A STUDY OF

THE EFFECT OF FERTILIZERS ON THE COMPOSITION AND THE RATE OF UPTAKE OF NUTRIENTS BY SUGAR BEETS

A THESIS

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1. INTRODUCTION

During the past four years extensive experiments with the use of Commercial Fertilizers have been conducted throughout Western Canada. The results from these experiments have shown that remarkable results have been obtained from the use of Triple Superphosphate (0--4--0) and Ammonium Phosphate (10--48--0) when the fertilizer was drilled in with the seed.

In addition to the experiments with Triple Superphosphate and Ammonium Phosphate, Ellis[21] in 1929, started the Junior Co-Operative Fertilizer Trials, in which Nitrogen, Phosphate, and Potash were used alone and in all possible combinations. This experiment has now been continued for three years and the results obtained on the Red River Valley soils are summarized in Table No. 1. The beneficial effects derived from the use of phosphate have not been confined to soils low in phosphorus which has given rise to the theory that the increases that have been obtained with the fertilizers used are due to the fact that the soils of Western Canada have a temporary deficiency of available phosphorus during the early period of growth, even though many of the soils show a satisfactory total phosphorus content. This lack of available supply early in the season has been attributed to the relatively cold conditions of the soil in the spring which inhibit the normal liberation of available phosphate. Pierre and Parker[56] in discussing the availa-

bility of inorganic and organic phosphorus suggest conclusions which support this theory, from experiments in which they found that when the inorganic phosphorus was separated from the organic, plants readily absorbed the inorganic, but absorbed only small traces of the organic. They state:

> "The unavailability of the organic phosphate does not "mean that such phosphate may not be made available to "the plant by biological agencies within the soil. It "is probable that in all soils organic phosphates are "being decomposed and the phosphorus is being made "available by bacterial action".

It has been observed generally in Manitoba that increased yields have not been obtained when fertiliser was broadcasted on the surface, but only when drilled in the row in contact with the seed. This would suggest the problem is not that of a deficient soil, but simply one of providing a small quantity of available phosphorus to provide the nutrients required during the early period of plant growth when the above mentioned temporary deficiency occurs. Mitchell[48] in Saskatchewan showed a significant correlation between the increase in yield from phosphorus treated plots when the fertiliser was drilled in with the seed, and the content of available phosphorus in untreated soils. He states that where the available phosphorus is below 20 p.p.m. increases in yield from phosphate application may be expected. The advantage of drilling in fertiliser with the seed was observed by

Duley[20] at Kansas, who found that much better results were obtained from superphosphate when drilled in with the seed than by applying broadcast. However, his experiments show a substantial increase in plots where the fertiliser was broadcasted when compared with the control plots receiving no treatment.

Table No. 1

Summary of Fertiliser Trials with Wheat

Average Yield per Acre of Fertiliser Trials at Various Points on Red River Valley Soils, 1929--1930--1931

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Symbol	1929		1930		1931	
	Avg. Yield of all plots in Pounds per Acre	Avg. Yield in per cent of Mean	Avg. Yield of all plots in Pounds per Acre	Avg. Yield in per cent of Mean	Avg. Yield of all plots in Pounds per Acre	Avg. Yield in per cent of Mean
N.P.K.	29.5+	114.08	26.00-	116.07	25.3-	117.53
N.P.	29.4	114.49	26.31	116.61	25.2	116.66
P.	27.3	106.45	23.47	101.50	22.9	106.45
P.K.	27.1	106.79	23.26	100.46	25.6	109.23
A.	24.4	95.30	23.26	100.46	20.59	95.50
N.K.	24.1	93.97	22.24	96.05	19.52	90.54
K.	22.9	89.37	21.43	92.54	18.60	86.27
N.	23.2	90.59	20.78	89.72	19.22	89.15
C.	22.9	89.37	20.79	89.77	19.10	88.59
Standard Error	.715	2.79	2.31	9.96	.674	3.12

+ Each yield is the average of 20 records (10 points in duplicate.)
* Each yield is the average of 22 records (11 points in duplicate.)
- Each yield is the average of 10 records (5 points in duplicate.)

Statement of Problem:

The present study was undertaken to determine the rate of intake of nutrients by wheat plants when various fertilizers were drilled in close to the seed, in comparison with unfertilized plants, and to use the relative rate of intake by the plants as an index of availability of nutrients early in growth. This entailed the determination of the nitrogen, phosphate and potash content of the plants at various stages of growth as affected by the fertilizer treatments.

Literature Review:

Many different experiments have been conducted in order to determine the amounts of plant food nutrients in the soil by means of the plant, such as the seedling methods of Neubauer[51,52] and of Ames and Gerdel[6]; and the chemical methods of Hoffer[39]. Numerous other workers have used the analysis of plants as a guide to the available nutrients in the soil and the effect on the composition of the plants when different fertilizer ingredients were supplied. Salter and Ames[57] have given a fairly complete review of the work on this problem. Gilbert and Kerdan[32] report that in general the current concentration of mineral nutrients in the solution of crop plants correlated directly with the application of those nutrients as chemical fertilizers. They suggest further that the current mineral nutrient content of the plant solution be considered as an index of fertilizer needs. Alway, Shaw and Methley[1] have shown that the phosphorus content of hay, straw,

and grains, when grown on phosphate hungry peats, was increased markedly by the application of phosphate fertiliser. The percentage in straw was increased several hundred per cent; in hays 20 to 50 per cent; and in grain 10 to 80 per cent. Hartwell and Pember[37] using an application of Nitrogen, Phosphorus and Potash in pot experiments found that the lowest percentage of an element in the plants occurred when that element was withheld from the fertiliser applied. Hartwell[36] points out that crops differ so very widely as to their response that they must be grouped according to their response to each of the fertiliser ingredients. Parker[53], and Parker and Pierre[54] report results from experiments growing plants in culture solutions of varying concentrations of phosphate. They showed that increasing concentrations of phosphate in plants were observed with an increasing concentration of phosphate in the culture mentioned. Mather[47] and Malcomb[35] report increased relative quantities of phosphorus in hays when subjected to applications of phosphate fertilisers. Ames and Katsuta[4] found that with an application of Rock phosphate the per cent phosphate in the plants was increased. Brown[14] showed that with an application of superphosphate an increase of as much as 60 per cent was noted in phosphorus content of the pastures and also that in 11 out of 12 comparisons the addition of potash increased the potassium content of the herbage. Hunter[49] in an experiment to determine the fertiliser requirement of sugar beets main-

tains that the soil is to be considered deficient in phosphorus if the ratio of phosphoric acid to nitrogen in beet leaves from nitrogen treated plots is greater than 5:1. If the ratio is less than 20:7 on the potash and phosphorus treated plots the soil is deficient in nitrogen. Jordan[40] points out that the proportion of phosphoric acid to the growth of dry matter increased with the increase in availability of phosphate used for fertilization. McCool[45] and McCool and Weldon[46] found that by an application of mineral nutrients to the soil the percentage of those elements in the expressed plant sap was substantially increased. They also found that if an element is a deciding limiting factor, it permits excess concentration of other elements in the plants. MacHaggart[44] showed that the application of any fertilizer to legumes with the exception of gypsum, resulted in an increased nitrogen content of the plants. Phosphorus, in general, gave the largest increases.

The work on the potassium content of plants as an index of soil fertility has also been very extensive. Bartholomew[7] at Arkansas found that the potassium content of plants was increased by an application of barnyard manure. Bartholomew and Jansson[10,9] show that when the soil contains a sufficient supply of potash, plants normally will absorb large quantities early in growth and when potash fertilizers are added to deficient soils a marked increase in the concentration of potassium in the plants will result. Bartholomew and

Janssen[11] show that when plants were grown in culture solutions with potash supplied, an increase in the per cent potash of the plants occurred. Trapp[26] reports that a high correlation exists between the active potash lost from the soil in cropping and the potash content of the crops grown. Ames and Gordel[5] found that the application of potash stimulated the growth of wheat seedlings and the potash content of corn plants grown beyond the seedling stage in undiluted soil varied consistently with the available supply in the soil. Goldewski[30] reporting the results of four year's experiments with cereals shows that the potash content of the straw reached two per cent while the same crop grown on a deficient soil the potash content became as low as 0.5 per cent.

Considerable work has been done in studying the changes in composition of plants and the relative rate of intake of elements that take place throughout the growing period. Fonder[25] found a decided increase in the potash content of alfalfa as growth continued. Burd[16] states that the absorption of soil constituents by barley is characterised by three distinct periods. The first, ending about heading time, covers a period of progressively increasing rate of absorption. The second is noted by substantial losses of nitrogen and potassium. The third or the ripening period, is marked by a complete cessation in absorption and in most cases, an actual loss of constituents.

Bailey[7] has given a review of the literature on the growth and development of the wheat plant. Liebscher[42] states that the absorption of plant food in wheat proceeds more rapidly in proportion to dry matter formation during the early stages of growth. He points out that the proportion of nitrogen to dry matter decreases rapidly during the first three stages of growth. Gericke[29] concluded from growing wheat in nutrient solutions with and without phosphorus that the plant absorbed practically all the phosphorus early in growth. Geddes and Winkler[27] and Davidson and Le Clerc[19] show that the application of nitrogen depressed the percentage phosphorus in the grain. Lawes and Gilbert [41] found that the application of fertilizers had no consistent effect on the composition of wheat.

A great deal of work has been done on the effect of fertilizers on per cent protein in the grain. Geddes and Winkler[27] show that the application of phosphorus has a tendency to depress the protein content of wheat, but nitrogenous fertilizers increased the per cent protein. They found no effect resulting from the application of potash. Russell[56] found the protein content of barley was increased by the application of nitrogen and potash but phosphate fertilizers had no particular effect. Gericke[31] showed that for the production of a high protein wheat, nitrates should be applied at heading time as well as earlier. Reidig and Snyder[50] found that the yields and nitrogen content of wheat were both increased by the appli-

cation of available nitrogen. Within a certain range, increasing the quantity of nitrogen increased the per cent nitrogen. Gericke[20,30,31]; Headen[38]; Davidson[16]; Davidson and Le Clerc[17,18]; McIntyre[43]; Snyder[56,59]; and Ames[2] found that with the application of nitrogenous fertilizers the protein content of the wheat was increased and a further increase was generally obtained when nitrates were applied at heading time as well as earlier.

Ames and Bolts[3] found that the application of phorphorus caused a decrease in the per cent nitrogen in the grain.

The above references show that the composition of plants in many cases may be affected by availability of nutrients in the soil and in many cases that analysis of the plant has been used as an index of fertilizer needs in deficient soils.

In the present study an attempt was made to ascertain the extent to which the composition of wheat plants was affected when the fertilizer was drilled in close to the seed where only an apparent temporary deficiency may be present in the soil.

II. EXPERIMENTAL PROCEDURE

Field Method:

The plant material used for analysis was grown on a plot on the College farm in 1930. This plot was arranged according to the plan adopted by Ellis[21] in the Junior Co-Operative Fertilizer Trials in Manitoba. The plot consisted of replicated rod row tests which were laid out as in the following diagram:

Row 1			Guard row
	2 - 3	A.	--Ammonium Sulphate
Row 4			Guard row
	5 - 6	N.	--Sodium Nitrate
Row 7			Guard row
	8 - 9	P.	--Triple Superphosphate
Row 10			Guard row
	11 - 12	K.	--Potash
Row 13			Guard row
	14 - 15	N.P.	--Nitrate & Triple Superphosphate
Row 16			Guard row
	17 - 18	N.K.	--Nitrate & Potash
Row 19			Guard row
	20 - 21	P.K.	--Triple Superphosphate & Potash
Row 22			Guard row
	23 - 24	N.P.K.	--Complete Fertiliser
Row 25			Guard row
	26 - 27	C.	--No fertiliser
Row 28			Guard row
	29 - 30	A.	--Ammonium Sulphate
Row 31			Guard row
	32 - 33	N.	--Sodium Nitrate
Row 34			Guard row
	35 - 36	P.	--Triple Superphosphate
Row 37			Guard row
	38 - 39	K.	--Potash
Row 40			Guard row
	41 - 42	N.P.	--Nitrate & Triple Superphosphate
Row 43			Guard row
	44 - 45	N.K.	--Nitrate & Potash
Row 46			Guard row
	47 - 48	P.K.	--Triple Superphosphate & Potash
Row 49			Guard row
	50 - 51	N.P.K.	--Complete fertiliser
Row 52			Guard row
	53 - 54	C.	--No fertiliser
Row 55			Guard row

The seed was planted and the fertiliser applied by hand in the drills below the seed on May 3rd. The fertiliser used and rates of application are summarised in Table No. 2.

Table No. 2

Fertilizers Used and Rates of Application

Treatment	Symbol	Rate of Application in Pounds per Acre	Fertilizer Ingredients Pounds per Acre		
			N	P_2O_5	K_2O
1. Ammonium Sulphate	N	112.5	22.5		
2. Sodium Nitrate	$NaNO_3$	160	24		
3. Triple Superphosphate	P	75		33	
4. Potassium Sulphate	K	50			24
5. Ammonium Sulphate Triple Superphosphate	N.P.	112.5 75	22.5	33	
6. Ammonium Sulphate Potassium Sulphate	N.K.	112.5 50	22.5		24
7. Triple Superphosphate Potassium Sulphate	P.K.	75 50		33	24
8. Ammonium Sulphate Triple Superphosphate Potassium Sulphate	N.P.K.	112.5 75 50	22.5	33	24
9. Check. No Fertilizer	0				

The crop emerged on May 25rd, and the first sampling was made on June 17th, or 20 days after emergence. A measured portion was pulled from each row and a composite sample was made of each duplicate row. The samples were brought into the laboratory and the roots were washed free from all soil. The samples were then dried for several hours in a forage crop drier. The air dried weights were obtained for all samples. The samples were ground later in a Wiley mill, and stored in air tight cans. The second sampling was made on July 10th, at heading time or 23 days after the first sampling. These samples were treated in the same manner as the first group. The third sampling was made on July 24th, or 14 days after the second, when the crop was in the early dough stage, and the fourth sampling was made August 11th, at maturity. Weights were secured for grain and straw separately.

The various dates of sampling and stages of maturity are summarised in Table No. 3.

