

NUTRIENT UPTAKE OF WHEAT FROM SEVERAL FERTILIZERS  
AS EVALUATED BY LABORATORY ANALYSES

by

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TABLE OF CONTENTS

Document

INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	3
EXPERIMENTAL METHODS . . . . .	13
Description of Soils. . . . .	13
Precipitation . . . . .	14
Description of Fertilizer Material. . . . .	14
Design of the Experiment and Planting Methods . . . . .	16
Collection and Preparation of Samples for Analyses. . . . .	17
Harvesting Operations . . . . .	18
Chemical Analyses of Wheat Samples. . . . .	19
DISCUSSION OF RESULTS. . . . .	20
Agronomy Farm, Manhattan. . . . .	21
Yield of Nitrogen per Acre as Influenced by Fertilizer Treatments . . . . .	22
Yield of Phosphorus per Acre as Influenced by Fertilizer Treatments . . . . .	24
Effects of Phosphatic Fertilizers. . . . .	25
Calculated Recovery of N and P from Fertilizer Materials . . . . .	27
Ashland Agronomy Farm . . . . .	28
Richard Evans Farm, Hutchinson. . . . .	29
Yields of Nitrogen per Acre as Influenced by Fertilizer Treatments . . . . .	29
Yields of Phosphorus per Acre as Influenced by Fertilizer Treatments . . . . .	31
Effects of Phosphatic Fertilizers. . . . .	33
Calculated Recovery of N and P from Fertilizer Materials . . . . .	34

Newton Experiment Field, Newton . . . . .	35
Yields of Nitrogen per Acre as Influenced by Fertilizer Treatments . . . . .	36
Yields of Phosphorus per Acre as Influenced by Fertilizer Treatments . . . . .	37
Effects of Phosphatic Fertilizers. . . . .	39
Calculated Recovery of P From Fertilizer Materials .	41
SUMMARY AND CONCLUSIONS. . . . .	41
ACKNOWLEDGMENT . . . . .	44
LITERATURE CITED . . . . .	45
TABLES . . . . .	48
PLATES AND FIGURES . . . . .	61

## INTRODUCTION

Considerable attention has been given to the study of the chemical composition of wheat plants and seed. By determining the chemical composition of the crop, the nutrient requirements for wheat may be better understood. When associated with increased yields, any factor which tends to improve efficiency may be considered well worth the attention of those interested in wheat production. After determining the chemical composition of the wheat plant at successive stages of growth, fertilizer recommendations may be made more accurately. Regardless of the elemental composition of the soil, the elements found in the plant are those available for metabolic processes. Both soil and plant tissue analysis should be used simultaneously in determining nutrient requirements for wheat in any locality.

With regard to wheat production, both quality and quantity of the wheat are important. Milling quality is dependent on the strength of flour which is governed in part by the chemical composition of the wheat from which the flour was milled. The properties of the wheat grain, aside from those determined by genetic composition of the wheat plant, reflect environmental conditions and soil fertility. Usually environmental conditions can be modified only to a limited degree, except where additional moisture is supplied by irrigation. With respect to soil fertility, marked improvement may be initiated by accurate and timely applications of fertilizer materials.

In evaluating the nutrient requirements of wheat a relatively

precise method involves the collection of successive samples of the above ground portion of the plant followed by quantitative analyses of the same. By so doing, the actual quantity of each as well as the proportionate amounts of each element taken up by the wheat plants can be ascertained. After determining the percentage of an element present in the sample collected from a specified area, the total assimilation per acre may be calculated. This procedure was followed in this experiment in an effort to determine the effect of various fertilizer combinations on the rates of assimilation and the total amounts of mineral nutrients assimilated by the wheat plants.

During the past, numerous trials have been conducted to measure yield response of wheat to various applications of nitrogenous and phosphatic fertilizers. In this particular experiment both the quantity and the nature of the materials applied were varied. One purpose of this writing is to present the effects of various experimental treatments used on the total nutrient uptake and the yield of wheat harvested. It must be realized that climatic and edaphic factors varied considerably among the four locations utilized in this experiment. By properly interpreting results of tissue analyses, valid recommendations can be made as to the most desirable fertilizer applications for specific localities.

In view of these facts and because of the economic importance of wheat to Kansas, this study was developed to determine chemical composition of the plant and seed in relation to certain applications of nitrogen and phosphorus. The following objectives were pursued in this experiment:

1. To evaluate a new commercial grade of ammonium nitrate-phosphate fertilizer (30-10-0) in comparison with other nitrogenous and phosphatic fertilizers.
2. To compare a new high analysis phosphatic fertilizer (0-56-0) and ammonium polyphosphate (15-60-0) with other phosphatic fertilizers.
3. To compare broadcasting and row application of ammonium nitrate.
4. To determine yield response of wheat to two combinations of N plus  $P_2O_5$ ; namely, 50 pounds of N plus 17 pounds of available  $P_2O_5$  and 75 pounds of N plus 25 pounds of available  $P_2O_5$ .
5. To determine the amount of nitrogen and phosphorus present in the plant tissue at progressive stages of growth in relation to the quantities of these elements applied to the soil.

#### REVIEW OF LITERATURE

With regard to the evaluation of various fertilizer materials by tissue analysis, numerous citations can be made from the vast amount of research reported on this subject.

Ames, Boltz and Stenius (2) reported the effects of fertilizers on the chemical and physical properties of wheat. The percentage of phosphorus, which is closely associated with the formation of carbohydrates in the grain, depends not only upon the amounts of phosphorus and nitrogen, but also upon the form of nitrogen supplied. The greatest percentage of phosphorus was

found in grain with the best development. This also was associated with the highest yield. However, the greatest percentage of protein was in wheat produced on soil deficient in phosphorus, but well supplied with available nitrogen. Also, the ratio of phosphorus to nitrogen in the wheat grain was in the same order as these two supplied to the soil.

In a physiological study, Emmert (5) investigated nutrient absorption as affected by transpiration and ion interaction within the plant. Ion interaction had an enhancing or depressing influence on the accumulation of other ions in plant tissues. Usually a shift in one ion was invariably accompanied by secondary changes in the tissue content of dissimilar ions. Ion pair interaction seemed to be fairly stable within a given tissue and was not influenced by external conditions. Ions that allowed increased uptake of other ions are positively correlated with these ions. Nitrogen was positively correlated with calcium and magnesium and negatively correlated with phosphorus and potassium. Since it is known that roots of different species of plants are selective in the accumulation of nutrients, the process of ion interaction which causes modification of internal allocation, may be a second important factor in changes of the affinity of plant tissue for different elements.

In considering nutrient assimilation and ion interaction, Fajersson (6) found that wheat having a high protein content generally did not yield the greatest number of bushels per acre and vice versa. Apparently, this situation is affected by ion interaction. Different applications of calcium nitrate produced

significant differences in the crude protein content of five varieties used in the experiment. There was not a significant difference between varieties in regard to their ability to synthesize protein in the grain. It was difficult to detect any regularities in the relation between yield and protein content from year to year. Climatic conditions during the growing season tended to govern development. A moderately cool season with enough moisture prolonged the period of kernel development and favored starch formation.

The increased demand for nitrogen at the late stage of seed development was emphasized. The fact was established that total nitrogen content of the wheat kernel increased during the entire period of growth, but most during the latter part. By the application of nitrogenous fertilizers the gluten content of the flour increased relatively more than the protein content of the grain.

Mallock and Newton (13), Neatby and McCalls (16), Waldron (24), and Fajersson (6) reported an inverse relationship between yield and protein content. Results indicated that high yielding varieties had a tendency to be consistently low in protein content. Generally, the authors previously mentioned considered that by appropriate nitrogen fertilization, relatively high protein content could be obtained simultaneously with a high yield.

In relation to the foregoing discussion, slightly different results were obtained by Schrenk and King (19) in determining the elemental composition of three varieties of wheat grown in different locations in Kansas.

Areas which received the most rainfall produced the highest



yields of wheat that was slightly below average in ash and protein content. A definite correlation existed between available soil nutrients and the chemical content of the wheat. Areas of high nutrient availability coincided with those producing wheat of high ash and protein content.

Murphy, (15) reported that neither nitrogen nor potassium increased yields of wheat on a poorly drained sandy loam soil. Phosphorus and potassium combinations gave larger yields than phosphorus and nitrogen. These observations differed somewhat from results obtained with other fertility experiments. When nitrogen was used in large amounts, kernels shriveled considerably and were not so plump as kernels produced on unfertilized plots.

Mineral nutrition was studied by Donaldson, (4) in an experiment where spring wheat was grown on rather infertile soil so as to accentuate fertilizer response. Results indicated that uptake of mineral nutrients takes place at a rapid pace early in the growth of the wheat plant. Rapid development of the plant during early stages was favored by a supply of readily available nutrients. When potassium was added with phosphorus, the plants made less growth than when phosphorus was added alone. When nitrogen was added the deleterious effect of potassium was not apparent.

Six sampling dates were utilized during this experiment with spring wheat. On July 6, 45 days after the emergence of the wheat, 85 per cent of the total amount of nitrogen assimilated was found in the crop.

The heads comprised almost 50 per cent of the total weight at harvest, regardless of the fertilizer treatment applied.

Approximately 85 per cent of the phosphorus and 75 per cent of the nitrogen assimilated by the plant was found in the heads.

In determining variables that influence protein content in wheat, Swanson, (23) concluded that available nitrogen in the soil, particularly during the latter stages of growth, is the most important factor. In this experiment, seeding wheat in the latter part of August or the first of September gave wheat of lower yield and lower protein content as compared with seeding during the latter part of September. A low protein content was associated with a high percentage of yellowberry and a high protein content with a low percentage of yellowberry.

Smith (21) reported highly significant yield increases in studying the effects of time, rate, and method of application of fertilizer on the yield and quality of winter wheat. Largest yield increases were obtained from the following fertilizer applications: 25 pounds of superphosphate at seeding in combination with 25 pounds of nitrogen as a spring top-dressing; a complete fertilizer at seeding which contained 25 pounds per acre each of N,  $P_2O_5$  and  $K_2O$ ; a mixed fertilizer providing 25 pounds per acre each of N and  $P_2O_5$ ; a mixed fertilizer on the plowsole that supplied 50 pounds per acre each of N and  $P_2O_5$ .

A reduction in yield resulted from application of 25 pounds of N per acre on the plowsole. The application of potash fertilizer in combination with nitrogenous or phosphatic fertilizer did not produce sizeable increases in yield. Fertilizer treatments did not produce significant increases in test weight, protein content or yield of protein of wheat. Most of the treatments

which received nitrogen fertilizer produced a higher average yield of protein than was obtained from unfertilized plots.

Carpenter, Haas and Miles, (3) determined the relationship between total soil nitrogen and nitrogen availability under field conditions on soils of the same type at Mandan, North Dakota. The greatest quantities of nitrates were found in the 12 to 24 inch depth and on plots that had been summer fallowed. Soil nitrates were low at heading time, due to the lack of moisture which hindered nitrate development. The greatest increase in nitrates occurred on plots that had received manure or had been fallowed. The quantity of nitrogen taken up by plants after heading was nearly three times as great on the high as on the low nitrogen soils.

Highly significant correlations were obtained between nitrogen percentage in plants and the readings from a rapid test for plant nitrates at the tillering, jointing and heading stages. Correlations were higher between yield and nitrogen taken up by plants than between yield of grain and the nitrogen content of the soil for the 0- to 6- and 6-12 inch depths of soil. High correlations were obtained between grain yields and the quantities of nitrogen in plants at all stages. The amount at jointing gave the best estimate of yield.

