INVESTIGATION OF THE NUTRIENT STATUS OF CORN WITH SPECIAL REFERENCE TO NITROGEN AND PHOSPHORUS

by

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A Thesis

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INTRODUCTION

Study of the nutritional status of crops as evidenced by plant analysis was begun as early as 1804. Recently efforts have been made by a number of workers to establish, by study of data on yields and the levels of different nutrients in specific plant parts, the response of these plants to applications of fertilizer. Further work has suggested the possibility of using the level of a leaf constituent at a specific physiological stage as a criterion of the state of supply of certain elements. The possible diagnostic use of these methods in evaluating soil fertility and the prediction of crop response is inviting.

Corn (Zea mays), a member of the grass family of considerable economic importance, has received special attention in this respect.

The present work was undertaken, after the manner of Tyner (1946), to study the effects of nitrogen and phosphorus fertilization on the leaf composition of this crop at the flowering stage. The possibility of observing a potash deficiency on a soil under additional stress by the use of heavy nitrogen fertilization and heavy rates of seeding was envisaged. Since individual leaves of Wisconsin No. 7 corn contributed ample material for chemical analyses, this opportunity was taken to study the variation between individual members normally included in a composite sample.

HISTORICAL REVIEW

1. Early Work.

Early work on plant tissue anlaysis was carried out by de Saussure in 1804 (33), in a study on the ash content of plants. He showed that this portion of the tissue varied with the species, the plant part involved, the stage of development and the soil on which the plant grew. In 1840 Von Liebig (27) suggested that the fertility of the soil could be maintained by returning to the soil the nutrients removed by the crop as determined by ash analysis. This simple "Law of Restitution" became untenable as knowledge was acquired. He failed to reckon with phosphorus and potassium fixation in different soils, nor did he realize the importance of nitrogen in plant growth.

In 1862 Weinhold (46) suggested that plants growing most abundantly in one location were well adapted to the nutrients available in that soil, so ash analysis would provide information on the relative status of the assimilable nutrients present. This is the first diagnostic approach to plant analysis. Although Weinhold failed to establish his idea, Hellriegel (18) three years later, growing barley in sand culture, found the potassium content in straw and grain increased with increasing supply. Consequently he proposed that the analysis of crop plants might provide an index of nutrient availability in the soil. For the next sixty years Hellriegel's work stimulated investigation in this direction in Europe.

Goodall and Gregory (16) in their historical review outline this advance critically. Heinrich suggested a specific plant part might be more appropriate than a gross plant sample. Analysing oat roots, he proposed his "Law of the Minimum", a reduced level to which an element in low supply would go in the root. This "Law of the Minimum", which must not be confused with the same term used by Liebig (27), was amended by Von Dikow who suggested a "Law of the Maximum". This amendment suggested that there was a typical concentration of a nutrient in the root characteristic of adequate nutrition. This level had to be reached if a fertilizer was to be considered as exerting its maximum effect on plant growth. Stahl-Schroder rejected this "Law of the Maximum" because he found evidence of luxury consumption. Both he and Helmkampf doubted the advisability of selecting roots for analysis. It remained for Atterberg of Sweden to continue the work using the aerial portions of oats. He set up ratios of N/P_2O_5 of 1.7 for grain and 2.22 for tissue. This established a trend for subsequent work during the late 19th century. By 1889 Von Seelhorst carried out a fertilizer experiment on twenty four different soils in pot cultures. The plant composition was correlated to some degree with yield responses due to fertilizer treatments. He emphasized that consideration of the concentration of one nutrient alone was not sufficient to predict a response. Differences of opinion were wide among workers of the time as to the plant part most suit-

able for diagnostic techniques.

In 1905, Hall (17), Director of Rothamsted Experimental Station used data from crops harvested in the long term manurial trials there. From these results he doubted that plant analysis might be more useful than soil analysis. He suggested, as a means of overcoming the variations which existed, that some plant or weed fairly common to all soils be chosen as an indicator plant. His results showed that practical use of plant analysis was not yet possible, and this marked the end of an era of study.

Ulrich (45) points out that between 1905 and 1919 little serious work was carried out on plant tissue analysis. In 1919 Pfeiffer, Simmermacher and Rippel (31) published results of investigations on dried plant tissue. In 1927 Gilbert and Hardin (14) undertook analysis of fresh plant material in America. From these beginnings followed two modes of investigation, and methods of interpreting results. One avenue of research was the investigation of dried or preserved plant tissues by means of quite complex chemical analyses, accounting for the overall chemical composition of the material. These data were employed in attempts to understand the nutrient relationships indicated by the deposition of these elements or compounds in the plant tissues. The second approach led to the study of fewer tissue components in fresh or living plant parts by means of the so-called "quick" tests. In this case information could be gathered

from larger plant populations on some relatively mobile constituent considered indicative of the adequacy of supply of some nutrient.

Goodall and Gregory (16) point out that the expansion of research owed much to the subsequent change in emphasis in this field. Less attention is being given to interpretation of the results in terms of soil fertility and more in terms of the nutritional status of the plant.

2. Current Review.

Recently the major objectives of plant analysis, as outlined by Ulrich (45), have been to predict the nutrient requirements of crops on the basis of a single sample taken in mid-season, and to determine the nutrient status of the crop at that time. This involves some study of yield response, at different levels of a limiting nutrient correlated with the per cent of this element in the plant tissue.

Liebig (27) proposed a "Law of the Minimum" which states that the growth of a plant is governed by the nutrient which is in minimum supply. He envisaged this relationship as linear between the yield and the amount of nutrient supplied. Mitscherlich (30) proposed a different "Law of the Minimum", a diminishing returns relationship, in which a yield increase,

in response to a nutrient increase, will depend on the level of the nutrient already present. He states that the increase in yield per unit of limiting nutrient applied is directly proportional to the decrement from the maximum yield.

In 1936 Macy (29) proposed a relationship between the sufficiency of a nutrient and its percentage content in the plant. He stated that "the central concept is a critical percentage of each nutrient in each kind of plant, above which there is luxury consumption, and below which there is poverty adjustment, which is almost proportional to the deficiency until a minimum percentage is reached." He showed that the theory was compatible with the results of the earlier workers. That is, in the "minimum percentage" portion of the curve, when the level of nutrient in the plant is constant, the Liebig law holds. During "poverty adjustment", when the slope of the curve begins to rise so that response to the supply of nutrient decreases progressively, Mitscherlich's law holds. When the "critical percentage" or level of sufficiency is reached, luxury consumption sets in and Liebig's law holds again. It is in this zone of transition between the "minimum percentage" and luxury consumption that many crops fall in practice, an observation which gained Mitscherlich's hypothesis wide popularity.

The next year, Thomas (38) published a criticism of

the concepts of Liebig and others, whom he said assessed plant nutrition in a quantitative sense only. In addition to the amount of the elements present in a leaf at any given time, he stressed that the ratios or physiological relations between the elements were also an important expression of the adequacy of plant nutrition. He coined the term, quantity or intensity of nutrition, in reference to the sum of the percentages of nitrogen, phosphorus and potassium in the dried tissue at the moment of sampling. The ratios existing between these elements he referred to as the quality of nutrition. From data collected on corn grown at the Jordan fertility plots of the Pennsylvania Agricultural Experiment Station he showed that different treatments could change the ratios between the elements without changing the intensity of nutrition. Likewise the intensity could change with changes in the quality of nutrition. It is possible that a situation might exist where conditions could change the levels of nitrogen, phosphorus and potassium in the leaf without correcting an inferior $N-P_2O_5-K_2O$ equilibrium.

Ulrich (45), granting the interest of the work carried out by Thomas and others, suggested that the far simpler procedure of examining the data in the light of critical concentrations for each element accomplished a similar interpretation of results. The nutrient balance concept advanced by Thomas did not gain popularity in this field of research.

One of the first studies on the life history of corn was conducted in 1888 by Schweitzer (35). He found that the fibre weight, or dry weight of the stalk and leaves increased rapidly during the early part of the season, levelling off in late July. After flowering, ear development accounted for an increasing proportion of the total weight gained. He observed the avidity with which the young plant appeared to take up nitrogen. However, after flowering, there seemed to be a lessened degree of nitrogen accumulation in the stalk and leaves, and a corresponding increase in the ears. Schweitzer wrote, "after this (August 6) the stores are emptied into the ear and the grain...", which suggests in some measure an idea of translocation. By harvest time 135 pounds of nitrogen per acree were removed from the soil, of which 86 pounds of this element were found in the ear.

Jones and Houston (22), working at Purdue University, Indiana, found the major tissue constituents in corn increased uniformly until October 1. During the following week these constituents continued to increase with the exception of potassium. However, between August 28 and September, although potash registered an increase for the whole plant, it appeared to increase in the ear at the expense of this component in the vegetative parts. They could not separate the effects of leaching from those of translocation of potash to the ear in explaining the decrease in the vegetative portions of the plant. They found that the nitrogen

content continued to increase overall, but from August 28 to October 8 the stalk content dropped from 53.5 to 31.8 pounds per acre.

More recently Sayre (34) carried out similar experiments on the growth of corn. Using the double-cross, Ohio K35, he accounted for a total dry matter production of 12,884 pounds per acre, nearly half of which developed between July 20 and August 20. This crop, capable of producing a 100 bu. yield of corn per acre, took up 144 pounds of nitrogen, 30 pounds of phosphorus and 114 pounds of potash per acre. Other data compiled from many sources (20) estimate the requirements of a 100 bu. corn crop to be 148 pounds of nitrogen, 23 pounds of phosphorus and 71 pounds of potassium. The discrepancy between these figures is not large.

Sayre found during late July the nitrogen consumption was nearly 4.0 pounds per acre per day. Similarly potassium uptake averaged 3.2 pounds per day during the early part of July. Although marked translocation of nitrogen and phosphorus from the vegetative tissues to the ear and grain of the plant occurred, potash exhibited a net loss amounting to 16 pounds per acre during the latter stages of growth.

In such a changing system as the one described, the stage of growth and the choice of plant tissue sampled is extremely

important. This phase of the technique has been reviewed by several investigators (45, 16).

A number of workers (22, 34, 11, 12) have analyzed different tissues, as described before, in order to study the development and composition of the corn plant, relating each organ to the whole. For diagnostic or interpretative purposes, Ulrich (43) suggested the concentration of a nutrient in a plant or plant part is a function of the soil, the climate, the plant, the time of sampling, previous management and some other probable factors. He also stressed the importance of movement and accumulation of certain nutrient elements at certain stages. This movement may be exhibited most strikingly between the vegetative and reproductive tissues with the development of the fruiting organs. Thomas (39) stressed the advantages of the use of leaf analysis. He suggested that "since growth and development represent an integration of metabolic reactions within the leaf, it is experimentally sound to include elaborated and unelaborated material when the purpose is to relate nutrition to yields". In this manner, in an endeavour to fix critical nutrient levels for certain plants, workers using leaf tissue, studied the response of plant to different treatments.

Boynton and Compton (6) obtained indifferent success in using the analysis of fruit tree leaves for nutritional

diagnosis.

Tremblay and Bauer (40) attempted to find some means of assessing the adequacy of potash nutrition in a pea-producing area under intensive cultivation. They were able to select leaves which were suitable representative samples of the pea plants, that accurately reflected the potash status of the soil in so far as it affected the growth of the crop. They set tentative values on the tissue concentration in leaves from the pre-bloom to blossoming stage which enabled them to designate certain areas on the basis of potash supplying power as superior or satisfactory.

In 1950, Ulrich (44) used the petioles and blades of sugar beets to determine the critical levels of nitrate nitrogen in relation to yield and sucrose concentration.

Other workers (41, 42, 25, 5) have used certain leaves on the corn plant selected at a definite physiological stage related to the flowering period to establish levels of adequacy of nutrition, and the effects of different levels of nutrient supply.

Tyner and Webb (42) attempted to determine the efficiency of utilization of applied fertilizers. They found that as the increment of nitrogen application increased, the level

of leaf nitrogen increased. However, the potassium content of the tissue was decreased and the efficiency of the nitrogen application appeared to be lowered as indicated by the unit of yield response per unit of nutrient added. Conversely when the potash supply alone was increased, the level of leaf nitrogen was depressed, but yields did not seem to be affected. Phosphorus applications seemed to be without effect on yield or on the levels of nitrogen and potassium in the leaf. It also appeared that increased supplies of potassium and nitrogen were without effect on the phosphorus content.

Another publication by Tyner (41) carried this work another step. He set the critical levels of nitrogen, phosphorus and potassium in the sixth leaf of corn at the bloom stage as 2.90%, 0.295% and 1.30% respectively. Highly significant correlation and regression coefficients were found to exist for the relation of yield to these percentage constituents of the leaves. It was calculated, for each 0.1% change in nitrogen, phosphorus and potassium in the leaf at the stage sampled, a yield response of 4.43, 25.3 and 2.05 bu. of corn per acre might be obtained respectively. He considered that nitrogen supply, perhaps of all the nutrients, was the biggest factor determining yield potentials. Accordingly he evaluated the critical concentrations of phosphorus and potassium at yield levels associated

with the critical nitrogen concentration.

In 1953 Bennett et al (5) reported the effect of nitrogen fertilization on yield and the associated levels of the three major nutrients in the leaf tissue of the corn plant. They obtained a significant increase in yield from nitrogen fertilization in field tests on five out of eight experimental sites. A highly significant correlation of 0.96 existed between increases in yield and increases in the nitrogen content of the leaf. Examination of the yield data indicated that little response to nitrogen fertilization occurred at or above the 2.8 per cent level in the leaf tissue. Contrary to work reported previously (42), it was found that the leaf phosphorus percentage was increased by nitrogen application. However, in agreement with the earlier work, application of nitrogen decreased the percentage of potassium in the leaf.

Krantz and Chandler (25) also reported an increase in leaf phosphorus in response to nitrogen application. However, they also observed an uptake of potash at high levels of soil potash under a similar treatment. This differs from the results presented by the other workers.

Although considerable attention has been given to the stage and site of sampling of plant tissue for diagnostic procedures, little work has been reported on the variation existing

between corn plants within a plot. No direct statement has been made concerning the adequacy of sampling for statistical purposes. Earlier work (19) reported a disturbing irregularity between the results from individual corn stalks from a single plot, when tested for nitrates with diphenylamine reagent. It was not established that this variation was entirely due to the nature of the nutrient form under investigation.

EXPERIMENTAL MATERIALS AND METHODS

1. The Corn Variety.

The experiments described in the following work were conducted with the corn variety Wisconsin No. 7, used as the male parent in the production of seed at the Quebec Provincial Seed Farm. This is a large, open-pollinated variety of dent corn, capable of producing heavy vegetative growth. The maturation of seed is limited by the length of the growing season in this area.

2. The Experimental Sites.

The plots were situated at the Quebec Provincial Seed Farm on Chicot fine sandy loam, Figure 1. They were laid out in Ranges B and C of Fields 1 and 2. This soil has been described by Lajoie and Millette (26) as being formed on thin alluvial material over calcareous till. This layer may range from a few inches to about four feet in thickness. These soils are moderately well drained, subject to a degree of water erosion and exhibit fair water-holding capacity. The Ac layer is described texturally as a fine sandy loam, very friable, with a fine crumb structure. The reaction of this layer is reported as about pH 6.0.