Table No. 5

Summary of Plant Samplings

Sampling Period	Stage of Growth	Date of Sampling	Days after Seeding	Interval in days between sampling periods
First	Shot Blade	June 17	45	35 (a)
Second	Heading	July 10	68	23
Third	Early Dough	July 24	82	14
Final	Mature	Aug. 11	100	18

(a) Representing number of days from crop emergence and first sampling.

Analytical Methods:

A two gram sample was used for moisture determinations and drying was carried out in a vacuum oven.

The per cent Nitrogen was determined in all samples by the Kjeldahl method and the results were calculated on a moisture free basis.

The amount of phosphorus was determined in all samples and the results reported as per cent phosphorus. The method of Fiske and Subbarow[24] modified by Mather[47] was used for this determination.

For the analysis of potash in the plants, a modification of the Colorimetric determination of potash devised by Briggs and used by Bartholomew and Janssen[10] was tried. It was found unsatisfactory however, due to the extremely rapid

fading of the color even though very large dilutations were made. The color did not appear to develop uniformly and difficulty was encountered in checking results of duplicate samples. The Cobalti-Nitrite method of Bowser[12] was then adopted in this experiment. In order to overcome the difficulty experienced in ashing the samples a modification of the wet oxidation method of Emmert[22] was employed, as follows: One gram of sample was weighed into a Kjeldahl flask and 30 cc. of concentrated H_2SO_4 were added. The mixture was digested for half an hour, cooled and 5 cc. of concentrated HNO_3 were added. Digestion was continued for half an hour after the solution cleared. The samples were cooled and the contents of the flask were transferred to 600 cc. beakers and the sulphuric acid was driven off by heating over a low flame in a fume chamber. The residue was then taken up with a few cc. of distilled water and the procedure continued as described by Bowser[12] .

Statistical Methods:

The analysis of variance described by Fisher[23] and modified by Goulden[24] was used in testing the significance of the data.

III. EFFECT OF FERTILISERS ON THE COMPOSITION OF WHEAT

The first phase of the investigation shows the effect of the fertiliser on the percentage composition of the wheat plants harvested at the various stages of growth.

a. Effect of Fertilisers on Phosphate Content of Plants at Various Stages of Growth:

The results for the analysis of phosphate in plants samples June 17th, are shown in Table No. 4 and the statistical analysis of these data is summarized in Table No. 5.

Table No. 4

Percentage P_2O_5 in the Total Plant 88 Days after Emergence

Treatment	N	P	K	N.P.	N.K.	N.P.	N.P.K.	C
1	0.770	0.713	0.680	0.668	0.776	0.715	0.687	0.623
2	0.751	0.684	0.657	0.701	0.753	0.700	0.625	0.629
3	0.731	0.668	0.640	0.611	0.702	0.749	0.761	0.602
4	0.727	0.676	0.651	0.707	0.754	0.750	0.754	0.678
Total	2.979	2.741	2.628	2.971	3.045	2.901	2.755	2.612
Mean	0.740	0.685	0.650	0.743	0.761	0.725	0.689	0.653
% of Mean	104.02	97.10	92.03	105.84	107.96	102.76	97.69	92.62

General Mean = 0.706. Standard Error = 0.02

Table No. 5

Analysis of Variance for the Data in Table No. 4

Comparing the Effect of the Different Treatments

On the Per Cent of P_2O_5 in the Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0004	3	0.0002	0.2799	0.5613
Difference between Nitrogen and no nitrogen	0.0841	1	0.0841	1.3661	0.7322
Difference between phosphate and no phosphate	0.0007	1	0.0007		
Difference between potash and no potash	0.0000	1	0.0000		
Interaction between nitrogen and phosphate	0.0058	1	0.0058	0.0459	0.7322
Interaction between nitrogen and potash	0.0024	1	0.0024	0.2087	0.7322
Interaction between phosphate and potash	0.0005	1	0.0005		
Second order interaction of nitrogen, phosphate and potash	0.0171	1	0.0171	0.1545	0.7322
Random Error	0.0529	21	0.0016		
Total	0.0916	31			

The data in Table No. 4 have been summarized in Table No. 6 to compare the per cent Phosphate in plants from all plots receiving nitrogen, phosphate and potash with the per cent phosphate in plants from plots not receiving any of the respective element.

Table No. 6

The Mean Per Cent P2O5 of all Determinations in Table No. 5 From Plots Receiving (a) Nitrogen (b) Phosphate (c) Potash Compared with the Corresponding Plots Not Receiving any of the Respective Element

Treatments	Mean per cent P2O5	Standard Error
(a) With nitrogen	0.733	0.01
Without nitrogen	0.670	0.01
Difference	0.063	
(b) With phosphate	0.711	0.01
Without phosphate	0.702	0.01
Difference	0.010	
(c) With potash	0.706	0.01
Without potash	0.705	0.01
Difference	0.001	

From the analysis of variance, plots receiving nitrogen have increased significantly the percentage phosphate in the plants when compared with those plots receiving no nitrogen.

The phosphate and potash application do not appear to have a significant effect on the percent phosphate in the plants as the t values are smaller than the 5 per cent point.

None of the first order interactions are significant.

The second order interaction of nitrogen, phosphate and potash appears to be significant as the χ^2 value is higher than the 5 per cent point.

In order to interpret the second order interaction the data from Table No. 4 are rearranged in Table No. 7.

Table No. 7

Per Cent Egg in Total Plant

Mean of 4 Determinations from Data in Table No. 4

Section of Table	Treatment	With Potash	Without Potash
(a)	Nitrogen & Phosphate	0.696	0.743
	Phosphate	0.725	0.666
		With Phosphate	**Without Phosphate**
(b)	Nitrogen & Potash	0.669	0.761
	Nitrogen	0.743	0.740
		With Nitrogen	**Without Nitrogen**
(c)	Phosphate & Potash	0.669	0.725
	Potash	0.761	0.650

The summary given in Table No. 7 shows the following results:

Section of Table	Treatment	Effect on percent Eggs
(a)	N & P & K compared with P & K	Nitrogen causes decrease.
	N & P compared with P	Nitrogen causes increase.
(b)	N & P & K compared with N & P	Potash causes decrease.

Section of Table	Treatment		Effect on Percent P_2O_5
(b) cont'd.	N & K	compared with N	Potash causes increase
(c)	N & P & K	compared with N & K	Phosphate causes decrease.
	P & K	compared with K	Phosphate causes increase.

It is evident that all sections of Table No. 7 contribute to the significance of the second order interaction.

The results for the analysis of phosphate in plants sampled July 10th, are shown in Table No. 8 and the statistical analysis is summarized in Table No. 9.

Table No. 6

Percentage Ash in the Total Plant 45 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	C
1	0.276	0.351	0.321	0.316	0.298	0.336	0.331	0.321
2	0.276	0.325	0.327	0.325	0.299	0.338	0.341	0.321
3	0.275	0.298	0.321	0.306	0.314	0.379	0.321	0.346
4	0.27	0.283	0.328	0.308	0.330	0.379	0.320	0.321
Total	1.108	1.217	1.297	1.251	1.241	1.434	1.313	1.309
Mean	0.278	0.304	0.324	0.313	0.310	0.359	0.328	0.365
% of Mean	88.49	94.41	100.62	97.05	96.28	111.25	101.86	113.19

General Mean = 0.322

Standard Error = 0.007

Standard Error in % of G.M. = 5.17

Table No. 9

Analysis of Variance for the Data in Table No. 6 Comparing The Effect of the Different Treatments on the Per Cent of P2O5 in the Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0003	3	0.0001		0.0013
Difference between Nitrogen and no Nitrogen	0.0070	1	0.0070	1.6510	0.7322
Difference between Phosphate & no Phosphate	0.0004	1	0.0004	0.8467	0.7322
Difference between Potash and no Potash	0.0020	1	0.0020	1.1513	0.7322
Interaction between Nitrogen & Phosphate	0.0030	1	0.0030	1.3041	0.7322
Interaction between Nitrogen & Potash	00.0007	1	0.0007	0.4265	0.7322
Interaction between Phosphate & Potash	0.0028	1	0.0028	1.3197	0.7322
Second order interaction of Nitrogen, Phosphate and Potash	0.0007	1	0.0007	1.7550	0.7322
Random Error	0.0052	21	0.0002		
Total	0.0201	31			

The data in Table No. 6 have been summarised in Table No. 10 to compare the per cent phosphate in plants from all plots receiving nitrogen, phosphate and potash with the per cent phosphate in plants from plots not receiving any of the

respective element.

Table No. 10

The Mean Per Cent P_2O_5 of all Determinations in Table No. 8 From Plots Receiving (a) Nitrogen (b) Phosphate (c) Potash Compared with the Corresponding Plots Not Receiving any of the Respective Element

Treatments	Mean Percent P_2O_5	Standard Error
(a) With Nitrogen	0.307	0.004
Without Nitrogen	0.338	0.004
Difference	-0.031	
(b) With Phosphate	0.326	0.004
Without Phosphate	0.319	0.004
Difference	0.007	
(c) With Potash	0.330	0.004
Without Potash	0.314	0.004
Difference	0.016	

In this case a significant decrease in per cent phosphate in the plant occurs from the application of nitrogen. The analysis of variance show that the F value is higher than the 5 per cent point.

Plots receiving phosphate do not appear to be significantly different from those receiving no phosphate. The F value is considerably lower than the 5 per cent point.

The application of potash has increased significantly the per cent phosphate in the plant at this time of sampling as the F value is higher according to the analysis of variance.

The effect of the interaction between nitrogen and phosphate on the per cent of phosphate in the plants is significant. These results are summarized in Table No. 11.

Table No. 11

Per Cent P_2O_5 in Plants

Mean of 6 Determinations from Data in Table 8

Per element	Nitrogen	No Nitrogen
With Phosphate	0.320	0.331
Without Phosphate	0.293	0.244

The data in Table No. 11 indicate that if phosphate is applied without nitrogen the per cent phosphate in the plant is decreased; but when applied in combination with nitrogen, the percent phosphate in the plant is increased over that of the plant receiving no phosphate. The interaction of phosphate and potash also has a significant effect on the per cent phosphate in the plants at this time of sampling as the F value is higher than the 5 per cent point.

The effect of the interaction of phosphate and potash on the per cent phosphate in the plants at this date is significant. These results are summarized in Table No. 12.

Table No. 12

Per Cent P_2O_5 in Plants

Mean of 8 Determinations from Data in Table No. 8

Treatment	With Potash	Without Potash
With Phosphate	0.343	0.306
Without Phosphate	0.317	0.320

The data from Table No. 12 indicate that phosphate when applied with potash tends to increase the per cent phosphate in the plants when compared with plots receiving no phosphate, but by the application of phosphate without potash, the per cent of phosphate in the plant is decreased below that of the plots receiving no phosphate.

The second order interaction of nitrogen, phosphate and potash is also significant, the 5 value being higher than the 5 per cent point.

In order to interpret the second order interaction the data from Table No. 8 may be arranged as in Table No. 13.

Table No. 13

Per Cent Phosphate in Plants

Mean of 4 Determinations from Data in Table No. 8

Section	Treatment	With Potash	Without Potash
(a)	Nitrogen and Phosphate	0.328	0.313
	Phosphate	0.309	0.304

		With Phosphate	Without Phosphate
(b)	Nitrogen and Potash	0.328	0.310
	Nitrogen	0.313	0.275

		With Nitrogen	Without Nitrogen
(c)	Phosphate and Potash	0.328	0.309
	Potash	0.310	0.284

Summary

Section Table 13	Treatment			Effect on % Ash
(a)	N & P & K	compared with	P & K	Nitrogen causes decrease
	N & P	compared with	P	Nitrogen causes increase
(b)	N & P & K	compared with	N & P	Potash causes increase
	N & K	compared with	N	Potash causes increase
(c)	N & P & K	compared with	N & K	Phosphate causes increase
	P & K	compared with	K	Phosphate causes increase

This Summary shows that only Section (a) is contributing to the second order interaction.

The results of the per cent phosphate in the plants at the third date of sampling are shown in Table No. 14 and the statistical analysis of these results is summarised in Table No. 15.

Table No. 14

Percentage P2O5 in the Total Plant 68 Days after Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	0.349	0.382	0.393	0.356	0.388	0.418	0.367	0.390
2	0.345	0.383	0.384	0.352	0.362	0.416	0.366	0.379
3	0.358	0.374	0.414	0.352	0.336	0.361	0.379	0.397
4	0.384	0.366	0.414	0.356	0.355	0.360	0.390	0.407
Total	1.416	1.524	1.605	1.426	1.391	1.537	1.502	1.573
Mean	0.354	0.381	0.401	0.356	0.348	0.384	0.375	0.393
% of Mean	94.59	101.60	107.21	95.26	92.98	102.67	100.33	105.06

General Mean = 0.374

Standard Error = 0.009

Standard Error in % of G.M. = 2.41

Table No. 15

Analysis of Variance of Data in Table No. 14

Combined Effect of All Treatments on

Per Cent P_2O_5 in the Total Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5 % Point
Difference between replications	0.0002	3	0.0000		
Difference between Nitrogen and no Nitrogen	0.0060	1	0.0060	1.0417	0.7522
Difference between Phosphate and no Phosphate	0.0000	1	0.0000		
Difference between Potash and no Potash	0.0005	1	0.0005		
Interaction between Nitrogen and Phosphate	0.0006	1	0.0006	0.3466	0.7522
Interaction between Nitrogen and Potash	0.0000	1	0.0000		
Interaction between Phosphate and Potash	0.0002	1	0.0002		
Second order interaction of Nitrogen, Phosphate and Potash	0.0016	1	0.0016	0.8370	0.7522
Random Error	0.0066	21	0.0003		
Total	0.0177	31			

The data in Table No. 14 have been summarized in Table No. 16 to compare the per cent phosphate in plants from all plots receiving nitrogen, phosphate and potash with the per cent phosphateiin plants from plots not receiving any of the respective element.

