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# The effect of potash fertilization on mineral composition, yield, and stalk breakage in corn at different nitrogen levels

Harry Wittels

To the Graduate Council:

I am submitting herewith a thesis written by Harry Wittels entitled "The effect of potash fertilization on mineral composition, yield, and stalk breakage in corn at different nitrogen levels." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Lloyd F. Seats, Major Professor

We have read this thesis and recommend its acceptance:

Royal E. Shanks

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

December 4, 1951

To the Graduate Council:

I am submitting to you a thesis written by Harry Wittels entitled "The Effect of Potash Fertilization on Mineral Composition, Yield, and Stalk Breakage in Corn at Different Nitrogen Levels." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Lloyd F. Seatz
Major Professor

We have read this thesis
and recommend its acceptance:

Royal E. Shanks

J. K. Leasure

Accepted for the Council:

E. A. Waters
Dean of the Graduate School

# THE EFFECT OF POTASH FERTILIZATION ON MINERAL COMPOSITION, YIELD, AND STALK BREAKAGE IN CORN AT DIFFERENT NITROGEN LEVELS

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A THESIS

Submitted to
The Graduate Council
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Master of Science

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by

Harry Wittels

December 1951

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## INTRODUCTION

Variety, climate, soil treatment, and soil composition are believed to be the principal factors causing variation in yield, composition, and stalk breakage in corn but the specific effects of each factor are not well understood. Although when all but one of these factors are controlled it should be possible to determine definite relationships between variations in this factor and plant growth and composition, relatively few such relationships have been established. The interrelations among soil fertility status, crop yield, plant composition, and growth habits on specific soils should be known for more efficient soil management and fertilizer use.

As a contribution to this general objective, the objectives of the present research have been to:

(1) to study the influence of time and rate of potassium fertilization on yield and amount of stalk breakage in corn at different nitrogen levels.

(2) to determine the effect of time and rate of potassium application on the potash and calcium composition of a corn hybrid.

## LITERATURE REVIEW

The literature dealing with the essential functions of the potassium ion only indicates the relationship that apparently exists between potassium and some of the vital processes in plant metabolism and growth. The exact mechanism by which this ion functions is still unknown since it occurs in plants mainly in the ionic form and as soluble inorganic salts.

Hoffer (12)[1], Wall (24), Loew (17), Gregory (10), and Hoagland (11) agree that potassium in some way controls the synthesis of starch and carbohydrate metabolism. These same investigators present conflicting experimental data concerning the role of potassium in the synthesis of proteins. The American investigators believe that potassium directly affects nitrogen metabolism; whereas the English investigators claim potassium has no direct effect on nitrogen metabolism, stating that the increase in soluble organic nitrogen usually found in potassium-deficient plants, is due to abnormally rapid synthesis and hydrolysis of protein.

The literature dealing with influences of potassium upon the structure of stems is mostly concerned with work done on grains to determine influences of potassium upon stiffness of straw. Almost without exception this work is considered solely on the basis of the potash treatment of the plants. Nightingale (19) believes that the carbohydrate content of the plant, as brought about by seasonal conditions or treatments imposed, should be emphasized. He states that

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[1]Numbers in parentheses refer to references in the bibliography, pages 45, 46, and 47.

stiff straw is most frequently obtained when carbohydrates are abundant. The potassium-nitrogen relationship in this respect is an essential factor in determining the carbohydrate status in the plant. Carbohydrates tend to accumulate most readily when the nitrate supply is not excessive.

It has been emphasized that, directly or indirectly, potassium is essential for carbohydrate synthesis and therefore it is obviously important in relation to cell wall formation and stiffness of stems. Jansen and Bartholomew (13) indicate that corn plants low in potassium contain well-developed sclerenchyma cells and mechanical tissue of the vascular system and a smaller development of the cortex cells, both in number and size, whereas in plants containing an ample supply of potassium the reverse is true. The cortex of the corn stem predominantly supports the corn plant.

Beckenbach et al. (2) investigating the nutrient ion effect upon growth in corn using nutrient solutions, reports the relative concentration of cations is dependent upon the amount of nitrate present in the substrate. At low concentrations of nitrate little importance can be attached to the relative proportions of the three cations $Ca^{++}$, $K^{+}$, and $Mg^{++}$. At high concentrations of nitrate the necessity for higher relative proportions of $K^{+}$ and $Ca^{++}$ in the substrate for maximum response to the nitrate is brought out. Hoagland (11) supports these ideas in a general discussion of the potassium-nitrogen relationship.

Woodruff (27), relating the introduction of lime and legumes on the fertility plots of the Missouri Agricultural Experiment Station in the early twenties, believes these practices aided in exaggerating potassium deficiencies. The removal of large legume hay crops, which feed heavily upon potassium, drained the available potassium supply. The calcium applied as lime hindered the absorption of potassium. Corn yields declined and severe lodging occurred presumably due to the diminishing potassium supply. Stanford et al. (23), investigating the relation of potassium deficiency in corn grown on high lime soils naturally low in potassium, concluded that: (1) poor growth of corn on these soils was due largely to a failure of the plants to absorb adequate amounts of potassium from the soil, and (2) a consequence of the low rate of potassium absorption is an unfavorable balance between cations in the plant.

Foureman (6) studied the potassium relation in corn by analyzing corn samples periodically throughout the growing season. He reports the content of potassium, as per cent dry weight, varied from 1 per cent to 3.6 per cent in the early stages of growth, and from 0.4 per cent to 1.06 per cent at maturity. This variation was due to differential potash applications. These percentages agree with the compilations of Beeson (3), Wimer (26), and Goodall and Gregory (9), however, these authors relate greater variation in the maximum and minimum percentages.

Weeks and Fergus (25), investigating composition and yield of corn crops grown on Kentucky fertility plots, found that applications of potash and nitrogen fertilizers had slight effect on composition and little effect on corn yields. The fertility level of these plots probably was quite high; therefore, additional applications of these nutrients did not materially affect composition or yield. Duley and Miller (5) state that ear production is determined largely by the nutrient supply available during the period of sixty to ninety days from planting. Fair ears were produced with a lower supply of nutrients provided the corn had received an ample supply of nutrients in the previous period of growth. This was said to indicate that the nutrient material had been stored in the stalks and leaves for later use in development of the ears; therefore agreeing with the investigations of Bartholomew and Janson (1) who found that plants absorb considerably more potassium during the early stages of growth than is necessary for the normal processes of growth. It was suggested by (1) that the luxury consumption of potassium followed by translocation and reutilization of the potassium in the plant is an important process in the assimilation of potassium by plants. Gerdel (8) states that the maximum leaf area, stalk diameter and height of the corn plant were produced at levels of fertility considerably below that which still produced increases in yields. Translocation and reutilization of potassium would therefore be of more concern at low levels of fertility. Sayre (20) noted the potassium accumulation reached a maximum about three weeks after silking. There was a loss of potassium after that time, largely from the leaves and stems. He states, "A probable explanation is that potassium was partly washed from the leaves and stems back into the soil through the root system.

Both Frear (7) and Scovell and Peter (21) found the potassium content in the stover to be more variable than in the grain. When potassium was applied with either nitrogen or phosphorus, or both, large increases in yields were obtained. The difference in composition of either stover or grain due to fertilizer treatment were generally less than those caused by soil variation. Woods and Gibson (28), conducting a similar investigation, found that the great variation in the composition of corn stover was less dependent upon fertilization than it was upon the difficulty of securing representative stover samples and upon the yield of grain. The large variation in composition of mature corn stover may be explained by the "leaching effect" of potassium from dead plant tissue.

## EXPERIMENTAL METHODS

The single cross T13 x T61, known to be susceptible to stalk breakage, was grown on a soil low in "available" potash at two different nitrogen levels. Potash fertilizer was applied at different rates and at different periods. Potassium and calcium content of the plants was determined periodically throughout the growing season. The amount of stalk breakage and final yields were determined.

The soil type on which the experiment was conducted is classified as Staser fine sandy loam. This soil type develops from alluvial material, is slightly to medium acid, gray brown in color and friable to a depth of approximately thirty inches. The surface and internal drainage is good. However, the internal drainage of the experimental field was not uniform.

Soil samples were obtained from the experimental field and analyzed. The test results indicated a pH of 5.4, 60 pounds per acre of available potassium and very low in available phosphorus.

Concentrated superphosphate (48 per cent) at the rate of 60 pounds $P_2O_5$ per acre, was applied in the row at planting. Ammonium nitrate was applied in the row at the rates of 120 pounds and 60 pounds nitrogen per acre, one half at planting and one half forty eight days after planting. Potash was applied in the form of 60 per cent muraite of potash. The various potash treatments are summarized in Table I. Where potash was side dressed the fertilizer was applied by hand with the nitrogen side dressing. The deep placement potash treatments were placed approximately 6 inches below the surface. Before planting, the row was opened and the deep placement treatments applied by hand. The row was then closed and the remaining applications were applied in the usual manner.

The field plan was laid out in randomized block form. Each plot was 1/100 acre in size, being 31 feet long and 14 feet wide and consisting of 4 rows 3-1/2 feet apart. Eight different potash treatments were applied in one block at the high nitrogen level and the same fertilizer treatments were applied in a block at the low nitrogen level. These eight treatments at the two nitrogen levels, replicated four times, represented the total of sixty four plots in the entire experiment.

The corn crop was planted on May 10 at a rate of one kernel every nine inches. When the crop emerged, the field was thinned to an individual plant every eighteen inches making possible a complete stand. The experimental plots were cultivated three times during the growing season. The crop was harvested on October 22.

