THE EFFECT OF FOLIAR APPLIED NITROGEN, PHOSPHORUS, AND POTASSIUM ON THE GROWTH AND COMPOSITION OF CORN

DISSERTATION

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THE EFFECT OF FOLIAR APPLIED NITROGEN, PHOSPHORUS, AND POTASSIUM ON THE GROWTH AND COMPOSITION OF CORN

INTRODUCTION

A great deal of work has been done in recent years in applying nitrogen to the foliage of plants with varying degrees of success. Much less has been done with phosphorus, except when used in combination with the other major fertilizer elements. No reports were found in the literature where potassium was applied singly to the foliage of plants. Most of the experiments with foliar sprays were conducted under field conditions and consisted primarily of spraying a solution of the material on the plant with a power sprayer. As a result of this technique, a great deal of the fertilizer eventually reached the soil where it could have been absorbed by the roots. In the final analysis, no definite conclusions could be drawn relative to the absorption efficiency of the leaves versus roots. The objectives of the experiment were: (1) To determine the response of field crop plants to foliar application of nitrogen, phosphorus, and potassium; (2) To compare the effectiveness of foliar applied fertilizer materials with fertilization of the rooting medium; (3) To compare the relative rate of absorption of nitrogen, phosphorus, and potassium and their effect on the composition of the plant when applied to the foliage and rooting medium.

REVIEW OF LITERATURE

The fairly consistent success of using minor elements in foliar sprays has led investigators in recent years to use the same method of application for nitrogen, phosphorus and potassium. Hamilton et al. (6) found that sprays containing urea could be used on the foliage of apple trees without visible injury. They reported that its use increased the nitrogen content of the leaves. Fisher and Cook (5) claimed that McIntosh apples could be produced equally as well with urea sprays as with nitrogen added to the soil. Nitrogen sprays have been used with some degree of success by other investigators (3 and 4).

The investigations on the use of urea sprays for peaches are conflicting. Weinberger et al. (14) reported that there was no significant effect on foliage color, nitrogen content of the leaves, color or time of fruit ripening, or on the terminal growth of the trees from the application of urea sprays. On the other hand Merrill (10) reported highly significant results when urea was used at the rate of 15 pounds per 100 gallons of water.

Most of the work published reports no significant effect of potassium when used as foliar sprays. Monterlaro et al. (10) was unable to increase the yield of tomatoes with urea sprays. Danielson (2) failed to secure yield responses with various concentrations of urea sprays applied to snap beans, radishes and spinach. He also failed to increase the yield of potatoes, tomatoes, snap beans, and

lima beans when they were sprayed at regular intervals with a solution containing a 5-10-5 fertilizer.

Significant increases in vegetable crop yields as a result of applying foliar sprays were reported by Hester (7). He reported that three sprays of urea, which supplied a total of 90 pounds of nitrogen per acre, increased the yield of carrots by 27 per cent. However, with tomatoes Hester found no such response. When he used an 0-10-10 fertilizer with ten spray applications of urea, as compared to a 5-10-10 fertilizer, the yields were approximately the same.

Silberstein and Wittwer (13) used phosphorus sprays on certain vegetable crops and found that the growth of tomato, bean, and corn plants grown at low phosphorus levels increased when foliar treated with phosphorus. Early yields, but not total yields, of field tomatoes were increased significantly by four weekly sprays of a 25-millimolar solution of ortho-phosphoric acid. Silberstein and Wittwer also reported that tracer studies with foliar-applied radioactive ortho-phosphoric acid revealed that phosphorus was rapidly absorbed by leaves of tomato, corn, bean, and squash plants and translocated to the root tips and other centers of high metabolic activity. Mayberry and Wittwer (9) likewise reported responses to foliar applied material. They found that four successive foliage spray applications of a 0.5 per cent solution of urea during fruit development significantly increased the yield of greenhouse tomatoes. With field tomatoes, they found that urea sprays increased the early, but not the total, yield. Mayberry and Wittwer also found that

celery responded favorably to urea foliage sprays. Best results were obtained from foliar applied nitrogen when it was used in combination with soil applied nitrogen.

Brasher et al. (1) over a period of four years applied, singly and in various combinations, foliar sprays containing nitrogen, phosphorus, potassium and many minor elements to tomato, lima beans, cantaloupe, cucumber and potato plants. They concluded that a nutrient spray program on any crop was not economically sound. Some sprays improved foliage color but in no case did a significant increase in yield result from the use of the sprays when a standard soil application of fertilizer was applied prior to planting the crop. They also reported that the only significant yield increases from nutrient sprays occurred when Nu Green and Nutri-Leaf (1-1-1 ratio fertilizer material) were sprayed on tomato plants which grew on unfertilized plots. Eleven applications of Nutri-Leaf increased the yield by 0.58 tons as compared to an increase of 3.2 tons per acre for standard soil applications of fertilizer.

MATERIALS AND METHODS

Corn plants growing in greenhouse soil beds during the spring of 1952 were sprayed with various molar concentrations of urea ($CO(NH_2)_2$), potassium chloride (KCl) and monobasic potassium phosphate (KH_2PO_4), in order to determine the maximum salt concentration which could be applied without injury to the plant. It was ascertained that the maximum concentration appeared to be approximately 0.1 molar for each compound. Therefore, 3 to 5 grams of both urea and potassium chloride and 8 to 10 grams of monobasic potassium phosphate per 1000 milliliters of water, with a commercial wetting agent, were used in the following experiments.

Corn (Zea Mays), C-54 variety, was grown in 3 gallon glazed pots containing washed quartz gravel. An automatic irrigation system, Figure 1, was used. A 5 gallon distilled water bottle was used as a reservoir and 13 liters of culture solution made up for each pot. It required approximately 3.3 liters of solution to flood the gravel.

The solution was forced up into the gravel with low pressure air from a small Crowell-type air pump. When the pump stopped the solution drained back into the reservoir by allowing the air in the solution bottle to be forced back through the pump and the by-pass valves. As the solution drained back into the reservoir, the fresh supply of air which was drawn into the gravel furnished aeration for the root system. The air pressure was adjusted with by-pass valves so that the gravel was flooded in approximately 10 minutes. The cycles of irrigation were five to six times a day.