Table No. 16

Mean Per Cent P_2O_5 of all Determinations in Table No. 14 From Plots Receiving

(a) Nitrogen; (b) Phosphate; (c) Potash Compared with the Corresponding Plots Receiving None of the Respective Element

Treatment	Mean per cent P_2O_5	Standard Error
(a) With Nitrogen	0.356	0.004
Without Nitrogen	0.390	0.004
Difference	-0.052	
(b) With Phosphate	0.374	0.004
Without Phosphate	0.374	0.004
Difference	0.000	
(c) With Potash	0.377	0.004
Without Potash	0.371	0.004
Difference	0.006	

The application of nitrogen has again significantly decreased the per cent phosphate in the plants at this period of sampling. The F value from the analysis of variance is considerably higher than the 5 per cent point.

The application of phosphate and of potash has had no significant effect on the per cent phosphate in the plant, the F

values being considerably lower than the 5 per cent point.

None of the first order interactions are significant according to the analysis of variance, but the second order interaction of nitrogen, phosphate and potash is significant.

For the interpretation of the second order interaction the data from Table No. 14 may be arranged in Table No. 17.

Table No. 17

Per Cent P2O5 in Plants

Mean of 4 Determinations from Data in Table No. 14

Section	Treatment	With Potash	Without Potash
(a)	Nitrogen & Phosphate	0.375	0.356
	Phosphate	0.394	0.381
(b)		With Phosphate	Without Phosphate
	Nitrogen and Potash	0.375	0.348
	Nitrogen	0.356	0.354
(c)		With Nitrogen	Without Nitrogen
	Phosphate and Potash	0.375	0.384
	Potash	0.348	0.401

Summary of Table No. 17

Section of Table	Treatment	Effect of P2O5
(a)	N & P & K compared with P & K	Nitrogen causes decrease
	N & P compared with P	Nitrogen causes decrease
(b)	N & P & K compared with N & P	Potash causes increase
	N & K compared with N	Potash causes decrease

Section of Table	Treatment		Effect of P_2O_5
(c)	N & P & K	compared with N & K	Phosphate causes increase
	P & K	compared with K	Phosphate causes decrease

From the summary we may assume that section (b) and (c) of Table No. 17 are responsible for the significance of the second order interaction.

The effect of fertilisers on the per cent phosphate in the grain at maturity are shown by results in Table No. 18 and the statistical analysis is summarised in Table No. 19.

Table No. 18

Per Cent P_2O_5 in the Grain 80 Days After Emergence

Treat-ment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	1.001	0.960	1.053	0.811	0.959	1.026	0.822	1.056
2	0.961	0.940	1.016	0.811	0.939	1.020	0.822	1.020
3	0.956	0.877	1.061	0.859	0.874	0.939	0.762	1.035
4	0.900	0.897	1.061	0.875	0.870	0.940	0.769	1.050
Total	3.796	3.674	4.173	3.356	3.612	3.927	3.195	4.146
Mean	0.948	0.918	1.043	0.839	0.903	0.984	0.799	1.036
% of Mean	101.36	98.37	111.73	89.88	96.71	105.41	85.54	111.00

General Mean = 0.934

Standard Error = 0.016

Standard Error in % of G.M. = 1.71.

Table No. 19

Analysis of Variance of Data in Table No. 16 Comparing the Effect of All Fertilizer Treatments on The Per Cent P_2O_5 in The Grain

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replications	0.0072	3	0.0024	0.4377	0.8612
Difference between Nitrogen and no Nitrogen	0.1286	1	0.1286	2.4045	0.7322
Difference between Phosphate and no Phosphate	0.0756	1	0.0756	2.1657	0.7322
Difference between Potash and No Potash	0.0001	1	0.0001		
Interaction between Nitrogen and Phosphate	0.0006	1	0.0006		
Interaction between Nitrogen and Potash	0.0122	1	0.0122	1.2507	0.7322
Interaction between Phosphate and Potash	0.0019	1	0.0019	0.3810	0.7322
Second order interaction of Nitrogen, Phosphate and Potash	0.0016	1	0.0016	0.2360	0.7322
Random Error	0.0807	41	0.0010		
Total	0.2425	51			

The data in Table No. 18 have been summarized in Table No. 20 to compare the per cent phosphate in the grain from 11 plots receiving nitrogen, phosphate and potash with the per cent phosphate in the grain from all plots not receiving any of the respective element.

Table No. 20

Mean Per Cent P_2O_5 of all Determinations in Table No. 18 of All Plots Receiving

(a) Nitrogen; (b) Phosphate; (c) Potash compared With The Corresponding Plots Receiving None of the Respective Element

	Treatment	Mean percent P_2O_5	Standard Error
(a)	With Nitrogen	0.872	0.008
	Without Nitrogen	0.996	0.008
	Difference	-0.124	
(b)	With Phosphate	0.865	0.008
	Without Phosphate	0.962	0.008
	Difference	-0.097	
(c)	With Potash	0.932	0.008
	Without Potash	0.935	0.008
	Difference	-0.003	

The application of nitrogen has lowered significantly the per cent phosphate in the grain when compared with the per cent phosphate in the plants which received no nitrogen, as the t value is equal to 8.4045 and the 5 per cent point 0.7382. Also the application of phosphate has apparently had a depressing effect on the per cent phosphate in the

grain when compared with the plots receiving no phosphate. This effect is significant as the F value is 2.1027 and the 5 per cent point is 0.7582.

The interaction between nitrogen andpotash has a significant effect on the per cent phosphate in the grain as the F value equalling 1.2507 is higher than the 5 per cent point .7582, and the results are summarized in Table No. 21.

Table No. 21

Per Cent P_2O_5 in Grain

Mean of 6 Determinations from Data in Table No. 20

Treatment	With Potash	Without Potash
With Nitrogen	0.651	0.693
Without Nitrogen	1.014	0.977

From Table No. 21 it appears that when potash is applied with nitrogen a decrease in per cent phosphate in the grain results when compared with plots receiving no potash. On the other hand, when potash is applied without nitrogen there is an increase in per cent phosphate in the grain when compared with the plots receiving no potash.

The interaction between nitrogen and phosphate, phosphate and potash and the second order of nitrgoren, phosphate and potash cannot be considered significant as the F values are all lower than the 5 per cent points.

The effect of fertilizers on the per cent phosphate in the mature straw are shown by the results in Table No. 22 and the statistical results are summarised in Table No. 23.

Table No. 22

Per Cent P_2O_5 in the Straw at Maturity

90 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	C
1	0.168	0.160	0.197	0.160	0.160	0.164	0.164	0.175
2	0.168	0.164	0.166	0.149	0.161	0.154	0.144	0.172
3	0.167	0.169	0.169	0.169	0.160	0.168	0.155	0.169
4	0.166	0.169	0.160	0.160	0.159	0.173	0.158	0.166
Total	0.667	0.165	0.178	0.164	0.160	0.168	0.152	0.170
Mean	0.164	0.165	0.170	0.164	0.160	0.162	0.152	0.170
% of Mean	100.46	101.07	109.17	94.50	97.66	99.24	92.97	104.28

General Mean = 0.165

Standard Error = 0.005

Standard Error in % of G.M. = 3.07

Table No. 23

Analysis of Variance Data in Table No. 22 Comparing the Effect of All Fertilizer Treatments on Per Cent Fats in The Mature Straw

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5 % Point
Difference between replicates	0.0001	3			
Difference between Nitrogen and no Nitrogen	0.0010	1	0.0010	1.0368	0.7522
Difference between Phosphate and no Phosphate	0.0009	1	0.0009	0.9846	0.7522
Difference between Potash and no Potash	0.0000	1	0.0000		
Interaction between Nitrogen and Phosphate	0.0008	1	0.0008	0.8314	0.7522
Interaction between Nitrogen and Potash	0.0001	1	0.0001		
Interaction between Phosphate and Potash	0.0000	1	0.0000		
Second order interaction of Nitrogen Phosphate and Potash	0.0000	1	0.0000		
Random Error	0.0013	21	0.0001		
Total	0.0055	31			

The data in Table No. 22 have been summarized in Table No. 24 to compare the per cent phosphate in the mature straw from all plots receiving nitrogen, phosphate and potash with the per cent phosphate in the mature straw from all plots not receiving any of the respective element.

Table No. 24

Mean Per Cent P_2O_5 of all Determinations in Table No. 22 From All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, compared with the Corresponding Plots Receiving None of the Respective Element

Treatment	Mean Per cent P_2O_5	Standard Error
(a) With Nitrogen	0.158	0.002
Without Nitrogen	0.169	0.002
Difference	-0.011	
(b) With Phosphate	0.169	0.002
Without Phosphate	0.166	0.002
Difference	-0.003	
(c) With Potash	0.165	0.002
Without Potash	0.164	0.002
Difference	-0.001	

The per cent phosphate in the mature straw on plots which received nitrogen is significantly lower than the plots receiving no nitrogen as the t value according to the analysis of variance is lower than the 5 per cent point.

The application of phosphate appears to have caused a significant decrease in the per cent phosphate in the straw

as the t value is lower than the 5 per cent point.

None of the first order interactions or the second order interactions are significant.

b. Effect of Fertilisers on Nitrogen Content of Plants at Various Stages of Growth:

The effect of fertilisers on the per cent Nitrogen in the total plant at the first period of sampling are shown by results in Table No. 25, and the statistical analysis of these results is summarised in Table No. 26.

Table No. 25

Per Cent Nitrogen in Total Plant at First Sampling Period 26 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	4.41	4.76	4.68	4.67	4.67	4.62	4.35	4.56
2	4.45	4.83	4.66	4.66	4.69	4.51	4.38	4.22
3	4.64	4.93	4.59	4.41	4.11	4.37	4.55	4.52
4	4.68	4.97	4.42	4.41	4.11	4.35	4.56	4.55
Total	18.16	19.51	17.97	17.94	17.56	17.75	17.84	17.85
Mean	4.54	4.88	4.49	4.48	4.39	4.44	4.46	4.39
% of Mean	100.66	108.15	99.61	99.44	97.45	98.89	98.89	97.58

General Mean = 4.51

Standard Error = 0.06

Standard Error in % of G.M. = 1.77

Table No. 26

Analysis of Variance for the Data in Table No. 25 Comparing The Effects of the Different Treatments on the Per Cent Nitrogen in the Total Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0049	3	0.0016		
Difference between Nitrogen and no Nitrogen	0.0496	1	0.0496	0.2049	0.7322
Difference between Phosphate and no Phosphate	0.0990	1	0.0990	0.6104	0.7322
Difference between Potash and no Potash	0.1275	1	0.1275	0.7570	0.7322
Interaction between Nitrogen and Phosphate	0.0903	1	0.0903	0.5565	0.7322
Interaction between Nitrogen and Potash	0.0136	1	0.0136		
Interaction between Phosphate and Potash	0.0903	1	0.0903	0.5565	0.7322
Second order interaction of Nitrogen, Phosphate and Potash	0.2812	1	0.2812	1.1876	0.7322
Random Error	0.6140	21	0.0292		
Total	1.3104	31			

The data in Table No. 26 have been summarised in Table No. 27 to compare the per cent Nitrogen in plants from all plots receiving Nitrogen, Phosphate and Potash with the per cent Nitrogen in plants from all plots not receiving any of the respective element.

Table No. 27

Mean Per Cent N in the Total Plant of All Determinations in Table No. 26 from Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with the Corresponding Plots not Receiving Each Element

Treatment	Mean Per cent N	Standard Error
(a) With Nitrogen	4.47	0.04
Without Nitrogen	4.55	0.04
Difference	-0.08	
(b) With Phosphate	4.56	0.04
Without Phosphate	4.45	0.04
Difference	0.11	
(c) With Potash	4.45	0.04
Without Potash	4.57	0.04
Difference	-0.12	

Applying nitrogen appears to have no significant effect on the per cent nitrogen in the plant in the first sampling. as the P value in the analysis of variance is lower than the 5 per cent point.

Phosphate when applied shows some tendency to increase the nitrogen content of the plant, but the result is barely significant so no conclusive result can be drawn.

Potash has significantly lowered the nitrogen content in the plant at this time of sampling as the Z value is higher than the 5 per cent point.

None of the first order interactions appear to be significant. The second order interaction between Nitrogen, Phosphate and Potash appears to be significant as the Z value is higher than the 5 per cent point.

For interpretation of the second order interaction the data from Table No. 25 may be arranged as in Table No. 26.

Table No. 26

Per Cent Nitrogen in Total Plants

Mean of 4 Determinations from Data in Table No. 25

Section	Treatment	With Potash	Without Potash
(a)	Nitrogen & Phosphate	4.46	4.48
	Phosphate	4.44	4.88
		With Phosphate	Without Phosphate
(b)	Nitrogen & Potash	4.46	4.39
	Nitrogen	4.48	4.54
		With Nitrogen	Without Nitrogen
(c)	Phosphate & Potash	4.46	4.44
	Potash	4.39	4.49

Summary of Table No. 28

Section of Table	Comparison	Effect on % N
(a)	N & P & K compared with P & K	Nitrogen causes increase
	N & P compared with P	Nitrogen causes decrease
(b)	N & P & K compared with N & P	Potash causes decrease
	N & K compared with N	Potash causes decrease
(c)	N & P & K compared with N & K	Phosphate causes increase
	P & K compared with K	Phosphate causes decrease

Sections (a) and (c) are apparently contributing to the significance of the second order interaction as no second order interaction is evident in section (b).

The effect of fertilisers on the per cent Nitrogen in the total plants at the second sampling period are shown by results in Table No. 29. The statistical analysis of these is summarised in Table No. 30.

Table No. 29

Per Cent Nitrogen in the Total Plant 48 Days after Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	2.20	1.94	2.00	1.96	2.06	1.95	1.95	2.06
2	2.20	1.96	2.05	1.94	2.06	1.90	1.97	2.06
3	2.06	1.95	2.00	2.11	2.15	2.04	2.04	2.07
4	2.07	1.95	2.00	2.09	2.13	2.03	2.04	2.06
Total	8.50	7.80	8.05	8.10	8.39	7.90	8.00	8.25
Mean	2.12	1.95	2.01	2.02	2.10	1.97	2.00	2.07
% of Mean	104.88	95.94	98.77	99.63	103.20	97.17	98.40	101.97

General Mean = 2.03

Standard Error = 0.026

Standard Error in % of G.M. = 1.36

Table No. 30

Analysis of Variance for the Data in Table No. 29 Concerning the Effects of the Different Treatments on the Per Cent Nitrogen in the Total Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	$	5% Point
Difference between replications	0.0081	3	0.0027		
Difference between Nitrogen and no Nitrogen	0.0294	1	0.0294	1.1090	0.7522
Difference between Phosphate and no Phosphate	0.0021	1	0.0021	1.4829	0.7522
Difference between Potash and no Potash	0.0043	1	0.0043	0.1478	0.7522
Interaction between Nitrogen and Phosphate	0.0009	1	0.0009		
Interaction between Nitrogen and Potash	0.0001	1	0.0001		
Interaction between Phosphate and Potash	0.0043	1	0.0043	0.1478	0.7522
Second order interaction of Nitrogen, Phosphate and Potash	0.0030	1	0.0030	0.0890	0.7522
Random Error	0.0602	21	0.0002		
Total	0.1212	31			

The data in Table No. 29 have been summarised in Table No. 31 to compare the per cent Nitrogen in plants from all plots receiving Nitrogen, Phosphate and Potash with the per cent Nitrogen in all plants receiving none of the respective element.