Representative samples were taken at two-week intervals throughout the growing season until plant metabolism was quite low. The plant part obtained for analysis depended upon the stage of growth of the corn crop at that particular sampling date. The sampling data are summarized in Table II. The samples collected were obtained from the outside rows of the four-row plots. The two inside rows of each plot remained intact for the determination of grain yields and stalk breakage.

TABLE I

RATE AND TIME OF POTASH APPLICATION AT EACH NITROGEN LEVEL

| Treatment | Potash in Pounds Per Acre | | | |
|---|---|---|---|---|
| | At Planting | Deep Placement | Side Dressing | Total |
| 1 | .. | .. | .. | No potash applied |
| 2 | 20 | .. | .. | 20 |
| 3 | 40 | .. | .. | 40 |
| 4 | 80 | .. | .. | 80 |
| 5 | 40 | .. | 40 | 80 |
| 6 | 40 | 40 | .. | 80 |
| 7 | 80 | 80 | .. | 160 |
| 8 | 80 | 120 | .. | 200 |

TABLE II

SAMPLING DATE, AGE OF PLANTS, AND PLANT PART TAKEN FOR ANALYSIS AT EACH DATE

| Sample Number | Sample Date | Age Days from Planting | Plant Part Sampled |
|---|---|---|---|
| 1 | June 12 | 34 | Entire plant |
| 2 | June 26 | 48 | Entire plant |
| 3 | July 10 | 62 | Leaves, stalks* |
| 4 | July 24 | 76 | Leaves, stalks, and husks |
| 5 | August 7 | 90 | Upper leaves<br>Lower leaves<br>Stalks |

*Sampling 3 and 4 - middle leaves
3, 4, 5 - lower part of stalk

The first two samplings consisted of six plants from each plot and the remaining samplings consisted of two plants per plot. Similar portions of the plants from each plot were combined for analysis.

Each bi-monthly sampling was brought to dry weight using a hay drier at 65 degrees C. The dried samples were ground in a Wiley mill, mixed thoroughly, and a representative sample was bottled for analysis. Samples from each of the four replicates were analyzed separately. The results recorded for each treatment consisted of the average analyses of the four replicates. If the analysis of a sample varied more than 20 per cent from the mean, a duplicate sample was analyzed. If duplicate samples varied more than 25 per cent from the mean, only three plots were averaged. The analytical results, with few exceptions, indicated no appreciable variations from the mean and it was assumed the sampling procedure was adequate in representing the experimental plots. Ladd (16) found that the probable error of the mean of sixteen plants was only slightly less than that of eight plants. Therefore, a larger number of plants probably would not have increased appreciably the accuracy of the work, although it would have added greatly to the problem of collection and preparation of the samples.

The percentage of plants with broken stalks in the two inside rows of each plot was determined prior to harvesting.

Yields were determined by harvesting the grain from the two inside rows of each plot and the field weights were then converted to bushels per acre on a 15-1/2 per cent moisture basis.

For chemical analyses a 1.00 gm sample of dried plant tissue was weighed into a 150 ml. beaker. Five ml. of concentrated nitric acid was added, the beaker covered, and heated gently until 1/2 ml. of solution remained. When cool, 5 ml. of a 1:1 solution of nitric acid and 5 ml. of 70 per cent perchloric acid were added. The beaker was again covered and the solution evaporated to almost dryness by boiling. Five ml. of a 1:1 hydrochloric acid solution and 10 ml. of distilled water were added upon cooling. The solution was warmed gently and filtered into a 100 ml. volumetric flask. The beakers were rinsed carefully and the solution brought to volume. The above procedure is a modification of the "Wet Ash Method," as related in (22).

The potassium and calcium content was determined by the "direct method," using a Perkin-Elmer Model 52-C Flame Photometer. In the determination of potassium and calcium the gases used were propane and acetylene respectively.

## RESULTS

### Stalk Breakage

Actual stalk breakage of the corn plants was the only phase of lodging investigated in this experiment. Root lodging and plants damaged by insects, although no serious damage by either occurred, were not considered.

The data concerning stalk breakage, as summarized in Table III, indicate that potash fertilization at the high nitrogen level decreased the number of broken stalks. Stalk breakage was most prevalent in the check plots and plots receiving the lowest potash application at this nitrogen level. During the growing season, especially in late August and early September, stalk breakage was noticeable in these plots. In the plots receiving larger applications of potash (40 pounds potash per acre or more) the stalks did not break until early October. The percentage of stalks standing in the check plots at the high nitrogen level was approximately 24 per cent, whereas in plots receiving more than 40 pounds of potash per acre the percentage ranged from 67 to 87 per cent.

Potash fertilization at the lower level of nitrogen showed little effect in reducing the number of broken stalks. The percentage of stalks standing at this nitrogen level ranged from 79 per cent in the check plots to a low of 66 per cent in one of the potash treated plots. Where no potash was applied the low nitrogen level contained approximately three times the number of plants standing than did the higher nitrogen level. Except for the check plots and those receiving the lowest rate of potash at the high nitrogen level, there is no appreciable difference in stalk breakage between any 2 potash treatments at either nitrogen level. The different methods of potash application, as summarized in Table I, produced similar effects upon stalk breakage.

## Yield

The yield data presented in Table IV was subjected to statistical analysis by analysis of variance as summarized in Table V.

A significant yield difference at the .05 level was approximately 14 bu. The only potassium treatment indicating a significant yield increase over the check treatment at the high nitrogen level was 40 pounds potash per acre at planting. Significant yield increases over the check treatment at the low nitrogen level were applications of 20 pounds potash per acre at planting and 80 pounds potash per acre at planting plus 120 pounds potash per acre deep placement. These increases above the check treatments amounted to approximately 20 per cent, 22 per cent, and 19 per cent respectively. At both nitrogen levels a majority of the potassium-treated plots, although not quite significant at the .05 level, show considerable yield increase over the check plots.

By averaging the yields of similar potassium-treated plots at both nitrogen levels another L.S.D. may be obtained. By averaging these plots the differential response to the nitrogen fertilizer was eliminated. On this basis, 10 bushels per acre was the significant yield difference. A majority of the potassium-treated plots gave significant yield increases over the check plots. Omitting the deep placement potash treatments which were somewhat retarded in growth, no significant difference is shown between any two potash treatments. The yield data also indicate that in general there is no significant difference between the various methods of potash application. The statistical analysis in Table V also shows the effect of the fertilizer constituents on plant growth and yield. A definite response to the different treatments is indicated by the F test. The treatments were separated to determine the effect of potassium, nitrogen, and the interaction of these constituents. There was very little response to nitrogen, potassium response borders on significance, but the interaction of these two constituents brought about a definite response in plant growth and yields, as shown by the F test. The variation between replicates was not significant as indicated by the F test.

## Mineral Composition

Tables VI-VIII represent the summary of potassium and calcium content of the corn plants. The data in Figures 1-8 were extracted from these summary tables.

The plant potassium levels for the different potash applications at both nitrogen levels were quite similar throughout the growing season (Figures 1-4). At the first two samplings the entire aerial portions of the plants were analyzed since the plant was not well differentiated at this time.

The potassium content of the entire plant (Figures 1-4) varied considerably because of the different potash applications. Maximum variation due to potassium fertilization occurred at the second sampling. The potassium content ranged from 6.3 per cent potassium in the highest potash treatment to 1.1 per cent in the check plots.

During the early periods of growth the calcium content of the crop (Figures 5-8) showed little variation because of the different potash treatments except for the check plots which were higher than the potassium-treated plots. The calcium content of the treated plots at both nitrogen levels was approximately 0.5 per cent, deviating only 0.05 per cent due to the different potash applications. The check plots at both levels were somewhat higher in calcium content, ranging from 0.59 per cent to 0.68 calcium at the high and low nitrogen levels respectively.

Two months after planting the potassium content of both leaves and stalks (Figures 1-4) dropped considerably except for the check plots which did not markedly accumulate potassium at the early samplings. The check plots contained approximately 1.0 per cent potassium at this time, whereas the potassium content of the treated plots ranged from this percentage to a maximum of 2.5 per cent potassium at the highest potash treatment.

The calcium content of the stalks (Figures 7 and 8) in mid-season was approximately the same regardless of the potash or nitrogen treatment.