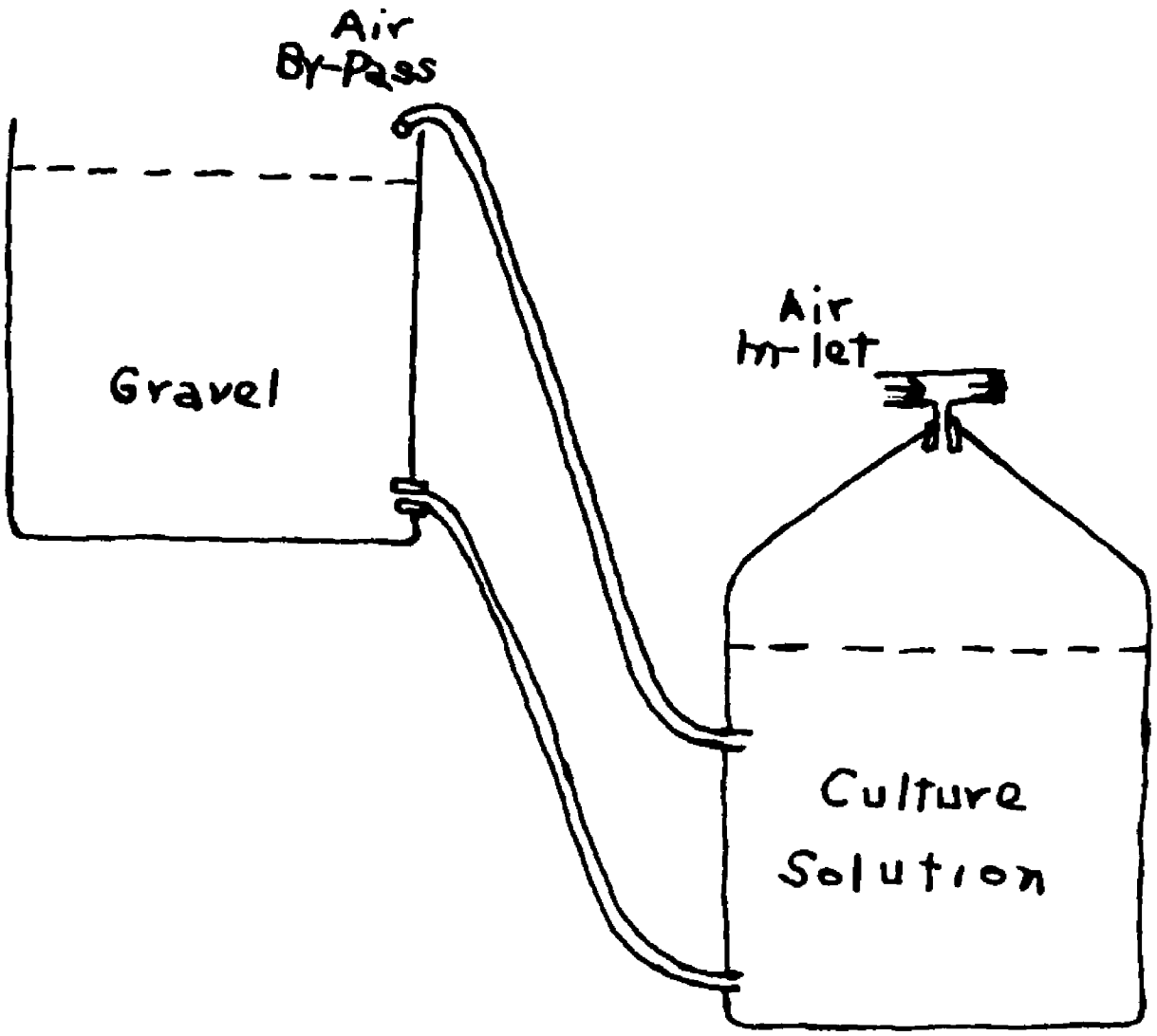

Figure 1. Diagram of system used in experiments employing gravel culture.

The corn in the first experiment was planted in a row of 4 plants. Aluminum foil was placed over the surface of the pot to prevent contamination of the pot while making the spray applications. The aluminum cover was made by cutting a piece of the material of a sufficient size to cover the top and part of the side of the 3 gallon pots. It was then cut into two pieces of equal size and notches were cut in one piece so that it would fit around the base of the stem of the four corn plants. The other piece was then placed against the stem and over a portion of the notched piece that extended out from around the stem of the plants. These pieces were then sealed with paraffin to prevent the fertilizer solution from reaching the rooting medium. The respective fertilizer solutions were applied with a 3 gallon compression sprayer operated at 20 to 25 pounds of pressure. A small hand sprayer was used in those tests that employed soil as the rooting medium when the volume of solution applied was not measured. However, in order to duplicate field conditions, the containers were not covered.

Tests were carried out to compare the growth of corn plants receiving the same volume of fertilizer solution applied to foliage and rooting medium. This was accomplished by delivering the solution from a 1-milliliter pipette into the funnel of the growing tip formed by the leaf blades of the corn plant. This has been suggested as a convenient region for placing the solution and there is evidence to indicate that when thus placed, it is rapidly absorbed and translocated to other portions of the plant (15). Therefore, after ascertaining

the total volume that the funnels of the corn plants of one pot would hold, the same volume was added to the culture solution or soil of another. This procedure was repeated for each replication.

The corn was irrigated with rain water until 7 to 10 days after germination at which time the respective stock solutions were added to provide the desired concentration of the various elements. The compounds and the parts per million of the various elements supplied by each are given in Table 1.

The stock solution of minor elements was prepared with the indicated quantity of the compounds in Table 2. One milliliter of this solution per liter of solution was added to each solution or reservoir bottle. Magnetite was used as a source of iron. A few grams of the powder were sprinkled on the gravel before the corn was planted.

Table 1. Compounds, Elements and Parts Per Million Supplied in Solution.

Compounds	Elements and Parts per Million Supplied					
	K	Ca	Mg	$N(NO_3)$	$N(NH_4)$	P
$Ca(NO_3)_2.4H_2O$		129		90		
[1]$Ca\ Cl_2.2H_2O$		51				
$(NH_4)_2SO_4$					10	
[2]KH_2PO_4	36					30
[3]KCl	64					
$MgSO_4.7H_2O$			55			
Total	100	180	55	90	10	30

[1]Increased to supply 180 ppm Ca when nitrogen is eliminated.

[2]KCl increased, when P is eliminated, to supply 100 ppm K.

[3]$NaH_2PO_4.H_2O$ is substituted for KH_2PO_4 and KCl when K is eliminated.

