	36.7	38.3	41.8	29.9	21.7	31.7	43.1	42.5	47.6
C3	28.4	32.6	28.8	40.9	40.4	35.2	26.8	22.1	30.6	49.2	40.5	42.0
D1	26.2	19.9	25.7	27.5	39.0	42.0	27.5	24.5	24.7	36.1	38.4	39.5
D2	28.2	26.2	25.5	34.1	30.8	38.1	25.1	23.4	28.1	39.2	30.8	47.1
D3	26.0	27.4	27.0	38.6	41.7	49.1	26.1	27.2	26.9	44.5	43.5	43.8
E1	28.6	26.2	22.9	29.0	41.5	35.5	20.9	24.9	27.3	36.3	32.8	37.8
E2	28.5	23.2	32.1	31.1	39.2	30.9	31.1	23.8	26.0	43.0	39.5	51.7
E3	26.1	23.0	36.4	43.7	41.0	42.1	28.3	30.9	29.9	39.1	47.7	43.3
F1	26.6	27.5	28.0	39.3	22.4	36.6	29.1	23.6	25.6	46.2	35.7	44.6
F2	25.5	22.6	27.6	31.4	35.0	38.3	28.1	28.6	26.4	44.7	46.4	44.0
F3	24.7	24.9	22.8	37.2	39.4	49.7	29.1	25.5	31.5	42.7	41.5	42.4

* These figures denote the replicates.

Table 35. Experiment I. 3rd cut, 1964; Yield of fresh grass, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	23.0	19.3	25.7	29.5	30.3	28.3	21.4	21.3	23.1	30.1	33.8	34.7
0	23.1	21.8	22.5	28.4	28.6	31.8	19.6	22.0	22.7	31.7	32.2	30.6
A1	27.7	23.8	24.9	35.9	31.3	34.2	23.9	20.8	21.6	37.9	35.9	38.6
A2	25.4	23.2	23.8	37.1	32.3	33.4	21.5	23.8	26.5	39.3	41.6	40.7
A3	23.6	21.4	27.4	35.0	37.0	40.3	23.4	20.1	26.9	42.0	44.3	46.6
B1	25.3	18.9	24.9	35.7	32.5	27.5	28.2	19.9	24.3	35.5	38.8	39.0
B2	24.3	23.3	25.1	37.5	37.0	42.9	21.0	24.1	25.0	40.6	39.9	41.8
B3	24.3	18.8	24.9	37.6	37.1	38.1	23.3	20.3	27.8	45.8	45.3	47.9
C1	22.8	16.2	24.2	36.1	29.6	36.6	22.3	22.0	27.2	37.1	34.0	42.5
C2	20.2	24.2	23.5	31.5	29.9	38.2	21.0	24.9	26.3	39.9	40.6	45.0
C3	23.3	22.7	22.7	35.9	32.7	34.9	21.3	23.6	25.5	41.2	43.9	46.3
D1	21.5	24.3	21.9	31.2	34.3	33.7	21.9	21.6	24.4	41.1	34.3	40.6
D2	23.8	24.6	25.6	37.0	27.2	38.8	22.7	27.7	25.8	40.3	40.6	44.3
D3	25.7	21.6	23.3	35.2	32.5	40.0	22.1	23.0	25.7	43.6	42.2	46.0
E1	23.0	24.5	25.4	33.6	35.6	34.0	26.2	21.9	25.4	41.4	37.6	41.2
E2	23.0	25.2	27.3	36.0	35.8	35.3	23.5	22.9	21.9	39.5	39.6	45.1
E3	21.8	21.2	26.7	32.5	36.1	43.9	23.4	22.5	25.8	40.7	41.8	47.3
F1	23.2	22.8	25.8	32.7	31.9	36.7	23.4	25.2	24.0	41.0	24.8	38.3
F2	26.5	20.7	28.1	31.9	34.4	40.4	22.6	23.1	26.7	42.5	38.7	42.2
F3	20.8	20.0	24.9	34.4	28.6.	37.0	23.1	23.2	26.2	48.7	38.8	48.9

* These figures denote the replicates.

Table 36. Experiment I. 1st cut, 1964; % dry matter in the grass

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	26.8	24.1	25.8	28.1	24.4	24.7	26.5	27.0	25.0	26.9	25.8	24.6
0	26.9	25.7	26.4	27.8	27.1	25.7	27.4	27.1	26.4	27.2	24.6	26.1
A1	26.3	26.8	26.5	28.1	28.7	27.1	28.1	26.4	25.9	28.1	26.5	26.4
A2	26.5	25.9	25.5	28.2	28.1	27.1	26.2	26.9	27.1	26.9	28.5	27.8
A3	26.3	25.6	26.8	26.1	27.4	29.6	25.4	25.2	25.7	29.1	25.5	25.2
B1	25.3	26.3	25.5	27.9	28.3	28.4	27.3	27.1	27.3	25.2	28.3	27.5
B2	25.7	25.9	27.2	27.6	28.0	27.0	23.2	25.5	23.5	27.8	28.8	27.7
B3	26.1	27.2	26.0	28.7	27.9	27.5	25.5.	25.6	24.6	26.4	27.4	26.9
C1	26.8	27.7	25.6	27.4	26.3	26.3	23.5	27.4	22.5	27.3	27.7	27.6
C2	25.9	26.1	26.5	24.7	26.9	26.7	26.3	27.0	25.3	29.6	26.6	28.6
C3	27.9	27.3	25.9	27.2	28.4	27.7	22.7	25.5	25.8	28.0	28.5	26.6
D1	25.8	25.1	27.1	31.3	24.6	27.6	27.1	27.1	26.1	28.5	28.4	27.3
D2	26.9	26.6	25.5	28.5	29.0	27.4	26.7	26.4	26.6	29.6	26.8	28.2
D3	26.2	26.5	26.4	27.2	28.8	27.6	26.7	25.9	26.0	27.2	27.8	26.8
E1	27.0	26.6	26.9	30.0	28.6	27.2	27.4	27.9	26.1	29.5	28.0	27.9
E2	25.8	27.0	25.7	28.0	29.2	28.0	25.5	25.8	25.8	25.9	26.6	26.4
E3	25.8	27.2	25.9	26.0	27.0	27.5	24.8	24.5	25.2	24.6	27.4	26.8
F1	26.3	27.4	26.0	28.0	27.2	28.6	26.1	26.6	27.8	28.5	25.4	27.7
F2	25.7	25.6	26.4	27.5	26.3	28.2	26.2	25.9	25.4	27.7	28.1	27.8
F3	25.7	27.4	26.7	25.8	28.1	27.8	25.5	24.6	24.2	27.4	26.3	28.1

* These figures denote the replicates.

Table 37. Experiment I. 2nd cut, 1964; % dry matter in the grass

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	37.5	38.3	37.2	37.8	38.8	37.9	36.0	37.8	37.8	34.7	35.9	36.1
0	36.6	36.8	40.0	36.3	37.9	37.9	36.7	37.8	37.8	36.2	36.1	35.8
A1	36.6	36.6	38.6	35.8	38.4	37.4	35.5	37.0	37.6	35.6	35.0	35.9
A2	35.8	36.7	37.3	36.0	38.8	41.3	36.4	37.8	38.8	34.2	34.7	36.1
A3	36.4	42.3	40.4	34.8	37.7	38.6	36.0	37.6	36.6	36.4	35.2	35.5
B1	37.5	37.5	39.0	36.4	38.8	42.0	36.0	37.1	38.4	32.9	35.5	35.5
B2	38.7	37.0	39.1	36.2	36.3	37.6	36.4	37.3	37.8	35.2	36.3	37.2
B3	39.3	38.9	39.6	36.9	35.6	38.7	36.4	36.9	36.8	34.6	35.3	36.7
C1	36.6	37.6	36.5	37.4	37.7	39.9	35.5	36.3	37.7	34.9	35.8	36.3
C2	37.5	39.0	42.1	35.4	37.7	38.5	36.4	38.1	37.9	36.2	34.8	36.4
C3	38.4	37.4	38.9	36.2	39.6	38.9	34.1	37.3	37.7	33.9	35.8	36.0
D1	36.6	38.6	38.8	36.1	37.7	37.9	36.2	36.7	38.1	35.2	35.2	36.2
D2	37.9	38.3	39.6	36.5	37.4	39.6	37.6	37.1	37.9	33.7	35.4	36.8
D3	36.3	37.8	39.4	36.8	37.7	38.5	35.3	38.2	38.4	34.0	35.5	35.2
E1	37.0	36.6	41.1	36.8	39.5	37.7	36.9	37.6	37.7	33.9	35.0	35.9
E2	36.5	38.3	38.9	36.4	38.3	38.3	37.4	35.7	38.5	34.9	36.4	34.4
E3	36.9	38.3	39.5	37.5	39.3	38.4	36.3	35.9	37.1	35.5	36.7	35.6
F1	36.9	36.7	39.2	36.3	38.2	38.3	34.7	37.8	37.5	35.7	35.5	36.2
F2	35.7	38.4	40.0	38.6	38.1	37.9	35.9	37.0	38.7	33.8	35.9	35.9
F3	38.1	39.4	40.0	36.0	37.1	37.4	35.9	36.3	37.2	33.9	36.5	36.0

* These figures denote the replicates

Table 38. Experiment I. 3rd cut, 1964; % dry matter in the grass

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	28.0	28.5	28.2	27.1	27.6	27.2	27.5	28.0	28.0	27.2	26.0	26.0
0	29.1	27.7	29.3	27.0	26.5	27.0	28.1	29.0	27.4	26.3	27.8	25.9
A1	30.5	28.3	28.1	29.6	27.7	29.6	27.9	27.9	27.4	26.0	26.4	26.8
A2	29.1	28.5	28.7	27.4	28.1	30.6	27.8	27.6	28.3	26.0	26.6	26.4
A3	28.1	29.7	30.4	27.1	28.8	29.7	28.4	25.7	28.4	27.7	27.1	27.7
B1	30.8	27.3	30.5	28.9	29.0	28.3	30.5	27.6	28.4	26.5	26.4	26.3
B2	27.2	28.7	27.5	27.5	27.8	28.5	27.3	28.0	27.2	29.3	26.8	27.0
B3	29.7	28.7	29.3	29.4	28.1	29.7	27.2	27.3	29.4	27.6	27.2	27.5
C1	28.0	26.7	28.2	28.3	27.2	28.7	27.2	27.8	27.5	27.2	25.5	28.0
C2	28.9	29.6	29.0	27.7	26.6	28.1	28.0	28.2	28.3	27.4	26.6	27.4
C3	28.7	28.3	28.8	28.3	27.4	29.9	26.8	28.1	29.4	27.3	27.2	28.3
D1	28.4	28.8	28.0	28.4	27.7	26.8	27.4	28.3	28.6	28.1	27.3	26.3
D2	29.3	29.0	29.9	28.6	28.1	29.4	28.2	28.5	28.6	27.9	26.7	27.2
D3	28.3	28.7	30.3	29.3	28.3	28.8	27.8	27.6	30.1	27.5	27.0	27.4
E1	28.9	28.9	29.0	28.9	29.7	30.0	28.6	28.3	28.3	27.6	27.0	27.2
E2	28.3	28.7	29.3	28.7	28.3	29.3	27.7	27.6	28.4	26.8	26.9	27.0
E3	27.1	28.3	29.2	28.8	29.0	28.0	28.1	27.3	28.2	26.9	27.1	27.3
F1	27.2	28.6	29.1	27.5	27.7	29.8	27.7	30.3	28.7	26.1	25.5	27.4
F2	28.3	29.2	29.3	28.4	28.9	29.2	28.2	28.1	28.4	27.1	26.4	26.6
F3	29.6	28.5	28.1	28.2	29.0	29.8	28.3	27.5	27.5	27.4	25.8	28.1

* These figures denote the replicates.

Table 39. Experiment I. 1st cut, 1964; Yield of dry matter, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	8.13	6.75	5.62	11.34	6.55	7.67	6.34	5.37	3.17	8.68	7.85	5.31
0	8.59	4.33	5.37	9.33	8.37	8.27	6.33	3.85	5.40	9.13	8.28	6.65
A1	6.20	5.83	5.79	10.72	9.25	11.16	8.51	5.11	4.78	12.56	7.40	8.08
A2	8.30	5.75	5.71	10.78	12.32	9.70	6.72	6.73	5.60	10.15	8.97	9.15
A3	6.46	2.53	6.22	9.66	10.87	11.36	7.52	4.89	5.13	10.13	7.07	9.59
B1	6.10	6.75	5.20	11.56	10.75	10.67	6.77	5.60	5.53	8.10	9.99	7.98
B2	5.63	7.07	5.80	9.77	10.24	10.90	2.93	3.75	3.60	12.04	10.55	10.00
B3	6.14	6.20	6.45	11.58	10.71	11.61	6.04	4.44	5.28	9.17	10.58	10.75
C1	6.87	5.59	3.78	11.38	8.45	9.93	4.15	5.30	3.49	11.17	9.68	8.53
C2	7.04	6.03	6.00	8.85	8.05	9.68	6.24	5.52	4.33	11.50	9.35	11.70
C3	6.70	6.90	6.03	10.81	10.14	10.48	5.42	5.64	4.57	12.50	9.18	9.91
D1	7.10	5.09	7.00	10.10	6.33	10.45	7.07	4.28	3.97	10.30	9.95	9.96
D2	6.07	7.00	6.33	11.35	12.02	10.79	6.51	5.96	6.30	10.28	9.57	10.00
D3	6.86	6.50	6.32	10.14	9.85	11.40	5.99	4.87	5.90	11.17	10.75	8.74
E1	6.53	6.19	7.51	10.70	9.77	10.03	6.54	7.24	3.78	11.15	9.50	9.78
E2	7.80	6.13	5.56	12.08	10.67	10.38	4.52	4.77	4.85	9.98	8.81	9.00
E3	6.94	7.15	6.60	9.88	11.04	11.23	6.25	4.42	4.03	8.90	9.51	11.58
F1	7.12	6.00	5.40	9.98	8.50	10.80	5.82	4.09	5.50	9.97	8.51	10.91
F2	5.68	6.32	6.43	9.61	8.29	9.76	5.77	5.00	6.03	11.34	9.20	8.75
F3	5.91	6.68	6.85	10.83	9.95	11.93	5.33	4.71	4.45	12.08	8.33	9.98

* These figures denote the replicates.

Table 40. Experiment I. 2nd cut, 1964; Yield of dry matter, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	7.91	10.30	11.40	12.87	12.90	11.62	10.54	9.40	10.11	11.82	12.72	11.91
0	10.34	11.50	9.01	14.35	12.39	12.31	9.78	8.50	10.30	12.50	8.70	13.20
A1	10.37	10.28	9.50	11.32	11.30	17.58	9.10	9.28	10.70	14.76	14.15	14.39
A2	9.91	9.79	10.52	14.93	13.71	16.65	10.42	10.62	11.75	13.13	14.62	11.79
A3	11.40	10.60	9.20	15.93	15.80	14.89	10.25	7.38	9.39	15.83	15.99	17.10
B1	9.51	10.62	9.15	12.47	14.58	12.28	8.21	9.85	10.49	13.56	13.25	15.20
B2	10.78	11.10	9.50	14.82	15.17	16.23	11.16	10.00	11.50	16.70	15.28	16.61
B3	9.57	10.37	12.61	15.09	16.02	18.73	11.50	8.40	9.49	15.17	12.79	16.35
C1	9.18	7.30	9.78	15.77	9.20	15.42	8.66	8.51	11.01	13.44	13.75	13.30
C2	9.29	10.06	10.40	13.02	14.45	16.08	10.90	8.28	12.00	15.60	14.78	17.32
C3	10.90	12.18	11.20	14.80	16.01	13.70	9.12	8.25	11.55	16.68	14.49	15.10
D1	9.58	7.70	9.95	9.94	14.70	15.95	9.97	8.98	9.40	12.69	13.52	14.30
D2	10.69	10.02	10.10	12.43	11.53	15.09	9.42	8.68	10.65	13.19	10.90	17.34
D3	9.45	10.35	10.61	14.21	15.71	18.91	9.20	10.40	10.31	15.15	15.42	15.42
E1	10.58	9.60	9.40	10.70	16.39	13.40	7.70	9.38	10.29	12.30	11.47	13.55
E2	10.40	8.91	12.49	11.30	14.98	11.82	11.60	8.50	10.00	15.00	14.38	17.80
E3	9.65	8.79	10.41	16.37	16.11	16.19	10.27	11.10	11.08	13.88	17.50	15.40
F1	9.81	10.11	11.00	14.25	8.55	14.00	10.07	8.90	9.61	16.50	15.65	16.12
F2	9.12	8.65	11.04	12.12	13.35	14.51	10.10	10.59	10.20	15.13	16.62	15.79
F3	9.40	9.80	9.12	13.38	14.60	18.58	10.46	9.26	11.70	14.50	15.14	15.28

* These figures denote the replicates

Table 41. Experiment I. 3rd cut, 1964; Yield of dry matter, g/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	6.45	5.50	7.24	7.99	8.35	7.70	5.88	5.98	6.47	8.20	8.80	9.01
0	6.72	6.04	6.60	7.67	7.58	8.60	5.50	6.39	6.21	8.31	8.94	7.93
A1	8.45	6.75	6.99	10.61	8.65	10.11	6.65	5.80	5.91	9.85	9.50	10.35
A2	7.37	6.61	6.83	10.19	9.06	10.22	5.97	6.57	7.50	10.23	11.06	10.75
A3	6.63	6.36	8.32	9.50	10.65	11.95	6.64	5.16	7.65	11.64	11.98	12.91
B1	7.80	5.14	7.60	10.30	9.43	7.77	8.61	5.50	6.90	9.40	10.24	10.24
B2	6.60	6.70	6.90	10.29	10.27	12.20	5.73	6.74	6.80	11.91	10.71	11.30
B3	7.21	5.40	7.30	11.07	10.42	11.31	6.33	5.53	8.15	12.65	12.33	13.15
C1	6.39	4.33	6.82	10.22	8.06	10.53	6.07	6.11	7.50	10.10	8.67	11.91
C2	5.84	7.16	6.82	8.72	7.94	10.75	5.87	7.02	7.42	10.93	10.80	12.34
C3	6.70	6.40	6.54	10.16	8.96	10.42	5.70	6.64	7.24	11.23	11.94	13.12
D1	6.09	7.00	6.14	8.86	9.49	9.03	5.98	6.13	6.96	11.54	9.37	10.70
D2	6.97	7.13	7.67	10.60	7.64	11.42	6.40	7.90	7.37	11.22	10.81	12.05
D3	7.29	6.20	7.05	10.31	9.21	11.51	6.13	6.33	7.74	12.00	11.93	12.60
E1	6.65	7.08	7.36	9.69	10.55	10.20	7.49	6.20	7.20	11.43	10.13	11.20
E2	6.52	7.24	8.00	10.34	10.14	10.33	6.51	6.32	6.20	10.58	10.68	12.18
E3	5.90	6.00	7.81	9.36	10.45	12.30	6.57	6.14	7.27	10.95	11.32	12.90
F1	6.30	6.52	7.50	9.00	8.80	10.95	6.46	7.63	6.89	10.70	6.33	10.48
F2	7.48	6.03	8.21	9.07	9.95	11.82	6.37	6.49	7.57	11.52	10.21	11.23
F3	6.17	5.70	6.98	9.72	8.28	11.03	6.53	6.37	7.20	13.35	10.01	13.75

* These figures denote the replicates.

Table 42. Experiment I. 1st cut, 1964; % P in the dry matter.

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	0.117	0.123	0.112	0.084	0.116	0.097	0.104	0.126	0.116	0.096	0.099	0.102
0	0.117	0.128	0.117	0.083	0.094	0.090	0.111	0.104	0.108	0.087	0.089	0.083
A1	0.138	0.116	0.132	0.107	0.092	0.083	0.140	0.124	0.128	0.120	0.114	0.098
A2	0.142	0.153	0.149	0.103	0.097	0.134	0.171	0.162	0.131	0.130	0.131	0.115
A3	0.164	0.174	0.138	0.135	0.114	0.146	0.177	0.205	0.196	0.135	0.148	0.156
B1	0.139	0.146	0.128	0.089	0.098	0.100	0.154	0.140	0.125	0.116	0.103	0.097
B2	0.159	0.138	0.154	0.101	0.096	0.112	0.209	0.171	0.191	0.122	0.120	0.117
B3	0.161	0.153	0.156	0.138	0.120	0.129	0.192	0.185	0.191	0.138	0.126	0.129
C1	0.115	0.115	0.139	0.115	0.107	0.106	0.172	0.143	0.161	0.110	0.103	0.104
C2	0.159	0.136	0.146	0.132	0.121	0.104	0.156	0.171	0.158	0.125	0.123	0.116
C3	0.154	0.147	0.162	0.141	0.117	0.118	0.227	0.178	0.167	0.138	0.143	0.137
D1	0.136	0.142	0.110	0.104	0.105	0.091	0.139	0.140	0.147	0.102	0.097	0.098
D2	0.144	0.135	0.152	0.107	0.090	0.106	0.164	0.166	0.147	0.112	0.122	0.117
D3	0.160	0.140	0.163	0.130	0.123	0.132	0.177	0.192	0.193	0.146	0.138	0.134
E1	0.116	0.116	0.127	0.098	0.087	0.103	0.152	0.116	0.154	0.104	0.100	0.116
E2	0.141	0.143	0.156	0.112	0.108	0.107	0.163	0.178	0.158	0.130	0.130	0.136
E3	0.160	0.162	0.169	0.133	0.120	0.125	0.210	0.204	0.186	0.146	0.137	0.142
F1	0.132	0.112	0.127	0.108	0.092	0.098	0.137	0.144	0.152	0.115	0.111	0.094
F2	0.145	0.140	0.137	0.123	0.112	0.104	0.179	0.161	0.162	0.127	0.112	0.116
F3	0.160	0.155	0.159	0.145	0.126	0.126	0.192	0.200	0.196	0.151	0.144	0.134

* These figures denote the replicates.

Table 43. Experiment I. 2nd cut, 1964; % P in the dry matter.

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	0.067	0.069	0.081	0.050	0.051	0.055	0.072	0.075	0.071	0.056	0.055	0.058
0	0.080	0.054	0.069	0.049	0.051	0.054	0.069	0;068	0.075	0.054	0.054	0.054
A1	0.083	0.091	0.081	0.060	0.061	0.067	0.094	0.087	0.082	0.068	0.068	0.066
A2	0.094	0.092	0.092	0.059	0.060	0.083	0.101	0.090	0.094	0.082	0.082	0.077
A3	0.099	0.097	0.090	0.068	0.067	0.071	0.104	0.104	0.120	0.082	0.085	0.084
B1	0.085	0.083	0.077	0.052	0.064	0.061	0.090	0.090	0.089	0.074	0.074	0.069
B2	0.081	0.096	0.088	0.062	0.059	0.065	0.104	0.098	0.108	0.073	0.074	0.068
B3	0.097	0.073	0.092	0.071	0.070	0.064	0.122	0.098	0.110	0.084	0.081	0.081
C1	0.083	0.073	0.097	0.060	0.060	0.064	0.104	0.097	0.087	0.064	0.067	0.066
C2	0.087	0.097	0.086	0.067	0.070	0.064	0.097	0.109	0.097	0.072	0.078	0.078
C3	0.097	0.107	0.094	0.067	0.064	0.063	0.121	0.197	0.106	0.084	0.085	0.089
D1	0.080	0.083	0.081	0.056	0.054	0.058	0.085	0.083	0.090	0.066	0.068	0.069
D2	0.084	0.084	0.086	0.063	0.061	0.071	0.101	0.099	0.097	0.072	0.081	0.072
D3	0.101	0.097	0.096	0.063	0.061	0.076	0.107	0.097	0.112	0.082	0.079	0.081
E1	0.092	0.082	0.077	0.055	0.060	0.063	0.096	0.082	0.091	0.071	0.072	0.070
E2	0.090	0.083	0.100	0.065	0.062	0.059	0.102	0.107	0.106	0.076	0.078	0.085
E3	0.090	0.094	0.097	0.066	0.070	0.069	0.111	0.114	0.108	0.089	0.081	0.089
F1	0.076	0.083	0.076	0.058	0.055	0.054	0.100	0.090	0.091	0.069	0.068	0.068
F2	0.089	0.078	0.084	0.061	0.065	0.065	0.112	0.098	0.102	0.076	0.074	0.070
F3	0.078	0.090	0.090	0.073	0.064	0.072	0.111	0.109	0.114	0.089	0.087	0.078

* These figures denote the replicates.

Table 44. Experiment I. 3rd cut, 1964; % P in the dry matter.

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	0.132	0.120	0.123	0.085	0.092	0.080	0.107	0.129	0.118	0.081	0.089	0.080
0	0.111	0.134	0.120	0.085	0.080	0.090	0.127	0.110	0.112	0.084	0.083	0.081
A1	0.132	0.143	0.122	0.089	0.081	0.098	0.156	0.142	0.135	0.108	0.112	0.099
A2	0.144	0.157	0.145	0.090	0.092	0.117	0.140	0.154	0.142	0.113	0.130	0.108
A3	0.182	0.139	0.144	0.104	0.102	0.108	0.169	0.133	0.188	0.123	0.126	0.140
B1	0.145	0.139	0.124	0.087	0.087	0.084	0.146	0.164	0.136	0.104	0.111	0.097
B2	0.133	0.185	0.130	0.096	0.099	0.100	0.149	0.156	0.181	0.120	0.121	0.109
B3	0.169	0.155	0.173	0.104	0.108	0.104	0.187	0.180	0.173	0.139	0.116	0.116
C1	0.144	0.116	0.148	0.092	0.090	0.090	0.146	0.158	0.125	0.108	0.092	0.092
C2	0.140	0.150	0.138	0.104	0.111	0.097	0.150	0.160	0.150	0.105	0.110	0.115
C3	0.152	0.203	0.162	0.115	0.104	0.098	0.193	0.164	0.162	0.129	0.122	0.140
D1	0.128	0.129	0.126	0.085	0.089	0.084	0.153	0.144	0.133	0.104	0.092	0.102
D2	0.132	0.151	0.153	0.094	0.090	0.100	0.170	0.162	0.150	0.104	0.115	0.117
D3	0.162	0.162	0.180	0.095	0.104	0.101	0.178	0.165	0.182	0.121	0.119	0.120
E1	0.133	0.148	0.115	0.087	0.088	0.095	0.151	0.137	0.126	0.102	0.098	0.100
E2	0.155	0.130	0.171	0.098	0.096	0.087	0.158	0.165	0.172	0.110	0.117	0.125
E3	0.149	0.150	0.159	0.135	0.105	0.111	0.144	0.184	0.171	0.128	0.119	0.133
F1	0.147	0.121	0.126	0.090	0.081	0.090	0.165	0.134	0.149	0.098	0.088	0.089
F2	0.135	0.144	0.144	0.103	0.092	0.096	0.177	0.172	0.150	0.128	0.116	0.107
F3	0.132	0.138	0.147	0.121	0.099	0.111	0.171	0.175	0.187	0.139	0.115	0.117

* These figures denote the replicates.