TABLE III

THE EFFECT OF TIME AND RATE OF POTASH APPLICATION ON STALK BREAKAGE IN CORN AT DIFFERENT NITROGEN LEVELS

| Potash Treatment Lbs./A | Percent Stalks Standing Prior to Harvest | |
|---|---|---|
| | 120 Lbs.N/A | 60 Lbs.N/A |
| No potash | 24* | 79 |
| 20 at Planting | 40 | 78 |
| 40 at Planting | 79 | 81 |
| 80 at Planting | 67 | 82 |
| 40 at Planting + 40 Side Dressing | 70 | 80 |
| 40 at Planting + 40 Deep Placement | 80 | 76 |
| 80 at Planting + 80 Deep Placement | 87 | 85 |
| 80 at Planting + 120 Deep Placement | 73 | 66 |

*--Average of 4 plots

TABLE IV

CORN YIELD AS AFFECTED BY DIFFERENT POTASH TREATMENTS
AT TWO NITROGEN LEVELS

| Treatment (Potash/A) | Bushels Per Acre | | |
|---|---|---|---|
| | 120 Lbs.N/A | 60 Lbs.N/A | Average |
| Check | 82[a] | 79 | 80[b] |
| 20 at Planting | 88 | 101* | 94* |
| 40 at Planting | 103* | 83 | 93* |
| 80 at Planting | 93 | 79 | 86 |
| 40 x 40 Side Dressing | 92 | 88 | 90* |
| 40 x 40 Deep Placement | 79 | 89 | 84 |
| 80 x 80 Deep Placement | 71 | 85 | 78 |
| 80 x 120 Deep Placement | 87 | 97 | 92* |

L.S.D. at the .05 level--14Bu/A
L.S.D. at the .05 level--10 Bu/A (Average of Potash Treatment of Both Nitrogen Levels)

a - Average of 4 plots
b - Average of 8 plots
* - Significant yield increase

TABLE V

ANALYSIS OF VARIANCE

| Source of Variation | Degrees Freedom | Sum of Squares | Variance | F Value |
|---|---|---|---|---|
| Total | 63 | 13,644 | .. | .. |
| Replicates | 3 | 540 | 180 | 1.91 |
| Treatments | 15 | 4,425 | 295 | 3.12** |
| Potassium | 7 | 2,038 | 291 | 3.08* |
| Nitrogen | 1 | 9 | 9 | .. |
| Nitrogen and Potassium | 7 | 2,378 | 340 | 3.70** |
| T x R (Error) | 45 | 4,254 | 94.53 | .. |

* Significant at .05 level
** Highly significant at .01 level

TABLE VI

PERCENT POTASSIUM CONTENT IN CORN AT DIFFERENT STAGES OF GROWTH AS AFFECTED BY DIFFERENT POTASH APPLICATIONS

| Age—Days After Planting | 34 | 48 | 62 | | 76 | | | 90 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant Part | Entire Plant | Entire Plant | Leaves | Stalks | Leaves | Stalks | Husks | Upper Leaves | Lower Leaves | Stalks |
| Potash Treatment | | | High Nitrogen Level (120 Lbs.N/A) | | | | | | | |
| No potash | 1.91 | 1.10 | 0.79 | 0.48 | 0.96 | 0.22 | 0.92 | 1.20 | 0.48 | 0.11 |
| 20 Lbs. at P. | 3.92 | 2.13 | 1.12 | 0.60 | 1.29 | 0.21 | 1.03 | 1.19 | 0.95 | 0.14 |
| 40 Lbs. at P. | 4.75 | 2.72 | 1.47 | 1.01 | 1.66 | 0.25 | 1.12 | 1.70 | 1.33 | 0.18 |
| 80 Lbs. at P. | 4.90 | 4.24 | 1.96 | 1.20 | 1.90 | 0.40 | 1.10 | 1.68 | 1.87 | 0.33 |
| 40 Lbs. at P. + 40 Lbs. S.D. | 4.56 | 2.93 | 1.49 | 1.18 | 1.75 | 0.29 | 1.06 | 1.51 | 1.27 | 0.18 |
| 40 Lbs. at P. + 40 Lbs. D.P. | 4.52 | 3.95 | 1.85 | 1.19 | 1.54 | 0.35 | 1.25 | 1.89 | 1.75 | 0.24 |
| 80 Lbs. at P. + 80 Lbs. D.P. | 4.83 | 5.76 | 2.64 | 2.61 | 2.16 | 0.61 | 1.54 | 1.83 | 1.95 | 0.55 |
| 80 Lbs. at P. + 120 Lbs. D.P. | 4.95 | 6.33 | 2.56 | 2.61 | 2.09 | 0.85 | 1.34 | 1.88 | 2.46 | 0.79 |
| | | | Low Nitrogen Level (60 Lbs.N/A) | | | | | | | |
| No potash | 2.03 | 1.80 | 1.24 | 0.60 | 1.51 | 0.21 | 1.04 | 1.33 | 0.95 | 0.10 |
| 20 Lbs. at P. | 3.85 | 2.24 | 1.21 | 0.62 | 1.62 | 0.25 | 1.30 | 1.49 | 0.98 | 0.12 |
| 40 Lbs. at P. | 4.61 | 2.69 | 1.56 | 1.08 | 1.66 | 0.28 | 1.18 | 1.60 | 1.36 | 0.16 |
| 80 Lbs. at P. | 5.43 | 4.15 | 2.03 | 1.38 | 1.89 | 0.41 | 1.29 | 1.66 | 2.04 | 0.30 |
| 40 Lbs. at P. + 40 Lbs. S.D. | 4.80 | 2.84 | 1.62 | 1.16 | 2.09 | 0.44 | 1.19 | 1.70 | 1.70 | 0.21 |
| 40 Lbs. at P. + 40 Lbs. D.P. | 5.16 | 4.42 | 2.08 | 1.70 | 1.83 | 0.40 | 1.19 | 1.78 | 1.83 | 0.18 |
| 80 Lbs. at P. + 80 Lbs. D.P. | 5.22 | 5.49 | 2.51 | 2.40 | 2.05 | 0.72 | 1.26 | 1.93 | 2.18 | 0.61 |
| 80 Lbs. at P. + 120 Lbs. D.P. | 4.99 | 6.14 | 2.67 | 2.86 | 2.25 | 0.84 | 1.35 | 2.08 | 2.49 | 0.87 |

TABLE VII

PERCENT CALCIUM CONTENT IN CORN AT DIFFERENT STAGES OF GROWTH
AS AFFECTED BY DIFFERENT POTASH APPLICATIONS

| Age—Days After Planting | 34 | 48 | 62 | | 76 | | | 90 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant Part | Entire Plant | Entire Plant | Leaves | Stalks | Leaves | Stalks | Husks | Upper Leaves | Lower Leaves | Stalks |
| Potash Treatment | | | | | High Nitrogen Level (120 Lbs.N/A) | | | | | |
| No potash | 0.59 | 0.57 | 0.65 | 0.21 | 0.63 | 0.20 | 0.11 | 0.62 | 0.85 | 0.12 |
| 20 Lbs. at P. | 0.48 | 0.52 | 0.59 | 0.21 | 0.59 | 0.19 | 0.10 | 0.64 | 0.59 | 0.12 |
| 40 Lbs. at P. | 0.48 | 0.49 | 0.42 | 0.21 | 0.53 | 0.15 | 0.10 | 0.50 | 0.65 | 0.14 |
| 80 Lbs. at P. | 0.46 | 0.42 | 0.31 | 0.21 | 0.52 | 0.18 | 0.11 | 0.52 | 0.57 | 0.12 |
| 40 Lbs. at P. + 40 Lbs. S.D. | 0.47 | 0.47 | 0.28 | 0.23 | 0.46 | 0.18 | 0.10 | 0.57 | 0.67 | 0.13 |
| 40 Lbs. at P. + 40 Lbs. D.P. | 0.52 | 0.47 | 0.50 | 0.24 | 0.55 | 0.17 | 0.10 | 0.48 | 0.63 | 0.12 |
| 80 Lbs. at P. + 80 Lbs. D.P. | 0.47 | 0.40 | 0.26 | 0.21 | 0.34 | 0.14 | 0.12 | 0.43 | 0.59 | 0.13 |
| 80 Lbs. at P. + 120 Lbs. D.P. | 0.51 | 0.35 | 0.31 | 0.15 | 0.36 | 0.16 | 0.11 | 0.40 | 0.58 | 0.12 |
| | | | | | Low Nitrogen Level (60 Lbs.N/A) | | | | | |
| No potash | 0.68 | 0.55 | 0.50 | 0.23 | 0.54 | 0.17 | 0.11 | 0.55 | 0.71 | 0.11 |
| 20 Lbs. at P. | 0.53 | 0.51 | 0.54 | 0.22 | 0.52 | 0.18 | 0.10 | 0.60 | 0.82 | 0.12 |
| 40 Lbs. at P. | 0.49 | 0.49 | 0.51 | 0.25 | 0.49 | 0.15 | 0.11 | 0.54 | 0.55 | 0.12 |
| 80 Lbs. at P. | 0.46 | 0.40 | 0.26 | 0.21 | 0.40 | 0.13 | 0.12 | 0.53 | 0.58 | 0.11 |
| 40 Lbs. at P. + 40 Lbs. S.D. | 0.49 | 0.48 | 0.48 | 0.21 | 0.35 | 0.17 | 0.09 | 0.52 | 0.68 | 0.12 |
| 40 Lbs. at P. + 40 Lbs. D.P. | 0.50 | 0.41 | 0.32 | 0.19 | 0.51 | 0.14 | 0.11 | 0.55 | 0.58 | 0.12 |
| 80 Lbs. at P. + 80 Lbs. D.P. | 0.47 | 0.42 | 0.27 | 0.23 | 0.37 | 0.15 | 0.09 | 0.48 | 0.50 | 0.11 |
| 80 Lbs. at P. + 120 Lbs. D.P. | 0.45 | 0.41 | 0.32 | 0.24 | 0.28 | 0.16 | 0.11 | 0.43 | 0.52 | 0.11 |

