SEED GERMINATION AS AFFECTED BY FERTILIZER APPLICATIONS

by

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INTRODUCTION

In the past few years there has been a sharp increase in the production and use of chemical fertilizers in the field of agriculture. This has taken place because of increased technology in the fertilizer industry and the increased need for the addition of plant nutrients to the soil to obtain maximum yields of crops.

With the increased use of chemical fertilizers the proper placement of these fertilizers has become an important factor in obtaining maximum effectiveness of the fertilizers used.

This investigation was a study of one type of fertilizer placement and its effect upon the germination of seed.

REVIEW OF LITERATURE

Ayers (1) states that an appreciation of soil moisture stress is necessary for adequate evaluation of the effects of soil moisture and soil salinity upon the germination of seeds. For a seed to obtain water from the soil, two main groups of forces must be overcome: (1) the surface force action of the soil particles which accounts for the moisture retentive properties of the soil and which is usually referred to as soil moisture tension; and (2) the osmotic force action which is due to the dissolved materials in the soil solution. Investigations at the Salinity Laboratory (7, 8) have shown a high correlation between the sum of these two forces, soil moisture stress, and the growth of a number of plants. Soil moisture stress is a measure of the "availability of soil water," and it logically follows that the factors which affect it should also affect the germination of seed.

Shive (5) investigated the effect of different salt concentrations on seed germination. These salt concentrations reduced the amount of water that could be absorbed by the seed. This in turn retarded its germination. He stated that germination may not necessarily be prevented by high salt concentrations, but it may be retarded. This retardation is directly related to the reduction in the amount of water absorbed by the seed, which in turn is dependent upon the concentration of the soil solution.

Ewart (3) reported that if wheat and superphosphate were placed together in dry soil, germination was affected. The germination was even more seriously affected where there was a small amount of free moisture present in the soil at the time of planting and a drying period followed. When the superphosphate was placed one to three inches below the seed and rapid germination took place, the fertilizer instead of injuring the seed or seedling increased the growth and the yield.

Investigations by Olson and Dreier (4) in both the field and in the constant temperature laboratory suggest that it is a low moisture level at which the most serious damage of fertilizer salts to germination occurs, but full germination is not assured at any soil moisture level without a surface increment to leach fertilizer salts away from the seed. In general, nitrogen materials are more detrimental per unit weight than potassium materials, and the latter more than phosphate. Experimental data showed that damage to germination under critical soil moisture is apparent at 10 pounds of nitrogen per acre, increasing to the point of stand elimination with 160 pounds of nitrogen per acre. It was also shown that fertilizer and seed need not be in immediate contact for germination inhibition, as evidenced by appreciable migration of nitrogen and phosphate to the

imbibing seed.

In an experiment conducted at Kansas State College in 1955 and '56 by Smika and Smith (6) the effects of fertilizer on germination of seed were studied under both greenhouse and controlled humidity conditions.

In the greenhouse investigations three germination media were used: soil from the Agronomy Farm, Soil from Ashland Agronomy Farm, and washed fine sand. The fertilizer was applied at rates varying from 20 to 80 pounds per acre.

In the controlled humidity study the soil from the Agronomy Farm, with various moisture contents, was used. The fertilizer was applied at rates varying from 10 to 40 pounds per acre.

The greenhouse trials indicated that irrespective of the germinating media or the way the treatments were applied there generally was a delay in the date of both the initial germination and the final date on which maximum germination was achieved.

Biuret, which may be present in commercial pelleted urea, caused marked damage to the germination of wheat. Damage increased as the percentage of biuret in urea increased.

The trials under controlled humidity indicated that the amount of soil moisture present had an effect on the germination of wheat seeds when fertilizer was present. Damage increased as the soil moisture decreased.

In an experiment conducted in 1950 on two highly calcareous clay soils in Texas, Collier (2) reported that ammonium nitrate (33.5 per cent N), when applied with the seed at the rates of 0, 100, 200 and 300 pounds per acre, reduced both the stand and yield of corn.

Muriate of Potash (60 per cent K_2O) applied at the rate of 0 and 100 pounds per acre reduced the stand only slightly on one soil and did not

reduce yields significantly on either soil type.

Superphosphate (20 per cent P_2O_5) applications of 0, 150, and 300 pounds per acre had practically no effect on the plant population and caused small but significant increases in yield on only one soil type.

The results of this experiment were compared with the results of a fertilizer-spacing experiment in which the fertilizer was applied three months before the planting of the seeds. In comparing the data, Collier concluded that only a small portion of the reduction in yield resulting from fertilizer applications with the seed may be attributed to the reduction in plant population. The major portion of the yield reduction is the result of retarded emergence and the reduced seedling and plant vigor caused by excessive concentrations of salts from the fertilizer materials.

MATERIALS AND METHODS

Description of Soil Used

The soil for this experiment was obtained from the Agronomy Farm of Kansas State College located at Manhattan, Kansas. It can best be described as an alluvial soil with a light silty clay loam profile. The slope upon which this soil lies is from one to two per cent and it is well drained. Determinations of the moisture equivalent value and the wilting coefficient were made. The results of these and other determinations are tabulated in Table 7 in the Appendix.

Experimental Procedure

Germination trials with wheat were conducted in small porcelain pans which were approximately four inches deep and between seven and eight inches

in diameter. The seeds were planted in a circle which had a diameter of five inches and a circumference of 15.7 inches. Assuming the use of a grain drill with a space of seven inches between rows, this length (15.7 inches) was equivalent to 0.0000174 acres. A planting rate of approximately five pecks per acre was used. It was calculated that between 20 and 25 seeds would be needed for each individual pan. Twenty-five was the number used. This allowed for easy computation.

Two fertilizers, ammonium nitrate (33.5-0-0), and muriate of potash (0-0-60), were applied at five different rates, 20, 40, 60, 80, and 100 pounds per acre of actual nutrient element constituent (N or K_2O). Control cultures to which fertilizer was not added were included for each trial. Thus, the equivalent of six treatments was employed.

The equivalent of 750 grams of oven dry soil were placed in each pan. This soil had previously been brought to the desired moisture level. In a furrow about 3/4 inch deep and five inches in diameter, the seeds (Ponca wheat which had a germination of 95 per cent) and the appropriate amount of fertilizer were placed. These were covered with soil and a slight amount of firming was accomplished to insure intimate contact between the seed and moist soil. Duplicate trials of a given portion of the experiment were conducted simultaneously.

After the planting operation, the pans were placed into a germination chamber. This was a sheet metal box, three feet wide, four feet long, and one foot deep. A false bottom in this box allowed for the retention of a layer of water below the pans. This maintained the relative humidity near the saturation point. Thus evaporation of soil moisture was largely prevented. This germination chamber was kept in a constant temperature room at a temperature of $26\pm1^{\circ}$ C.

Seed germination was allowed to progress until no more seedlings emerged. Later these values were plotted so as to portray rate of emergence.

The germination chamber held 24 pans. This permitted inclusion of one complete set (two replications) of each fertilizer substance.