Reference to Figure 1 will indicate that in the field

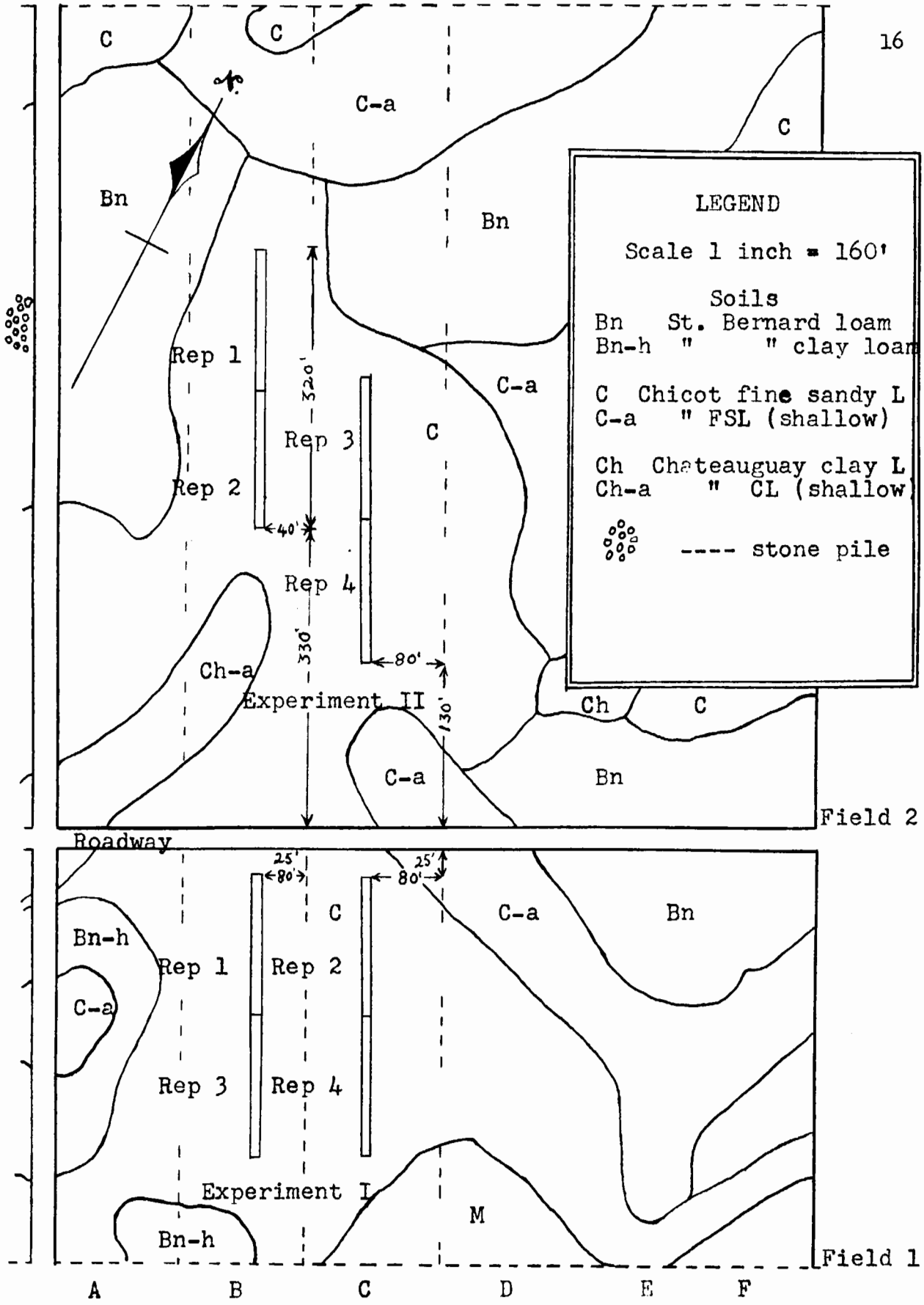

FIG. 1 THE SITES OF EXPERIMENTS I AND II, 1952.
QUEBEC PROVINCIAL SEED FARM

this soil is found in a complex association with members of the St. Bernard and Chateauguay soil series.

Both ranges of these fields had received a basal spring application of 400 pounds of 4-12-6 fertilizer per acre prior to seeding. This was part of the practiced rotation of corn, grain, grain, clover, timothy and grain. Whereas this application was made before discing, an additional 200 pounds of the same fertilizer was banded beside the seed at seeding time.

3. Experiment I.

Experiment I was laid out in a north-south direction on Ranges B and C of Field 1. The location of the male rows of corn seeded according to custom by the farm management is recorded in Figure 1, measuring from the edges of the roadway separating Fields 1 and 2, and from the boundaries between Ranges B and C, and C and D respectively.

The corn was planted on May 29, 1952 with the field planter, in rows 3 feet apart, approximately 18 inches between plants. This gave a stand density of about 9,500 plants per acre. A 2x2 factorial design was superimposed over this giving four plots in each block. This involved treatments with nitrogen and phosphorus, applied singly and in combination. The experiment was replicated four times, the treatments having been assigned at random, Figure 2.

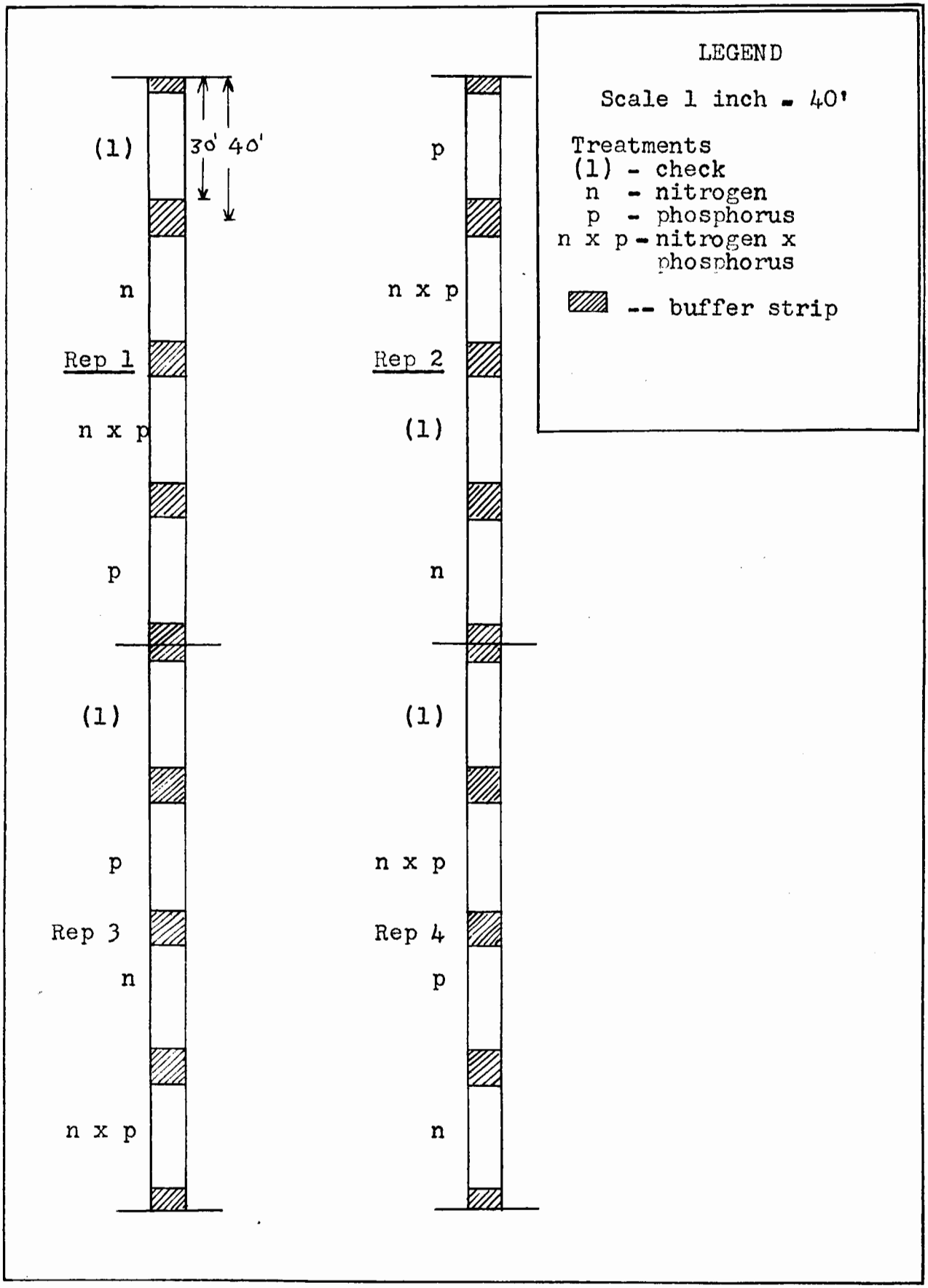

FIG. 2 FIELD PLAN OF EXPERIMENT I

The nitrogen treatment, 230 pounds of 33% ammonium nitrate per acre, was applied as a side-dressing at the time of the last cultivation on July 15, 1952. It was placed several inches deep, six inches on each side of the corn row with a suitably adjusted Planet Jr. handseeder.

The plots treated with phosphorus received 360 pounds of 20% superphosphate per acre. This was applied at seeding time, about five inches deep, by use of the Planet Jr. seeder operating in shallow furrows on each side of the seeded rows.

The plots were four rows wide, and forty feet long, allowing a border of 5 feet at each end, so that 10 feet separated individual plots. The two outside rows were retained as border rows. They received the same treatment as the two center rows, but they were not sampled.

Sampling was conducted at the pollen shedding stage, when 50% of the plants were estimated to be shedding pollen. This occurred on August 8 of this season. The plants which were sampled on this date were harvested for yield data on September 18, 1952.

4. Experiment II.

Experiment II was laid out in a north-south direction on Ranges B and C of Field 2. Additional information, as in

Experiment I is provided in Figure 1.

This experiment was laid out as a 2x2 factorial design in which the main plots were split to permit three dates of sampling. In addition to the basal application of 4-12-6 described above, these plots received a further basal application of 360 pounds of 20% superphosphate per acre as tested in Experiment I. The same manner and depth of placement was used as before.

On May 29, 1952, during the regular pass of the field seeder, the seed supply was shut off before entering these plots. The 4-12-6 fertilizer was laid down as usual, and the traces were used to mark the rows. The corn was then seeded with a Planet Jr. hand seeder, delivering at least two seeds to the linear foot. The object was to adjust the stand densities later by thinning out the seedlings. Due to bird damage to the seedling on emergence, these plots were reseeded on June 9. This placed Experiment II behind Experiment I in growth and maturity by about 10 days.

The nitrogen treatment involved a side-dressing with 230 pounds of 33% ammonium nitrate per acre, applied on July 15, using a suitably adjusted hand seeder.

The other treatment involved testing an increase in the rate of seeding, in which the plants were thinned to about 6 inches and 12 inches apart, respectively, giving acre popula-

tions of 29,000 and 14,500 plants. The lesser population served as the check plot, the other plots being combinations of two rates of seeding with and without nitrogen over a heavy basal application of phosphorus.

It was desirable to sample this material on three dates; at the pre-pollen, pollen and post-pollen shedding stages, each about a week apart. Accordingly each 40 foot plot, after allowing a 5 foot border on each end, was subdivided into three 10 foot plots for sampling purposes. Since the affect of sampling on adjacent plants was considered slight, further borders between the sub-plots were dispensed with. The main-plot and sub-plot treatments were assigned at random in turn, Figure 3. The whole was replicated four times.

This experiment was sampled on August 11-12, August 18 and August 25, which dates were selected to represent the pre-pollen shedding, pollen shedding and post-pollen shedding stages respectively. Although these dates are each one week apart, it must be emphasized that selection of the pre-pollen shedding stage is arbitrary and not easily recognized by any physiological manifestation.

5. Sampling and Sample Preparation.

(a) Leaf Tissue.

The leaf arising from the ear node was selected from ten normally competitive plants in each plot, selecting five from each of the two center rows. Wherever possible, plants

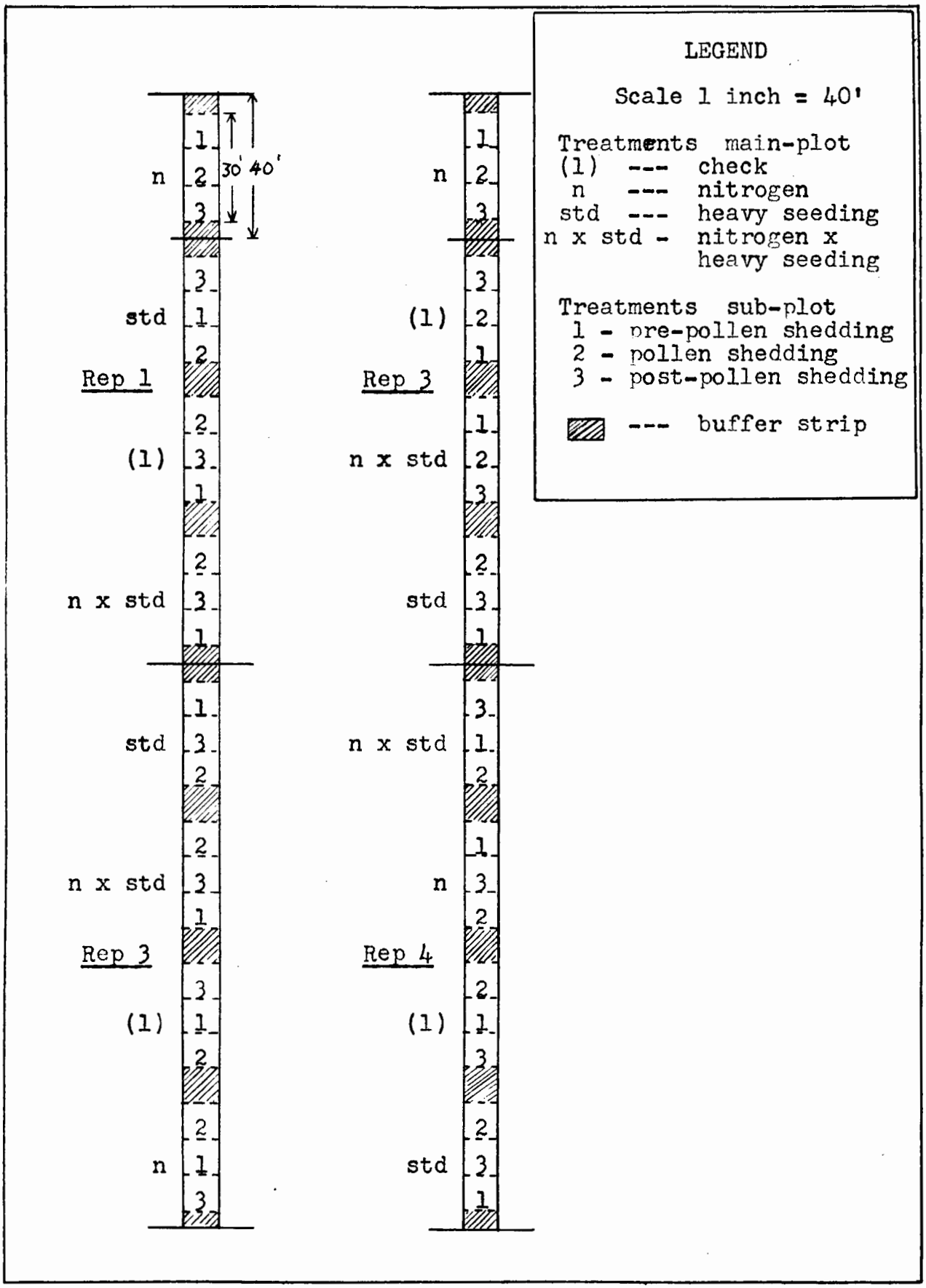

FIG. 3 FIELD PLAN OF EXPERIMENT II

suffering from borer damage were excluded. The leaf was severed at its base, and the individual blade placed in a perforated paper bag. The top of the bag was folded over and stapled. The selected plants were tagged with numbered shipping tags fastened to the stalk by a twist of aluminium wire. This enabled the subsequent harvest of plants which had been sampled.