Table 45. Experiment I. 1st cut, 1964; P-uptake by grass, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	9.51	8.30	6.29	9.53	7.60	7.44	6.59	6.77	3.68	8.33	7.77	5.42
0	10.05	5.54	6.28	7.74	7.87	7.44	7.03	4.00	5.83	7.94	7.37	5.52
A1	8.56	6.76	7.64	11.47	8.51	9.26	11.91	6.34	6.12	15.07	8.44	7.92
A2	11.79	8.80	8.51	11.10	11.95	13.00	11.49	10.90	7.34	13.20	11.75	10.52
A3	10.59	4.40	8.58	13.04	12.39	16.59	13.31	10.02	10.05	13.68	10.46	14.96
B1	8.48	9.86	6.66	10.29	10.54	10.67	10.43	7.84	6.91	9.40	10.29	7.74
B2	8.95	9.76	8.93	9.87	9.83	12.21	6.12	6.41	6.88	14.69	12.66	11.70
B3	9.89	9.49	10.06	15.98	12.85	14.98	11.60	8.21	10.08	12.65	13.33	13.87
C1	7.90	6.43	5.25	13.09	9.04	10.53	7.14	7.58	5.62	12.29	9.97	8.87
C2	11.19	8.20	8.76	11.68	9.74	10.07	9.73	9.44	6.84	14.38	11.50	13.57
C3	10.32	10.14	9.77	15.24	11.86	12.37	12.30	10.04	7.63	17.25	13.13	13.58
D1	9.66	7.23	7.70	10.50	6.65	9.51	9.83	5.99	5.84	10.51	9.65	9.76
D2	8.74	9.45	9.62	12.14	10.82	11.44	10.68	9.89	9.26	11.51	11.68	11.70
D3	10.98	9.10	10.30	13.18	12.12	15.05	10.60	9.35	11.39	16.20	14.84	11.71
E1	7.57	7.18	9.54	10.49	8.50	10.33	9.94	8.40	5.82	11.60	9.50	11.34
E2	11.00	8.77	8.67	13.53	11.52	11.11	7.37	8.49	7.66	12.97	11.45	12.24
E3	11.10	11.58	11.15	13.14	13.25	14.04	13.13	9.02	7.50	12.99	13.03	16.44
F1	9.40	6.72	6.86	10.78	7.82	10.58	7.97	5.89	8.36	11.47	9.45	10.26
F2	8.24	8.85	8.81	11.82	9.28	10.15	10.33	8.05	9.77	14.40	10.30	10.15
F3	9.46	10.35	9.30	15.70	12.54	15.03	10.23	9.42	8.72	18.24	12.00	13.37

* These figures denote the replicates.

Table 46. Experiment I. 2nd cut, 1964; P-uptake by grass, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	5.30	7.12	9.23	6.44	6.58	6.39	7.59	7.05	7.18	6.62	7.00	6.91
0	8.27	6.21	6.22	7.03	6.32	6.65	6.75	5.78	7.73	6.75	4.70	7.13
A1	8.61	9.35	7.70	6.79	6.89	11.78	8.55	8.07	8.77	10.04	9.62	9.50
A2	9.32	9.01	9.68	8.81	8.23	13.82	10.52	9.56	11.05	10.77	11.99	9.08
A3	11.29	10.28	8.28	10.83	10.59	10.57	10.66	7.68	11.27	12.98	13.59	14.36
B1	8.08	8.81	7.05	6.48	9.33	7.49	7.39	8.87	9.34	10.03	9.81	10.49
B2	8.73	10.66	8.36	9.19	8.95	10.55	11.61	9.80	12.42	12.19	11.31	11.29
B3	9.28	7.57	11.60	10.71	11.21	11.99	12.88	8.23	10.44	12.74	10.36	13.24
C1	7.62	5.33	9.49	9.46	5.52	9.87	9.01	8.25	9.58	8.60	9.21	8.78
C2	8.08	9.76	8.94	8.72	10.12	10.29	10.57	8.94	11.64	11.23	11.53	13.51
C3	10.57	13.03	10.53	9.92	10.25	8.63	11.04	8.00	12.24	14.01	12.31	13.44
D1	7.66	6.39	8.06	5.57	7.94	9.25	8.47	7.45	8.46	8.38	9.19	9.87
D2	8.98	8.42	8.69	7.83	7.03	10.71	9.51	8.59	10.33	9.50	8.83	12.48
D3	9.54	10.04	10.19	8.95	9.58	14.37	9.84	10.09	11.55	12.42	12.18	12.49
E1	9.73	7.87	7.24	5.89	9.83	8.44	7.39	7.69	9.36	8.73	8.26	9.49
E2	9.36	7.40	12.49	7.35	9.29	6.97	11.83	9.10	10.60	11.40	11.22	15.13
E3	8.69	8.26	10.10	10.80	11.28	11.17	11.40	12.65	11.97	12.35	14.18	13.71
F1	7.46	8.39	8.36	8.27	4.70	7.56	10.07	8.01	8.75	11.39	10.64	10.96
F2	8.12	6.75	9.27	7.39	8.68	9.43	11.31	10.38	10.40	11.50	12.30	11.05
F3	7.33	8.82	8.21	9.77	9.34	13.38	11.61	10.09	13.34	12.91	13.17	11.92

* These figures denote the replicates.

Table 47. Experiment I. 3rd cut, 1964; P-uptake by grass, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
0	8.51	6.60	8.91	6.79	7.68	6.16	6.29	7.71	7.63	6.64	7.83	7.21
0	7.46	8.09	7.92	6.52	6.06	7.74	6.99	7.03	6.96	6.98	7.42	6.42
A1	11.15	9.65	8.53	9.44	7.01	9.91	10.37	8.24	7.98	10.64	10.64	10.25
A2	10.61	10.39	9.90	9.17	8.34	11.96	8.36	10.12	10.65	11.56	14.38	11.61
A3	12.07	8.84	11.98	9.88	10.86	12.91	11.22	6.86	14.38	14.32	15.09	18.07
B1	11.31	7.14	9.42	8.96	8.20	6.53	12.57	9.02	9.38	9.78	11.37	9.93
B2	8.78	12.40	8.97	9.88	10.17	12.20	8.54	10.51	12.31	14.29	12.96	12.32
B3	12.18	8.37	12.63	11.51	11.25	11.76	11.84	9.95	14.10	17.58	14.30	15.25
C1	9.20	5.02	10.09	9.40	7.25	9.48	8.86	9.65	9.38	10.91	7.98	10.96
C2	8.18	10.74	9.41	9.07	8.81	10.43	8.81	11.23	11.13	11.48	11.88	14.19
C3	10.18	12.99	10.59	11.68	9.32	10.21	11.00	10.89	11.73	14.49	14.57	18.37
D1	7.80	8.89	7.74	7.53	8.45	7.59	9.15	8.83	9.26	12.00	8.62	10.91
D2	9.20	10.77	11.74	9.96	6.88	11.42	10.88	12.80	10.06	11.67	12.43	14.10
D3	11.81	10.04	12.69	9.79	9.58	11.63	10.91	10.44	14.09	14.52	14.20	15.12
E1	8.84	10.48	8.46	8.43	9.28	9.69	11.31	8.49	9.08	11.66	9.93	11.20
E2	10.11	9.41	13.68	10.13	9.73	8.99	10.29	10.43	10.66	11.64	12.50	15.23
E3	8.79	9.00	12.42	12.64	10.97	13.65	9.46	11.30	12.43	14.02	13.47	17.16
F1	9.26	7.89	9.45	8.10	7.13	9.86	10.66	10.22	10.27	10.49	5.57	9.33
F2	10.10	8.68	11.82	9.34	9.15	11.35	11.27	11.16	11.36	14.75	11.84	12.02
F3	8.14	7.87	10.26	11.76	8.20	12.24	11.17	11.15	13.46	18.56	11.51	16.09

* These figures denote the replicates

Table 48. Experiment I. 1st cut, 1964; Apparent recovery of applied-P, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	0.90	-0.90	-0.02	3.53	0.57	1.32	6.26	0.69	0.47	8.01	1.38	0.86
A2	4.31	1.14	0.85	3.16	4.01	5.06	5.84	5.25	1.69	6.14	4.69	3.46
A3	2.93	-3.26	0.92	5.10	4.45	8.65	7.66	4.37	4.40	6.62	3.40	7.90
B1	0.82	2.20	-1.00	2.35	2.60	2.73	4.78	2.19	1.26	2.34	3.23	0.68
B2	1.29	2.10	1.27	1.93	1.89	4.27	0.47	0.76	1.23	7.63	5.60	4.64
B3	2.23	1.83	2.40	8.04	4.91	7.04	5.95	2.56	4.43	5.59	6.27	6.81
C1	0.24	-1.23	2.41	5.15	1.10	2.59	1.49	1.93	-0.03	5.23	2.91	1.81
C2	3.53	0.54	1.10	3.74	1.80	2.13	4.08	3.79	1.19	7.32	4.44	6.51
C3	2.66	2.48	2.11	7.30	3.92	4.43	6.65	4.39	1.98	10.19	6.07	6.52
D1	2.00	-0.43	0.04	2.56	-1.29	1.57	4.18	0.34	0.19	3.45	2.59	2.70
D2	1.08	1.79	1.96	4.20	2.88	3.50	5.03	4.24	3.61	4.45	4.62	4.64
D3	3.32	1.44	2.64	5.24	4.18	7.11	4.95	3.70	5.74	9.14	7.78	4.65
E1	-0.09	-0.48	1.88	2.55	0.56	2.39	4.29	2.75	0.17	4.54	2.44	4.28
E2	3.34	1.11	1.01	5.59	3.58	3.17	1.72	2.84	2.01	5.91	4.39	5.18
E3	3.44	3.92	3.49	5.20	5.31	6.10	7.48	3.37	1.85	5.93	5.97	9.38
F1	1.74	-0.94	-0.80	2.84	-0.12	2.64	2.32	0.24	2.71	4.41	2.39	3.20
F2	0.58	1.19	1.15	3.88	1.34	2.21	4.68	2.40	4.12	7.34	3.24	3.09
F3	1.80	2.69	1.64	7.76	4.60	7.09	4.58	3.77	3.07	11.18	4.94	6.31

* These figures denote the replicates.

Table 49. Experiment I. 2nd cut, 1964; Apparent recovery of applied-P, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	1.55	2.29	0.64	0.22	0.32	5.21	1.54	1.06	1.76	3.52	3.10	2.98
A2	2.26	1.95	2.62	2.24	1.66	7.25	3.51	2.55	4.04	4.25	5.47	2.56
A3	4.23	3.22	1.22	4.26	4.02	4.00	3.65	0.67	4.26	6.46	7.07	7.84
B1	1.02	1.75	-0.01	-0.09	2.76	0.92	0.38	1.86	2.33	3.51	3.29	3.97
B2	1.67	3.60	1.30	2.62	2.38	3.98	4.60	2.79	5.41	5.67	4.79	4.77
B3	2.22	0.51	4.54	4.14	4.64	5.42	5.87	1.22	3.43	6.22	3.84	6.72
C1	0.56	-1.73	2.43	2.89	-1.05	3.30	2.00	1.24	2.57	2.08	2.69	2.26
C2	1.02	2.70	1.88	2.15	3.55	3.72	3.56	1.93	4.63	4.71	5.01	6.99
C3	3.51	5.97	3.47	3.35	3.68	2.06	4.03	0.99	5.23	7.49	5.79	6.92
D1	0.60	-0.67	1.00	-1.00	1.37	2.68	1.46	0.44	1.45	1.86	2.67	3.35
D2	1.92	1.36	1.63	1.26	0.46	4.14	2.50	1.58	3.32	2.98	2.31	5.96
D3	2.48	2.98	3.13	2.38	3.01	7.80	2.83	3.08	4.54	5.90	5.66	5.97
E1	2.67	0.81	0.18	-0.68	3.26	1.87	0.38	0.68	2.35	2.21	1.74	2.97
E2	2.30	0.36	5.43	0.78	2.72	0.40	4.82	2.09	3.59	4.88	4.70	8.61
E3	1.63	1.20	3.04	4.23	4.71	4.60	4.39	5.64	4.96	5.83	7.66	7.19
F1	0.40	1.33	1.30	1.70	1.87	0.99	3.06	1.00	1.74	4.87	4.12	4.44
F2	1.06	-0.31	2.21	0.82	2.11	2.86	4.30	3.37	3.39	4.98	5.78	4.53
F3	0.27	1.76	1.15	3.20	2.77	6.81	4.60	3.08	6.33	5.39	6.65	5.40

* These figures denote the replicates.

Table 50. Experiment I. 3rd cut, 1964; Apparent recovery of applied-P, mg P/pot

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	3.23	1.71	0.61	2.61	0.18	3.08	3.27	1.14	0.88	3.56	3.56	3.17
A2	2.69	2.47	1.98	2.34	1.51	5.13	1.26	3.02	3.55	4.48	7.30	4.53
A3	4.15	0.92	4.06	3.05	4.03	6.08	4.12	-0.24	7.28	7.24	8.01	10.99
B1	3.39	-0.78	1.50	2.13	1.37	-0.30	5.47	1.92	2.28	2.70	4.29	2.85
B2	0.86	4.48	1.05	3.05	3.34	5.37	1.44	3.41	5.21	7.22	5.88	5.24
B3	4.26	0.45	4.71	4.68	4.42	4.93	4.74	2.85	7.00	10.50	7.22	8.17
C1	1.28	-2.90	2.17	2.57	0.42	2.65	1.76	2.55	2.28	3.83	0.90	3.88
C2	0.26	2.82	1.49	2.24	1.98	3.60	1.71	4.13	4.03	4.40	4.80	7.11
C3	2.26	5.09	2.67	4.85	2.49	3.38	3.90	3.79	4.63	7.41	7.49	10.29
D1	-0.12	0.97	-0.18	0.70	1.62	0.76	2.05	1.73	2.16	4.92	1.54	3.83
D2	1.28	2.85	3.82	3.13	0.05	4.59	3.78	5.70	3.96	4.59	5.35	7.02
D3	3.89	2.12	4.77	2.96	2.75	4.80	3.81	3.34	6.99	7.44	7.12	8.04
E1	0.92	2.56	0.54	1.60	2.45	2.86	4.21	1.39	1.97	4.58	1.85	4.12
E2	2.19	1.49	5.76	3.30	2.90	2.16	3.19	3.33	3.56	4.56	5.42	7.15
E3	0.87	1.08	4.50	5.81	4.14	6.82	2.36	4.20	5.33	6.94	6.39	10.08
F1	1.34	-0.03	1.53	1.27	0.30	3.03	3.56	3.12	3.17	3.41	-1.51	2.25
F2	2.18	0.74	3.90	2.50	2.32	4.52	4.17	4.06	4.26	6.67	4.76	4.94
F3	0.22	-0.05	2.34	4.93	1.37	5.41	4.07	4.05	6.36	11.48	4.43	9.01

* These figures denote the replicates.

Table 51. Experiment I. 1st cut, 1964; % Apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	1.1	-1.1	0.0	4.4	0.7	1.5	7.0	0.8	0.5	9.0	1.5	1.0
A2	2.7	0.7	0.5	2.0	2.5	3.1	3.3	2.9	0.9	3.4	2.6	1.9
A3	1.2	-1.4	0.4	2.1	1.8	3.6	2.9	1.6	1.6	2.5	1.3	3.0
B1	1.0	2.7	-1.2	2.9	3.2	3.4	5.4	2.5	1.4	2.6	3.6	0.8
B2	0.8	1.3	0.8	1.2	1.2	2.7	0.3	0.4	0.7	4.3	3.1	2.6
B3	0.9	0.8	1.0	3.3	2.0	2.9	2.2	1.0	1.7	2.1	2.3	2.5
C1	0.3	-1.5	3.0	6.4	1.4	3.2	1.7	2.2	0.0	5.9	3.3	2.0
C2	2.2	0.3	0.7	2.3	1.1	1.3	2.3	2.1	0.7	4.1	2.5	3.7
C3	1.1	1.0	0.9	3.0	1.6	1.8	2.5	1.6	0.7	3.8	2.3	2.4
D1	2.5	-0.5	0.0	3.2	-1.6	2.0	4.7	0.4	0.2	3.9	2.9	3.0
D2	0.7	1.1	1.2	2.6	1.8	2.2	2.8	2.4	2.0	2.5	2.6	2.6
D3	1.4	0.6	1.1	2.2	1.7	3.0	1.9	1.4	2.1	3.4	2.9	1.7
E1	-0.1	-0.6	2.3	3.2	0.7	3.0	4.8	3.1	0.2	5.1	2.7	4.8
E2	2.1	0.7	0.6	3.5	2.2	2.0	1.0	1.6	1.1	3.3	2.4	2.9
E3	1.4	1.6	1.4	2.2	2.2	2.5	1.8	1.3	0.7	2.2	2.2	3.5
F1	2.2	-1.2	-1.0	3.5	-0.1	3.3	2.6	0.3	3.0	4.9	2.7	3.6
F2	0.4	0.7	0.7	2.4	0.8	1.4	2.6	1.3	2.3	4.1	1.8	1.7
F3	0.7	1.1	0.7	3.2	1.9	2.9	1.7	1.4	1.1	4.2	1.8	2.4

* These figures denote the replicates.

Table 52. Experiment I. 2nd cut, 1964; % Apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1					
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	1.9	2.9	0.8	0.3	0.4	6.5	1.7	1.2	2.0	3.9	3.5	3.3
A2	1.4	1.2	1.6	1.4	1.0	4.5	2.0	1.4	2.3	2.4	3.1	1.4
A3	1.8	1.3	0.5	1.8	1.7	1.7	1.4	0.3	1.6	2.4	2.6	2.9
B1	1.3	2.2	0.0	-0.1	3.4	1.1	0.4	2.1	2.6	3.9	3.7	4.5
B2	1.0	2.2	0.8	1.6	1.5	2.5	2.6	1.6	3.0	3.2	2.7	2.7
B3	0.9	0.2	1.9	1.7	1.9	2.2	2.2	0.5	1.3	2.3	1.4	2.5
C1	0.7	-2.2	3.0	3.6	-1.3	4.1	2.2	1.4	2.9	2.3	3.0	2.5
C2	0.6	1.7	1.2	1.3	2.2	2.3	2.0	1.1	2.6	2.6	2.8	3.9
C3	1.5	2.5	1.4	1.4	1.5	0.9	1.5	0.4	2.0	2.8	2.2	2.6
D1	0.7	-0.8	1.2	-1.2	1.7	3.3	1.6	0.5	1.6	2.1	3.0	3.8
D2	1.2	0.8	1.0	0.8	0.3	2.6	1.4	0.9	1.9	1.7	1.3	3.3
D3	1.0	1.2	1.3	1.0	1.2	3.2	1.1	1.2	1.7	2.2	2.1	2.2
E1	3.3	1.0	0.2	-0.8	4.1	2.3	0.4	0.8	2.6	2.5	2.0	3.3
E2	1.4	0.2	3.4	0.5	1.7	0.2	2.7	1.2	2.0	2.7	2.6	4.8
E3	0.7	0.5	1.3	1.8	2.0	1.9	1.6	2.1	1.9	2.2	2.9	2.7
F1	0.5	1.7	1.6	2.1	2.3	1.2	3.4	1.1	2.0	5.5	4.6	5.0
F2	0.7	-0.2	1.4	0.5	1.3	1.8	2.4	1.9	1.9	2.8	3.2	2.5
F3	0.1	0.7	0.5	1.3	1.1	2.8	1.7	1.2	2.4	2.0	2.5	2.0

* These figures denote the replicates.

Table 53. Experiment I. 3rd cut, 1964; % Apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	4.0	2.1	0.8	3.3	0.2	3.8	3.7	1.3	1.0	4.0	4.0	3.6
A2	1.7	1.5	1.2	1.5	0.9	3.2	0.7	1.7	2.0	2.5	4.1	2.5
A3	1.7	0.4	1.7	1.3	1.7	2.5	1.5	-0.1	2.7	2.7	3.0	4.1
B1	4.2	-1.0	1.9	2.7	1.7	-0.4	6.1	2.2	2.6	3.0	4.8	3.2
B2	0.5	2.8	0.7	1.9	2.1	3.3	0.8	1.9	2.9	4.1	3.3	2.9
B3	1.8	0.2	2.0	1.9	1.8	2.0	1.8	1.1	2.6	3.9	2.7	3.1
C1	1.6	-3.6	2.7	3.2	0.5	3.3	2.0	2.9	2.6	4.3	1.0	4.4
C2	0.2	1.8	0.9	1.4	1.2	1.7	1.0	2.3	2.3	2.5	2.7	4.0
C3	0.9	2.1	1.1	2.0	1.0	1.4	1.5	1.4	1.7	2.8	2.8	3.8
D1	-0.1	1.2	-0.2	0.9	2.0	0.9	2.3	1.9	2.4	5.5	1.7	4.3
D2	0.8	1.8	2.4	1.9	0.0	2.9	2.1	3.2	2.2	2.6	3.0	3.9
D3	1.6	0.9	2.0	1.2	1.1	2.0	1.4	1.2	2.6	2.8	2.7	3.0
E1	1.1	3.2	0.7	2.0	3.1	3.6	4.7	1.6	2.2	5.1	2.1	4.6
E2	1.4	0.9	3.6	2.1	1.8	1.3	1.8	1.9	2.0	2.6	3.0	4.0
E3	0.4	0.4	1.9	2.4	1.7	2.8	0.9	1.6	2.0	2.6	2.4	3.8
F1	1.7	0.0	1.9	1.6	0.4	3.8	4.0	3.5	3.6	3.8	-1.7	2.5
F2	1.4	0.5	2.4	1.6	1.4	2.8	2.3	2.3	2.4	3.7	2.7	2.8
F3	0.1	0.0	1.0	2.0	0.6	2.2	1.5	1.5	2.4	4.3	1.7	3.4

* These figures denote the replicates.

Table 54. Experiment I. Total of 3 cuts, 1964; % apparent recovery of applied-P

Treatment	SOIL X						SOIL Y					
	N1			N2			N1			N2		
	i*	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
A1	7.0	3.9	1.6	8.0	1.3	11.8	12.4	3.3	3.5	16.9	9.0	7.9
A2	5.8	3.4	3.3	4.9	4.4	10.8	6.0	6.0	5.2	8.3	9.8	5.8
A3	4.7	0.3	2.6	5.2	5.2	7.8	5.8	1.8	5.9	7.6	6.9	10.0
B1	6.5	3.9	0.7	5.5	8.3	4.1	11.9	6.8	6.6	9.5	12.1	8.5
B2	2.3	6.3	2.3	4.7	4.8	8.5	3.7	3.9	6.6	11.6	9.1	8.2
B3	3.6	1.2	4.9	6.9	5.7	7.1	6.2	2.6	5.6	8.3	6.4	8.1
C1	2.6	-7.3	8.7	13.2	0.6	10.6	5.9	6.5	5.5	12.5	7.3	8.9
C2	3.0	3.8	2.8	5.0	4.5	5.3	5.3	5.5	5.6	9.2	8.0	11.6
C3	3.5	5.6	3.4	6.4	4.1	4.1	5.5	3.4	4.4	9.4	7.3	8.8
D1	3.1	-0.1	1.0	2.9	2.1	6.2	8.6	2.8	4.2	11.5	7.6	11.1
D2	2.7	3.7	4.6	5.3	2.1	7.7	6.3	6.5	6.1	6.8	6.9	9.8
D3	4.0	2.7	4.4	4.4	4.0	8.2	4.4	3.8	6.4	8.4	7.7	6.9
E1	4.3	3.6	3.2	4.4	7.9	8.9	9.9	5.5	5.0	12.7	6.8	12.7
E2	4.9	1.8	7.6	6.1	5.7	3.5	5.5	4.7	5.1	8.6	8.0	11.7
E3	2.5	2.5	4.6	6.4	5.9	7.2	4.3	5.0	4.6	7.0	7.5	10.0
F1	4.4	0.5	2.5	7.2	2.6	8.3	10.0	4.9	8.6	14.2	5.6	11.1
F2	2.5	1.0	4.5	4.5	3.5	6.0	7.3	5.5	6.6	10.6	7.7	7.0
F3	0.9	1.8	2.2	6.5	3.6	7.9	4.9	4.1	5.9	10.5	6.0	7.8

* These figures denote the replicates.

APPENDIX II

Plant analysis and yield-results of Experiment II (1964)

Table 55. The layout of Experiment II (1964)

2C1*	2C2	1F3	4C0	5F1	1C1	1F1	2F2	2G2	5G3	4C1	2G0	3F3	1G0	5G2
1F2	3G2	3F1	3G1	4C3	4F0	5C1	3C1	1C0	5C2	2C3	2F3	1C3	3F2	2C0
5G0	3C0	5C3	3C3	4G3	2G3	4C2	3F0	1C2	4G1	5F0	1G3	2F1	4F2	2G1
3G0	5F2	4F1	4G0	2F0	5F3	1F0	3C2	3G3	5G1	1G1	4G2	4F3	5C0	1G2

Replicate i

3G0	5G0	5F3	2C1	5F1	4F3	2G0	4G0	5F2	2C0	4G2	2F1	2C3	1G0	3C3
4G3	2C2	1F2	4F0	4F1	3C2	5F0	5C0	5C2	1F0	2F3	4C1	3F2	1G3	4G1
1C1	1F3	5G3	2F2	5G1	3C0	4F2	1C2	3G2	3F3	2G3	4C0	3C1	1F1	5C3
5C1	1C3	3G1	3G3	2G1	4C3	1G2	5G2	1C0	2G2	2F0	4C2	1G1	3F0	3F1

Replicate ii

* 1st digit = N-rate. C = Na-trimetaphosphate. F = Na-orthophosphate.

2nd digit = P-rate. G = Na metaphosphate glass.

Table 56. The analysis of variance of the results of Experiment II (1964) was as follows:

(a) For results in which the control (PO) was included:

Treatments	Degrees of freedom
Replicates	1
N	4
P-form (F)	2
P-level (P)	3
NF	8
NP	12
FP	6
NFP	24
Error	59
Total	119

(b) For results in which the control (PO) was not included, e.g. apparent recovery.