Table 2. Compounds Used to Prepare Stock Solution of Minor Elements.

Compounds	Grams per Liter
H_3BO_3	1.0
$MnCl_2.4H_2O$	0.5
$ZnSO_4.7H_2O$	0.2
$CuSO_4.5H_2O$	0.07
MnO_3	0.05

DISCUSSION AND RESULTS

Comparison of Growth and Composition of Corn Resulting from Foliar Applied Urea and Urea Applied to Culture Solution

An experiment was conducted to determine if corn would respond, in terms of growth to the foliar application of urea. Four replications of the following treatments were used: Plants of Treatment A received only an initial 5 ppm of nitrogen in the culture solution; Plants of Treatment B received an initial 5 ppm of nitrogen in the culture solution plus a urea solution (5 gms/l) spray applied to foliage; The plants of Treatment C received an initial 100 ppm of nitrogen in the culture solution. All treatments received the optimum amount of the other elements.

The corn was planted in rows of 8 plants per pot on May 20, 1952. The row method of planting was used so that the plants could be covered later with aluminum foil. The corn was up to a good stand by May 26th and thinned to 4 plants per pot. The appropriate culture solutions were added 7 days after emergence.

All pots were covered with aluminum foil before the spray applications were started, in order to prevent contamination. The corn of Treatment B was sprayed for the first time 14 days after emergence and every fourth day thereafter until three applications had been made. Three additional applications were made every other day to make a total of six. The spray applications were made with a 3 gallon compression sprayer operated at 20 to 25 pounds of pressure.

At the time that the spray applications were started, the plants which had initially received 5 ppm of nitrogen in the culture solution (Treatments A and B) were approximately 8 inches in height as compared with an approximate height of 12 inches for those plants that received 100 ppm of nitrogen in the culture solution at the same time. The plants of Treatment A and B were a yellowish-green color while the plants of Treatment C appeared to be healthy and vigorous.

At no time during the course of the test did the corn that initially received 5 ppm of nitrogen in the culture solution plus the urea spray (Treatment B) appear to be superior to the check (Treatment A) that received only 5 ppm of nitrogen in the culture solution. A pronounced nitrogen deficiency, poor growth, and yellowish-green coloration of the plants, which progressed with time, were apparent in both. As may be expected the growth rate of both was less than that of the plants that initially received 100 ppm of nitrogen in the culture solution.

An examination of the data in Table 3 reveals that there is no significant difference between the dry weight of Treatment A and B. The dry weight of Treatment C, as may be expected is significantly greater than either A or B. A definite lack of response of the corn to spray applications of urea in this test may be at least partially explained on the basis that the spray applications, because of a combination of low volume and low concentration, did not increase the nitrogen level or status enough to result in any significant increase in growth.

Table 3. Dry Weight of Corn that Received an Initial 5 ppm Nitrogen in Culture Solution, an Initial 5 ppm Nitrogen in Culture Solution Plus Foliar Applications of Urea, and an Initial 100 ppm Nutrogen Supplied in Culture Solution.

Replication	An Initial 5 ppm N in Culture Solution (Treatment A)	An Initial 5 ppm N in Culture Solution Plus Foliar Applied N (Treatment B)	An Initial 100 ppm N in Culture Solution (Treatment C)
	Grams	Grams	Grams
1	9.2	8.7	45.3
2	9.2	11.4	55.2
3	9.3	11.8	50.4
4	9.6	11.2	56.1
Total	36.3	43.1	207.0
Mean	9.07	10.77	51.75

L.S.D. (.05) = 4.57

Corn was planted August 24, 1952 to compare the growth and per cent of nitrogen in tissue of plants receiving a solution of urea (5 gms./l.) applied to the foliage (Treatment B) with plants receiving the same amount at the same time applied to the rooting medium (Treatment C). A minus nitrogen (Treatment A) was used as a check and also a "complete" (Treatment D) that initially received 100 ppm of nitrogen in the culture solution. There were six replications of each. An average of 74 milliliters of urea solution containing 0.37 gram of urea was used for each replication of Treatments B and C. The foliar application of the urea solution (Treatment B) was made by delivering it from a 1 milliliter pipette to the funnels formed by the leaf blades of the corn plant. The same volume of the solution was then added to the culture solution (Treatment C) of another pot in the same replication. The applications were made several times a day from September 13th to September 30th.

There was no apparent difference in the rate of growth between those plants which received foliar applied nitrogen and those that received an equal amount of nitrogen applied to the culture solution or rooting medium. However, the foliar applications did improve the foliage color of t .e plants. Both treatments were superior to the minus nitrogen treatment, but were very inferior to the plants that initially received 100 ppm of nitrogen in the culture solution. The dry weight of tops and roots of the six replications of the four treatments is presented in Tables 4 and 5.

Table 4. Dry Weight of Corn that Received No Nitrogen, Urea Solution Applied to Foliage, Urea Solution Applied to Rooting Medium and 100 ppm Nitrogen Initially Supplied in Culture Solution.

Replication	Minus N (Treatment A)	N Applied to Foliage (Treatment B)	N Applied to Rooting Medium (Treatment C)	100 ppm N Initially Supplied in Culture Solution (Treatment D)
	Grams	Grams	Grams	Grams
1	2.6	9.0	8.3	70.0
2	3.4	8.1	7.0	62.0
3	2.4	9.3	8.0	66.0
4	2.1	9.5	10.6	71.0
5	2.9	8.5	7.5	66.0
6	3.3	9.3	8.1	69.0
Total	16.7	53.7	49.5	404.0
Mean	2.78	8.95	8.25	67.33

L.S.D. (.05) = 1.87

Table 5. Apparent Dry Root Weight of Corn That Received No Nitrogen, Urea Solution Applied to Foliage, Urea Solution Applied to Rooting Medium and 100 ppm Nitrogen Initially Supplied in Culture Solution.

Replication	Minus N (Treatment A)	N Applied to Foliage (Treatment B)	N Applied to Rooting Medium (Treatment C)	100 ppm N Initially Supplied in Culture Solution (Treatment D)
	Grams	Grams	Grams	Grams
1	1.2	2.5	1.8	16.8
2	1.0	2.1	1.8	16.6
3	0.9	1.9	2.2	17.2
4	1.1	2.4	2.5	20.7
5	1.3	2.5	1.9	20.7
6	1.2	2.5	1.9	18.2
Total	6.7	13.9	12.1	110.2
Mean	1.11	2.31	2.01	18.36

An examination of the data indicates that there is no significant difference in the dry weight of plants that received the foliar (Treatment B) and irrigation solution applied urea (Treatment C). Treatment D which received an initial 100 ppm of nitrogen was significantly greater than either.