All sampling was carried out between 10.00 a.m. and 4.30 p.m. on the same day. In a case where this was impossible sampling was stopped between replicates.

The leaves were dried in the forced air drier maintained by the Agronomy Department. The temperature was adjusted to not exceed 200°F. for a period of four to five hours. This was carried out on the evening of the day of collection.

The dried leaves were individually ground in a "Mikro-Samplmill" using the 1/16 inch round perforation screen and stored in paper envelopes. The mill was opened and cleaned with a small brush to recover all the material from each leaf.

It was from these individual leaf samples that the individual leaf analyses for Experiment I were taken. Five of the samples from each plot in replicates I and III were selected at random, these were disignated as Group I. Later the remaining five samples from these two replicates were used similiarly, and these designated as Group II.

The chemical analyses to obtain plot values for both

experiments were obtained by compositing 0.25 g. of material from each of the ten leaf samples for each plot. These were mixed thoroughly and packaged.

(b) Soil Samples.

At the time the corn leaves were sampled in each experiment, a soil core was taken opposite the sampled plant, midway between it and the border row. A $\frac{3}{4}$ inch sampling tube was used to a depth of 6 inches. These cores were air-dried and sieved separately. Composite samples were prepared for each plot by taking a level teaspoonful from each of the ten individual samples for mixing. Trial indicated the variation between the weights of the aliquots of dry soil was less than that existing between the weights of the dired soil cores following sieving.

6. Chemical Analyses.

All samples analyzed were first arranged in a random order with respect to treatment and replication by the use of tables of random numbers (9). Duplicate determinations, not reported in this work, were carried out from time to time to as a verification of the results.

Total nitrogen was determined on the plant tissue by a Kjeldahl digestion using 0.30 g. of leaf powder and 25ml.

of sulphuric acid in a 500 ml. Kjeldahl flask as outlined by A.O.A.C. (2) omitting the use of zinc dust. Upon the completion of digestion, the cooled mixture was made up to a 100 ml. volume, and a 10 ml. aliquot distilled into 4% boric acid in a conventional micro-kjeldahl still. Using methyl red-methylene blue as a mixed indicator, the titration was carried out using standard 0.02N HCl.

Total phosphorus was determined on suitable aliquots from 0.20 g. of leaf powder digested with 10 ml. of concentrated nitric acid and 7 drops of 60% perchloric acid, followed by digestion with an additional 5 ml. of nitric-sulphuric acid mixture. The blue colour was developed according to the method of Shelton and Harper (36) using sodium molybdate and hydrazine sulphate. The density of the colour was read in an Evelyn colorimeter with a 660 μ filter.

Acetic acid soluble phosphorus was extracted from the corn leaf tissue using 0.20 g. of dry material treated with 25 ml. of 2% acetic acid for five minutes as outlined by Ulrich (4). A suitable aliquot was evaporated with hydrogen peroxide, taken up in water and the colour developed as outlined by Shelton and Harper (36).

The "adsorbed" phosphorus in the soil was estimated

by the method of Bray and Kurtz (8) using 0.03N ammonium fluoride and 0.025 N HCl extractant in a ratio of 7:1 with soil. 4 g. of air dry soil was extracted by swirling for one minute on a rotary shaker. Following filtration of the extract, color development was carried out by using the modified Truog method employing ammonium molybdate solution in the presence of sodium bisulphite with reduction by stannous chloride. Color intensity was read in an Evelyn colorimeter using a 660μ filter, adjusting the instrument against a reagent blank for each run.

Bray and Kurtz (8) suggest that the "adsorbed" phosphorus fraction is the most readily available source to the plants. Their results favoured the use of the "adsorbed plus acid-soluble" fractions in estimating the available phosphorus on the basis of yield response. Kempthorne et al (24) and MacLean et al (28), however, reported "adsorbed" phosphorus values that gave highly significant correlations with plant uptake of phosphorus on a number of different soils. It appeared suitable in this work for detecting differences arising from different intensities of crop nutrition due to the use of nitrogen fertilizer and heavier than normal seeding.

7. Yield Data.

Since the length of the growing season in this area did not permit maturation of the variety, Wisconsin No. 7, the

sampled and tagged stalks were harvested prior to the first danger of frost. The N x P experiment, otherwise designated Experiment I was harvested September 18. The N x Std. experiment was harvested September 20-21.

Drying facilities were not immediately available, so the sheaves of ten stalks per plot were cut in three foot lengths with separation of the ears from the husks. The stalk material was placed in beet pulp bags, weighed and stored in a forced air drier, without benefit of heat. The ears were weighed and stored in a similar manner.

The following week, this material was reweighed, chopped by machine, mixed and duplicate 500 g. samples taken for dry weight determinations. These were dried in the Agronomy drier to constant weight, the means between duplicates being taken to determine the dry matter yields.

The lots of ears were dried to constant weight and weighed directly.

Although there was no active spoilage during the storage periods, some changes in the weight may have occurred, making the results valid on a comparitive basis only. Consequently no effort was made to use these data in terms of absolute yield for this variety under the conditions existing.

RESULTS AND DISCUSSION

Experiment I

1. Studies on the Adequacy of Sampling.

For this section of the work, tissue samples analyzed in the laboratory were individual leaves from the experiment testing the effects of the nitrogen and phosphorus treatments singly and in combination. It was hoped that by doing the individual leaf samples, some information on the variability of the material and the adequacy of sampling could be obtained.

At first one quarter of the material available, five samples from each plot in replicates I and III were chosen at random for analysis. This constituted Group I. The remainder of the samples in the same two replicates were analyzed later and these designated as Group II.

From the values determined for total phosphorus, soluble phosphorus and total nitrogen, given in Appendix Tables 1, 2, and 3, the following analyses of variance were carried out.

Table I - Analysis of Variance of Total Phosphorus Data
2 Replicates x 4 Treatments x 5 Samples (coded 100x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	39	430.26					
" -plots	7	138.82					
Replicates	1	2.50	2.50		0.36	10.13	34.12
Treatments	3	115.71	38.57		5.51	9.28	29.46
Error	3	21.00	7.00	$E_s^2 + 5E_s^2$			
Between samples within plot	32	291.44	9.10	E_s^2			

Table II - Analysis of Variance of Soluble Phosphorus Data
2 Replicates x 4 Treatments x 5 Samples (coded 100x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	39	256.44					
" -plots	7	81.61					
Replicates	1	9.22	9.22		4.63	10.13	34.12
Treatments	3	65.84	21.95		11.03	9.28	29.46
N	1	(31.68)	31.68		15.92	10.13	34.12
P	1	(1.02)	1.02		-----	"	"
NP	1	(33.12)	33.12		16.64	"	"
Error	3	5.97	1.99	$E_s^2+5E_e^2$			
Between samples within plots	32	174.83	5.46	E_s^2			

Table III - Analysis of Variance of Total Nitrogen Data
2 Replicates x 4 Treatments x 5 Samples (coded 10x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	39	356.75					
" -plots	7	180.23					
Replicates	1	2.91	2.91		----		
Treatments	3	164.81	54.94		13.18	9.28	29.46
N	1	(125.32)	125.32		30.05	10.13	34.12
P	1	(0.29)	30.29		-----	"	"
NP	1	(39.20)	39.20		9.40	"	2
Error	3	12.52	4.17	$E_s^2 + 52_s^2$			
Between samples within plots	32	176.51	5.52	E_s^2			

Kempthorne (23) has shown that an estimate of the variance of treatment comparisons having "r" replicates and "s" samples per plot is proportional to

$$\frac{E_s^2}{rs} + \frac{E_e^2}{r}$$

where E_s^2 represents the sampling variance and E_e^2 represents the treatment variance. From this summation it can be seen that the estimate of the variance of treatment comparisons may be reduced by increasing the number of samples, the number of replicates or both. Since the expected mean square values (E.M.S.) for the error variance is given by the sum, $E_s^2 + sE_e^2$,

it is clear that the variance for sampling must make up a fraction of the estimate of the variance for error used to test the treatment comparisons. In Tables I, II and III it is shown that the estimate of E_s^2 exceeds the estimate of $E_s^2 + 5E_e^2$ in all determinations on Group I material.

Subsequently Group II was analyzed in the same manner as Group I. The analyses of variance are presented in Tables IV, V and VI, the individual sample values in Group II of Appendix Tables 1, 2 and 3.

Table IV - Analysis of Variance of Total Phosphorus Data
2 Replicates x 4 Treatments x 5 Samples (coded 100x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	39	325.79					
" -plots	7	142.05					
Replicates	1	30.28	30.28		10.37	10.13	34.12
Treatments	3	103.00	34.33		11.76	9.28	29.46
N	1	(82.37)	82.37		28.21	10.13	34.12
P	1	(16.90)	16.90		5.79	"	"
NP	1	(3.72)	3.72		1.28	"	"
Error	3	8.77	2.92	$E_s^2 + 5E_e^2$			
Between samples within plots	32	183.74	5.74	E_s^2			

Table V - Analysis of Variance of Soluble Phosphorus Data
2 Replicates x 4 Treatments x 5 Samples (coded 100x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	39	227.86					
" -plots	7	86.25					
Replicates	1	30.63	30.63		9.31	10.13	34.12
Treatments	3	45.76	15.25		4.64	9.28	29.46
N	1	(34.60)	34.60		10.52	10.13	34.12
P	1	(4.76)	4.76		1.45	"	"
NP	1	(6.40)	6.40		1.95	"	"
Error	3	9.87	3.29	$E_s^2 + 5E_e^2$			
Between samples within plots	32	141.60	4.43	E_s^2			

Table VI - Analysis of Variance of Total Nitrogen Data
2 Replicates x 4 Treatments x 5 Samples (code 10x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	39	275.07					
" -plots	7	134.47					
Replicates	1	1.76	1.76		----		
Treatments	3	96.06	32.02		2.62	9.28	29.46
N	1	(87.32)	87.32		7.15	10.13	34.12
P	1	(4.83)	4.83		----		
NP	1	(3.91)	3.91		----		
Error	3	36.66	12.22	$E_s^2 + 5E_s^2$			
Between samples within plots	32	140.59	4.39	E_s^2			

The variation exhibited between samples, E_s^2, in Group II is larger than the combined estimate of the error variance $E_s^2 + 5E_e^2$, in both the total phosphorus and soluble phosphorus determinations. Although this sample variance is of the same magnitude for total nitrogen in Group II as in Table III of Group I, due to a larger mean square for error (Table VI), it gives a value capable of statistical manipulation. The sampling error, E_s^2, constitutes 36 per cent of the source of random variation, $E_s^2 + 5E_e^2$, (from Table VI, 4.39/12.22 x 100 = 36%).

The proportional variance of a treatment comparison is given by $\frac{E_s^2}{rs} + \frac{E_e^2}{r}$

From Table VI, if $E_s^2 \quad 5E_e^2 = 12.22$

and $E_s^2 = 4.39$

then $E_e^2 = \frac{12.22 - 4.39}{5}$

$E_e^2 = 1.57$

These values are used to calculate an estimate of the variance of treatment comparisons assuming different combinations of replication and sample numbers in Table VII.

Table VII - Estimates of Variance of Treatment Comparisons For r Replicates and s Samples

(r)	(s)	$\frac{E_s^2}{rs}$	$\frac{E_e^2}{r}$	$\frac{E_s^2}{rs} + \frac{E_e^2}{r}$
2	2	1.10	0.79	1.89
	5	0.44	0.79	1.23
	10	0.22	0.79	1.01
4	2	0.55	0.39	0.94
	5	0.22	0.39	0.61
	10	0.11	0.39	0.50
6	2	0.37	0.26	0.63
	5	0.15	0.26	0.41
	10	0.07	0.26	0.33
8	2	0.27	0.20	0.47
	5	0.11	0.20	0.31
	10	0.06	0.20	0.26

Assuming there is no change in the random variable it appears that six replicates employing five samples renders information superior to that offered by four replicates employing ten samples, effecting a saving of forty samples in the 2^2 design. Further, one may obtain an equivalent amount of information from eight replicates, with two samples from each plot, as suggested by estimates of variance of 0.47 and 0.50 respectively. However, there may be a practical limit to which replications may be increased, even with decreased sample numbers, Table VII. One problem would be the increased proportion of the plot area

utilized for border strips on experimental sites of limited size when replications are increased.

It was felt that this result on wuarter of the material available, in face of contradictory and variable results in Group I, eould not be accepted without reservation. Accordingly the data from Group I and Group II were pooled, making use of one half of the experiment. Since the chemical analyses on these two groups were conducted at different times, the differences observed between means for total phosphorus and total nitrogen as indicated in Appendix Tables 1, 2, and 3, did not preclude the possibility of a change in composition or technique. The Chi-square test for homogeneity of error variances outlined by Bartlett (3) was carried out on the total phosphorus, soluble phosphorus and total nitrogen data for both groups, Table VIII.

Table VIII - Chi-Square Test for Homogeneity of Error Variance.

Tissue Constituent	X^2		Probability
Total phosphorus	0.828	d.f. n-1=1	$P > 0.30 < 0.50$
Soluble Phosphorus	0.282		$P > 0.50 < 0.70$
Total nitrogen	1.245		$P > 0.20 < 0.30$

In all cases it was concluded that the error variances were drawn from the same population and that the group data could be pooled safely.

Tables IX and X indicate that the variation between samples within plots for the estimation of total and soluble phosphorus is excessively large. One is unable to make any observations concerning the number of samples and the replications required to reduce the estimate of the variance of treatment comparisons efficiently. No advantage was gained in this respect by pooling the data from Group I and Group II.

Table IX - Analysis of Variance of Total Phosphorus Data
2 Replicates x 4 Treatments x 10 Samples (code 100x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	79	930.39					
" -plots	7	219.71					
Replicates	1	7.87	7.87		7.09	10.13	34.12
Treatments	3	208.51	69.50		62.51	9.28	29.46
N	1	(160.60)	160.60		144.69	10.13	34.12
P	1	(17.02)	17.02		15.33	"	"
NP	1	(29.89)	28.89		26.93	"	"
Error	3	3.33	1.11	$E_s^2+10E_s^2$			
Between samples within plots	72	710.69	9.87	E_s^2			

Table X - Analysis of Variance of Soluble Phosphorus Data
2 Replicates x 4 Treatments x 10 Samples (code 100x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	79	488.62					
" -plots	7	87.60					
Replicates	1	3.12	3.12		1.18	10.13	34.12
Treatments	3	76.55	25.52		9.67	9.28	29.46
N	1	(66.25)	66.25		25.10	10.13	34.12
P	1	(5.10)	5.10		1.93	"	"
NP	1	(5.20)	5.20		1.97	"	"
Error	3	7.93	2.64	$E_s^2 + 10E_e^2$			
Between samples within plots	72	401.02	5.57	E_s^2			

Table XI - Analysis of Variance of Total Nitrogen Data
2 Replicates x 4 Treatments x 10 Samples (code 10x)

Source	D.F.	S.S.	M.S.	E.M.S.	F	.05	.01
Total-samples	79	686.44					
" -plots	7	276.78					
Replicates	1	0.02	0.02			10.13	34.12
Treatments	3	248.60	82.87		8.83	9.28	29.46
N	1	(210.93)	210.93		22.46	10.13	34.12
P	1	(3.74)	3.74		-----	"	"
NP	1	(33.93)	33.93		3.61	"	"
Error	3	28.16	9.39	$E_s^2 + 10E_e^2$			
Between samples within plots	72	409.66	5.69	E_s^2			

The information on nitrogen in Table XI indicates, that of the two groups represented in Tables III and VI, the variance for sampling in the second group so weights that in the first, that the estimated variance for sampling remains 60.6 per cent of the estimated error variance. Using the values for the sampling variable (E_s^2) and the random variable (E_e^2) obtained in Table XI, estimates of the variance of treatment comparisons for different replication (r) and sampling (s) values are given in Table XII. The $\frac{E_s^2}{rs} + \frac{E_e^2}{r}$ values calculated in this instance follow the same trend as the similar estimates afforded in Table VII.

$$\text{If } E_s^2 \quad E_s^2 = 9.39$$

$$\text{and} \quad E_s^2 = 5.69$$

$$\text{then} \quad E_e^2 = \frac{9.39 - 5.69}{10}$$

$$E_e^2 = 0.37$$

Table XII - Estimates of the Variance of Treatment Comparisons For r Replicates and s Samples.