Treatments	Degrees of freedom
Replicates	1
N	4
P-form (F)	2
P-level (P)	2
NF	8
NP	8
FP	4
NFP	16
Error	44
Total	89

Table 57. Experiment II (1964): 1st cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i*	ii	i	ii	i	ii	i	ii	i	ii
C0	3.39	2.36	2.69	3.57	2.78	2.24	2.07	2.10	3.00	2.10
C1	20.69	22.91	15.60	29.69	29.70	23.00	25.78	17.80	27.07	19.33
C2	32.30	28.07	36.42	40.22	43.78	40.17	40.80	42.26	43.70	40.07
C3	33.71	30.95	47.50	52.24	49.17	44.66	53.78	51.15	48.58	51.72
F0	2.91	2.02	2.76	2.31	2.57	2.23	3.73	2.13	2.80	1.78
F1	22.75	25.17	30.37	31.01	30.40	30.16	35.85	29.44	31.60	33.53
F2	28.86	30.69	40.32	35.88	47.03	46.37	49.65	43.14	49.20	45.15
F3	32.04	31.57	47.00	44.56	50.07	53.98	53.73	51.86	55.22	52.09
G0	2.32	2.61	2.10	2.95	2.85	2.97	2.29	2.80	1.87	2.91
G1	27.60	26.66	27.57	33.23	27.12	31.24	28.57	23.72	29.68	26.41
G2	32.91	30.79	38.72	39.97	40.81	40.72	47.21	55.23	38.70	44.70
G3	33.66	31.53	41.47	43.72	45.93	51.10	50.68	48.74	52.14	40.98

Table 58. Experiment II (1964): 2nd cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	2.01	8.03	5.98	8.48	6.61	8.37	7.97	7.38	7.32	5.74
C1	27.84	26.55	35.50	39.12	41.94	32.37	45.12	39.15	40.64	31.50
C2	31.48	29.23	48.20	50.25	54.40	55.62	60.80	49.93	53.42	59.56
C3	29.71	28.30	51.47	44.67	63.21	48.11	67.70	72.46	71.47	66.26
F0	7.62	7.28	7.44	7.83	6.90	7.68	7.82	6.70	6.43	5.84
F1	27.95	25.70	35.90	37.81	41.26	37.57	42.07	45.98	43.35	38.18
F2	28.77	29.85	50.20	43.48	53.03	54.60	58.73	53.60	58.71	50.67
F3	31.12	29.55	53.83	45.47	68.67	58.52	65.43	55.92	75.43	53.66
G0	7.76	8.62	6.90	7.80	5.27	7.99	4.94	6.70	4.08	6.32
G1	27.83	24.94	36.59	40.58	42.00	38.35	46.19	33.73	42.63	42.32
G2	24.28	30.31	51.73	39.58	55.88	56.22	61.88	53.15	53.97	53.04
G3	29.30	28.03	54.22	46.00	63.45	59.00	75.64	76.97	81.05	70.01

* These figures denote the replicates in this table and all tables of Appendix II

Table 59. Experiment II (1964): 3rd cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	4.80	15.75	11.62	12.16	13.00	12.36	13.36	14.02	10.05	12.84
C1	21.03	18.93	32.62	32.65	46.58	49.53	52.66	43.56	48.34	35.22
C2	21.80	24.09	40.53	42.32	44.37	45.84	64.77	53.36	55.06	69.83
C3	34.03	24.70	45.92	46.42	61.42	58.77	72.90	79.23	81.70	91.42
F0	9.90	10.68	10.23	16.65	12.37	17.58	18.00	11.70	11.24	7.84
F1	21.18	19.70	34.37	33.72	42.26	41.18	51.50	51.39	50.12	45.13
F2	21.48	22.92	43.08	39.58	55.80	50.90	68.46	59.84	63.27	64.10
F3	24.05	23.55	47.86	49.33	65.13	67.60	81.30	68.72	80.23	65.34
G0	12.37	11.11	13.88	10.38	9.44	10.00	6.80	12.01	6.94	11.84
G1	17.96	21.50	36.90	33.74	43.14	43.80	51.70	45.31	43.30	44.03
G2	20.08	27.32	43.90	49.02	47.04	61.30	64.90	63.87	72.86	68.89
G3	21.68	24.47	46.07	51.63	56.98	60.02	76.62	75.92	100.00	79.44

Table 60. Experiment II (1964): 4th cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	13.13	14.67	23.92	20.28	21.66	22.39	18.09	22.95	18.82	16.07
C1	20.83	21.86	33.10	39.23	50.07	49.23	45.36	48.69	57.78	41.47
C2	25.41	22.08	25.82	48.21	60.71	60.63	69.58	65.56	69.21	68.66
C3	23.94	24.13	48.68	48.55	61.59	59.54	76.66	72.38	82.88	89.50
F0	15.09	17.44	18.30	15.13	25.28	19.09	28.67	27.56	21.38	20.79
F1	20.21	22.81	37.57	38.24	44.23	46.90	60.14	59.18	52.34	54.28
F2	25.20	24.90	40.77	47.16	55.78	62.03	77.18	76.99	84.65	83.12
F3	19.29	27.35	50.31	49.96	61.21	66.93	80.56	85.00	107.57	85.48
G0	13.62	13.45	15.13	19.48	18.67	18.52	16.30	25.00	18.62	22.52
G1	20.93	17.90	40.10	36.53	46.93	45.35	58.20	62.66	59.83	54.98
G2	19.30	20.65	43.40	38.35	51.99	63.98	77.61	77.22	78.34	52.16
G3	24.70	26.43	50.68	48.90	71.06	58.57	81.10	80.70	97.69	97.77

Table 61. Experiment II. (1964): 5th cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	20.10	16.05	19.97	19.82	22.27	15.17	14.15	15.20	24.25	13.37
C1	19.06	15.87	14.87	32.77	39.78	24.80	37.50	22.31	26.32	36.92
C2	19.45	14.92	16.57	30.96	54.62	35.38	51.93	59.20	36.55	28.26
C3	17.53	17.23	34.82	36.97	53.03	55.22	62.40	62.42	63.90	65.16
F0	16.93	13.79	22.07	19.17	21.94	21.66	24.80	14.74	25.56	17.33
F1	18.38	14.62	29.34	29.84	36.08	44.88	37.92	18.62	33.16	33.03
F2	18.42	14.09	35.36	32.98	37.94	40.89	46.84	58.39	68.13	60.20
F3	11.45	17.51	34.42	28.49	53.75	46.40	70.96	68.43	77.92	73.25
G0	16.30	14.82	17.53	23.65	20.80	25.67	23.48	29.69	23.97	21.86
G1	17.56	15.48	31.95	31.02	36.05	35.70	27.30	33.72	44.78	22.33
G2	17.42	16.06	36.47	37.43	43.65	36.41	62.57	63.36	71.08	40.32
G3	17.16	16.14	37.33	32.42	56.05	55.55	65.96	55.86	75.12	53.60

Table 62. Experiment II (1964): 6th cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	12.51	12.66	26.11	24.74	27.57	25.65	13.50	30.70	36.20	32.02
C1	8.28	9.27	12.98	15.20	28.18	28.36	35.92	42.35	26.83	41.50
C2	6.18	8.28	14.01	14.73	19.66	18.62	36.75	32.97	14.96	64.03
C3	7.76	8.75	10.30	12.02	16.51	19.31	31.27	27.97	54.20	30.81
F0	9.78	11.02	31.57	30.52	28.98	33.50	32.78	35.40	33.35	44.10
F1	7.83	7.71	11.06	13.61	35.12	25.46	47.65	45.90	28.09	45.57
F2	6.67	9.28	12.93	12.40	16.16	19.51	26.25	32.00	56.84	61.58
F3	4.26	9.08	12.06	11.17	20.17	15.84	28.36	33.80	34.30	66.77
G0	13.70	10.40	21.38	29.45	34.91	35.96	38.10	43.67	27.89	33.05
G1	9.69	9.46	14.00	16.55	34.35	35.18	36.61	49.96	52.35	44.36
G2	10.21	10.21	12.60	12.96	20.73	19.10	30.43	31.80	43.55	52.08
G3	6.61	7.87	9.83	11.46	17.69	19.96	22.77	26.50	29.14	59.40

Table 63. Experiment II (1964): 7th cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	10.46	10.28	14.00	16.80	21.07	25.26	12.95	30.77	28.63	32.99
C1	8.43	10.40	11.72	19.38	25.13	27.38	22.12	36.32	39.61	29.17
C2	10.94	9.37	19.31	18.62	28.30	26.59	31.68	18.21	13.69	39.34
C3	11.62	10.60	15.04	20.16	27.65	26.63	34.30	36.67	40.06	19.59
F0	10.63	10.29	19.31	18.37	20.61	23.58	30.17	27.41	32.35	37.07
F1	9.36	17.90	19.14	17.00	27.92	25.48	27.46	31.52	23.68	33.66
F2	9.91	8.62	14.30	20.00	16.58	31.40	26.07	38.02	33.61	40.62
F3	8.45	10.25	20.53	18.65	30.07	30.61	34.82	40.38	44.69	46.99
G0	11.57	10.81	16.43	17.38	24.66	22.09	29.14	26.41	26.36	29.80
G1	10.43	18.77	19.42	17.57	26.02	23.99	24.80	30.90	31.26	41.60
G2	10.79	10.30	17.52	20.80	24.16	28.23	34.45	32.11	37.22	39.34
G3	9.93	9.37	19.47	23.51	29.49	30.40	30.31	33.86	28.06	44.77

Table 64. Experiment II (1964): 8th cut; Yield of fresh grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	15.21	17.84	14.24	25.75	27.61	28.47	22.78	34.83	41.11	52.14
C1	14.97	19.71	22.90	33.57	30.97	37.31	26.34	44.38	56.30	30.63
C2	18.24	18.52	26.00	35.47	48.39	44.53	50.20	44.82	30.88	52.56
C3	17.30	18.54	28.26	36.67	50.15	43.41	58.57	54.35	53.70	56.60
F0	16.70	17.97	23.42	24.68	27.00	30.17	36.10	24.87	26.35	46.73
F1	15.94	35.57	28.43	30.20	34.00	36.67	32.65	39.04	29.09	45.83
F2	18.51	17.98	24.11	35.48	31.37	42.77	35.91	51.09	36.64	51.54
F3	15.16	19.51	29.86	33.65	37.91	54.11	62.22	63.74	63.97	56.00
G0	15.28	16.65	15.45	21.91	24.04	21.06	36.92	31.90	36.82	44.93
G1	17.31	33.77	26.86	31.15	33.71	32.78	23.81	30.11	40.35	41.85
G2	19.73	19.84	29.20	37.96	40.88	43.44	57.20	50.02	24.80	48.14
G3	16.21	17.64	35.91	36.49	53.47	49.90	59.72	48.72	47.72	61.48

Table 65. Experiment II (1964): 1st cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.57	0.38	0.48	0.63	0.42	0.41	0.34	0.38	0.49	0.40
C1	2.49	2.99	1.93	3.90	4.00	3.23	3.30	2.60	3.72	2.52
C2	3.97	3.83	4.17	5.12	5.51	5.30	4.86	5.48	5.74	5.40
C3	4.47	4.11	5.80	7.02	5.44	6.28	6.79	6.30	5.73	6.96
F0	0.48	0.33	0.45	0.33	0.44	0.34	0.63	0.38	0.48	0.32
F1	2.76	3.45	3.74	3.95	3.74	4.18	4.50	3.96	4.04	4.67
F2	3.78	4.18	4.94	5.10	6.10	6.14	6.00	5.89	6.16	6.11
F3	3.82	4.35	6.13	6.31	5.74	7.10	6.70	6.90	6.93	6.96
G0	0.36	0.45	0.35	0.51	0.46	0.52	0.38	0.50	0.30	0.53
G1	3.65	3.56	3.48	4.18	3.47	4.06	3.70	3.38	3.88	3.72
G2	4.62	4.02	4.62	5.28	4.88	5.39	5.98	7.35	5.00	5.91
G3	4.42	4.71	4.83	6.06	5.73	6.32	5.67	6.84	6.15	5.30

Table 66. Experiment II (1964): 2nd cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.34	1.18	0.89	1.27	1.01	1.24	1.19	1.14	1.22	0.92
C1	4.44	4.48	4.76	5.74	5.86	5.34	6.52	5.60	5.88	4.72
C2	5.19	5.05	7.24	7.62	8.49	8.60	8.85	7.96	7.70	8.91
C3	4.84	4.77	7.70	7.47	8.57	8.04	9.53	10.40	10.20	10.24
F0	1.13	1.07	1.15	1.20	1.02	1.19	1.17	1.06	0.98	0.96
F1	4.57	4.59	5.78	5.52	5.72	6.56	6.46	6.76	7.68	5.87
F2	4.68	5.07	7.80	7.38	8.50	8.84	8.86	8.38	8.89	7.92
F3	5.00	5.02	8.31	7.60	10.08	9.02	9.99	8.55	11.06	7.96
G0	1.14	1.35	1.03	1.19	0.78	1.19	0.79	1.07	0.69	0.94
G1	5.08	4.63	5.50	6.42	5.66	5.85	6.75	5.40	6.62	6.73
G2	4.52	5.30	7.88	6.90	7.74	8.59	9.82	8.24	8.37	8.28
G3	4.93	4.98	8.30	7.94	10.00	8.89	10.17	11.04	11.14	9.84

Table 67. Experiment II (1964): 3rd cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.75	2.30	1.86	1.79	1.97	1.90	1.95	2.26	1.67	2.30
C1	3.24	3.15	4.47	4.49	6.43	7.66	7.23	6.50	6.91	4.90
C2	3.67	4.00	5.94	6.51	6.60	7.40	9.60	7.95	8.19	10.57
C3	3.92	3.56	7.00	7.02	8.85	9.22	10.03	10.80	11.13	13.71
F0	1.15	1.77	1.57	2.54	2.03	2.86	2.64	1.97	1.90	1.43
F1	3.29	3.31	5.64	4.78	5.75	6.69	7.30	7.72	7.16	6.38
F2	3.20	3.90	6.32	6.26	8.38	8.14	10.53	9.31	8.66	9.27
F3	3.62	3.92	7.08	7.94	9.23	10.48	11.79	9.59	10.93	8.78
G0	1.81	1.70	2.02	1.56	1.41	1.49	1.10	1.90	1.17	1.71
G1	2.89	3.81	5.87	4.90	5.70	5.92	7.84	7.02	6.32	6.86
G2	3.35	4.47	6.22	7.50	6.38	9.54	9.44	8.87	10.51	9.77
G3	3.73	4.30	7.00	8.60	8.34	8.70	10.98	11.27	13.24	11.14

Table 68. Experiment II (1964): 4th cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	1.98	2.20	3.50	3.18	3.08	3.32	2.65	3.57	3.20	2.43
C1	3.00	3.37	4.82	5.60	6.62	7.22	6.04	6.68	7.62	5.85
C2	3.60	3.35	4.34	6.56	8.45	8.52	9.00	9.26	9.10	8.99
C3	3.51	3.34	6.72	6.78	8.18	8.89	9.46	9.64	9.99	12.50
F0	2.26	2.69	2.72	2.35	3.62	3.00	4.04	4.06	3.20	3.53
F1	2.89	3.63	5.43	5.29	5.68	6.93	8.01	7.88	7.11	7.42
F2	3.52	3.69	5.56	6.51	7.58	9.16	9.94	10.71	10.89	10.86
F3	2.96	4.10	6.73	6.88	8.09	9.04	10.93	11.27	13.65	10.94
G0	1.98	2.11	2.21	2.96	2.71	2.90	2.03	3.74	2.92	3.34
G1	3.30	2.88	5.70	5.30	5.97	6.28	7.73	9.48	8.13	7.71
G2	3.39	3.01	5.87	5.38	6.61	8.75	10.06	9.93	10.37	6.91
G3	3.78	4.07	6.65	7.09	9.70	8.53	10.18	10.53	12.28	12.00

Table 69. Experiment II (1964): 5th cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	3.13	2.50	3.00	3.11	3.24	2.36	2.57	2.49	4.25	2.08
C1	3.21	2.60	2.67	5.02	5.50	3.60	5.80	3.19	3.89	4.82
C2	2.80	2.47	2.87	4.32	8.47	4.82	6.47	8.33	5.47	3.86
C3	2.68	2.66	5.00	5.68	6.60	8.52	8.16	8.48	7.41	8.80
F0	3.02	2.69	3.52	3.12	2.91	3.46	3.60	2.23	4.24	2.78
F1	3.04	2.35	4.67	4.54	5.13	6.75	5.53	2.60	5.30	4.86
F2	3.00	2.17	5.47	4.79	5.35	5.72	6.39	8.11	9.27	8.70
F3	2.28	2.85	4.82	4.01	7.83	6.47	10.68	9.88	10.50	9.68
G0	2.83	2.51	2.92	3.80	3.36	4.12	3.91	4.70	3.68	3.43
G1	3.18	2.62	4.77	4.43	5.06	4.81	3.81	4.90	6.85	3.28
G2	3.35	2.50	5.42	5.66	6.14	4.96	9.52	8.80	9.82	5.42
G3	2.86	2.62	5.03	4.78	8.78	7.89	8.54	7.24	10.21	6.80

Table 70. Experiment II (1964): 6th cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	2.52	2.78	4.75	4.05	4.20	4.35	2.37	4.94	6.09	4.93
C1	1.71	2.07	2.31	2.77	5.11	5.50	5.89	6.67	3.81	6.78
C2	1.15	1.91	2.70	2.97	3.84	3.60	6.26	6.67	2.45	9.63
C3	1.54	1.81	2.25	2.44	2.94	4.04	5.40	5.45	8.08	6.36
F0	2.00	2.26	5.23	5.56	4.58	5.80	4.93	5.67	5.13	6.90
F1	1.56	1.73	2.26	2.76	5.49	5.11	6.94	7.02	4.51	7.06
F2	1.23	1.98	2.77	2.52	3.42	4.01	5.31	6.29	9.62	10.03
F3	0.84	2.01	2.48	2.26	3.78	3.28	5.43	6.34	6.22	10.63
G0	2.63	2.30	3.57	4.69	5.60	5.68	5.89	6.38	4.55	5.00
G1	2.10	2.14	2.65	3.60	5.42	6.54	5.47	8.21	8.07	6.90
G2	2.37	2.26	2.53	2.74	3.70	3.80	6.02	5.92	7.91	8.00
G3	1.33	1.71	1.90	2.31	3.47	3.99	4.38	5.20	5.65	10.18

Table 71. Experiment II (1964): 7th cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	1.59	1.63	2.28	2.52	2.87	3.90	1.90	4.64	4.32	4.50
C1	1.19	1.46	1.72	2.64	3.38	4.58	3.31	5.22	4.73	4.37
C2	1.61	1.43	2.71	2.45	3.78	3.60	4.06	3.34	2.00	5.40
C3	1.76	1.70	1.99	2.92	3.31	3.95	4.19	5.28	4.76	3.43
F0	1.64	1.58	2.78	3.12	2.90	3.86	3.81	3.95	4.72	5.20
F1	1.37	2.62	2.80	2.43	3.83	4.19	3.70	4.40	3.44	4.57
F2	1.38	1.27	1.90	2.89	2.30	4.84	3.73	5.77	4.58	5.89
F3	1.17	1.43	2.93	2.62	3.94	4.51	4.79	5.31	5.78	6.02
G0	1.74	1.76	2.56	2.56	3.42	3.17	3.89	3.68	3.70	3.92
G1	1.54	2.73	2.77	2.60	3.41	3.64	3.75	4.90	4.44	5.96
G2	1.71	1.64	2.31	3.27	3.08	4.02	4.88	4.47	5.31	5.69
G3	1.53	1.45	2.59	3.68	4.06	4.49	3.86	4.33	3.77	5.81

Table 72. Experiment II (1964): 8th cut; Yield of dry grass, g/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	3.06	3.07	2.51	4.10	4.20	4.24	3.36	5.14	6.65	7.30
C1	2.60	3.26	3.54	5.30	5.38	6.15	4.03	6.40	7.72	6.22
C2	3.19	2.88	4.23	5.57	7.83	6.98	7.62	7.51	4.68	7.53
C3	3.04	3.08	4.80	5.95	7.31	7.78	9.30	10.17	7.97	8.99
F0	2.96	3.07	3.79	4.32	4.11	4.85	5.31	3.94	4.22	6.78
F1	2.89	5.78	5.10	5.20	5.29	6.70	5.21	5.83	4.05	7.02
F2	3.10	2.96	4.21	5.69	5.03	6.96	5.80	8.37	6.01	8.39
F3	2.50	3.10	5.28	5.18	6.74	8.48	10.50	10.20	10.90	8.89
G0	2.98	2.90	2.62	3.51	4.03	3.73	5.96	4.86	6.23	7.20
G1	2.94	5.79	4.73	5.32	5.41	5.36	3.71	5.06	6.44	6.10
G2	3.50	3.27	5.10	6.61	6.37	6.53	9.39	8.04	4.90	9.24
G3	2.90	2.77	5.18	5.83	8.95	9.10	8.72	8.96	7.36	9.18

Table 73. Experiment II (1964): 1st cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	16.8	16.1	17.8	17.7	15.1	18.3	16.4	18.1	16.3	19.1
C1	12.0	13.1	12.4	13.1	13.5	14.0	12.8	14.6	13.7	13.1
C2	12.3	13.6	11.5	12.7	12.6	13.2	11.9	13.0	13.1	13.5
C3	13.3	13.3	12.2	13.4	11.1	14.1	12.6	12.3	11.8	13.5
F0	16.5	16.3	16.3	14.3	17.1	15.3	16.9	17.8	17.1	18.0
F1	12.1	13.7	12.3	12.7	12.3	13.9	12.6	13.5	12.8	13.9
F2	13.4	13.6	12.3	14.2	13.0	13.2	12.1	13.7	12.5	13.5
F3	11.9	13.8	13.0	14.2	11.5	13.2	12.5	13.3	12.6	13.4
G0	15.5	17.2	16.7	17.3	16.1	17.5	16.6	17.9	16.0	18.2
G1	13.2	13.4	12.6	12.6	12.8	13.0	13.0	14.3	13.1	14.1
G2	14.0	13.1	11.9	13.2	12.0	13.2	12.7	13.3	12.9	13.2
G3	13.1	14.9	11.7	13.7	12.5	12.4	11.2	14.0	11.8	12.9

Table 74. Experiment II (1964): 2nd cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	16.9	14.7	14.9	15.0	15.3	14.8	14.9	15.4	16.7	16.0
C1	15.9	16.9	13.4	14.7	14.0	16.5	14.5	14.3	14.5	15.0
C2	16.5	17.3	15.0	15.2	15.6	15.5	14.6	15.9	14.4	15.0
C3	16.3	16.9	15.0	16.7	13.6	16.7	14.1	14.4	14.3	15.5
F0	14.8	14.7	15.5	15.3	14.8	15.5	15.0	15.8	15.2	16.4
F1	16.4	17.9	16.1	14.6	13.9	17.5	15.4	14.7	17.7	15.4
F2	16.3	17.0	15.5	17.0	16.0	16.2	15.1	15.6	15.1	15.6
F3	16.0	17.0	15.4	16.7	14.7	15.4	15.3	15.3	14.7	14.8
G0	14.7	15.7	14.9	15.3	14.8	14.9	16.0	16.0	16.9	14.9
G1	18.3	18.6	15.0	15.8	13.5	15.3	14.6	16.0	15.5	15.9
G2	18.6	17.5	15.2	17.4	13.9	15.3	15.9	15.5	15.5	15.6
G3	16.8	17.8	15.3	17.3	15.8	15.1	13.4	14.3	13.7	14.1

Table 75. Experiment II (1964): 3rd cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	15.6	14.6	16.0	14.7	15.2	15.4	14.6	16.1	16.6	17.9
C1	15.4	16.6	13.7	13.8	13.8	15.5	13.7	14.9	14.3	13.9
C2	16.8	16.6	14.7	15.4	14.9	16.1	14.8	14.9	14.9	15.1
C3	16.3	14.4	15.2	15.1	14.4	15.7	13.8	13.6	13.6	15.0
F0	15.3	16.6	15.3	15.3	16.4	16.3	14.7	16.8	16.9	18.2
F1	15.5	16.8	16.4	14.2	13.6	16.2	14.2	15.0	14.3	14.1
F2	14.9	17.0	13.7	15.8	15.0	16.0	15.4	15.6	13.7	14.5
F3	15.1	16.6	14.8	16.1	14.2	15.5	14.5	14.0	13.6	13.4
G0	14.6	15.3	14.6	15.0	14.9	14.9	16.2	15.8	16.9	14.4
G1	16.1	17.7	15.9	14.5	13.2	13.5	15.2	15.5	14.6	15.6
G2	16.7	16.4	14.2	15.3	13.6	15.6	14.5	13.9	14.4	14.2
G3	17.2	17.6	15.2	16.7	14.6	14.5	14.3	14.8	13.2	14.0

Table 76. Experiment II (1964): 4th cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	15.1	15.0	14.6	14.3	14.2	14.8	14.6	15.6	17.0	15.1
C1	14.4	15.4	14.6	14.3	13.2	14.7	13.3	13.7	13.2	14.1
C2	14.2	15.2	16.8	13.6	13.9	14.1	12.9	14.1	13.1	13.1
C3	14.7	13.8	13.8	14.0	13.3	14.9	12.3	13.3	12.1	14.0
F0	15.0	15.4	14.9	15.5	14.3	15.7	14.1	14.7	15.0	17.0
F1	14.3	15.9	14.5	13.8	12.8	14.8	13.3	13.3	13.6	13.7
F2	14.0	14.8	13.6	13.8	13.6	14.8	12.9	13.9	12.9	13.1
F3	15.3	15.0	13.4	13.8	13.2	13.5	13.6	13.3	12.7	12.8
G0	14.5	15.7	14.6	15.2	14.5	15.7	12.5	15.0	15.7	14.8
G1	15.8	16.1	14.2	14.5	12.7	13.8	13.3	15.1	13.6	14.0
G2	17.6	14.6	13.5	14.0	12.7	13.7	13.7	12.9	13.2	13.2
G3	15.3	16.0	13.1	14.5	13.7	14.6	12.6	13.0	12.6	12.3

Table 77. Experiment II (1964): 5th cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	15.6	15.6	15.0	15.7	14.5	15.6	18.2	16.4	17.5	15.6
C1	16.8	16.4	18.0	15.3	13.8	14.5	15.5	14.3	14.8	13.1
C2	14.4	16.6	17.3	14.0	15.5	13.6	12.5	14.1	15.0	13.7
C3	15.3	15.4	14.4	15.4	12.4	15.4	13.1	13.6	11.6	13.5
F0	17.8	19.5	15.9	16.3	13.3	16.0	14.5	15.1	16.6	16.0
F1	16.5	16.1	15.9	15.2	14.2	15.0	14.6	14.0	16.0	14.7
F2	16.2	15.4	15.5	14.5	14.1	14.0	13.6	13.9	13.6	14.5
F3	19.9	16.3	14.0	14.1	14.6	13.9	15.1	14.4	13.5	13.2
G0	17.4	16.9	16.7	16.1	16.2	16.0	16.7	15.8	15.4	15.7
G1	18.1	16.9	14.9	14.3	14.0	13.5	14.0	14.5	15.3	14.7
G2	19.2	15.6	14.9	15.1	14.1	13.6	15.2	13.9	13.8	13.4
G3	16.7	16.2	13.5	14.7	15.7	14.2	12.9	13.0	13.6	12.7

Table 78. Experiment II (1964): 6th cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	20.1	22.0	18.2	16.4	15.2	17.0	17.6	16.1	16.8	15.4
C1	20.7	22.3	17.8	18.2	18.1	19.4	16.4	15.7	14.2	16.3
C2	18.6	23.1	19.3	18.9	19.5	19.3	17.0	20.2	16.4	15.0
C3	19.8	20.7	21.8	20.3	17.8	20.9	17.3	19.5	14.9	20.6
F0	20.4	20.5	16.6	18.2	15.8	17.3	15.0	16.0	15.4	15.6
F1	19.9	22.4	20.4	20.3	15.6	20.1	14.6	15.3	16.1	15.5
F2	18.4	21.3	21.4	20.3	21.2	20.6	20.2	19.7	16.9	16.3
F3	19.7	22.1	20.6	20.2	18.7	20.7	19.1	18.8	18.1	15.9
G0	19.2	22.1	16.7	15.9	16.0	15.8	15.5	14.6	16.3	15.1
G1	21.7	22.6	18.9	21.8	15.8	18.6	14.9	16.4	15.4	15.6
G2	23.2	22.1	20.1	21.1	17.8	19.9	19.8	18.6	18.2	15.4
G3	20.1	21.7	19.3	20.2	19.6	20.0	19.2	19.6	19.4	17.1

Table 79. Experiment II (1964): 7th cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	15.2	15.9	16.3	15.0	13.6	15.4	14.7	15.1	15.1	13.6
C1	14.1	14.0	14.7	13.6	13.5	16.7	15.0	14.4	11.9	15.0
C2	14.7	15.3	14.0	13.2	13.4	13.5	12.8	18.3	14.6	13.7
C3	15.1	16.0	13.2	14.5	12.0	14.8	12.2	14.4	11.9	17.5
F0	15.4	15.4	14.4	17.0	14.1	16.4	12.6	14.4	14.6	14.0
F1	14.6	14.6	14.6	14.3	13.7	16.4	13.5	14.0	14.5	13.6
F2	13.9	14.7	13.3	14.5	13.9	15.4	14.3	15.2	13.6	14.5
F3	13.8	14.0	14.3	14.0	13.1	14.7	13.8	13.2	12.9	12.8
G0	15.0	16.3	15.6	14.7	13.9	14.4	13.3	13.9	14.0	13.2
G1	14.8	14.5	14.3	14.8	13.1	15.2	15.1	15.9	14.2	14.3
G2	15.8	15.9	13.2	15.7	12.7	14.2	14.2	13.9	14.3	14.5
G3	15,4	15.5	13.3	15.7	13.8	14.8	12.7	12.8	13.4	13.0

Table 80. Experiment II (1964): 8th cut; % Dry matter in the grass

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	20.1	17.2	17.6	15.9	15.2	14.9	14.7	14.8	16.2	14.0
C1	17.4	16.5	15.5	15.8	17.4	16.5	15.3	14.4	13.7	20.3
C2	17.5	15.6	16.3	15.7	16.2	15.7	15.2	16.8	15.2	14.3
C3	17.6	16.6	17.0	16.2	14.6	17.9	15.9	18.7	14.8	15.9
F0	17.7	17.1	16.2	17.5	15.2	16.1	14.7	15.8	16.0	14.5
F1	18.1	16.2	17.9	17.2	15.6	18.3	16.0	14.9	13.9	15.3
F2	16.7	16.5	17.5	16.0	16.0	16.3	16.2	16.4	16.4	16.3
F3	16.5	15.9	17.7	15.4	17.8	15.7	16.9	16.0	17.0	15.9
G0	19.5	17.4	17.0	16.0	16.8	17.7	16.1	15.2	16.9	16.1
G1	17.0	17.1	17.6	17.1	16.0	16.4	15.6	16.8	16.0	14.6
G2	17.7	16.5	17.5	17.4	15.6	15.0	16.4	16.1	19.8	19.2
G3	17.9	15.7	14.4	16.0	16.7	18.2	16.4	18.4	15.4	14.9