Table No. 31

Mean Per Cent Nitrogen of all Determinations In Table 29 From Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with the Corresponding Plots Receiving None of the Respective Element

	Treatment	Mean per-cent N	Standard Error
(a)	With Nitrogen	2.06	0.014
	Without Nitrogen	2.00	0.014
	Difference	0.06	
(b)	With Phosphate	1.99	0.014
	Without Phosphate	2.00	0.014
	Difference	-0.09	
(c)	With Potash	2.02	0.014
	Without Potash	2.04	0.014
	Difference	-0.02	

A significant increase in the per cent Nitrogen in the total plant has resulted from the application of Nitrogen when compared with plots receiving no nitrogen. The 5 value in the analysis of variance being 1.1090 and the 5 per cent point 0.7362. The application of phosphate however, has effected a significant decrease in per cent Nitrogen in the

total plant when compared with plots receiving no Phosphate. The t value in this case is 1.4629 and the 5 per cent point 0.7555.

The application of Potash has no significant effect on the per cent Nitrogen in the plant. None of the first order interactions or the second order interaction of Nitrogen, Phosphate and Potash are significant.

The effect of fertilisers on the per cent Nitrogen in the plants at the third sampling period are shown by the results in Table No. 32. and the statistical analysis is summarised in Table No. 33.

Table No. 32

Per Cent Nitrogen in Total Plant 62 Days after Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	1.41	1.40	1.32	1.27	1.42	1.36	1.38	1.46
2	1.46	1.46	1.38	1.37	1.44	1.37	1.41	1.42
3	1.49	1.37	1.41	1.36	1.90	1.39	1.72	1.56
4	1.51	1.38	1.41	1.33	1.87	1.41	1.74	1.56
Total	5.84	5.66	5.46	5.22	6.63	5.52	6.25	6.00
Mean	1.46	1.41	1.36	1.30	1.60	1.38	1.56	1.50
% of Mean	100.34	97.25	93.81	89.69	108.76	94.84	107.89	103.09

General Mean = 1.43

Standard Error = 0.052

Standard Error in % of G.M. = 3.64

Table No. 33

Analysis of Variance for the Data in Table No. 32 Comparing the Effects of the Different Treatments On the Per Cent Nitrogen in the Total Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5 % Point
Difference between replicates	0.1489	3	0.0401	0.7515	0.5613
Difference between Nitrogen and no Nitrogen	0.0528	1	0.0528	0.7981	0.7322
Difference between Phosphate and no Phosphate	0.0512	1	0.0512	0.7826	0.7322
Difference between Potash and no Potash	0.0406	1	0.0406	0.6667	0.7322
Interaction between Nitrogen and Phosphate	0.0162	1	0.0162	0.2074	0.7322
Interaction between Nitrogen and Potash	0.1953	1	0.1953	1.4522	0.7322
Interaction between Phosphate and Potash	0.0126	1	0.0126	0.0806	0.7322
Second order Interaction of Nitrogen, Phosphate and Potash	0.0009	1	0.0009		
Random Error	0.0243	21	0.0107		
Total	0.5400	31			

The data in Table No. 32 are summarized in Table No. 34 to compare the per cent Nitrogen in plants from all plots receiving Nitrogen, Phosphate and Potash with the per cent Nitrogen in plants from all plots not receiving any of the respective element.

Table No. 34

Mean Per Cent Nitrogen in Total Plant of All Determinations in Table No. 32 from Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with the Corresponding Plots not Receiving Any of the Respective Element

Treatment	Mean per-cent N	Standard Error
(a) With Nitrogen	1.50	0.026
Without Nitrogen	1.42	0.026
Difference	0.08	
(b) With Phosphate	1.42	0.026
Without Phosphate	1.50	00026
Difference	-0.08	
(c) With Potash	1.49	0.026
Without Potash	1.42	0.026
Difference	0.07	

A significant increase in the p r cent Nitrogen in the plant at this period of sampling has resulted from the application of Nitrogen. In a comparison of the plots receiving Nitrogen the Z value is 0.7961 and the 5 per cent point 0.7322.

The application of Phosphate has again depressed significantly the per cent of Nitrogen in the total plant when plots receiving phosphate are compared with those receiving no phosphate. The F value is 0.7828 and the 5 per cent point is 0.7322.

The application of Potash has had no significant effect on the per cent Nitrogen at this date of sampling, although there appears to be a tendency for the plants receiving Potash to have a higher per cent Nitrogen than those not receiving Potash. The F value of 0.6667 closely approaches the 5 per cent point of 0.7322.

The interaction of nitrogen and potash can be considered significant as the F value 1.4332 is higher than the 5 per cent point 0.7322. The data are summarised in Table No. 35.

Table No. 35

Per Cent Nitrogen in Total Plant

Mean of 8 Determinations from Data in Table No. 34

Treatment	With Potash	Without Potash
With Nitrogen	1.61	1.30
Without Nitrogen	1.37	1.46

The data in Table No. 35 would indicate that when Nitrogen is used in combination with Potash the per cent Nitrogen in the total plant is increased when compared with plots receiving no Nitrogen. On the other hand, when

Nitrogen is used without Potash the per cent nitrogen in the total plant is lower than the per cent nitrogen in the plants from plots receiving no nitrogen.

The interaction between nitrogen and phosphate, phosphate and potash, and the second order interaction of nitrogen, phosphate and potash cannot be considered significant as the F values in the analysis of variance are lower than the corresponding 5 per cent point.

The effect of fertiliser treatments on the nitrogen cont n. of the grain is shown by results in Table No. 36 and the statistical analysis is summarised in Table No. 37.

Table No. 36

Per Cent Nitrogen in the Grain at Maturity

60 Days after Emergence

Treatments	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	2.62	2.64	2.50	2.67	2.67	2.55	2.57	2.60
2	2.64	2.63	2.48	2.69	2.67	2.64	2.59	2.65
3	2.63	2.49	2.72	2.69	2.79	2.47	2.75	2.71
4	2.63	2.47	2.69	2.66	2.77	2.49	2.74	2.71
Total	12.52	10.22	10.59	10.71	10.90	10.05	10.64	10.66
Mean	2.63	2.55	2.50	2.68	2.72	2.51	2.66	2.64
% of Mean	106.70	96.42	96.02	101.04	102.63	94.61	100.38	99.63

General Mean = 2.65

Standard Error = 0.038

Standard Error in % G.M. = 1.43

Table No. 37

Analysis of Variance of Data in Table No. 36 Concerning the Effect of all Fertilizer Treatments on the Per Cent Nitrogen in the Grain

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0214	3	0.0071	0.1696	0.2613
Difference between Nitrogen and no Nitrogen	0.1740	1	0.1740	0.7092	0.7322
Difference between Phosphate and no Phosphate	0.0741	1	0.0741	1.2824	0.7322
Difference between Potash and no Potash	0.0210	1	0.0210	0.6619	0.7322
Interaction between Nitrogen and Phosphate	0.0018	1	0.0018		
Interaction between Nitrogen and Potash	0.0008	1	0.0008		
Interaction between Phosphate and Potash	0.0036	1	0.0036		
Second order interaction of Nitrogen, Phosphate, Potash	0.0042	1	0.0042		
Random Error	0.1193	21	0.0057		
Total	0.4196	31			

The data in Table No. 36 are summarized in Table No. 38 to compare the per cent nitrogen in grain at maturity from all plots receiving nitrogen, phosphate and potash with the per cent nitrogen in the grain from all plots not receiving any of the respective elements.

Table No. 38

Mean Per Cent Nitrogen in Grain of All Determinations From Plots Receiving (a) Nitrogen; (b) Phosphate; and (c) Potash, Compared with the Corresponding Plots Not Receiving any of the Respective Element

	Treatment	Mean per-cent N	Standard Error
(a)	With Nitrogen	2.72	0.02
	Without Nitrogen	2.58	0.02
	Difference	0.14	
(b)	With Phosphate	2.60	0.02
	Without Phosphate	2.70	0.02
	Difference	-0.10	
(c)	With Potash	2.62	0.02
	Without Potash	2.68	0.02
	Difference	-0.06	

The application of nitrogen appears from Table No. 38 to have increased the per cent nitrogen in the grain when compared with grain from plots receiving no nitrogen. This increase may be considered significant as the t value is 1.7092 and the 5 per cent point is 0.7328.

The application of phosphate however, has resulted in

a decrease in per cent nitrogen in the grain in comparison with that of grain from plots receiving no phosphate. This decrease is significant, the t value being 1.2824 and the 5 per cent point 0.7322.

The use of potash has apparently had no significant effect on the per cent nitrogen in the grain, the t value of 0.6819 being lower than the 5 per cent point.

The effects of fertilizers on the nitrogen content of the mature grain expressed as crude protein are shown by results in Table No. 59.

Table No. 59

Mean Per Cent Protein (13.5 per cent Moisture Basis) in Grain at Maturity

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	13.90	13.02	12.65	13.16	13.16	12.87	13.07	12.72
2	14.00	12.97	13.23	13.26	13.16	12.62	12.72	12.67
3	12.95	13.20	13.41	13.26	13.75	13.18	13.66	13.30
4	13.98	13.18	13.26	13.12	13.06	13.30	13.61	13.36
Total	56.83	52.40	52.55	52.80	53.73	49.95	53.46	52.01
Mean	13.95	13.60	13.01	13.20	13.43	12.59	13.11	13.00
% of Mean	106.01	96.48	96.08	101.07	102.85	94.87	100.38	99.64

General Mean = 13.06

Standard Error = 0.630

Standard Error in % C.M. = 1.48

The data in Table 39 are summarized in Table No. 40 to compare the per cent protein in the grain from all plots receiving nitrogen, phosphate and potash with the per cent protein in grain from all plots not receiving any of the respective element.

Table No. 40

Mean Per Cent Protein (13.5% Moisture Basis) in Grain From All Plots Receiving Nitrogen, Phosphate and Potash And the Per Cent Protein in Grain from All Plots Not Receiving Any of the Respective Elements

Treatment	Per Cent Protein (13.5 per cent basis)	Difference in Per Cent
With Nitrogen	13.42	0.72
Without Nitrogen	12.70	
With Phosphate	12.88	-0.48
Without Phosphate	13.30	
With Potash	12.93	-0.23
Without Potash	13.19	

The data in Table No. 40 show the application of Nitrogen* at the time of seeding has increased the protein content of the grain by 0.72%. The application of phosphate has lowered the per cent protein in the grain 0.48%. These results are significant. The application of potash

*Note: All nitrogen applied in combination with phosphate and potash used in the form of ammonium sulphate.

also has resulted in a slight decrease in the per cent protein, but this decrease is not significant. (See Table No. 37).

The effects of fertilizers on the per cent nitrogen in the straw are shown by results in Table No. 41 and the statistical analysis of the data is summarised in Table No. 42.

Table No. 41

Per Cent Nitrogen in Mature Straw Harvested 100 Days After Seeding and 80 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	O
1	0.99	0.85	0.79	0.82	0.82	0.89	0.80	0.85
2	0.99	0.82	0.80	0.81	0.81	0.89	0.81	0.84
3	0.92	0.75	0.82	0.90	0.95	0.81	0.90	0.89
4	0.92	0.73	0.84	0.94	0.94	0.80	0.89	0.89
Total	3.82	3.15	3.25	3.55	3.63	3.36	3.40	3.47
Mean	0.95	0.79	0.80	0.88	0.88	0.77	0.85	0.87
% of Mean	118.68	98.92	98.87	104.15	104.15	87.90	100.89	102.36

General Mean = 0.85

Standard Error = 0.026

Standard Error in % of G.M. = 3.06

Table No. 42

Analysis of Variance of Data in Table No. 41 Comparing the Effects of the Fertilizer Treatments On the Per Cent Nitrogen in the Mature Straw

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0198	3	0.0066	0.4810	0.8612
Difference between Nitrogen and no Nitrogen	0.0639	1	0.0639	1.8636	0.7522
Difference between Phosphate and no Phosphate	0.0519	1	0.0519	1.2164	0.7522
Difference between Potash and no Potash	0.0205	1	0.0205	0.0984	0.7522
Interaction between Nitrogen and Phosphate	0.0069	1	0.0069		
Interaction between Nitrogen and Potash	0.0000	1	0.0000		
Interaction between Phosphate and Potash	0.0014	1	0.0014		
Second order interaction of Nitrogen, Phosphate and Potash	0.0003	1	0.0003		
Random Error	0.0580	21	0.0028		
Total	0.1967				

The data in Table No. 41 are summarized in Table No. 43 to compare the per cent nitrogen in mature straw from all plots receiving nitrogen, phosphate and potash with the per cent nitrogen in mature straw from all plots not receiving any of the respective element.

Table No. 43

Mean Per Cent Nitrogen in Mature Straw of All Determinations in Table No. 41 From all Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with the Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Per-cent N	Standard Error
(a) With Nitrogen	0.90	0.013
Without Nitrogen	0.80	0.013
Difference	0.10	
(b) With Phosphate	0.82	0.013
Without Phosphate	0.88	0.013
Difference	-0.06	
(c) With Potash	0.82	0.013
Without Potash	0.87	0.013
Difference	-0.05	

The application of nitrogen has increased the per cent nitrogen in the straw when compared with plots receiving no nitrogen. According to the analysis of variance the F value is 1.5650 while the 5 per cent point is 0.7722.