Another attempt to ascertain an indicator of yield was made by Haas (7) in a cooperative project with various experiment stations. Their objective was to determine if there was a relationship between yield response to fertilizer and the chemical composition of grain. In making comparisons between fertilized and

nonfertilized plots a ratio was used. This ratio, the relative yield, was equal to the yield of the fertilized plot divided by the yield of nonfertilized plot times 100. The highest coefficient (-.799) was obtained from the correlation of the N/P ratio of grain from the nonfertilized plots and the relative yield of the nitrogen fertilizer treatments. On the other hand, the second highest coefficient was obtained from percentage nitrogen in the grain and relative yield of the nitrogen fertilizer treatment.

When the N/P ratio was greater than 6.0, the chance of obtaining a yield response to nitrogen was slight. As the N/P ratio decreased below 6.0 the chance of obtaining a yield response was greater. If the N/P ratio were to be used as a basis for nitrogen fertilizer recommendations, then there should be a close relationship between N/P ratio of the grain in one year and the yield response the following year.

Hunter et al. (11) applied nitrogenous fertilizers at varying rates to pastry wheat produced in the Columbia Basin of Oregon. Protein content increased gradually. Where nitrogen applications were associated with reductions in yield, it was believed this adverse response was due to the stimulation of excessive tillering and foliage early in the season which resulted in the exhaustion of moisture too early in the physiological development of the plant. Applications of N in the fall increased yields of wheat significantly on 95 of 131 farms, compared with significant yield increases produced by spring applied N on 100 of 133 farms. This research indicates that N can be applied to the point of maximum yield increase without increasing the protein content of the wheat.

In evaluating the effect of spring nitrogen fertilization on plant characteristics, Hobbs (10) concluded that season had a great effect on yield, growth characteristics and protein content. When phosphate fertilizer was applied in the fall, followed by a top-dressing of nitrogen in spring, there was a greater yield response than where phosphate was not applied. Tillering, plant height, and protein content of the grain were increased significantly by spring applications of nitrogen fertilizer. Increase in yield from spring applications of nitrogen resulted from both the increase in tillers and the increase in kernels per head.

Early work has shown that applications of phosphorus decreased the percentage protein in wheat. Singh and Lamb (20) found that nitrogen fertilizer applications gave significant increases in yield on locations of low fertility. However, this was not the case at a second location with substantially higher fertility. Where nitrogen was deficient, applications of phosphorus decreased the protein content. The uptake of mineral elements by the wheat plant and the final amount and composition of the ash of the grain are greatly influenced by the availability of the elements in the soil, the pH of the soil, the presence and conditions of soil organic matter, and the moisture content.

Haunold, Johnson and Schmidt (9) determined the protein content of two soft winter wheat varieties, Atlas 50 and 66, and two hard red winter wheat varieties, Wichita and Comanche. In greenhouse studies, plants of Wichita and Comanche that were low in protein produced larger yields than higher-protein plants, Atlas 50 and 66. The inverse ratio of protein content to grain yield

existed throughout the experiment. Although Atlas 50 and 66 were considered high-protein varieties, they were separated into high, medium, and low protein groups in this study. The intermediate protein classes had the highest mean yield, while the low- and high-protein groups of Atlas 50 and 60 were low in yield.

Under field conditions the four varieties used in experiments at four locations in Oklahoma and Texas showed highly significant differences in protein, but nonsignificant yield differences among varieties. Presumably, the level of nitrogen in the plant influences the amount translocated to the wheat grain.

In a study by Hardy and Garrett (8) relative to the response of wheat to nitrogen and different phosphate sources an increase of eight bushels per acre was received when 40 pounds of nitrogen was applied. Concentrated superphosphate applied with nitrogen produced an additional four bushels per acre. All nitrogen was applied in a band and no important differences were observed between fall and spring applications of nitrogen.

In another investigation where wheat was fertilized with calcium metaphosphate and orthophosphate fertilizer, Nord (17) concluded that the response was similar for the two fertilizer materials. One-tenth of orthophosphate applied could be accounted for in tissue analysis of the plant. With calcium metaphosphate the quantity of water soluble material increases slowly over a long period of time. The reason for this activity is believed to lie in the structure of calcium metaphosphate and its hydration and hydrolysis in the soil. This fertilizer material is a granular form, nonhygroscopic and provides phosphate in both available and

unavailable forms. It was believed that after the fertilizer was applied to the soil, the unavailable form was converted to a water soluble compound.

In relation to the availability of phosphatic fertilizer, Metzger (14) used several soil types in Kansas, and showed a high correlation between the  $Fe_2O_3$  and  $Al_2O_3$  contents of the soil and the phosphorus-fixing capacity of the soil. The percentage of reduction of the soils' fixing capacity was proportional to the percentage of  $Fe_2O_3$  removed by a dilute acid extraction. Also, soil horizons having high percentages of the total  $Fe_2O_3$  extractable by dilute acid were those with high organic matter contents. In view of this condition, organic matter must be important in maintaining a portion of inorganic phosphorus in a form available for plants due to the reducing action of the organic matter on the iron combined with phosphates.

Olson, Drier, Lowery and Flowerday (18) considered the availability of phosphate carriers to small grains in relation to soil type and method of fertilizer placement. Results showed the fertilizers ranked in the following order on acid soils in relation to availability: equally available normal and concentrated superphosphate, ammonium phosphate, ammoniated superphosphate, metaphosphate, water soluble nitric phosphate, tricalcium phosphate and rock phosphate. On calcareous soils ammonium phosphate and concentrated superphosphate appeared somewhat superior. Fertilizer phosphorus placed in the row is superior to that which is broadcast. Very high utilization of ammonium phosphate in the early growth stages is related to the presence of  $NH_4$ -nitrogen in physical contact

with phosphorus. In soils having a high fixing capacity, fertilizer material should be placed in an area readily accessible to plant roots.

## EXPERIMENTAL METHODS

### Description of Soils

Four locations were utilized for experimental plots. The first was on the Agronomy Farm, Manhattan, Kansas. Generally this location was relatively high in fertility, well drained and sloped in an eastern direction. Wheat had preceded this experimental crop of wheat.

The experiment on the Ashland Agronomy Farm, Manhattan, Kansas, was located on an area that had been packed during the process of leveling the land for irrigation. This created a relatively impermeable layer. As a result of this, normal physiological development of the wheat was inhibited severely. This fact is verified by the abnormally low yields. The crop preceding the experiment was wheat.

A third experiment was on the Richard Evans Farm, Hutchinson, Kansas. Relatively good fertility prevailed at this site, which sloped in an eastern direction. Possibly fertility increased in passing eastward across the plots. The physical condition of this soil was desirable at the time of harvest. This area had been devoted to more or less continuous wheat production for a number of years.

At the Newton Experiment Field the experiment was established



on a soil containing considerable clay. The area was rather level and drainage was retarded slightly. Oats preceded this crop of wheat.

### Precipitation

Moisture was abundant during the fall and winter, but precipitation was not sufficient during the months of April and May. In June considerable moisture was received at each of the four locations. Rainfall data for the 1961-62 wheat experiment by months for all locations is reported in Table 1.

### Description of Fertilizer Material

Two sources of nitrogen and four sources of phosphorus were utilized in the experiment. The following materials were used:

1. Ammonium nitrate (33.5-0-0) is a common source of nitrogen. Commercial production of this material involves neutralizing nitric acid with ammonia. Nitrogen is supplied in both the ammonium ( $\text{NH}_4$ ) and nitrate ( $\text{NO}_3$ ) forms which are readily available.
2. Triple superphosphate (0-45-0) is produced by the acidulation of phosphate rock with phosphoric acid. This fertilizer was included to provide a basis for comparison with other phosphatic fertilizers. Since triple superphosphate has been used in extensive fertilizer trials with wheat, its effects on yield of wheat are well known.
3. Ammonium phosphate (11-48-0) is produced by neutralizing phosphoric acid with anhydrous ammonia. This forms a

commercial grade of mono-ammonium phosphate. An advantage of this fertilizer is that the ammonium ion is supplied in chemical combination with phosphorus. Produced in a granular form, the material is easily handled.

4. Ammonium polyphosphate (15-60-0) is manufactured by the Tennessee Valley Authority. Insofar as this fertilizer has been tested, results have been comparable to the results obtained with use of either (0-45-0) or (11-48-0). This free flowing fertilizer material is produced in granular form, and is relatively non-hygroscopic.
5. High Analysis phosphate (0-56-0) is another product of Tennessee Valley Authority. The material was initially released in August, 1961, for test demonstration. Production involves blending of two-thirds calcium metaphosphate (0-60-0) and one-third triple superphosphate (0-45-0). It is believed that calcium metaphosphate becomes more available to plants as a result of hydration and hydrolysis in the soil. Also, this phosphatic fertilizer is granular in form and relatively non-hygroscopic.
6. Ammonium nitrate-phosphate (30-10-0) is a product of recent origin which is a blend of ammonium nitrate and ammonium phosphate in a ratio of 4 to 1, respectively. The material is produced in pellet form which facilitates handling. In physical appearance, this fertilizer resembles ammonium nitrate rather closely.

Information pertaining to the fertilizer materials used in the experiment are presented in Table 2.

## Design of the Experiment and Planting Methods

The design of the experiment used at all locations was randomized complete block with treatments fixed and blocks placed at random. Only one measurement per treatment and block were possible in sampling procedures employed in this experiment.

Plots were 6.42 feet x 100 feet at the Agronomy Farm, Manhattan, Kansas, since drilling was accomplished with a John Deere FB-B drill that had 11 disk openers spaced at seven inch intervals. On the Richard Evans Farm, Hutchinson, Kansas, and on the Newton Experiment Field plots were 5.25 feet x 100 feet. At the Agronomy farm, blocks were arranged side by side in a row to utilize the field space available for the experiment. At the other three locations blocks were arranged in a grid pattern so that Blocks I and II were adjoining and directly in front of Blocks III and IV, which were adjoining. An alley way of 25 feet separated Blocks I and II from Blocks III and IV.

At each experimental site random samples of soil were collected and composited. Chemical analyses of the soil was performed by the Kansas State Soil Testing Laboratory on the composited samples. Determinations included pH, lime requirements, available phosphorus, exchangeable potassium and organic matter. Characterization of the soil types and the chemical properties of the soils are given in Table 3.

Fertilizer materials were applied at the time of seeding. The various materials used supplied either N or available  $P_2O_5$  separately or in certain combinations. These combinations pro-

vided the fertilizer grades desired. Applications of ammonium nitrate were made either as part of the seeding operation or by independent broadcasting of the material near the surface of the soil. This was done by leaving the discs of the drill in a relatively raised position.

Planting of the experimental plots was completed as quickly as the weather and the work schedule would allow. As a result of adverse weather conditions during October, 1961, there was a spread among the dates of planting at the various locations. Varieties planted, date of planting and date of harvest are given in Table 4. Good stands of wheat were established at all locations; however, a slight reduction in the stand occurred at the Newton Experiment Field. This reduction probably was due to excessive moisture.

#### Collection and Preparation of Samples for Analyses

Because nutrient assimilation by the wheat in relation to fertilization was to be determined in the experiment, samples of the above ground portion of the plants were taken during active vegetative growth in the spring and at maturity. The first sample, which will be referred to hereafter as the vegetative stage, was collected on either April 19 or 20, 1962. This sample consisted of five, one-foot row lengths which were secured at random within each plot. A second sample, the mature sample, was collected at the four locations between June 23, 1962 and June 25, 1962. Three 8 foot row lengths of mature plants were collected at random from each plot.