Table 81. Experiment II (1964): 1st cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.088	0.147	0.115	0.145	0.147	0.133	0.145	0.150	0.154	0.133
C1	0.210	0.223	0.199	0.210	0.181	0.193	0.204	0.178	0.199	0.205
C2	0.306	0.281	0.279	0.254	0.265	0.248	0.274	0.238	0.253	0.239
C3	0.335	0.358	0.338	0.290	0.345	0.269	0.274	0.290	0.303	0.281
F0	0.160	0.168	0.145	0.143	0.133	0.110	0.121	0.158	0.125	0.165
F1	0.230	0.216	0.214	0.191	0.210	0.198	0.228	0.195	0.209	0.196
F2	0.300	0.274	0.279	0.241	0.248	0.221	0.274	0.243	0.274	0.245
F3	0.395	0.354	0.326	0.295	0.300	0.298	0.323	0.279	0.335	0.286
G0	0.129	0.154	0.140	0.155	0.133	0.140	0.147	0.143	0.135	0.135
G1	0.236	0.220	0.199	0.213	0.206	0.203	0.211	0.186	0.223	0.201
G2	0.281	0.298	0.281	0.258	0.273	0.261	0.274	0.248	0.256	0.228
G3	0.404	0.330	0.345	0.320	0.340	0.323	0.335	0.294	0.320	0.313

Table 82. Experiment II (1964): 2nd cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.132	0.160	0.178	0.169	0.173	0.167	0.166	0.161	0.157	0.155
C1	0.170	0.161	0.194	0.176	0.169	0.142	0.163	0.174	0.164	0.167
C2	0.280	0.202	0.176	0.190	0.160	0.170	0.176	0.153	0.164	0.163
C3	0.315	0.281	0.236	0.221	0.232	0.193	0.180	0.191	0.195	0.185
F0	0.169	0.162	0.162	0.118	0.169	0.138	0.168	0.163	0.161	0.158
F1	0.172	0.146	0.159	0.172	0.175	0.126	0.158	0.160	0.148	0.159
F2	0.239	0.240	0.171	0.169	0.158	0.161	0.167	0.162	0.180	0.180
F3	0.328	0.302	0.233	0.221	0.193	0.218	0.203	0.198	0.204	0.196
G0	0.161	0.155	0.172	0.166	0.173	0.162	0.166	0.166	0.158	0.163
G1	0.167	0.158	0.162	0.147	0.177	0.150	0.166	0.154	0.153	0.143
G2	0.219	0.247	0.173	0.146	0.198	0.173	0.159	0.174	0.158	0.148
G3	0.338	0.288	0.232	0.226	0.298	0.227	0.217	0.199	0.206	0.212

Table 83. Experiment II (1964): 3rd cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.172	0.186	0.201	0.163	0.206	0.180	0.198	0.183	0.193	0.158
C1	0.256	0.226	0.243	0.233	0.224	0.176	0.224	0.215	0.214	0.203
C2	0.330	0.312	0.254	0.243	0.201	0.168	0.215	0.197	0.209	0.168
C3	0.429	0.423	0.297	0.287	0.223	0.254	0.178	0.234	0.237	0.209
F0	0.190	0.155	0.195	0.185	0.154	0.183	0.203	0.184	0.181	0.123
F1	0.252	0.238	0.208	0.185	0.220	0.180	0.216	0.190	0.202	0.212
F2	0.335	0.300	0.240	0.218	0.212	0.201	0.198	0.194	0.227	0.201
F3	0.326	0.379	0.325	0.283	0.256	0.243	0.213	0.231	0.251	0.199
G0	0.188	0.140	0.196	0.195	0.201	0.191	0.198	0.177	0.191	0.205
G1	0.272	0.223	0.213	0.220	0.234	0.211	0.193	0.188	0.217	0.168
G2	0.284	0.276	0.221	0.226	0.254	0.196	0.206	0.219	0.205	0.167
G3	0.381	0.353	0.310	0.272	0.281	0.263	0.226	0.225	0.221	0.199

Table 84. Experiment II (1964): 4th cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.181	0.194	0.169	0.155	0.172	0.163	0.175	0.158	0.147	0.191
C1	0.254	0.234	0.211	0.189	0.194	0.182	0.190	0.198	0.193	0.183
C2	0.308	0.303	0.278	0.235	0.217	0.212	0.209	0.187	0.205	0.218
C3	0.360	0.347	0.276	0.266	0.241	0.234	0.237	0.218	0.245	0.217
F0	0.160	0.168	0.157	0.175	0.154	0.157	0.170	0.159	0.154	0.134
F1	0.254	0.231	0.206	0.202	0.197	0.196	0.195	0.188	0.180	0.175
F2	0.286	0.285	0.233	0.225	0.227	0.202	0.217	0.198	0.201	0.191
F3	0.383	0.345	0.271	0.273	0.237	0.248	0.230	0.197	0.162	0.206
G0	0.172	0.165	0.173	0.150	0.173	0.147	0.157	0.162	0.166	0.157
G1	0.233	0.221	0.208	0.205	0.203	0.182	0.187	0.156	0.172	0.171
G2	0.270	0.283	0.237	0.245	0.227	0.213	0.203	0.206	0.214	0.218
G3	0.340	0.322	0.268	0.261	0.234	0.252	0.237	0.218	0.234	0.213

Table 85. Experiment II (1964): 5th cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.147	0.159	0.158	0.147	0.161	0.159	0.180	0.153	0.133	0.172
C1	0.232	0.206	0.214	0.168	0.170	0.163	0.155	0.205	0.171	0.165
C2	0.310	0.267	0.235	0.207	0.189	0.210	0.206	0.169	0.215	0.209
C3	0.335	0.315	0.239	0.218	0.218	0.198	0.190	0.182	0.242	0.198
F0	0.157	0.161	0.139	0.140	0.173	0.139	0.156	0.173	0.139	0.136
F1	0.235	0.216	0.180	0.171	0.162	0.153	0.172	0.198	0.166	0.165
F2	0.260	0.271	0.203	0.209	0.212	0.189	0.200	0.180	0.191	0.170
F3	0.320	0.300	0.230	0.277	0.186	0.201	0.183	0.180	0.191	0.197
G0	0.144	0.147	0.142	0.142	0.141	0.135	0.132	0.145	0.155	0.139
G1	0.223	0.218	0.177	0.173	0.171	0.167	0.200	0.157	0.163	0.172
G2	0.268	0.257	0.191	0.187	0.183	0.199	0.171	0.173	0.165	0.197
G3	0.320	0.304	0.240	0.224	0.209	0.189	0.202	0.200	0.193	0.209

Table 86. Experiment II (1964): 6th cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.160	0.168	0.117	0.115	0.130	0.121	0.188	0.129	0.127	0.135
C1	0.378	0.303	0.215	0.265	0.159	0.130	0.140	0.137	0.208	0.130
C2	0.409	0.357	0.239	0.306	0.282	0.278	0.176	0.176	0.234	0.148
C3	0.418	0.371	0.368	0.313	0.306	0.281	0.236	0.246	0.174	0.201
F0	0.177	0.173	0.111	0.108	0.118	0.112	0.135	0.136	0.133	0.130
F1	0.368	0.301	0.255	0.246	0.137	0.166	0.145	0.135	0.158	0.123
F2	0.403	0.361	0.331	0.288	0.295	0.229	0.207	0.193	0.162	0.129
F3	0.483	0.355	0.339	0.334	0.285	0.271	0.255	0.232	0.235	0.155
G0	0.135	0.155	0.129	0.100	0.127	0.114	0.125	0.127	0.112	0.135
G1	0.346	0.301	0.285	0.227	0.152	0.130	0.166	0.120	0.135	0.129
G2	0.339	0.332	0.315	0.290	0.365	0.250	0.218	0.215	0.160	0.143
G3	0.418	0.380	0.318	0.301	0.304	0.269	0.258	0.258	0.258	0.152

Table 87. Experiment II (1964): 7th cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.210	0.220	0.183	0.171	0.178	0.157	0.223	0.175	0.184	0.200
C1	0.337	0.318	0.242	0.245	0.217	0.171	0.210	0.187	0.229	0.174
C2	0.445	0.398	0.276	0.308	0.285	0.268	0.251	0.272	0.285	0.198
C3	0.456	0.439	0.360	0.326	0.331	0.288	0.282	0.270	0.264	0.328
F0	0.212	0.228	0.173	0.150	0.174	0.152	0.200	0.183	0.191	0.185
F1	0.337	0.248	0.254	0.227	0.194	0.198	0.204	0.185	0.232	0.183
F2	0.392	0.418	0.311	0.288	0.305	0.224	0.265	0.212	0.242	0.191
F3	0.413	0.418	0.355	0.342	0.298	0.288	0.279	0.258	0.265	0.223
G0	0.188	0.202	0.179	0.164	0.176	0.155	0.197	0.171	0.179	0.194
G1	0.380	0.265	0.260	0.236	0.215	0.184	0.229	0.171	0.184	0.173
G2	0.423	0.390	0.332	0.305	0.286	0.246	0.246	0.232	0.203	0.200
G3	0.456	0.428	0.355	0.313	0.325	0.288	0.301	0.290	0.298	0.243

Table 88. Experiment II (1964): 8th cut; % P in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.143	0.155	0.168	0.130	0.131	0.138	0.194	0.146	0.139	0.156
C1	0.241	0.288	0.191	0.159	0.158	0.138	0.207	0.155	0.160	0.120
C2	0.305	0.315	0.228	0.212	0.174	0.168	0.151	0.162	0.222	0.159
C3	0.361	0.363	0.283	0.229	0.206	0.216	0.173	0.167	0.187	0.188
F0	0.153	0.152	0.140	0.121	0.135	0.120	0.140	0.148	0.178	0.148
F1	0.220	0.156	0.167	0.142	0.135	0.137	0.179	0.145	0.213	0.133
F2	0.300	0.297	0.217	0.206	0.207	0.165	0.217	0.142	0.210	0.137
F3	0.337	0.356	0.268	0.254	0.237	0.203	0.171	0.159	0.167	0.154
G0	0.149	0.148	0.184	0.129	0.149	0.153	0.152	0.135	0.130	0.138
G1	0.243	0.162	0.184	0.154	0.140	0.138	0.224	0.165	0.139	0.159
G2	0.302	0.289	0.227	0.198	0.181	0.173	0.154	0.153	0.164	0.130
G3	0.361	0.369	0.236	0.242	0.210	0.194	0.181	0.179	0.231	0.179

Table 89. Experiment II (1964): 1st cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.50	0.56	0.55	0.91	0.62	0.55	0.49	0.57	0.76	0.53
C1	5.23	6.67	3.84	8.19	7.24	6.23	6.73	4.63	7.40	5.19
C2	12.15	10.76	11.63	13.01	14.60	13.14	13.32	13.04	14.52	12.91
C3	14.98	14.71	19.60	20.36	18.77	16.89	18.61	18.27	17.36	19.56
F0	0.77	0.55	0.65	0.47	0.59	0.37	0.76	0.60	0.60	0.53
F1	6.35	7.45	8.00	7.55	7.85	8.28	10.26	7.72	8.44	9.15
F2	11.34	11.45	13.78	12.29	15.13	13.57	16.44	14.31	16.88	14.97
F3	15.09	15.40	19.98	18.62	17.22	21.16	21.64	19.25	23.22	19.91
G0	0.46	0.70	0.49	0.79	0.61	0.73	0.56	0.72	0.41	0.72
G1	8.61	7.83	6.93	8.90	7.15	8.24	7.81	6.29	8.65	7.48
G2	12.98	11.98	12.98	13.62	13.32	14.07	16.39	18.23	12.80	13.48
G3	17.86	15.54	16.66	19.39	19.48	20.41	19.00	20.11	19.68	16.59

Table 90. Experiment II (1964): 2nd cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.45	1.89	1.58	2.15	1.75	2.07	1.98	1.84	1.92	1.43
C1	7.55	7.21	9.23	10.10	9.90	7.58	10.63	9.74	9.64	7.88
C2	14.53	10.20	12.74	14.48	13.58	14.62	15.58	12.18	12.63	14.52
C3	15.25	13.40	18.17	16.51	19.88	15.52	17.15	19.86	19.89	18.94
F0	1.91	1.73	1.86	1.42	1.72	1.64	1.97	1.73	1.58	1.52
F1	7.86	6.70	9.19	9.49	10.01	8.27	10.21	10.82	11.37	9.33
F2	11.19	12.17	13.34	12.47	13.45	14.23	14.80	13.58	16.00	12.99
F3	16.40	15.16	19.36	16.80	19.45	19.66	20.28	16.93	22.56	15.60
G0	1.84	2.09	1.77	1.98	1.35	1.93	1.31	1.78	1.09	1.53
G1	8.48	7.32	8.91	9.44	10.02	8.78	11.21	8.32	10.13	9.62
G2	9.90	13.09	13.63	10.07	15.33	14.86	15.61	14.34	13.23	12.25
G3	16.66	14.34	19.26	17.94	20.80	20.18	22.07	21.97	22.95	20.86

Table 91. Experiment II (1964): 3rd cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	1.29	4.28	3.74	2.92	4.06	3.42	3.86	4.14	3.22	3.63
C1	8.29	7.12	10.86	10.46	14.40	13.48	16.20	13.98	14.79	9.95
C2	12.11	12.48	15.09	15.82	13.27	12.43	20.64	15.66	17.12	17.76
C3	16.82	15.06	20.79	20.15	19.74	23.42	17.85	25.27	26.38	28.65
F0	2.19	2.74	3.06	4.70	3.13	5.23	5.36	3.63	3.44	1.76
F1	8.29	7.88	11.73	8.84	12.65	12.04	15.77	14.67	14.46	13.53
F2	10.72	11.70	15.17	13.65	17.77	16.36	20.85	18.06	19.66	18.63
F3	11.80	14.86	23.01	22.47	23.63	25.47	25.11	22.15	27.43	17.47
G0	3.40	2.38	3.96	3.04	2.83	2.85	2.18	3.36	2.24	3.51
G1	7.86	8.50	12.50	10.78	13.34	12.49	15.13	13.20	13.71	11.53
G2	9.51	12.34	13.75	16.95	16.21	18.70	19.45	19.43	21.55	16.32
G3	14.21	15.18	21.70	23.39	23.44	22.88	24.82	25.36	29.26	22.17

Table 92. Experiment II (1964): 4th cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	3.58	4.27	5.92	4.93	5.30	5.41	4.64	5.64	4.70	4.64
C1	7.62	7.89	10.17	10.58	12.84	13.14	11.48	13.23	14.71	10.71
C2	11.09	10.15	12.07	15.42	18.34	18.06	18.81	17.32	18.66	19.60
C3	12.64	11.59	18.55	18.04	19.71	20.80	22.42	21.02	24.48	27.13
F0	3.62	4.52	4.27	4.11	5.58	4.71	6.87	6.46	4.93	4.73
F1	7.34	8.39	11.19	10.69	11.19	13.58	15.62	14.81	12.80	12.99
F2	10.07	10.52	12.96	14.65	17.21	18.50	21.57	21.21	21.89	20.74
F3	11.34	14.15	18.24	18.78	19.17	22.42	24.91	22.20	22.11	22.54
G0	3.41	3.48	3.82	4.44	4.69	4.26	3.19	6.06	4.85	5.24
G1	7.69	6.37	11.86	10.87	12.12	11.43	14.46	14.79	13.98	13.18
G2	9.15	8.52	13.68	12.11	15.01	18.64	20.42	20.46	22.19	15.06
G3	12.85	13.11	18.02	19.36	22.70	21.50	24.13	22.96	28.74	25.56

Table 93. Experiment II (1964): 5th cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	4.60	3.98	4.74	4.57	5.22	3.75	4.63	6.50	5.65	3.58
C1	7.45	5.36	5.71	8.43	9.35	5.87	8.99	6.54	6.65	7.95
C2	8.68	6.59	6.74	8.94	16.01	10.12	13.33	14.08	11.76	8.07
C3	8.98	8.38	11.95	12.38	14.39	16.87	15.50	15.43	17.93	17.42
F0	4.74	4.33	4.89	4.37	5.03	4.81	5.62	3.86	5.89	3.78
F1	7.14	5.08	8.41	7.76	8.31	10.33	9.51	5.15	8.80	8.02
F2	7.80	5.88	11.10	10.01	11.34	10.81	12.78	14.60	17.71	14.79
F3	7.30	8.55	11.09	9.10	14.56	13.00	19.54	17.78	20.01	19.07
G0	4.08	3.69	4.15	5.40	4.74	5.56	5.16	6.82	5.70	4.77
G1	7.09	5.71	8.44	7.66	8.65	8.03	7.62	7.69	11.17	5.64
G2	8.98	6.43	10.35	10.58	11.24	9.87	16.28	15.22	16.20	10.68
G3	9.15	7.96	12.07	10.71	18.35	14.91	20.62	14.48	19.71	14.21

Table 94. Experiment II (1964): 6th cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	4.03	4.67	5.56	4.66	5.46	5.26	4.46	6.37	7.73	6.66
C1	6.46	6.27	4.97	7.34	8.12	7.15	8.25	9.14	7.92	8.81
C2	4.70	6.82	6.45	9.09	10.83	10.09	11.02	11.74	5.73	14.25
C3	6.44	6.72	8.28	7.64	9.00	11.35	12.74	13.41	14.06	12.78
F0	3.54	3.91	5.81	6.00	5.40	6.50	6.66	7.71	6.82	8.97
F1	5.74	5.21	5.76	6.79	7.52	8.48	10.06	9.48	7.13	8.68
F2	4.96	7.15	9.17	7.26	10.09	9.18	10.99	12.14	15.58	12.94
F3	4.06	7.14	8.41	7.55	10.77	8.89	13.85	14.71	14.62	16.48
G0	3.55	3.57	4.61	4.69	7.11	6.48	7.36	8.10	5.10	6.75
G1	7.27	6.44	7.55	8.17	8.24	8.50	9.08	9.85	10.89	8.90
G2	8.03	7.50	7.97	7.95	13.51	9.50	13.12	12.73	12.66	11.44
G3	5.56	6.50	6.04	6.95	10.55	10.73	11.30	13.42	14.58	15.47

Table 95. Experiment II (1964): 7th cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	3.34	3.59	4.17	4.31	5.11	6.12	4.24	8.12	7.95	9.00
C1	4.01	4.64	4.16	6.47	7.33	7.83	6.95	9.76	10.78	7.60
C2	7.16	5.69	7.48	7.55	10.77	9.65	10.19	9.08	5.70	10.69
C3	8.03	7.46	7.16	9.52	10.96	11.38	11.82	14.26	12.57	11.25
F0	3.48	3.60	4.81	4.68	5.05	5.87	7.62	7.23	9.02	9.62
F1	4.62	6.50	7.11	5.52	7.43	8.30	7.55	8.14	7.98	8.36
F2	5.41	5.31	5.91	8.32	7.02	10.84	9.88	12.23	11.08	11.25
F3	4.83	5.98	10.41	8.96	11.74	12.99	13.36	13.70	15.32	13.42
G0	3.27	3.56	4.58	4.20	6.02	4.91	7.66	6.29	6.62	7.60
G1	5.85	7.23	7.20	6.14	7.33	6.70	8.59	8.38	8.17	10.31
G2	7.23	6.40	7.67	9.97	8.81	9.89	12.00	10.37	10.78	11.38
G3	6.98	6.21	9.19	11.52	13.20	12.93	11.62	12.56	11.23	14.12

Table 96. Experiment II (1964): 8th cut; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	4.38	4.76	4.22	5.33	5.50	5.85	6.52	7.50	9.24	11.39
C1	6.27	9.39	6.76	8.43	8.50	8.49	8.34	9.92	12.35	7.46
C2	9.73	9.07	9.64	11.81	13.62	11.73	11.51	12.17	10.39	11.97
C3	10.97	11.18	13.58	13.63	15.06	16.80	16.09	16.98	14.90	16.90
F0	4.53	4.67	5.31	5.23	5.55	5.82	7.43	5.83	7.51	10.03
F1	6.36	9.02	8.52	7.38	7.14	9.18	9.33	8.45	8.63	9.34
F2	9.30	8.79	9.14	11.72	10.41	11.48	12.59	11.89	12.62	11.49
F3	8.43	11.04	14.15	13.16	15.97	17.21	17.96	16.22	18.20	13.69
G0	4.44	4.29	4.82	4.53	6.00	5.71	9.06	6.56	8.10	9.94
G1	7.14	9.38	8.70	8.19	7.57	7.40	8.31	8.35	8.95	9.70
G2	10.57	9.45	11.58	13.09	11.53	11.30	14.46	12.30	8.04	12.01
G3	10.47	10.22	12.22	14.11	18.80	17.65	15.78	16.04	17.00	16.43

Table 97. Experiment II (1964): Total of 8 cuts; P-uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	22.2	28.0	30.5	29.8	33.0	32.4	30.8	40.7	41.2	40.9
C1	52.9	54.6	55.7	70.0	77.7	69.8	77.6	76.9	84.2	65.6
C2	80.2	71.8	81.8	96.1	111.0	99.8	114.4	105.3	96.5	109.8
C3	94.1	88.5	118.1	118.2	127.5	133.0	132.2	144.5	147.6	152.6
F0	24.8	26.1	30.7	31.0	32.1	35.0	42.3	37.1	39.8	40.9
F1	53.7	56.2	69.9	64.0	72.1	78.5	88.3	79.2	79.6	79.4
F2	70.8	73.0	90.6	90.4	102.4	105.0	119.9	118.0	131.4	117.8
F3	79.3	92.3	124.7	115.4	132.5	140.8	156.6	142.9	163.5	138.2
G0	24.5	23.8	28.2	29.1	33.4	32.4	36.5	39.7	34.1	40.1
G1	60.0	58.8	72.1	70.2	74.4	71.6	82.2	76.9	85.7	76.4
G2	76.4	75.7	91.6	94.3	105.0	106.8	127.7	123.1	117.5	102.6
G3	93.7	89.1	115.2	123.4	147.3	141.2	149.3	146.9	163.2	145.4

Table 98. Experiment II (1964): 1st cut; Soil-P uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.50	0.56	0.55	0.90	0.62	0.55	0.49	0.57	0.76	0.53
C1	1.92	2.36	1.41	3.08	2.28	2.13	2.11	1.77	2.30	1.65
C2	2.98	2.18	2.54	2.72	2.81	3.12	2.73	0.71	3.21	3.03
C3	2.02	2.17	2.95	3.44	3.32	2.45	5.51	2.39	2.69	2.79
F0	0.77	0.55	0.65	0.47	0.59	0.37	0.76	0.60	0.60	0.53
F1	1.91	2.24	2.43	2.34	2.17	1.59	3.06	2.45	2.46	2.66
F2	2.12	2.21	2.52	1.73	2.44	2.27	2.52	2.00	2.34	2.44
F3	2.52	1.83	6.19	1.46	5.45	1.99	3.01	3.03	4.37	3.07
G0	0.46	0.69	0.49	0.79	0.61	0.73	0.56	0.72	0.41	0.72
G1	2.92	2.21	2.61	0.79	2.33	2.31	2.85	1.90	3.02	2.20
G2	2.82	2.13	2.86	2.48	2.78	2.70	3.05	3.53	3.00	3.02
G3	3.32	3.01	5.84	2.91	2.92	3.03	3.41	3.28	3.20	2.44

Table 99. Experiment II (1964): 2nd cut; Soil-P uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	0.45	1.88	1.57	2.14	1.74	2.06	1.97	1.83	1.91	1.42
C1	3.24	2.73	3.95	4.07	3.86	3.04	3.78	4.48	3.70	2.92
C2	4.05	1.92	2.60	3.20	2.63	3.78	3.99	2.71	3.16	3.92
C3	2.57	1.62	3.77	2.47	3.25	2.74	2.57	3.22	3.06	3.48
F0	1.90	1.72	1.85	1.41	1.71	1.63	1.96	1.72	1.57	1.51
F1	2.83	2.43	2.83	3.47	3.60	2.69	3.17	4.06	3.77	3.17
F2	2.20	3.30	2.58	2.51	2.74	3.00	2.31	2.02	2.93	2.06
F3	2.65	1.56	3.07	2.82	3.02	1.89	2.20	3.42	3.54	2.39
G0	1.83	2.08	1.76	1.97	1.34	1.92	1.31	1.77	1.09	1.52
G1	3.30	2.88	3.63	3.21	4.13	2.93	4.26	3.30	3.77	3.23
G2	2.26	3.66	3.39	2.48	3.72	2.49	3.53	3.05	3.27	3.31
G3	3.45	3.23	4.40	3.49	3.10	3.56	3.87	3.20	3.90	3.54

Table 100. Experiment II (1964): 3rd cut; Soil-P uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	1.29	4.26	3.73	2.91	4.04	3.41	3.85	4.12	3.21	3.62
C1	3.92	2.99	5.59	4.76	6.62	5.59	7.09	7.02	6.50	4.51
C2	3.56	3.16	6.83	3.45	4.29	3.77	7.58	4.05	6.06	5.08
C3	4.00	3.06	3.85	3.79	4.34	3.97	2.10	6.15	6.79	4.93
F0	2.17	2.73	3.04	4.67	3.11	5.20	5.33	3.61	3.42	1.75
F1	3.82	3.48	5.36	3.87	5.58	4.61	6.35	6.49	6.58	5.49
F2	2.30	2.42	4.62	3.76	4.95	4.31	4.32	4.00	3.99	5.47
F3	2.89	2.59	4.04	5.00	5.35	3.67	4.60	2.87	5.24	1.40
G0	3.39	2.37	3.95	3.03	2.82	2.84	2.17	3.35	2.23	3.50
G1	3.76	2.94	6.10	4.31	5.76	4.68	7.21	6.18	6.69	4.67
G2	2.37	3.58	3.67	2.85	3.26	5.25	6.23	4.88	6.84	3.52
G3	3.02	3.05	4.97	5.16	4.17	4.35	4.40	4.40	6.75	3.57

Table 101. Experiment II (1964): 4th cut; Soil-P uptake by grass, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C0	3.57	4.25	5.90	4.91	5.28	5.39	4.62	5.62	4.69	4.62
C1	4.11	4.45	5.64	5.15	6.77	6.93	5.74	7.28	7.55	4.92
C2	3.42	3.38	4.61	6.17	7.27	7.75	6.39	4.45	8.10	7.10
C3	3.55	2.74	5.04	4.75	4.74	4.26	4.73	3.48	4.80	3.50
F0	3.60	4.50	4.25	4.09	5.55	4.69	6.84	6.44	4.91	4.71
F1	3.76	4.03	5.87	5.61	5.74	6.44	7.77	7.25	6.33	6.24
F2	2.92	3.25	4.95	5.21	5.61	6.59	5.77	6.54	5.77	6.84
F3	2.79	4.35	5.05	4.61	2.99	4.79	6.45	2.48	3.27	2.41
G0	3.40	3.47	3.81	4.42	4.67	4.25	3.18	6.04	4.83	5.22
G1	4.09	2.91	6.62	5.83	6.75	5.84	8.12	8.25	7.64	6.70
G2	2.68	2.59	5.52	3.93	5.95	6.13	6.85	5.66	8.61	5.46
G3	2.91	1.84	0.73	4.18	5.82	4.87	5.50	4.43	7.86	8.16

Table 102. Experiment II (1964): 1st cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	4.70	6.14	3.11	7.46	6.65	5.64	6.20	4.10	6.60	4.39
C2	11.62	10.23	10.90	12.28	14.01	12.55	12.79	12.51	13.72	12.11
C3	14.45	14.18	18.87	19.63	18.18	16.30	18.08	17.74	16.56	18.76
F1	5.69	6.79	7.44	6.99	7.37	7.80	9.58	7.04	7.87	8.58
F2	10.68	10.79	13.22	11.73	14.65	13.09	15.74	13.63	16.31	14.40
F3	14.43	14.74	19.42	18.06	16.74	20.68	20.96	18.57	22.65	19.34
G1	8.03	7.25	6.29	8.26	6.48	7.57	7.17	5.65	8.08	6.91
G2	12.40	11.40	12.34	12.98	12.65	13.40	15.75	17.59	12.23	12.91
G3	17.28	14.96	16.02	18.75	18.81	19.74	18.36	19.47	19.11	16.02