The application of phosphate shows a slight depression in the per cent nitrogen compared with plots receiving no phosphate. This depression in the per cent nitrogen may be considered significant as the t value being 1.2164 is higher than the 5 per cent point 0.7382.

The application of potash has also decreased the per cent nitrogen in the mature straw below that of straw harvested from plots receiving no potash. This decrease may be considered significant as the t value is 0.9954 and the 5 per cent point 0.7382. None of the first order interactions are significant and the second order interaction is also not significant.

c. The Effect of Fertilizers on the Potash Content of Plants at Various Stages of Growth.

The effects of fertilizers on the percent potash in the plants at the first period of sampling are shown by results in Table No. 44 and the statistical analysis of the data is summarized in Table No. 45.

Table No. 44

Per Cent K$_2$O in Total Plant Sampled

85 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	C
1	5.89	5.43	4.74	4.68	5.08	4.77	4.46	4.61
2	5.85	4.78	4.79	4.38	4.85	4.76	4.68	4.52
3	4.72	4.75	4.21	4.11	4.20	4.08	4.00	4.65
4	4.78	4.64	4.22	4.51	4.20	4.35	3.96	4.75
Total	19.99	19.40	17.96	17.68	18.03	17.96	17.10	18.61
Mean	5.00	4.85	4.49	4.42	4.51	4.49	4.27	4.65
% of Mean	109.06	105.84	97.98	96.45	98.36	97.98	93.29	100.98

General Mean = 4.58

Standard Error = 0.060

Standard Error in % of G.M. = 5.10

Table No. 45

Analysis of Variance of Data from Table No. 44 Comparing the Effects of all Fertilizer Treatments On the Per Cent K₂O in the Total Plant

Variance due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replications	1.3966	3	0.4662	1.0404	0.6612
Difference between Nitrogen and no Nitrogen	0.0358	1	0.0358		
Difference between Phosphate and no Phosphate	0.1726	1	0.1726	0.8435	0.7522
Difference between Potash and no Potash	0.0413	1	0.0413	1.1999	0.7522
Interaction between Nitrogen and Phosphate	0.0380	1	0.0380	1.1078	0.7522
Interaction between Nitrogen and Potash	0.0004	1	0.0004		
Interaction between Phosphate and Potash	0.0078	1	0.0078		
Second order interaction of Nitrogen, Phosphate and Potash	0.1610	1	0.1610	0.6066	0.7522
Random Error	1.2216	21	0.0582		
Total	4.1761	31			

The data in Table No. 44 are summarised in Table No. 45 to compare the per cent potash in plants from all plots receiving nitrogen, phosphate and potash, with the per cent potash in plants from all plots not receiving any of the respective elements.

Table No. 46

Mean Per Cent K_2O of all Determinations in Table No. 44 From Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with the Corresponding Plots Not Receiving any of the Respective Element

	Treatment	Mean per-cent K_2O	Standard Error
(a)	With Nitrogen	4.88	0.12
	Without Nitrogen	4.61	0.12
	Difference	-0.06	
(b)	With Phosphate	4.51	0.12
	Without Phosphate	4.66	0.12
	Difference	-0.15	
(c)	With Potash	4.44	0.12
	Without Potash	4.72	0.12
	Difference	-0.28	

The application of nitrogen has had no significant effect on the per cent potash in the plant at this date of sampling when compared with the percent potash in plants receiving no nitrogen. Also the application of phosphate has had no significant effect on the per cent potash in the plant as the t value for the comparison of

nitrogen and no nitrogen is negative and the 5 per cent point is 0.7522 and the t value for the comparison of phosphate and no phosphate is 0.8436 and the 5 per cent point is equal to 0.7522.

The application of potash has apparently decreased the per cent potash in the plants at this period of sampling when a comparison is made of the per cent potash in plants sampled from plots receiving no potash. This decrease may be considered significant because of the t value of 1.1099 being higher than the 5 per cent point of 0.7522.

The interaction between nitrogen and phosphate has a significant effect on the per cent potash at this date of sampling. The t value is 1.1072 and the 5 per cent point is 0.7522. The results are summarised in Table No. 47.

Table No. 47

Per Cent K₂O in Plants

Mean of 6 Determinations from Data in Table No. 44

Treatment	With Phosphate	Without Phosphate
With Nitrogen	4.35	4.75
Without Nitrogen	4.67	4.86

The data in Table No. 47 indicate that both nitrogen and phosphate when applied without phosphate or nitrogen respectively, tend to increase the per cent potash in the plants harvested at this date, but when either element is applied in combination with the other the per cent potash

tends to decrease.

The interaction between nitrogen and phosphate, phosphate and potash and the second order interaction of phosphate and potash may not be considered significant as the F values are all lower than the corresponding 5 per cent points.

Also, the analysis of variance in Table No. 48 shows that the variance due to the difference between replicates is significant as the F value 1.0404 is considerably higher than the 5 per cent point 0.8611. This would indicate that a considerable variation between replicate determinations occurred.

The effects of fertilizers on the per cent potash in plants at the second period of sampling are shown by results in Table No. 48 and the statistical analysis of the data is summarized in Table No. 49.

Table No. 46

For Corn Ear in Total Plant at Period of Second Sampling

48 Days After Emergence

Treat-ment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	2.66	3.06	3.70	3.42	2.82	3.62	3.50	3.36
2	2.72	2.66	3.74	3.57	3.08	3.60	3.79	3.82
3	3.20	3.33	3.68	3.60	3.65	3.65	3.56	3.70
4	3.33	3.37	3.82	3.60	3.60	3.42	3.63	3.70
Total	11.91	12.42	14.94	14.19	13.60	14.29	14.48	14.60
Mean	2.98	3.10	3.73	3.55	3.37	3.57	3.62	3.67
% of Mean	86.06	89.74	107.96	102.83	97.64	103.25	104.62	106.07

General Mean = 3.46

Standard Error = 0.057

Standard Error in % of G.M. = 1.66

Table No. 49

Analysis of Variance of Data in Table No. 48 Comparing the Effect of all Fertiliser Treatments on the Per Cent K_2O in the Total Plant Samples at This Date

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.5395	3	0.1700	0.6162	0.5612
Difference between Nitrogen and no Nitrogen	0.1815	1	0.1815	0.4834	0.7522
Difference between Phosphate and no Phosphate	0.0002	1	0.0002		
Difference between Potash and no Potash	0.4346	1	0.4346	1.0610	0.7322
Interaction between Nitrogen and Phosphate	1.0041	1	1.0041	1.5832	0.7522
Interaction between Nitrogen and Potash	0.0088	1	0.0088		
Interaction between Phosphate and Potash	0.0109	1	0.0109		
Second order interaction of Nitrogen, Phosphate and Potash	0.3161	1	0.3161	0.7065	0.7322
Random Error	1.0916	21	0.0520		
Total	3.5073	31			

The data in Table No. 46 are summarized in Table No. 50 to compare the per cent potash in plants from all plots receiving nitrogen, phosphate and potash, with the per cent potash in plants from all plots not receiving any of the respective element.

Table No. 50

Mean Per Cent K_2O of all Determinations in Table No. 46 From Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with the Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Per-cent K_2O	Standard Error
(a) With Nitrogen	3.40	0.057
Without Nitrogen	3.52	0.057
Difference	-0.12	
(b) With Phosphate	3.46	0.057
Without Phosphate	3.44	0.057
Difference	0.02	
(c) With Potash	3.80	0.057
Without Potash	3.74	0.057
Difference	0.06	

The application of nitrogen has had no significant effect on the per cent potash in plants sampled from plots receiving nitrogen when compared with the percent potash in plants from plots receiving no nitrogen. The t value for this comparison is 0.4854 and the 5 per cent point 0.7522. The use of phosphate has not had any significant

effect on the per cent potash in plants from plots receiving phosphate compared with the per cent potash in plants from plots which received no phosphate. The $ value in this case is negative, while the 5 per cent point is 0.7522.

In this date of sampling we find the opposite effect to that observed in the first date of sampling of the application of potash on the per cent potash in the plants. At this period there appears to be a significant increase in the per cent potash in plants sampled from plots which received potash when compared with plants which received no potash. In this analysis also we notice that the variance due to difference between replicates is significant as the $ value is 0.6152 and the 5 per cent point 0.5612; this again indicates a wide variation in per cent potash in plants receiving the same treatment. Hence, too much reliability cannot be placed on the occurrence of directly opposite effects from the application of potash at two consecutive periods of sampling on subsequent per cent potash in the plants when significant variations exist between replicate determinations.

The interaction of nitrogen and phosphate again has a significant effect on the per cent potash in the plant at this period of sampling. The $ value is 1.5232 and the 5 per cent point 0.7522. The summary of this interaction is shown in Table No. 51.

Table No. 51

Per Cent K_2O in Plants

Mean of 8 Determinations from Data in Table No. 46

Treatment	With Phosphate	Without Phosphate
With Nitrogen	5.68	5.51
Without Nitrogen	5.54	5.70

The data in Table No. 51 indicate that when phosphate is used with nitrogen the per cent potash from plants receiving this treatment is higher than the per cent potash in plants from plots receiving no phosphate. However, when phosphate is used without nitrogen the per cent potash in the total plant is lower than that of plants sampled from plots receiving no phosphate.

The interaction between nitrogen and potash, phosphate and potash and the second order interaction of nitrogen, phosphate and potash may not be considered significant as the F values are all below the corresponding 5 per cent points.

The effects of fertilizers on the per cent potash in the plants at the third period of sampling are shown by results in Table No. 52 and the statistical analysis of the data is summarized in Table No. 53.

Table No. 62

Per Cent K_2O in Total Plant at Period of Third Sampling 62 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	2.12	1.82	1.85	1.99	1.83	1.99	2.13	2.42
2	2.11	1.91	2.10	1.89	1.90	2.06	2.11	2.56
3	2.38	2.06	1.70	1.93	2.03	2.16	1.80	2.15
4	2.22	2.03	2.03	2.10	2.08	2.18	2.00	2.17
Total	8.77	7.82	7.68	7.91	7.84	8.32	8.12	9.08
Mean	2.19	1.96	1.92	1.98	1.91	2.08	2.03	2.27
% of Mean	107.36	95.72	94.00	96.82	93.51	101.84	99.39	111.14

General Mean = 2.04

Standard Error = 0.060

Standard Error in % of G.M. = 5.53

Table No. 53

Analysis of Variance of Data in Table No. 52

Comparing the Effects of all Fertilizer Treatments

On the Per Cent K_2O in the Total Plants

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Squares	χ^2	5% Point
Difference between replications	0.0481	3	0.0148		
Difference between Nitrogen and no Nitrogen	0.0066	1	0.0066		
Difference between Phosphate and no Phosphate	0.0512	1	0.0512	0.2668	0.7322
Difference between Potash and no Potash	0.1066	1	0.1066	0.8668	0.7322
Interaction between Nitrogen and Phosphate	0.0018	1	0.0018		
Interaction between Nitrogen and Potash	0.0000	1	0.0000		
Interaction between Phosphate and Potash	0.3280	1	0.3280	1.4430	0.7322
Second order interaction of Nitrogen, phosphate, and potash	0.0100	1	0.0100		
Random Error	0.3048	21	0.0163		
Total	0.9067	31			

The data in Table No. 52 are summarized in Table No. 54 to compare the per cent potash in plants from all plots receiving nitrogen, phosphate and potash with the per cent potash in plants from all plots not receiving any of the respective element.

Table No. 54

Mean Per Cent K_2O of all Determinations in Table No. 52 From Plots which Received (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with the Corresponding Plots Which Received None of the Respective Element

Treatment	Mean Per-cent K_2O	Standard Error
(a) With Nitrogen	2.05	0.034
Without Nitrogen	2.06	0.034
Difference	-0.03	
(b) With Phosphate	2.01	0.034
Without Phosphate	2.07	0.034
Difference	-0.06	
(c) With Potash	1.98	0.034
Without Potash	2.10	0.034
Difference	-0.12	

The application of nitrogen has not had a significant effect on the per cent potash in the plant as the t value is lower than the 5 per cent point. The application of phosphate has not significantly affected the potash content of the plant as the t value for a comparison of all plots

receiving phosphate with all not receiving phosphate is lower than the 5 per cent point.

The application of potash shows a slight decrease in the per cent potash in the plants from all plots receiving potash when compared with all plots receiving no potash. This effect may be considered just above the level of significance as the t value is only slightly higher than the 5 per cent point.

The interaction of phosphate and potash has a significant effect on the per cent potash in the plants when sampled at this date. The summary of this interaction is given in Table No. 56.

Table No. 56

Mean Per Cent K_2O in Plants

Mean of 6 Determinations from Data in Table No. 52

Treatment	With Potash	Without Potash
With Phosphate	2.05	1.97
Without Phosphate	1.91	2.23

The data in Table No. 56 indicate that the application of phosphate in combination with potash has a tendency to increase the per cent potash in the plant when compared with plots which received no phosphate. When phosphate is applied without potash the per cent potash in the plant shows a tendency to decrease when compared with plots receiving no phosphate.

The interaction between nitrogen and phosphate, nitrogen and potash, and the second order interaction of nitrogen, phosphate and potash may not be considered significant as the 5 values are all lower than the corresponding 5 per cent points.

The effects of fertilizers on the per cent potash in the grain at maturity are shown by results in Table No. 56 and the statistical analysis of the data is summarized in Table No. 57.