In preparation of the samples for chemical analyses, the samples of the vegetative stage were dried in an oven at approximately 60 degrees centigrade for 3 days. Dry weight was determined followed by grinding the samples in a Cristy-Norris Mill. Weight of the mature stage was determined on a triple beam balance. Samples were threshed with a Vogler nursery thresher, the seed was collected, and a sample of the straw was retained after threshing for analysis. Weight of the wheat seed, threshed from the mature sample, was determined, while the weight of the straw was calculated by subtracting the weight of the seed from the total weight of the mature sample. The final step in preparation for chemical analysis was grinding of the seed and the straw.

#### Harvesting Operations

Harvesting was accomplished by using conventional small combines that cut a swath six feet wide during one passage of the combine over the plot. At the Agronomy Farm, Manhattan, Kansas, and the Ashland Agronomy Farm, Manhattan, Kansas, two passages with the combine were required, since the plots were 6.42 feet wide. One passage of the combine was adequate at the Newton Experiment Field and the Richard Evans Farm, Hutchinson, Kansas, where the plots were 5.25 feet wide. Seed from the plots was collected in burlap sacks. Weight of grain from each plot was determined and a sample sufficiently large for test weight determination was retained after the weighing procedure.

At the time of harvest, weeds had grown large enough that absolute separation during the combining operation was impossible

at the Ashland Agronomy Farm and the Newton Experiment Field.

#### Chemical Analyses of Wheat Samples

Only nitrogenous and phosphatic fertilizer materials were applied in the experiment. From the results of previous investigations, it was believed that potassium was adequate in the soil for the production of desirable yields of wheat at the four locations utilized. Since the variables N and P were supplied systematically, chemical analyses were completed on all samples for these two elements. Procedures used for the determination of nitrogen and phosphorus are given in the following paragraphs.

Nitrogen. This element was determined for all plant samples by the Keldhal-Gunning method (1) with slight modifications. Principal modifications included the use of a 4% boric acid solution with methyl purple as an indicator for the collection of ammonia during distillation. Titration of the basic distillate was accomplished by using approximately 0.0714  $N$   $H_2SO_4$ . Duplicate determinations of each sample were made in order to provide a limited check for errors. One blank determination was made for every 11 sample determinations. These were titrated and the volumes required for titrating the blanks were averaged for each day and subtracted from the volume of acid used in titrating sample determination when calculating the percentage of nitrogen in the sample. The volume of acid required to titrate the blanks varied only from 0.0 ml. to 0.2 ml.

Phosphorus. Determination of P was accomplished by wet ashing of the sample followed by the employment of the molybdenum

blue method as described by Jackson (12) to ascertain the concentration of P in the digest. A 0.4 g. sample of material was ignited in 5 ml. of  $Mg(C_2H_3O_2)_2$  on a hot plate until fumes were not evident. The sample was ashed for at least 2 hours in a muffle furnace at  $550^\circ C$ . After the ash cooled, it was dissolved with 10 ml. 2N HCL, the digest was filtered into a 100 ml. volumetric flask. An aliquot of 10 ml. was taken when using samples of the vegetative stage or the wheat seed and pipetted into a 50 ml. volumetric flask.

An aliquot of 20 or 25 ml. was taken in the case of mature straw samples and pipetted into a 50 ml. volumetric flask. Two drops of 0.25% 2,4-dinitrophenol indicator were added and a pH of 3 was secured by adding 0.2N NaOH until a faint yellow color appeared. Flasks were brought to volume and emptied into 125 ml. Erlenmeyer flasks, 1 ml. of  $(NH_4)_2MoO_4-HCl$  solution was added, mixed and 2 ml. of 1-amino-2-naphthol-4-sulfonic acid in solution with  $Na_2SO_3$  and  $Na_2S_2O_5$  was added and mixed. After 15 minutes the intensity of the molybdenum blue color was determined on a Coleman Junior Spectrophotometer at a wave length setting of 660 mu. From the percent transmittance determined the concentration in the sample was read from a standard curve made from known concentration of  $KH_2PO_4$ .

#### DISCUSSION OF RESULTS

Data for the experiment are reported in Tables 6 to 13 and are presented graphically in figures 1 to 21, inclusive. Comparisons of the effects of the twenty-one treatments used in this

experiment will not be made between locations. Considerable variations in climatic and edaphic factors prevailed among the four locations. This seemed to make impractical accurate comparisons among the locations. Thus results will be considered individually for each location. However, general conclusions in regard to the previously stated objectives of the study will also be attempted.

Statistical analyses of the data was performed in the manner prescribed by Snedecor (22).

#### Agronomy Farm, Manhattan

Annual precipitation was deficient during much of the spring season (Table 1); however, precipitation at this location during May was more than two inches higher than at Newton and more than three inches higher than at Hutchinson.

An available phosphorus content amounting to 43 pounds per acre and an organic matter content corresponding to 1.8 per cent were indicated by the soil test (Table 3). Both of these medium values for available phosphorus and organic matter would suggest that beneficial results might be received from the application of both N and P. Data for this location verify this assumption. The influence of P, applied at the time of seeding, was quite obvious even though more available P was present than at any of the three other locations. Since P was assimilated by the plants from the fertilizer applications in the early stages of growth, this nutrient was present for development of the root system of the plant which was required to assimilate moisture and nutrients



during the spring while moisture in the surface soil was limited. The conditions which facilitated extensive development of the root system soon after the establishment of the wheat seedlings were believed to be largely responsible for the significant increases in dry weights of the vegetative samples, yields of grain and yields of both N and P. These data are reported in Tables 6 to 13 and are presented graphically in Figures 1 to 20.

Yield of Nitrogen per Acre as Influenced by Fertilizer Treatments. Vegetative Stage. Statistically significant increases prevailed among the values for both the percentages of N, and yields of N per acre in the vegetative samples collected on April 21. Differences were significant because the fertilizer applications provided N and P that were required for additional growth as compared with plants that were not fertilized. Each fertilizer treatment stimulated plant growth significantly. However, some treatment effects were not significantly different than others. Wheat that received 75 pounds per acre of N yielded from 22 to 28 pounds of N per acre more than the control. The average increases in yields of N at the vegetative stage were 18.54 and 24.25 pounds per acre for applications of 50 and 75 pounds of N, respectively. Treatments producing plants with the highest percentages of N were also the highest yielding treatments in terms of pounds of N assimilated per acre. At the time of sampling the vegetative stage, growth was abundant at this location compared with the three other locations.

Mature Straw. Treatments which produced the highest yields at the vegetative stage also yielded larger amounts of N in the

mature straw. Treatments containing the highest percentage of N also produced the highest weights of straw per acre and yielded more pounds of N per acre. Treatments 5, 7, 9, 11, 13, 15 and 21 were outstanding. Each of these supplied 75 pounds N and 25 pounds of available  $P_2O_5$  (Table 5). It must be recognized that the greatest amounts of N assimilated were achieved when both N and P were supplied. Applications of 50 and 75 pounds of N by itself gave increases in yield of N in mature straw of 2.7 and 3.7 pounds. Combining nitrogen with phosphorus gave increases of 1.9 and 5.8 pounds of N per acre above treatments 2 and 3 that received N only.

Seed. Nitrogen content of the seed and yield of N assimilated per acre are associated with the total yield of grain per acre. The treatments previously enumerated which provided 75 pounds N and 25 pounds  $P_2O_5$  were found to yield the largest amount of N.

The relatively high percentage of N in the straw and seed suggests that considerable assimilation of the N from fertilizer applications occurred during the growth of the crop. Definitely, the level of N in the plant must have influenced the amount that was translocated to the seed. This condition parallels the results of Haunold, Johnson and Schmidt (9).

Uptake of nitrogen by the seed was slightly affected by the type of fertilizer material. In general the amount of N assimilated was related to the amount of fertilizer applied in pounds per acre of N and P.

Yield of Phosphorus per Acre as Influenced by Fertilizer Treatments. Vegetative Stage. Wheat that received both N and P at the Agronomy Farm produced more growth at the vegetative stage than wheat at other locations even with the same treatments. Significant treatment effects prevailed among the values for dry weights and percentages and yields of phosphorus in the vegetative stage. This would be expected since the organic matter content, 1.8, was only medium and since the available soil phosphorus content was 43 pounds per acre as determined by the soil test. It should be recognized that one inch more precipitation was received during March at the Agronomy Farm than at other locations. This additional moisture may have enabled greater growth response at that location.

Highest yields in terms of dry weight and pounds of phosphorus assimilated were produced from treatments 5, 9, 11, 15, 19 and 21. These treatments provided 75 pounds N and 25 pounds  $P_2O_5$ . Highest percentage of phosphorus in the vegetative material was associated with the higher yields.

Mature Straw. Similar trends existed for percentages and yields of phosphorus in the mature straw. Highest yielding treatments involved the higher level of fertilizer - 75 pounds of N plus 25 pounds of available  $P_2O_5$ . Apparently, this level of fertilizer effected the greatest assimilation of P in the straw whether N and P were applied together or as separate constituents. Because there was approximately one inch more of moisture received at this location during March, nutrients assimilated were utilized in active metabolic processes which produced

considerable plant material and large yields of grain. Probably because phosphorus was assimilated early in the growth of the wheat, extensive root systems were developed and these were efficient in securing nutrients required later in the life cycle of the plants.

Seed. In terms of yield of P per acre, treatment with 17 and 25 pounds of available  $P_2O_5$  produced yield increases of 2.5 and 4.0 pounds of P, respectively. Without exception a larger increase in the yield of P in the seed prevailed when the high rate of fertilizer was supplied as compared to the combination of N and P at the low rate. It should be emphasized that wheat receiving the high rate of fertilizer produced seed that contained the highest percentage of P and yielded the greatest amount of P per acre. Wheat receiving treatments 1, 2 and 3, which did not supply P, produced seed containing a lower percentage of P than wheat that had received P from fertilizer treatments.

Effects of Phosphatic Fertilizers. At this location the apparent recovery of fertilizer P from the treatment was exceptionally high when compared with that for other locations. In general, the percentage of recovery was greater from the higher rate of applied phosphorus (25 pounds per acre of available  $P_2O_5$ ). Applications of either 0-56-0 or 11-48-0 plus  $NH_4NO_3$  with seed and the same fertilizers plus  $NH_4NO_3$  broadcast were different because the lower rate of application gave the higher recovery of P. The average percentage of recovery of P by the crop receiving the lower rate of fertilizer was 34.0 percent, while the recovery for the higher rate of fertilizer was 36.2 percent.

It was extremely difficult to determine which type of phosphatic fertilizer was superior to the others. At the Agronomy Farm, Manhattan, the highest yield of P for the vegetative stage and mature straw was produced by wheat which received 30-10-0, while the yield of P was greatest in the seed from treatments containing 15-60-0. Ammonium nitrate-phosphate (30-10-0) provides a very soluble form of P. This condition might have allowed for more rapid assimilation of this fertilizer material during the early stages of growth. Ammonium polyphosphate (15-60-0) is somewhat less rapidly available and therefore its assimilation might have been deferred until later in the development of the wheat plant. In general, 15-60-0, 11-48-0, and 30-10-0 gave similar response. High analysis phosphate (0-56-0) seemed to be less consistent in initiating high yields of phosphorus. Apparently, there was a favorable effect when N and P were applied in a chemical combination. Such beneficial influence on plant response to the chemical combination of the ammonium ion and phosphorus was reported by Olson, Drier, Lowery and Flowerday (17).

When considering the grain harvested per acre, yield increases were above average where 30-10-0 fertilizer was applied. The same held for the yield of P in the vegetative stage and in the mature straw. Slightly below average yields of P in the seed were noted where this fertilizer was applied. The latter condition might have resulted from a depressing influence of N upon the assimilation of P, since both nutrients were supplied in an available form.