Six trials were conducted during the course of the investigations. These were done with moisture percentages of 30, 25, 20, 17, 12 and 10 and were started on May 15, February 21, April 10, March 10, June 18 and August 9, 1958, respectively.

Relative germination for each treatment for each day was calculated as a percentage of the control. These were converted to arc $\sin\sqrt{\text{percentage}}$. Analyses of variance were made on these values. Variations among treatments were detected by use of the values for least significant difference.

RESULTS AND DISCUSSION

Trial I.

This trial was conducted with both muriate of potash and ammonium nitrate treatments. The soil contained 30 per cent moisture which corresponded very closely to the moisture equivalent value of this soil.

The muriate of potash treatments caused very slight differences in Ponca wheat germination. Only on the third day after planting were these differences significant. All treatments (20, 40, 60, 80, and 100 pounds per acre of K_2O) were significantly lower than the check and applications of 80 and 100 pounds per acre produced germination significantly lower than did applications of 20 and 40 pounds per acre (Table 1, Plate I, Appendix).

The ammonium nitrate treatments had somewhat greater effect upon germination than did the muriate of potash treatments of comparable application rates. The ammonium nitrate treatments not only delayed germination longer than did the muriate of potash treatments but also caused a greater reduction in the final germination percentage.

Treatment six (100 pounds per acre N) reflected significantly less germination than the control from the third through the eighth day after planting, then this difference disappeared. Treatments five and six did not differ significantly. Treatment five (80 pounds N per acre) had significantly less germination than the control from the third through the fifth days. The application of 80 pounds of nitrogen per acre also caused less germination than did the applications of 20, 40, or 60 pounds per acre on the fourth and fifth days after germination. Treatment three and four (40 and 60 pounds of N per acre, respectively) had significantly less germination than either the check or treatment 2 (20 pounds of N per acre) for the third and fourth days after planting.

The satistical analyses for both the ammonium nitrate and muriate of potash treatments revealed significant variations among treatments at the .01 level. Likewise, the variation between days were significant at the same level. There was no indication of a significant interaction between days and treatments (Table 1, Plate II, Appendix).

Trial II.

Trial number two like trial number one was conducted using both muriate of potash and ammonium nitrate treatments. A soil moisture content of 25 per cent was used.

The three heaviest rates of application of muriate of potash (100 pounds, 80 pounds, and 60 pounds per acre of K_2O) resulted in significantly less germination of wheat than occurred with control cultures and either treatments two or three (20 or 40 pounds per acre of K_2O). Use of 100 pounds of K_2O did not produce significantly less germination than did use of 80 pounds. It (100 pounds per acre) reduced germination significantly more than 60 pounds of K_2O only on the fifth day. The reduction in germination caused by 80 pounds of K_2O was significantly greater than that caused by 60 pounds for the fifth and sixth days after planting. Applications of 40 pounds of K_2O per acre reduced germination significantly below that which occurred in the control cultures and in those to which 20 pounds of K_2O had been added only on the fifth day after planting. Treatment two (20 pounds of K_2O) did not have a significant influence on germination when compared to the control (Table 2, Plate III, Appendix).

The two heaviest rates of application of ammonium nitrate (80 and 100 pounds of N) caused significant losses in germination in all cases when compared to the check. One hundred pounds of nitrogen reduced germination more than 80 pounds for the first 13 days after planting. Similarly application of 80 pounds of nitrogen reduced germination more than 60 pounds of nitrogen through the first twelve days of germination. The same level of added nitrogen (80 pounds per acre) reduced germination more than either 20 or 40 pounds of nitrogen during the first 14 days of experimentation. The effect of 60 pounds of nitrogen was greater than that of lower rates of nitrogen until the eighth day, the effect of 40 pounds of nitrogen was greater than that of lower rates up to and including the sixth day. However, use of 20 pounds of nitrogen had no effect at any time.

According to the analysis of variance, the effects of treatments, days and the interaction of these two each produced significant effects at the .01 level (Table 2, Plate IV, Appendix).

Trial III.

The soil used in this investigation contained 20 per cent moisture. Again both muriate of potash and ammonium nitrate were used as the fertiliser treatments.

Applications of 60, 80 or 100 pounds of K_2O reduced germination significantly at all times when compared to the check. Use of 100 pounds of K_2O reduced germination between the seventh and ninth days when compared to 80 pounds, but thereafter this effect did not prevail. This heavy treatment also had significantly less germination than either 20 or 40 pounds of K_2O up to and including the 12th day but after that the difference was insignificant. Application of 80 pounds of potash resulted in lower germination of wheat than did use of 60 pounds up to the 14th day and when compared to the lower rates it resulted in significantly less germination throughout the period. Sixty pounds of K_2O lowered germination significantly when compared to 40 pounds per acre only through the tenth day. The application of 40 pounds decreased germination more than did the use of 20 pounds of K_2O for the fourth and fifth days only and it reduced germination below the check until the eighth day. Germination on the treatment receiving 20 pounds of K_2O was significantly below the check until the sixth day (Table 3, Plate V, Appendix).

Every rate of applied nitrogen except the lowest (20 pounds per acre of N) resulted in significantly less germination than the control. Various rates of application resulted in significantly less germination than certain

lower rates. One-hundred pounds of nitrogen reduced germination more than 20, 40, or 60 pounds did and in the final analysis (last three days of trial) it resulted in less germination than occurred with 80 pounds. Applications of 80 pounds per acre of nitrogen reduced germination more than applications of 20, 40, or 60 pounds per acre. Treatment number four (60 pounds per acre of N) produced germination that were significantly lower than treatment three (40 pounds of N per acre) until the 18th day and lower than those of treatment two (20 pounds per acre of N) throughout the period. Applications of 40 pounds per acre resulted in significantly lower germination of wheat than did applications of 20 pounds per acre through the period. Twenty pounds per acre caused a significant reduction in germination when compared to the check only until the eighth day.

In the analysis of variance it was found that the effect of treatments, days and the interaction of these two each produced significant effects at the .01 level (Table 3, Plate VI, Appendix).

Trial IV.

The moisture level of the soil for this trial was 17 per cent. The fertilizers that were applied were muriate of potash and ammonium nitrate.

One-hundred pounds of K_2O (supplied by muriate of potash) caused significant reductions in germination when compared to each treatment through the first twelve days, and was significantly lower than the check for thirteen days. Eighty pounds of K_2O was never significantly more harmful than 60 pounds but it caused greater delays in germination than any of the other treatments (0, 20 or 40 pounds per acre of K_2O) for the first eleven days. Applications of 60 pounds of K_2O resulted in significantly lower germinations

than did applications of 0 or 20 pounds for the first ten days. It was significantly lower than 40 pounds per acre only until the eighth day. Forty pounds of K_2O per acre caused significantly less germination of wheat than did 0 or 20 pounds per acre only on the sixth day. The 20 pound application rate never reduced germination significantly (Table 4, Plate VII, Appendix).