(r)	(s)	$\frac{E_s^2}{rs}$	$\frac{E_e^2}{r}$	$\frac{E_s^2}{rs} + \frac{E_e^2}{r}$
2	2	1.42	0.19	1.61
	5	0.57	0.19	0.76
	10	0.29	0.19	0.48
4	2	0.71	0.09	0.80
	5	0.29	0.09	0.68
	10	0.14	0.09	0.38
6	2	0.47	0.06	0.53
	5	0.19	0.06	0.25
	10	0.10	0.06	0.16
8	2	0.36	0.05	0.41
	5	0.14	0.05	0.19
	10	0.07	0.05	0.12

It is apparent that there is a great deal of variation between individuals in this experiment. That this variation did not arise in the chemical determinations is suggested by the close agreement obtained between duplicate determinations on individual samples. Wisconsin No. 7 is an open pollinated variety of corn. It appears to exhibit variations of genetic origin which may limit its use for experimental work of this nature. This is true if the chemical composition of the leaf is directly or indirectly influenced by genetic factors. A third suggestion might be the existence of micro-variations in the availability of nutrients in the soil, sufficient to cause plant to plant variation in the corn row. It is felt that there is little evidence present to support or deny this possibility. Although a disparity appears to exist between the variations found in the phosphorus data and those in the nitrogen data, it must be pointed out that order comes to the latter through plot to plot variation included in the error variance, rather than through any reduction in variation between samples within plots.

It is to be noted that little attention has been given to the variability of plant tissues included in composite samples from groups of individual plants used for foliar analysis.

2. Leaf tissue analyses.

Composite samples were made up of 0.25 g. of each of

the individual leaf powders taken from ten plants per plot. These were used for the determination of total phosphorus, acetic acid-soluble phosphorus and total nitrogen. The complete data are reported in Appendix Tables 4, 6 and 8, the mean values from four replicates are presented in Table XIII.

Table XIII - Composition of Corn Leaf Tissue Determined on Composite Samples of 10 Individual Leaves.

Treatment		% Total P	% Soluble P	% Total N
n		0.259	0.157	2.75
p		0.251	0.145	2.42
np		0.276	0.165	2.93
Check		0.248	0.137	2.50
L.S.D.	0.05	0.025	0.011	0.24
	0.01	0.035	0.016	0.34

At the outset, several points on the presentation of the data are brought to the attention of the reader. The mean values for plots receiving different treatments are reported in the text. These tables furnish information relative to the actual data, along with a means of identifying statistically, differences between plot values. The analysis of variance tables, which indicate the effects of the different treatments and their degree of significance, and the individual values from which these tables are derived are recorded in the Appendix. Frequent reference will be made in the discussion to both the plot

values and the treatment effects.

The per cent content of total phosphorus in the leaf samples is highest from those plots which received nitrogen and phosphorus together. However, the analysis of variance in Appendix Table 5 indicates that the effect of the nitrogen application alone was significant in increasing the concentration of phosphorus in the corn leaf. The phosphorus application was without significant effect, as was the interaction of nitrogen and phosphorus applied together. Some response in the phosphorus content of the leaf to the effect of phosphorus fertilization was evidenced in the analysis of variance on the individual leaf data from two replicates, Table IX. However, this is the only place where the information suggests a significant response to superphosphate on the basis of the nitrogen and phosphorus analyses. Since the sampling variation was large, and analysis of the remaining leaf samples failed to render substantiating data, this observation will not be enlarged upon. On the other hand, the effect of the ammonium nitrate application on the level of leaf phosphorus was consistently significant throughout these experiments.

The fraction of the phosphorus soluble in 2% acetic acid exhibited a similar response to nitrogen fertilization as did the total phosphorus. It appeared to respond more to the

increase in phosphorus fertilizer applied than did the total component. Since the acetic acid-soluble phosphorus is a fraction of the total in the tissue, the ratio of these two estimates are of interest, Appendix Table 10. The mean values presented in Table XIV indicate the nature of the variation.

Table XIV - The Fraction of Total Phosphorus Soluble in 2% Acetic Acid

Treatment	Per Cent of Total
n	60.5
p	57.8
np	60.0
check	55.3

Analysis of variance of the transformed data (angle = arc sin $\sqrt{\text{percentage}}$) (37), as presented in Appendix Table 11, indicates that the effect of the nitrogen treatment on the solubility of the leaf phosphorus was highly significant.

The percentage of total nitrogen in the leaf tissue, Table XIII, was significantly higher on the plots receiving nitrogen alone or nitrogen in combination with phosphorus than on either the check or phosphorus plots. However, the effect of the nitrogen treatment alone was significant. In contrast the lowest nitrogen values occurred on plots which received phosphorus alone, although this effect did not achieve significance.

Correlation coefficients between total phosphorus and total nitrogen, and soluble phosphorus and total nitrogen were 0.751 and 0.787 respectively. Both were found to be highly significant (d.f. = 14) when compared to the required values (37) at the 5% and 1% levels of significance. Inspection of these coefficients indicates little difference in the degree of correlation between them.

If r is the correlation coefficient and r^2 is the coefficient of determination, a measure of the per cent of the total variation attributable to the two factors (13), then 62% of the total variation is considered in the comparison of the soluble phosphorus and total nitrogen figures. In the same manner 56% of the variation in the total phosphorus and total nitrogen values may be associated. Phosphorus fertilization did not increase the level of either phosphorus or nitrogen in the corn leaf, while ammonium nitrate applications appeared to increase the level of both. The nitrogen content of the leaf tissue appeared to vary independently of the phosphorus, which in turn appeared to be influenced by the nitrogen supply, as indicated by the correlations above.

These results differ, in part, from earlier work (42, 41) in which it was found that phosphorus fertilization was without apparent effect on yield or the level of nitrogen

in the tissue. However, in addition, these workers remarked that increased supplies of nitrogen and potash were without effect on the concentration of phosphorus in the sixth leaf of the corn plant. The results obtained in the present investigation agree with those of other workers (25, 5) who found that nitrogen fertilization did increase the level of phosphorus in the leaf. Bennett (5) attributed this increase to more vigorous root development or increased physiological activity in the plant resulting in increased phosphorus uptake. Krantz and Chandler (25) on the other hand found the phosphorus content of corn leaves was not appreciably increased by phosphorus applications, but was markedly affected by the level of soil phosphorus. Duley and Miller (11) found corn plants grown in sand cultures developed relatively large root systems at low supplies of nutrients. Root growth alone does not seem to offer an explanation for the increased uptake. The possibility of increased physiological activity or of increased availability of soil phosphorus on application of ammonium nitrate suggests the need for further study of phosphorus uptake.

Cation analyses of the leaf tissue undertaken in another project[x] may be considered here for the nitrogen x phosphorus experiment, Table XV.

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x The spectrophotometric analyses of cations in soil and plant tissue samples by Mr. D.C. MacKay, Graduate Assistant, Macdonald College, are gratefully acknowledged.

Table XV - Cation Analyses of Composite Leaf Samples From the Nitrogen x Phosphorus Experiment

Treatment		K	Ca	Mg
		(per cent of dry matter)		
n		1.77	0.59	0.26
p		1.96	0.60	0.26
np		2.02	0.62	0.25
check		1.61	0.59	0.24
L.S.D.	0.05	N.S.	N.S.	N.S.
	0.01			

Although the soil was placed under stress at this point by fairly heavy fertilization with nitrogen and phosphorus, there appeared to be little or no change in the concentration of potassium, calcium or magnesium in the leaf tissue. The results of the analysis of variance, presented in abbreviated form in Appendix Table 15 indicate no significant treatment effects on any of these three cation constituents in the leaf. From the results of some workers (42, 5), one might expect depressed levels of potassium in the leaf at high levels of nitrogen supply, in spite of a rather different result reported by Krantz and Chandler (25). Although the concentrations of the cations did not seem to change significantly, as sampled at the blossom stage, it is well to observe that there was a yield increase due to the effect of the ammonium nitrate application, Appendix Table 17, as obtained

at harvest time. This may indicate an increase in the total uptake of cations.

Tyner (41) listed the critical levels of nitrogen, phosphorus and potassium in the sixth leaf of corn at the blossom stage as 2.90%, 0.295% and 1.30% respectively. Potassium was the only member of the three to exceed the critical level consistently in this experiment. The only nitrogen concentrations in the leaf to equal the critical level were obtained on those plots which received ammonium nitrate and superphosphate together, Table XIII. The phosphorus data indicated the level of this constituent in the tissue fell short of the critical level under all treatments.

This information suggests that one might predict some yield response to nitrogen fertilizer, had a very definite response to increased phosphorus supply. It will be shown from the yield data that ammonium nitrate did increase the dry weight of the crop, but there was no response to 360 pounds of superphosphate. This discussion will be resumed in a later section.

3. Soil Analysis.

The dry, sieved samples of soil, composited from individual cores taken opposite each corn stalk selected in the experiment, were extracted for estimation of adsorbed phosphorus using the method of Bray (8). The mean values for four replicates

are presented in Table XVI.

Table XVI - Adsorbed Soil Phosphorus, Means of Four Replicates

Treatment	P p.p.m.
n	15.69
p	17.26
np	18.18
check	19.39

The mean values indicate a very slight trend towards decreasing supply under treatments different from that of the check plots. The heavy phosphorus supply, banded about one foot from the site of the soil sample found no expression in these results. The treatments, as indicated by the analysis of variance, Appendix Table 13, were without significant effect on the adsorbed phosphorus levels between plots. These levels are quite low, when compared to fractions of soil phosphorus termed "adsorbed" phosphorus by Bray and Dickman (7). They used 0.1 N., neutral ammonium fluoride to extract the most readily available forms of phosphorus, followed by extraction with 0.1 N ammonium fluoride in a 0.01 N HCl solution. For a number of soils containing an average of 15 p.p.m. of phosphorus in fraction 1, and 22 p.p.m. in fraction 2, they found good responses to superphosphate on corn, oats and legumes. The method of extraction used in the present investigation

utilized a later method (8) involving 0.03 N ammonium fluoride in 0.025 N HCl. The soils rated higher in phosphorus due to a smaller degree of response to superphosphate by Bray and Dickman (7) contained averages of 36 p.p.m. and 89 p.p.m. of phosphorus for fractions 1 and 2 described above.

4. Dry Matter Yield.

The stalks previously sampled were harvested and the ears separated from the husk. Stored for a week in a forced air drier, the plants were chopped, mixed and duplicate 500 gm. samples dried to constant weight. The ears were bagged, dried to prevent spoilage and stored. Later in the season these were returned to the drier and dried to constant weight.

Total dry matter weight for stalks and ears, and ears alone is presented for each plot in Appendix Table 16, with the appropriate analysis of variance tables, Appendix Tables 17 and 18.

The mean treatment values in Table XVII show that the differences are small.

The analysis of variance of the total dry matter figures indicate the nitrogen treatment alone increased yield. Inspection of the data suggests a depression in yield under high phosphorus fertilization, but this trend is not conclusive.

The variations observed in ear weight, harvested during the late milk or early dough stage, do not indicate a response to treatment.

Table XVII - Pounds of Dry Matter Per Ten Stalks.

Treatment		Total D.M.	Ears
n		9.34	3.83
p		8.02	3.29
np		9.70	3.76
check		8.60	3.60
L.S.D.	0.05	0.93	
	0.01	1.34	N.S.

The yield response was most highly correlated with the level of nitrogen found in the leaf tissues at the pollen shedding stage, Table XVIII. This was followed by the correlation with soluble phosphorus and lastly by the correlation with total phosphorus in the leaf tissue, in decreasing order of magnitude.

Table XVIII - Correlation Coefficients Between Yield and Tissue Constituents

Source	ryx	0.05 (d.f. = 14)	0.01
Yield and total N	0.738	0.497	0.623
" " soluble P	0.613	"	"
" " total P	0.567	"	"

The increase in yield due to nitrogen fertilization,

and the lack of response to phosphorus applications has been recorded in the past few years by other workers (42, 41, 25, 5).

Using data from the sixth leaf of the corn plant, Tyner (41) obtained correlation coefficients of 0.768 (d.f. = 103) and 0.850 (d.f. = 87) between total nitrogen and yield and total phosphorus and yield respectively. Bennett (5) obtained a higher correlation of 0.960 between yield response and increase in nitrogen content of the tissue, using the data from twenty experiments. Apparently this afforded twenty pairs of comparisons for the calculation of the correlation coefficient. Other workers (1) studying crop rotations found a correlation of 0.97 between total nitrogen content in the leaf and yield. No report was made of the degrees of freedom involved. The present correlation for 16 pairs of comparisons is lower than the figures quoted but still achieves high significance.

5. Field Observations.

The material in this experiment, planted with the field seeder, had a stand density in the row of 9,616 plants per acre, estimated from the 3,200 feet of row used in the experiment.

Growth and development were good. At pollen shedding no visual effects of the treatments were evident, although individual plant variation was obvious. At harvest time the

same was true. The ears were well filled and heavy, characteristic of the variety. The removal of the ear-node leaf did not appear to exert any adverse influence. Borer damage was very heavy in this area in 1952. As a result breakage and lodging of damaged plants took place before autumn. A count of this damage, expressed as the per cent of the plants broken or leaning per plot was made, Table XIX. Analysis of variance carried out on the transformed data, Appendix Table 20, showed no response to breakage or borer damage attributable to the fertilizer treatments.

Borer damage was probably responsible for most of the breakage included in these counts. However, Krantz and Chandler (25) found only a slight tendency for heavy nitrogen fertilization to increase lodging in corn, although marked yield increases were obtained.

Table XIX - Per Cent of Plants Lodged or Broken Per Plot

	Treatment			
Replications	n	p	np	check
1	13.3	13.3	8.7	17.5
2	13.6	8.5	10.2	21.7
3	6.7	15.2	14.0	2.8
4	12.5	20.8	7.1	4.7

Experiment II

The second experiment involved two rates of seeding with and without a side dressing of 75 pounds of nitrogen over a heavy uniform application of phosphorus. The stand densities on the resulting plots represented 14,500 and 29,040 plants per acre. This experiment, seeded ten days later than Experiment I, exhibited slower germination and seedling emergence. This retardation of growth carried through to harvest with a corresponding delay or lag in maturation.

Ten plants were sampled on dates representing the pre-pollen shedding, pollen shedding and post-pollen shedding stages. Composite samples of tissue made up from aliquots of individual leaves were analyzed as in Experiment I. These data are presented in Appendix Tables 21, 23 and 25.