Above average yield increases of P were produced by the seed

where 0-45-0 fertilizer was applied. Below average increases of P prevailed in the vegetative stage and the mature straw.

In comparing growth responses due to the application of 0-56-0, above average yields of P was obtained in only the vegetative stage.

Higher than average yields of P were detected in mature straw and seed where wheat received 11-48-0 fertilizer. However, wheat receiving 15-60-0 treatments yielded larger amounts of P than where other phosphatic fertilizers were applied.

The differences in yield of P by wheat receiving applications of various phosphatic fertilizers was small. Yield increases of P assimilated were relatively satisfactory for all of the fertilizers used. At this location the available phosphorus content (43 lbs./A) of the soil was relatively high. Consequently, wheat seed from the control plots contained considerable P (0.251%).

Calculated Recovery of N and P from Fertilizer Materials.  
In determining the amount of N and P assimilated, under field conditions for all locations from the low and high applications of N and P, the yields of these elements by the control plots were subtracted from the yields of wheat receiving these fertilizer applications. The difference in pounds of N and P assimilated for the vegetative stage and the mature plants was averaged. As a result of these calculations, data shown in figure 21 were obtained. Wheat at the vegetative stage had assimilated 12.7 pounds of N and approximately one pound P from the lower rate of fertilizer application, while 23.4 pounds of N and approximately two pounds of P were assimilated from the higher level of

application. Where mature plants were considered 23.2 pounds of N and 2.5 pounds of P per acre were assimilated from the lower fertilizer rate, whereas 34.9 pounds of N and 3.9 pounds of P per acre were assimilated from the higher rate of application of N and P.

#### Ashland Agronomy Farm

At this location the site of the experiment was on an area which had been leveled in preparation for irrigation. Because the soil had been packed excessively and had developed a relatively impermeable layer, normal physiological development of the wheat was inhibited. Therefore, yields of grain, dry weights of the samples of the immature plants, and the yields in pounds per acre of nitrogen and phosphorus for all material analyzed were abnormally low. Statistically significant differences were found among the dry weight at the vegetative stage and the yield in pounds per acre of phosphorus as shown in Tables 7 and 11.

With the advance of the growing season for wheat, normal development was inhibited even more. At the time of collection of the vegetative stage, the normal physiological development of the wheat plants had not been so drastically disrupted; consequently, certain significant differences were noted in this stage.

Because of the compacted soil, root penetration and development would be inhibited. Moisture and nutrient uptake would be retarded and aeration would be poor. A combination of these factors resulted in the stunted growth and retarded development of the wheat.

Because of the extremely irregular response of the wheat to various fertilizer treatments at this location, valid comparisons and accurate conclusions could not be made.

Richard Evans Farm, Hutchinson

Total precipitation at this location was about the same as at other locations (Table 1). Rainfall was quite limited during March, April and May and this drought period created additional stress on the wheat. Soil test determination showed 26 pounds per acre of available P. Moisture deficiency and inadequate available phosphorus would cause severe stress on plant growth. Because of these conditions, it would seem that applications of P should have alleviated, to a certain extent, the growth stress existing at this location. This belief was substantiated when the plots were observed during the growing season and again when the data obtained during laboratory analyses of plant material were observed. Wheat plants receiving P assimilated this nutrient during the early stages of growth. Apparently this allowed the development of extensive root systems of the plants. Even though moisture was limited during the spring when the plants initiated rapid growth, enough moisture was obtained by the previously established root systems to allow nearly normal development of the crop.

Yields of Nitrogen per Acre as Influenced by Fertilizer Treatments. Vegetative Stage. In regard to yield of N per acre in the early vegetative stage, this location was excelled only by the wheat at the Agronomy Farm. Significantly higher yields of dry matter and N assimilated per acre for the vegetative



samples were obtained due to the addition of nutrients from fertilizer treatments as shown in Table 7 and 8. Treatments 5, 7, 11, 15, 17, 19 and 21 (75 pounds N and 25 pounds  $P_2O_5$ ) produced the highest yields at the early vegetative stage. When N and P were added simultaneously, plants assimilated additional amounts of N. Some of the increase in yields of N may have occurred because of favorable effects which were produced when the fertilizer treatments contained both N and P. All yields of N for treated plots were significantly higher than yields from unfertilized plots. At the time of the early vegetative stage, wheat that had received 50 pounds of N had assimilated 4.8 pounds of N per acre more than that which was unfertilized. An increase of 10.88 pounds of N was associated with treatments involving 75 pounds of N per acre. The average increase in yield of N above unfertilized wheat for treatments involving 50 pounds N and 17 pounds of available  $P_2O_5$  per acre was 16.6 pounds while the average increase in yield of N for treatments which involved 75 pounds N plus 25 pounds of available  $P_2O_5$  per acre was 25.2 pounds.

Mature Straw. The same trend as observed for yield of N in the vegetative stage was maintained in the mature straw (Table 9). The higher percentage of N in the straw also was associated with the production of more straw. Obviously, the yield of N from these treatments should have been superior to yields of N for treatments in which the percentages of N and the weights of the straw was less. The yield of N in the straw increased with the higher rate of fertilizer. In considering the yields of N for straw, treatments involving 50 and 75 pounds N per acre were

responsible for increases in yield of N of 4.7 and 13.1 pounds, respectively. The average yield increases for the low and high levels of fertilization were 3.9 and 7.9 pounds N, respectively. Definitely, the amount of N and  $P_2O_5$  applied affected the assimilation of N by the wheat plants as shown in Figure 15.

Seed. The percentages of N in the wheat straw and seed followed essentially the same pattern. Higher percentages of N were associated with the highest yields of both N and grain. Treatments 5, 7, 9, 13, 17, 19 and 21, which provided 75 pounds of N plus 25 pounds of available  $P_2O_5$ , were superior to other treatments in terms of yields of N and grain. With treatments 2 and 3 (Table 10) increases of 11.1 and 14.3 pounds of N were assimilated. An increased yield of 4.8 and 5.6 bushels per acre for the previous comparison existed. The average yield increase above the yield of the control of N for the low and high treatments containing both N and P were 13.9 and 19.9 pounds N per acre, respectively. From the results previously stated, it is evident that the yield of N was superior for those treatments containing both N and P when compared to treatments which involved only N. In so far as grain production is concerned, the level of nitrogen in the plant is directly related to the amount of nitrogen translocated to the developing seed.

Yields of Phosphorus per Acre as Influenced by Fertilizer Treatments. Vegetative Stage. Treatments 5, 7, 9, 13, 19 and 21 gave superior yields of dry weight and P at the early vegetative stage, because these treatments provided 75 pounds of N and 25 pounds of available  $P_2O_5$  (Tables 7 and 11 and Figure 13).

Every treatment involving P was superior to a treatment which involved only N. The average yield increases of P in the vegetative stage for the low and high levels of fertilizer involving both N and P were one and 1.5 pounds, respectively.

**Mature Straw.** The general trend which prevailed at the early vegetative stage also could be detected in the yields of P at maturity. Wheat that had received N and  $P_2O_5$  initiated marked growth and produced the higher yield of P in the straw. In the yield of P in the mature straw there was less difference between the unfertilized and fertilized wheat than there was in the yield of P for the vegetative stage and also for the seed. Average differences in yields of P between unfertilized wheat and the low and high rates of fertilizer application that involved both N and P were 0.3 and 1.0 pounds per acre, respectively.

**Seed.** Percentage composition and yield of P by the seed followed a definite trend (Table 13). The accumulation of P during the early stage of growth and the influence of this nutrient on the physiological processes of the wheat contributed materially to the statistically significant increases in the yields of P and the yields of grain per acre (Tables 6 and 13, and Figures 1 and 16). Treatments 5, 7, 9, 11, 15, 19 and 21 which were associated with the highest percentages and yields of nitrogen were superior. Wheat seed from treatment 2 and 3 (Table 13) produced 0.5 and 0.8 pounds P more than seed produced without fertilization. The average increase in yield of P over the unfertilized plots for the low and high treatments containing N and P were 0.7 and 1.1 pounds per acre, respectively. The

average yield increase for the low level of application, 50 pounds N plus 17 pounds  $P_2O_5$ , over the unfertilized wheat was 12.3 bushels. For the same comparison for the high level of application 75 pounds N and 25 pounds  $P_2O_5$ , there was an increase in yield of 16 bushels per acre.

Effects of Phosphatic Fertilizers. It was difficult to detect a definite trend in the selection of the most effective phosphatic fertilizer material. Apparently, the fertilizers in which N and P were combined chemically were assimilated more completely. When considering both levels of fertilizer applications, ammonium polyphosphate (15-60-0), ammonium phosphate (11-48-0) and ammonium nitrate-phosphate (30-10-0) were superior in producing the highest yields of P and bushels of grain per acre (Figures 1 and 16).

Above average increases in yield of P were observed in the vegetative stage where wheat received applications of 30-10-0. For the mature straw and seed samples, yields of P for wheat were below the average trend where other phosphatic fertilizers were used. This fertilizer provided a soluble source of N and P that was applied with the seed in a pellet form. Both N and P would be assimilated quickly which would contribute to the high content of P in the vegetative stage.

Wheat receiving treatment of 0-45-0 gave yield increases equal to or greater than the yields where other phosphatic fertilizers were applied for the vegetative sample, mature straw and seed. Since the response of wheat to applications of 0-45-0 fertilizer has been known for many years, this material was used

as a means of comparing the response of wheat to applications of 30-10-0, 0-56-0, and 15-60-0 which are new commercial fertilizers.

The yield increase of P produced by the application of 0-56-0 was less than the yield increase obtained when other fertilizer was applied. Where 0-56-0 was applied, P yields in the vegetative stage were comparable to values measured where other phosphatic fertilizers were applied.

Wheat receiving applications of 11-48-0 yielded an average of 0.2 pounds more P than where other fertilizers were used, with the exception of wheat that received 15-60-0.

Increases in yields of P obtained with wheat which received applications of 15-60-0 were from 0.2 to 0.4 pounds per acre higher in the vegetative stage, mature straw, and seed than where other fertilizers were applied. It would be reasonable to assume that P assimilation was increased, because this fertilizer contained phosphate which was chemically combined with the ammonium ion.

The fertilizer materials were found to rank in the following order when considering the percentages of phosphorus recovered from them by wheat: ammonium phosphate (11-48-0), concentrated superphosphate (0-45-0), ammonium polyphosphate (15-60-0), high analysis phosphate (0-56-0) and ammonium nitrate-phosphate (30-10-0).

#### Calculated Recovery of N and P from Fertilizer Materials.

After completing the necessary calculations, information presented in figure 21 was obtained. Mature wheat plants at the Richard Evans Farm, Hutchinson, Kansas, which had received the lower rate

of fertilizer application assimilated 19.6 pounds of N and one pound of P from the fertilizer applied. Mature wheat plants assimilated 30.5 pounds N and approximately two pounds of P from the combination of N and P applied at the higher rate.

#### Newton Experiment Field, Newton

As a result of excessive rain in October, 1961, planting of wheat at this location was later than at other locations. In addition to the delay in planting, excessive moisture and severe climatic conditions during the winter produced conditions unfavorable for the optimum growth and development of the wheat plants. However, rainfall at this location was limited during March, April, and May which retarded maximum growth of the wheat plants during the spring season.

At harvest time wet soil conditions and abnormally humid atmospheric conditions at this location impaired normal harvesting operations. To a certain degree, weed growth interfered with normal separation of seed and straw during the harvesting operation. Consequently, yields of grain per acre were lower than at the Agronomy Farm, Manhattan, and the Richard Evans Farm, Hutchinson.