The germination obtained by the application of 80 and 100 pounds of nitrogen per acre (from ammonium nitrate) was significantly lower than that obtained from any other treatment although there was never a significant difference between the two. Application of 60 pounds of nitrogen per acre resulted in a significant decline in germination when compared to all lower applications until the 14th day. Forty pounds per acre of nitrogen produced germinations significantly lower than did 0 or 20 pounds per acre until the eighth day. Applications of 20 pounds of nitrogen per acre reduced germination significantly when compared to the check only until the sixth day.

Analysis of variance showed that the effect of treatments, days, and the interaction of treatments times dates each produced significant effects at the .01 level of significance (Table 4, Plate VIII, Appendix).

Trial V.

Soil for this investigation contained 12 per cent moisture which corresponds closely to the permanent wilting point. Again treatments of both muriate of potash and ammonium nitrate were used.

Treatments 4, 5, and 6 (60, 80 and 100 pounds of K_2O per acre) reduced germination more than did all lower rates of application but the differences in germination among those three treatments were not significant. Application

of 40 pounds of K_2O per acre resulted in germinations significantly lower than those produced by the check and lower than those of the 20 pound application until the 19th day. Twenty pounds of K_2O per acre resulted in germination of Ponca wheat that was significantly lower than the check for 11 days (Table 5, Plate IX, Appendix).

Each level of applied nitrogen caused significant reductions in germination. The use of 80 or more pounds prevented all germination. Applications of 40 and 60 pounds of nitrogen per acre reduced germination of wheat significantly when compared to the check and application of 20 pounds per acre; however they did not vary significantly from each other.

According to the analysis of variance, the effect of treatments, days, and the interaction of these two each produced highly significant effects (Table 5, Plate X, Appendix).

Trial VI.

Soil for this investigation had a moisture content of 10 per cent. Muriate of potash and ammonium nitrate were the fertilizers that were used.

From the trials in which muriate of potash was used all levels of application reduced the germination significantly below that obtained in the check. Treatments three, four, five, and six (40, 60, 80, and 100 pounds of K_2O per acre) did not vary significantly from each other but did result in significantly lower germination than did the application of 20 pounds per acre (Table 6, Plate XI, Appendix).

With ammonium nitrate treatments the application of 40, 60, 80 and 100 pounds per acre of nitrogen prevented any germination of wheat. Applications of 20 pounds of nitrogen per acre resulted in a significant reduction

in germination when compared to the check.

From the analysis of variance the effect of the treatments and days were highly significant and the interaction of treatments times days was significant (Table 6, Plate XII, Appendix).

SUMMARY AND CONCLUSIONS

Controlled humidity studies were conducted to determine the effects of ammonium nitrate and muriate of potash upon germination when placed in contact with Ponca wheat seed.

Six such controlled humidity studies were conducted in a closed container which had water standing in the bottom under a wire screen on which the pans containing the soil, treatments, and seed were placed. Fertilizer applications were based on a row width of seven inches and rates of application ranging from 20 to 100 pounds of nitrogen (N) and potash (K_2O) per acre. An unfertilized culture was used as a control. Soil from the Agronomy Farm, with various moisture contents, was used as the germination media. Both the seed and the fertilizer treatments were placed in one furrow in direct contact with each other.

The following conclusions were drawn from this study.

1. The soil moisture percentage, from just below the permanent wilting point to the moisture equivalent, had only a slight effect upon the germination of Ponca wheat seed when fertilizer was not used.

2. Fertilizer salts placed with the seed at planting time in soil that is at or near field capacity have little effect upon final germination. There will be some delay in seedling emergence, however. The heavier rates of application will cause the greatest delays.

3. If fertilizers are placed in direct contact with the seed and the soil moisture is at or near the permanent wilting point the germination will be reduced greatly or even prevented by heavy applications of fertilizer.

4. Ammonium nitrate when used at rates which supply amounts of nitrogen (N) directly comparable to amounts of potash (K_2O) furnished by muriate of potash will cause greater delays in germination and greater final losses than will the latter fertilizer material.

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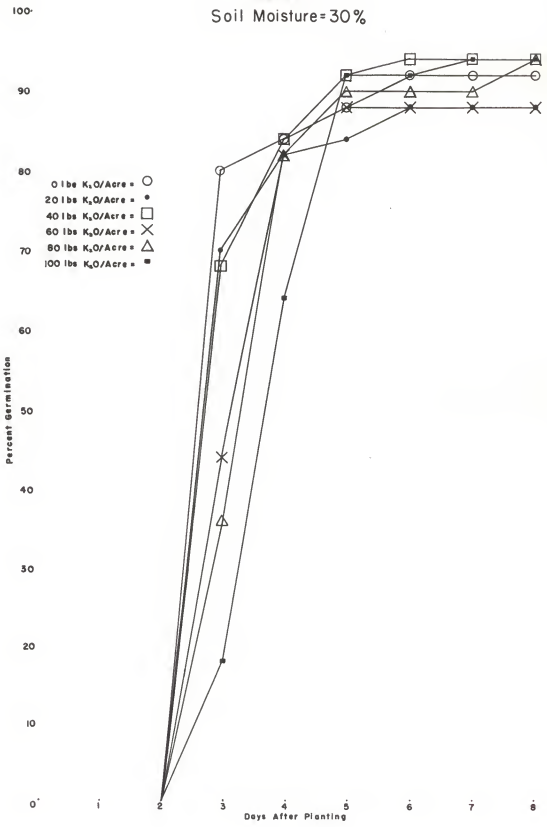
Appreciation is also expressed to persons other than those on the Agronomy Staff who aided in the preparation of this thesis.

APPENDIX

EXPLANATION OF PLATE I

The effect of various rates of potash on the germination of Ponca wheat seed planted on May 15, 1958 in soil with 30 per cent moisture.

PLATE I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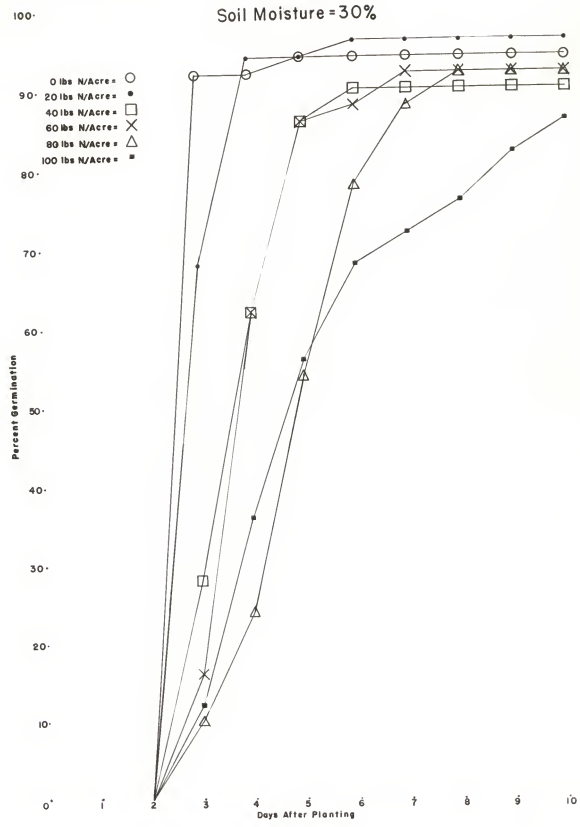
20 lbs K_2O/Acre =
40 lbs K_2O/Acre =
60 lbs K_2O/Acre =
80 lbs K_2O/Acre =
100 lbs K_2O/Acre =
Percent Germination
Days After Planting
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8

EXPLANATION OF PLATE II

The effect of various rates of nitrogen on the germination of Ponca wheat seed planted on May 15, 1958 in soil with 30 per cent moisture.