Table No. 66

Per Cent K_2O in the Grain Harvested 100 Days After Seeding and 60 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	0.820	0.753	0.830	0.715	0.758	0.846	0.716	0.806
2	0.842	0.718	0.764	0.707	0.795	0.758	0.759	0.761
3	0.755	0.693	0.824	0.788	0.765	0.736	0.746	0.770
4	0.733	0.708	0.847	0.810	0.831	0.770	0.726	0.814
Total	3.150	2.863	3.265	3.020	3.147	3.100	2.950	3.150
Mean	0.787	0.716	0.811	0.787	0.787	0.775	0.781	0.787
% of Mean	102.24	92.92	105.32	99.80	102.14	100.62	94.94	102.24

General Mean = 0.770

Standard Error = 0.020

Standard Error in % of G.M. = 2.60

Table No. 57

Analysis of Variance for Data in Table No. 56

Comparing the Effects of all Fertilizer Treatments

On the Per Cent K$_2$O in the Grain

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicate	0.0027	3	0.0009		
Difference between Nitrogen and no Nitrogen	0.0001	1	0.0001		
Difference between Phosphate and no Phosphate	0.0169	1	0.0169	1.2110	0.7388
Difference between Potash and no Potash	0.0016	1	0.0016	0.0012	0.7388
Interaction between Nitrogen and Phosphate	0.0005	1	0.0005		
Interaction between Nitrogen and Potash	0.0071	1	0.0071	0.7774	0.7388
Interaction between Phosphate and Potash	0.0000	1	0.0000		
Second order interaction of Nitrogen, Phosphate and Potash	0.0019	1	0.0019	0.1165	0.7388
Random Error	0.0311	21	0.0015		
Total					

The data in Table No. 56 are summarized in Table No. 58 to compare the per cent potash in the grain from all plots receiving nitrogen, phosphate and potash with the per cent potash in the grain from all plots not receiving any of the respective element.

Table No. 58

Mean Per Cent K_2O in Grain of All Determinations in Table No. 56 From all Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with the Corresponding Plots not Receiving any of the Respective Element

Treatment	Mean per-cent K_2O	Standard Error
(a) With Nitrogen	0.77	0.010
Without Nitrogen	0.77	0.010
Difference	0.00	
(b) With Phosphate	0.75	0.010
Without Phosphate	0.79	0.010
Difference	-0.04	
(c) With Potash	0.78	0.010
Without Potash	0.76	0.010
Difference	0.02	

The use of phosphate has a tendency to decrease the per cent potash in the grain when all plots which received phosphate were compared with those receiving no phosphate. This decrease may be considered significant as the 5 value is higher than the 5 per cent point. The application of nitrogen and potash have not had any significant effect on

the per cent potash in the grain but the interaction of nitrogen and potash appears to be significant.

The effect of the interaction of nitrogen and to potash on the potash content of the grain is significant, the 1 value being higher than the 5 per cent point. The results are summarized in Table No. 59.

Table No. 59

Per Cent K_2O in Grain

Mean of 8 Determinations from Data in Table No. 56

Treatment	With Potash	Without Potash
With Nitrogen	0.76	0.78
Without Nitrogen	0.79	0.76

The data in Table No. 57 indicate that the use of nitrogen in combination with potash tends to decrease the per cent potash in the grain when compared with plots which received no nitrogen. However, when nitrogen is applied without potash the per cent potash in the grain is increased when a comparison is made with plots receiving no nitrogen.

The interaction between nitrogen and phosphate, phosphate and potash, and the second order interaction of nitrogen, phosphate and potash cannot be considered significant as the 1 values are all lower than the corresponding 5 per cent points.

The effects of fertilizers on the per cent potash in the mature straw are shown by results in Table No. 60 and the statistical analysis of the data is summarised in Table No. 61.

Table No. 60

Per Cent K_2O in Mature Straw Harvested

100 Days After Seeding and

80 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	C
1	2.59	2.42	2.46	2.48	2.61	2.54	2.58	2.60
2	2.57	2.15	2.63	2.60	2.64	2.49	2.59	2.50
3	2.40	2.48	2.54	2.62	2.63	2.50	2.57	2.59
4	2.60	2.50	2.51	2.44	2.64	2.38	2.54	2.59
Total	10.16	9.55	10.04	10.04	10.42	9.91	9.68	9.68
Mean	2.54	2.39	2.51	2.51	2.60	2.48	2.47	2.47
% of Mean	101.60	95.69	100.60	100.60	104.41	99.30	99.00	99.00

General Mean = 2.49

Standard Error = 0.049

Standard Error in % of G.M. = 1.97

Table No. 61

Analysis of Variance of Data in Table No. 60

Comparing the Effects of all Fertilizer Treatments

On the Per Cent K₂O in the Mature Straw

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0071	3	0.0023		
Difference between Nitrogen and no Nitrogen	0.0368	1	0.0368	0.6965	0.7322
Difference between Phosphate and no Phosphate	0.0368	1	0.0368	0.6965	0.7322
Difference between Potash and No Potash	0.0120	1	0.0120	0.1116	0.7322
Interaction between Nitrogen and Phosphate	0.0012	1	0.0012		
Interaction between Nitrogen and Potash	0.0056	1	0.0056		
Interaction between Phosphate and Potash	0.0015	1	0.0015		
Second order interaction of Nitrogen, Phosphate and Potash	0.0150	1	0.0150	0.1116	0.7322
Random Error	0.3021	81	0.0036		
Total	0.3200	91			

The data in Table No. 60 are summarised in Table No. 62 to compare the per cent potash in mature straw from all plots receiving nitrogen, phosphate and potash with the per cent potash in the mature straw from all plots not receiving any of the respective element.

Table No. 62

Mean Per Cent K_2O of all Determinations in Table No. 60 From All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with all Corresponding Plots Not Receiving any of the Respective Element

	Treatment	Mean per-cent K_2O	Standard Error
(a)	With nitrogen	2.53	0.024
	Without nitrogen	2.46	0.024
	Difference	0.07	
(b)	With Phosphate	2.46	0.024
	Without phosphate	2.53	0.024
	Difference	-0.07	
(c)	With potash	2.52	0.024
	Without potash	2.48	
	Difference	0.04	

The application of nitrogen has no significant effect on the per cent potash in the straw when all plots receiving nitrogen are compared with all plots receiving no nitrogen. The application of phosphate has no significant effect on the per cent potash as the t value for the comparison of all plots which received phosphate with those which receiv-

ed no phosphate, is lower than the 5 per cent point.

The application of potash also has had no significant effect on the per cent potash in the straw as again the t value is lower than the 5 per cent point when all plots receiving potash are compared with all those which did not receive potash.

None of the interactions may be considered significant as all the t values are lower than the corresponding 5 per cent points.

4. The Effect of Fertilizers on the Ash Content of Wheat Plants at the Various Stages of Growth.

The effects of fertilizers on the per cent ash in the plants at the first period of sampling are shown by results in Table No. 63 and the statistical analysis of the data is summarized in Table No. 64.

Table No. 63

Per Cent Ash in Total Plants at

First Period of Sampling

Harvested 28 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	17.30	16.36	16.07	17.43	16.28	17.25	17.01	16.54
2	17.42	16.03	16.26	17.69	16.56	17.22	16.93	16.76
3	17.29	16.10	17.56	17.16	17.60	17.11	17.11	16.89
4	17.68	16.16	17.70	17.11	17.86	17.68	17.11	16.83
Total	69.74	64.64	67.58	69.21	68.30	69.20	68.16	65.02
Mean	17.43	16.16	16.89	17.30	17.07	17.30	17.04	16.56
% of Mean	102.91	95.38	99.72	102.12	100.78	102.11	100.58	98.38

General Mean = 16.94

Standard Error = 0.24

Standard Error in % of G.M. = 1.42

Table No. 64

Analysis of Variance of Data in Table No. 65

Comparing the Effects of All Fertilizer Treatments

On the Per Cent Ash in the Plants

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	z	5% Point
Difference between replications	0.0512	3	0.1092		
Difference between Nitrogen and no Nitrogen	2.3490	1	2.3490	1.1709	0.7522
Difference between Phosphate and no Phosphate	0.0023	1	0.0023		
Difference between Potash and no Potash	0.0959	1	0.0959	0.4767	0.7522
Interaction between Nitrogen and Phosphate	0.0010	1	0.0010		
Interaction between Nitrogen and Potash	2.7066	1	2.7066	1.3422	0.7522
Interaction between Phosphate and Potash	0.0074	1	0.0074		
Second order interaction of Nitrogen, Phosphate and Potash	0.3936	1	0.3936	0.1950	0.7522
Random Error	4.7446	21	0.2259		
Total	10.6737	31			

The data in Table No. 65 are summarised in Table No. 66 to compare the per cent ash in plants from all plots receiving nitrogen, phosphate and potash, with the per cent ash in plants from all plots not receiving any of the respective element.

Table No. 66

Mean Per Cent Ash of All Determinations in Table No. 65 From Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with All Corresponding Plots Not Receiving any of the Respective Element

	Treatment	Mean per-cent ash	Standard Error
(a)	With Nitrogen	17.21	0.12
	Without Nitrogen	16.67	0.12
	Difference	0.54	
(b)	With Phosphate	16.98	0.12
	Without Phosphate	16.93	0.12
	Difference	0.05	
(c)	With Potash	17.06	0.12
	Without Potash	16.81	0.12
	Difference	0.27	

The application of nitrogen has increased significantly the per cent ash in the plants sampled at this period. When all plots receiving nitrogen are compared with all those receiving no nitrogen the S value is higher than the 5 per cent point. The use of phosphate or potash has had no significant effect on the per cent ash in the plants sampled

at this period.

From the analysis of variance a significant interaction between nitrogen and potash is shown, the F value being higher than the 5 per cent point.

Table No. 66

Per Cent Ash in Plant at 1st Sampling

Mean of 8 Determinations from Data in Table No. 62

Treatment	With Potash	Without Potash
With Nitrogen	17.06	17.37
Without Nitrogen	17.13	16.84

From the data in Table No. 66 it appears that when nitrogen is applied in combination with potash the per cent ash in the plant is slightly decreased when compared with plots receiving no nitrogen, but when nitrogen is applied alone the per cent ash in the plants is considerably increased over that in plants grown on plots which received no nitrogen.

The interaction between nitrogen and phosphate, phosphate and potash and the second order interaction of nitrogen, phosphate and potash are not significant, the F values being lower than the corresponding 5 per cent points.

The effects of fertilisers on the per cent ash in plants at the second period of sampling are shown by results in Table No. 67 and the statistical analysis of the data is

summarised in Table No. 66.

Table No. 67

Per Cent Ash in Plants at Period of Second Sampling

Harvested 40 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	12.86	13.13	11.99	12.70	13.86	13.20	10.88	11.76
2	12.49	13.10	11.94	12.71	13.30	13.16	10.77	11.90
3	13.00	11.71	13.16	10.98	11.97	11.64	11.99	13.68
4	13.88	11.49	13.86	11.14	11.97	11.66	11.92	13.80
Total	51.86	49.43	50.35	47.63	50.50	50.06	44.96	51.16
Mean	12.81	12.36	12.89	11.80	12.62	12.52	11.24	12.79
% of Mean	103.74	100.04	101.90	96.20	102.20	101.36	90.99	103.64

General Mean = 12.35

Standard Error = 0.44

Standard Error in % of G.M. = 3.56

Table No. 68

Analysis of Variance of Data in Table No. 67 Comparing the Effects of All Fertilizer Treatments on the Per Cent Ash in the Plants at Harvest Time

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	S	5 % Point
Difference between replicates	0.0434	3	0.0145		
Difference between Nitrogen and no Nitrogen	1.4323	1	1.4323	0.2990	0.7328
Difference between Phosphate and no Phosphate	3.9692	1	3.9692	0.8288	0.7328
Difference between Potash and no Potash	0.3606	1	0.3606		
Interaction between Nitrogen and Phosphate	1.6516	1	1.6516	0.3706	0.7328
Interaction between Nitrogen and Potash	0.3140	1	0.3140		
Interaction between Phosphate and Potash	0.0036	1	0.0036		
Second order interaction of Nitrogen, Phosphate and Potash	0.3342	1	0.3342		
Random Error	16.5502	21	0.7879		
Total	24.6623	31			

The data in Table No. 67 are summarised in Table No. 69 to compare the per cent ash in plants from all plots receiving nitrogen, phosphate and potash with the per cent ash in plants from plots not receiving any of the respective element.

Table No. 69

Mean Per Cent Ash of all Determinations in Table No. 67 From all Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with All Corresponding Plots Not Receiving Any of the Respective Element

Treatment	Mean per-cent Ash	Standard Error
(a) With Nitrogen	12.14	0.22
Without Nitrogen	12.56	0.22
Difference	-00.42	
(b) With Phosphate	12.00	0.22
Without Phosphate	12.70	0.22
Difference	-00.70	
(c) With Potash	12.24	0.22
Without Potash	12.46	0.22
Difference	-00.22	

The application of phosphate has resulted in a significant decrease in the per cent ash in the plants sampled at heading time when all plots receiving phosphate are compared with all those which received no phosphate. The effect is significant, the t value being slightly higher than the 5 per cent point.

The use of nitrogen or potash and none of the interactions may be considered significant as the t values are

all lower than the corresponding 5 per cent points.

The effects of fertilisers on the per cent ash in the plants at the third sampling are shown by results in Table No. 70, and the statistical analysis of the data is summarised in Table No. 71.

Table No. 70

Per Cent Ash in the Total Plant

At Period of Third Sampling

Harvested 62 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	10.20	10.16	9.92	8.59	9.09	9.24	8.71	10.00
2	10.32	9.94	9.66	8.82	8.97	9.72	8.77	10.30
3	9.22	8.90	9.53	8.51	9.37	9.25	9.12	8.43
4	9.26	8.76	9.05	8.40	9.60	8.99	8.96	8.52
Total	39.00	37.75	38.14	33.72	37.02	37.20	35.56	37.25
Mean	9.75	9.69	9.53	8.43	9.26	9.30	8.89	9.31
% of Mean	105.52	102.14	103.19	91.25	100.16	100.65	96.27	100.78

General Mean = 9.24

Standard Error = 0.23

Standard Error in % of G.M. = 2.49

Table No. 71

Analysis of Variance of Data in Table No. 70 Comparing the Effects of all Fertilizer Treatments On the Per Cent Ash in the Total Plant

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	2.0101	3	0.6633	0.5569	0.5612
Difference between Nitrogen and no Nitrogen	0.7875	1	0.7875	0.6446	0.7522
Difference between Phosphate and no Phosphate	1.6021	1	1.6021	0.9997	0.7522
Difference between Potash and no Potash	0.0016	1	0.0025		
Interaction between Nitrogen and Phosphate	1.2324	1	1.2324	0.6664	0.7522
Interaction between Nitrogen and Potash	0.0066	1	0.0066		
Interaction between Phosphate and Potash	0.1800	1	0.1800		
Second order interaction of Nitrogen, Phosphate and Potash	0.6712	1	0.6712	0.6951	0.7522
Random Error	4.6564	21	0.2169		
Total	11.2468	31			

The data in Table No. 70 are summarized in Table No. 72 to compare the per cent ash in plants from all plots receiving nitrogen, phosphate and potash, with the per cent ash in plants from all plots not receiving any of the respective element.