Statistically significant differences occurred among the dry weights of the material produced at the early vegetative stage, yields of grain per acre, and yields of nitrogen and phosphorus in pounds of elements assimilated in the early vegetative stage, straw and seed. The treatments that were associated consistently with the highest yields of grain and nutrients were not necessarily the same treatments as were responsible for these effects at the

Agronomy Farm, Manhattan, and the Richard Evans Farm, Hutchinson. Possibly this difference could be attributed to the clay loam type of soil at this location. This acid soil seemed to allow for the utilization of phosphate in fertilizers that were not necessarily regarded as being readily available.

Each treatment was significantly superior to that culture which did not involve any fertilizer, since fertilization provided additional nitrogen and phosphorus in amounts sufficiently large to allow additional growth and additional yield of grain.

Yields of Nitrogen per Acre as Influenced by Fertilizer Treatments. Vegetative Stage. Treatments 5, 7, 11, 13, 17, 19 and 21 (Table 5) produced the highest percentages and yields of nitrogen per acre. Due to excessive moisture during the winter and rather drouthy conditions during the spring, the crop was unable to respond to the application of nitrogen as would have been anticipated. The yield of N for the early vegetative stage was much less than at the Agronomy Farm and the Richard Evans Farm. The higher rate of fertilization generally was accompanied by the higher yield of nitrogen in the plant material. Treatments that produced relatively high yields of N at the early vegetative stage generally produced the highest yields of plant material (grain and straw) at harvest time.

Mature Straw. Quite similar trends prevailed for the percentages and yields of N in the mature straw. With use of the lower rate of N, (50 pounds per acre) seven pounds per acre of nitrogen was found in the straw. Significantly different treatment effects were found among the values representing percentages

and yields of N per acre. In general, the application of 75 pounds of N per acre initiated greater yields of N than did use of 50 pounds regardless of the method of application.

Seed. Yield of grain and the yield of nitrogen per acre in all plant material was closely related. These results are presented in Tables 6, 8, 9 and 10. Because yields of grain were not exceptionally high, nitrogen content of grain was not particularly reduced as a result of excessive stimulation by use of phosphorus alone. Application of 50 pounds per acre of N (treatment 2, Table 2) increased the yield more than two bushels per acre. In terms of yields of nitrogen per acre by the mature crop, an increase amounting to 12.1 pounds of N from treatment 2 was obtained from the application of 50 pounds of N as compared to the unfertilized wheat.

Possibly some of the increase in yield of N could be associated with an interaction which might be produced with the application of N and P, simultaneously. In considering the yield of N per acre, treatments 2 and 3 received nitrogen only, whereas other treatments provided N and P. Therefore, it would be reasonable to assume that both nutrients, affected the total yield of N in the plant material. These data are presented in Tables 8, 9, and 10, and graphically on Figure 19.

Yield of Phosphorus per Acre as Influenced by Fertilizer Treatments. In addition to insufficient rainfall, the soil test revealed only sixteen pounds of available phosphorus per acre. It would be logical to expect marked growth response from phosphatic fertilizers. Such material, applied at the time of seeding,



was assimilated in the early stages of growth and was present in the plant during the spring. Even though moisture was limited, phosphorus was in the plant and was a primary factor that contributed to the significant effects of the treatments.

**Vegetative Stage.** Yields of phosphorus per acre were relatively low in the early vegetative stage, because the total growth initiated by the plants was limited at the time of sampling. Treatment 5, 7, 11, 15, 17, 19 and 21 (Table 5) produced the highest percentages and yields of phosphorus per acre. Since these treatments included most of the heavier applications of fertilizer, this was not surprising. With the exception of treatments 2 and 3, all others yielded significantly more than the wheat which had not been fertilized. Treatments 2 and 3, of course, did not include phosphorus. In terms of yields of phosphorus per acre in the vegetative stage, treatments which involved 30-10-0 and 15-60-0 fertilizers were somewhat above those involving other phosphatic carriers.

**Mature Straw.** A similar trend was produced in the percentages and yields of phosphorus in the straw at harvest. The treatments that gave the highest yields of phosphorus provided 75 pounds of N and 25 pounds of available  $P_2O_5$ . Phosphatic carriers which were most effective were those in which some N was combined chemically with the  $P_2O_5$  supplied. Overall the mature straw was exceptionally low in amount of phosphorus regardless of fertilizer treatment.

**Seed.** Insofar as yields in bushels and amounts of phosphorus assimilated by the seed, the same trend was apparent that

existed for the vegetative stage and mature straw as shown in Tables 11, 12 and 13. Percentage of phosphorus was higher for those treatments supplying the higher levels of nutrients and vice versa.

Significant increases in yields of P in the seed were found. Some variation did occur in the yield of P per acre where the high rate of fertilizer was applied. This variation was due to the loss of plants from excessive moisture during the winter. In a few areas of the plots, water had covered the plants. Since there was not a wide margin between the yield of P in the seed between wheat plots that received the low and high rates of fertilizer, the loss of a limited number of plants on the plots disrupted the general trend.

Effects of Phosphatic Fertilizers. In comparing 30-10-0 with other phosphatic sources, yield increases in P were above average for the vegetative stage and the seed. However, the yield of P was below average for the mature straw when compared to wheat that received other phosphatic fertilizers. Increases of P were above average for the vegetative stage and seed where 30-10-0 was applied at either the low or the high rate. Since the soil at this location contained a relatively low amount of available P, 16 pounds per acre, applications of 30-10-0 provided P in a readily available form for assimilation by the plants.

Yield increases in P assimilated by wheat receiving applications of 0-45-0 fertilizer were equal to or above average when compared to other phosphatic fertilizers for all plant material analyzed. This fertilizer contains a predominance of monocalcium

phosphate, which is readily available. Since available phosphorus at this location was limited, wheat receiving applications of 0-45-0 assimilated this soluble form of P readily. Therefore, the wheat contained P required for rapid growth in the spring.

For all plant material analyzed, plants that had received applications of 0-56-0 did not yield amounts of P as large as those found in plants that received other sources of P. Even though the soil was slightly acid in nature, 0-56-0 was probably less available during the early stages of growth than other sources of P.

Yield increases of P assimilated by wheat receiving applications of 11-48-0 (ammonium phosphate) were equal to or above the average yields obtained for all plant material when compared with the other phosphatic carriers. Increases were higher for the vegetative stage than for the mature straw and seed. This fertilizer provides a readily available source of both N and P. During the early stages of growth, seedlings could assimilate nutrients from this material easily. Since this soil contained a relatively high percentage of clay, some fertilizer could be fixed in a relatively unavailable form.

In comparison with other sources of P, wheat receiving applications of 15-60-0 produced yield increases from 0.2 to 0.4 pounds of P per acre above yields produced by wheat receiving other fertilizer material for the mature straw and seed. However, the yield of P for the vegetative stage was approximately 0.2 pounds below the average of wheat that had received other phosphatic fertilizers.

### Calculated Recovery of P from Fertilizer Materials.

Percentage of phosphorus recovered by the mature plant from the fertilizer applications varied considerably. The highest recovery obtained was 15.7 per cent from treatment 15 (0-45-0 plus  $\text{NH}_4\text{NO}_3$ ) at the high rate of application. To a great extent, the highest recovery was obtained from 0-45-0, because a large portion of the material is monocalcium phosphate which is readily available. Recovery of 11.2 and 10.7 percent were obtained with treatment 19, (11-48-0 plus  $\text{NH}_4\text{NO}_3$ ) and treatment 21 (15-60-0 plus  $\text{NH}_4\text{NO}_3$ ), respectively.

For other treatments where the percentages of recovery were less than the treatments cited, the trend was related to the quantity of fertilizer applied.

### SUMMARY AND CONCLUSIONS

During the growth of the 1961-1962 wheat crop in the area of Kansas where plots were located for this study, there was a pronounced response to the application of phosphatic fertilizers. This response was apparent through visual observation when vegetative samples were collected from the plots during the third week of April as well as during the collection of mature samples during the period of June 21-24. From visual observation at the four locations, it was apparent that vigorous growth was not made until fertilizer treatments provided both nitrogen and phosphorus. Fertilizer applications were designed to provide two combinations of N and  $\text{P}_2\text{O}_5$ ; namely, 50 pounds of N plus 17 pounds of  $\text{P}_2\text{O}_5$  and

75 pounds of N plus 25 pounds of  $P_2O_5$ . Also, N was supplied alone at two levels, 50 pounds and 75 pounds per acre.

Reliable comparisons of the increased assimilation of N and P as influenced by fertilizer treatments can be made at the three other locations. Due to compacted soil at the Ashland Agronomy Farm, normal physiological processes of the wheat plants were impaired and comparisons are not considered to be valid at this location.

From observation of the results of this fertility study with wheat, the following conclusions were drawn:

1. The yield increase of N and P assimilated by wheat that received ammonium nitrate-phosphate (30-10-0) was as high or higher than the fertilizers used as standards for comparisons (0-45-0 and 11-48-0). The yield increase of P for the vegetative stage was slightly higher where wheat received 30-10-0.
2. Yield increases of N and P assimilated by wheat receiving applications of ammonium polyphosphate (15-60-0) were superior to wheat that received other fertilizers. Wheat receiving high analysis phosphate (0-56-0) assimilated slightly smaller amounts of N and P than where other fertilizer materials were applied.
3. Method of placement of ammonium nitrate had a very minor effect on the yield increase of wheat.
4. Highest increases of N and P assimilated in the vegetative stage and mature plants were obtained from wheat that received the high rate of fertilizer application

(75 pounds N plus 25 pounds  $P_2O_5$ ). Wheat that received such fertilizer applications had produced more plant material when the vegetative sample was collected than wheat that received other treatments.

5. Approximately 14 pounds of N and one pound of P were assimilated at the time of the vegetative stage from fertilizer applications providing 50 pounds N plus 17 pounds  $P_2O_5$ , while mature plants assimilated approximately 21 pounds N and two pounds P.
6. In the vegetative stage, wheat that received 75 pounds N plus 25 pounds  $P_2O_5$  assimilated 24 pounds N and 1.5 pounds P, while the mature plants assimilated approximately 32 pounds N and 3 pounds P.

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conditions of high temperature and low moisture. Jour.  
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**TABLES**

Table 1. Rainfall at the various locations for the wheat fertility trials, 1961-1962.

Month - Year	: Agronomy : Farm : Manhattan	: Ashland : Agronomy : Farm : Manhattan	: Hutchinson : Experiment : Field : Hutchinson <sup>1</sup>	: Newton : Experiment : Field : Newton
September 1961	7.82	7.96	3.07	6.07
October "	3.87	4.27	1.43	4.23
November "	1.99	1.98	1.95	2.41
December "	0.76	0.51	0.58	0.55
January 1962	0.83	1.01	1.01	0.44
February "	1.06	1.19	0.61	0.48
March "	2.07	1.38	0.31	1.15
April "	1.20	1.07	1.07	1.26
May "	5.98	7.27	2.68	3.76
June "	4.40	3.74	6.70	7.12

<sup>1</sup>Rainfall data were not obtained at the Richard Evans Farm, Hutchinson, Kansas. This site was located approximately three miles from the Hutchinson Experiment Station where rainfall data were recorded.

Table 2. Characterization of certain fertilizers used in the 1961-1962 wheat experiment.

Fertilizer	: Manufacturer's : guaranteed : analysis	: Characterization of Phosphorus (P <sub>2</sub> O <sub>5</sub> basis)		
		: Total : %	: Available : %	: Water Soluble : %
Ammonium nitrate- Phosphate	30-10-0	10	10	10
Ammonium phosphate	11-48-0	50.4	49.05	42.9
Concentrated super- phosphate	0-45-0	47.7	45.3	44.3
High analysis phosphate	0-56-0	58.7	55.9	26.7
Ammonium poly- phosphate	15-60-0	60.0	59.8	59.8

Table 3. Soil types and chemical properties of soils used in wheat fertilizer trials, 1961-1962.