PLATE II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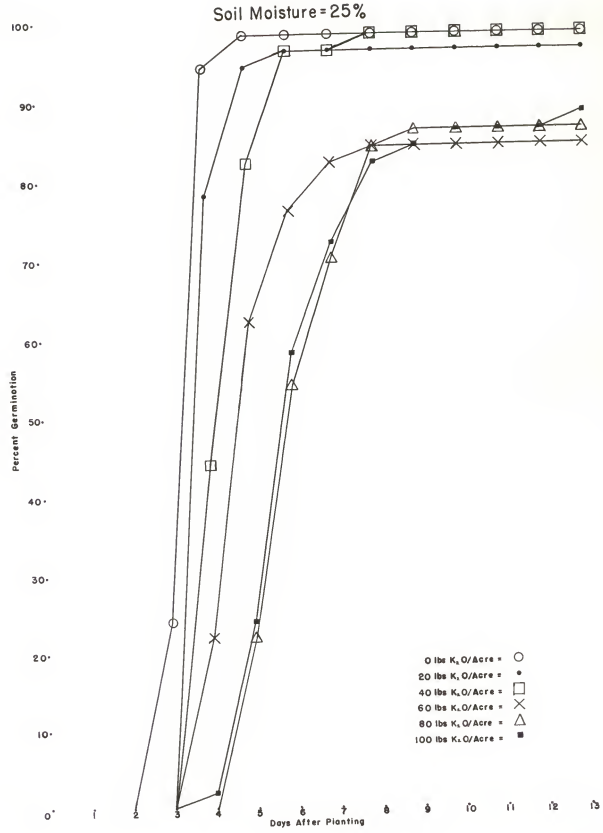
0 lbs N/Acre =
20 lbs N/Acre =
40 lbs N/Acre =
60 lbs N/Acre =
80 lbs N/Acre =
100 lbs N/Acre =
Percent Germination
Days After Planting
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10

EXPLANATION OF PLATE III

The effect of various rates of potash on the germination of Ponca wheat seed planted on February 21, 1958 in soil with 25 per cent moisture.

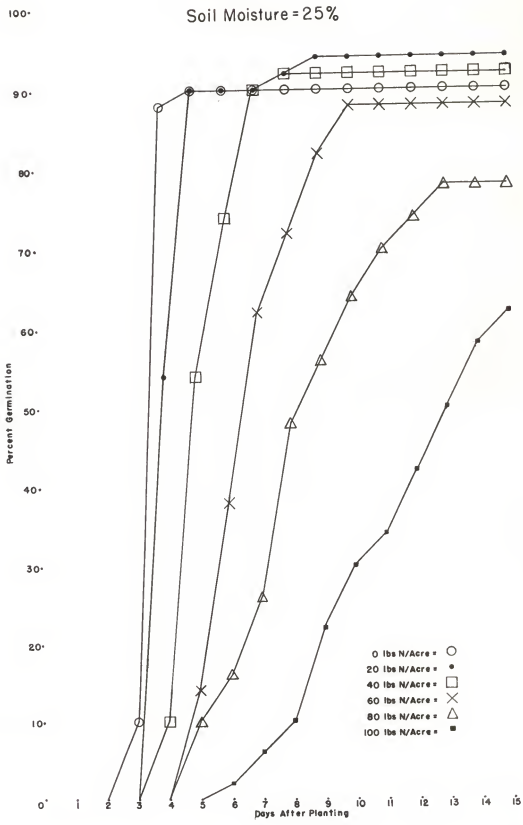
PLATE III


Soil Moisture = 25%
Percent Germination
Days After Planting
0 lbs K₂O/Acre =
20 lbs K₂O/Acre =
40 lbs K₂O/Acre =
60 lbs K₂O/Acre =
80 lbs K₂O/Acre =
100 lbs K₂O/Acre =

EXPLANATION OF PLATE IV

The effect of various rates of nitrogen on the germination of Ponca wheat seed planted on February 21, 1958 in soil with 25 per cent moisture.

PLATE IV

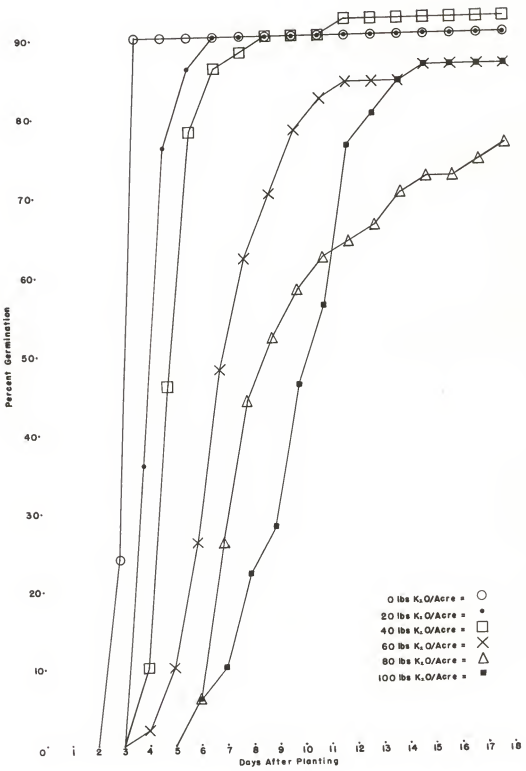

Soil Moisture = 25%
Percent Germination
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Days After Planting
0 lbs N/Acre
20 lbs N/Acre
40 lbs N/Acre
60 lbs N/Acre
80 lbs N/Acre
100 lbs N/Acre

EXPLANATION OF PLATE V

The effect of various rates of potash on the germination of Ponca wheat seed planted on April 10, 1958 in soil with 20 per cent moisture.