1. Total phosphorus.

Table XX - Per Cent Total Phosphorus in the Leaf Tissue Means of Four Plots

Treatment	Stage of Sampling: Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	0.281	0.260	0.256
std.	0.237	0.218	0.209
n x std.	0.244	0.241	0.224
Check	0.259	0.242	0.257

L.S.D. for treatment means within one date	0.05...0.024 0.01...0.033
L.S.D. for dates within one treatment	0.05...0.020 0.01...0.027

In Table XX the total phosphorus in the leaf tissue was highest on the plots receiving the nitrogen treatment. This is in agreement with the results previously discussed. Due to the overall treatment with superphosphate the plots receiving nitrogen corresponded to the plots receiving nitrogen plus phosphorus in the first experiment. The second date of sampling, at pollen shedding, in Experiment II, corresponded to the same physiological stage as was sampled in Experiment I. Material from these plants shedding pollen showed a slight decrease in phosphorus content from the result reported in Table XIII for comparable treatments. It may be pointed out that the departure from 9,616 plants per acre to 14,520, as the normal stand density, renders this change reasonable due to increased competition.

The increase in stand density produced the most consistent and highly significant change in leaf phosphorus. On all three sampling dates the leaf tissue from those plots with the higher plant population gave the lowest values. The reduction in total leaf phosphorus from that of the check plots amounted to 0.022, 0.024 and 0.048 per cent for each of the three dates respectively. Comparison with L.S.D. values for treatment means within any one date indicate these differentes approach significance for the first sampling and are significant or highly significant for the second and third sampling dates.

The change in concentration with date was found to express highly significant linear regression, Table XXI. The check received a heavy uniform application of phosphorus. It was the only treatment to exhibit a significant drop in tissue concentration within the first week from the pre-pollen to the pollen shedding stage, and then a significant increase to almost the original level in the second week, from the pollen shedding to the post-pollen shedding stage. Inspection of Table XXVIII shows a continuous drop in the "adsorbed" soil phosphorus on these plots. The drop was slightly greater in the second week.

Table XXI - Comparison of the Regression Components of the Variation Between Dates in the Total P Data

Source	d.f.	S.S.	M.S.	F	.05	.01
Dates	2	30.47	15.24	8.24	3.20	5.10
Linear regression	1	27.20	27.20	14.70	4.26	7.82
Deviations	1	3.26	3.26	1.76	"	"
Error (b)	24	44.44	1.85	----	----	----

There is no indication of increased availability during the second week as reflected in the third tissue sampling, but translocation to the sites of reproduction at this stage may have masked the rate of uptake as evidenced by leaf content. This contention might be supported by Sayre's work (34) in which marked uptake and translocation occurred together during a period of heavy demand.

2. Acetic Acid Soluble Phosphorus.

The same trend is observable in the soluble phosphorus values, Table XXII, as was remarked above. The effect of the nitrogen application was significant in increasing the level of soluble phosphorus, while the effect of stand density afforded a highly significant decrease in this component.

Table XXII - Per Cent Soluble Phosphorus in the Leaf Tissue Means of Four Plots

Treatment	Stage of Sampling		
	Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	0.165	0.142	0.141
std.	0.131	0.116	0.113
n x std.	0.143	0.124	0.124
check	0.150	0.126	0.149
L.S.D. for treatment means within one date			0.05...0.020 0.01...0.027
L.S.D. for dates within one treatment			0.05...0.020 0.01...0.027

Since the soluble phosphorus determinations bear some relation to the total phosphorus content, a measure of the acetic acid-soluble form of this element present in the tissue, the per cent solubility of the total phosphorus, was calculated. These data, with transformed values, are given in Appendix Table 27. The mean values for four replications

recorded in Table XXIII show that the portion of the phosphorus soluble in 2% acetic acid varied with the date of sampling.

Table XXIII - Per Cent of the Total Phosphorus Soluble in 2% Acetic Acid

Treatment	Stage of Sampling		
	Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	58.9	55.0	55.0
std.	55.4	53.0	54.1
n x std.	58.7	51.6	55.9
check	57.8	51.8	58.1

Analysis of variance on the transformed data, Appendix Table 28, indicate no significant change in solubility due to treatment effects. However, variation due to date exhibited a significant quadratic response, the solubility of the total phosphorus decreasing from the first sampling date to the second, and then increasing again at the post-pollen shedding stage. The response to fertilizer treatment at this point is in agreement with Experiment I. The effects of phosphorus alone, and the interaction effect of nitrogen x phosphorus on the solubility of the phosphorus constituent in the leaf were not significant in either experiment. These values are compared in Table XXIV.

Table XXIV - Comparison of the Per Cent Solubility of Total Phosphorus in Two Experiments

Experiment I 9,500 plants/ac		Experiment II 14,500 plants/ac			
			Date		
Treatment	Treatment	1	2[x]	3	
p	57.8[x] check (basal P)	57.8	55.0	55.0	
np	60.0 n " "	58.9	51.8	58.1	

x--pollen shedding stage

In this table the mean values for the second date, when compared with the values for the samples taken at the same physiological stage in Experiment I (Table XIV), exhibit a change not readily explainable. The solubility of the total phosphorus in the leaf at the pollen shedding stage in the first experiment appears to be more closely related to the solubility percentages at the pre-pollen shedding stage in the second experiment. There was only a three day difference between these two dates of sampling, but there was about a ten day difference in the stage of development of the plants. Al though there is a difference in the plant populations it is suggested that the effects of environmental factors at any given date may be important.

3. Total Nitrogen.

Table XXV - Per Cent Total Nitrogen in the Leaf Tissue Means of Four Plots

Treatment	Stage of Sampling		
	Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	2.83	2.68	2.74
std.	2.33	2.17	2.12
n x std.	2.54	2.52	2.47
check	2.51	2.45	2.41
L.S.D. for treatment means within one date			0.05...0.23 0.01...0.32
L.S.D. for dates within one treatment			0.05...0.14 0.01...0.19

The data for total nitrogen determinations given in Appendix Table 25 are summarized in Table XXV. The application of ammonium nitrate significantly increased the per cent of total nitrogen in the tissue. On the other hand the effect of heavier stand gave a highly significant decrease in nitrogen content. The values on the plots receiving the latter treatment singly were the lowest encountered in the experiment. It is apparent that the effect of the interaction is no more than the additive effect of each singly, when applied over a heavy uniform phosphorus application, as indicated by the analysis of variance, Appendix Table 26.

Table XXVI - Comparison of the Regression Components of the Variation Between Dates in the Total N Data

Source	d.f.	S.S.	M.S.	F	.05	.01
Dates	2	12.73	6.37	6.92	3.20	5.10
Linear regression	1	11.25	11.28	12.26	4.26	7.82
Deviations	1	1.45	1.45	1.51	"	"
Error (b)	24	22.07	0.92	----	-----	----

Analysis of variance indicates a highly significant change in leaf composition with respect to nitrogen over the two week period, Table XXVI. This is not expressed by the L.S.D. figures for dates within one treatment, Table XXV.

Correlation coefficients were calculated for the three leaf constituents determined, Appendix Table 29. A highly significant correlation of 0.833 (d.f. = 46) was found to exist between the levels of total nitrogen and total phosphorus. The coefficient of determination is 0.694, so nearly 70% of the variation in these two leaf constituents appears to be associated. The correlation coefficient between the phosphorus soluble in 2% acetic acid and the total nitrogen is 0.683. Although this is also significant (d.f. = 46), the coefficient of determination is only 0.467. In this experiment, unlike Experiment I, the total phosphorus values appear to be more

closely correlated with nitrogen content in the tissue, than are the figures for the acid-soluble fraction of the phosphorus.

4. Total Cation Analyses.

Table XXVII - Per Cent Cation Content of the Corn Leaf Tissue Means of Four Plots

Treatment	%K	%Ca	%Mg
Pre-pollen Shedding.			
n	2.06	0.48	0.24
std.	1.89	0.47	0.29
n x std.	2.01	0.51	0.27
check	1.96	0.49	0.26
Pollen Shedding.			
n	1.80	0.65	0.28
std.	1.71	0.65	0.31
n x std.	1.80	0.55	0.28
check	1.83	0.69	0.32
Post-pollen Shedding.			
n	1.57	0.58	0.26
std.	1.53	0.53	0.30
n x std.	1.50	0.57	0.31
check	1.60	0.54	0.27
Treatment means within one sampling date:			
L.S.D. 0.05	N.S.	N.S.	N.S.
0.01			
Between dates within one treatment:			
L.S.D. 0.05	0.184	0.035	0.047
0.01	0.253	0.047	0.064

The cation contents[x] of the tissue samples are given in Table XXVII. The individual plot values and appropriate analyses of variance may be found in Appendix Tables 30 - 33.

No significant change is evident in the cation contents which is attributable to the treatments applied in Experiment II. Previous work (42, 5) indicated that applications of nitrogenous fertilizers tended to decrease the uptake of potassium. However, Krantz and Chandler (25) found that nitrogen applications resulted in increased concentration of potassium as well as phosphorus on soils which were supplied with these elements. The levels for potassium found in the corn leaf are above Tyner's critical level of 1.30 per cent (41). Consequently there does not appear to be evidence of an inadequate supply of potash on this soil under the rates of crop production dealt with in these experiments.

A highly significant difference between the cation contents at different physiological stages appears to exist. The potassium content decreased uniformly in the ear-node leaf from the pre-pollen to the post-pollen shedding stage. The calcium

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x The spectrophotometric analyses of cations in soil and plant tissue samples by Mr. D. C. MacKay, Graduate Assistant, Macdonald College, are gratefully acknowledged.

response is not linear, but showed a significant increase from the first date to the second, after which it decreased in the next week. An exception is noted in the case of the combined nitrogen and heavy stand treatment, in which case the accumulation rises steadily. This may indicate differences in the degree of maturity of the leaf. Between the first and second sampling dates accumulation of calcium took place. Cessation of cell growth, with fixation of calcium in the tissue may have been completed after pollen shedding. The subsequent decrease might be attributed to translocation of still mobile forms of those cations which remained to younger growing points. Magnesium exhibits a less definite trend. There was no response to the effects of the nitrogen application or the heavy rate of seeding, singly or in combination, Appendix Table 33, but a significant change did occur between the dates of sampling. Like calcium, the period between the first two sampling dates gave a general increase from the lowest to the highest concentrations of magnesium in the corn leaf. The second week showed a slight lowering effect on concentration, changes which were most marked in the results from the check plots. The plots which were under the combined stress of heavy nitrogen and heavy plant populations showed a small but steady increase in magnesium content of the leaf tissue. This increase approaches but does not achieve significance in this experiment.

The analyses of variance, Appendix Tables 31 to 33, indicate highly significant variation between blocks for potassium and magnesium content of the tissue. The variation between replications was significant for the calcium data on the same material. This may indicate, as suggested by DeLong et al (10), that the experimental blocks were not laid out on a soil of uniform type. Reference to the soil map, Fig. 1, confirms the possibility of the influence of adjacent soils whose boundaries are not critically defined on the map.

5. Soil Analysis.

Soil samples were collected in mid-row at the time of tissue sampling as before. These were treated in the same manner, and analyzed for Bray adsorbed phosphorus as in Experiment I. Table XXVIII presents the mean values of treatments from data in Appendix Table 34, the analysis of variance is presented in Appendix Table 35.

Inspection of the data, Appendix Table 34, indicates that there is a great deal of variation between plots. Some of this variation may be attributed to the nature of this phosphorus fraction in the soil, to the variation in sampling and to the variation between extractions with the ammonium fluoride solution. Analysis of variance on these figures indicates no significant effect on the level of readily available soil phosphorus

due to treatment with nitrogen or heavy seeding. There was a highly significant change due to the date of sampling over the two week period, with a drop in the amount of phosphorus being shown between samples taken at the pre-pollen shedding stage, and those collected a week after pollen shedding. Although the analysis of variance, Appendix Table 35, indicates a significant effect attributable to the sampling date in spite of the plot to plot variation, it is felt that this variability cannot be neglected in the interpretation.

Table XXVIII - Adsorbed Phosphorus and Total Cation Contents of Soil Samples

Treatment	Adsorbed P p.p.m.	K	Ca (m.e./100 grams)	Mg
Pre-pollen Shedding.				
n	21.46	-----	----	----
std.	18.81	-----	-----	-----
n x std.	19.25	-----	-----	-----
check	21.64	-----	-----	-----
Pollen shedding				
n	21.30	0.201	6.05	1.52
std.	18.90	0.189	7.50	1.78
n x std.	20.47	0.261	6.59	1.76
check	19.87	0.219	7.30	2.04
Post-pollen Shedding.				
n	21.60	-----	----	-----
std.	16.69	-----	----	-----
n x std.	17.81	-----	----	-----
check	17.88	-----	----	-----
Between treatment means within one sampling date				
L.S.D. 0.05	N.S.	N.S.	N.S.	N.S.
0.01				
Between dates within one treatment				
L.S.D. 0.05	1.79	-----	----	-----
0.01	2.43			

The indication that there is a change in the readily available phosphorus from week to week, coupled with the lack of difference due to the treatments suggests some other factor may have exerted considerable influence on the availability of the soil phosphorus. Accordingly Meterological data recorded for August, 1952, by the Horticulture Department, Macdonald College, is presented in Appendix Table 37. It is of interest that 2.46 inches of rain fell between July 15 and August 5. These were moderate rains, recorded on nine different days, ranging from 0.03 to 0.42 inches each, with one exception when 0.88 inches of rain were recorded. During the period following the first sampling 3.58 inches of rain fell over four different days. Mid-week between the first and second samplings, 1.28 inches of precipitation was recorded for Aug. 16; similarily between the second and third dates 1.53 inches of rainfall was recorded on August 21. It is possible that the changes observed in the level of adsorbed phosphorus in the soil might reflect changes resulting from periodic heavy rainfall prior to the last two sampling dates.

The information on the exchangeable cations in the soil is limited. However, from determinations carried out on samples taken at the pollen shedding stage, there appear to be no significant differences due to the effects of the treatments.

6. Dry Matter Yield.

Table XXIX - Pounds of Dry Matter Per Ten Stalks Used For Tissue Sampling.

Treatment	Stage of Sampling		
	Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	7.31	7.81	7.24
std.	4.85	4.75	4.82
n x std.	5.07	5.25	4.54
check	6.63	6.90	7.19

L.S.D. for treatment means within one date 0.05...1.23
0.01...1.72

N.S.D. for dates within one treatment.

The later date of seeding, and the higher plant populations reduced the growth of individual plants in this experiment, as compared to Experiment I. The recorded yields per ten plants are presented in Table XXIX. This record is the dry weight of stalks and immature ears harvested in September, 103 days after seeding. The ears were in the late milk stage.

Heavy fertilization with ammonium nitrate did not increase the yield over the check to any significant degree. Due to crowding, increasing the stand density to 29,500 plants per acre reduced the average weight of the individual plants in all cases. This order is reversed, Table XXX, when the yields per plot are converted to yields on an acre basis.

Table XXX - Dry Matter Yield Per Ten Stalks Converted To Tons Per Acre

Treatment	Stage of Sampling		
	Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	5.30	5.67	5.26
std.	6.90	6.89	6.88
n x std.	7.36	7.62	6.59
check	4.81	5.01	5.22

L.S.D. for treatment means within one date 0.05...1.37
0.01...1.92

N.S.D. for dates within one treatment

The increase in yield per acre was highly significant on the plots supporting the greater stand densities. In this comparison no appreciable increase could be attributed to the effect of the fertilizer treatment, Appendix Table 39. It is interesting to note that a positive yield response was obtained in Experiment I to an application of nitrogen fertilizer. It appears that failure to obtain a significantly large yield response in this experiment, under conditions of heavier stand and a relatively high basal application of phosphorus, would suggest that some factor relative to plant competition was limiting growth. This might be a lack of water during dry periods with a subsequent decrease in the utilization of carbohydrate and growth. The nitrogen content, below the critical level

(41) in this experiment, was increased by the nitrogen application to a significant degree.