TABLE VIII

PERCENT POTASSIUM PLUS CALCIUM CONTENT IN CORN AT DIFFERENT STAGES OF GROWTH AS AFFECTED BY DIFFERENT POTASH APPLICATIONS

| Age--Days After Planting | 34 | 48 | 62 | | 76 | | | 90 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant Part | Entire Plant | Entire Plant | Leaves | Stalks | Leaves | Stalks | Husks | Upper Leaves | Lower Leaves | Stalks |
| **Potash Treatment** | | | **High Nitrogen Level (120 Lbs.N/A)** | | | | | | | |
| No potash | 2.50 | 1.67 | 1.44 | 0.69 | 1.59 | 0.42 | 1.03 | 1.82 | 1.33 | 0.23 |
| 20 Lbs. at P. | 4.40 | 2.62 | 1.71 | 0.81 | 1.88 | 0.40 | 1.13 | 1.83 | 1.54 | 0.26 |
| 40 Lbs. at P. | 5.23 | 3.21 | 1.89 | 1.22 | 2.19 | 0.40 | 1.22 | 2.20 | 1.98 | 0.32 |
| 80 Lbs. at P. | 5.36 | 4.66 | 2.27 | 1.41 | 2.42 | 0.58 | 1.21 | 2.20 | 2.44 | 0.45 |
| 40 Lbs. at P. + 40 Lbs. S.D. | 5.03 | 3.40 | 1.77 | 1.41 | 2.21 | 0.47 | 1.16 | 2.08 | 1.94 | 0.31 |
| 40 Lbs. at P. + 40 Lbs. D.P. | 5.04 | 4.42 | 2.35 | 1.43 | 2.09 | 0.52 | 1.35 | 2.37 | 2.38 | 0.36 |
| 80 Lbs. at P. + 80 Lbs. D.P. | 5.30 | 6.16 | 2.90 | 2.82 | 2.50 | 0.75 | 1.66 | 2.26 | 2.54 | 0.68 |
| 80 Lbs. at P. + 120 Lbs. D.P. | 5.46 | 6.68 | 2.87 | 2.76 | 2.45 | 1.01 | 1.45 | 2.28 | 3.04 | 0.91 |
| | | | **Low Nitrogen Level (60 Lbs.N/A)** | | | | | | | |
| No potash | 2.71 | 2.35 | 1.74 | 0.83 | 2.05 | 0.38 | 1.15 | 1.88 | 1.66 | 0.21 |
| 20 Lbs. at P. | 4.38 | 2.75 | 1.75 | 0.84 | 2.14 | 0.43 | 1.40 | 2.09 | 1.80 | 0.24 |
| 40 Lbs. at P. | 5.10 | 3.18 | 2.07 | 1.33 | 2.15 | 0.43 | 1.29 | 2.14 | 1.91 | 0.28 |
| 80 Lbs. at P. | 5.89 | 4.55 | 2.29 | 1.59 | 2.29 | 0.54 | 1.41 | 2.19 | 2.62 | 0.41 |
| 40 Lbs. at P. + 40 Lbs. S.D. | 5.29 | 3.32 | 2.10 | 1.37 | 2.44 | 0.61 | 1.28 | 2.22 | 2.38 | 0.33 |
| 40 Lbs. at P. + 40 Lbs. D.P. | 5.66 | 4.83 | 2.40 | 1.89 | 2.34 | 0.54 | 1.30 | 2.33 | 2.41 | 0.30 |
| 80 Lbs. at P. + 80 Lbs. D.P. | 5.69 | 5.91 | 2.78 | 2.63 | 2.42 | 0.87 | 1.35 | 2.41 | 2.68 | 0.72 |
| 80 Lbs. at P. + 120 Lbs. D.P. | 5.44 | 6.55 | 2.99 | 3.10 | 2.53 | 1.00 | 1.46 | 2.51 | 3.01 | 0.98 |

**LEGEND**

| | |
|---|---|
| ______________ | Check |
| ____ ____ ____ | 20 Lbs. $K_2O$/A at Planting |
| ____ - ____ - ____ | 40 Lbs. $K_2O$/A at Planting |
| - - - - - - - - - - - - | 80 Lbs. $K_2O$/A at Planting |
| ____ - - ____ - - ____ | 40 Lbs. $K_2O$/A at Planting + 40 Lbs. Side Dressing |
| ____ . ____ . ____ | 40 Lbs. $K_2O$/A at Planting + 40 Lbs. Deep Placement |
| ____ . . ____ . . ____ | 80 Lbs. $K_2O$/A at Planting + 80 Lbs. Deep Placement |
| ____ . - ____ . - ____ | 80 Lbs. $K_2O$/A at Planting + 120 Lbs. Deep Placement |

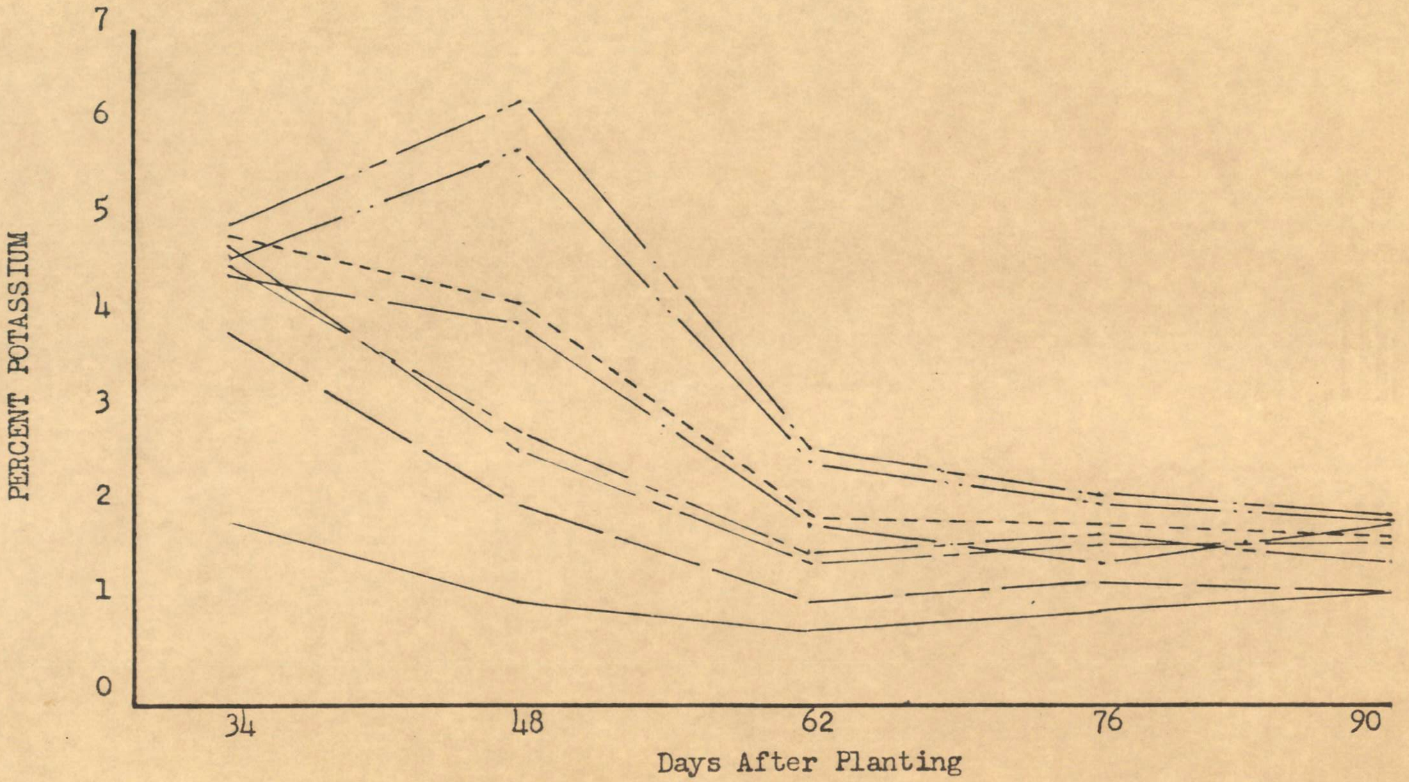


Figure 1. PERCENT POTASSIUM CONTENT IN CORN LEAVES AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE HIGH NITROGEN LEVEL