PLATE V

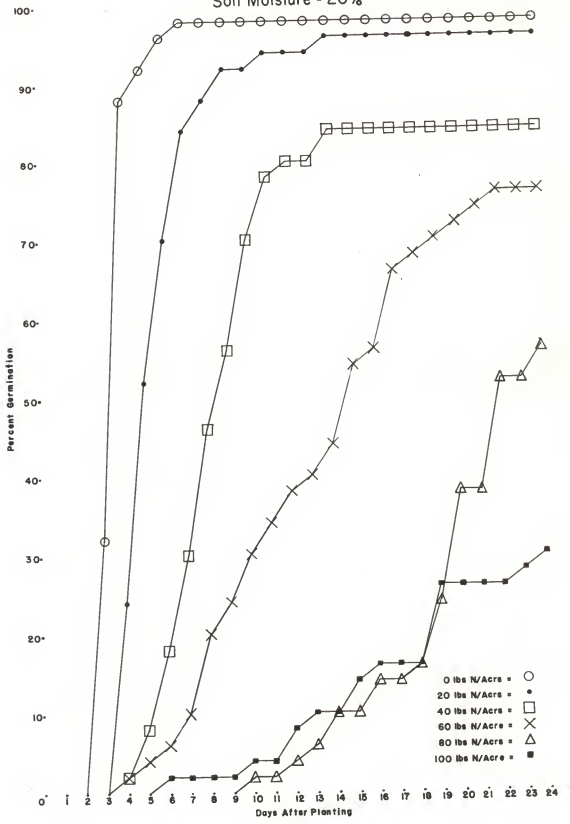
Soil Moisture = 20%



EXPLANATION OF PLATE VI

The effect of various rates of nitrogen on the germination of Ponca wheat seed planted on April 10, 1958 in soil with 20 per cent moisture.

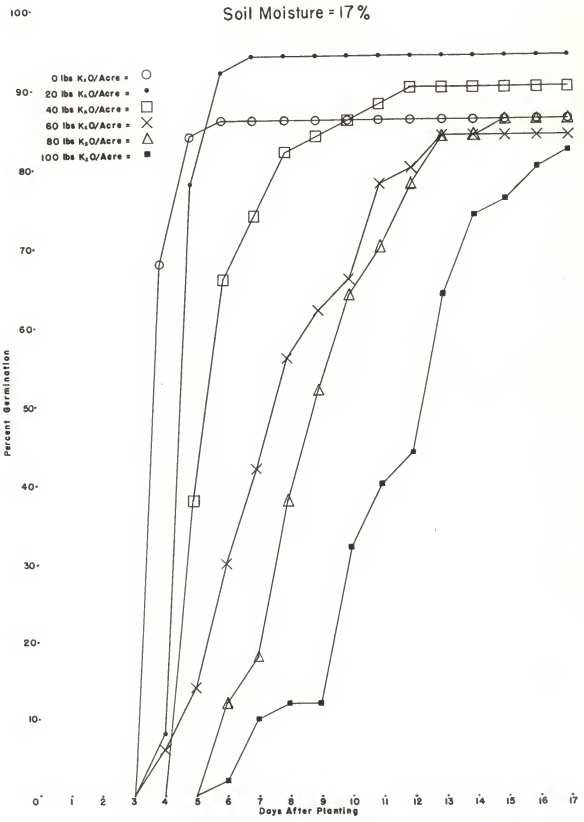
PLATE VI


Soil Moisture = 20%
Percent Germination
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Days After Planting
0 lbs N/Acre
20 lbs N/Acre
40 lbs N/Acre
60 lbs N/Acre
80 lbs N/Acre
100 lbs N/Acre

EXPLANATION OF PLATE VII

The effect of various rates of potash on the germination of Ponca wheat seed planted on March 10, 1958 in soil with 17 per cent moisture.

PLATE VII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40 lbs K₂O/Acre =
60 lbs K₂O/Acre =
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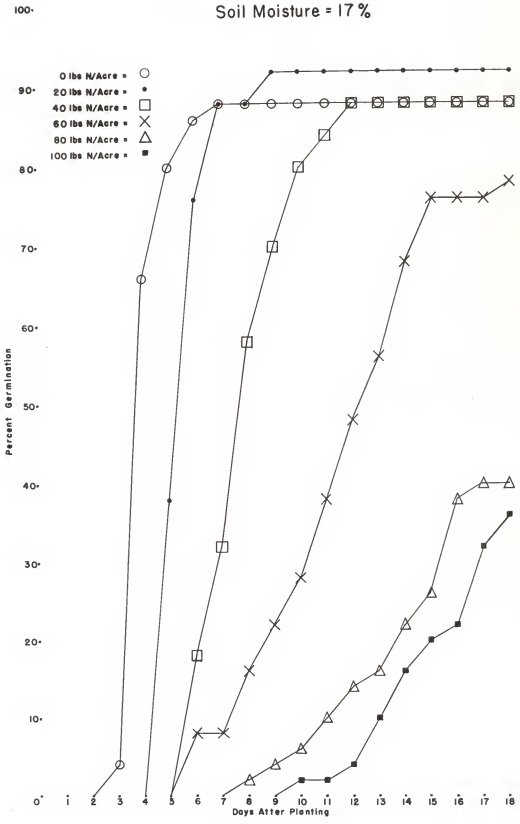
100 lbs K₂O/Acre =
Percent Germination
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Days After Planting

EXPLANATION OF PLATE VIII

The effect of various rates of nitrogen on the germination of Ponca wheat seed planted on March 10, 1958 in soil with 17 per cent moisture.

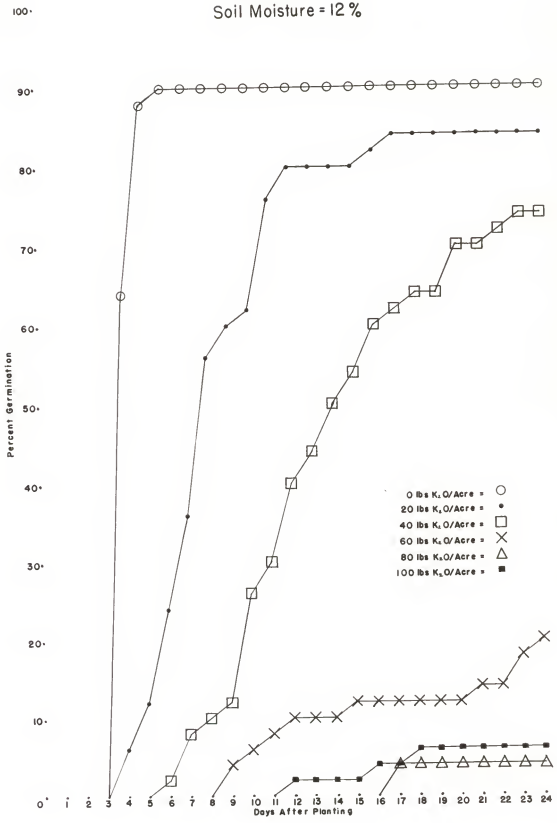
PLATE VIII


Soil Moisture = 17 %
0 lbs N/Acre =
20 lbs N/Acre =
40 lbs N/Acre =
60 lbs N/Acre =
80 lbs N/Acre =
100 lbs N/Acre =
Percent Germination
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Days After Planting

EXPLANATION OF PLATE IX

The effect of various rates of potash on the germination of Ponca wheat seed planted on June 18, 1958 in soil with 12 per cent moisture.