Another experiment was carried out to compare the growth and composition of corn receiving the same amount of urea applied to the foliage and rooting medium. The test consisted of four replications of the following treatments: (A) 5 ppm nitrogen in culture solution; (B) 5 ppm nitrogen in culture solution plus urea solution (5 gms./l.) sprayed on foliage; (C) 5 ppm nitrogen in culture solution plus the additional volume of the urea solution that was sprayed on the foliage in Treatment B.

The corn was planted, as previously described, on April 17, 1953 and was up to a good stand by April 24th. The appropriate culture solution was added April 29th. The culture solutions were changed May 16th and the foliar treatments started. An average of 37.5 milliliters of the urea solution containing approximately 0.19 gram of urea was used for each replication of Treatments B and C. The foliar application of urea solution was made by delivering it with a one milliliter pipette to the funnels formed by the leaf blades of the corn plants. The same total volume was added at the same time to the culture solution of the plants comprising Treatment C. The applications were made several times a day between May 16th and June 1st.

The plants were observed each day and at no time was there any apparent difference between the three treatments.

The corn was harvested June 5th, thoroughly washed, dried and ground for analysis. The dry weight and per cent of nitrogen in the tissue are given in Tables 6 and 7 respectively.

Contrary to appearance, both the foliar and culture solution applied urea significantly increased the dry weight of the corn but there was no significant difference in the two treatments.

It is interesting to note that in regard to the per cent of nitrogen in the tops, there is little difference between Treatments B and C and both are slightly higher than Treatment A. However, the per cent of nitrogen in the roots is practically the same for all treatments. This would appear to indicate that there was little accumulation of nitrogen in the roots under the conditions of the experiment.

Table 6. Dry Weight of Corn that Received an Initial 5 ppm Nitrogen in Culture Solution, an Initial 5 ppm Nitrogen in Culture Solution Plus Urea Solution Applied to Foliage, and an Initial 5 ppm Nitrogen Plus Urea Solution Applied to Rooting Medium.

Replication	An Initial 5 ppm N in Culture Solution (Treatment A)		An Initial 5 ppm N in Culture Solution Plus Urea Solution Applied to Foliage (Treatment B)		An Initial 5 ppm N Plus Urea Solution Added to Rooting Medium (Treatment C)	
	Tops (Grams)	Roots (Grams)	Tops (Grams)	Roots (Grams)	Tops (Grams)	Roots (Grams)
1	16.4	6.1	23.4	6.7	24.4	6.8
2	18.6	7.0	21.4	8.3	23.2	6.9
3	17.4	7.2	21.0	6.6	19.8	6.8
4	17.0	6.2	22.5	7.1	21.2	6.8
Total	69.4	26.5	88.3	28.7	88.6	27.3
Mean	17.35	6.62	22.07	7.17	22.15	6.82

L.S.D. (.05) = 2.39 (Tops)

Table 7. Per cent of Nitrogen in Tissue of Corn That Received an Initial 5 ppm Nitrogen in Culture Solution, an Initial 5 ppm Nitrogen Plus Urea Solution Applied to Foliage and an Initial 5 ppm Nitrogen Plus Urea Solution Added to Rooting Medium.

Replication	An Initial 5 ppm N in Culture Solution (Treatment A)		An Initial 5 ppm N in Culture Solution Plus Urea Solution Applied to Foliage (Treatment B)		An Initial 5 ppm N Plus Urea Solution Added to Rooting Medium (Treatment C)	
	Top	Roots	Top	Roots	Top	Roots
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1	.580	.580	.680	.595	.625	.565
2	.555	.555	.695	.555	.595	.510
3	.610	.610	.560	.580	.690	.610
4	.510	.510	.735	.560	.625	.520
Total	2.255	2.255	2.670	2.290	2.535	2.205
Mean	.5367	.5367	.6675	.5725	.6337	.5512

Comparison of Growth and Composition of Corn Resulting From Foliar Applied Phosphorus and Phosphorus Applied to Rooting Medium

An experiment was conducted to determine the effects of foliar application of phosphorus on corn growth. Four replications of the following treatments were used: (A) No phosphorus; (B) Monobasic potassium phosphate solution (10 gms./l.) applied to foliage; (C) 30 ppm phosphorus initially supplied in culture solution.

The corn was planted in rows of 8 plants per pot on May 20, 1952. The row method of planting was used so that the plants could be covered later with aluminum foil. The corn was up to a good stand by May 26th. It was thinned to 4 plants per pot and the appropriate culture solutions were added 7 days after emergence.

All pots were covered with aluminum foil before the spray applications commenced in order to prevent contamination. The corn of Treatment B was sprayed for the first time 14 days after emergence and every fourth day thereafter until three applications were made. Three additional applications were made every other day to make a total of six. The spray applications were made with a 3 gallon compression sprayer operated at 20 to 25 pounds of pressure.

No phosphorus deficiency symptoms were apparent in either of the minus phosphorus treatments (A and B) until the plants were about 4 weeks old. At this time the plants sprayed with the monobasic potassium phosphate solution (Treatment B) were more vigorous, of better color, and eventually produced more dry matter than the untreated

plants (Treatment A) but less than that produced by those plants which initially received 30 ppm phosphorus in the culture solution. The dry weight of the four replications of each treatment is given in Table 8.

The response of corn to foliar and root applied phosphorus in the form of KH_2PO_4 was compared by applying the following treatments: (A) No phosphorus; (B) Monobasic potassium phosphate solution (8 gms./l.) applied to foliage; (C) Same concentration and volume of monobasic potassium phosphate solution used in Treatment B was added to culture solution and (D) 30 ppm phosphorus initially added to culture solution. Each treatment was replicated six times.

Eight kernels of corn were planted in each pot on April 11, 1953. The corn was up to a good stand by April 24th and thinned to 5 uniform plants per pot on May 2nd. The treatments were started May 16th.

At the termination of the treatments on May 21st, an average of 41 milliliters of the solution containing approximately 0.33 gram of KH_2PO_4 had been used on each replication of Treatments B and C. The solution was applied to the foliage by delivering it with a one milliliter pipette to the funnel formed by the leaf blades of the corn plants.