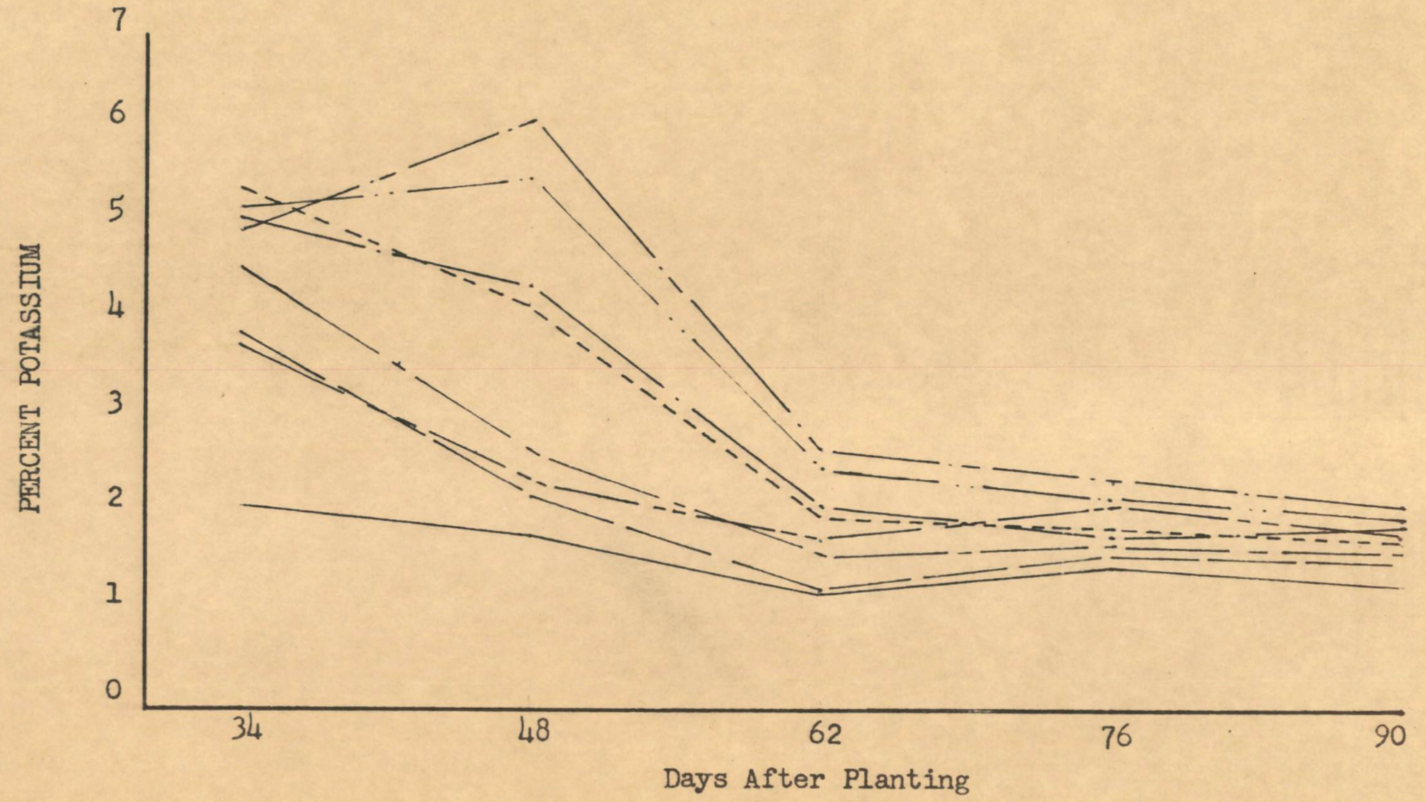


Figure 2. PERCENT POTASSIUM CONTENT IN CORN LEAVES AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE LOW NITROGEN LEVEL

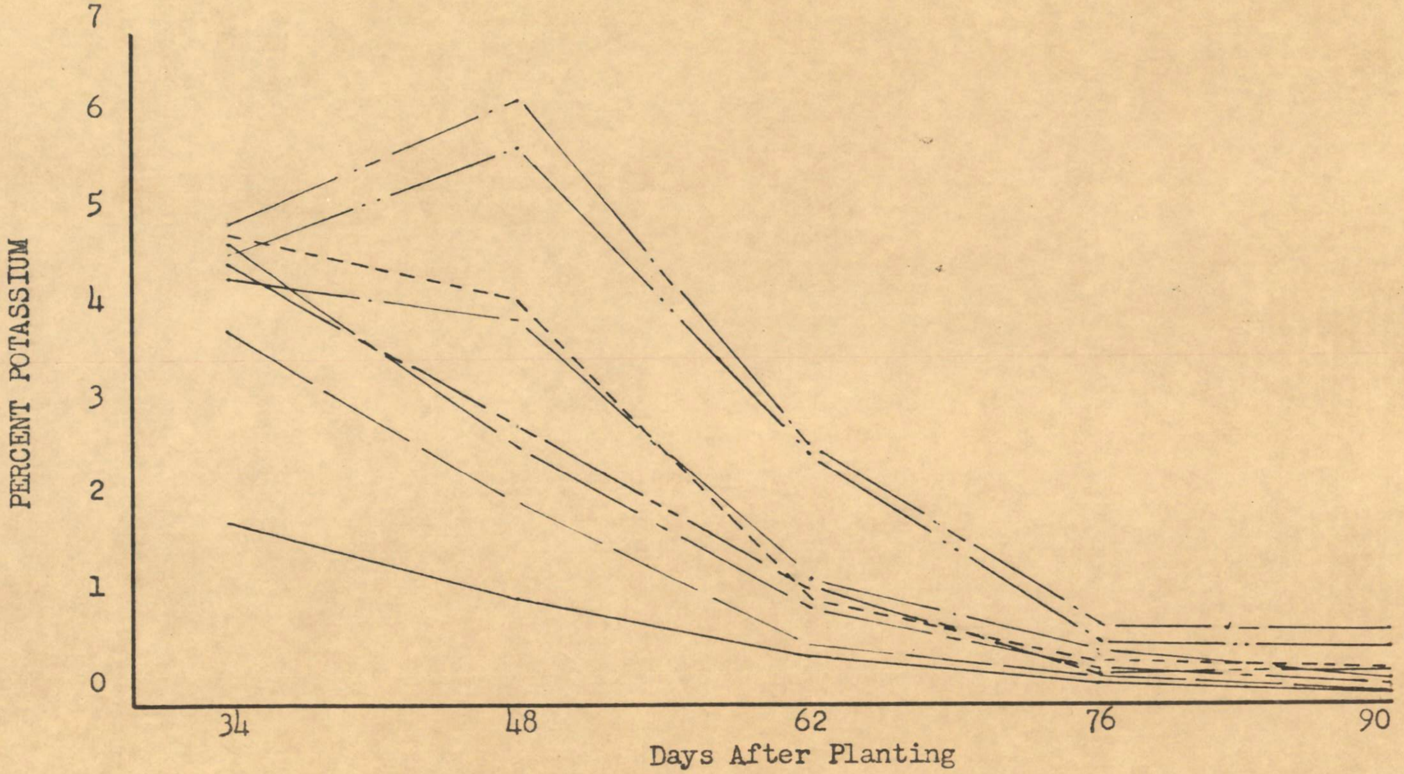


Figure 3. PERCENT POTASSIUM CONTENT IN CORN STALKS AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE HIGH NITROGEN LEVEL

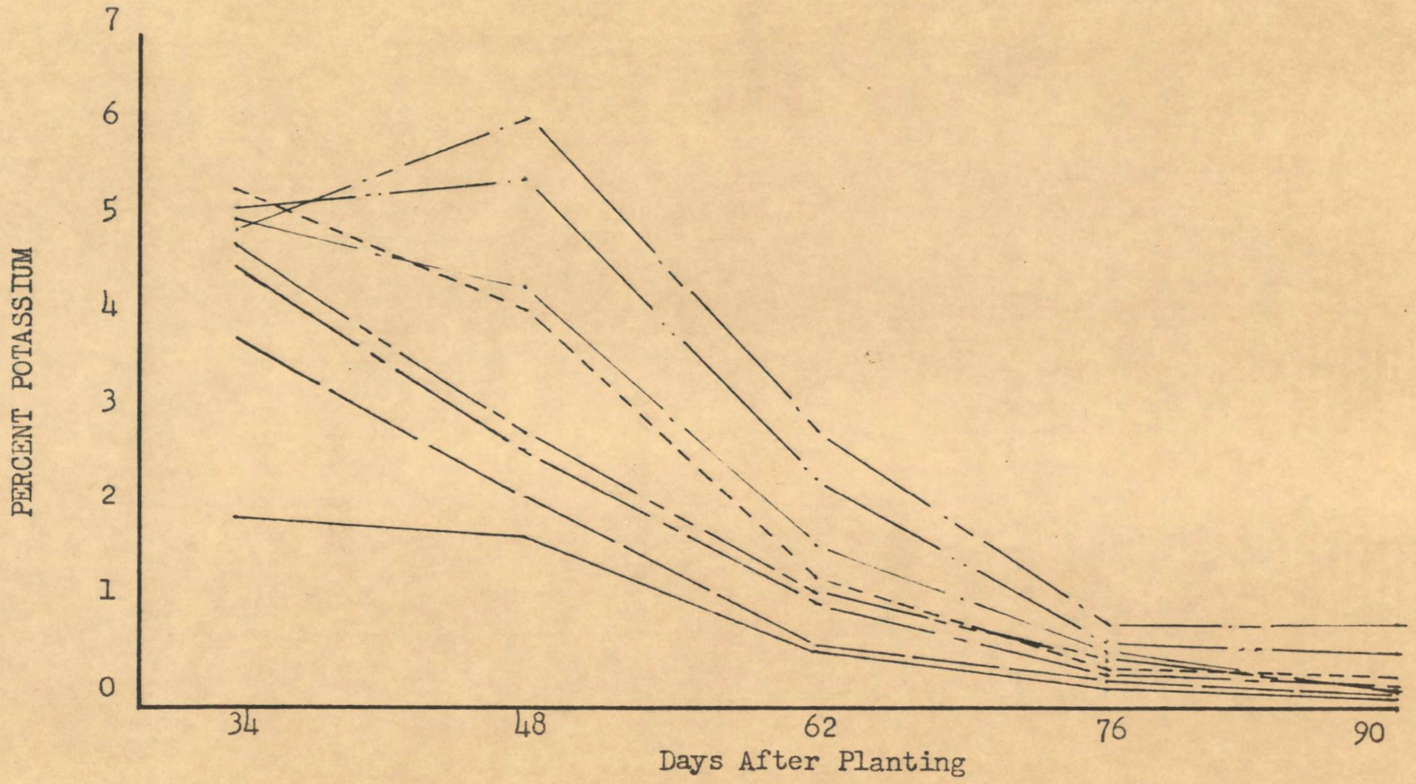


Figure 4. PERCENT POTASSIUM CONTENT IN CORN STALKS AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE LOW NITROGEN LEVEL