Table 103. Experiment II (1964): 2nd cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	6.38	6.04	7.36	8.23	7.99	5.67	8.72	7.83	7.96	6.20
C2	13.36	9.03	10.87	12.61	11.67	12.71	13.67	10.27	10.95	12.84
C3	14.08	12.23	16.30	14.64	17.97	13.61	15.24	17.95	18.21	17.26
F1	6.04	4.88	7.55	7.85	8.33	6.59	8.36	8.97	9.82	7.78
F2	9.37	10.35	11.70	10.83	11.77	12.55	12.95	11.73	14.45	11.44
F3	14.58	13.34	17.72	15.16	17.77	17.98	18.73	15.08	21.01	14.05
G1	6.51	5.35	7.03	7.56	8.38	7.14	9.66	6.77	8.82	8.31
G2	7.93	11.12	11.75	8.19	13.69	13.22	14.06	12.79	11.92	10.94
G3	14.69	12.37	17.38	16.06	19.16	18.54	20.52	20.42	21.64	19.55

Table 104. Experiment II (1964): 3rd cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	5.50	4.33	7.53	7.13	10.67	9.75	12.20	9.98	11.36	6.52
C2	9.32	9.69	11.76	12.49	9.44	8.70	16.64	11.66	13.69	14.33
C3	14.03	12.27	17.46	16.82	16.01	10.69	13.85	21.27	22.95	25.22
F1	5.82	5.41	7.85	4.96	8.47	7.86	11.27	10.17	11.86	10.93
F2	8.25	9.23	11.29	9.77	13.59	12.18	16.35	13.56	17.06	16.03
F3	9.33	12.39	19.13	18.59	19.45	21.29	20.61	17.65	24.83	14.87
G1	4.97	5.61	9.00	7.28	10.50	9.65	12.36	10.43	10.83	8.65
G2	6.62	9.45	10.25	13.45	13.37	15.86	16.68	16.66	18.67	13.44
G3	11.32	12.29	18.20	19.89	20.60	20.04	22.05	22.59	26.38	19.29

Table 105. Experiment II (1964): 4th cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.69	3.96	4.74	5.15	7.48	7.78	6.34	8.09	10.04	6.04
C2	7.16	6.22	6.64	9.99	12.98	12.70	13.67	12.18	13.99	14.93
C3	8.71	7.66	13.12	12.61	14.35	15.44	17.28	15.88	19.81	22.46
F1	3.27	4.32	7.00	6.50	6.04	8.43	8.95	8.14	7.97	8.16
F2	6.00	6.45	8.77	10.46	12.06	13.35	14.90	14.54	17.06	15.91
F3	7.27	10.08	14.05	14.59	14.02	17.27	18.24	15.53	17.28	17.71
G1	3.62	2.92	7.73	6.74	7.64	6.95	9.83	10.16	8.93	8.13
G2	5.70	5.07	9.55	7.98	10.53	14.16	15.79	15.83	17.14	10.01
G3	9.40	9.66	13.89	15.23	18.22	17.02	19.50	18.33	23.69	20.51

Table 106. Experiment II (1964): 5th cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.16	1.07	1.05	3.77	4.36	0.88	3.42	0.97	2.03	3.33
C2	4.39	2.30	2.08	4.28	11.02	5.13	7.76	8.51	7.14	3.45
C3	4.69	4.09	7.29	7.72	9.40	11.88	9.93	9.86	13.21	12.80
F1	2.60	0.54	3.78	3.13	3.39	5.41	4.77	0.41	3.96	3.18
F2	3.26	1.34	6.47	5.38	6.42	5.89	8.04	9.86	12.87	9.95
F3	2.76	4.01	6.46	4.47	9.64	8.08	14.80	13.04	15.17	14.23
G1	3.21	1.83	3.66	2.88	3.50	2.88	1.63	1.70	5.94	0.41
G2	5.10	2.55	5.57	5.80	6.09	4.72	10.29	9.23	10.97	5.45
G3	5.27	4.08	7.29	5.93	13.10	9.76	14.63	8.49	14.48	8.98

Table 107. Experiment II (1964): 6th cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	2.11	1.92	-0.14	2.23	2.76	1.79	2.83	3.72	0.72	1.61
C2	0.35	2.47	1.34	3.98	5.47	4.73	5.60	6.32	-1.47	7.05
C3	2.09	2.37	3.17	2.53	3.64	5.99	7.32	7.99	6.86	5.58
F1	2.01	1.48	-0.15	0.88	1.57	2.53	2.87	2.29	-0.77	0.78
F2	1.23	3.42	3.26	1.35	4.14	3.23	3.80	4.95	7.68	5.04
F3	0.33	3.41	2.50	1.64	4.82	2.94	6.66	7.52	6.72	8.58
G1	3.71	2.88	2.90	3.52	1.44	1.70	1.35	2.12	4.96	2.97
G2	4.47	3.94	3.32	3.30	6.71	2.70	5.39	5.00	6.73	5.51
G3	2.00	2.94	1.39	2.30	3.75	3.93	3.57	5.69	8.65	9.54

Table 108. Experiment II (1964): 7th cut; Apparent recovery of applied-P, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	0.54	1.17	-0.08	2.23	1.71	2.21	0.77	3.58	2.30	-0.88
C2	3.71	2.22	3.24	3.31	5.15	4.03	4.01	2.90	-2.78	2.21
C3	4.56	3.99	2.99	5.28	5.34	5.76	5.64	8.08	4.09	2.77
F1	1.08	2.96	2.36	0.77	1.97	2.84	0.12	0.71	-1.32	-0.96
F2	1.87	1.77	1.16	3.57	1.56	5.38	2.45	4.80	1.76	1.93
F3	1.29	2.44	5.66	4.21	6.28	7.53	5.93	6.27	6.00	4.10
G1	2.43	3.81	2.81	1.75	1.86	1.23	1.61	1.40	1.06	3.20
G2	3.81	2.98	3.28	5.58	3.34	4.42	5.02	3.39	3.67	4.27
G3	3.56	2.79	4.80	7.13	7.73	7.46	4.64	5.58	4.12	7.01

Table 109. Experiment II (1964): 8th cut; Apparent recovery of applied-P mg, P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	1.70	4.82	1.98	3.65	2.82	2.81	1.33	2.91	2.03	-2.86
C2	5.16	4.50	4.86	7.03	7.94	6.05	4.50	5.16	0.07	1.65
C3	6.40	6.61	8.80	8.85	9.38	11.12	9.08	9.97	4.58	6.58
F1	1.76	4.42	3.25	2.11	1.45	3.49	2.70	1.82	-0.14	0.57
F2	4.70	4.19	3.87	6.45	4.72	5.79	5.96	5.26	3.85	2.72
F3	3.83	6.44	8.88	7.89	10.28	11.52	11.33	9.59	9.43	4.92
G1	2.77	5.01	4.02	3.51	1.71	1.54	0.50	0.54	-0.07	0.68
G2	6.20	5.08	6.90	8.41	5.67	5.44	6.65	4.49	-0.98	2.99
G3	6.10	5.85	7.54	9.43	12.94	11.79	7.97	8.23	7.98	7.41

Table 110. Experiment II (1964): Total of 8 cuts; Apparent recovery of applied-P mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	27.8	29.5	25.6	39.9	44.4	36.5	41.8	41.2	43.0	24.4
C2	55.1	46.7	51.7	66.0	77.7	66.6	78.6	69.5	55.3	68.6
C3	69.0	63.4	88.0	88.1	94.3	99.8	96.4	108.7	106.3	111.4
F1	28.3	30.8	39.1	33.2	38.6	45.0	48.6	39.6	39.3	39.0
F2	45.4	47.5	59.7	59.5	68.9	71.5	80.2	78.3	91.0	77.4
F3	53.8	66.9	93.8	84.6	99.0	107.3	117.3	103.3	123.1	97.8
G1	35.3	34.7	43.4	41.5	41.5	38.7	44.1	38.8	48.6	39.3
G2	52.2	51.6	63.0	65.7	72.1	73.9	89.6	85.0	80.4	65.5
G3	69.6	64.9	86.5	94.7	114.3	108.3	111.2	108.8	126.0	108.3

Table 111. Experiment II (1964): 1st cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	4.8	6.3	3.2	7.7	6.8	5.8	6.4	4.2	6.8	4.5
C2	6.0	5.2	5.6	6.3	7.2	6.4	6.6	6.4	7.0	6.2
C3	4.9	4.8	6.5	6.7	6.2	5.6	6.2	6.1	5.7	6.4
F1	5.8	7.0	7.6	7.2	7.6	8.0	9.8	7.2	8.1	8.8
F2	5.5	5.5	6.8	6.0	7.5	6.7	8.1	7.0	8.4	7.4
F3	4.9	5.0	6.6	6.2	5.7	7.1	7.2	6.4	7.7	6.6
G1	8.2	7.4	6.5	8.5	6.6	7.8	7.4	5.8	8.3	7.1
G2	6.4	5.8	6.3	6.7	6.5	6.9	8.1	9.0	6.3	6.6
G3	5.9	5.1	5.5	6.4	6.4	6.8	6.3	6.7	6.5	5.5

Table 112. Experiment II (1964): 2nd cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	6.5	6.2	7.5	8.4	8.2	5.8	8.9	8.0	8.2	6.4
C2	6.9	4.6	5.6	6.5	6.0	6.5	7.0	5.3	5.6	6.6
C3	4.8	4.2	5.6	5.0	6.1	4.7	5.2	6.1	6.2	5.9
F1	6.2	5.0	7.7	8.1	8.5	6.8	8.6	9.2	10.1	8.0
F2	4.8	5.3	6.0	5.6	6.0	6.4	6.6	6.0	7.4	5.9
F3	5.0	4.6	6.1	5.2	6.1	6.1	6.4	5.2	7.2	4.8
G1	6.7	5.5	7.2	7.8	8.6	7.3	9.9	6.9	9.0	8.5
G2	4.1	5.7	6.0	4.2	7.0	6.8	7.2	6.6	6.1	5.6
G3	5.0	4.2	5.9	5.5	6.6	6.3	7.0	7.0	7.4	6.7

Table 113. Experiment II (1964): 3rd cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	5.6	4.4	7.7	7.3	10.9	10.0	12.5	10.2	11.7	6.7
C2	4.8	5.0	6.0	6.4	4.8	4.5	8.5	6.0	7.0	7.4
C3	4.8	4.2	6.0	5.8	5.5	6.7	4.7	7.3	7.8	8.6
F1	6.0	5.5	8.1	5.1	8.7	8.1	11.6	10.4	12.2	11.2
F2	4.2	4.7	5.8	5.0	7.0	6.2	8.4	7.0	8.8	8.2
F3	3.2	4.2	6.5	6.4	6.7	7.3	7.0	6.0	8.5	5.1
G1	5.1	5.8	9.2	7.5	10.8	9.9	12.7	10.7	11.1	8.9
G2	3.4	4.8	5.3	6.9	6.9	8.1	8.6	8.5	9.6	6.9
G3	3.9	4.2	6.2	6.8	3.6	6.9	7.5	7.7	9.0	6.6

Table 114. Experiment II (1964): 4th cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.8	4.1	4.9	5.3	7.7	8.0	6.5	8.3	10.3	6.2
C2	3.7	3.2	3.4	5.1	6.7	6.5	7.0	6.2	7.2	7.7
C3	3.0	2.6	4.5	4.3	4.9	5.3	5.9	5.4	6.8	7.7
F1	3.4	4.4	7.2	6.7	6.2	8.6	9.2	8.3	8.2	8.4
F2	3.1	3.3	4.5	5.4	6.2	6.8	7.6	7.5	8.8	8.2
F3	2.5	3.4	4.8	5.0	4.8	5.9	6.2	5.3	5.9	6.0
G1	3.7	3.0	7.9	6.9	7.8	7.1	10.1	10.4	9.2	8.3
G2	2.9	2.6	4.9	4.1	5.4	7.3	8.1	8.1	8.8	5.1
G3	3.2	3.3	4.8	5.2	6.2	5.8	6.7	6.3	8.4	7.0

Table 115. Experiment II (1964): 5th cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.2	1.1	1.1	3.9	4.5	0.9	3.5	1.0	2.1	3.4
C2	2.3	1.2	1.1	2.2	5.7	2.6	4.0	4.4	3.7	1.8
C3	1.6	1.4	2.5	2.6	3.2	4.1	3.4	3.4	4.5	4.4
F1	2.7	0.6	3.9	3.2	3.5	5.5	4.9	0.4	4.1	3.3
F2	1.7	0.7	3.3	2.8	3.3	3.0	4.1	5.1	6.6	5.1
F3	0.9	1.4	2.2	1.5	3.3	2.8	5.1	4.5	5.2	4.9
G1	3.3	1.9	3.8	3.0	3.6	3.0	1.7	1.7	6.1	0.4
G2	2.6	1.3	2.9	3.0	3.1	2.4	5.3	4.7	5.6	2.8
G3	1.8	1.4	2.5	2.0	4.5	3.3	5.0	2.9	5.0	3.1

Table 116. Experiment II (1964): 6th cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	2.2	2.0	-0.1	2.3	2.8	1.8	2.9	3.8	0.7	1.7
C2	0.2	1.3	0.7	2.0	2.8	2.4	2.9	3.2	-0.8	3.6
C3	0.7	0.8	3.1	0.9	1.2	2.0	2.5	2.7	2.3	1.9
F1	2.1	1.5	-0.2	0.9	1.6	2.6	2.9	2.3	-0.8	0.8
F2	0.6	1.8	1.7	0.7	2.1	1.7	1.9	2.5	3.9	2.6
F3	0.1	1.2	0.9	0.6	1.6	1.0	2.3	2.6	2.3	2.9
G1	3.8	3.0	3.0	3.6	1.5	1.7	1.4	2.2	5.1	3.0
G2	2.3	2.0	1.7	1.7	3.4	1.4	2.8	2.6	3.5	2.8
G3	0.7	1.0	0.5	0.8	1.3	1.3	1.2	1.9	3.0	3.3

Table 117. Experiment II (1964): 7th cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	0.6	1.2	-0.1	2.3	1.8	2.3	0.8	3.7	2.4	-0.9
C2	1.9	1.1	1.7	1.7	2.6	2.1	2.1	1.5	-1.4	1.1
C3	1.6	1.4	1.0	1.8	1.8	2.0	1.9	2.8	1.4	0.9
F1	1.1	3.0	2.4	0.8	2.0	2.9	0.1	0.7	-1.4	-1.0
F2	1.0	0.9	0.6	1.8	0.8	2.8	1.3	2.5	0.9	1.0
F3	0.4	0.8	1.9	1.4	2.1	2.6	2.0	2.1	2.1	1.4
G1	2.5	3.9	2.9	1.8	1.9	1.3	1.7	1.4	1.1	3.3
G2	2.0	1.5	1.7	2.9	1.7	2.3	2.6	1.7	1.9	2.2
G3	1.2	1.0	1.6	2.4	2.6	2.6	1.6	1.9	1.4	2.4

Table 118. Experiment II (1964): 8th cut; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	1.7	4.9	2.0	3.7	2.9	2.9	1.4	3.0	2.1	-2.9
C2	2.6	2.3	2.5	3.6	4.1	3.1	2.3	2.6	0.0	0.8
C3	2.2	2.3	3.0	3.0	3.2	3.8	3.1	3.4	1.6	2.3
F1	1.8	4.5	3.3	2.2	1.5	3.6	2.8	1.9	-0.1	0.6
F2	2.4	2.1	2.0	3.3	2.4	3.0	3.1	2.7	2.0	1.4
F3	1.3	2.2	3.0	2.7	3.5	3.9	3.9	3.3	3.2	1.7
G1	2.8	5.1	4.1	3.6	1.8	1.6	0.5	0.6	-0.1	0.7
G2	3.2	2.6	3.5	4.3	2.9	2.8	3.4	2.3	-0.5	1.5
G3	2.1	2.0	2.6	3.2	4.4	4.0	2.7	2.8	2.7	2.5

Table 119. Experiment II (1964): Total of 8 cuts; % Apparent recovery of applied-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	28.4	30.2	26.2	40.9	45.6	37.5	42.9	42.2	44.3	25.1
C2	28.4	23.9	26.6	33.8	39.9	34.1	40.4	35.6	28.3	35.2
C3	23.6	21.7	32.2	30.1	32.1	34.2	32.9	37.2	36.3	38.1
F1	29.1	31.5	40.0	34.2	39.6	46.1	49.9	40.4	40.4	40.1
F2	23.3	24.3	30.7	30.6	35.3	36.6	41.1	40.3	46.8	39.8
F3	18.3	22.8	32.0	29.0	33.8	36.7	40.1	35.4	42.1	33.4
G1	36.1	35.6	44.6	42.7	42.6	39.7	45.4	39.7	49.8	40.2
G2	26.9	26.3	32.3	33.8	36.9	38.0	46.1	43.5	41.3	33.5
G3	23.8	22.2	29.6	32.3	35.6	37.0	38.0	37.2	43.4	37.1

Table 120. Experiment II (1964): 1st cut; labelled-P % in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	0.133	0.144	0.126	0.131	0.124	0.127	0.140	0.110	0.137	0.140
C2	0.231	0.224	0.218	0.201	0.214	0.189	0.218	0.225	0.197	0.183
C3	0.290	0.305	0.287	0.241	0.284	0.230	0.193	0.252	0.256	0.241
F1	0.161	0.151	0.149	0.132	0.152	0.151	0.160	0.133	0.148	0.139
F2	0.244	0.221	0.228	0.207	0.208	0.184	0.232	0.209	0.236	0.205
F3	0.329	0.312	0.225	0.272	0.205	0.270	0.278	0.235	0.272	0.242
G1	0.156	0.158	0.124	0.194	0.131	0.146	0.134	0.130	0.145	0.142
G2	0.220	0.245	0.219	0.211	0.216	0.211	0.223	0.200	0.196	0.177
G3	0.329	0.266	0.224	0.272	0.298	0.275	0.275	0.246	0.268	0.267

Table 121. Experiment II (1964): 2nd cut; labelled-P % in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	0.097	0.100	0.111	0.105	0.103	0.085	0.105	0.094	0.101	0.105
C2	0.202	0.164	0.140	0.148	0.129	0.126	0.131	0.119	0.123	0.119
C3	0.262	0.247	0.187	0.188	0.194	0.159	0.153	0.160	0.165	0.151
F1	0.110	0.093	0.110	0.109	0.112	0.085	0.109	0.100	0.099	0.105
F2	0.192	0.175	0.138	0.135	0.126	0.127	0.141	0.138	0.147	0.138
F3	0.275	0.271	0.196	0.184	0.163	0.197	0.181	0.158	0.172	0.166
G1	0.102	0.096	0.096	0.097	0.104	0.100	0.103	0.093	0.096	0.095
G2	0.169	0.178	0.130	0.110	0.150	0.144	0.123	0.137	0.119	0.108
G3	0.268	0.223	0.179	0.182	0.177	0.187	0.179	0.170	0.171	0.176

Table 122. Experiment II(1964): 3rd cut; labelled-P % in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	0.135	0.131	0.118	0.127	0.121	0.103	0.126	0.107	0.120	0.111
C2	0.233	0.233	0.139	0.190	0.136	0.117	0.136	0.146	0.135	0.120
C3	0.327	0.337	0.242	0.233	0.174	0.211	0.157	0.177	0.176	0.173
F1	0.136	0.133	0.113	0.104	0.123	0.111	0.129	0.106	0.110	0.126
F2	0.263	0.238	0.167	0.158	0.153	0.148	0.157	0.151	0.181	0.142
F3	0.246	0.313	0.268	0.220	0.198	0.208	0.174	0.201	0.203	0.183
G1	0.142	0.146	0.109	0.132	0.133	0.132	0.101	0.100	0.111	0.100
G2	0.213	0.196	0.162	0.188	0.203	0.141	0.140	0.164	0.140	0.131
G3	0.300	0.282	0.239	0.212	0.231	0.213	0.186	0.186	0.170	0.167

Table 123. Experiment II (1964): 4th cut; labelled-P % in the dry matter

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	0.117	0.102	0.094	0.097	0.092	0.086	0.095	0.089	0.094	0.099
C2	0.213	0.202	0.172	0.141	0.131	0.121	0.138	0.139	0.116	0.139
C3	0.259	0.265	0.201	0.196	0.183	0.186	0.187	0.182	0.197	0.189
F1	0.124	0.120	0.098	0.096	0.096	0.103	0.098	0.096	0.091	0.091
F2	0.203	0.197	0.144	0.145	0.153	0.130	0.159	0.137	0.148	0.128
F3	0.289	0.239	0.196	0.206	0.200	0.195	0.171	0.175	0.138	0.184
G1	0.109	0.120	0.092	0.095	0.090	0.089	0.082	0.069	0.078	0.084
G2	0.191	0.197	0.143	0.172	0.134	0.143	0.128	0.149	0.131	0.139
G3	0.263	0.277	0.257	0.202	0.174	0.195	0.183	0.176	0.170	0.145

Table 124. Experiment II (1964): 1st cut; labelled-P uptake, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.31	4.31	2.43	5.11	4.96	4.10	4.62	2.86	5.10	3.54
C2	9.17	8.58	9.09	10.29	11.79	10.02	10.59	12.33	11.31	9.88
C3	12.96	12.54	16.65	16.92	15.45	14.44	13.10	15.88	14.67	16.77
F1	4.44	5.21	5.57	5.21	5.68	6.69	7.20	5.27	5.98	6.49
F2	9.22	9.24	11.26	10.56	12.69	11.30	13.92	12.31	14.54	12.53
F3	12.57	13.57	13.79	17.16	11.77	19.17	18.63	16.22	18.85	16.84
G1	5.69	5.62	4.32	8.11	4.82	5.93	4.96	4.39	5.63	5.28
G2	10.16	9.85	10.12	11.14	10.54	11.37	13.34	14.70	9.80	10.46
G3	14.54	12.53	10.82	16.48	16.56	17.38	15.59	16.83	16.48	14.15

Table 125. Experiment II (1964): 2nd cut; labelled-P uptake, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	4.31	4.48	5.28	6.03	6.04	4.54	6.85	5.26	5.94	4.96
C2	10.48	8.28	10.14	11.28	10.95	10.84	11.59	9.47	9.47	10.60
C3	12.68	11.78	14.40	14.04	16.63	12.78	14.58	16.64	16.83	15.46
F1	5.03	4.27	6.36	6.02	6.41	5.58	7.04	6.76	7.60	6.16
F2	8.99	8.87	10.76	9.96	10.71	11.23	12.49	11.56	13.07	10.93
F3	13.75	13.60	16.29	13.98	16.43	17.77	18.08	13.51	19.02	13.21
G1	5.18	4.44	5.28	6.23	5.89	5.85	6.95	5.02	6.36	6.39
G2	7.64	9.43	10.24	7.59	11.61	12.37	12.08	11.29	9.96	8.94
G3	13.21	11.11	14.86	14.45	17.70	16.62	18.20	18.77	19.05	17.32

Table 126. Experiment II (1964): 3rd cut; labelled-P uptake, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	4.37	4.13	5.27	5.70	7.78	7.89	9.11	6.96	8.29	5.44
C2	8.55	9.32	8.26	12.37	8.98	8.66	13.06	11.61	11.06	12.68
C3	12.82	12.00	16.94	16.36	15.40	19.45	15.75	19.12	19.59	23.72
F1	4.47	4.40	6.37	4.97	7.07	7.43	9.42	8.18	7.88	8.04
F2	8.42	9.28	10.55	9.89	12.82	12.05	16.53	14.06	15.67	13.16
F3	8.91	12.27	18.97	17.47	18.28	21.80	20.51	19.28	22.19	16.07
G1	4.10	5.56	6.40	6.47	7.58	7.81	7.92	7.02	7.02	6.86
G2	7.14	8.76	10.08	14.10	12.95	13.45	13.22	14.55	14.71	12.80
G3	11.19	12.13	16.73	18.23	19.27	18.53	20.42	20.96	22.51	18.60

Table 127. Experiment II (1964): 4th cut; labelled-P uptake, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.51	3.44	4.53	5.43	6.07	6.21	5.74	5.95	7.16	5.79
C2	7.67	6.77	7.46	9.25	11.07	10.31	12.42	12.87	10.56	12.50
C3	9.09	8.85	13.51	13.29	14.97	16.54	17.69	17.54	19.68	23.63
F1	3.58	4.36	5.32	5.08	5.45	7.14	7.85	7.56	6.47	6.75
F2	7.15	7.27	8.01	9.44	11.60	11.91	15.80	14.67	16.12	13.90
F3	8.55	9.80	13.19	14.17	16.18	17.63	18.69	19.72	18.84	20.13
G1	3.60	3.46	5.24	5.04	5.37	5.59	6.34	6.54	6.34	6.48
G2	6.47	5.93	8.39	9.25	9.06	12.51	13.57	14.80	13.58	9.60
G3	9.94	11.27	17.09	14.32	16.88	16.63	18.63	18.53	20.88	17.40

Table 128. Experiment II (1964): Total of 4 cuts; labelled-P uptake, mg P/pot

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	15.50	16.36	17.51	22.27	24.85	22.74	26.32	21.03	26.49	19.73
C2	35.87	32.95	34.95	43.19	42.79	39.83	47.66	46.28	42.40	45.66
C3	47.55	45.17	61.50	60.61	62.45	63.21	61.12	69.18	70.77	79.58
F1	17.52	18.24	23.62	21.28	24.61	26.84	31.51	27.77	27.93	27.44
F2	33.78	34.66	40.58	39.85	47.82	46.49	58.74	52.60	59.40	50.52
F3	43.78	49.24	62.24	62.78	62.66	76.37	75.91	68.73	78.90	66.25
G1	18.57	19.08	21.24	25.85	23.66	25.18	26.17	22.97	25.35	25.01
G2	31.41	33.97	38.83	42.08	44.16	49.70	52.21	55.34	48.05	41.80
G3	48.88	47.04	59.50	63.48	70.41	69.16	72.84	75.09	78.92	67.47

Table 129. Experiment II (1964): 1st cut; % Recovery of labelled-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.39	4.42	2.49	5.24	5.09	4.20	4.74	2.93	5.23	3.63
C2	4.71	4.40	4.66	5.28	6.05	5.14	5.43	6.33	5.80	5.07
C3	4.43	4.29	5.69	5.79	5.28	4.94	4.48	5.43	5.02	5.74
F1	4.55	5.34	5.71	5.34	5.83	6.86	7.38	5.40	6.13	6.66
F2	4.73	4.74	5.78	5.42	6.51	5.80	7.14	6.32	7.46	6.43
F3	4.30	4.64	4.72	5.87	4.03	6.56	6.37	5.55	6.45	5.76
G1	5.84	5.76	4.43	8.32	4.94	6.08	5.09	4.50	5.77	5.42
G2	5.21	5.05	5.19	5.72	5.41	5.83	6.84	7.54	5.03	5.37
G3	4.97	4.29	3.70	5.64	5.66	5.94	5.33	5.76	5.64	4.84

Table 130. Experiment II (1964): 2nd cut; % Recovery of labelled-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	4.42	4.59	5.42	6.18	6.19	4.66	7.03	5.39	6.09	5.09
C2	5.37	4.25	5.20	5.79	5.62	5.56	5.95	4.86	4.86	5.44
C3	4.34	4.03	4.92	4.80	5.69	4.37	4.99	5.69	5.76	5.29
F1	5.16	4.38	6.52	6.17	6.57	5.72	7.22	6.93	7.79	6.32
F2	4.61	4.55	5.52	5.11	5.50	5.76	6.41	5.93	6.71	5.61
F3	4.70	4.65	5.57	4.78	5.62	6.08	6.18	4.62	6.50	4.52
G1	5.31	4.55	5.42	6.39	6.04	6.00	7.13	5.15	6.52	6.55
G2	3.92	4.84	5.25	3.89	5.96	6.35	6.20	5.79	5.11	4.59
G3	4.52	3.80	5.09	4.94	6.05	5.68	6.22	6.42	6.52	5.92

Table 131. Experiment II (1964): 3rd cut; % Recovery of labelled-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	4.48	4.24	5.40	5.85	7.98	8.09	9.34	7.14	8.50	5.58
C2	4.39	4.78	4.24	6.35	4.61	4.44	6.70	5.96	5.67	6.51
C3	4.38	4.10	5.79	5.60	5.27	6.65	5.39	6.54	6.70	8.11
F1	4.58	4.51	6.53	5.10	7.25	7.62	9.66	8.39	8.08	8.25
F2	4.32	4.76	5.41	5.07	6.58	6.18	8.48	7.21	8.04	6.75
F3	3.05	4.20	6.49	6.73	6.25	7.46	7.01	6.59	7.59	5.50
G1	4.20	5.70	5.55	6.64	7.77	8.01	8.12	7.20	7.20	7.04
G2	3.66	4.49	5.17	7.23	6.64	6.90	6.78	7.47	7.55	6.57
G3	3.83	4.15	5.72	6.23	6.59	6.34	6.98	7.17	7.70	6.36