Experimental Location	Soil Type	pH	Lime Requirements :Lbs./A	Organic Matter %	Available :Lbs./A	Exchangeable K Lbs./A
Agronomy Farm Manhattan	silty clay loam	5.9	3,000	1.8	43	550
Ashland Agronomy Farm Manhattan	fine, sandy loam	7.4	(not re- quired)	0.4	55	435
Richard Evans Farm Hutchinson	silt loam	5.7	1,000	1.3	26	535
Experiment Station Newton	clay loam	6.0	3,000	2.6	16	550

Table 4. Varieties planted, dates of planting and dates of harvest, 1961-1962.

Location	Wheat Variety Planted	Date of Planting	Date Harvested
Agronomy Farm Manhattan	Ottawa	October 4	June 25
Ashland Agronomy Farm Manhattan	Ottawa	October 3	June 26
Richard Evans Farm Hutchinson	Triumph	October 8	June 14
Newton Experiment Field Newton	Triumph	October 19	June 25

Table 5. Fertilizer treatments employed at the Agronomy Farm, Manhattan, the Ashland Agronomy Farm, Manhattan, the Richard Evans Farm, Hutchinson, and the Newton Experiment Field, Newton, 1961-1962.

Treatment No.	: Pounds/A of Fer-					Total Lbs/A Fertili- zer
	: Pounds of	: P <sub>2</sub> O <sub>5</sub>	: Ammo-	: Phos-	: Nitrate	
	: N/A	: /A	: Nitrum	: or Mixed	: Ferti-	
	:	:	:	:	: lizer	:
1. No treatment	0	0	0	0		0
2. NH <sub>4</sub> NO <sub>3</sub> with seed	50	0	150	0		150
3. " " " "	75	0	225	0		225
4. 30-10-0 " "	50	17	0	167		167
5. " " "	75	25	0	250		250
6. 0-45-0 NH <sub>4</sub> NO <sub>3</sub> with seed	50	17	150	37		187
7. " " " "	75	25	225	55		280
8. 0-56-0 " " " "	50	17	150	30		180
9. " " " "	75	25	225	45		270
10. 11-48-0 " " " "	50	17	138	35		173
11. " " " "	75	25	207	52		259
12. 15-60-0 " " " "	50	17	138	28		166
13. " " " "	75	25	207	42		249
14. 0-45-0 with seed NH <sub>4</sub> NO <sub>3</sub> broadcast	50	17	150	37		187
15. Same as above	75	25	225	55		280
16. 0-56-0 with seed NH <sub>4</sub> NO <sub>3</sub> broadcast	50	17	150	30		180
17. Same as above	75	25	225	45		270
18. 11-48-0 with seed NH <sub>4</sub> NO <sub>3</sub> broadcast	50	17	138	35		173
19. Same as above	75	25	207	52		259
20. 15-60-0 with seed NH <sub>4</sub> NO <sub>3</sub> broadcast	50	17	138	28		166
21. Same as above	75	25	207	42		249

Table 6. The effects of fertilizer treatments on the yield of wheat in Kansas, 1961-1962.<sup>1</sup>

Treatment: No.	Locations and yields in bu./A			
	: Agronomy Farm: : Manhattan	: Ashland : Agronomy Farm:	: Richard Evans: Farm	: Newton : Experiment : Field, Newton
1	34.0	4.2	25.4	13.2
2	41.3	8.1	30.2	16.0
3	45.2	5.4	31.0	15.2
4	46.8	8.6	32.8	18.2
5	49.7	7.4	36.4	17.0
6	46.0	3.9	36.9	18.5
7	49.1	4.0	37.8	18.1
8	47.0	7.5	32.8	17.3
9	49.6	3.0	35.0	16.2
10	49.2	7.4	34.8	20.4
11	48.3	4.8	35.8	18.4
12	43.7	4.3	34.2	19.0
13	52.3	5.7	36.0	19.0
14	48.0	4.3	34.4	21.3
15	50.1	5.4	36.1	20.8
16	45.2	4.6	32.4	17.5
17	48.6	8.7	35.2	18.8
18	47.7	7.7	33.0	18.7
19.	50.1	10.2	38.2	19.1
20	43.4	11.4	34.6	17.7
21	52.3	7.9	37.7	18.6
LSD (.05)	5.6	N.S.	2.9	3.5
LSD (.01)	7.4	N.S.	3.9	4.6

<sup>1</sup>Results are means of 4 replications at the various locations.



Table 7. The effects of fertilizer treatments on the dry weight of the samples at the vegetative stage.<sup>1</sup>

Location and dry weight of vegetative stage (lbs/A)				
Treat- ment No.:	Agronomy Farm: Manhattan	Ashland Agronomy Farm:	Richard Evans: Farm	Newton Experiment Field, Newton
1.	955.2	373.9	983.4	368.7
2.	1,416.7	715.8	940.1	269.9
3.	1,531.5	508.2	1,191.5	358.8
4.	1,321.2	492.0	1,595.3	611.4
5.	1,705.7	665.3	1,972.4	690.8
6.	1,399.9	689.6	1,851.1	580.7
7.	1,757.8	497.3	2,006.2	524.3
8.	1,756.8	719.3	1,568.6	467.3
9.	1,685.6	390.0	1,900.6	532.3
10.	1,392.3	667.8	1,723.6	530.4
11.	1,654.6	573.8	1,798.5	638.8
12.	1,328.8	694.4	1,930.9	505.8
13.	1,647.4	571.9	2,044.1	531.0
14.	1,513.3	700.9	1,732.5	695.8
15.	1,963.5	803.0	1,980.5	808.3
16.	1,314.9	651.5	1,562.1	685.0
17.	1,613.8	594.3	1,763.5	685.3
18.	1,340.7	904.1	1,686.2	638.4
19.	1,990.6	811.6	2,192.5	824.9
20.	1,360.1	644.5	1,655.8	726.1
21.	1,959.6	662.0	2,056.4	746.4
LSD(.05)	429.2	283.2	318.0	138.4
LSD(.01)	570.8	376.6	422.9	184.1

<sup>1</sup>Each weight reported is an average of 4 replications.

Table 8. The effects of fertilizer treatments on the nitrogen content and nitrogen yield of vegetative stage of wheat, 1961-1962.<sup>1</sup>

Treat- ment No.	Location, N content (%) and N yield (Lbs/A)							
	Agronomy Farm:		Ashland		Richard Evans:		Newton Experiment Farm : most Field	
	Manhattan		Manhattan		Hutchinson		Newton	
	Percent:	Lbs/A	Percent:	Lbs/A	Percent:	Lbs/A	Percent:	Lbs/A
:	N	:	N	:	N	:	N	
1.-	2.30	21.94	1.98	7.43	2.24	22.03	3.32	11.87
2.	2.72	40.48	1.76	12.73	2.90	26.91	4.06	10.98
3.	3.22	46.19	1.74	8.88	2.76	32.91	3.91	14.14
4.	2.46	32.73	1.65	8.20	2.25	35.78	3.59	21.94
5.	2.60	44.46	1.57	10.40	2.22	44.14	4.13	28.53
6.	2.48	34.61	1.66	11.53	2.34	42.82	3.68	21.54
7.	2.66	46.69	1.70	8.30	2.52	50.46	4.33	27.31
8.	2.48	43.88	1.61	11.59	2.35	36.66	3.99	18.58
9.	2.74	45.97	1.64	6.42	2.47	46.92	4.35	23.16
10.	2.54	37.00	1.69	11.24	2.24	38.67	4.18	22.18
11.	2.62	43.16	1.67	9.38	2.43	43.56	4.06	25.85
12.	2.51	33.43	1.46	10.18	2.25	43.64	4.05	21.95
13.	2.67	43.56	1.90	10.55	2.43	49.71	4.25	21.12
14.	2.47	36.20	1.75	12.25	2.22	38.66	3.96	30.96
15.	2.35	48.04	1.71	13.55	2.36	46.88	4.25	30.63
16.	2.42	31.86	1.28	8.35	2.33	36.43	3.79	25.96
17.	2.48	40.45	1.59	9.27	2.49	43.31	4.00	27.36
18.	2.28	30.77	1.62	14.73	2.24	37.71	3.91	24.99
19.	2.50	50.02	2.15	17.36	2.38	52.11	4.19	34.56
20.	2.33	31.66	1.46	9.38	2.29	37.55	3.82	27.73
21.	2.36	46.08	2.02	13.94	2.34	47.90	3.83	28.71
LSD (.05)	.21	12.16	.08	N.S.	.11	8.28	.37	6.22
LSD (.01)	.28	16.17	.01	N.S.	.14	11.01	.50	8.27

<sup>1</sup>Results reported is the mean of 4 replications

Table 9. The effects of fertilizer treatments on the nitrogen content and nitrogen yield of the mature straw, 1961-1962.<sup>1</sup>

Location, N content (%) and N yield (Lbs/A)								
Treat- ment No.	Agronomy Farm: Manhattan		Ashland Agronomy Farm: Manhattan		Richard Evans: Farm Hutchinson		Newton Experiment Field Newton	
	Percent: N	Lbs/A N	Percent: N	Lbs/A N	Percent: N	Lbs/A N	Percent: N	Lbs/A N
1.	.30	11.75	.84	5.48	.34	9.61	.46	5.41
2.	.35	14.41	.74	10.18	.47	16.31	.56	10.42
3.	.34	15.44	.84	8.11	.53	22.72	.68	11.25
4.	.31	14.86	.76	11.90	.29	12.76	.48	8.92
5.	.39	23.46	.78	12.01	.34	13.41	.54	9.61
6.	.32	15.72	.84	7.49	.30	12.29	.53	9.83
7.	.36	21.08	.84	6.43	.37	17.22	.57	11.82
8.	.28	18.55	.74	9.72	.35	12.77	.54	9.06
9.	.40	19.91	.82	5.44	.39	17.06	.57	10.76
10.	.30	18.87	.71	9.82	.38	12.72	.47	10.00
11.	.33	20.83	.87	7.95	.36	18.04	.53	12.20
12.	.30	14.36	.75	7.20	.33	12.55	.45	10.17
13.	.39	21.49	.90	8.56	.39	16.10	.57	13.32
14.	.32	15.97	.80	8.18	.42	19.79	.46	11.13
15.	.38	20.67	.77	8.70	.39	16.54	.48	10.54
16.	.32	17.41	.81	6.03	.36	15.58	.49	8.53
17.	.42	20.41	.77	10.80	.39	16.43	.42	8.71
18.	.34	18.68	.74	7.49	.29	11.23	.51	9.72
19.	.34	19.90	.72	11.44	.38	18.88	.53	11.34
20.	.29	12.02	.77	13.24	.33	12.41	.45	9.40
21.	.33	24.24	.79	9.26	.42	20.40	.53	10.94
LSD (.05)	.06	5.70	.10	N.S.	.08	6.26	.06	3.44
LSD (.01)	.07	7.58	.13	N.S.	.10	8.32	.08	4.57

<sup>1</sup>Results reported is the mean of 4 replications.