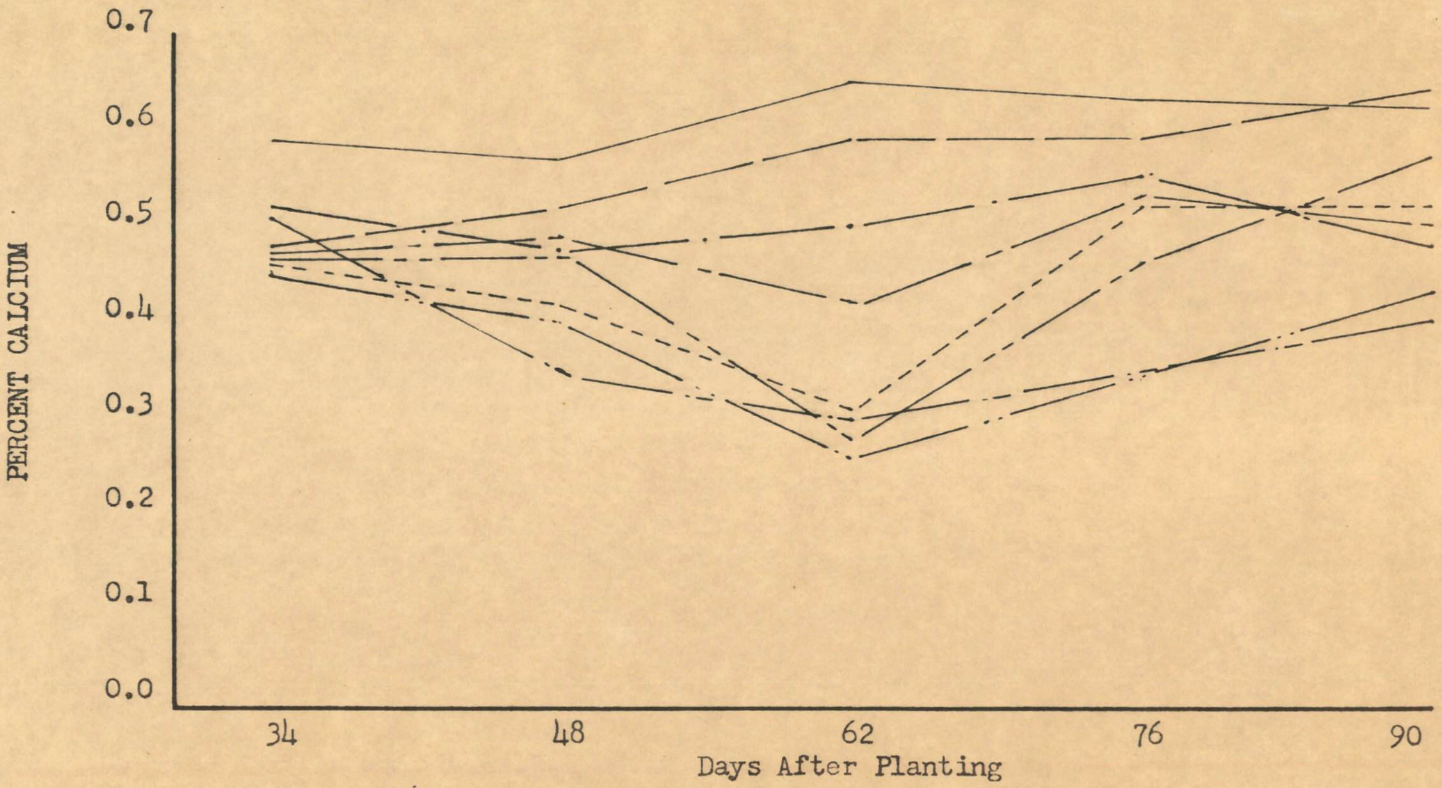


Figure 5. PERCENT CALCIUM CONTENT IN CORN LEAVES AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE HIGH NITROGEN LEVEL

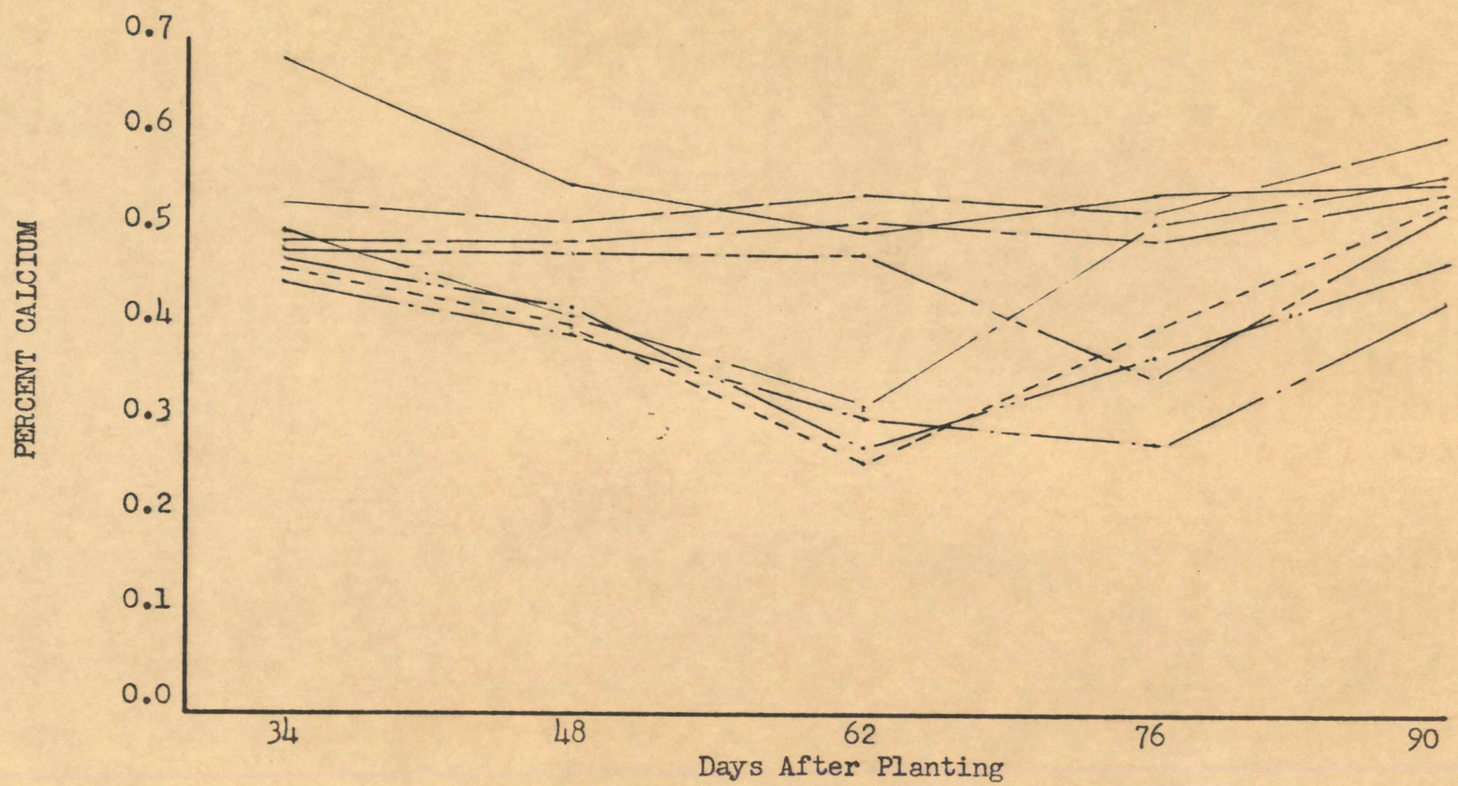


Figure 6. PERCENT CALCIUM CONTENT IN CORN LEAVES AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE LOW NITROGEN LEVEL