Table No. 72

Mean Per Cent Ash of All Determinations in Table No. 70 From All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with All Corresponding Plots Not Receiving Any of the Respective Element

Treatment		Mean Per-cent Ash	Standard Error
(a)	With Nitrogen	9.08	0.12
	Without Nitrogen	9.40	0.12
	Difference	-0.32	
(b)	With Phosphate	9.02	0.12
	Without Phosphate	9.46	0.12
	Difference	-0.44	
(c)	With Potash	9.25	0.12
	Without Potash	9.25	0.12
	Difference	0.00	

The application of phosphate has resulted in a decrease in the per cent ash in the plants sampled at this period when all plots receiving phosphate are compared with all those which received no phosphate. This decrease may be considered significant as the t value is higher than the 5 per cent point.

The application of nitrogen or potash has had no significant effect on the per cent ash in the plant.

The interaction of nitrogen and phosphate appears to have a significant effect as the 2 value is higher than the 5 per cent point.

The results are summarised in Table No. 75.

Table No. 75

Per Cent Ash in Plant at Second Sampling Period

Mean of 8 Determinations from Data in Table No. 70

Treatment	With Phosphate	Without Phosphate
With Nitrogen	8.66	9.50
Without Nitrogen	9.37	9.44

The data in Table No.n75 show that if nitrogen and phosphate are applied in combination a decrease in per cent ash in the plants result when compared with plots receiving no nitrogen, but if nitrogen is applied alone, an increase in per cent ash results when compared with plots which receive no nitrogen.

None of the remaining interactions are significant as the 2 values are all lower than the corresponding 5 per cent points.

The effects of fertilisers on the per cent ash in the grain at maturity are shown by the results in Table No. 76 and the statistical analysis of the data is summarised in Table No. 75.

Table No. 74

Per Cent Ash in Grain Harvested 100 Days After Seeding and 80 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	1.93	1.65	1.86	1.69	1.76	1.94	1.70	1.87
2	2.07	1.92	1.71	1.67	1.80	2.04	1.62	1.94
3	1.84	1.73	2.09	1.67	1.65	1.60m	1.59	1.69
4	1.86	1.80	1.91	1.67	1.67	1.56	1.60	1.87
Total	7.70	7.08	7.57	6.70	6.76	7.14	6.59	7.37
Mean	1.92	1.77	1.89	1.67	1.74	1.78	1.65	1.89
% of Mean	107.84	99.16	106.02	93.84	94.68	100.00	92.30	106.02

General Mean = 1.78

Standard Error = 0.06

Standard Error in % of G.M. = 3.37

Table No. 75

Analysis of Variance of Data in Table No. 74

Comparing the Effects of all Fertilizer Treatments

On the Per Cent Ash in the Grain

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	F	5% Point
Difference between replicates	0.0630	3	0.0206	0.1574	0.5612
Difference between Nitrogen and no Nitrogen	0.0810	1	0.0810	0.6172	0.7522
Difference between Phosphate and no Phosphate	0.1365	1	0.1365	1.0760	0.7522
Difference between Potash and no Potash	0.0306	1	0.0306	1.3304	0.7522
Interaction between Nitrogen and Phosphate	0.0020	1	0.0020		
Interaction between Nitrogen and Potash	0.0585	1	0.0585	0.4453	0.7522
Interaction between Phosphate and Potash	0.0585	1	0.0585	0.4453	0.7522
Second order interaction of Nitrogen, Phosphate and Potash	0.0048	1	0.0048		
Random Error	0.5321	81	0.0159		
Total	0.7270	91			

The data in Table No. 74 are summarized in Table No. 76 to compare the per cent ash in the grain from all plots receiving nitrogen, phosphate and potash with the per cent ash in the grain from all plots receiving none of the respective element.

Table No. 76

Mean Per Cent Ash in Grain

Of All Determinations in Table No. 74

From all Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with all Those Plots Not Receiving Any of the Respective Element

Treatment	Mean Per-cent Ash	Standard Error
(a) With Nitrogen	1.73	0.03
Without Nitrogen	1.84	0.03
Difference	-0.11	
(b) With Phosphate	1.72	0.03
Without Phosphate	1.85	0.03
Difference	-0.13	
(c) With Potash	1.75	0.03
Without Potash	1.82	0.03
Difference	-0.07	

The application of nitrogen has decreased the per cent ash in the grain when all plots which received nitrogen are compared with all those receiving no nitrogen. The application of phosphate has also decreased the per cent ash in the grain when a comparison is made of all plots receiving

no phosphate. These decreases in per cent ash may be considered significant as the χ^2 values are slightly higher than the 5 per cent points. The use of potash has had no significant effect on the per cent ash.

None of the interactions are significant as the χ^2 values are all lower than the corresponding 5 per cent points.

The effects of fertilizers on the per cent ash in the mature straw are shown by the results in Table No. 77 and the statistical analysis is summarized in Table No. 78.

Table No. 77

Per Cent Ash in Mature Straw

Harvested 100 Days After Seeding

And 60 Days After Emergence

Treatment	N	P	K	N.P.	N.K.	P.K.	N.P.K.	0
1	10.08	10.64	12.28	10.51	10.19	10.98	10.66	11.35
2	10.32	10.74	11.56	10.11	10.01	10.62	10.39	11.05
3	10.63	10.98	11.24	9.56	10.60	10.46	10.35	11.23
4	10.43	10.38	11.15	9.66	10.77	10.34	10.31	11.16
Total	42.34	42.74	46.23	40.04	41.47	42.62	41.91	44.69
Mean	10.56	10.68	11.56	10.01	10.37	10.65	10.48	11.17
% of mean	96.99	100.26	108.44	93.92	97.89	99.98	98.31	104.83

General Mean = 10.66

Standard Error = 0.16

Standard Error in % of G.M. = 1.50

Table No. 78

Analysis of Variance of Data in Table No. 77

Comparing the Effects of all Fertiliser Treatments

On the Per Cent Ash in the Mature Straw

Variance Due to	Sum of Squares	Degrees of Freedom	Mean Square	z	5% Point
Difference between replicates	0.4594	3	0.1516	0.2269	0.5612
Difference between Nitrogen and no Nitrogen	4.1472	1	4.1472	1.6814	0.7322
Difference between Phosphate and no Phosphate	1.2880	1	1.2880	1.2971	0.7322
Difference between Potash and no Potash	0.3655	1	0.3655	0.6668	0.7322
Interaction between Nitrogen and Phosphate	0.6903	1	0.6903	0.9848	0.7322
Interaction between Nitrogen and Potash	0.0105	1	0.0105		
Interaction between Phosphate and Potash	0.0002	1	0.0002		
Second order interaction of Nitrogen, Phosphate and Potash	0.3613	1	0.3613	0.6612	0.7322
Random Error	2.0254	21	0.0965		
Total	9.3458	31			

The data in Table No. 77 are summarised in Table No. 79 to compare the per cent ash in the mature straw from all plots receiving nitrogen, phosphate and potash with the per cent ash in the mature straw from all plots not receiving any of the respective element.

Table No. 79

Mean Per Cent Ash in Mature Straw

Of All Determinations in Table No. 75

From All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with the Corresponding Plots Not Receiving Any of the Respective Element

Treatment	Mean Per-cent Ash	Standard Error
(a) With Nitrogen	10.30	0.08
Without Nitrogen	11.02	0.08
Difference	-00.72	
(b) With Phosphate	11.46	0.08
Without Phosphate	10.66	0.08
Difference	-00.40	
(c) With Potash	10.76	0.08
Without Potash	10.55	0.08
Difference	00.21	

The application of nitrogen has resulted in a decrease in per cent ash in the mature straw when a comparison is made of all plots receiving nitrogen, with all plots receiving no nitrogen. The application of phosphate has also resulted in a decrease in per cent ash when a similar comparison is made.

These two decreasing effects may be considered significant as the 5 values are higher than the corrogponding 5 per cent points.

The use of Potash has had no significant effect on the per cent ash in the mature straw.

The interaction of nitrogen and phosphate is significant from the analysis of variance. The result of the interaction is shown in Table No. 80.

Table No. 80

Per Cent Ash in Mature Straw

Mean of 8 Plots From Data in Table No. 77

Treatment	With Phosphate	Without Phosphate
With Nitrogen	10.84	10.85
Without Nitrogen	10.67	11.36

From data in Table No. 80 where nitrogen is applied in combination with phosphate the per cent ash is decreased below that of plots receiving no nitrogen to a much less extent than the decrease of per cent ash which occurs when nitrogen is applied alone, when compared with plots receiving no nitrogen.

None of the remaining interactions may be considered significant as the 5 values are all lower than the corresponding 5 per cent points.

IV. COMPARISON OF THE AMOUNTS REMOVED AND THE RELATIVE RATE OF INTAKE OF NUTRIENTS BY PLANTS

The second phase of the study deals with the amount of nutrients removed per acre, and the time and relative rate of intake of nutrients by the wheat plants, when treated with the different fertilisers.

a. The Amounts of Nutrients Removed When Treated with Different Fertilisers

The amounts of nitrogen, phosphate and potash removed per acre by the plants, twenty-five days after emergence and at maturity were calculated from the percentage composition and weight of dry matter per acre at the respective dates.

The yields of dry matter of plants in pounds per acre, sampled 25 days after emergence are shown in Table No. 61.

Table No. 81

Mean Weight of Dry Matter from All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with All Corresponding Plots not Receiving any of the Respective Input

25 Days After Emergence

Treatment	Mean yield dry matter in pounds	Differ-ence in Pounds
(a) With Nitrogen	668.5	51.9
Without Nitrogen	616.6	
(b) With Phosphate	715.4	145.6
Without Phos-phate	569.8	
(c) With Potash	698.0	92.9
Without Potash	605.1	

The total yield of dry matter of plants in pounds per acre at maturity are shown in Table No. 82.

Table No. 62

Mean Weight of Dry Matter from All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with All Those not Receiving Any of the Respective Element

At Maturity

Treatment	Mean Yield of Dry Matter in Lbs.	Difference in Pounds
(a) With Nitrogen	4884.0	551.1
Without Nitrogen	4332.9	
(b) With Phosphate	5126.0	1015.2
Without Phosphate	4110.8	
(c) With Potash	4484.2	-208.4
Without Potash	4692.6	

The data in Table No. 61 indicate that the total dry matter in the plants sampled June 17th has been increased by the use of each element when a comparison is made with all plots receiving no application of the respective element. The application of phosphate is obviously the most influential in producing the increase in dry matter, yielding a difference of 145.6 pounds per acre when all plots which received phosphate are compared with those receiving no phosphate. Nitrogen and potash also have resulted in an increase in total dry matter.

The data in Table No. 62 which summarize the total dry matter in the plants at maturity again show that the

use of phosphate has resulted in a marked increase in dry matter of 1016.8 pounds. The application of nitrogen has increased the yield 531.1 pounds, but an average decrease of 265.4 pounds is noted on all those receiving potash.

The total weights of phosphate removed by the plants early in growth are computed and shown in Table No. 85.

Table No. 85

Mean Weight of P_2O_5 in Pounds per Acre Removed by Plants Harvested June 17th, 1930

The Weights in Plants from All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash as Compared with All the Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Weight P_2O_5 in Pounds	Difference in Pounds
(a) With Nitrogen	4.88	0.35
Without Nitrogen	4.53	
(b) With Phosphate	5.42	1.43
Without Phosphate	3.99	
(c) With Potash	4.66	0.31
Without Potash	4.35	

The marked increase in the weight of phosphate removed by plants grown on plots which received phosphate compared with the plots receiving no phosphate is entirely due to the increased weight of dry matter produced by the application of phosphate. Slight increases in the weights of

phosphate in plants from plots which received nitrogen and also from plots which received potash are observed. These increases also are due to the increased dry matter produced by the use of these elements.

The amounts of phosphate removed per acre by plants at maturity are shown in Table No. 64.

Table No. 64

Mean Weights of P_2O_5 in Pounds per Acre in Total Plants at Maturity

The Weights in Plants from Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with All Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Weight P_2O_5 in Pounds per Acre	Difference in Pounds
(a) With Nitrogen	16.06	-0.20
Without Nitrogen	16.26	
(b) With Phosphate	17.16	1.98
Without Phosphate	15.17	
(c) With Potash	15.64	
Without Potash	16.79	

The data in Table No. 64 show that the application of nitrogen has decreased the total weight of phosphate removed by the plants. The lower amounts of phosphate removed by plants from plots receiving nitrogen are the result of a decrease in per cent phosphate from this

treatment, which more than off-sets the increase in dry matter.

The weight of phosphate removed by the plants which received phosphate is increased. This increase is due to the increased total dry matter per acre on plots receiving phosphate. The amount of phosphate removed by the plants from plots which received potash is decreased. This is due to the decrease in total dry matter resulting from this treatment.

The amounts of nitrogen per acre removed by plants at first period of sampling are computed and shown in Table No. 66.

Table No. 66

Mean Weight per Acre of Nitrogen in Plants At First Sampling from All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash, Compared with all Plots Not Receiving Any of the Respective Element

Treatment	Mean weight Nitrogen in Lbs. per Acre	Difference in Pounds
(a) With Nitrogen	29.67	1.84
Without Nitrogen	28.05	
(b) With Phosphate	32.64	7.18
Without Phosphate	25.56	
(c) With Potash	30.64	3.38
Without Potash	27.26	

Increases in weight of nitrogen per acre are affected by all three elements. This increase is almost entirely due to the increases in total dry matter recorded in Table No. 61.

The amounts of nitrogen per acre removed by plants at maturity are computed and shown in Table No. 66.