Table 10. The effect of fertilizer treatments on the nitrogen content and nitrogen yield per acre in the wheat seed, 1961-1962.<sup>1</sup>

: Location, N content (%) and N yield (Lbs/A)									
Treat-	Agronomy Farm:		Ashland		Richard Evans:		Newton Experi-		
ment :	Manhattan		Agronomy Farm:		Farm		ment Field		
No. :			Manhattan		Hutchinson		Newton		
	Percent:	Lbs/A	Percent:	Lbs/A	Percent:	Lbs/A	Percent:	Lbs/A	
	: N	: N	: N	: N	: N	: N	: N	: N	: N
1.	1.85	37.61	2.68	6.86	2.11	32.01	2.36	18.51	
2.	1.96	52.42	2.67	12.80	2.39	43.20	2.68	25.62	
3.	2.16	58.72	2.68	8.58	2.49	46.31	2.85	25.92	
4.	1.86	52.62	2.68	13.55	2.21	43.49	2.49	25.67	
5.	2.02	60.27	2.66	11.94	2.35	51.37	2.62	27.84	
6.	1.92	53.03	2.80	6.55	2.26	50.10	2.55	28.06	
7.	2.04	60.34	2.73	6.46	2.45	55.23	2.69	29.03	
8.	1.90	53.87	2.65	11.93	2.30	44.50	2.63	25.69	
9.	2.01	59.78	2.84	5.14	2.42	50.74	2.67	27.36	
10.	1.88	55.74	2.61	11.65	2.26	47.06	2.63	29.23	
11.	2.02	58.63	2.64	7.58	2.33	50.08	2.68	32.18	
12.	1.87	49.26	2.78	7.17	2.22	45.66	2.48	27.92	
13.	2.01	63.14	2.67	9.20	2.43	52.46	2.70	30.56	
14.	1.80	51.89	2.68	6.85	2.17	44.63	2.45	31.30	
15.	1.94	58.39	2.63	8.75	2.34	50.58	2.66	33.08	
16.	1.92	52.04	2.79	7.52	2.31	45.96	2.52	26.30	
17.	1.96	57.14	2.62	13.62	2.44	51.40	2.56	28.49	
18.	1.85	53.06	2.62	12.03	2.28	45.03	2.60	28.69	
19.	2.03	60.97	2.60	15.72	2.32	53.11	2.70	30.89	
20.	1.86	48.40	2.64	17.94	2.26	47.05	2.59	27.21	
21.	2.00	62.95	2.68	12.79	2.34	52.90	2.75	30.58	
LSD (.05).	.136	8.28	N.S.	N.S.	0.12	4.62	.148	4.98	
LSD (.01).	.180	11.01	N.S.	N.S.	0.16	6.14	.196	6.63	

<sup>1</sup>Results reported is the mean of 4 replications.

Table 11. The effect of fertilizer treatments on the phosphorus content and phosphorus yield of the vegetative stage of wheat, 1961-1962.<sup>1</sup>

Location, P content (%) and P yield (Lbs/A)									
Treat- ment No.	Agronomy Farm:		Ashland		Richard Evans Farm		Newton Field		Experiment
	Manhattan		Manhattan		Hutchinson		Newton		
	Percent	Lbs/A	Percent	Lbs/A	Percent	Lbs/A	Percent	Lbs/A	
	P	P	P	P	P	P	P	P	P
1.	.243	2.30	.320	1.19	.212	2.09	.298	1.08	
2.	.252	3.27	.336	2.39	.195	1.96	.288	.77	
3.	.236	3.95	.358	1.82	.199	2.20	.281	1.02	
4.	.244	3.23	.350	2.04	.178	3.14	.325	1.99	
5.	.256	4.38	.381	2.52	.182	3.92	.331	2.26	
6.	.227	3.17	.334	2.30	.175	3.22	.314	1.69	
7.	.228	4.02	.305	1.51	.202	4.10	.332	1.89	
8.	.233	3.68	.342	2.46	.176	2.76	.293	1.37	
9.	.239	4.46	.369	1.43	.186	3.55	.313	1.66	
10.	.232	3.29	.361	2.41	.171	2.94	.312	1.77	
11.	.250	4.06	.345	1.92	.188	3.37	.337	1.96	
12.	.246	3.32	.303	2.09	.177	3.43	.302	1.60	
13.	.257	4.29	.345	1.94	.176	3.61	.320	1.61	
14.	.257	3.92	.305	2.10	.182	3.20	.305	2.18	
15.	.236	4.62	.371	2.96	.175	3.47	.320	2.53	
16.	.230	3.02	.348	2.26	.178	2.79	.316	2.05	
17.	.244	3.95	.398	2.31	.188	3.29	.301	2.18	
18.	.237	3.19	.349	3.12	.198	3.34	.287	1.83	
19.	.244	4.86	.349	2.83	.199	4.36	.304	2.50	
20.	.232	3.17	.381	2.43	.194	3.18	.298	2.16	
21.	.254	4.94	.362	2.37	.185	3.80	.301	2.25	
LSD (.05)	.01	1.12	.027	.88	.01	.76	.03	.44	
LSD (.01)	.02	1.48	.034	1.17	.02	1.01	.04	.58	

<sup>1</sup>Results reported is the mean of 4 replications.

Table 12. The effect of fertilizer treatments on the phosphorus content and phosphorus yield of the mature wheat straw, 1961-1962.<sup>1</sup>

Location, P content (%) and P yield (Lbs/A)								
Treat- ment No.	Agronomy Farm:		Ashland		Richard Evans Farm		Newton Experiment Field	
	Manhattan		Manhattan		Hutchinson		Newton	
	Percent: P	Lbs/A	Percent: P	Lbs/A	Percent: P	Lbs/A	Percent: P	Lbs/A
1.	.071	2.12	.112	.75	.040	1.15	.061	.72
2.	.068	2.60	.091	1.24	.049	1.73	.058	.90
3.	.068	2.98	.125	1.24	.065	2.78	.069	1.28
4.	.061	2.38	.091	1.35	.032	1.25	.054	.89
5.	.073	3.37	.100	1.60	.039	1.75	.055	1.12
6.	.066	2.68	.099	.88	.030	1.18	.055	.94
7.	.067	3.22	.107	.84	.048	2.32	.056	1.25
8.	.065	2.86	.092	1.28	.040	1.44	.054	.77
9.	.071	3.28	.099	.65	.042	1.86	.051	1.04
10.	.059	2.82	.084	1.17	.034	1.18	.047	1.00
11.	.074	3.40	.110	1.08	.043	2.16	.047	1.13
12.	.071	2.70	.091	.88	.045	1.71	.053	1.05
13.	.078	3.89	.102	.97	.046	1.92	.057	1.47
14.	.066	2.96	.107	1.09	.040	1.49	.059	1.08
15.	.068	3.33	.083	.94	.046	2.75	.056	1.57
16.	.072	3.04	.104	.74	.035	1.40	.061	.82
17.	.067	3.16	.091	1.28	.044	1.98	.054	1.25
18.	.072	3.20	.085	.88	.038	1.49	.047	1.00
19.	.072	3.96	.094	1.52	.050	2.49	.061	1.29
20.	.069	2.82	.094	1.70	.044	1.61	.055	1.02
21.	.070	3.59	.114	1.46	.040	1.90	.060	1.41
LSD (.05)	.008	.89	.004	N.S.	.010	.50	.010	.32
LSD (.01)	.010	1.18	.006	N.S.	.018	.66	.013	.42

<sup>1</sup>Results reported is the mean of 4 replications.

Table 13. The effects of fertilizer treatments on the phosphorus content and phosphorus yield per acre in wheat seed, 1961-1962.<sup>1</sup>

Location, P content (%) and P yield (Lbs/A)								
Treat-	Agronomy Farm:		Ashland :		Richard Evans:		Newton Experi-	
ment :	Manhattan :		Agronomy Farm:		Farm :		ment Field	
No. :	:		Manhattan :		Hutchinson :		Newton	
	Percent:	Lbs/A :	Percent:	Lbs/A:	Percent:	Lbs/A :	Percent:	Lbs/A
	: P :	P :	: P :	P :	: P :	P :	: P :	P
1.	.251	5.09	.268	.66	.213	3.24	.284	2.22
2.	.246	6.56	.289	1.42	.208	3.76	.254	2.31
3.	.252	6.83	.268	.86	.216	4.01	.244	2.34
4.	.244	6.82	.295	1.48	.191	3.76	.238	2.49
5.	.258	7.31	.309	1.37	.185	4.23	.241	2.57
6.	.256	6.95	.292	.69	.188	3.98	.245	2.35
7.	.268	7.99	.273	.64	.186	4.41	.231	2.87
8.	.241	6.78	.295	1.29	.176	3.47	.232	2.20
9.	.249	7.40	.266	.49	.206	4.31	.235	2.50
10.	.245	7.12	.294	1.26	.193	4.04	.214	2.38
11.	.250	7.23	.272	0.77	.196	4.21	.225	2.69
12.	.258	7.42	.312	.85	.193	3.95	.238	2.71
13.	.253	7.99	.308	1.04	.193	4.18	.245	2.78
14.	.252	7.28	.286	.74	.199	4.11	.229	2.94
15.	.262	7.90	.279	.91	.194	4.21	.249	3.09
16.	.264	7.15	.260	.76	.190	3.70	.224	2.35
17.	.266	7.73	.275	1.44	.189	4.00	.211	2.38
18.	.229	6.48	.295	1.38	.199	3.93	.233	2.59
19.	.245	7.42	.293	1.80	.200	4.61	.252	2.88
20.	.238	6.17	.250	1.70	.201	4.16	.247	2.63
21.	.268	8.37	.276	1.30	.207	4.68	.242	2.70
LSD (.05)	.020	.48	.022	N.S.	.018	.51	.006	.50
LSD (.01)	.027	.63	.029	N.S.	.023	.67	.007	.66

<sup>1</sup>Results reported is the mean of 4 replications.

PLATES AND FIGURES



PLATE I

Fig. 1. Effect of various fertilizer treatments on the yield of wheat grain, Richard Evans Farm, Hutchinson, Kansas.

Fig. 2. Effect of various fertilizer treatments on the yield of wheat grain, Agronomy Farm, Manhattan, Kansas.



PLATE II

Fig. 3. Effect of various fertilizer treatments on the yield of wheat grain, Ashland Agronomy Farm, Manhattan, Kansas.

Fig. 4. Effect of various fertilizer treatments on the yield of wheat grain, Newton Experiment Field, Newton, Kansas.



PLATE III

Fig. 5. Effect of various fertilizer treatments on the yield of phosphorus for the vegetative stage of wheat, Agronomy Farm, Manhattan, Kansas.

Fig. 6. Effect of various fertilizer treatments on the yield of nitrogen for the vegetative stage of wheat, Agronomy Farm, Manhattan, Kansas.

## PLATE III



Fig. 5

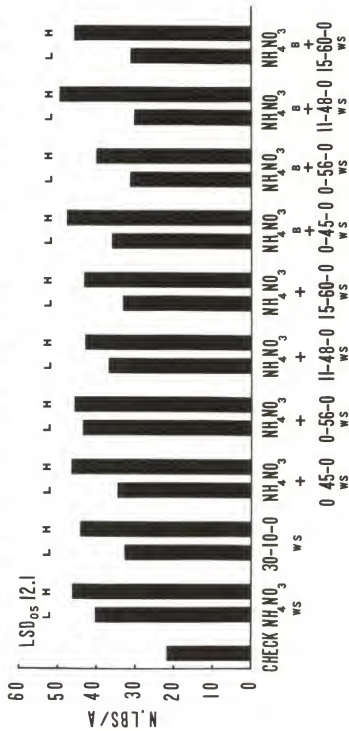


Fig. 6

PLATE IV

Fig. 7. Effect of various fertilizer treatments on the total yield of nitrogen for the mature plants, Agronomy Farm, Manhattan, Kansas.