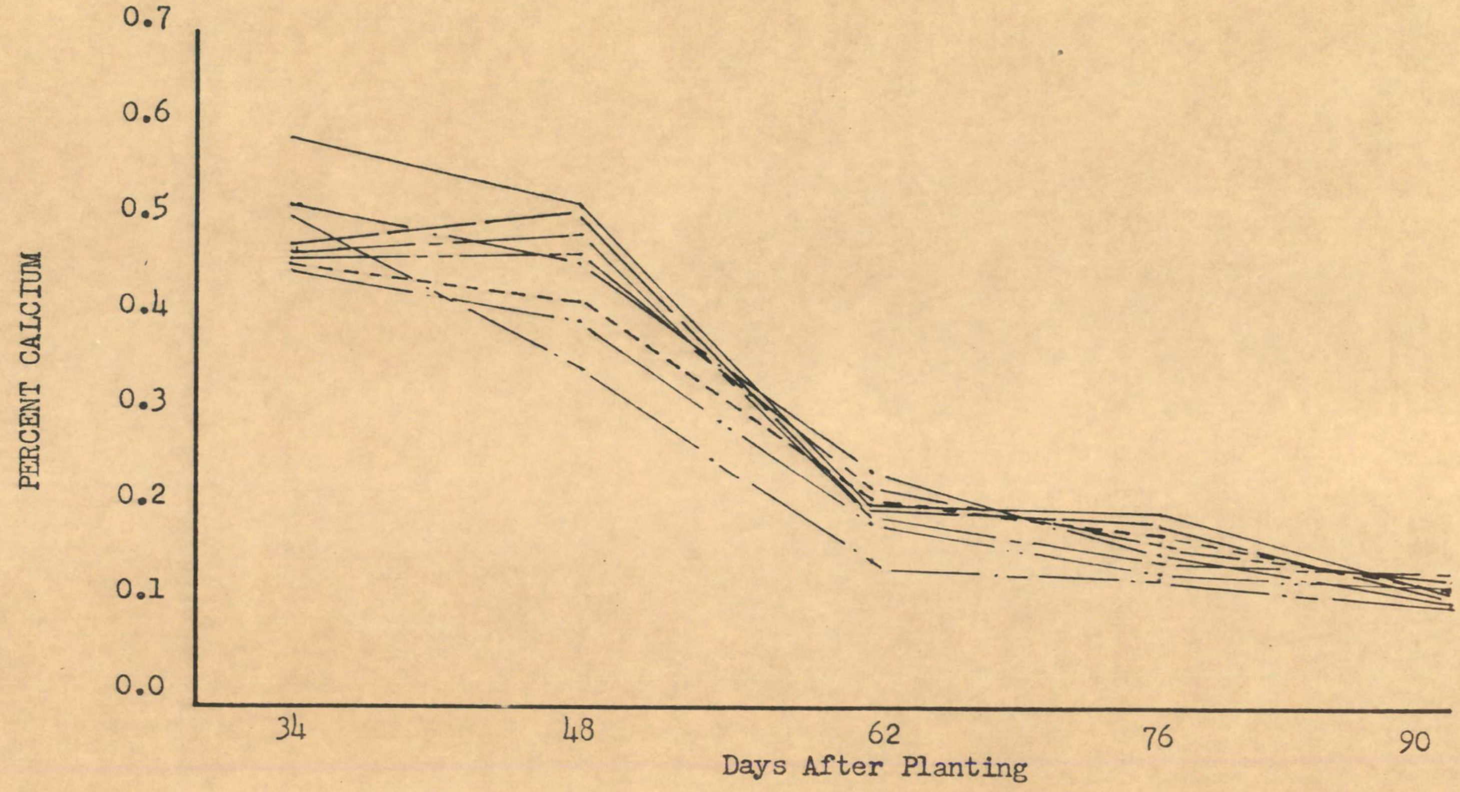


Figure 7. PERCENT CALCIUM CONTENT IN CORN STALKS AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE HIGH NITROGEN LEVEL

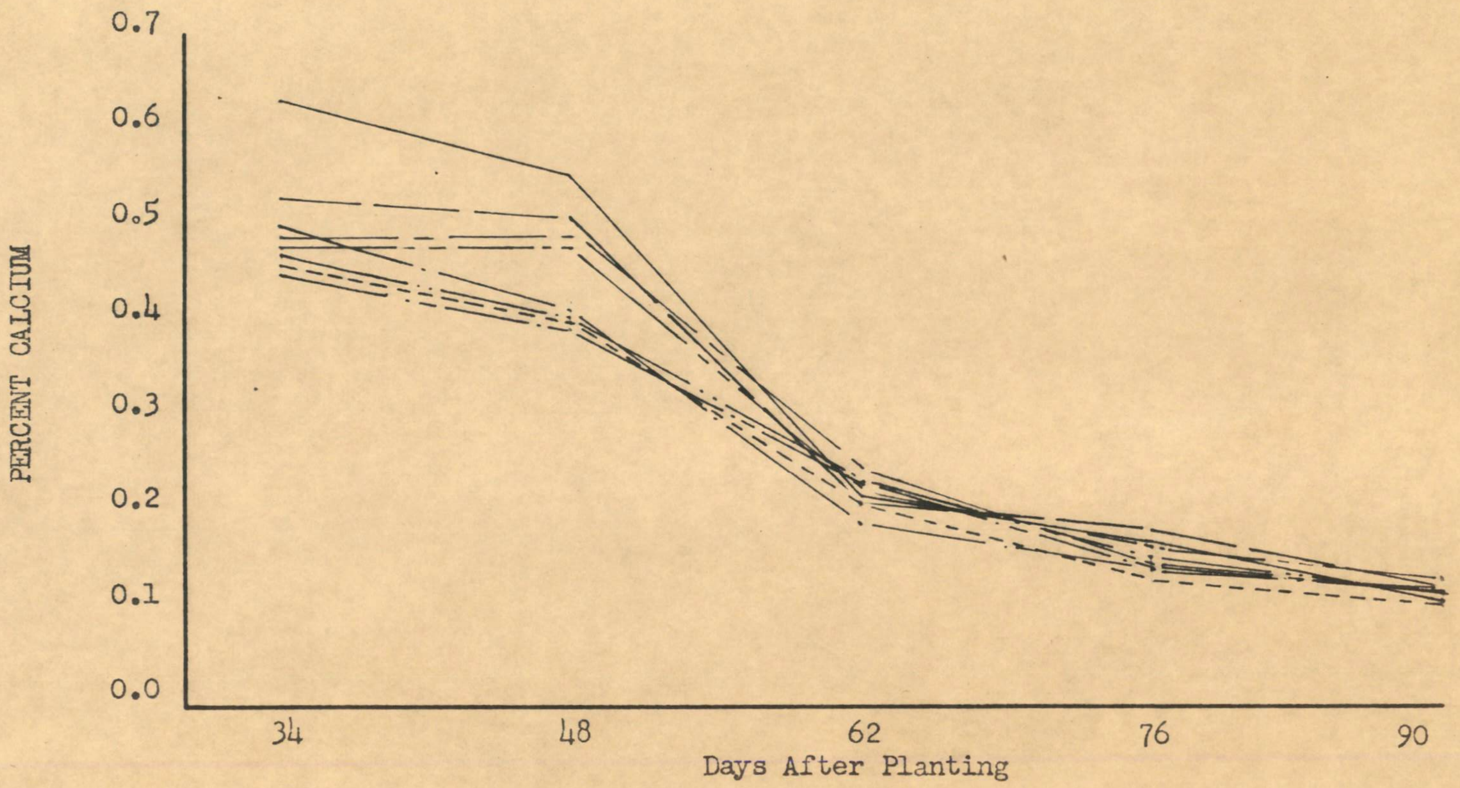


Figure 8. PERCENT CALCIUM CONTENT IN CORN STALKS AT DIFFERENT SAMPLING DATES AS AFFECTED BY DIFFERENT POTASH APPLICATIONS AT THE LOW NITROGEN LEVEL

The calcium content of the leaves (Figures 5 and 6) was considerably higher than in the stalks at both nitrogen levels and increased as the potash application decreased. Also the calcium content of the leaves varied considerably at the different nitrogen levels. At the high nitrogen level the calcium content varied from 0.25 per cent in the potash-treated plots to 0.65 per cent calcium in the check plots, whereas these same plots at the lower nitrogen level range from 0.27 per cent to 0.50 per cent calcium.

Towards the latter part of the growing season the potassium content of both leaves and stalks (Figures 1-4) at both nitrogen levels seemed to approach a constant level regardless of potash treatment. The potassium content of the leaves varied from 1.2 per cent in the check plots to 2.1 per cent in the plots receiving the highest potash application. The potassium content of the stalks was considerably lower than the leaves and varied as in the plots mentioned above from 0.1 per cent to 0.9 per cent potassium.

The calcium content of the crop (Figures 5-8) in the latter stages of growth in both leaves and stalks was approximately the same at both nitrogen levels. The stalks, regardless of the potash application, contained about 0.15 per cent calcium. The leaves, although considerably higher in calcium content, varied inversely in calcium content with the potash application. Calcium content of the check plots was approximately 0.65 per cent, whereas the calcium content of the plots receiving the highest potash application was 0.4 per cent.

Total mineral content throughout the growing season at both nitrogen levels followed the same pattern as potassium alone. Table VIII represents the summation of total cation content of the crop throughout the growing season. The inverse calcium or potassium relationship again is shown since the cation content tended to be lower at high potassium contents and higher at low potassium contents when compared with respective potash levels.

The potassium content of the crop was approximately the same at similar rates of potash application regardless of the method of application.

## DISCUSSION

### Stalk Breakage

Although many investigators (27, 15) have found positive correlations between potassium and stalk breakage in cereal crops, other investigators (4, 19) report little correlation.

The potassium-nitrogen relationship in the plant (19) seems to be a major factor involved in determining the strength of stalk, if the inherent morphological structure of the plant tends to be weak. The single cross corn, used in this experiment is believed to have an inherently weak structure. Potassium fertilization at the high nitrogen level seems to have overcome this defect somewhat as shown by the comparison of the percentage of stalk breakage between the treated and check plots.

At the low level of nitrogen sufficient potassium was present in the check plots, because there is little difference in percentage of broken stalks.

The data in Table III indicate that potassium in some manner is related to stalk breakage. Potash application above 40 pounds per acre at the high nitrogen level has no beneficial effect in further reducing stalk breakage.

Individual cell wall structure which is essentially the basic factor determining stalk strength is influenced markedly by the potassium-nitrogen-carbohydrate ratio. The cell walls consist of carbohydrate compounds predominantly. If the potassium supply is below the critical level needed for the physiological functions of the plant, complex carbohydrates will not accumulate in the cell walls. With an ample supply of potassium these carbohydrates may accumulate and form thick cell walls.

The nitrogen factor becomes increasingly important when the available potassium supply is abundant. Carbohydrates will not be utilized in this manner at high nitrogen levels.

Stalk breakage would probably be more influenced by other factors, such as variety and seasonal conditions, when the supply of potassium and nitrogen is plentiful.

Carbohydrate synthesis is influenced greatly when sufficient potassium is present. Nitrogen, in the nitrate form in the plant, aids in directing the utilization of carbohydrates. It is believed (19) that the accumulation of carbohydrates in the cell walls is associated with stalk strength. Therefore, it is suggested that the potassium-nitrogen-carbohydrate relationship in the plant is one of the major factors influencing stalk breakage.