At no time was there any obvious difference (Figure 2) in the plants which received the foliar applied KH_2PO_4 solution (Treatment B) and those that received the same volume applied to the rooting medium (Treatment C). However, the solution had slightly injured the plants of Treatment B, which was contributed to the unusually high

Table 8. Dry Weight of Corn that Received No Phosphorus, KH_2PO_4 Solution Applied to Foliage, and an Initial 30 ppm Phosphorus in Culture Solution.

Replication	Check (Treatment A)	Foliar Applied P (Treatment B)	An Initial 30 ppm of P in Culture Solution (Treatment C)
	Grams	Grams	Grams
1	15.7	35.4	51.3
2	21.6	36.2	59.3
3	20.2	37.6	43.0
4	20.5	31.8	46.4
Total	78.0	141.0	200.0
Mean	19.50	35.25	50.00

L.S.D. (.05) = 7.58

Figure 2. Comparative growth of corn that received (A) no phosphorus, (B) 41 mls. KH_2PO_4 solution applied to foliage, (C) 41 ml. KH_2PO_4 solution added to culture solution, and (D) 30 ppm phosphorus (P) initially supplied in culture solution.

temperatures in the greenhouse during a portion of this experiment. The plants of Treatment A were characterized by stunted growth and purplish coloration of a portion of the leaves, a symptom that was not apparent in those plants which had received foliar or root applied phosphorus.

The corn plants were harvested June 5th. The dry weights of tops and roots are given in Tables 9 and 10 respectively.

An examination of the data indicate that those plants which received phosphorus applied to the roots produced a great dry weight than when the phosphorus was applied to the foliage. The limited phosphorus application to either the roots or the foliage produced a two to three fold dry weight increase when compared to the no phosphorus treatment.

The corn receiving Treatments A, B, and C was analyzed to determine the per cent of phosphorus in the tissue (Table 11).

The phosphorus content of the top portion of the plants that received the KH_2PO_4 solution applied to foliage or roots was 25 and 17 per cent greater respectively than the plants that received no phosphorus. The phosphorus content of the roots of the plants which had received foliar and root applied phosphorus was 13 and 7 per cent greater respectively than that of the check.

An experiment, similar to the solution culture experiment described above, was carried out to compare phosphorus application to the roots with phosphorus application to the foliage when the corn plants are grown in soil.

Table 9. Dry Weight of Corn that Received No Phosphorus, KH_2PO_4 Solution Applied to Foliage, KH_2PO_4 Solution Applied to Rooting Medium, and an Initially 30 ppm Phosphorus in Culture Solution (Tops).

Replication	No Phosphorus (Treatment A)	P Applied to Foliage (Treatment B)	P Applied to Rooting Medium (Treatment C)	An Initial 30 ppm P in Culture Solution (Treatment D)
	Grams	Grams	Grams	Grams
1	17.5	47.7	48.7	123.5
2	26.2	48.5	58.3	124.7
3	15.5	53.2	72.1	93.6
4	14.7	49.0	54.8	128.0
5	22.0	50.2	61.6	130.7
6	25.2	50.9	63.7	140.6
Total	121.1	299.5	359.2	741.1
Mean	20.18	49.75	59.70	123.51

L.S.D. (.05) = 10.65

Table 10. Apparent Dry Root Weight of Corn that Received No Phosphorus, KH_2PO_4 Solution Applied to Foliage, KH_2PO_4 Solution Applied to Rooting Medium, and an Initially 30 ppm Phosphorus in Culture Solution.

Replication	No Phosphorus (Treatment A)	P Applied to Foliage (Treatment B)	P Applied to Rooting Medium (Treatment C)	An Initial 300 ppm P in Culture Solution (Treatment D)
	Grams	Grams	Grams	Grams
1	5.0	10.7	11.8	23.8
2	6.8	9.8	13.1	24.8
3	4.8	13.5	14.7	23.8
4	4.9	10.1	12.7	28.4
5	5.6	10.5	13.8	25.0
6	5.2	9.0	11.1	23.2
Total	32.3	63.6	77.20	149.00
Mean	5.38	10.60	12.86	24.83

Table 11. Per cent of Phosphorus in Tissue of Corn that Received No Phosphorus, KH_2PO_4 Solution Applied to Foliage, and KH_2PO_4 Solution Added to Rooting Medium.

Replication	No Phosphorus (Treatment A)		P Applied to Foliage (Treatment B)		P Applied to Rooting Medium (Treatment C)	
	Top	Roots	Top	Roots	Top	Roots
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1	0.082	0.066	0.087	0.067	0.100	0.068
2	0.081	0.067	0.100	0.072	0.087	0.075
3	0.062	0.057	0.100	0.081	0.080	0.062
4	0.065	0.58	0.100	0.071	0.083	0.065
Total	0.290	0.248	0.387	0.291	0.350	0.270
Mean	0.072	0.062	0.096	0.072	0.087	0.067

The soil used was taken from a check plot of an alfalfa-trefoil experiment. The available phosphorus (P) content of this soil was 30 pounds per acre. The test consisted of the following three treatments with six replications of each: (A) No phosphorus added; (B) Monobasic potassium phosphate solution (8 gms./l.) applied to foliage; (C) Same volume of monobasic potassium phosphate solution used in Treatment B applied to soil.

A basic application of 300 pounds of 60 per cent potassium chloride and 300 pounds of 32 per cent ammonium nitrate per acre were applied. The fertilizer was mixed separately with each replication of the three treatments in order to achieve maximum uniformity.

Eight kernels of corn were planted in each pot May 26, 1953. The corn was up to a good stand by June 2nd and was thinned to five plants per pot June 12th. The respective treatments started July 1st and terminated July 7th during which time an average of 96.5 milliliters of the solution which contained approximately 0.77 gram of KH_2PO_4 was added to each replication of Treatment B and C.

When the plants were observed July 5th, a purplish coloration of a portion of the leaves was apparent in all the replications of Treatment A, which received neither soil nor foliar applied phosphorus. On those plants which received either soil or foliar applied phosphorus the phosphorus deficiency symptom was not apparent. When observed July 16th the growth of plants receiving the foliar (Treatment B) and irrigation solution applied phosphorus (Treatment C) appeared to be about equal but both were superior to Treatment A (Figure 3). The plants were harvested July 21st and the dry weight

and per cent of phosphorus in the tissue determined (Tables 12 and 13).