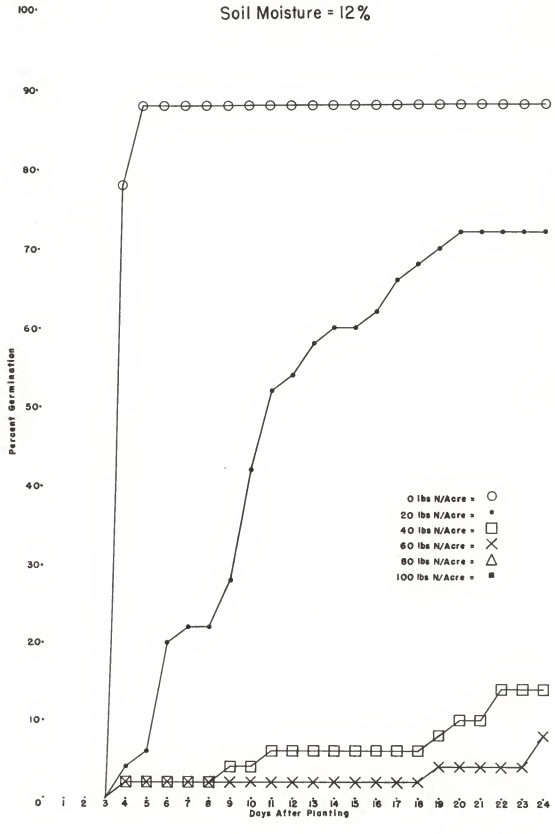
PLATE IX


Soil Moisture = 12 %
Percent Germination
Days After Planting
0 lbs K₂O/Acre =
20 lbs K₂O/Acre =
40 lbs K₂O/Acre =
60 lbs K₂O/Acre =
80 lbs K₂O/Acre =
100 lbs K₂O/Acre =

EXPLANATION OF PLATE X

The effect of various rates of nitrogen on the germination of Ponca wheat seed planted on June 18, 1958 in soil with 12 per cent moisture.

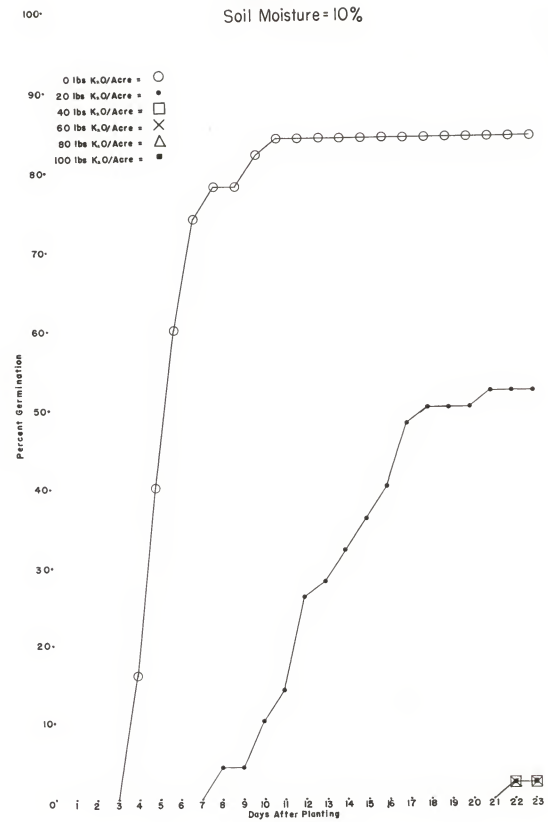
PLATE X


Soil Moisture = 12%
Percent Germination
Days After Planting
0 lbs N/Acre =
20 lbs N/Acre =
40 lbs N/Acre =
60 lbs N/Acre =
80 lbs N/Acre =
100 lbs N/Acre =

EXPLANATION OF PLATE XI

The effect of various rates of potash on the germination of Ponca wheat seed planted on August 9, 1958 in soil with 10 per cent moisture.

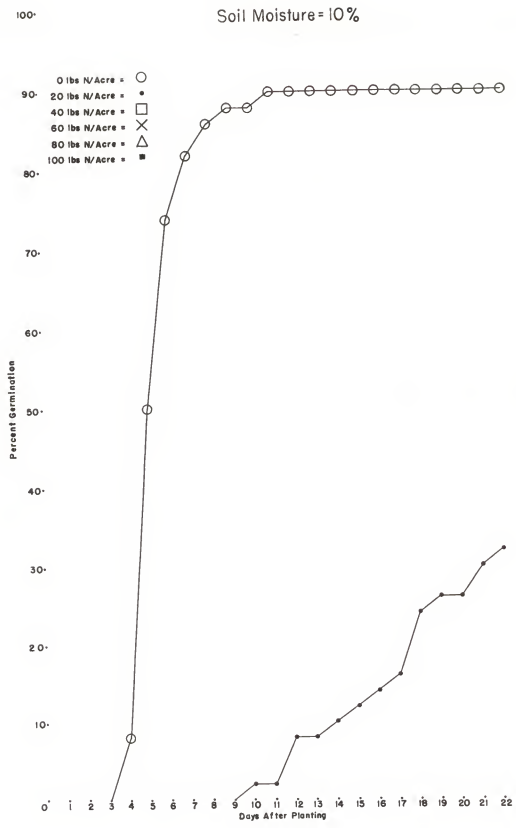
PLATE XI


Soil Moisture = 10%
0 lbs K₂O/Acre =
20 lbs K₂O/Acre =
40 lbs K₂O/Acre =
60 lbs K₂O/Acre =
80 lbs K₂O/Acre =
100 lbs K₂O/Acre =
Percent Germination
Days After Planting
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

EXPLANATION OF PLATE XII

The effect of various rates of nitrogen on the germination of Ponca wheat seed planted on August 9, 1958 in soil with 10 per cent moisture.

PLATE XII


Soil Moisture = 10%
0 lbs N/Acre =
20 lbs N/Acre =
40 lbs N/Acre =
60 lbs N/Acre =
80 lbs N/Acre =
100 lbs N/Acre =
Percent Germination
Days After Planting
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
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13
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15
16
17
18
19
20
21
22

Table 1. The arc sine transformation of the germination expressed as per cent of check for soil containing 30 per cent moisture.

Treatments	Date							
	5-18	5-19	5-20	5-21	5-22	5-23	5-24	5-25
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	62.89	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-3	26.44	58.72	76.71	80.27	80.27	80.27	80.27	80.27
N-4	18.79	57.97	78.02	83.02	83.28	83.28	83.28	83.28
N-5	13.68	29.96	50.68	75.35	77.92	83.98	83.98	83.98
N-6	15.94	38.03	53.02	60.12	62.64	66.30	70.62	74.22
K-2	64.49	79.18	74.58	76.02	76.02	76.02	76.02	76.02
K-3	62.89	81.22	84.76	86.99	86.99	86.99	86.99	86.99
K-4	44.18	79.18	79.53	76.56	76.56	76.56	76.56	76.56
K-5	38.30	75.02	84.76	80.27	80.27	86.99	86.99	86.99
K-6	16.84	59.30	90.00	83.98	86.99	86.99	86.99	86.99
	L. S. D. = 22.65							

L. S. D. = Least significant difference
N = Ammonium nitrate treatments
K = Muriate of potash treatments
2 = 20 pounds per acre N or K_2O
3 = 40 pounds per acre N or K_2O
4 = 60 pounds per acre N or K_2O
5 = 80 pounds per acre N or K_2O
6 = 100 pounds per acre N or K_2O

Table 2. The arc sine transformation of the germination expressed as per cent of check for soil containing 25 per cent moisture.