In this experiment the check plots at the high nitrogen level exhibited the largest amount of stalk breakage. The limited supply of potassium in the plots containing a high rate of nitrogen may have affected the potassium-nitrogen-carbohydrate ratio to the extent of materially decreasing the strength of the stalk. The abundant supply of nitrogen resulted in more of the carbohydrate material going into the growing portions of the plant and less being synthesized into cell walls. In those plots receiving over 40 pounds potash the potassium-nitrogen-carbohydrate equilibrium may have been more balanced as indicated by a much smaller percentage of broken stalks.

## Yield

The yield data, as summarized in Table IV, indicate that the higher nitrogen level had no appreciable effect in increasing yields. This may be accounted for by the non-uniformity of the experimental field and the retarded growth of the deep placement plots. Comparing the first five treatments in Table IV one may note a slight increase in yield due to the larger nitrogen application. Statistical analysis indicates that crop response was not materially influenced by this element. The yield response at the high nitrogen level might have been greater if the moisture conditions during the growing season had been improved. Apparently the nitrogen supply in the soil plus the nitrogen application constituting the lower level were sufficient for adequate growth and appropriate yield. During the growing season "firing" occurred at both nitrogen levels; however, it was noticeable much earlier at the lower level. Toward the latter part of the growing season considerable difference in the degree of "firing" between nitrogen levels was shown.

Yield response was greatest at the high nitrogen level where 40 pounds of potash per acre had been applied. Twenty pounds of potash per acre gave the highest yield increase at the low nitrogen level. Potash application above these levels had no significant effect upon yield.

The nitrogen-potassium relationship (11) may explain the greater utilization of potassium at the higher nitrogen level. Potassium utilization might have been improved if more moisture had been available during the growing season. There was no significant yield difference shown between any potash treatment when similar treatments at both nitrogen levels were averaged. Probably sufficient potassium became available during the growing season or potassium was not utilized to the fullest extent. The majority of potash-treated plots showed some increase in yield over the check plots. The F test indicated that this general response to potash bordered on significance.

The statistical analysis also revealed a significant response to the mutual effect of potassium and nitrogen but yields were only slightly increased as indicated in Table V.

## Mineral Content

Throughout the growing season the potassium and calcium content of the corn crop varied inversely at the respective potash treatments. It is generally believed that potassium and calcium are negatively correlated (5, 18). This investigation indicated similar results for larger applications of potash resulted in a decrease in the calcium content. The potassium content of the plants in the check plots was approximately 2 per cent and calcium 0.6 per cent, whereas in plots receiving large applications of potash the potassium content of the plants was about 5 per cent and calcium 0.5 per cent. Apparently a rather large potassium increase is needed to bring about a small decrease in calcium as reported by Stanford et al. (23).

Potassium content of the plant at the first two samplings and the leaves at later samplings were practically the same at both nitrogen levels at the respective potash treatments. During the same periods the potassium content of the corn plants varied somewhat between nitrogen levels in the check plots in the first two samplings. In the remaining samplings the potassium content of the leaves obtained from the check plots was similar at both nitrogen levels. The percentages of potassium in the stalks were correspondingly alike throughout the growing season in all treatments and at both nitrogen levels.

The potassium curves in Figures 1-4 indicate that potash treatment at the same rate of application produced similar potassium contents in plants at both nitrogen levels. The larger application of nitrogen did not materially aid the utilization of potassium agreeing with the results of the statistical analysis which indicated that the yield response to the larger nitrogen application was not significant.

The calcium contents of the stalks at both nitrogen levels were similar throughout the growing season. The calcium contents of the leaves varied considerably throughout the growing season at the two nitrogen levels. Since calcium is relatively immobile in the plant the potassium-nitrogen relationship probably affected the absorption of this element.

Forty eight days after seeding the maximum potassium content per unit dry weight was obtained. At this stage of growth the corn plants had developed extensive root systems enabling the plants to absorb considerable quantities of this element. The percentage potassium increase above the check plots (Figures 1-4) ranges from 0.5 per cent to 4 per cent potassium or a maximum increase of 200 per cent. Luxury consumption of potassium (1) at this stage evidently had occurred.

It is believed (1) that potassium can be accumulated in rather large quantities, translocated, and reutilized. Translocation of potassium is evident because in mid-season there was a marked decrease in potassium, especially in the stalks. The intensive growth of the crop at this time probably exerted a "dilution effect," but the marked decrease of potassium in the plants growing on the potash-treated plots as compared to plants in the check plots indicates translocation. Field observations at this stage of growth indicated no appreciable difference in the size of stalk between plants in the potash-treated plots and the check plots. Meristematic tissues usually contains a constant potassium content (6) and potassium probably was transported to these regions.

Some investigators (6, 14) have suggested that the potassium content of plants may be decreased as the plant approaches maturity by the potassium moving back into the root system or potassium leaching from the leaves. It seems doubtful if these two processes could account for the reduced percent potassium found in this study.

A potassium-nitrogen-calcium relationship is indicated (Figures 1-8) for the side dressing of potash caused a marked decrease in calcium content at the high nitrogen level, whereas the same application had no apparent effect at the time upon calcium at the lower nitrogen level. This result probably was caused by the different rate of potassium utilization by the plants at the different nitrogen levels.

The potassium content of both leaves and stalks at both nitrogen levels approached a constant level towards the latter part of the growing season. As noted in Figures 1-4 the potassium content of both leaves and stalks at both nitrogen levels is somewhat higher when potash had been applied as compared with the check treatment. Goodall and Gregory (9) list potassium contents of the lower stem of corn plants during late summer as inadequate for normal growth when the per cent potassium is less than 0.083 and ample when the per cent potassium is more than 0.166. In this investigation the corn plants in the potash-treated plots showed potassium contents well above corn plants in the check plots until the latter part of the growing season. At this time field observations indicate that potassium deficiencies were prevalent in corn plants growing in the check plots at both nitrogen levels. Figures 3 and 4 show the potassium content of the lower stems to be approximately 0.10 per cent at both nitrogen levels, which agrees with the conclusions listed above.

In the three instances where 80 pounds of potash were applied by different methods it seems that applying all at planting is as efficient as a split application. Applying 40 pounds of potash at planting and

40 pounds in deep placement was just as efficient as 80 pounds at planting and slightly more efficient than 40 pounds at planting and 40 pounds as a side dressing.

The data indicate no apparent relationship between the potassium content of the plants from the different potash applications and the yields obtained. An application of 40 pounds of potash at the high nitrogen level gave the highest yield. The data concerning percentage composition shows much higher potassium contents throughout the growing season because of greater rates of potash application. Even though no increase in yield was obtained beyond the 40-pound potash application at the high nitrogen level, the potassium content of the plants can be increased materially by increasing the available potassium supply to the plants by potash fertilization.

Stalk breakage at the low nitrogen level was similar in all plots regardless of the potash treatment indicating that sufficient potash was available in the soil without added potassium fertilization to keep stalk breakage at a minimum. The potassium content of the plants on the check plots was the same (Figures 1-4) at both nitrogen levels but stalk breakage was three times as great at the high nitrogen level. The 40-pound potash application at the high nitrogen level decreased the number of broken stalks, whereas further increments of potash increased the potassium content of the plant but was not more effective in decreasing stalk breakage.

When stalk breakage was noticeable in the high nitrogen level plots the potassium content of the stalks in the check and 40 pound per acre potash treated plots was 0.21 per cent and 0.25 per cent potassium respectively. The critical content in the upper leaves at this same period of growth was 1.7 per cent potassium. Throughout the entire growing season plants fertilized with the 40-pound potash application contained 0.3 to 1 per cent more potassium than plants in the check treatment.

Since the 40-pound application of potash at the high nitrogen level produced the highest yield, was as effective as any other treatment in decreasing stalk breakage, and field observations indicated no appreciable difference in plant growth, it is suggested that applications of potash above this level do not materially benefit the crop under the conditions of this experiment.

SUMMARY

The single-cross T13 x T61 was grown with eight different potash treatments at two nitrogen levels. Grain yields, per cent stalk breakage, and the potassium and calcium content of the corn plots was determined--the latter periodically throughout the growth period. The following results were obtained:

1. The potassium content of the plant was directly related to the amount of potash applied.

2. The maximum potassium content of the plant was observed 48 days after planting. The potassium content decreased percentage-wise during the later stages of growth.

3. The potassium content of the plants at each potash treatment was approximately the same at the two nitrogen levels.

4. The 40-pound potash per acre application at the high nitrogen level and 20-pound potash per acre application at the low nitrogen level were the only potash treatments to yield significantly more than the check treatments at their respective nitrogen levels.

5. One hundred twenty pounds of nitrogen per acre did not result in a significantly greater yield than 60 pounds of nitrogen per acre.

6. At the low nitrogen level none of the potash treatments were effective in reducing the amount of stalk breakage while at the high nitrogen level an application of 40 pounds of potash or more per acre resulted in decreased stalk breakage.

Applications greater than 40 pounds of potash per acre were no more effective than the 40-pound treatment.

7. A general reciprocal relationship was found between the potassium content and the calcium content of the plants. The calcium content was greatest in the check plots and least in the heavily potash fertilized plots.

8. When comparing the three methods of potash application at the same rate, no method was superior to the other in affecting yield, lodging, or plant composition.

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# A P P E N D I X

Figure 9. Close-up of a Typical Corn Stalk Broken During the Growing Season

Figure 10. Stalk Breakage During the Growing Season in the Plots Not Fertilized with Potash at the High Nitrogen Level

Figure 11. Serious Stalk Breakage at Harvest Time in the Plots Not Fertilized with Potash at the High Nitrogen Levels

Figure 12. **Relatively few Broken Stalks at Harvest Time in the Potash-treated Plots**