An examination of the data reveal a statistically significant increase in dry weight of Treatments B and C respectively over Check (Treatment A).

The per cent of phosphorus in the corn receiving Treatments B and C was 47 and 35 per cent higher respectively than the Check (Treatment A). About 18 per cent more phosphorus was found in the corn receiving Treatment B than that corn receiving Treatment C.

Table 12. Dry Weight of Corn that Received No Phosphorus, KH_2PO_4 Solution Applied to Foliage and KH_2PO_4 Solution Applied to Soil.

Replication	No P (Treatment A)	P Applied to Foliage (Treatment B)	P Applied to Soil (Treatment C)
	Grams	Grams	Grams
1	23.0	39.1	40.7 -
2	22.0	44.0	39.3
3	27.4	39.1	45.8
4	31.2	42.3	49.0
Total	103.6	164.5	174.8
Mean	25.90	41.12	43.70

L.S.D. (.05) = 5.13

Table 13. Per Cent of Phosphorus in Tissue of Corn that Received No Phosphorus, KH_2PO_4 Solution Applied to Foliage, and KH_2PO_4 Solution Applied to Soil.

Replication	No P (Treatment A)	P Applied to Foliage (Treatment B)	P Applied to Soil (Treatment C)
	Pct.	Pct.	Pct.
1	0.783	1.433	1.333
2	1.021	1.692	1.425
3	0.783	1.658	1.242
4	0.783	1.658	1.229
Total	3.370	6.441	5.229
Mean	.842	1.610	1.307

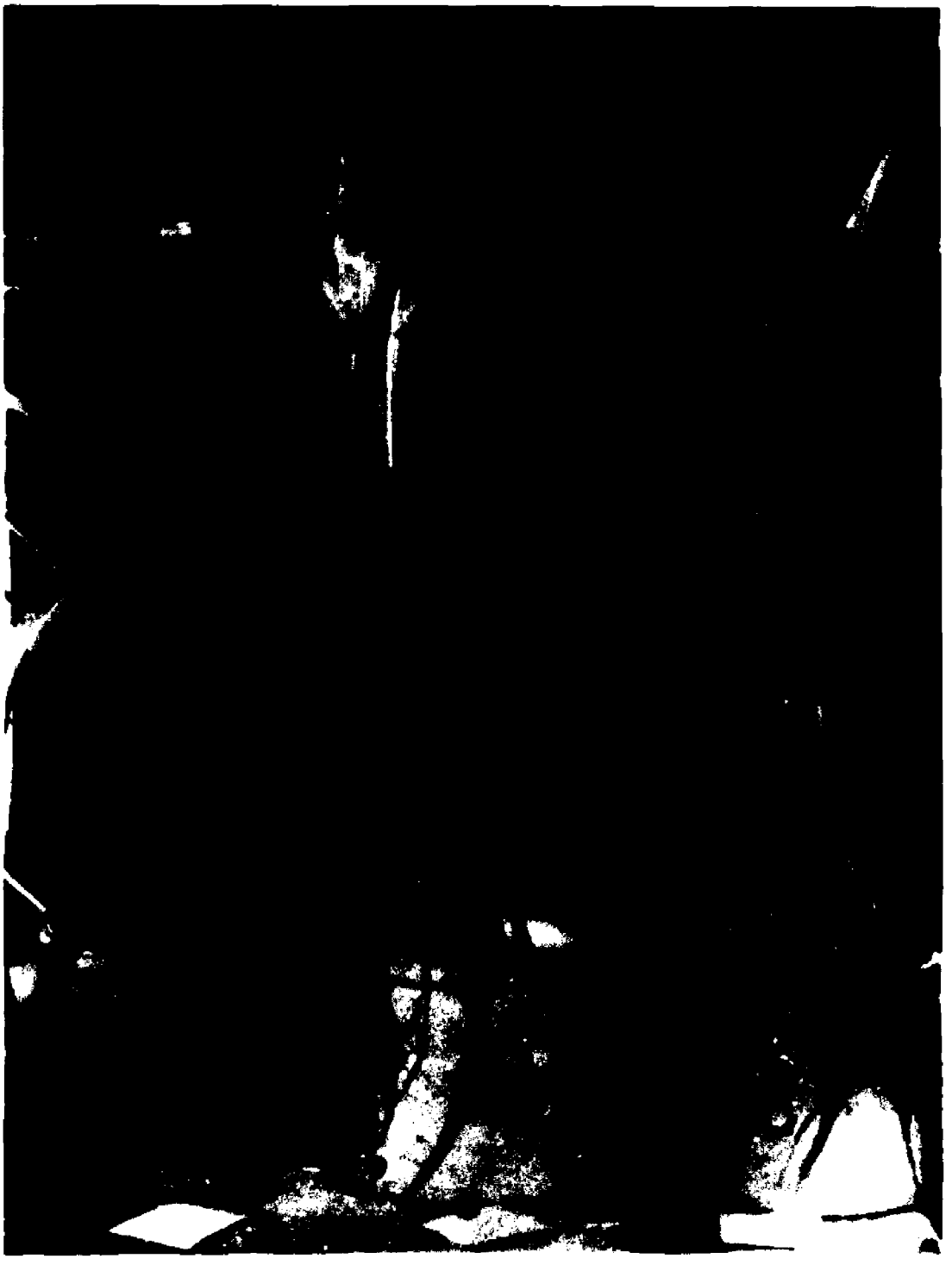

Figure 3. Comparative growth of corn that received (A) No additional phosphorus, (B) 96.5 mls. of KH_2PO_4 solution applied to foliage, (C) 96.5 mls. of KH_2PO_4 solution applied to soil.

The Effect of the Method of Application on the Relative Rates of Absorption and Movement of Radioactive Phosphorus[1]

An unreplicated test, employing gravel culture, minus phosphorus, was utilized to compare the relative rates of absorption and movement of radioactive phosphorus (P32), in the form of KH_2PO_4, when applied to the foliage and culture solution. The corn was planted July 10 and the following treatments carried out on August 19, when the plants were approximately four feet in height: (1) Five milliliters of a solution containing 30.656 gms./l/ KH_2PO_4 were placed in each of four funnels which were formed by leaf blades of the corn plants; (2) the same total volume (20 mls.) was then added to the culture solution of another pot.