PLATE IV

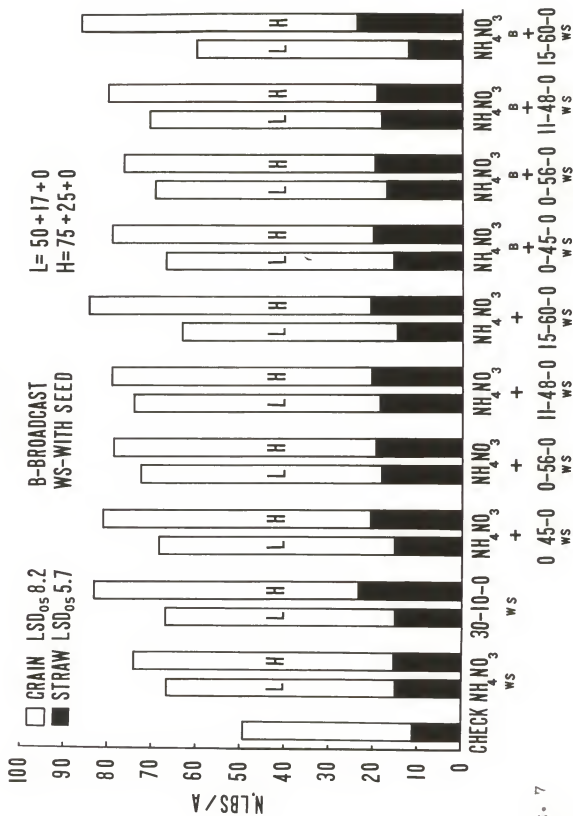


Fig. 7



PLATE V

Fig. 8. Effect of various fertilizer treatments on the total yield of phosphorus for the mature plants, Agronomy Farm, Manhattan, Kansas.



PLATE VI

Fig. 9. Effect of various fertilizer treatments on the yield of phosphorus for the vegetative stage, Ashland Agronomy Farm, Manhattan, Kansas.

Fig. 10. Effect of various fertilizer treatments on the yield of nitrogen for the vegetative stage, Ashland Agronomy Farm, Manhattan, Kansas.

PLATE VI

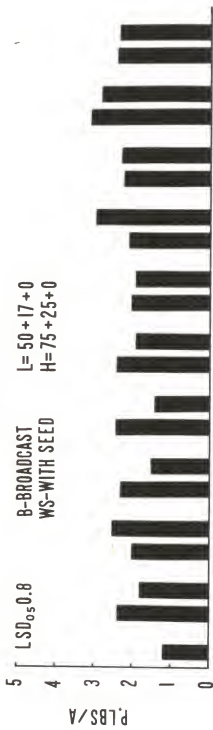


FIG. 9



FIG. 10

PLATE VII

FIG. 11. Effect of various fertilizer treatments on the total yield of nitrogen for the mature plants, Ashland Agronomy Farm, Manhattan, Kansas.



PLATE VIII

Fig. 12. Effect of various fertilizer treatments on the total yield of phosphorus for the mature plants, Ashland Agronomy Farm, Manhattan, Kansas.





PLATE IX

Fig. 13. Effect of various fertilizer treatments on the yield of phosphorus for the vegetative stage, Richard Evans Farm, Hutchinson, Kansas.

Fig. 14. Effect of various fertilizer treatments on the yield of nitrogen for the vegetative stage, Richard Evans Farm, Hutchinson, Kansas.



PLATE X

Fig. 15. Effect of various fertilizer treatments on the total yield of nitrogen for the mature plants, Richard Evans Farm, Hutchinson, Kansas.



PLATE XI

Fig. 16. Effect of various fertilizer treatments on the total yield of phosphorus for the mature plants, Richard Evans Farm, Hutchinson, Kansas.



PLATE XII

Fig. 17. Effect of various fertilizer treatments on the yield of phosphorus for the vegetative stage, Newton Experiment Field, Newton, Kansas.

Fig. 18. Effect of various fertilizer treatments on the yield of nitrogen for the vegetative stage, Newton Experiment Field, Newton, Kansas.

PLATE XII

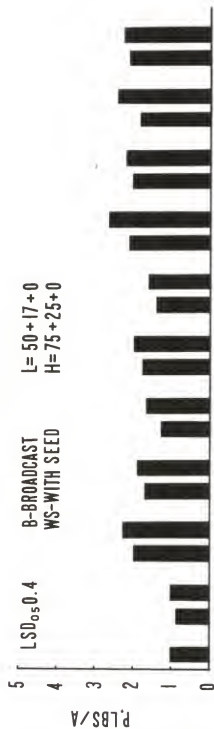


Fig. 17

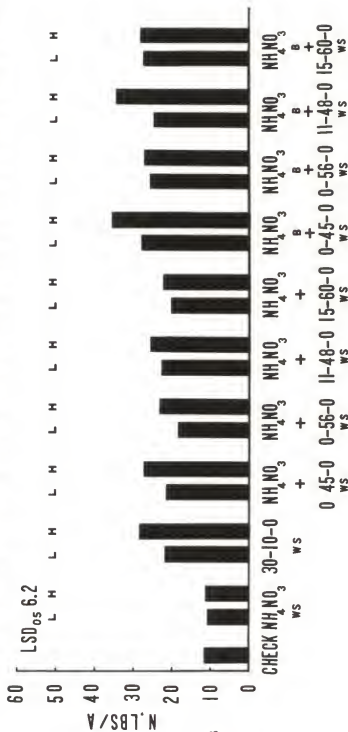


Fig. 18



PLATE XIII

Fig. 19. Effect of various fertilizer treatments on the total yield of nitrogen for the mature plants, Newton Experiment Field, Newton, Kansas.



PLATE XIV

Fig. 20. Effect of various fertilizer treatments on the total yield of phosphorus for the mature plants, Newton Experiment Field, Newton, Kansas.

PLATE XIV

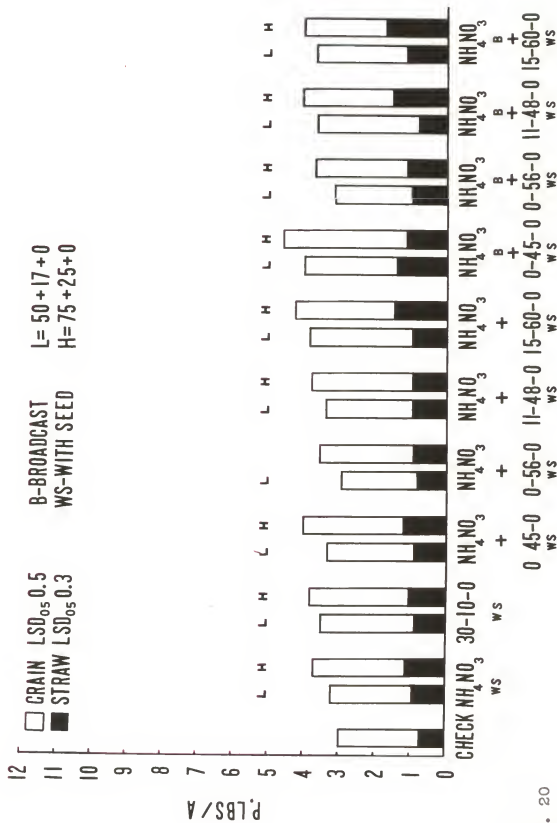


FIG. 20

PLATE XV

Fig. 21. Calculated average amounts of nitrogen and phosphorus per acre recovered by wheat from the fertilizer treatments at the Agronomy Farm, Manhattan, Kansas, and the Richard Evans Farm, Hutchinson, Kansas.

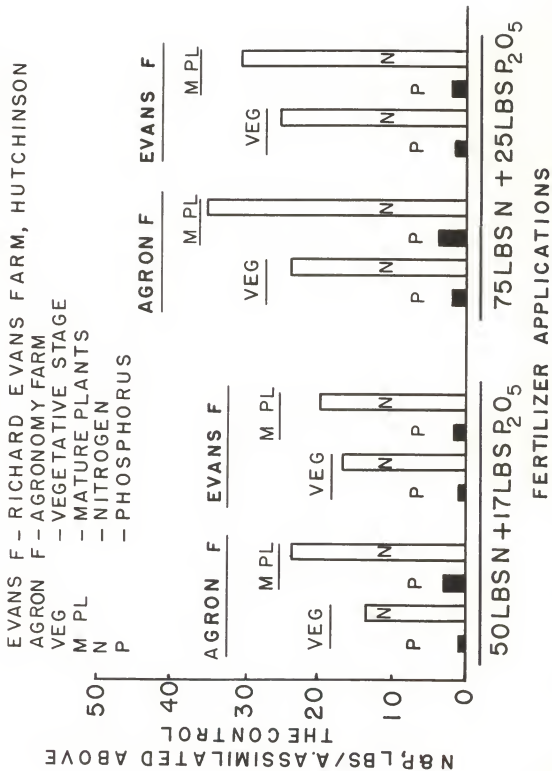


Fig. 21

NUTRIENT UPTAKE OF WHEAT FROM SEVERAL FERTILIZERS  
AS EVALUATED BY LABORATORY ANALYSES

by

DAVID L. LINDELL

B. S., Kansas State University of  
Agriculture and Applied Science, 1955

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AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Agronomy

Kansas State University  
of Agriculture and Applied Science

1963

## ABSTRACT

Determination of the chemical composition should permit better understanding of the nutrient requirements of wheat. After determining the nutrient requirements, fertilizer applications may be made more specifically.

Four locations were used for these fertility plots. A randomized complete block design of 21 treatments replicated in four blocks was used. Early vegetative samples and mature samples of plant material were collected. Determinations were made on an air dry basis of total N and P contained in the vegetative stage, mature straw, and seed fractions. After determining the percentages of total N and P in plant material, yields of these elements on a per acre basis were calculated. The general purpose of this study was to evaluate the effects of various fertilizer treatments on the uptake of N and P and the yield of wheat grain.

Objectives of the experiment were:

1. To evaluate a new commercial grade of ammonium nitrate-phosphate fertilizer (30-10-0).
2. To compare ammonium polyphosphate (15-60-0) and high analysis phosphate (0-56-0) with conventional phosphatic fertilizers (0-45-0 and 11-48-0).
3. To compare broadcasting and row application of ammonium nitrate.
4. To compare yield responses to two rates of N and available  $P_2O_5$ ; namely, 50 pounds of N plus 17 pounds of available  $P_2O_5$ , and 75 pounds N plus 25 pounds of available  $P_2O_5$ .



5. To determine the amounts of N and P in plant material at early and late stages of growth in relation to the amounts of these elements applied as fertilizer treatments.

The following conclusions were made after the data were considered:

1. The increases in N and P assimilated by wheat that received ammonium nitrate-phosphate (30-10-0) were as high or higher than those obtained from proven fertilizers (0-45-0 and 11-48-0). The yield increase of P at the vegetative stage was slightly higher for use of 30-10-0.

2. Yield increases of N and P assimilated by wheat receiving applications of ammonium polyphosphate (15-60-0) were superior to those obtained for other fertilizers. Wheat receiving high analysis phosphate (0-56-0) assimilated slightly smaller amounts of N and P than did wheat which received other fertilizer materials.

3. Method of placement of ammonium nitrate had a very minor effect on the grain yield increase of wheat.

4. Most N and P was assimilated in both the vegetative stage and mature plants where the higher rate of fertilizer application was applied. Wheat which received such fertilizer applications produced more plant material by the time the vegetative sample was collected.

5. By calculation, it was determined that approximately 14 pounds of N and one pound of P from fertilizers were assimilated by the time of the vegetative stage from the lower fertilizer applications. At maturity, approximately 21 pounds N and two pounds P had been assimilated from fertilizer sources.

6. In the vegetative stage, wheat that received the heavier rate of fertilizer had assimilated about 24 pounds of N and 1.5 pounds of P. At maturity, the amounts were 32 pounds of N and three pounds of P.

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