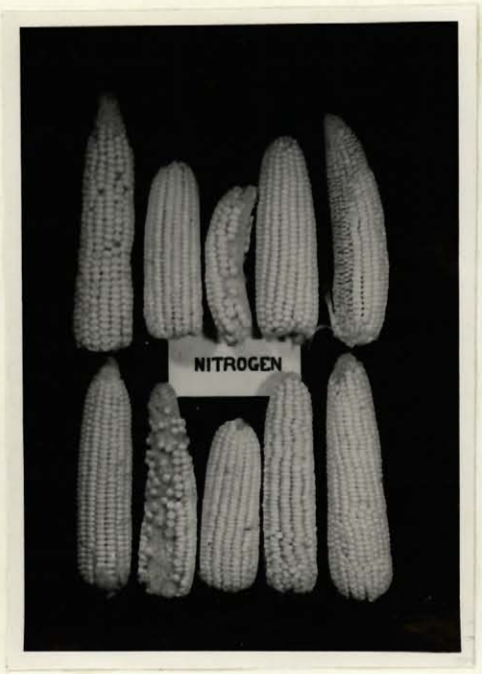
Contrary to results in Experiment I, the dry weight of the immature ears was quite variable. In the former case large size and excellent filling took place on all treatments, with no significant response to any. In Experiment II, ear development was less satisfactory. Random samples of 10 ears from each treatment were chosen and photographed, Fig. 4. The check (a) gave the best formed ears, although one stalk sampled did not yield an ear at all. The remaining treatments show lack of proper filling and curving of the nubbins toward the stalk, which was also the barren side. This is marked on the plots which supported the heavier population. A similar tendency, though less marked, is shown under nitrogen fertilization. The ear weights in Appendix Table 38 are summarized in Table XXXI. The only difference in ear weight were decreases under heavy stand as suggested

Table XXXI - Ear Weight in Pounds of Dry Matter From Ten Stalks.

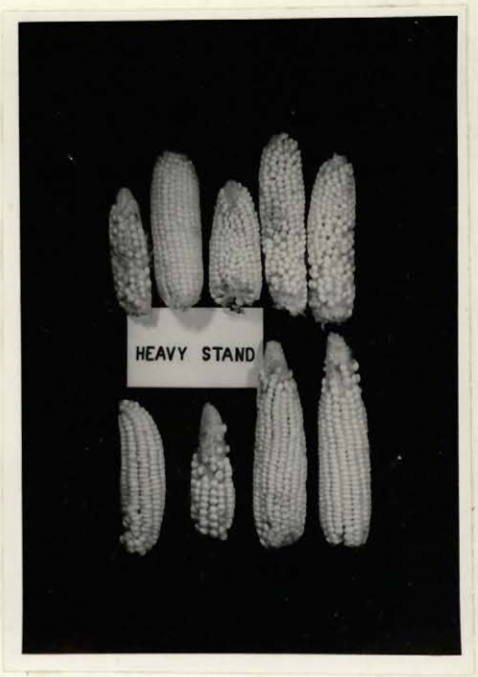
Treatment	Stage of Sampling		
	Pre-pollen Shedding	Pollen Shedding	Post-pollen Shedding
n	3.05	2.70	2.51
std.	1.47	1.30	1.33
n x std.	1.37	1.73	1.34
check	1.94	2.28	2.29

L.S.D. for treatment means within one date 0.05...0.70
0.01...0.97

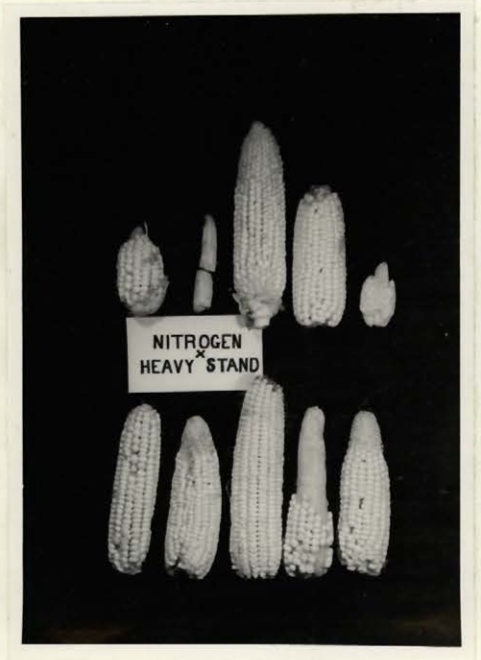
N.S.D. for dates within one treatment.



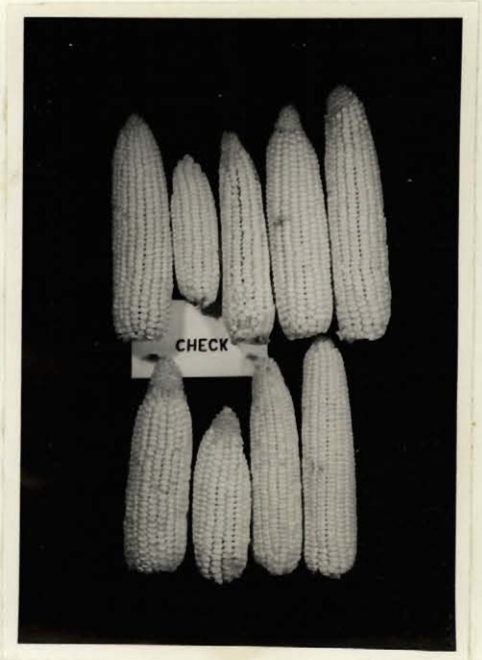
(a) Nitrogen Treatment



(b) Heavy Stand Treatment



(c) Nitrogen x Heavy Stand Treatment



(d) Check Plot

Fig. 4 Photographs of Representative Lots of Ears From Plants Selected for Chemical Analyses, Experiment II.

above. Although this response was highly significant, the variation attributable to the effect of the nitrogen treatment was not significant, Appendix Table 40.

Table XXXII - Correlation Coefficients Between Yield and Nutrient Constituents

Date	Total P		Soluble P		Total N	
	r	z	r	z	r	z
1	0.795	1.085	0.733	0.935	0.762	1.001
2	0.541	0.606	0.781	1.048	0.709	0.885
3	0.756	0.987	0.625	0.733	0.500	0.549

"r" ..... 0.05 (d.f. = 14) 0.497
0.01 (" ") 0.623

L.S.D. 0.05 for $z = 0.768$ ($Sd_z 2 = 0.392$, d.f. $= \infty$)
$z_1 - z_2$

Individual correlation coefficients were calculated between yield and the phosphorus and nitrogen contents of the leaves. As may be seen in Table XXXII, these were significant or highly significant for all dates, as determined by Fisher's table of correlation coefficients ($n - 2 = 14$). These were also transformed to the z quantity as outlined by Fisher, after Snedecor (37). No significant differences are apparemt between them so it is assumed that the samples were drawn from the same population on the different dates.

7. The Critical Percentages of Nutrients in the Tissue.

Tyner (41) selected levels of nutrient constituents in the leaf at the bloom stage, above which he considered any response to further application of the element as fertilizer was unlikely. These values were 2.90%, 0.295% and 1.30% for nitrogen, phosphorus and potassium respectively. In Experiment I the values obtained at the bloom stage approached or exceeded the critical value for nitrogen on the plots which received nitrogen. They approached but never achieved the level of phosphorus designated as critical. The mean plot values for potassium equalled or exceeded the critical values without exception. In Experiment II, at the corresponding bloom stage, the per cent values of nitrogen, phosphorus and potassium were uniformly lower on the plots which received similar treatments (as in Table XXIV). The total phosphorus and total nitrogen values do not reach the critical level, whereas the potassium values exceed the level suggested as separating luxury consumption from the zone of poverty adjustment (29, 41).

The levels of phosphorus found in the leaf tissue suggest that it rather than nitrogen or potassium is the limiting factor. However, there was no marked response to 360 pounds of superphosphate per acre applied in these experiments, in either tissue content or yield. Since the phosphorus values were below

the critical level of 0.295% in the corn leaf, the fate of the phosphorus fertilizer is of interest. Further work suggested by this would involve assessment of the phosphorus-fixing capacity of Chicot fine sandy loam in an effort to establish the degree to which soluble applied phosphates remain available.

Increased supplies of nitrogen, however, appeared to increase the nitrogen content, the phosphorus content and the yield. There was not a simultaneous response in the cation content. Further study is suggested on the differential effects of ammonia and nitrate ions, as sources of nitrogen, on the uptake of phosphorus and its content in the corn leaf. This further suggests the possibility of examining the effects of foliar application of part of the nitrogen supply, as against the convential application of nitrogen fertilizer on the uptake of phosphorus.

Unfortunately no measure of relative plant growth was obtained at the time of sampling. Yield data collected a month or more following tissue sampling may be correlated with leaf analysis for prediction purposes. However, it is too far removed to serve as a measure of the relative, quantitative uptake of nutrients. In Wisconsin 7 corn, variation in the size of individual plants was apparent and might conceivably affect the percentage composition of the leaf tissue. Glover (15)

found that plants at adequate levels of nitrogen and phosphorus nutrition in sand culture ceased to take up nitrogen some days before those growing on lower nitrogen supplies in the presence of adequate phosphorus. The latter, by reason of their continued uptake of nitrogen, were able to attain yield weights as high as those of the apparently better nourished plants.

8. Field Observations.

The appearance of the corn in Experiment II was quite different to that in Experiment I. Due to the later date of seeding and the increased stand density these plants did not reach a great height, and early assumed a somewhat stunted appearance. The stalks were more slender, the leaves smaller than this variety seeded at a rate of 9,500 plants per acre.

Following the side dressing with ammonium nitrate on July 15, 1952, no noticable effect was apparent. By pollen shedding time, some indication, in the darker green colour of the foliage, marked the plots which had received nitrogen. The most marked disparity existed between the plots with 14,500 plants per acre receiving nitrogen and those carrying double that population but without additional nitrogen. By harvest time these symptoms became more marked, with loss of the lower leaves and "firing" of the upper ones under conditions of crowding and low nitrogen supply. A reddish colour marked the stalks of some

of the corn plants during the stages following flowering. At first this was thought to indicate a potassium deficiency, since it characterized those plants receiving extra nitrogen, and those on plots densely seeded without additional nitrogen. This colour was less intense on the widely spaced plants, and did not occur at all in Experiment I. There was no further evidence to identify this coloration as a potassium deficiency.

9. The Selection of Sampling Dates.

If it is assumed that the concentration of a major nutrient constituent increases in the tissue with increasing yield throughout the range of poverty adjustment (29), one may study the correlations between individual leaf constituents and yield. The data in Table XXXII show that the correlation between yield and total phosphorus is highest prior to or a week after pollen shedding. On the other hand the correlations between soluble phosphorus and total nitrogen and yield are highest for the first two sampling dates. The correlation coefficients existing at the pollen shedding stage in both experiments are very similar. Although no significant differences in correlation coefficients, as shown by the "z" test, are apparent between dates, the highest correlations between total phosphorus and total nitrogen, and yield existed one week prior to pollen shedding. Unfortunately this is a physiological stage difficult to define. At the more recognizable stage of pollen shedding,the acetic acid-

soluble phosphorus fraction and total nitrogen gave correlation coefficients representing 50 per cent or more associated variation. On the third sampling date the correlation between total nitrogen and yield falls off. From these observations it is concluded that the pollen shedding stage appears to be the most suitable for the study of both the phosphorus and nitrogen contents of the leaf as related to yield.

The three dates compared in Experiment II are August 11, 18, and 25. The second date was based on an estimated 50% of the plants shedding pollen from the upper half of the tassel, the remainder having shed pollen the previous day, or bore only the tip of the terminal spike with dehiscing anthers. The estimation of the sampling date, one week prior to pollen shedding is more difficult. To duplicate it with certainty would require experience and familiarity with the growth characteristics of the variety of corn involved. Accordingly, a suggestion is made concerning the use of accumulated heat units or degree days for prediction purposes.

Table XXXIII - Accumulated Degree Days Above 50°F

	Experiment I	Experiment II
Accumulated degree days, seeding to pollen shedding stage	1325.0	1392.0
Accumulated degree days, seeding to seven days prior to pollen shed.	1198.0	1251.0
Seven day accumulation	127.0	141.0
ten year average per day for period	19.5	20.0
	July 28-Aug.4)	(Aug. 6-13)
Estimated number of days required to accumulate observed no. of degree days	6.5	7.1

Accordingly (Table XXXIII) degree days, estimated from temperatures above 50°F were studied (21). For the 1952 season it may be seen that choosing the accumulated degree days to one week prior to pollen shedding would have permitted the prediction of the pollen shedding date 6.5 to 7.1 days later, respectively. Since two dates of seeding, and three rates of population density are involved this approach offers some encouragement. Insufficient data is available on the Wisconsin 7 variety to establish the year to year variation. It is suggested that stages based on accumulated degree days might be of assistance in defining stages not readily recognized physiologically.

SUMMARY AND CONCLUSIONS

The present is a study of the chemical composition of the leaf tissue of Wisconsin 7, an open pollinated variety, with respect to nitrogen and phosphorus when the supply of these elements is augmented by fertilization. Cation analyses and yield data are also recorded.

The four rows of Wisconsin 7 used as the male parent in seed production at the Provincial Seed Farm were utilized The sites chosen were on Chicot sandy loam which had received a basal application of 600 pounds of 4-12-6 per acre prior to seeding. This fertilization was part of the practice involving a rotation of corn, grain, grain, clover, timothy and grain. Experiment I received an additional 76 pounds of nitrogen and 72 pounds of phosphorus alone and in combination as the treatments. The stand density was about 9,600 plants per acre, samples being taken at the pollen shedding stage only. Experiment II received the phosphorus tested above in addition to the 4-12-6 as a basal application. The treatments involved seedings at the rates of 14,500 and 29,000 plants per acre, with and without additional nitrogen. The plots were subdivided to provide three dates of sampling, a week apart, before and after the pollen shedding stage.

Chemical analyses were carried out on the leaf powders from the individual leaves of ten normal competitive plants. The ear node leaf was severed, and dried separately at moderate temperatures for four to five hours.

Soil samples were collected at each sampling date, mid-row, adjacent to the selected plants.

Relative yield data were obtained at harvest time when the sampled plants were harvested, the immature ears being dried separately.

The first portion of the work involved chemical analysis of two groups of individual leaves from Experiment I. It was found in all cases for the different phosphorus data, involving both total and acetic acid soluble estimates, that the variation between samples within plots exceeded the total variation used for the estimate of the error variance. Only in the case of nitrogen does a reasonable relationship, capable of statistical manipulation, exist between the two.

Due to the inherent variation observed in the material, it was concluded that the corn variety Wisconsin No. 7 was unsuitable for experimental work of this nature. It is pointed out that such variation may be masked by the practice of compositing samples from a random selection of individuals. These

results also contribute information towards more efficient sampling of the material available with respect to the number of samples and the number of replications.

Chemical analyses for diagnostic purposes were conducted on composite samples made up by combining aliquots from individual leaf powders.

Without exception the highest tissue concentrations of total phosphorus, acetic acid soluble phosphorus and total nitrogen were recorded for the plots which received nitrogen and phosphorus together. A significant correlation existed between these constituents and the yields. When the treatment effects are separated out in the analysis of variance, it appears that nitrogen alone had a significant or highly significant effect on the increase in the level of phosphorus in the leaf as well as the level of nitrogen and total yield. The solubility of the total phosphorus was also increased by the nitrogen treatment. The only significant effect observed for phosphorus applications in this work appeared in the increase in the acetic acid soluble fraction for Experiment I.