Disc samples of plants receiving each treatment were taken from the tip and near the center of each mature leaf at 24, 48 and 72 hours after application. Samples of leaf sections were taken after 72 hours from top and base of a plant representing the two methods of application. Autoradiographs were made on August 28 on Type K Industrial X-Ray films after two hours of exposure by employing the method used by Sayre (12).

The autoradiographs (Figs. 4 and 5) reveal that the phosphorus in the tissue of the plant, to which the material has been applied to foliage or in the culture solution increased with time, but the

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[1]The radioactive phosphorus used in this work was obtained from the Isotopes Division of the Atomic Energy Commission, Oak Ridge, Tennessee through Dr. J. D. Sayre of the Ohio Agricultural Experiment Station and Bureau of Plant Industry and Soils, United States Department of Agriculture, Wooster, Ohio.

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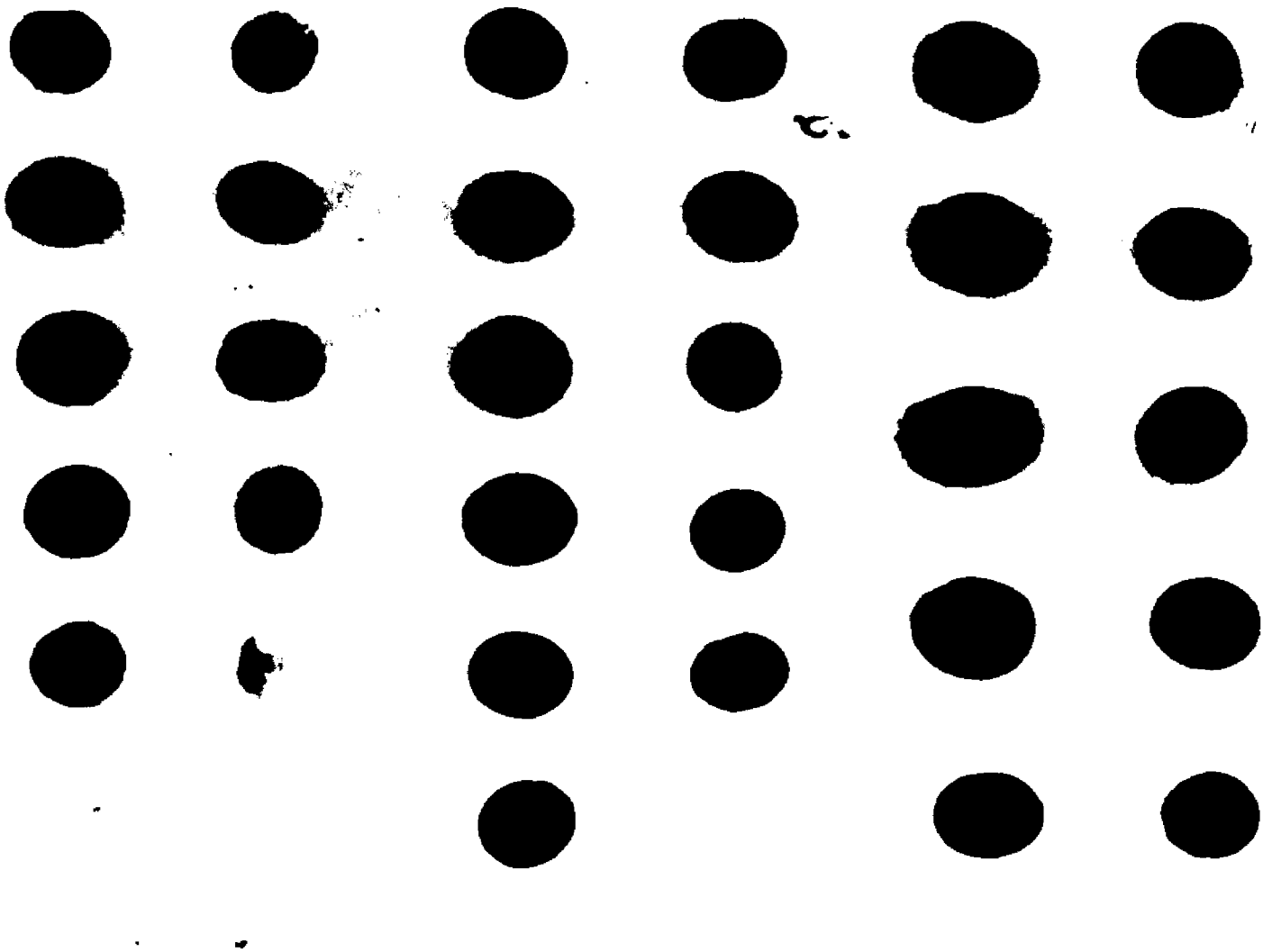

Figure 4. Disc samples taken from corn leaves near base of plant to top as they appear on autoradiograph. The relative rates of absorption of radioactive phosphorus may be seen (left to right). (1) 24 hours after P32 was applied to the culture solution; (2) 24 hours after P32 was applied to foliage; (3) 48 hours after P32 was applied to the culture solution; (4) 48 hours after P32 was applied to foliage; (5) 72 hours after P32 was applied to culture solution; (6) 72 hours after P32 was applied to foliage. (Darker color indicates greater concentration.)

Figure 5. Relative amount of radioactive phosphorus in corn leaf sections at 72 hours (left to right). (1) Near top of plant when P32 was applied to culture solution; (2) Near top of plant when P32 was applied to foliage; (3) Near base of plant when P32 was applied to culture solution; (4) Near base of plant when P32 was applied to foliage. (Darker color indicates greater concentration.)

relative amount for any given time was greater when the material was applied to the rooting medium.

Comparison of Growth and Composition of Corn Resulting from Foliar Applied Potassium and Potassium Applied to Rooting Medium.

An experiment was conducted to determine the effect of foliar applied potassium chloride on corn growth. Four replications of the following treatments were used: (A) No phosphorus; (B) Potassium chloride solution (5 gms./l.) applied to foliage; (C) An initial 100 ppm potassium supplied in culture solution.

The corn was planted in rows of 8 plants per pot May 20, 1952. The corn was up to a good stand by May 26 and was thinned to 4 plants per pot and the appropriate culture solutions were added 7 days after emergence.