Table 132. Experiment II (1964): 4th cut; % Recovery of labelled-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	3.60	3.53	4.65	5.57	6.23	6.37	5.89	6.10	7.34	5.94
C2	3.94	3.47	3.83	4.75	5.68	5.29	6.37	6.60	5.42	6.41
C3	3.11	3.03	4.62	4.55	5.12	5.66	6.05	6.00	6.73	8.08
F1	3.67	4.47	5.46	5.21	5.59	7.32	8.05	7.75	6.64	6.92
F2	3.67	3.73	4.11	4.84	5.95	6.11	8.11	7.53	8.27	7.13
F3	2.92	3.35	4.51	4.85	5.53	6.03	6.39	6.74	6.44	6.88
G1	3.69	3.55	5.37	5.17	5.51	5.73	6.50	6.71	6.50	6.65
G2	3.32	3.04	4.30	4.75	4.65	6.42	6.96	7.59	6.97	5.93
G3	3.40	3.85	5.84	4.90	5.77	5.69	6.37	6.34	7.14	5.95

Table 133. Experiment II (1964): Total of 4 cuts; % Recovery of labelled-P

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	15.89	16.78	17.96	22.84	25.49	23.32	27.00	21.56	27.16	20.24
C2	18.41	16.90	17.93	22.17	21.96	20.43	24.45	23.75	21.75	23.43
C3	16.26	15.45	21.02	20.74	21.36	21.62	20.91	23.66	24.21	27.22
F1	17.96	18.70	24.22	21.82	25.24	27.52	32.31	28.47	28.64	28.15
F2	17.33	17.78	20.82	20.44	24.54	23.85	30.14	26.99	30.48	25.92
F3	14.97	16.84	21.29	22.23	21.43	26.13	25.95	23.50	26.98	22.66
G1	19.04	19.56	20.77	26.52	24.26	25.82	26.84	23.56	25.99	25.66
G2	16.11	17.42	19.91	21.59	22.66	25.50	26.78	28.39	24.66	22.46
G3	16.72	16.09	20.35	21.71	24.07	23.65	24.90	25.69	27.00	23.07

Table 134. Experiment II (1964): 1st cut; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	56.5	53.4	56.5	58.8	44.8	50.7	44.6	60.3	44.2	45.2
C2	63.2	49.6	54.3	51.5	46.3	60.9	49.9	11.3	55.3	59.5
C3	45.6	50.8	52.0	59.5	62.7	49.6	122.9	44.1	53.6	48.4
F1	42.0	42.0	42.6	43.8	37.2	23.2	41.4	45.5	40.2	40.0
F2	44.8	46.6	43.7	32.0	37.4	39.1	35.2	31.7	31.5	37.9
F3	58.2	39.5	131.4	24.7	135.7	30.3	47.2	54.9	67.7	53.2
G1	50.0	38.3	59.0	9.5	47.2	38.1	56.0	42.0	52.5	40.6
G2	54.0	42.2	55.0	43.4	51.5	46.3	44.5	46.9	59.5	56.2
G3	66.8	70.4	158.1	51.6	51.6	51.2	63.7	56.9	56.5	50.4

Table 135. Experiment II (1964): 2nd cut; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	70.8	56.9	71.1	62.4	59.2	62.5	51.3	80.6	57.6	55.4
C2	71.9	43.1	47.6	52.4	44.1	64.6	63.4	52.1	61.2	68.4
C3	56.8	38.5	72.0	48.6	53.9	59.8	49.3	53.5	50.6	62.2
F1	52.3	52.6	40.9	53.3	51.6	43.7	40.6	55.3	45.5	46.9
F2	45.6	69.0	43.9	46.4	46.7	49.1	33.4	32.0	40.4	34.5
F3	54.1	32.0	52.7	55.6	51.5	29.0	33.1	69.9	50.9	49.8
G1	58.5	59.5	64.0	46.0	64.9	45.9	56.7	61.3	54.4	46.7
G2	54.6	72.0	61.3	60.0	59.2	37.1	53.0	48.8	60.7	68.2
G3	72.5	81.3	83.2	66.8	48.3	58.7	58.7	47.1	56.5	57.0

Table 136. Experiment II (1964): 3rd cut; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	80.7	64.2	95.3	71.3	73.7	63.0	67.0	90.1	67.7	73.7
C2	73.0	60.3	145.5	48.3	82.1	75.7	100.1	60.5	95.4	69.9
C3	83.3	68.3	59.3	60.5	73.4	54.3	35.4	83.4	90.2	54.0
F1	75.3	69.7	72.0	67.2	67.4	52.9	56.2	67.7	70.1	58.0
F2	48.4	46.1	75.9	66.1	66.4	61.5	44.0	48.5	42.6	71.4
F3	86.3	55.9	56.0	75.0	77.1	43.0	57.3	39.2	60.1	22.8
G1	79.3	46.3	83.8	55.4	66.0	51.4	78.1	77.5	81.5	58.4
G2	58.7	71.7	63.6	35.6	43.5	66.9	79.8	56.6	81.3	48.4
G3	71.6	67.6	79.2	74.2	55.9	60.6	55.6	54.1	77.2	50.1

Table 137. Experiment II (1964): 4th cut; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	100.0	109.4	105.4	76.6	87.7	90.2	76.9	100.7	82.3	70.9
C2	74.2	84.2	103.5	107.3	107.0	124.3	82.2	55.9	132.7	91.8
C3	99.2	79.1	91.3	87.5	77.3	63.4	66.6	47.9	58.8	35.0
F1	87.7	77.2	87.5	89.9	82.5	70.1	73.0	74.3	74.5	70.9
F2	68.7	74.9	100.3	90.9	76.8	88.6	55.6	69.9	54.4	78.0
F3	83.9	114.3	93.2	79.1	45.5	63.6	81.3	30.7	40.4	29.5
G1	93.8	68.8	102.9	88.5	99.6	81.4	99.7	102.3	94.4	81.5
G2	70.4	72.9	108.3	68.8	104.8	77.3	78.7	59.1	101.7	92.7
G3	74.0	41.8	10.7	71.0	82.2	70.4	70.3	56.4	88.0	113.5

Table 138. Experiment II (1964): 1st and 2nd cuts; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	66.1	56.5	67.8	62.6	54.4	58.3	50.0	75.1	53.0	50.7
C2	69.6	47.5	52.1	53.4	46.6	64.6	59.2	30.7	59.9	66.0
C3	52.4	45.6	63.3	55.7	59.9	55.7	85.4	50.4	53.2	56.9
F1	48.9	48.0	43.0	50.5	46.5	34.1	42.6	52.7	44.6	44.8
F2	46.3	59.2	45.1	40.2	43.1	45.7	35.8	32.8	37.1	37.4
F3	57.4	36.5	89.8	40.3	87.8	30.7	41.4	63.3	61.2	53.2
G1	55.8	49.3	63.4	27.2	58.8	43.4	58.3	53.9	55.3	45.5
G2	55.6	58.5	59.9	51.5	57.2	42.5	50.6	49.3	61.9	63.6
G3	71.3	77.3	116.6	60.3	51.2	56.5	62.9	53.2	58.6	55.7

Table 139. Experiment II (1964): 1st + 2nd + 3rd cuts; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	73.9	61.0	82.4	68.9	66.4	63.4	61.6	85.8	63.1	62.3
C2	73.2	54.0	84.7	53.7	59.9	70.3	79.2	43.7	76.2	70.6
C3	65.5	55.3	64.2	59.9	67.3	57.4	68.6	66.4	71.7	58.6
F1	59.8	57.3	56.5	58.3	57.8	44.0	51.8	62.6	58.3	53.4
F2	48.4	56.6	58.2	51.2	54.7	54.0	41.6	41.3	41.6	53.1
F3	66.8	44.5	79.1	55.7	86.8	37.6	50.0	55.7	64.2	43.3
G1	65.0	50.2	75.1	38.9	65.3	49.3	70.3	67.5	69.2	53.2
G2	58.2	65.0	63.6	46.3	54.3	54.7	64.6	55.0	74.3	59.5
G3	73.6	75.9	104.9	68.6	55.7	60.7	62.9	56.1	69.9	55.7

Table 140. Experiment II (1964): Total of 4 cuts of grass; 'A' values

Treatment	N1		N2		N3		N4		N5	
	i	ii	i	ii	i	ii	i	ii	i	ii
C1	83.1	74.8	92.6	74.8	76.6	76.0	69.5	95.2	73.9	68.3
C2	76.2	62.9	92.6	70.3	77.3	90.0	84.7	50.3	94.3	81.6
C3	74.5	62.0	74.0	69.9	73.1	62.0	71.3	64.6	71.7	54.0
F1	68.6	65.0	68.0	70.0	67.8	55.8	62.9	71.2	66.9	62.3
F2	55.0	62.9	70.6	64.6	64.3	67.8	49.6	54.0	49.3	65.0
F3	72.6	57.6	86.4	64.6	78.7	47.2	62.5	50.4	60.7	41.0
G1	73.9	55.8	87.2	53.4	78.2	61.0	83.7	83.4	81.1	65.5
G2	62.9	68.5	77.7	54.3	69.2	65.0	73.6	60.2	88.0	71.4
G3	75.9	69.0	78.7	72.6	66.4	66.8	69.0	59.5	80.6	76.8

APPENDIX III

Yield results and plant-analysis of experiment III

Table 141. The layout of the cage experiment III (1964), West Mains Rd., Edinburgh.

1st digit = Rate of N. L = Liquid application. W = acid soil.

1st letter = P-compound. S = Solid application. D = calcareous soil

2nd digit = Rate of P_2O_5.

Replicate 1					Replicate 2				
1C1SW	1G1SD	2F1SD	1G3DS	1C2SW	1F1SW	2G1LD	1G1SD	1-0LD	1C3SW
1F3SD	2G3LW	1C2SD	2F3LD	1C2LW	1G1LW	1C1SW	1C2SD	1C1LD	1C3LW
1C3LD	2F2LW	2G1LD	2G3SW	1F1SD	2-0SD	1F2SD	2C3SW	1C1LW	2F2SD
2-0LW	1F3LD	1G1LW	2F2SW	2C3LD	2G2LW	2C3LD	1G3SD	1F2SW	2G2LD
2C1SD	1C1SD	2F1LW	2G1LW	2F3LW	1-0SW	1-0SD	2F1LW	2-0SW	1F3SD
2G3SD	1F1SW	1F1LW	2G2SD	2-0LD	2C1SW	2F1LD	1F2LW	2G3SW	1-0LW
1G2SD	1F2LD	1F2SW	1F1LD	2C3LW	1C1SD	2F1SD	2F2LD	1C2LW	2C3LW
2G2LW	1G3LW	2G3LD	1-0SD	1F2LW	1F3LD	2G3SD	2C2SW	2C2SD	2F2SW
2C2SW	1G3SW	1-0LD	2C2LD	2C3SD	2F3LW	2F3SD	2-0LD	1F2LD	1F1SD
2C2SD	1C3LW	2-0SW	1C1LW	1-0SW	2C1LD	1F3LW	2G1LW	1G3LD	2G1SD
1G2LD	2F3SD	2F2LD	2G1SW	2C1LW	1G3LW	1G2LD	1C3SD	2C1LW	2G1SW
1C3SD	1F3LW	1-0LW	2F2SD	2G2SW	2F2LW	2F3SW	2C3SD	2C1SD	2C2LW
1G1LD	1C2LD	1C3SW	1G1SW	1G2SW	1G2LW	2G2SD	1F1LW	1C2SW	2G3LW
1C1LD	2C3SW	2C1SW	2C1LD	2G1SD	1C2LD	2C2LD	2F1SW	1F1LD	1G2SW
1G2LW	2F1LD	2F1SW	2C2LW	2G2LD	1C3LD	2G3LD	1G1LD	2G2SW	1G2SD
1F2SD	2F3SW	1G3LD	1F3SW	2-0SD	2F3LD	1F3SW	1G1SW	1G3SW	2-0LW

Table 142. The analysis of variance of results of Experiment III was as follows:

Treatments	Degrees of freedom
Replicates	1
Soils (X)	1
Method of application (M)	1
N	1
P-form (F)	2
P-rate (P)	2
XM	1
XN	1
XF	2
XP	2
MN	1
MF	2
MP	2
NF	2
NP	2
FP	4
XMN	1
XMF	2
XMP	2
XNF	2
XNP	2
XFP	4
MNF	2
MNP	2
MFP	4
NFP	4
XMNF	2
XMNP	2
XMFP	4
XNFP	4
MNFP	4
XMNFP	4
Error	71
Total	143

Table 143. Experiment III (1964): 1st cut; Yield of fresh grass, g/pot

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i*	ii	i	ii	i	ii	i	ii
0	31.0	30.9	38.0	25.1	35.4	37.4	47.7	36.8
C1	32.8	47.3	36.7	42.9	31.1	33.1	42.1	35.8
C2	37.2	44.7	48.0	44.5	33.1	41.7	37.2	48.3
C3	39.2	52.9	46.9	50.4	42.3	48.9	48.4	53.0
F1	31.0	37.4	35.8	45.1	30.3	31.3	39.5	38.9
F2	36.3	43.6	43.9	42.6	31.5	47.9	41.1	45.2
F3	36.0	44.9	46.9	47.6	29.1	31.3	38.8	49.9
G1	32.3	32.3	36.7	43.2	33.4	30.7	39.5	41.3
G2	32.9	39.3	40.9	45.5	36.2	42.6	46.1	41.6
G3	36.9	38.9	50.2	52.0	33.0	38.8	47.3	52.5

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	14.1	13.9	12.5	13.6	12.6	11.8	10.3	9.2
C1	28.3	34.3	42.0	38.5	23.9	25.8	36.5	45.5
C2	29.3	27.9	41.7	44.0	26.6	29.5	45.0	51.8
C3	25.7	21.3	43.8	43.4	25.5	30.8	36.1	43.6
F1	24.9	28.2	38.2	37.6	29.0	28.3	34.0	42.1
F2	26.3	27.0	42.7	43.9	19.7	30.9	42.4	45.5
F3	27.8	30.7	42.9	35.5	28.8	30.2	38.1	49.1
G1	29.4	25.6	41.2	44.2	25.2	28.6	40.6	43.7
G2	28.9	34.1	37.9	53.6	26.1	25.4	34.3	46.0
G3	25.3	31.4	39.7	41.9	27.2	31.2	38.8	49.1

* These figures denote the replicates in this table and all tables of Experiment III

Table 144. Experiment III (1964): 2nd cut; Yield of fresh grass, g/pot

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	30.8	31.5	43.1	35.8	29.9	33.4	43.7	42.7
C1	29.8	29.3	37.8	38.1	35.6	26.9	40.9	39.3
C2	36.9	30.8	39.5	43.1	37.4	28.7	46.1	40.5
C3	36.0	34.0	48.0	47.6	34.3	31.2	46.9	41.4
F1	32.0	31.8	43.0	40.2	32.6	30.1	41.3	37.2
F2	32.0	31.2	47.5	37.1	35.1	31.1	49.2	41.5
F3	30.8	26.3	53.1	40.4	28.4	25.8	39.7	32.8
G1	34.0	28.5	42.6	32.1	30.7	27.0	37.0	39.5
G2	34.4	27.5	45.5	42.3	31.2	29.8	38.5	40.3
G3	35.3	28.8	54.9	43.5	33.4	28.6	51.6	43.1

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	20.8	17.6	24.4	23.2	19.8	22.7	22.7	22.9
C1	27.3	26.6	44.4	41.9	30.7	28.2	49.6	41.8
C2	28.8	27.7	46.7	50.3	30.4	29.1	48.7	49.4
C3	31.3	25.7	59.6	44.3	30.0	27.7	50.1	46.0
F1	29.7	27.6	45.7	44.1	32.5	31.7	50.7	44.5
F2	30.7	27.6	52.5	49.7	30.2	29.5	44.9	53.5
F3	33.4	32.4	59.9	36.4	35.4	30.5	52.7	45.9
G1	28.6	30.1	52.2	41.1	33.4	28.8	45.1	46.2
G2	28.8	26.9	44.8	53.2	30.5	27.7	52.4	43.2
G3	29.2	32.4	54.4	47.4	34.6	31.3	49.2	49.7

Table 145. Experiment III (1964): 3rd cut; Yield of fresh grass, g/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	20.2	20.1	29.1	23.3	22.4	21.3	29.2	29.2
C1	26.2	24.7	31.7	31.3	22.4	23.4	28.1	30.5
C2	26.1	25.2	28.1	24.7	26.2	23.8	29.1	30.7
C3	24.2	23.3	33.2	22.9	26.0	19.6	27.0	32.0
F1	24.2	24.3	28.5	33.4	23.3	22.5	28.2	28.2
F2	25.5	25.8	28.0	29.0	25.6	26.4	32.5	25.3
F3	23.3	23.6	33.7	25.1	25.1	21.7	24.0	32.8
G1	24.2	25.7	28.5	30.7	24.1	21.4	29.9	24.8
G2	23.4	23.2	28.5	31.1	26.2	20.6	31.1	26.5
G3	23.9	25.7	31.5	21.9	24.6	22.3	30.3	29.1

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	17.5	20.5	23.1	24.8	19.0	19.0	22.5	22.8
C1	24.5	27.0	41.7	39.6	25.7	26.5	34.9	38.3
C2	26.0	26.9	53.8	50.1	25.9	28.5	44.9	49.4
C3	25.8	24.3	52.9	54.6	25.4	28.8	54.4	51.7
F1	27.0	26.2	38.8	40.4	26.4	25.6	40.8	40.0
F2	24.8	25.8	44.5	51.5	25.2	26.8	48.9	43.8
F3	26.1	27.9	54.8	44.0	26.5	28.1	48.0	52.8
G1	24.8	26.3	42.5	42.7	25.0	27.3	42.4	39.4
G2	25.6	26.4	49.7	44.3	25.9	26.2	52.9	49.7
G3	26.2	28.9	51.2	48.8	27.2	30.0	51.9	52.0

Table 146. Experiment III(1964): 1st cut; Yield of D.M., g/pot

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	5.37	5.23	6.00	3.92	6.30	6.03	7.83	5.61
C1	9.18	10.15	11.07	10.70	8.00	8.52	12.14	10.25
C2	10.99	10.73	13.82	11.64	10.00	10.20	12.68	13.10
C3	10.91	11.10	14.51	12.10	11.00	10.72	14.98	13.19
F1	9.33	9.78	11.13	11.38	8.60	8.54	11.62	10.94
F2	10.06	10.96	12.83	13.72	9.02	11.32	13.02	10.65
F3	9.76	11.04	14.38	13.68	8.65	9.18	12.88	13.83
G1	9.25	8.76	11.48	11.56	9.05	9.22	12.68	10.37
G2	10.37	10.88	13.86	13.22	10.93	10.23	13.36	11.36
G3	10.90	11.73	14.33	12.66	10.14	10.25	14.57	13.07

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	2.77	2.36	2.13	2.31	2.36	2.13	1.87	1.59
C1	6.72	7.92	11.68	11.28	5.62	6.28	10.73	11.36
C2	6.92	6.95	12.58	11.73	6.28	6.47	12.59	12.39
C3	5.92	5.70	12.62	12.07	5.68	7.26	11.87	12.01
F1	6.11	6.31	10.05	9.90	6.61	6.30	10.43	10.88
F2	6.50	6.43	11.80	11.55	6.00	7.11	11.46	11.32
F3	6.62	7.60	13.78	11.91	6.92	6.78	11.91	12.31
G1	7.00	6.34	11.87	12.48	6.90	6.99	11.47	10.56
G2	6.78	7.57	11.78	12.26	6.25	6.02	11.67	12.10
G3	7.05	7.30	12.22	11.56	7.21	7.00	11.85	12.12

Table 147. Experiment III (1964): 2nd cut; Yield of D.M., g/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	6.60	6.20	8.76	7.18	6.49	7.11	9.30	8.62
C1	6.69	6.21	9.05	8.55	7.43	5.87	8.86	8.82
C2	7.10	6.56	9.36	9.03	7.37	6.52	10.93	9.55
C3	7.66	6.70	11.06	9.88	7.09	6.34	10.48	9.08
F1	6.73	7.14	9.37	8.21	7.44	6.62	9.17	8.43
F2	6.70	6.83	10.62	9.50	7.41	6.47	9.89	8.69
F3	6.75	6.10	10.83	10.09	6.57	6.03	9.45	8.24
G1	6.94	6.20	8.99	7.83	6.76	6.21	9.00	8.10
G2	7.30	6.41	10.86	10.50	7.26	6.32	10.04	9.34
G3	7.55	6.66	11.63	9.35	7.40	6.83	10.21	9.38

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	4.65	3.61	5.94	4.73	4.58	5.12	4.78	4.73
C1	6.43	5.51	10.30	9.96	6.60	6.27	10.59	9.48
C2	6.40	6.03	11.00	10.73	6.53	6.12	10.99	10.81
C3	6.60	5.79	11.58	10.71	6.71	5.85	11.60	10.60
F1	6.58	6.10	10.11	10.60	6.52	6.43	10.41	10.28
F2	6.84	5.95	11.40	10.90	6.98	6.39	10.87	9.74
F3	6.99	7.21	11.30	9.77	7.13	5.73	11.32	10.54
G1	6.62	6.64	10.54	9.73	6.88	6.02	10.84	9.20
G2	6.46	6.02	11.00	10.30	6.80	5.88	10.71	10.40
G3	6.54	7.04	11.92	10.44	6.90	6.50	10.90	11.55

Table 148. Experiment III (1964): 3rd cut; Yield of D.M., g/pot

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	4.82	4.82	6.27	5.37	5.20	4.73	6.82	6.45
C1	6.33	5.87	8.19	7.22	5.35	5.70	7.52	7.10
C2	6.07	6.28	8.46	7.80	6.50	6.12	7.60	8.46
C3	5.94	6.20	9.20	8.06	6.08	5.83	8.35	9.54
F1	5.77	5.82	7.02	8.05	5.77	5.50	6.97	7.03
F2	6.02	6.38	7.56	8.58	6.07	6.36	8.36	7.41
F3	5.82	6.01	9.64	7.48	6.49	6.12	7.59	9.54
G1	5.76	6.15	6.96	7.76	6.08	5.91	7.61	6.73
G2	5.57	6.37	8.23	8.22	6.45	5.60	8.78	8.38
G3	6.10	6.97	9.10	7.79	6.13	5.87	8.44	9.36

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	4.16	4.66	5.00	5.25	4.51	4.27	5.02	4.77
C1	5.73	6.08	9.80	9.25	6.10	6.48	8.16	9.03
C2	5.92	6.46	12.67	11.30	6.02	6.62	9.75	10.84
C3	5.99	5.96	11.77	12.43	5.87	6.68	12.80	11.62
F1	6.49	6.08	9.11	9.60	6.08	6.08	9.73	9.27
F2	5.86	6.00	10.46	11.22	6.11	6.19	11.25	9.72
F3	6.19	6.65	11.79	12.05	6.08	6.37	11.18	11.38
G1	5.89	6.24	9.88	9.90	6.07	6.26	10.47	9.14
G2	5.89	6.27	11.44	10.11	5.93	6.00	11.86	11.90
G3	6.35	6.58	12.08	11.08	6.25	6.83	11.44	11.93

Table 149. Experiment III (1964): 1st cut; % D.M. in the grass

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	17.4	16.9	15.8	15.6	17.8	16.1	16.4	15.3
C1	28.0	21.5	30.1	24.9	25.7	25.7	28.8	28.7
C2	29.5	24.0	28.8	26.1	30.2	24.4	34.1	27.1
C3	27.8	21.0	31.0	24.0	26.0	21.9	31.0	24.9
F1	30.1	26.2	31.1	25.2	28.4	27.3	29.4	28.1
F2	27.7	25.1	29.2	32.2	28.6	23.6	31.7	23.6
F3	27.1	24.6	30.6	28.7	29.7	29.4	33.2	27.7
G1	28.6	27.1	31.3	26.8	27.1	30.1	32.1	25.1
G2	31.5	27.7	33.9	29.1	30.2	24.0	29.0	27.3
G3	29.6	30.1	28.5	24.4	30.7	26.4	30.8	24.9

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	19.6	17.0	17.0	17.0	18.7	18.0	18.1	17.2
C1	23.7	23.1	27.8	29.3	23.5	24.6	29.4	25.0
C2	23.6	24.9	30.2	26.7	23.6	22.0	28.0	23.9
C3	23.1	26.7	28.9	27.8	22.2	23.5	32.9	27.5
F1	24.6	22.3	26.3	26.3	22.8	22.3	30.7	25.8
F2	24.8	23.8	27.7	26.3	30.4	23.0	27.0	24.9
F3	23.8	24.7	32.1	33.6	24.0	22.5	31.2	25.1
G1	23.8	24.8	28.8	28.3	27.4	24.5	28.2	24.2
G2	23.4	22.2	31.1	22.9	23.9	23.7	34.0	26.3
G3	27.9	23.2	30.8	27.6	26.5	22.4	30.5	24.7

Table 150. Experiment III (1964): 2nd cut; % D.M. in the grass

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	21.4	19.7	20.3	20.1	21.7	21.3	21.3	20.2
C1	22.4	21.2	23.9	22.4	20.9	21.8	21.6	22.5
C2	19.3	21.3	23.7	20.9	19.8	22.7	23.7	23.6
C3	21.3	19.7	23.1	20.7	20.7	20.4	22.3	22.0
F1	21.0	22.5	21.8	20.4	22.8	22.0	22.2	22.7
F2	21.0	21.9	22.4	25.6	21.1	20.8	20.1	20.9
F3	22.0	23.2	20.4	25.0	23.1	23.4	23.8	25.1
G1	20.4	21.7	21.1	24.4	22.0	23.0	24.3	20.5
G2	21.2	23.4	23.9	24.8	23.3	21.2	26.1	23.2
G3	21.4	23.1	21.2	21.5	22.2	23.8	19.8	21.7

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	22.3	20.5	24.4	20.4	23.2	22.6	21.1	20.6
C1	23.6	20.8	23.2	23.8	21.5	22.3	21.3	22.7
C2	22.2	21.7	23.6	21.3	21.5	21.0	22.5	21.9
C3	21.1	22.5	19.4	24.2	22.4	21.1	23.2	23.0
F1	22.1	22.1	22.1	24.1	20.1	20.3	20.5	23.1
F2	22.3	21.6	21.7	21.9	23.1	21.7	24.2	18.2
F3	20.9	22.2	18.9	26.9	20.1	18.8	21.5	23.0
G1	23.2	22.1	20.2	23.7	20.6	20.9	24.0	19.9
G2	22.5	22.4	24.5	19.4	22.3	21.2	20.4	24.1
G3	22.4	21.7	21.9	22.0	20.0	20.8	22.1	23.3

Table 151. Experiment III (1964): 3rd cut; % D.M. in the grass

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	23.9	23.9	21.5	23.0	23.2	22.2	23.4	22.1
C1	24.2	23.8	25.9	23.0	23.9	24.3	26.8	23.3
C2	23.2	24.9	30.1	31.6	24.8	25.8	26.1	27.5
C3	24.5	26.6	27.7	35.2	23.3	29.7	30.9	29.8
F1	23.9	24.0	24.6	24.1	24.8	24.5	24.7	25.0
F2	23.6	24.8	27.0	29.6	23.7	24.1	25.7	29.3
F3	25.0	25.5	28.6	29.8	25.9	28.3	31.7	29.1
G1	23.8	23.9	24.4	25.3	25.2	27.7	25.5	27.1
G2	23.8	27.4	28.9	26.5	24.7	27.2	28.3	31.6
G3	25.5	27.2	28.9	35.5	24.9	26.4	27.9	32.2

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	23.8	22.7	21.6	21.2	23.7	22.5	22.3	20.9
C1	23.3	22.5	23.5	23.3	23.7	24.4	23.4	23.6
C2	22.8	24.0	23.6	22.5	23.3	23.3	21.7	21.9
C3	23.2	24.5	22.2	22.8	23.1	23.2	23.5	22.5
F1	24.0	23.2	23.5	23.8	23.0	23.8	23.8	23.2
F2	23.6	23.2	23.5	21.8	24.3	23.1	23.0	22.2
F3	23.7	23.9	21.5	27.4	23.0	22.7	22.3	21.5
G1	23.8	23.7	23.2	23.2	23.4	23.0	24.7	23.2
G2	23.0	23.8	23.0	22.8	22.9	22.9	22.4	23.9
G3	24.2	22.7	23.6	22.7	23.0	22.8	22.1	22.9

Key to Experiments

It may be helpful to the reader to use this chart of symbols used in the experiments.