With reference to Tyner's work, the highest percentage of nitrogen recorded equals his critical percentage of 2.90. The phosphorus values remained much below the critical level

of 0.295%, whereas the potash values exceeded the value deemed critical for this element.

The levels of nitrogen, phosphorus and potassium in the second experiment were similar to those of the first. Between the dates of sampling highly significant linear regressions existed for these constituents from the first sampling date to the third. The solubility of the phosphorus changed significantly, decreasing from the first to the second date, and then rising again. The effect of nitrogen on the leaf constituents were as before. The effect of stand however, served to decrease the levels of all constituents markedly. The weight of individual plants was similarly decreased by crowding, with poor filling of the ears, but the total yield per acre was significantly increased.

Although the soil was placed under stress by additional nitrogen fertilization and a heavier than normal rate of seeding, no variation due to treatment was noted in the level of the cations in the leaf tissue. This was particularly true of the potash data, which level in the tissue other workers found might be depressed by high levels of nitrogen. Potassium levels in the tissue decreased progressively with sampling stage, while the calcium content increased to the pollen shedding stage and then exhibited a slight decrease. Magnesium also increased at this stage, but

remained relatively constant during the following week.

The correlation coefficients between yield and tissue constituents were significant or highly significant. For prediction purposes, one week prior to pollen shedding gave the highest correlations with yield. Unfortunately that is a stage not readily defined in the field. At the more easily recognized pollen shedding stage, soluble phosphorus and total nitrogen determinations were most satisfactory. The last sampling date, although definable, offered a decreased correlation with nitrogen.

In conclusion it may be stated that the open pollinated variety, Wisconsin No. 7, exhibited variation between individual plants which rendered its use unsuitable for experimental work of this kind. This may be the result of genetic variation in the variety.

Applications of ammonium nitrate as a side-dressing increased yield in Experiment I, as well as the concentration of nitrogen and phosphorus in the leaf tissue in both experiments.

The cation level in the tissue showed no response to these treatments.

For prediction purposes, the percentages of nitrogen and phosphorus were more closely correlated with yield at the pollen shedding stage or a week earlier.

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APPENDIX TABLES

Appendix Table 1 - The Per Cent Total Phosphorus in Individual Leaves From Two Replications

Treatments			
Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
Replicate 1			
		Group 1	
0.298	0.247	0.247	0.289
0.304	0.297	0.267	0.320
0.254	0.285	0.285	0.326
0.306	0.257	0.338	0.295
0.274	0.314	0.244	0.316
		Group 2	
0.220	0.205	0.215	0.275
0.282	0.218	0.190	0.295
0.249	0.252	0.231	0.252
0.272	0.228	0.249	0.279
0.262	0.245	0.256	0.275
Replicate 3			
		Group 1	
0.287	0.200	0.316	0.344
0.301	0.254	0.264	0.308
0.281	0.298	0.268	0.256
0.289	0.211	0.254	0.305
0.285	0.289	0.298	0.358
		Group 2	
0.262	0.235	0.262	0.320
0.262	0.272	0.262	0.235
0.287	0.249	0.235	0.279
0.262	0.262	0.235	0.252
0.252	0.287	0.249	0.339

Appendix Table 2 - The Per Cent Soluble Phosphorus in Individual Leaves From Two Replications

Experiment I

Treatments			
Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
Replicate 1			
		Group 1	
0.158	0.133	0.128	0.162
0.178	0.138	0.141	0.188
0.127	0.154	0.171	0.187
0.178	0.146	0.201	0.178
0.146	0.181	0.130	0.183
		Group 2	
0.125	0.127	0.127	0.142
0.182	0.137	0.089	0.158
0.167	0.142	0.123	0.165
0.158	0.140	0.137	0.167
0.153	0.137	0.121	0.147
Replicate 3			
		Group 1	
0.143	0.101	0.178	0.213
0.176	0.115	0.131	0.160
0.144	0.151	0.149	0.133
0.152	0.111	0.144	0.150
0.136	0.162	0.169	0.198
		Group 2	
0.158	0.150	0.158	0.200
0.153	0.190	0.171	0.123
0.179	0.140	0.129	0.147
0.175	0.153	0.137	0.131
0.158	0.175	0.150	0.217

Appendix Table 3 - The Per Cent Total Nitrogen in Individual Leaves From Two Replicates

Experiment I

Treatments			
Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
Replicate 1			
		Group 1	
2.80	2.37	2.54	3.36
2.93	3.05	2.61	2.95
2.80	2.59	2.41	3.07
2.96	2.63	3.35	3.12
2.96	2.84	2.83	3.34
		Group 2	
2.64	2.47	1.91	3.03
2.94	2.15	2.57	3.22
2.52	2.57	2.54	3.13
2.94	2.43	2.43	3.08
2.57	2.80	2.57	2.68
Replicate 3			
		Group 1	
2.92	2.22	3.13	3.15
3.07	2.37	2.59	3.36
2.88	2.59	2.56	2.69
2.91	2.30	2.63	3.08
2.95	2.85	2.97	3.21
		Group 2	
2.94	2.47	2.52	3.03
2.75	2.45	2.68	2.47
2.75	2.57	2.73	2.61
2.57	2.82	2.66	2.66
3.03	2.66	2.71	3.06

Appendix Table 4 - The Per Cent Total Phosphorus in Composite Samples of Ten Leaves

Experiment I

Replicate	Treatment			
	Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
1	0.262	0.239	0.256	0.282
2	0.245	0.279	0.260	0.275
3	0.262	0.241	0.249	0.291
4	0.268	0.245	0.228	0.256

Appendix Table 5 - The Analysis of Variance of the Total Phosphorus Data (x 100)

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Calculated	F Values .05	F Values .01
Total	15	45.02	----	----	----	-----
Replicates	3	5.25	1.75	0.75	3.86	6.99
Treatments	3	18.73	6.24	2.67	"	"
N (1)		(12.96)	12.96	5.54	5.12	10.56
P (1)		(3.80)	3.80	1.62	"	"
NP (1)		(1.96)	1.96	0.84	"	"
Error	9	21.04	2.34	----	----	-----

Appendix Table 6 - The Per Cent Soluble Phosphorus in Composite Samples of Ten Leaves

Experiment I

Replicate	Treatment			
	Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
1	0.158	0.137	0.137	0.171
2	0.158	0.162	0.140	0.165
3	0.158	0.142	0.140	0.175
4	0.153	0.140	0.131	0.150

Appendix Table 7 - The Analysis of Variance of the Soluble Phosphorus Data (x 100)

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	26.80	-----	----	----	----
Replicates	3	3.65	1.21	2.42	3.86	6.99
Treatments	3	18.60	6.20	12.40	"	"
N	(1)	(15.80)	15.80	31.60	5.12	10.56
P	(1)	(2.81)	2.81	5.62	"	"
NP	(1)	-----	----	-----	"	"
Error	9	4.54	0.50			

Appendix Table 8 - The Per Cent Total Nitrogen in Composite Samples of Ten Leaves

Experiment I

Replicate	Treatment			
	Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
1	2.752	2.193	2.519	3.079
2	2.659	2.519	2.589	2.916
3	2.752	2.403	2.612	2.822
4	2.846	2.566	2.286	2.916

Appendix Table 9 - The Analysis of Variance of the Total Nitrogen Data (x 10)

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	86.32	-----	-----	----	----
Replicates	3	0.25	0.08	-----	3.86	6.99
Treatments	3	66.20	22.07	9.99	"	"
N (1)	(58.33)		58.33	26.39	5.12	10.56
P (1)	(1.00)		1.00	0.45	"	"
NP (1)	(6.88)		6.88	3.11	"	"
Error	9	19,86	2.21	-----	----	----

Appendix Table 10 - The Per Cent of Total Phosphorus Soluble in 2% Acetic Acid with Corresponding Transformed Values (angle = arc Sin $\sqrt{\%}$)

Replicate	Treatment							
	Nitrogen		Phosphorus		Check		Nitrogen x Phosphorus	
	%	angle	%	angle	%	angle	%	angle
1	60	50.8	57	49.0	54	47.3	61	51.4
2	65	53.7	58	49.6	54	47.3	60	50.8
3	60	50.8	59	50.2	56	48.5	60	50.8
4	57	49.0	57	49.0	57	49.0	59	50.2

Appendix Table 11 - The Analysis of Variance of the Transformed Percentages of Total Phosphorus Soluble in 2% Acetic Acid

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	38.86	———	-----	-----	-----
Replicates	3	2.62	0.87	-----	-----	-----
Treatments	3	23.58	7.86	5.58	3.86	6.99
N (1)	(19.36)		19.36	13.73	5.12	10.56
P (1)	(1.32)		1.32	-----	"	"
NP (1)	(2.89)		2.89	1.34	"	"
Error	9	12.66	1.41	-----	-----	-----

Appendix Table 12 - Bray "Adsorbed" Phosphorus Determined on Composite Samples of Soil, P.P.M.

Experiment I

Replicates	Treatment			
	Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
1	14.56	17.79	20.49	12.53
2	19.06	19.34	16.06	20.49
3	11.33	16.54	19.92	15.59
4	17.79	15.36	21.07	24.11

Appendix Table 13 - The Analysis of Variance of the Adsorbed Phosphorus Data

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	168.54	-----	----	----	----
Replicates	3	39.53	13.18	1.11	3.86	6.99
Treatments	3	29.22	9.74	----	"	"
N (1)	(7.71)		7.71	----	5.12	10.56
P (1)	(0.14)		0.14	----	"	"
NP (1)	(21.37)		21.37	1.80	"	"
Error	9	99.79	11.88	----	----	----

Appendix Table 14 - Cation Analyses of Composite Leaf Tissue Samples (Ten Each) from N x P Experiment

Replicates	K	Ca	Mg
		(per Cent of dry matter)	
Nitrogen treatment			
1	1.31	0.58	0.24
2	1.73	0.61	0.27
3	1.97	0.49	0.25
4	2.06	0.66	0.28
Phosphorus treatment			
1	1.95	0.59	0.27
2	1.87	0.65	0.30
3	1.96	0.63	0.27
4	2.06	0.52	0.20
Nitrogen x phosphorus treatment			
1	2.07	0.63	0.27
2	2.08	0.63	0.25
3	2.08	0.59	0.22
4	1.83	0.63	0.26
Check plot			
1	1.30	0.58	0.24
2	1.66	0.64	0.28
3	1.49	0.44	0.18
4	1.98	0.69	0.27

Appendix Table 15 - Calculated "F" Values From the Analyses of Variance

Source	K	Ca	Mg	Required for Significance	
				.05	.01
Blocks	1.63	1.72	1.0	3.86	6.99
Treatments	2.97	2.35	0.3	"	"

Appendix Table 16 - Pounds of Dry Matter per Ten Stalks on An Oven-Dry Basis

Experiment I

Replicates	Treatment			
	Nitrogen	Phosphorus	Check	Nitrogen x phosphorus
Total Dry Matter				
1	9.82	9.05	8.57	9.21
2	8.92	7.99	8.76	9.72
3	10.02	7.45	9.29	10.68
4	8.60	7.57	7.78	9.19
Ear Weight Alone				
1	3.75	4.02	3.57	3.52
2	2.99	3.09	3.61	3.77
3	4.69	2.63	3.64	4.02
4	3.87	3.43	3.59	3.72

Appendix Table 17 - Analysis of Variance of Total Yield Weight

Experiment I

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	12.47	----	----	----	-----
Replicates	3	2.64	0.88	----	----	-----
N	1	5.88	5.88	17.82	5.12	10.56
P	1	0.05	0.05	0.15	"	"
NP	1	0.89	0.89	2.70	"	"
Error	9	3.01	0.33	----	----	----

Appendix Table 18 - Analysis of Variance of Ear Weight

Experiment I

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	3.79	----	----	----	-----
Replicates	3	0.37	0.12	0.39	----	-----
N	1	0.47	0.47	1.52	5.12	10.56
P	1	0.14	0.14	0.45	"	"
NP	1	0.06	0.06	0.19	"	"
Error	9	2.75	0.31	----	----	-----

Appendix Table 19 - The Per Cent of the Plants Broken or Lodged at Harvest with Corresponding Transformed Values (angle = arc Sin $\sqrt{\%}$)

Experiment I

Replicate	Treatment							
	Nitrogen		Phosphorus		Check		Nitrogen x phosphorus	
	%	angle	%	angle	%	angle	%	angle
1	13.3	21.4	13.3	21.4	17.5	24.7	8.7	17.2
2	13.6	21.6	8.5	17.0	21.7	27.8	10.2	18.6
3	6.7	15.0	15.2	23.0	2.8	9.6	14.0	22.0
4	12.5	20.7	20.8	27.1	4.7	12.5	7.1	15.5

Appendix Table 20 - Analysis of Variance of the Transformed Data for Breakage at Harvest

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Total	15	380.27	-----	----	----	----
Replicates	3	41.72	13.91	----	3.86	6.99
Treatments	3	35.49	11.83	----	----	----
Error	9	303.06	33.67	----	----	----

Appendix Table 21 - The Per Cent Total Phosphorus in Composite Tissue Samples of Ten Leaves

Experiment II

Replicates	Treatment			
	Nitrogen	Stand	Check	Nitrogen x stand
Pre-pollen shedding				
1	0.279	0.215	0.279	0.223
2	0.279	0.220	0.235	0.228
3	0.249	0.252	0.268	0.262
4	0.315	0.260	0.252	0.262
Pollen shedding				
1	0.272	0.215	0.241	0.241
2	0.253	0.194	0.228	0.223
3	0.262	0.235	0.249	0.252
4	0.252	0.228	0.249	0.249
Post-pollen shedding				
1	0.249	0.200	0.252	0.218
2	0.262	0.183	0.231	0.228
3	0.256	0.235	0.295	0.228
4	0.256	0.218	0.249	0.228

Appendix Table 22 - Analysis of Variance of the Total Phosphorus Data (coded x100)

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	208.01	-----	-----	----	----
Replicates	3	41.12	13.71	3.49	3.86	6.99
Treatments	3	131.52	43.84	11.16	"	"
N (1)	(23.66)		23.66	6.02	5.12	10.56
Std (1)	(107.70)		107.70	27.41	"	"
N x Std (1)	(0.15)		0.15	-----	"	"
Error (a)	9	35.37	3.93	-----	----	-----
Differences Within Main Plots						
Dates	2	30.47	15.24	8.24	3.20	5.10
Linear Regression (1)	(27.20)		27.20	14.70	4.26	7.82
Deviations (1)	(3.26)		3.26	1.76	"	"
Date x Treat	6	15.58	2.60	1.41	2.30	3.22
Error (b)	24	35.37	3.93	----	----	----
Grand Total	47	298.50	-----	----	----	----

Appendix Table 23 - The Per Cent Soluble Phosphorus in Composite Tissue Samples of Ten Leaves

Experiment II

Replicate	Treatment			
	Nitrogen	Stand	Check	Nitrogen x stand
Pre-pollen shedding				
1	0.158	0.131	0.186	0.137
2	0.158	0.111	0.127	0.131
3	0.157	0.129	0.142	0.153
4	0.186	0.153	0.145	0.150
Pollen shedding				
1	0.142	0.131	0.186	0.137
2	0.145	0.104	0.110	0.123
3	0.147	0.127	0.131	0.131
4	0.134	0.120	0.134	0.123
Post-pollen shedding				
1	0.127	0.103	0.131	0.123
2	0.142	0.098	0.158	0.115
3	0.147	0.137	0.176	0.127
4	0.147	0.115	0.129	0.129