Treatments	Date					
	2-26	2-27	2-28	3-1	3-2	3-3
Check	90.00	90.00	90.00	90.00	90.00	90.00
N-2	78.51	78.51	78.51	82.68	82.68	82.68
N-3	49.32	62.58	78.51	81.67	81.67	81.67
N-4	22.22	39.36	54.38	62.00	71.37	78.64
N-5	18.96	24.22	31.58	45.64	50.90	57.08
N-6	0.0	5.98	10.48	18.16	28.91	34.38
K-2	85.84	90.00	90.00	90.00	90.00	90.00
K-3	69.14	85.84	85.84	90.00	90.00	90.00
K-4	54.31	64.18	69.14	71.32	71.32	71.32
K-5	28.91	49.28	59.84	72.88	74.48	74.48
K-6	30.29	51.77	61.16	69.72	71.32	73.18

Table 2 (Concl.)

Treatments	Date					
	3-4	3-5	3-6	3-7	3-8	3-9
Check	90.00	90.00	90.00	90.00	90.00	90.00
N-2	82.68	82.68	82.68	82.68	82.68	82.68
N-3	81.67	81.67	81.67	81.67	81.67	81.67
N-4	78.64	78.64	78.64	78.64	78.64	78.64
N-5	60.76	63.30	66.04	66.04	67.54	67.54
N-6	36.95	41.93	46.85	51.94	54.86	54.86
K-2	90.00	90.00	90.00	90.00	90.00	90.00
K-3	90.00	90.00	90.00	90.00	90.00	90.00
K-4	71.32	71.32	71.32	71.32	71.32	71.32
K-5	74.48	74.48	74.48	74.48	74.48	74.48
K-6	73.18	73.18	73.18	73.18	73.18	73.18
	L. S. D. = 15.40					

L. S. D. = Least significant difference
N = Ammonium nitrate treatments
K = Muriate of potash treatments
2 = 20 pounds per acre N or K_2O
3 = 40 pounds per acre N or K_2O
4 = 60 pounds per acre N or K_2O
5 = 80 pounds per acre N or K_2O
6 = 100 pounds per acre N or K_2O

Table 3. The arc sine transformation of the germination expressed as per cent of check for soil containing 20 per cent moisture.

Treatments	Date					
	4-13	4-14	4-15	4-16	4-17	4-18
Check	90.00	90.00	90.00	90.00	90.00	90.00
N-2	0.0	30.98	49.18	60.73	74.12	77.00
N-3	0.0	6.21	16.70	26.07	34.28	44.39
N-4	0.0	6.21	12.11	14.51	18.90	27.92
N-5	0.0	0.0	0.0	0.0	0.0	0.0
N-6	0.0	0.0	0.0	5.98	5.98	5.98
K-2	0.0	39.47	66.03	74.20	78.51	78.51
K-3	0.0	19.29	45.34	66.35	74.48	76.34
K-4	0.0	6.21	18.46	31.77	45.60	54.38
K-5	0.0	0.0	0.0	14.51	31.71	43.00
K-6	0.0	0.0	0.0	10.53	18.96	28.72

Table 3 (Cont.)

Treatments	Date							
	4-19	4-20	4-21	4-22	4-23	4-24	4-25	4-26
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	80.50	80.50	82.68	82.68	82.68	85.84	85.84	85.84
N-3	50.35	59.66	65.65	67.29	67.29	71.32	71.32	71.32
N-4	30.01	34.11	36.75	39.36	40.60	43.14	49.65	50.90
N-5	0.0	5.98	5.98	8.48	14.46	18.96	18.96	22.66
N-6	5.98	11.97	11.97	16.95	18.46	18.46	22.22	23.64
K-2	78.51	78.51	78.51	78.51	78.51	78.51	78.51	78.51
K-3	78.51	78.51	78.51	81.67	81.67	81.67	81.67	81.67
K-4	59.81	65.65	69.14	71.00	71.00	71.00	73.18	73.18
K-5	51.94	54.55	55.80	57.04	59.81	59.81	61.12	61.12
K-6	32.54	43.72	50.92	64.18	67.50	71.00	73.18	73.18

Table 3 (Concl.)

Treatments	Date							
	4-27	4-28	4-29	4-30	5-1	5-2	5-3	5-4
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	85.84	85.84	85.84	85.84	85.84	85.84	85.84	85.84
N-3	71.32	71.32	71.32	71.32	71.32	71.32	71.32	71.32
N-4	57.04	58.34	59.66	61.07	62.54	64.01	64.01	64.01
N-5	22.66	24.22	30.29	39.48	39.48	48.04	48.04	50.52
N-6	23.64	23.64	30.85	30.85	30.85	30.85	32.06	33.76
K-2	78.51	78.51	78.51	78.51	78.51	78.51	78.51	78.51
K-3	81.67	81.67	81.67	81.67	81.67	81.67	81.67	81.67
K-4	73.18	73.18	73.18	73.18	73.18	73.18	73.18	73.18
K-5	62.54	62.54	62.54	62.54	62.54	62.54	62.54	62.54
K-6	73.18	73.18	73.18	73.18	73.18	73.18	73.18	73.18
	L. S. D. = 12.41							

L. S. D. = Least significant difference
N = Ammonium nitrate treatments
K = Muriate of potash treatments
2 = 20 pounds per acre N or K_2O
3 = 40 pounds per acre N or K_2O
4 = 60 pounds per acre N or K_2O
5 = 80 pounds per acre N or K_2O
6 = 100 pounds per acre N or K_2O

Table 4. The arc sine transformation of the germination expressed as per cent of check for soil containing 17 per cent moisture.

Treatments	Date								
	3-16	3-17	3-18	3-19	3-20	3-21	3-22	3-23	3-24
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	72.04	84.68	84.68	90.00	90.00	90.00	90.00	90.00	90.00
N-3	27.20	37.35	54.86	70.32	77.75	81.78	90.00	90.00	90.00
N-4	12.78	12.70	24.68	29.98	34.36	41.28	48.00	53.41	62.69
N-5	0.0	0.0	6.20	8.83	10.90	18.90	23.16	25.24	30.18
N-6	0.0	0.0	0.0	0.0	6.20	6.20	12.39	18.90	23.48
K-2	85.64	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
K-3	61.20	67.87	79.60	69.60	81.78	81.78	84.68	84.68	84.68
K-4	35.92	44.02	53.41	57.62	60.62	71.39	73.57	79.37	79.37
K-5	21.97	27.93	41.34	50.76	59.93	66.37	76.08	81.78	81.78
K-6	6.26	14.33	15.84	15.84	37.00	42.66	45.35	59.08	67.36

Table A (Concl.)