P-compounds:

A = Na-tripolyphosphate (chains of 3 P-atoms).

B = Na-polyphosphate glass (chains of 8.5 P-atoms on average).

C = Na-trimetaphosphate (rings of 3 P-atoms).

D = Na-ultraphosphate (large molecules).

E = 4:1 mixture of B and F.

F = Na-dihydrogen orthophosphate

G = Na-metaphosphate glass (large molecules).

Soils:

D = a calcareous soil of pH 7.4

W = an acid soil of pH 5.4

X = an acid soil of pH 5.8

Y = a neutral soil of pH 6.8

Method of application:

L = P-fertilizers were applied in solution in a band 2½ in. below seed-level.

S = P-fertilizers were applied in solid-form in a band 2½ in. below seed-level.

Table 152. Experiment III (1964): 1st cut; % P in the dry matter

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	0.222	0.198	0.199	0.211	0.209	0.195	0.179	0.196
C1	0.154	0.143	0.136	0.131	0.125	0.138	0.137	0.121
C2	0.200	0.181	0.178	0.178	0.169	0.201	0.158	0.160
C3	0.217	0.228	0.207	0.199	0.237	0.218	0.186	0.181
F1	0.132	0.136	0.115	0.123	0.141	0.138	0.155	0.133
F2	0.207	0.176	0.156	0.162	0.184	0.182	0.162	0.167
F3	0.229	0.222	0.203	0.188	0.198	0.187	0.181	0.187
G1	0.132	0.137	0.120	0.123	0.178	0.133	0.137	0.136
G2	0.200	0.197	0.160	0.165	0.226	0.215	0.194	0.172
G3	0.216	0.218	0.188	0.218	0.216	0.220	0.189	0.199

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	0.121	0.149	0.144	0.135	0.128	0.133	0.131	0.135
C1	0.181	0.167	0.155	0.130	0.174	0.173	0.123	0.135
C2	0.217	0.231	0.196	0.195	0.219	0.232	0.165	0.177
C3	0.253	0.268	0.228	0.207	0.290	0.241	0.243	0.196
F1	0.184	0.189	0.143	0.135	0.191	0.172	0.111	0.135
F2	0.210	0.208	0.203	0.178	0.188	0.205	0.191	0.179
F3	0.245	0.218	0.169	0.191	0.224	0.228	0.189	0.227
G1	0.191	0.175	0.129	0.118	0.145	0.163	0.154	0.174
G2	0.222	0.229	0.204	0.190	0.229	0.229	0.167	0.184
G3	0.283	0.263	0.228	0.215	0.240	0.242	0.193	0.245

Table 153. Experiment III (1964): 2nd cut; % P in the dry matter

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	0.142	0.150	0.111	0.155	0.141	0.114	0.110	0.142
C1	0.177	0.178	0.135	0.131	0.133	0.159	0.132	0.120
C2	0.226	0.213	0.171	0.176	0.200	0.223	0.152	0.164
C3	0.261	0.287	0.213	0.238	0.261	0.277	0.184	0.198
F1	0.153	0.154	0.116	0.139	0.142	0.145	0.130	0.133
F2	0.227	0.212	0.155	0.159	0.211	0.241	0.165	0.166
F3	0.255	0.255	0.213	0.198	0.223	0.234	0.159	0.188
G1	0.159	0.168	0.135	0.135	0.191	0.165	0.129	0.139
G2	0.258	0.239	0.163	0.171	0.208	0.227	0.183	0.171
G3	0.277	0.272	0.226	0.242	0.250	0.268	0.200	0.225

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	0.094	0.114	0.106	0.103	0.096	0.098	0.114	0.107
C1	0.157	0.169	0.123	0.128	0.159	0.158	0.113	0.131
C2	0.208	0.234	0.177	0.193	0.207	0.222	0.179	0.200
C3	0.240	0.261	0.248	0.232	0.263	0.268	0.245	0.258
F1	0.155	0.162	0.137	0.116	0.162	0.161	0.122	0.120
F2	0.200	0.213	0.159	0.197	0.217	0.203	0.168	0.203
F3	0.245	0.225	0.245	0.229	0.234	0.280	0.229	0.220
G1	0.163	0.171	0.122	0.133	0.163	0.181	0.123	0.152
G2	0.223	0.206	0.186	0.223	0.213	0.248	0.202	0.200
G3	0.261	0.255	0.207	0.231	0.265	0.255	0.243	0.242

Table 154. Experiment III (1964): 3rd cut; % P in the dry matter

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	0.134	0.126	0.119	0.130	0.130	0.130	0.106	0.113
C1	0.183	0.174	0.123	0.135	0.142	0.160	0.118	0.139
C2	0.217	0.202	0.150	0.152	0.196	0.194	0.142	0.156
C3	0.239	0.245	0.193	0.179	0.246	0.226	0.177	0.182
F1	0.179	0.146	0.135	0.119	0.151	0.148	0.130	0.130
F2	0.216	0.199	0.146	0.142	0.210	0.198	0.160	0.150
F3	0.226	0.225	0.181	0.171	0.210	0.203	0.159	0.165
G1	0.175	0.185	0.133	0.130	0.168	0.152	0.123	0.139
G2	0.226	0.203	0.158	0.159	0.200	0.199	0.164	0.155
G3	0.243	0.223	0.198	0.198	0.227	0.239	0.184	0.181

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	0.109	0.108	0.106	0.101	0.097	0.110	0.103	0.109
C1	0.150	0.150	0.094	0.100	0.139	0.148	0.093	0.098
C2	0.205	0.194	0.152	0.163	0.185	0.208	0.169	0.170
C3	0.208	0.220	0.213	0.213	0.245	0.234	0.200	0.227
F1	0.140	0.147	0.102	0.097	0.160	0.142	0.098	0.103
F2	0.181	0.191	0.147	0.169	0.178	0.207	0.152	0.177
F3	0.210	0.202	0.193	0.195	0.202	0.225	0.202	0.193
G1	0.154	0.145	0.108	0.106	0.137	0.152	0.106	0.110
G2	0.212	0.191	0.164	0.193	0.194	0.211	0.171	0.171
G3	0.222	0.226	0.202	0.205	0.233	0.226	0.213	0.205

Table 155. Experiment III(1964): 1st cut; P-uptake, mg/pot

SOIL W

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	11.92	10.36	11.88	8.27	13.17	11.76	14.02	11.00
C1	14.14	14.51	15.06	14.02	10.00	11.76	16.63	12.40
C2	21.98	19.42	24.60	20.72	16.90	20.50	20.03	20.96
C3	23.67	25.31	30.04	24.08	26.07	23.37	27.86	23.87
F1	12.32	13.30	12.80	14.00	12.13	11.79	18.01	14.55
F2	20.82	19.29	20.01	22.23	16.60	20.60	21.09	17.79
F3	22.35	24.51	29.19	25.72	17.13	17.17	23.31	25.86
G1	12.21	12.00	13.78	14.22	16.11	12.26	17.37	14.10
G2	20.74	21.43	22.18	21.81	24.70	21.99	25.92	19.54
G3	23.54	25.57	26.94	27.60	21.90	22.55	27.54	26.01

SOIL D

Treatment	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	3.35	3.52	3.07	3.12	3.02	4.15	2.45	2.15
C1	12.16	13.23	18.10	14.66	9.78	10.86	13.20	15.34
C2	15.02	16.05	24.66	22.87	13.75	15.01	20.77	21.93
C3	14.98	15.28	28.77	24.98	16.47	17.50	28.84	23.54
F1	11.24	11.93	14.37	13.37	12.63	10.84	11.58	14.69
F2	13.65	13.37	23.95	20.56	11.28	14.58	21.89	20.26
F3	16.22	16.57	23.29	22.75	15.50	15.46	22.51	27.94
G1	13.37	11.10	15.31	14.73	10.01	11.39	17.66	18.37
G2	15.05	17.34	24.03	23.29	14.31	13.79	19.49	22.26
G3	19.95	19.20	27.86	24.85	17.30	16.94	22.87	29.69

Table 156. Experiment III (1964): 2nd cut; P-uptake, mg/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	9.37	9.30	9.72	11.13	9.15	8.11	10.23	12.24
C1	11.84	11.05	12.22	11.20	9.88	9.33	11.70	10.58
C2	16.05	13.97	16.01	15.89	14.74	14.54	16.61	15.66
C3	19.99	19.23	23.56	23.51	18.50	17.56	19.28	17.98
F1	10.30	11.00	10.87	11.41	10.56	9.60	11.92	11.21
F2	15.21	14.48	16.46	15.11	15.64	15.59	16.32	14.43
F3	17.21	15.56	23.07	19.98	14.65	14.11	15.03	15.49
G1	11.03	10.42	12.14	10.57	12.91	10.25	11.61	11.26
G2	18.83	15.32	17.70	17.96	15.10	14.35	18.37	15.97
G3	20.91	18.12	26.28	22.63	18.50	18.30	20.42	21.11

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	4.37	4.12	6.30	4.87	4.40	5.02	5.45	5.06
C1	10.10	9.31	12.67	12.75	10.49	9.91	11.97	12.42
C2	13.31	14.11	19.47	20.71	13.52	13.59	19.67	21.62
C3	15.84	15.11	28.72	24.85	17.65	15.68	28.42	27.35
F1	10.20	9.88	13.85	12.30	10.56	10.35	12.70	12.34
F2	13.68	12.67	18.13	21.47	15.15	12.97	18.26	19.77
F3	17.13	16.22	27.69	22.37	16.68	16.04	25.92	23.19
G1	10.79	11.35	12.86	12.94	11.21	10.90	13.33	13.98
G2	14.41	12.40	20.46	22.97	14.48	14.58	21.63	20.80
G3	17.07	17.95	24.67	24.12	18.29	16.58	26.49	27.95

Table 157. Experiment III (1964): 3rd cut; P-uptake, mg/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	6.46	6.07	7.46	6.98	6.76	6.15	7.23	7.29
C1	11.58	10.21	10.07	9.75	7.60	9.12	8.87	9.87
C2	13.17	12.69	12.69	11.86	12.74	11.87	10.79	13.20
C3	14.20	15.19	17.76	14.43	14.96	13.18	14.78	17.36
F1	10.33	8.50	9.48	9.58	8.71	8.14	9.06	9.14
F2	13.00	12.70	11.04	12.18	12.75	12.59	13.38	11.12
F3	13.15	13.52	17.45	12.79	13.63	12.42	12.07	15.74
G1	10.08	11.38	9.26	9.96	10.21	8.98	9.36	9.35
G2	12.59	12.93	13.00	13.07	12.90	11.14	14.40	12.99
G3	14.82	15.54	18.02	15.42	13.92	14.03	15.53	16.94

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	4.53	5.03	5.30	5.30	4.37	4.70	5.17	5.20
C1	8.60	9.12	9.21	9.25	8.48	9.59	7.59	8.85
C2	12.14	12.53	19.26	18.42	11.14	13.77	16.48	18.43
C3	12.46	13.11	25.07	26.50	14.38	15.63	25.60	26.38
F1	9.09	8.94	9.29	9.31	9.73	8.63	9.54	9.55
F2	10.61	11.46	15.38	18.96	10.88	12.81	17.10	17.20
F3	13.00	13.43	22.75	23.50	12.28	14.33	22.58	21.96
G1	9.07	9.05	10.67	10.49	8.32	9.52	11.10	10.05
G2	12.49	11.98	18.76	19.51	11.50	12.66	20.28	20.35
G3	14.10	14.87	24.40	22.71	14.56	15.44	24.37	24.46

Table 158. Experiment III (1964): Total P-uptake by 3 cuts of grass, mg/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	27.75	25.73	29.06	26.38	29.08	26.02	31.48	30.53
C1	37.56	35.77	37.35	34.97	27.48	30.21	37.20	32.85
C2	51.20	46.08	53.30	48.47	44.38	46.91	47.43	49.82
C3	57.86	59.73	71.36	62.02	59.53	54.11	61.92	59.21
F1	32.95	32.80	33.15	34.99	31.40	29.53	38.99	34.90
F2	49.03	46.47	47.51	49.52	44.99	48.78	50.79	43.34
F3	52.72	53.59	69.71	58.49	45.41	43.70	50.41	57.09
G1	33.32	33.80	35.18	34.75	39.23	31.49	38.34	34.71
G2	52.16	49.68	52.88	52.84	52.70	47.48	58.69	48.50
G3	59.27	59.23	71.24	65.65	54.32	54.88	63.49	64.06

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
0	12.25	12.67	14.67	13.29	11.79	13.87	13.07	12.41
C1	30.86	31.66	39.98	36.66	28.75	30.36	32.76	36.61
C2	40.47	42.69	63.39	62.00	38.41	42.37	56.92	61.92
C3	43.28	43.50	82.56	76.33	48.50	48.81	82.86	77.27
F1	30.53	30.75	37.51	34.98	32.92	29.82	33.82	36.58
F2	37.94	37.50	57.46	60.99	37.31	40.36	57.25	57.23
F3	46.35	46.22	73.73	68.62	44.46	45.83	71.01	73.09
G1	33.23	31.50	38.84	38.16	29.54	31.81	42.09	42.40
G2	41.95	41.72	63.25	65.77	40.29	41.03	61.40	63.41
G3	51.12	52.02	76.93	71.68	50.15	48.96	73.73	82.10

Table 159. Experiment III (1964): 1st cut; Apparent recovery of P, mg/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	3.00	3.37	4.98	3.94	-2.47	-0.71	4.12	-0.11
C2	10.84	8.28	14.52	10.64	4.43	8.03	7.52	8.45
C3	12.53	14.17	19.96	14.00	13.60	10.90	15.35	11.36
F1	1.18	2.16	2.72	3.92	-0.34	-0.68	5.50	2.04
F2	9.68	8.15	9.93	12.15	4.13	8.13	8.58	5.28
F3	11.21	13.37	19.11	15.64	4.66	4.70	10.80	13.31
G1	1.07	0.86	3.70	4.14	3.64	-0.21	4.86	1.59
G2	9.60	10.29	12.10	11.73	12.23	9.52	13.41	7.03
G3	12.40	14.33	16.86	17.52	9.43	10.08	15.03	13.50

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	8.72	9.79	15.00	11.56	6.19	7.27	10.90	13.04
C2	11.58	12.61	21.56	19.77	10.16	11.42	18.47	19.63
C3	11.54	11.84	24.78	21.88	12.88	13.91	26.54	21.24
F1	7.80	8.49	11.27	10.27	9.04	7.25	9.28	12.39
F2	10.21	9.93	20.85	17.46	7.69	10.99	19.59	17.96
F3	12.78	13.13	20.19	19.65	11.91	11.87	20.21	25.64
G1	9.93	7.66	12.21	11.63	6.42	7.80	15.36	16.07
G2	11.61	13.90	20.93	20.19	10.72	10.20	17.19	19.96
G3	16.51	15.76	24.76	21.75	13.71	13.35	20.57	27.39

Table 160. Experiment III (1964): 2nd cut; Apparent recovery of applied-P, mg/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	2.50	1.71	1.79	0.77	1.25	0.70	0.46	-0.66
C2	6.71	4.63	5.58	5.46	6.11	5.91	5.37	4.42
C3	10.65	9.89	13.13	13.08	9.87	8.93	8.04	6.74
F1	0.96	1.66	0.44	0.98	1.93	0.97	0.68	-0.03
F2	5.87	5.14	6.03	4.68	7.01	6.96	5.08	3.19
F3	7.87	6.22	12.64	9.55	6.02	5.48	3.79	4.25
G1	1.69	1.08	1.71	0.14	4.28	1.62	0.37	0.02
G2	9.49	5.98	7.27	7.53	6.47	5.72	7.13	4.73
G3	10.57	8.78	15.85	12.20	9.87	9.67	9.18	9.87

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	5.85	5.06	7.08	7.16	5.78	5.20	6.71	7.16
C2	9.06	9.86	13.88	15.12	8.81	8.88	14.41	16.36
C3	11.59	10.86	23.13	19.26	12.94	10.97	23.16	22.09
F1	5.95	5.63	8.26	6.71	5.85	5.64	7.44	7.08
F2	9.43	8.42	12.54	15.88	10.44	8.26	13.00	14.51
F3	12.88	11.97	22.10	16.78	11.97	11.33	20.66	17.93
G1	6.54	7.10	7.27	7.35	6.50	6.19	8.07	8.72
G2	10.16	8.15	14.87	17.38	9.77	9.87	16.36	15.54
G3	12.82	13.70	19.08	18.53	13.58	11.87	21.23	22.69

Table 161. Experiment III (1964): 3rd cut; Apparent recovery of applied-P, mg/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	5.31	3.94	2.85	2.53	1.14	2.66	1.61	2.61
C2	6.90	6.42	5.47	4.64	6.28	5.41	3.53	5.94
C3	7.93	8.92	10.54	7.21	8.50	6.72	7.52	10.10
F1	4.06	2.23	2.26	2.36	2.25	1.68	1.80	1.88
F2	6.73	6.43	3.82	4.96	6.29	6.13	6.12	3.86
F3	6.88	7.25	10.23	5.57	7.17	5.96	4.81	8.48
G1	3.81	5.11	2.04	2.74	3.75	2.52	2.10	2.09
G2	6.32	6.66	5.78	5.85	6.44	4.68	7.14	5.73
G3	8.55	9.27	10.80	8.20	7.46	7.57	8.27	9.68

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	3.82	4.34	3.91	3.95	3.94	5.05	2.40	3.66
C2	7.36	7.75	13.96	13.12	6.60	9.23	11.29	13.24
C3	7.68	8.33	19.77	21.20	9.84	11.09	20.41	21.19
F1	4.31	4.16	3.99	4.01	5.19	4.09	4.35	4.36
F2	5.83	6.68	10.08	13.66	6.34	8.27	11.91	12.01
F3	8.22	8.65	17.45	18.20	7.74	9.79	17.39	16.77
G1	4.27	4.27	5.37	5.19	3.78	4.98	5.91	4.86
G2	7.71	7.20	13.46	14.21	6.96	8.12	15.09	15.16
G3	9.32	10.09	19.10	17.41	10.02	10.90	19.18	19.27

Table 162. Experiment III (1964): Total apparent recovery of applied-P in 3 cuts of grass, mg P/pot

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	10.81	9.02	9.62	7.24	-0.08	2.65	6.19	1.84
C2	24.45	19.33	25.57	20.74	16.82	19.35	16.42	18.81
C3	31.11	32.98	43.63	34.29	31.97	26.55	30.91	28.20
F1	6.20	6.05	5.42	7.26	3.84	1.97	7.98	3.89
F2	22.28	19.72	19.78	21.79	17.43	21.22	19.78	12.33
F3	25.96	26.84	41.98	30.76	17.85	16.14	19.40	26.04
G1	6.57	7.05	7.45	7.02	11.67	3.93	7.33	3.70
G2	25.41	22.93	25.15	25.11	25.14	19.92	27.68	17.49
G3	31.52	32.38	43.51	37.92	26.76	27.32	32.48	33.05

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	18.39	19.19	25.99	22.67	15.91	17.52	20.01	23.86
C2	28.00	30.22	49.40	48.01	25.57	29.53	44.17	49.23
C3	30.81	31.03	67.68	62.34	35.66	35.97	70.11	64.52
F1	18.06	18.28	23.52	20.99	20.08	16.98	21.07	23.83
F2	25.47	25.03	43.47	47.00	24.47	27.52	44.50	44.48
F3	33.88	33.75	59.74	54.63	31.62	32.99	58.26	60.34
G1	20.74	19.03	24.85	24.17	16.70	18.97	29.34	29.65
G2	29.48	29.25	49.26	51.78	27.45	28.19	48.64	50.66
G3	38.65	39.55	62.94	57.94	57.69	37.31	60.98	69.35

Table 163. Experiment III (1964): 1st cut; % Apparent recovery of applied-P

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	3.1	3.4	5.1	4.0	-2.5	-0.7	4.2	-0.1
C2	5.5	4.2	7.4	5.4	2.3	4.1	3.8	4.3
C3	4.3	4.8	6.8	4.8	4.6	3.7	5.2	3.9
F1	1.2	2.2	2.8	4.0	-0.3	-0.7	5.6	2.1
F2	4.9	4.2	5.1	6.2	2.1	4.1	4.4	2.7
F3	3.8	4.5	6.5	5.3	1.6	1.6	3.7	4.5
G1	1.1	0.9	3.8	4.2	3.7	-0.2	5.0	1.6
G2	4.9	5.2	6.2	6.0	6.2	4.9	6.8	3.6
G3	4.2	4.9	5.7	6.0	3.2	3.4	5.1	4.6

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	8.9	10.0	15.3	11.8	6.3	7.4	11.1	13.3
C2	5.9	6.4	11.0	10.1	5.2	5.8	9.4	10.0
C3	3.9	4.0	8.4	7.4	4.4	4.7	9.0	7.2
F1	8.0	8.7	11.5	10.5	9.2	7.4	9.5	12.6
F2	5.2	5.1	10.6	8.9	3.9	5.6	10.0	9.2
F3	4.3	4.5	6.9	6.7	4.0	4.0	6.9	8.7
G1	10.1	7.8	12.4	11.9	6.5	8.0	15.7	16.4
G2	5.9	7.1	10.7	10.3	5.5	5.2	8.8	10.2
G3	5.6	5.4	8.4	7.4	4.7	4.5	7.0	9.3

Table 164. Experiment III (1964): 2nd cut; % Apparent recovery of applied-P

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	2.5	1.7	1.8	0.8	1.3	0.7	0.5	-0.7
C2	3.4	2.4	2.8	2.8	3.1	3.0	2.7	2.3
C3	3.6	3.4	4.5	4.4	3.4	3.0	2.7	2.3
F1	1.0	1.7	0.4	1.0	2.0	1.0	0.7	0.0
F2	3.0	2.6	3.1	2.4	3.6	3.5	2.6	1.6
F3	2.7	2.1	4.3	3.2	2.0	1.9	1.3	1.4
G1	1.7	1.1	1.7	0.1	4.4	1.7	0.4	0.0
G2	4.8	3.0	3.7	3.8	3.3	2.9	3.6	2.4
G3	3.6	3.0	5.4	4.1	3.4	3.3	3.1	3.4

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	6.0	5.2	7.2	7.3	5.9	5.3	6.8	7.3
C2	4.6	5.0	7.1	7.7	4.5	4.5	7.3	8.3
C3	3.9	3.7	7.9	6.5	4.4	3.7	7.9	7.5
F1	6.1	5.7	8.4	6.8	6.0	5.7	7.6	7.2
F2	4.8	4.3	6.4	8.1	5.3	4.2	6.6	7.4
F3	4.4	4.1	7.5	5.7	4.1	3.9	7.0	6.1
G1	6.7	7.2	7.4	7.5	6.6	6.3	8.2	8.9
G2	5.2	4.2	7.6	8.9	5.0	5.0	8.3	7.9
G3	4.4	4.7	6.5	6.3	4.6	4.0	7.2	7.7

Table 165. Experiment III (1964): 3rd cut; % Apparent recovery of applied-P

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	5.4	4.0	2.9	2.6	1.2	2.7	1.6	2.7
C2	3.5	3.3	2.8	2.4	3.2	2.8	1.8	3.0
C3	2.7	3.0	3.6	2.5	2.9	2.3	2.6	3.4
F1	4.1	2.3	2.3	2.4	2.3	1.7	1.8	1.9
F2	3.4	3.3	1.9	2.5	3.2	3.1	3.1	2.0
F3	2.3	2.5	3.5	1.9	2.4	2.0	1.6	2.9
G1	3.9	5.2	2.1	2.8	3.8	2.6	2.1	2.1
G2	3.2	3.4	2.9	3.0	3.3	2.4	3.6	2.9
G3	2.9	3.2	3.7	2.8	2.5	2.6	2.8	3.3

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	3.9	4.4	4.0	4.0	4.0	5.1	2.4	3.7
C2	3.8	4.0	7.1	6.7	3.4	4.7	5.8	6.8
C3	2.6	2.8	6.7	7.2	3.3	3.8	6.9	7.2
F1	4.4	4.2	4.1	4.1	5.3	4.2	4.4	4.4
F2	3.0	3.4	5.1	7.0	3.2	4.2	6.1	6.1
F3	2.8	2.9	5.9	6.2	2.6	3.3	5.9	5.7
G1	4.4	4.4	5.5	5.3	3.9	5.1	6.0	5.0
G2	3.9	3.7	6.9	7.2	3.5	4.1	7.7	7.7
G3	3.2	3.4	6.5	5.9	3.4	3.7	6.5	6.5

Table 166. Experiment III (1964): % Apparent recovery of applied-P; total of 3 cuts of grass

Treatment	SOIL W							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	11.0	9.1	9.8	7.4	0.0	2.7	6.3	1.9
C2	12.4	9.9	13.0	10.6	8.6	9.9	8.3	9.6
C3	10.6	11.2	14.9	11.7	10.9	9.0	10.5	9.6
F1	6.3	6.2	5.5	7.4	4.0	2.0	8.1	4.0
F2	11.3	10.1	10.1	11.1	8.9	10.7	10.1	6.3
F3	8.8	9.1	14.3	10.4	6.0	5.5	6.6	8.8
G1	6.7	7.2	7.6	7.1	11.9	4.1	7.5	3.7
G2	12.9	11.6	12.8	12.8	12.8	10.2	14.0	8.9
G3	10.7	11.1	14.8	12.9	9.1	9.3	11.0	11.3

Treatment	SOIL D							
	L				S			
	N1		N2		N1		N2	
	i	ii	i	ii	i	ii	i	ii
C1	18.8	19.6	26.5	23.1	16.2	17.8	20.3	24.3
C2	14.3	15.4	25.2	24.5	13.1	15.0	22.5	25.1
C3	10.4	10.5	23.0	21.1	12.1	12.2	23.8	21.9
F1	18.5	18.6	24.0	21.4	20.5	17.3	21.5	24.2
F2	13.0	12.8	22.1	24.0	12.4	14.0	22.7	22.7
F3	11.5	11.5	20.3	18.6	10.7	11.2	19.8	20.5
G1	21.2	19.4	25.3	24.7	17.0	19.4	29.9	30.3
G2	15.0	15.0	25.2	26.4	14.0	14.3	24.8	25.8
G3	13.2	13.5	21.4	19.6	12.7	12.2	20.7	23.5

APPENDIX IV

This includes the results of soil-analysis of experiments I and II.

Table 167. Effects of different extracting methods (used in extracting the soils for "available" P) and the development of the blue colour on the hydrolysis of polyphosphates. The measured PO_4 is calculated as per cent of the total P in solution.