Appendix Table 24 - Analysis of Variance of the Soluble Phosphorus Data (coded x100)

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	86.90	-----	-----	----	----
Replicates	3	16.04	5.35	4.05	3.86	6.99
Treatments	3	58.99	19.66	14.89	"	"
N (1)	(9.81)		9.81	7.43	5.12	10.56
Std (1)	(49.00)		49.00	37.12	"	"
N x Std (1)	(0.18)		0.18	-----	"	"
Error (a)	9	11.87	1.32	-----	----	-----
Differences Within Main Plots						
Dates	2	36.20	18.10	9.48	3.20	5.10
Linear regression (1)	(19.53)		19.53	10.23	4.26	7.82
Deviations (1)	(16.67)		16.67	8.73	"	"
Date x Treat	6	10.47	1.75	0.92	2.30	3.22
Error (b)	24	45.79	1.91	----	----	----
Grand Total	47	179.36	----	----	----	----

Appendix Table 25 - The Per Cent Total Nitrogen in Composite Tissue Samples of Ten Leaves

Experiment II

Replicate	Treatment			
	Nitrogen	Stand	Check	Nitrogen x stand
Pre-pollen shedding				
1	2.96	2.17	2.78	2.54
2	2.96	2.10	2.22	2.45
3	2.61	2.45	2.52	2.52
4	2.80	2.59	2.50	2.66
Pollen shedding				
1	2.66	2.05	2.43	2.43
2	2.68	2.02	2.27	2.50
3	2.73	2.38	2.54	2.52
4	2.66	2.24	2.57	2.61
Post-pollen shedding				
1	2.73	2.12	2.50	2.33
2	2.75	1.82	2.08	2.41
3	2.73	2.33	2.52	2.47
4	2.75	2.19	2.54	2.66

Appendix Table 26 - Analysis of Variance of the Total Nitrogen Data (coded x10)

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	252.82	------	-----	----	----
Replicates	3	29.89	10.00	2.15	3.86	6.99
Treatments	3	180.98	60.33	12.95	"	"
N	(1)	(107.70)	107.70	23.11	5.12	10.56
Std.	(1)	(73.26)	73.26	15.72	"	"
N x Std.	(1)	(0.02)	0.02	------	"	"
Error (a)	9	41.95	4.66	------	----	-----
Differences Within Main Plots						
Dates	2	12.73	6.37	6.92	3.20	5.10
Linear regression	(1)	(11.28)	11.28	12.26	4.26	7.82
Deviations	(1)	(1.45)	1.45	1.51	"	"
Dates x Treat.	6	4.47	0.75	0.78	2.30	3.22
Error (b)	24	22.07	0.92	----	----	----
Grand Total	47	292.09	----	----	----	----

Appendix Table 27 - The Per Cent of Total Phosphorus Soluble in 2% Acetic Acid with the Corresponding Transformed Values (angle = arc Sin $\sqrt{\%}$)

Replicate	Treatment							
	Nitrogen		Stand		Check		Nitrogen x stand	
	%	angle	%	angle	%	angle	%	angle
Pre-pollen shedding								
1	56.6	48.8	60.9	51.3	66.7	54.8	61.4	51.6
2	56.6	48.8	50.5	45.3	54.0	47.3	57.5	49.3
3	63.1	52.6	51.2	45.7	53.0	46.7	58.4	49.8
4	59.1	50.2	58.9	50.1	57.5	49.3	57.3	49.2
Pollen shedding								
1	52.2	46.3	51.6	45.9	52.7	46.6	49.8	44.9
2	57.5	49.3	53.6	47.1	48.2	44.0	55.2	48.0
3	56.0	48.5	54.0	47.3	52.6	46.5	52.0	46.2
4	53.2	46.8	52.6	46.5	53.8	47.2	49.4	44.7
Post-pollen shedding								
1	51.0	45.6	51.5	45.9	52.0	46.2	56.4	48.7
2	54.2	47.4	53.6	47.1	68.4	55.8	50.4	45.2
3	57.4	49.3	58.3	49.8	60.0	50.8	60.0	50.8
4	57.4	49.3	52.8	46.6	51.8	46.0	56.6	48.8

Appendix Table 28 - Analysis of Variance of the Transformed Solubility Data

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	F Values .05	F Values .01
Differences Between Main Plots						
Total	15	39.46	-----	-----	-----	-----
Replicates	3	4.96	1.65	-----	3.86	6.99
Treatments	3	10.17	3.39	1.26	"	"
N (1)	(2.21)		2.21	-----	5.12	10.56
Std. (1)	(6.98)		6.98	2.59	"	"
N x Std. (1)	(0.99)		0.99	-----	"	"
Error (a)	9	24.32	2.70	-----	-----	-----
Differences Within Main Plots						
Dates	2	64.32	32.16	4.50	3.20	5.10
Linear regression (1)	(9.57)		9.57	1.34	4.26	7.82
Deviations (1)	(54.75)		54.75	7.66	"	"
Date x Treat	6	19.91	3.32	-----	2.30	3.22
Error (b)	24	171.65	7.15	-----	----	----
Grand Total	47	295.34	----	-----	----	-----

Appendix Table 29 - Correlation Coefficients Between Phosphorus and Nitrogen Constituents

Experiment II

Factors	ryx	Significant ryx, d.f. = 46	
		0.05	0.01
Total Phosphorus and Total N	0.833	0.288	0.372
Soluble Phosphorus and Total N	0.683	0.288	0.372

Appendix Table 30 - The Per Cent Cationic Content of Corn Leaf Tissue (Composites of Ten Subsamples)

Treatment & Replicate	Stage of Sampling: Pre-pollen shedding K	Ca	Mg	Pollen shedding K	Ca	Mg	Post-pollen shedding K	Ca	Mg
Nitrogen									
1	1.97	0.53	0.25	1.72	0.62	0.29	1.46	0.62	0.31
2	1.74	0.44	0.25	1.69	0.79	0.29	1.50	0.65	0.26
3	2.13	0.47	0.25	1.85	0.64	0.30	1.60	0.58	0.26
4	2.40	0.46	0.20	1.92	0.55	0.22	1.72	0.46	0.20
Stand									
1	1.97	0.49	0.39	1.72	0.58	0.30	1.40	0.49	0.32
2	1.59	0.49	0.34	1.47	0.74	0.40	1.33	0.53	0.35
3	2.12	0.46	0.78	2.02	0.61	0.22	1.87	0.50	0.22
4	2.10	0.45	0.31	1.63	0.66	0.31	1.50	0.59	0.31
Check									
1	2.13	0.48	0.24	1.87	0.90	0.38	1.70	0.55	0.26
2	1.66	0.56	0.35	1.55	0.63	0.33	1.33	0.65	0.35
3	1.96	0.44	0.22	1.89	0.72	0.33	1.69	0.44	0.26
4	2.08	0.47	0.24	2.00	0.51	0.23	1.68	0.51	0.21
N x Stnd.									
1	1.65	0.53	0.36	2.02	0.54	0.32	1.60	0.54	0.27
2	1.71	0.49	0.31	1.62	0.61	0.38	1.33	0.58	0.43
3	2.17	0.49	0.21	1.80	0.57	0.23	1.54	0.58	0.22
4	2.50	0.53	0.21	1.76	0.48	0.20	1.77	0.51	0.21

Appendix Table 31 - Analysis of Variance of the Potash Data

Experiment II

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Difference Between Main Plots						
Total	15	1.456298	--------	-----	----	----
Replicates	3	1.075905	0.358635	10.38	3.86	6.99
Treatments	3	0.069573	0.023191	0.70	"	"
Error (a)	9	0.310809	0.034534	-----	----	----
Differences Within Main Plots						
Total	32	2.033400	--------	-----	----	----
Dates	2	1.491816	0.745908	48.42	3.55	6.01
Dates x treat	6	0.047730	0.007955	0.50	2.66	4.01
" x blocks	6	0.216546	0.036091	2.34	"	"
Error (b)	18	0.277308	0.015406	-----	----	----
Grand Total	47	3.489698	--------	-----	----	----

Appendix Table 32 - Analysis of Variance of the Calcium Data

Experiment II

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	0.009433	--------	----	----	----
Replicates	3	0.004870	0.001623	3.74	3.86	6.99
Treatments	3	0.000656	0.000219	0.40	"	"
Error (a)	9	0.003907	0.000434	----	----	----
Differences Within Main Plots						
Total	32	0.033900	--------	----	----	----
Dates	2	0.017599	0.008800	16.37	3.55	6.01
Dates x treat	6	0.004696	0.000783	1.40	2.66	4.01
Dates x blocks	6	0.001927	0.000321	0.50	"	"
Error (b)	18	0.009678	0.000538	----	----	----
Grand Total	47	0.043333	--------	----	----	----

Appendix Table 33 - Analysis of Variance of the Magnesium Data

Experiment II

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	0.15027	-------	----	----	----
Replicates	3	0.08912	0.02971	5.37	3.86	6.99
Treatments	3	0.01140	0.00380	0.69	"	"
Error (a)	9	0.04975	0.00553	----	----	----
Differences Within Main Plots						
Total	32	0.03580	-------	----	----	----
Dates	2	0.00768	0.00384	3.84	3.55	6.01
Dates x treat	6	0.00609	0.00102	1.02	2.66	4.01
Dates x blocks	6	0.00412	0.00069	0.69	"	"
Error (b)	18	0.01791	0.00100	----	----	----
Grand Total	47	0.18607	-------	----	----	----

Appendix Table 34 - Bray "Adsorbed" Phosphorus Determined on Composite Samples of Soil, P.P.M.

Experiment II

Replicate	Treatment			
	Nitrogen	Stand	Check	Nitrogen x stand
Pre-pollen shedding				
1	11.52	13.15	28.41	10.58
2	30.02	19.34	18.83	18.83
3	13.03	26.92	13.15	21.07
4	31.28	15.82	26.17	26.52
Pollen shedding				
1	16.78	11.33	14.90	16.54
2	24.80	15.82	16.54	9.62
3	14.01	27.67	15.36	22.50
4	29.62	20.78	32.66	32.20
Post-pollen shedding				
1	17.79	8.54	14.45	13.79
2	23.13	15.36	16.78	12.53
3	17.79	28.41	14.45	16.92
4	27.67	14.45	25.83	28.01

Appendix Table 35 - Analysis of Variance of the 'Adsorbed' Phosphorus Data

Experiment II.

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	1,791.33	-------	-----	----	----
Replicates	3	770.36	256.78	2.43	3.86	6.99
Treatments	3	70.59	23.53	-----	"	"
Error (a)	9	950.38	105.58	-----	----	----
Differences Within Main Plots						
Dates	2	30.73	15.37	10.18	3.20	5.10
Dates x treat	6	21.98	7.33	4.85	2.30	3.22
Error (b)	24	36.18	1.51	-----	----	----
Grand Total	47	1,879.86	-------	-----	----	----
Linear Regression on Dates	1	25.81	25.81	17.09	4.26	7.82
Deviations	1	4.91	4.91	3.25	"	"

Appendix Table 36 - Exchangeable Cations in the Soil

Experiment II

Pollen Shedding Stage

Plot	K	Ca	Mg
		(m.e./100 gm.)	
Nitrogen			
1	0.180	8.85	2.10
2	0.179	4.50	1.30
3	0.204	6.45	1.95
4	0.239	4.40	0.72
Stand			
1	0.170	8.30	1.97
2	0.180	8.80	2.40
3	0.200	5.30	0.76
4	0.204	7.60	2.00
Check			
1	0.190	8.70	2.60
2	0.193	7.50	2.60
3	0.268	8.20	1.94
4	0.224	4.80	1.00
Nitrogen x Stand			
1	0.263	8.55	2.45
2	0.189	8.95	2.92
3	0.233	4.45	0.80
4	0.360	4.40	0.86

Appendix Table 37 - Rainfall Recorded in Inches at Macdonald College During July and August, 1952.

Day	July Precipitation		August Precipitation	
	a.m.	p.m.	a.m.	p.m.
4	0.09	0.33		0.37
5				0.88
8			(Aug. 8, Pollen shedding, Exp. I)	
9	0.53	0.18		
10	0.89	2.58		
11				0.35
12			(Aug. 11 - 12, first sampling, Exp.II)	
16			1.28	
18			(Aug. 18, second sampling, Exp. II)	
19		0.03		
20	0.19			
21		0.18	1.53	
22		0.13		0.42
25			(Aug. 25, third sampling, Exp. II)	
26	0.22			
29		0.42	0.09	
31		0.04		

Appendix Table 38 - Pounds of Dry Matter per Ten Stalks on an Oven-Dry Basis

Experiment II

Replicates	Treatment			
	Nitrogen	Stand	Check	Nitrogen x stand
Total Dry Matter				
Pre-pollen shedding				
1	9.16	4.40	7.93	4.08
2	7.11	4.01	6.43	3.97
3	5.69	4.89	5.90	5.67
4	7.25	6.09	6.24	6.55
Pollen shedding				
1	8.28	4.79	6.56	4.56
2	8.50	4.19	6.80	5.41
3	7.92	4.77	6.53	5.29
4	6.53	5.25	7.70	5.72
Post-pollen shedding				
1	7.72	4.79	7.21	5.17
2	7.49	4.42	6.98	4.43
3	7.19	4.51	7.49	3.93
4	6.57	5.56	7.09	4.61
Ear Weight Alone				
Pre-pollen shedding				
1	4.71	1.21	2.25	1.10
2	3.04	1.37	2.30	1.31
3	1.95	1.34	1.48	1.81
4	2.50	1.95	1.73	1.27
Pollen shedding				
1	2.83	1.09	2.40	1.74
2	3.16	1.21	2.23	1.95
3	2.67	1.01	2.23	1.89
4	2.13	1.88	2.27	1.33
Post-pollen shedding				
1	2.66	1.34	2.33	1.73
2	2.79	1.22	2.25	1.43
3	2.30	1.16	2.05	0.83
4	2.29	1.61	2.54	1.38

Appendix Table 39 - Analysis of Variance of the Total Dry Matter Data (coded 10x)

Experiment II

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	7,633.05	-----	-----	-----	-----
Replicates	3	221.68	73.89	0.76	3.86	6.99
Treatments	3	6,541.39	2,180.46	22.56	"	"
N (1)	(142.49)		142.49	1.47	5.12	10.56
Std (1)	(6,350.30)		6,350.30	65.70	"	"
N x Std (1)	(48.60)		48.60	0.50	"	"
Error (a)	9	869.98	96.66	-----	-----	-----
Differences Within Main Plots						
Dates	2	52.21	26.11	-----	3.20	5.10
Date x Treat	6	200.53	33.42	-----	2.30	3.22
Error (b)	24	1,179.52	49.15	-----	----	----
Grand Total	47	9,065.31	-----	-----	----	----

Appendix Table 40 - Analysis of Variance of the Ear Weight Data (coded 10x)

Experiment II

Source	Degrees of Freedom	Sums of Squares	Variance	F Values Estimated	.05	.01
Differences Between Main Plots						
Total	15	1,888.12	------	----	-----	----
Replicates	3	101.01	33.67	1.08	3.86	6.99
Treatments	3	1,505.15	501.72	16.01	"	"
N (1)		(145.26)	145.26	4.64	5.12	10.56
Std (1)		(1,294.80)	1,294.80	41.33	"	"
N x Std (1)		(65.10)	65.10	2.07	"	"
Error (a)	9	281.96	31.33	-----	----	----
Differences Within Main Plots						
Date	2	14.43	7.22	-----	3.20	5.10
Date x Treat	6	121.06	20.18	1.32	2.30	3.22
Error (b)	24	366.34	15.26	-----	----	----
Grand Total	47	2,389.95	-----	-----	----	----