Table No. 66

Mean Weight in Pounds per Acre of Nitrogen in Plants at Maturity from All Plots Which Received (a) Nitrogen; (b) Phosphate; (c) Potash Compared with All the Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Weight Nitrogen in Lbs. per Acre	Difference in Pounds
(a) With Nitrogen	66.14	11.16
Without Nitrogen	55.98	
(b) With Phosphate	64.57	10.02
Without Phosphate	54.55	
(c) With Potash	56.35	-6.42
Without Potash	62.77	

The data in Table No. 66 show a greater increase in weight of nitrogen in the plant when nitrogen was applied than by the application of phosphate, even though the total weight of dry matter in plants from plots receiving nitrogen is considerably less than that of the plots to which phosphate was applied. This result is due to the increase

in per cent nitrogen in the plant affected by the application of nitrogen and a decrease in per cent nitrogen affected by the application of phosphate. The decrease in weight of nitrogen in plants from the plots receiving potash is due to the decrease in total dry matter in these plants.

The amounts of potash per acre removed by plants at first period of sampling are computed and the results shown in Table No. 87.

Table No. 87

Mean Weight in Pounds per Acre of Potash in Plants at First Sampling from All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with All Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Weight K_2O in Lbs. per Acre	Difference in Pounds
(a) With Nitrogen	30.08	1.68
Without Nitrogen	28.40	
(b) With Phosphate	32.08	5.68
Without Phosphate	26.40	
(c) With Potash	30.62	2.86
Without Potash	27.96	

The data in Table No. 87 indicate the total intake of potash by the plants is increased by the application of nitrogen, of phosphate and of potash. By comparing these increases with the increases in weight of dry matter in

Table No. 61 they are found to be in the same proportion.

The amounts of potash removed per acre by plants at maturity are computed and the results shown in Table No. 66.

Table No. 66

Mean Weight in Pounds per Acre of Potash in Plants at Maturity, From All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with all Corresponding Plots Not Receiving any of the Respective Element

Treatment	Mean Weight K_2O in Lbs. per Acre	Difference in Pounds
(a) With Nitrogen	102.55	13.40
Without Nitrogen	88.95	
(b) With Phosphate	104.86	18.42
Without Phosphate	86.44	
(c) With Potash	93.67	-3.96
Without Potash	97.63	

The increase in weight of potash in plants from plots which received nitrogen and the increase from plots which received phosphate are due to the increase in total dry matter affected by these treatments. (See Table No.61)

The decrease in weight of potash in plants from plots which received potash is due to the decrease in weight of total dry matter in plants from plots receiving that treatment.

The total amount of ash per acre removed by plants

at the first period of sampling are computed and the results are shown in table No. 89.

Table No. 89

Mean Weight in Pounds per Acre of Ash in Plants At First Sampling from All Plots Receiving (a) Nitrogen; (b) Phosphate; (c) Potash Compared with All Plots Not Receiving Any Of the Respective Element

Treatment	Mean Weight Ash in Lbs. per Acre	Difference in Pounds
(a) With Nitrogen	114.08	11.96
Without Nitrogen	103.02	
(b) With Phosphate	121.66	25.16
Without Phosphate	96.42	
(c) With Potash	117.70	17.48
Without Potash	100.26	

The data in Table No. 89 show the weight of ash in the plants at this sampling has been increased by application of each of the three elements. These increases are almost in direct proportion to the increases in dry matter resulting from the same treatments. (See Table 81)

The total amounts of ash per acre removed by plants at maturity are computed and the results shown in Table No. 90.

Table No. 90

Mean Weight in Pounds per Acre of Ash
In Plants at Maturity from All Plots Receiving
(a) Nitrogen; (b) Phosphate; (c) Potash
Compared with All Plots Not Receiving any
Of the Respective Element

Treatment	Mean Weight Ash in Lbs. per Acre	Difference in Pounds
(a) With Nitrogen	400.41	20.45
Without Nitrogen	379.96	
(b) With Phosphate	424.94	69.52
Without Phosphate	355.42	
(c) With Potash	383.84	-12.69
Without Potash	396.53	

The increases in weight of total ash in the plants at maturity resulting from the application of nitrogen and of phosphate are due to the increase in the total weight of dry matter which resulted from these treatments.

The decrease in total ash in plants from plots receiving potash is due to the decrease in total dry matter resulting from the application of potash.

b. Relation of the Amount of Nutrient Supplied in Fertiliser to the Amount Removed by Plants.

The relation of the amount of nitrogen, phosphate and potash per acre applied as fertiliser and the total amount per acre of the respective elements removed by plants at maturity are shown in Table No. 91.

Table No. 91

Relation of the Amount of (a) N; (b) P_2O_5; (c) K_2O Applied at Time of Seeding to the Total Mount of the Respective Element Removed by the Plant at Maturity

(a) Nutrient	Lbs. Nitrogen Applied	Lbs. Nitrogen Removed
With Nitrogen	22.5	65.14
Without Nitrogen	-	53.98
Difference	22.5	11.16
(b) Nutrient	**Lbs. Phosphate Applied**	**Lbs. Phosphate Removed**
With Phosphate	33.0	17.15
Without Phosphate	-	15.17
Difference	33.0	1.98
(c) Nutrient	**Lbs. Potash Applied**	**Lbs. Potash Removed**
With Potash	24.0	93.67
Without Potash	-	97.63
Difference	24.0	-3.96

The data in Table No. 91 show that from plots which received an application of 22 pounds of nitrogen per acre

an actual increase of 11.10 pounds of nitrogen per acre was removed by the plants which received this treatment. Also with an application of 33 pounds per acre of phosphate only 1.96 pounds per acre more phosphate was removed by the plants from plots which received this treatment. The application of 24 pounds of potash per acre has resulted in a decrease of 3.96 pounds of potash per acre. This decrease is due to the decrease in total weight of dry matter per acre in plants from plots which received potash.

These data indicate that smaller applications of nitrogen and particularly phosphate, should be sufficient to promote the same increase in total yield of dry matter and of grain under Red River Valley conditions.

The use of potash apparently is not only of no beneficial effect in the production of wheat on Red River Valley soils, but shows a considerable depressing effect, according to the results obtained in this experiment.

c. Daily Rate of Intake of Nutrients

Having secured data showing the number of pounds per acre of nitrogen, phosphate and potash removed by the plants at the time of the first sampling and also the quantity of each element removed by the mature plants, a calculation was made of the daily intake of nitrogen in pounds per acre from plots receiving nitrogen; of phosphate from plots receiving phosphate; and potash from plots receiving potash, compared with the daily intake from plots not receiving any of the

respective element. This study was made for the first 28 days after emergence and from this period to maturity.

The results for the relative daily rate of intake of nitrogen, in pounds per acre by plants at first period and at maturity are shown in Table No. 92.

Table No. 92

Daily Intake of Nitrogen by Plants

In Pounds Per Acre

Treatment	Growth Period	Length in Days	Lbs. of Nitrogen taken by plants	Daily Intake in Lbs.
With Nitrogen	May 23 to June 17	25	29.67	1.19
Without Nitrogen	May 23 to June 17	25	28.03	1.12
Difference			1.64	0.07
With Nitrogen	June 18 to Aug. 11	55	35.27	0.64
Without Nitrogen	June 18 to Aug. 11	55	25.95	0.47
Difference			9.32	0.17

In Table No. 92 the data show that in both periods of sampling there has been a more rapid intake of nitrogen by the plants from plots receiving nitrogen.

The figures show that a much more rapid intake of nitrogen took place during the first period of growth, but that the effect of the application of nitrogen at time of seeding on the rate of intake of nitrogen by the plant, is greater later in growth.

The relative daily rate of intake of phosphate in pounds per acre by plants at the first period of sampling and at maturity are shown in Table No. 93.

Table No. 93

Daily Intake of Phosphate by Plants

In Pounds per Acre

Treatment	Growth Period	Length in Days	Pounds of P_2O_5 taken by Plants	Daily intake in pounds
With Phosphate	May 23 to June 17	25	5.48	0.22
Without Phosphate	May 23 to June 17	25	3.99	0.16
Difference			1.49	0.06
With Phosphate	June 18 to Aug. 11	55	11.73	0.21
Without Phosphate	June 18 to Aug. 11	55	11.18	0.20
Difference			0.75	0.01

The results in Table No. 93 show that a lower intake of phosphate by plants from plots receiving no phosphate occurred early in growth. This fact explains the lower rate of growth invariably observed in untreated fields, when the growth is compared with those treated with phosphate drilled in with the seed.

Table No. 94

Daily Intake of Potash by Plants

In Pounds Per Acre

Treatment	Growth Period	Length in Days	Pounds of K_2O Taken by Plants	Daily Intake in Pounds
With Potash	May 23 to June 17	25	30.82	1.32
Without Potash	May 23 to June 17	25	27.96	1.18
Difference			2.86	0.14
With Potash	June 16 to Aug. 11	56	66.15	1.16
Without Potash	June 16 to Aug. 11	56	69.67	1.27
Difference			-6.52	-0.12

The rate of intake of potash by the plants takes place more rapidly during the first period according to the data in Table No. 94. There does not appear to be any great effect on the rapidity of intake due to the application of potash. In the first period an increase in daily intake was effected by applying potash and in the second period a decrease in intake resulted when potash was applied.

V. SUMMARY

The present study was made to ascertain the extent to which the composition of wheat plants and the amount, time and relative rate of intake of plant nutrients, was affected when fertilizers were drilled in close to the seed at the time of seeding.

Wheat was grown in rows treated with nitrogen, phosphate, and potash, applied singly and in all combinations, and plants were sampled at four different stages of growth. The nitrogen, phosphate, potash and total ash were determined in all samples.

Dry matter yields for the total plants at the first period of sampling and at maturity showed a substantial increase on phosphate treated plots. The application of nitrogen resulted in a slight increase in total dry matter of plants, but potash decreased the total dry matter in the plants at maturity.

The effects on the phosphate content of the plants by the application of fertilizers are as follows:

The application of nitrogen caused a significant increase in the per cent phosphate in the plants sampled at the first period and then resulted in a significant decrease in the per cent phosphate in the plants for all remaining periods, including both the grain and the straw, at maturity. The application of phosphate had no significant effect on the per cent phosphate in the plants at the first, second and third periods of sampling, but resulted in a decrease in per cent phosphate in both the grain and the straw. The application of potash had no consistent effect on the phosphate content of plants at the various periods of sampling.

The effects on the nitrogen content of plants by the different fertilizers are as follows:

The application of nitrogen had no significant effect on the nitrogen content of the plants sampled at the first period but for the remainder of the growing season, the nitrogen content of the plants was increased. The application of phosphate increased the nitrogen content of the plants at the first sampling and then caused a decrease in the per cent nitrogen for the remainder of the season. The application of potash showed a tendency to lower the per cent nitrogen in the plants sampled at the first period. No significant effect on the nitrogen content occurred in the second and third periods of sampling, nor in the grain at maturity. There was a slight decrease in the per cent nitrogen in the mature straw due to potash treatment.

The effects on the protein content of the mature grain by the different fertilizer treatments are as follows:

The application of nitrogen increased, and the application of phosphate decreased, the protein content of the grain at maturity, while the potash had no significant effect.

The effects on the potash content of plants by the different fertilizers are as follows:

The application of nitrogen had no apparent effect on the potash content of the plants throughout the various stages of growth. The application of phosphate resulted in a slight decrease in per cent potash in the grain at maturity and had no effect on the potash content of the mature straw or on the plants during the first three periods of growth. The application of potash lowered the potash content of the plants in the first sampling period, increased it in the second period, and resulted in a slight decrease in the third period, and had no effect on the potash content of the mature grain or straw.

The effects on the ash content of plants by the different fertilizer treatments are as follows:

The percentage ash in the plants at the first period was slightly increased by the application of nitrogen. There was no effect on the per cent ash from this treatment in the second or third dates of sampling, but a slight decrease resulted in the mature grain and straw. Phosphate application had no effect on the ash content of the plants at the first

period of sampling but lowered the per cent ash in all remaining periods, including both the mature grain and straw. The application of potash had no significant effect on the per cent ash in the plants throughout the growing season.

The quantities of nitrogen, phosphate and potash removed by the plants at the first period of sampling were increased by nitrogen, phosphate and potash treatment due to an increase in total dry matter in the plants resulting from these treatments. The quantities of the above elements removed by the plants at maturity were increased substantially by phosphate treatment, somewhat less by application of nitrogen, and decreased by applying potash. The increases and decreases were in general proportion to the effects of the fertilizer treatment on the total dry matter in the plants.

There was almost double the quantity of nitrogen supplied in fertilizer as the difference in the amount of nitrogen removed by plants which received nitrogen and the amount removed by plants which received no nitrogen. There was only 1.98 pounds more of phosphate per acre removed by plants from plots which received phosphate, while 33 pounds of phosphate per acre was applied as fertilizer. Because of the decrease in total dry matter of plants resulting from potash treatment 3.96 pounds more of potash per acre was removed by plants from plots receiving no potash. However, 24 pounds per acre of potash was applied as fertilizer.

The relative rate of intake of all elements was much more rapid during the early period of growth. The increase in the rate of intake of nitrogen as affected by an application of nitrogen was more marked during the last stages of growth.

The application of phosphate resulted in a marked increase in the rate of intake of phosphate by the plant early in growth. No effect on the rate of intake of phosphate by this treatment was evident during the period from 25 days after emergence to maturity.

The application of potash resulted in an increase in the rate of intake of potash by the plant early in growth followed by a decrease in the rate of intake later in growth.

VI. Conclusions

1. Phosphate fertilisers increased substantially the yield of grain, but showed a tendency to decrease the protein content of wheat.

2. The application of ammonium sulphate had no particular effect on yield of grain, but caused a marked increase in the protein content of the grain.

3. Potash fertilisers had a depressing effect on the total dry matter in plants and the yield of grain, but had no consistent effect on plant composition.

4. The rate of intake of phosphate by plants in the early period of growth was substantially increased by the application of phosphate, but no apparent difference in the rate of

intake was noted later in growth.

5. This marked increase in the rate of intake of phosphate by plants early in growth where phosphate was applied, shows that a temporary deficiency of available phosphate early in the growing season exists on Red River Valley soils.

6. Phosphate fertilizers should be drilled in with the seed to supply available phosphate and overcome this deficiency early in growth.

7. Ammonium phosphate should be used in preference to triple superphosphate to increase the protein content of the grain as well as to increase the yield.

8. The increase in protein content resulting from the addition of ammonia to the phosphate more than off-sets the depressing effect on the protein content of the grain when phosphate is applied alone.

9. The factors which inhibit the availability of phosphate early in the season should be investigated.

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