Treatments	Date								
	3-25	3-26	3-27	3-28	3-29	3-30	3-31	4-1	4-2
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-3	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-4	74.54	74.54	74.54	74.54	74.54	79.60	79.60	79.60	79.60
N-5	33.13	41.28	42.67	42.67	45.36	45.36	46.71	49.56	49.56
N-6	26.22	27.55	34.28	37.28	38.94	38.94	42.98	42.98	42.98
K-2	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
K-3	84.68	84.68	84.68	84.68	84.68	84.68	84.68	84.68	84.68
K-4	79.37	79.37	79.37	79.37	79.37	79.37	79.37	79.37	79.37
K-5	84.68	84.68	84.68	84.68	84.68	84.68	84.68	84.68	84.68
K-6	69.21	74.29	76.47	76.47	76.47	76.47	76.47	76.47	76.47
	L. S. D. = 23.03								

L. S. D. = Least significant difference
N = Ammonium nitrate treatments
K = Muriate of potash treatments
2 = 20 pounds per acre N or K_2O
3 = 40 pounds per acre N or K_2O
4 = 60 pounds per acre N or K_2O
5 = 80 pounds per acre N or K_2O
6 = 100 pounds per acre N or K_2O

Table 5. The arc sine transformation of the germination expressed as per cent of check for soil containing 12 per cent moisture.

Treatments	Date						
	6-22	6-23	6-24	6-25	6-26	6-27	6-28
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	9.82	10.82	28.20	29.82	29.82	34.09	43.36
N-3	6.84	6.12	6.12	6.12	6.12	12.25	14.86
N-4	6.84	6.12	6.12	6.12	6.12	6.12	6.12
N-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-2	12.14	20.35	30.54	39.28	52.80	56.10	58.06
K-3	0.0	0.0	6.12	16.90	18.68	21.28	32.31
K-4	0.0	0.0	0.0	0.0	0.0	8.73	14.86
K-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5 (Cont.)

Treatments	Date						
	6-29	6-30	7-1	7-2	7-3	7-4	7-5
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	49.92	51.32	54.09	55.66	55.66	57.39	61.78
N-3	14.86	14.86	14.86	14.86	14.86	14.86	14.86
N-4	6.12	6.12	6.12	6.12	6.12	6.12	6.12
N-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-2	70.98	74.03	74.03	74.03	74.03	75.46	78.77
K-3	35.20	41.90	44.66	48.76	51.80	56.44	58.06
K-4	16.90	19.51	19.51	19.51	21.28	21.28	21.28
K-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-6	0.0	6.21	6.21	6.21	6.21	12.25	12.25

Table 5 (Concl.)

Treatments	Date						
	7-6	7-7	7-8	7-9	7-10	7-11	7-12
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	63.08	64.40	65.74	65.74	65.74	65.74	65.74
N-3	14.86	16.90	18.68	18.68	21.78	21.78	21.78
N-4	6.12	8.73	8.73	8.73	8.73	8.73	12.55
N-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-2	78.77	78.77	78.77	78.77	78.77	78.77	78.77
K-3	60.48	60.48	64.69	64.69	65.74	67.15	67.15
K-4	21.28	21.28	21.28	22.89	22.89	26.44	28.20
K-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-6	14.86	14.86	14.86	14.86	14.86	14.86	14.86
	L. S. D. = 17.58						

L. S. D. = Least significant difference
N = Ammonium nitrate treatments
K = Muriate of potash treatments
2 = 20 pounds per acre N or K_2O
3 = 40 pounds per acre N or K_2O
4 = 60 pounds per acre N or K_2O
5 = 80 pounds per acre N or K_2O
6 = 100 pounds per acre N or K_2O

Table 6. The arc sine transformation of the germination expressed as per cent of check for soil containing 10 per cent moisture.

Treatments	Date							
	8-17	8-18	8-19	8-20	8-21	8-22	8-23	8-24
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	0.0	0.0	6.26	6.20	12.70	12.70	18.89	20.52
N-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-2	9.12	9.02	19.96	23.60	33.00	34.36	37.00	39.66
K-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6 (Concl.)

Treatments	Date							
	8-25	8-26	8-27	8-28	8-29	8-30	8-31	9-1
Check	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
N-2	22.04	24.68	30.18	31.50	31.50	34.15	35.52	35.52
N-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-2	42.42	48.37	50.04	50.04	50.04	51.89	51.89	51.89
K-3	0.0	0.0	0.0	0.0	0.0	0.0	6.20	6.20
K-4	0.0	0.0	0.0	0.0	0.0	0.0	6.20	6.20
K-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K-6	0.0	0.0	0.0	0.0	0.0	0.0	6.20	6.20
	L. S. D. = 15.01							

L. S. D. = Least significant difference
N = Ammonium nitrate treatments
K = Muriate of potash treatments
2 = 20 pounds per acre N or K_2O
3 = 40 pounds per acre N or K_2O
4 = 60 pounds per acre N or K_2O
5 = 80 pounds per acre N or K_2O
6 = 100 pounds per acre N or K_2O

Table 7. Some physical and chemical characteristics of the soil used in this investigation.

Textural class:	
Sand	7.2%
Silt	68.7%
Clay	24.1%
Moisture equivalent	30.3%
Permanent wilting point	11.9%
Cation exchange capacity	18 me./100 gm.

SEED GERMINATION AS AFFECTED BY FERTILIZER APPLICATIONS

by

John Stillman Chapin

B. S., Texas Technological College, 1957

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1959

In recent years the need for fertiliser in agricultural soils has been realised. Commercial fertilisers of ever increasing concentration are being applied at ever increasing rates. These two factors have necessitated fertiliser placement studies.

This investigation was designed to study the effects of fertiliser on seed germination when both are placed in the same furrow. Fertilisers used for this study were ammonium nitrate (33.5 per cent N) and muriate of potash (60 per cent K_2O). Rates of application were calculated on the length of row used and an assumed row spacing of seven inches. The fertilisers were applied at rates of 20, 40, 60, 80, and 100 pounds per acre of actual plant nutrient constituent (N or K_2O). A check pot to which fertiliser was not added was also included.

Six trials with Ponca Wheat seed were conducted under constant temperature and controlled humidity conditions. These trials were with soil moisture percentages of 30, 25, 20, 17, 12 and 10. The soil was an alluvial soil obtained from the Agronomy Farm. The moisture equivalent and permanent wilting point of this soil corresponded very closely to 30 per cent and 12 per cent, respectively.

The seed were allowed to continue germination until no more was obtained. Emerged seedlings were counted daily.

Results of this study indicate that the harmful effects of fertilisers upon the germination of seed are increased by low moisture contents of the soil. Ammonium nitrate when used at rates which supply amounts of nitrogen (N) directly comparable to amounts of potash (K_2O) supplied by muriate of potash caused greater delays and greater final losses than did the latter fertiliser material.