Method of extraction	P-compounds					
	A	B	C	D	E	G
Citric acid	2.5	9.8	5.0	15.6	23.8	6.8
Olsen	3.5	10.4	4.2	15.0	28.0	6.8
Morgan	4.0	10.9	5.0	18.0	29.7	7.2

Table 168. Experiment I, 1963: Extractable P in 1% citric acid extracts of the soil, mg P/100 soil-sand mixture

Sampling No.	SOIL X							SOIL Y						
	1	2		3		4		1	2		3		4	
Treatment	N.H.*	N.H.	H.	N.H.	H.	N.H.	H.	N.H.	N.H.	H.	N.H.	H.	N.H.	H.
0	3.06	3.14	3.45	2.37	3.05	2.73	3.40	2.70	2.75	3.00	2.01	2.67	2.44	2.83
0	2.75	3.34	3.89	2.32	3.01	2.93	2.51	2.36	2.85	2.98	1.98	2.62	2.44	2.36
A1	4.03	3.80	4.55	3.18	3.97	3.43	3.90	2.39	2.80	3.18	2.61	3.48	3.05	3.48
A2	3.78	3.73	4.78	2.73	3.48	3.72	3.72	3.73	4.19	4.45	3.10	3.78	3.63	4.02
A3	4.65	5.52	7.00	3.90	4.87	4.80	5.00	4.96	4.65	5.40	5.18	5.12	3.77	4.22
B1	3.55	3.60	4.06	3.05	4.02	3.63	3.65	3.32	4.88	5.45	2.68	3.60	3.23	3.40
B2	3.14	4.34	5.20	3.43	4.35	3.85	4.61	3.70	4.14	4.85	3.63	4.28	4.04	4.67
B3	4.32	5.55	6.78	4.42	5.32	5.62	5.78	3.91	4.75	5.92	4.67	5.39	4.40	5.53
C1	3.19	4.57	4.95	3.72	4.87	3.18	3.30	3.52	3.34	3.80	2.73	3.90	3.10	3.65
C2	3.91	4.52	5.45	4.04	5.12	4.04	4.54	3.57	3.88	4.50	2.93	3.72	4.00	4.41
C3	3.98	4.50	5.65	4.12	5.00	5.26	5.91	4.03	3.88	5.30	2.44	3.24	4.26	4.49
D1	2.49	4.32	4.65	3.23	4.28	2.86	3.05	2.96	3.50	4.03	2.97	3.97	3.18	4.10
D2	4.34	4.65	5.05	4.12	4.93	4.00	5.80	4.09	3.86	4.35	2.56	3.48	3.63	5.18
D3	4.16	4.65	6.45	3.90	4.80	4.58	5.32	3.98	4.37	5.50	5.00	5.91	4.67	4.93
E1	3.73	3.21	3.75	2.73	3.65	3.50	4.02	3.16	3.43	4.07	2.86	3.72	2.93	3.40
E2	4.14	4.47	4.35	3.50	4.67	3.85	4.93	3.78	4.11	4.50	3.63	4.55	3.72	4.28
E3	4.63	4.91	5.80	4.12	4.93	4.12	5.12	4.96	5.22	5.35	3.90	4.74	4.72	5.39
F1	3.68	3.73	4.00	3.18	4.28	4.04	4.87	2.90	3.52	3.75	2.37	3.12	3.36	4.02
F2	4.63	4.39	4.50	4.12	4.87	4.32	4.80	3.29	4.09	4.32	2.97	3.53	3.90	4.35
F3	5.55	5.71	5.50	4.53	5.32	4.67	5.53	3.70	4.96	4.80	4.00	4.87	4.18	4.15

* N.H. = not hydrolyzed extracts. H = hydrolyzed extracts

Table 168 (Contd.)

Sampling No.	SOIL X						SOIL Y					
	5		6		7		5		6		7	
Treatment	N. H.	H.	N. H.	H.	N. H.	H.	N. H.	H.	N. H.	H.	N. H.	H.
0	3.10	2.83	2.90	3.19	3.18	3.19	2.78	2.88	2.65	3.19	3.41	3.31
0	2.78	2.88	2.96	3.10	3.20	3.35	3.03	2.98	2.59	2.62	2.77	2.83
A1	3.57	3.31	3.49	3.81	3.60	3.66	3.47	3.02	2.73	2.81	3.28	3.24
A2	4.37	4.27	3.94	4.30	4.72	4.92	3.95	3.58	3.80	4.17	4.29	4.28
A3	5.97	6.07	4.89	5.63	5.50	6.00	4.48	4.11	4.30	4.60	4.77	4.85
B1	3.67	4.00	3.42	4.21	3.91	4.23	3.57	3.47	2.98	3.31	3.49	3.47
B2	4.23	4.16	3.82	4.53	4.72	4.81	3.42	3.42	3.15	3.53	4.13	4.17
B3	5.27	5.65	4.80	5.47	5.53	5.73	4.37	4.62	4.32	5.45	4.89	4.92
C1	3.78	3.70	3.18	3.50	3.96	4.18	3.15	3.47	3.39	3.71	3.52	3.35
C2	4.37	4.50	4.02	4.50	5.02	5.08	4.10	3.70	3.13	3.50	4.18	4.17
C3	4.63	4.85	4.68	5.34	5.58	5.73	4.48	4.39	3.72	4.08	4.60	4.81
D1	3.67	3.65	3.55	3.94	3.82	4.02	3.95	3.70	2.85	3.21	3.52	3.53
D2	4.31	4.11	4.00	4.64	4.37	4.62	4.16	4.23	3.43	3.79	4.60	4.50
D3	4.80	4.92	4.70	5.22	5.21	5.49	4.31	4.73	5.48	6.02	4.85	4.74
E1	3.63	3.88	3.71	4.14	3.96	3.93	3.42	2.98	2.94	3.12	3.56	3.47
E2	4.57	4.50	4.28	4.74	4.97	5.04	3.95	3.42	3.42	3.64	4.02	3.95
E3	4.48	4.80	4.47	5.34	5.45	5.65	4.73	4.92	4.39	4.78	4.77	4.62
F1	3.57	3.82	3.49	3.60	4.29	4.23	3.15	3.13	3.02	3.24	3.80	3.66
F2	3.89	4.27	3.67	4.08	4.72	4.73	3.67	3.42	3.45	3.45	3.69	3.82
F3	5.40	5.42	4.93	5.56	5.45	5.15	4.42	4.00	3.64	3.83	4.29	4.25

Table 169. Experiment I, 1963: Extractable P in Olsen's extracts of the soil, mg P/100 g soil/sand mixture

	SOIL X							SOIL Y						
Sampling No.	1	2		3		4		1	2		3		4	
Treatment	N.H.*	N.H.	H.	N.H.	H.	N.H.	H.	N.H.	N.H.	H.	N.H.	H.	N.H.	H.
0	0.77	0.70	0.58	0.83	0.91	0.66	1.24	0.54	0.75	0.48	0.55	0.72	0.45	0.59
0	0.90	0.82	0.73	0.95	1.03	0.84	1.33	0.54	0.49	0.48	0.66	0.80	0.26	0.77
A1	0.82	0.94	0.79	1.03	1.34	1.08	1.35	0.67	0.72	0.73	0.74	0.91	0.51	0.98
A2	0.88	1.07	1.14	1.46	1.96	1.41	1.63	0.90	1.00	0.78	1.06	1.16	0.62	1.15
A3	1.54	1.27	1.72	1.81	2.34	1.44	2.04	1.33	1.36	1.34	1.41	1.51	0.96	1.48
B1	0.72	0.98	0.77	0.98	1.26	1.02	1.30	0.74	1.10	1.00	0.92	1.01	0.72	1.04
B2	1.21	1.46	2.15	1.29	1.57	1.37	1.63	0.84	1.05	1.01	1.06	1.39	0.90	1.22
B3	1.14	1.46	1.52	1.75	2.22	1.70	2.06	1.07	1.58	1.42	1.32	1.44	1.17	1.42
C1	1.21	1.11	1.02	1.26	1.60	1.20	1.65	0.60	0.86	0.77	0.78	0.91	0.62	0.80
C2	1.19	1.39	1.35	1.18	1.28	1.17	1.59	0.89	1.08	0.91	1.08	1.26	0.66	1.10
C3	1.18	1.51	1.45	1.63	2.00	1.68	1.95	1.57	1.07	1.12	1.46	1.63	0.78	1.48
D1	1.08	1.01	1.08	1.24	1.63	0.98	1.48	0.80	0.84	1.08	0.72	0.85	0.78	1.04
D2	1.40	1.28	1.35	1.41	1.69	1.32	1.69	0.84	0.96	0.89	1.01	1.20	0.86	1.10
D3	1.16	1.37	1.71	1.75	2.30	1.74	2.16	1.23	1.37	1.15	1.38	1.71	1.22	1.45
E1	0.83	1.02	0.70	0.84	1.03	0.93	1.35	0.80	0.74	0.55	0.72	0.72	0.78	1.12
E2	1.08	1.25	1.14	1.26	1.44	1.22	1.57	1.28	1.07	0.96	1.12	1.26	0.86	1.30
E3	1.49	1.55	1.63	1.60	1.96	1.28	1.75	1.65	1.58	1.38	1.41	1.66	1.34	1.57
F1	1.12	1.17	0.92	0.98	1.22	1.02	1.45	0.88	0.96	0.64	0.83	1.07	0.75	0.94
F2	1.33	1.34	1.22	1.35	1.71	1.26	1.65	0.78	0.83	0.83	1.06	1.16	0.75	1.24
F3	1.55	1.45	1.29	1.54	1.84	1.74	2.01	1.53	1.55	1.46	1.41	1.84	0.86	1.33

* N.H. = Not hydrolyzed extracts H = Hydrolyzed extracts

Table 169 (Contd.)

Sampling No.	SOIL X						SOIL Y					
	5		6		7		5		6		7	
Treatment	N.H.	H.	N.H.	H.	N.H.	H.	N.H.	H.	N.H.	H.	N.H.	H.
0	0.86	0.95	0.60	0.76	1.00	1.21	0.68	0.79	0.47	0.61	0.76	0.80
0	0.90	1.05	0.60	0.82	1.00	1.05	0.66	0.80	0.34	0.57	0.59	0.68
A1	1.14	1.37	0.96	1.06	1.33	1.50	0.93	1.01	0.58	0.76	0.73	0.92
A2	1.49	1.49	1.36	1.48	1.59	1.82	1.36	1.46	0.93	1.03	1.17	1.42
A3	1.96	2.18	1.16	1.42	1.92	2.06	1.55	1.67	0.97	1.19	1.31	1.47
B1	1.24	1.37	0.90	1.09	1.56	1.62	0.89	1.22	0.68	0.78	0.84	0.98
B2	1.45	1.76	1.15	1.33	1.79	1.90	1.14	1.40	0.86	1.03	1.24	1.24
B3	1.92	2.20	1.42	1.56	1.93	2.16	1.52	1.73	1.09	1.18	1.64	1.68
C1	1.24	1.29	0.96	1.13	1.36	1.41	1.24	1.19	0.74	0.76	0.94	1.34
C2	1.64	1.64	1.15	1.21	1.74	1.95	1.26	1.37	0.80	0.97	1.03	1.21
C3	1.86	2.13	1.33	1.61	2.05	2.40	1.55	1.61	0.99	1.21	1.27	1.38
D1	1.14	1.19	1.16	1.38	1.36	1.47	1.07	1.40	0.69	0.80	0.82	0.84
D2	1.38	1.67	1.09	1.30	1.63	1.85	1.24	1.33	0.89	1.03	1.10	1.24
D3	1.86	1.95	1.49	1.67	1.96	2.14	1.58	1.75	0.99	1.12	1.33	1.59
E1	1.42	1.57	0.90	0.95	1.39	1.65	0.98	1.22	0.79	0.85	0.77	0.86
E2	1.55	1.76	1.05	1.30	1.64	1.77	1.30	1.40	0.82	1.03	1.03	1.26
E3	1.74	1.98	1.47	1.56	1.97	2.25	1.70	1.88	1.17	1.33	1.40	1.53
F1	1.52	1.43	0.93	1.01	1.36	1.61	0.98	1.13	0.74	0.97	0.82	0.93
F2	1.68	1.86	1.27	1.30	1.81	1.84	1.24	1.32	0.76	0.97	1.06	1.15
F3	1.89	2.27	1.36	1.51	2.02	2.05	1.42	1.42	0.96	1.13	1.27	1.44

Table 170. Experiment I, 1963: Extractable P in Morgan's extracts of the soil, mg P/100 g soil-sand mixture

	SOIL X							SOIL Y						
Sampling No.	1	2		3		4		1	2		3		4	
Treatment	N.H.*	N.H.	H.	N.H.	H.	N.H.	H.	N.H.	N.H.	H.	N.H.	H.	N.H.	H.
0	0.12	0.10	0.14	0.10	0.10	0.04	0.07	0.17	0.15	0.23	0.17	0.16	0.10	0.11
0	0.13	0.10	0.17	0.12	0.12	0.06	0.09	0.20	0.16	0.24	0.20	0.19	0.12	0.13
A1	0.17	0.13	0.24	0.14	0.18	0.09	0.11	0.24	0.21	0.30	0.27	0.23	0.16	0.18
A2	0.18	0.16	0.31	0.17	0.20	0.13	0.15	0.37	0.37	0.43	0.38	0.34	0.23	0.21
A3	0.25	0.22	0.34	0.26	0.27	0.18	0.20	0.53	0.54	0.62	0.50	0.53	0.42	0.40
B1	0.13	0.13	0.19	0.14	0.16	0.09	0.12	0.27	0.23	0.30	0.29	0.28	0.19	0.19
B2	0.20	0.19	0.33	0.17	0.20	0.14	0.15	0.31	0.44	0.56	0.42	0.44	0.31	0.27
B3	0.23	0.23	0.41	0.24	0.28	0.19	0.23	0.53	0.48	0.56	0.48	0.47	0.40	0.36
C1	0.17	0.13	0.17	0.16	0.17	0.09	0.13	0.26	0.24	0.27	0.31	0.29	0.18	0.20
C2	0.19	0.19	0.26	0.18	0.16	0.11	0.13	0.45	0.41	0.47	0.37	0.33	0.26	0.26
C3	0.24	0.22	0.33	0.23	0.26	0.19	0.18	0.45	0.50	0.55	0.48	0.51	0.39	0.37
D1	0.16	0.13	0.23	0.14	0.16	0.09	0.13	0.25	0.23	0.29	0.28	0.30	0.20	0.19
D2	0.16	0.19	0.19	0.23	0.27	0.14	0.15	0.32	0.32	0.38	0.37	0.33	0.29	0.26
D3	0.22	0.21	0.13	0.23	0.26	0.19	0.22	0.54	0.47	0.60	0.47	0.49	0.37	0.36
E1	0.13	0.12	0.19	0.14	0.12	0.06	0.08	0.29	0.24	0.31	0.29	0.24	0.20	0.15
E2	0.16	0.17	0.39	0.19	0.18	0.11	0.14	0.45	0.36	0.45	0.37	0.35	0.31	0.30
E3	0.24	0.22	0.35	0.22	0.20	0.15	0.16	0.67	0.59	0.76	0.60	0.57	0.47	0.45
F1	0.15	0.12	0.21	0.15	0.12	0.08	0.08	0.31	0.25	0.33	0.27	0.27	0.21	0.19
F2	0.20	0.18	0.27	0.20	0.18	0.09	0.10	0.39	0.37	0.46	0.39	0.37	0.30	0.29
F3	0.21	0.25	0.38	0.23	0.25	0.16	0.18	0.66	0.53	0.61	0.48	0.48	0.37	0.32

* N.H. = Not hydrolyzed extracts. H = Hydrolyzed extracts

Table 170. (Contd.)

Sampling No.	SOIL X						SOIL Y					
	5		6		7		5		6		7	
Treatment	N. H.	H.	N. H.	H.	N. H.	H.	N. H.	H.	N. H.	H.	N. H.	H.
0	0.06	0.07	0.06	0.10	0.06	0.14	0.14	0.13	0.13	0.15	0.11	0.15
0	0.07	0.08	0.09	0.08	0.06	0.10	0.11	0.12	0.14	0.13	0.10	0.13
A1	0.11	0.12	0.11	0.14	0.11	0.17	0.18	0.18	0.15	0.18	0.16	0.23
A2	0.13	0.15	0.15	0.17	0.15	0.18	0.26	0.26	0.29	0.31	0.31	0.35
A3	0.19	0.21	0.21	0.21	0.20	0.26	0.38	0.41	0.41	0.48	0.34	0.39
B1	0.12	0.11	0.13	0.16	0.13	0.19	0.23	0.21	0.22	0.26	0.22	0.24
B2	0.15	0.14	0.16	0.20	0.19	0.25	0.31	0.28	0.29	0.31	0.30	0.36
B3	0.20	0.22	0.22	0.25	0.22	0.28	0.41	0.39	0.43	0.48	0.42	0.47
C1	0.09	0.12	0.13	0.14	0.11	0.15	0.25	0.26	0.20	0.22	0.23	0.26
C2	0.19	0.19	0.16	0.19	0.18	0.20	0.27	0.27	0.32	0.34	0.27	0.30
C3	0.20	0.19	0.20	0.23	0.20	0.27	0.34	0.35	0.39	0.41	0.32	0.35
D1	0.10	0.12	0.13	0.14	0.12	0.15	0.24	0.22	0.21	0.23	0.22	0.22
D2	0.15	0.14	0.17	0.20	0.18	0.23	0.31	0.28	0.27	0.28	0.28	0.34
D3	0.18	0.21	0.24	0.26	0.19	0.26	0.35	0.35	0.38	0.42	0.36	0.44
E1	0.13	0.14	0.12	0.14	0.13	0.18	0.26	0.28	0.21	0.22	0.18	0.22
E2	0.17	0.15	0.17	0.18	0.17	0.24	0.27	0.28	0.29	0.32	0.26	0.31
E3	0.20	0.19	0.19	0.23	0.20	0.26	0.41	0.40	0.40	0.45	0.34	0.39
F1	0.15	0.16	0.13	0.13	0.13	0.18	0.22	0.21	0.24	0.25	0.17	0.23
F2	0.19	0.17	0.16	0.17	0.17	0.23	0.25	0.25	0.36	0.37	0.23	0.28
F3	0.23	0.20	0.21	0.24	0.23	0.25	0.32	0.34	0.36	0.38	0.32	0.32

Table 171. Experiment I, 1963: pH of the soils in the different soil-samplings

Treatment	SOIL X							SOIL Y						
	Sampling No.							Sampling No.						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
0	5.60	5.55	5.75	5.85	5.80	5.75	5.40	6.80	6.55	6.70	6.80	6.75	6.70	6.55
0	5.60	5.55	5.65	5.70	5.80	5.40	5.30	6.90	6.75	6.70	6.70	6.80	6.50	6.35
A1	5.80	5.65	5.75	5.80	5.80	5.30	5.30	6.75	6.70	6.70	6.70	6.80	6.45	6.25
A2	5.75	5.70	5.70	5.70	5.75	5.65	5.45	6.90	6.90	6.85	6.85	6.85	6.70	6.35
A3	5.90	5.70	5.65	5.65	5.80	5.75	5.75	6.95	6.95	6.85	6.80	6.85	6.70	6.30
B1	5.75	5.60	5.65	5.75	5.75	5.65	5.40	6.85	6.65	6.65	6.65	6.85	6.70	6.40
B2	5.75	5.60	5.70	5.80	5.80	5.45	5.65	6.80	6.70	6.60	6.60	6.80	6.45	6.30
B3	5.80	5.70	5.65	5.80	5.80	5.70	5.50	6.80	6.65	6.65	6.65	6.80	6.60	6.40
C1	5.65	5.55	5.60	5.65	5.70	5.65	5.35	6.80	6.75	6.70	6.65	6.75	6.60	6.50
C2	5.80	5.65	5.70	5.80	5.80	5.60	5.65	6.90	6.95	6.90	6.90	6.85	6.55	6.30
C3	5.80	5.60	5.55	5.45	5.80	5.70	5.40	6.75	6.70	6.70	6.70	6.75	6.70	6.35
D1	5.70	5.65	5.80	5.80	5.75	5.70	5.50	6.75	6.65	6.60	6.60	6.75	6.55	6.20
D2	5.70	5.55	5.65	5.70	5.85	5.70	5.65	6.60	6.65	6.60	6.50	6.65	6.60	6.40
D3	5.75	5.55	5.60	5.60	5.75	5.35	5.30	6.70	6.65	6.65	6.65	6.80	6.60	6.50
E1	5.80	5.65	5.70	5.80	5.80	5.40	5.70	6.70	6.65	6.65	6.70	6.75	6.65	6.50
E2	5.80	5.65	5.70	5.80	5.80	5.65	5.35	6.85	6.85	6.80	6.70	6.80	6.70	6.45
E3	5.90	5.65	5.70	5.80	5.85	5.80	5.60	6.60	6.60	6.60	6.65	6.75	6.65	6.45
F1	5.85	5.70	5.70	5.65	5.80	5.65	5.60	6.80	6.65	6.55	6.50	6.80	6.65	6.20
F2	5.85	5.60	5.70	5.80	5.75	5.70	5.70	6.85	6.75	6.70	6.70	6.70	6.55	6.25
F3	5.80	5.65	5.75	5.80	5.80	5.70	5.70	6.85	6.80	6.70	6.60	6.70	6.65	6.30

Table 172. Experiment II (1964): Extractable P from the soil by 1% citric acid, mg P/100 g soil.

(a) Unhydrolyzed extracts:

Treatment	Sampling number								
	1	2	3	4	5	6	7	8	9
C0	1.37*	0.95	0.98	1.41	1.47	1.57	1.22	1.26	1.11
C1	1.70	1.39	1.54	1.90	1.97	2.00	1.62	1.74	1.45
C2	2.20	1.97	2.02	2.42	2.69	2.33	2.27	2.50	2.04
C3	2.58	2.64	2.69	3.41	3.29	3.35	4.03	3.66	3.06
F0	1.28	0.95	1.02	1.26	1.25	1.68	1.54	1.05	1.16
F1	1.94	1.58	1.78	1.99	2.04	1.93	1.47	1.44	1.63
F2	2.98	2.34	2.54	2.96	3.54	3.04	2.66	2.56	2.22
F3	3.65	3.49	3.62	3.25	3.31	3.29	3.55	2.93	2.93
G0	1.17	0.99	1.00	1.40	1.29	1.36	1.13	1.20	1.14
G1	1.57	1.58	1.58	1.89	2.35	1.97	1.64	1.52	1.74
G2	2.04	1.95	2.18	2.31	2.67	2.67	2.83	2.00	2.37
G3	2.34	2.66	2.49	3.12	3.45	3.31	3.18	3.10	3.00

(b) Hydrolyzed extracts:

Treatment	Sampling number								
	1	2	3	4	5	6	7	8	9
C0	1.65*	1.07	1.04	2.10	1.72	1.89	1.64	1.52	1.37
C1	2.22	1.68	1.73	2.65	2.57	2.50	2.04	1.98	1.84
C2	2.98	2.43	2.34	3.22	3.40	3.00	2.82	2.90	2.30
C3	3.67	3.19	2.91	4.23	3.86	3.76	4.49	4.03	3.28
F0	1.51	1.15	1.05	1.62	1.73	2.05	1.79	1.42	1.45
F1	2.16	1.76	1.79	2.66	2.16	2.44	2.04	1.77	1.98
F2	2.98	2.40	2.40	3.62	3.79	3.40	3.18	2.66	2.36
F3	3.62	3.61	3.10	3.91	3.91	3.56	4.11	2.96	3.04
G0	1.45	1.07	0.94	1.91	1.71	1.87	1.40	1.59	1.40
G1	2.11	1.83	1.68	2.52	2.46	2.26	2.12	2.07	2.03
G2	2.76	2.42	2.41	3.26	3.32	3.06	3.02	2.46	2.70
G3	3.36	3.06	2.76	3.92	3.97	3.85	3.87	3.32	3.02

* Each figure is a mean of 2 replicates.

Table 173. Experiment II (1964): Extractable P from the soil by Olsen's method, mg P/100 g soil.

(a) Unhydrolyzed extracts:

Treatment	Sampling number								
	1	2	3	4	5	6	7	8	9
C0	0.16*	0.12	0.12	0.27	0.19	0.17	0.14	0.17	0.23
C1	0.46	0.27	0.29	0.36	0.34	0.30	0.33	0.30	0.40
C2	0.62	0.48	0.50	0.59	0.53	0.48	0.42	0.44	0.53
C3	0.93	0.70	0.78	0.73	0.73	0.72	0.80	0.59	0.84
F0	0.14	0.11	0.14	0.24	0.21	0.18	0.17	0.15	0.18
F1	0.61	0.28	0.31	0.33	0.34	0.32	0.36	0.28	0.39
F2	1.16	0.56	0.63	0.59	0.61	0.54	0.51	0.48	0.62
F3	1.45	0.95	0.92	0.78	0.74	0.65	0.77	0.64	0.77
G0	0.15	0.12	0.14	0.17	0.20	0.22	0.22	0.17	0.23
G1	0.29	0.27	0.31	0.34	0.35	0.33	0.35	0.31	0.42
G2	0.47	0.47	0.55	0.63	0.56	0.52	0.49	0.46	0.71
G3	0.76	0.78	0.83	0.83	0.77	0.68	0.66	0.60	0.83

(b) Hydrolyzed extracts:

Treatment	Sampling number								
	1	2	3	4	5	6	7	8	9
C0	0.25*	0.15	0.14	0.33	0.23	0.25	0.21	0.24	0.26
C1	0.55	0.38	0.35	0.52	0.52	0.46	0.49	0.42	0.43
C2	0.83	0.60	0.65	0.67	0.65	0.66	0.59	0.54	0.62
C3	1.17	0.80	0.86	0.91	0.93	0.85	0.94	0.79	0.88
F0	0.23	0.15	0.17	0.27	0.29	0.30	0.24	0.24	0.24
F1	0.63	0.34	0.38	0.47	0.49	0.44	0.49	0.43	0.43
F2	1.10	0.59	0.68	0.67	0.69	0.74	0.79	0.61	0.68
F3	1.53	0.99	0.95	0.97	0.90	0.81	0.95	0.82	0.84
G0	0.24	0.14	0.19	0.28	0.24	0.24	0.31	0.25	0.24
G1	0.49	0.37	0.37	0.51	0.49	0.48	0.51	0.45	0.46
G2	0.84	0.60	0.64	0.77	0.72	0.63	0.71	0.59	0.72
G3	1.02	0.90	0.92	1.00	0.91	0.88	0.83	0.79	0.87

* Each figure is a mean of 2 replicates.

Table 174. Experiment II (1964): Extractable P from the soil by Morgan's method, mg P/100 g soil.

Treatment	1st sampling		2nd sampling		3rd sampling	
	Not hydrolyzed	Hydrolyzed	Not hydrolyzed	Hydrolyzed	Not hydrolyzed	Hydrolyzed
C0	0.02*	0.04	0.01	0.00	0.01	0.03
C1	0.09	0.11	0.09	0.09	0.07	0.05
C2	0.17	0.24	0.24	0.19	0.19	0.19
C3	0.29	0.39	0.34	0.31	0.33	0.31
F0	0.03	0.05	0.02	0.00	0.00	0.04
F1	0.12	0.15	0.13	0.08	0.08	0.09
F2	0.29	0.35	0.25	0.25	0.22	0.23
F3	0.48	0.57	0.42	0.40	0.37	0.42
G0	0.03	0.04	0.05	0.00	0.00	0.02
G1	0.05	0.09	0.09	0.07	0.09	0.09
G2	0.12	0.19	0.20	0.21	0.21	0.24
G3	0.22	0.31	0.40	0.35	0.32	0.40

* Each figure is a mean of 2 replicates

Table 175. Experiment II (1964): Extractable labelled-P from the soil in the first 3 soil-samplings; mg P/100 g soil.

Treatment	1st sampling			2nd sampling			3rd sampling	
	i*	ii	iii	i	ii	iii	i	ii
C1	0.99**	0.26	0.08	0.60	0.16	0.06	0.56	0.15
C2	1.46	0.62	0.19	1.15	0.36	0.16	0.72	0.42
C3	2.13	0.91	0.31	1.92	0.66	0.24	1.52	0.74
F1	0.55	0.33	0.10	0.46	0.16	0.06	0.47	0.19
F2	1.28	0.81	0.29	1.14	0.44	0.19	0.99	0.43
F3	1.97	1.22	0.50	1.77	0.68	0.29	1.67	0.90
G1	0.52	0.25	0.06	0.52	0.19	0.06	0.53	0.30
G2	1.01	0.51	0.14	1.17	0.54	0.15	0.76	0.55
G3	1.76	0.87	0.26	1.77	0.68	0.29	1.36	0.69

* i = 1% citric acid extractant.
ii = Olsen's extractant.
iii = Morgan's extractant.

** Each figure is a mean of 2 replicates.

List of Figures

Fig. No.	Between Pages
1,2	68,69
3-6	69,70
7-13 and plate 1	71,72
14-16	73,74
17-24	75,76
25-30	77,78
31-42	80,81
43-51	82,83
52-54	84,85
55-62	85,86
63-72	87,88
73-75	88,89
75[a]	97,98
76	102,103
77	104,105
78	106,107
79-80	109,110