All pots were covered with aluminum foil before the spray applications were made in order to prevent contamination. The corn of Treatment B was sprayed for the first time 14 days after emergence and every fourth day thereafter until three applications were made. Three additional applications were made every other day to make a total of six. The spray applications were made with a 3 gallon compression sprayer operated at 20 to 25 pounds of pressure.

Potassium deficiency symptoms were very pronounced before spraying. The stems of the plants that did not receive potassium were too weak to fully support themselves. This was accompanied by a distinct browning of the borders of the older leaves. A slight

increase in vigor of the plants sprayed with potassium (Treatment B) over non sprayed plants (Treatment A) was apparent after the third application, i.e., the plants began to assume an upright position and the new plant tissue appeared healthy. The increased growth and vigor of the sprayed plants over check was proportionately much greater at the termination of the test. However, the sprayed plants were inferior to those that initially received 100 ppm potassium in the culture solution. The plants were harvested July 10, dried and then weighed. The dry weight of the four replications of each treatment is given in Table 14. The relative development of the tops and roots is shown in Figures 6 and 7 respectively.

Corn was planted July 10, 1952, as previously described, to compare the growth of plants receiving the following treatments: No potassium (Treatment A); Potassium chloride (5 gms./l.) applied to the foliage (Treatment B); The same amount of KCl was applied at the same time to the rooting medium (Treatment C); An initial treatment of 100 ppm of K in the culture solution (Treatment D). There were six replications of each. An average of 62 milliliters of the solution which contained a total of 0.31 gram of potassium chloride was applied to each replication of Treatments B and C. The foliar application of the potassium chloride solution (Treatment B) was made by delivering it from a 1 milliliter pipette into the funnels formed by the leaf blades of the corn plant. The same volume of the solution was then added to the culture solution (Treatment C) of the same replication. This solution was applied a few milliliters at a time several times a

day from July 30 to August 8. The volume applied in any application was determined by the capacity of the funnels of the four corn plants in each pot. Therefore, the volume varied from pot to pot and from day to day for the same pot.

Table 14. Dry Weight of Corn that Received No Potassium, Foliar Application of Potassium Chloride Solution, and 100 ppm Potassium Initially Supplied in Culture Solution.

Replication	Check (Treatment A)	Foliar Applied K (Treatment B)	100 ppm K in Culture Solution (Treatment C)
	Grams	Grams	Grams
1	5.1	28.2	63.0
2	9.0	21.8	67.1
3	7.3	30.1	69.4
4	8.0	15.9	66.3
Total	29.4	96.0	265.8
Mean	7.35	24.00	66.45

L.S.D. (.05) = 7.31

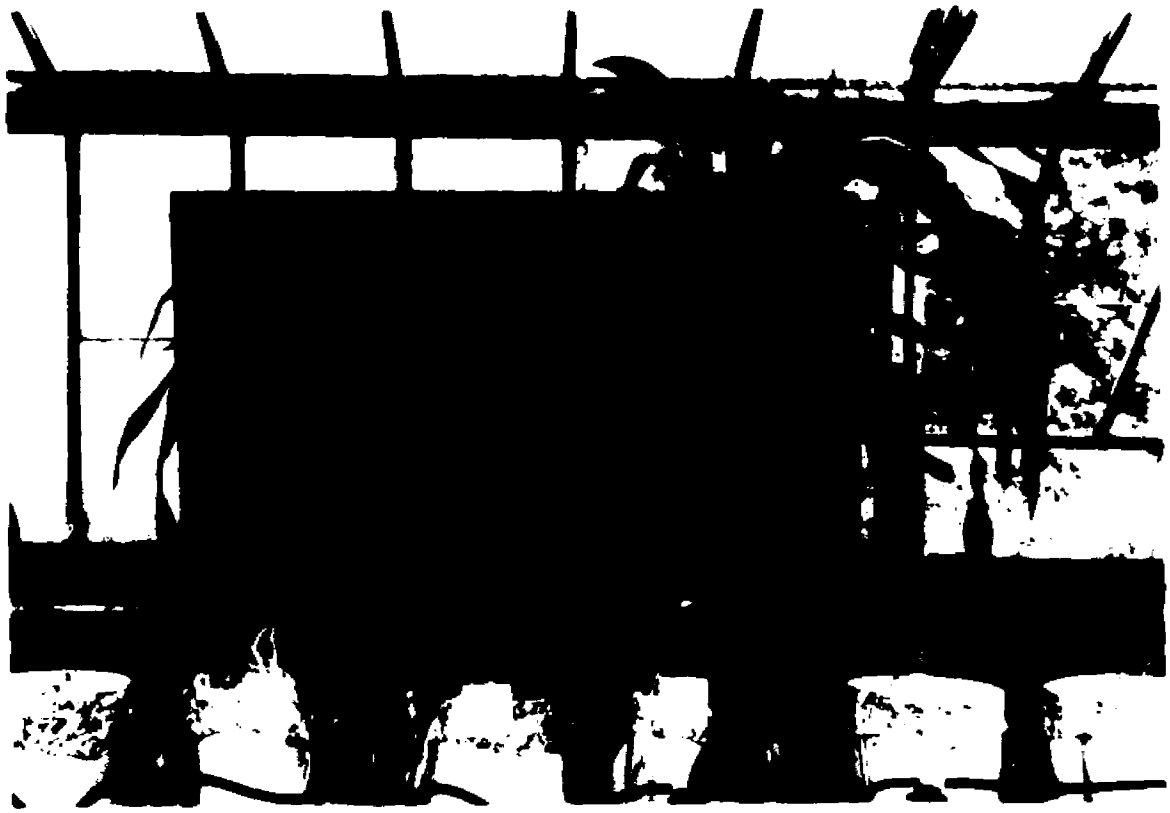

Figure 6. Relative growth of corn that received (A3) no potassium, (B3) potassium chloride solution applied to foliage, and (C3) potassium initially supplied in culture solution. (The pots to the right and left contained corn that was harvested before photograph was made.)

Figure 7. Relative development of roots of corn that received (KA) no potassium, (KB) potassium chloride solution applied to foliage, and (KC) potassium initially supplied in culture solution.

At the time the treatments were started the plants that initially received no potassium (Treatments A, B and C) were about 12 inches in height as compared with a height of approximately 18 inches for those that initially received 100 ppm potassium in the culture solution (Treatment D). In addition to retarded growth, the other potassium deficiency symptoms described previously were slightly visible.

After the treatments were started, the increased growth rate was at first more obvious in the plants to which the potassium chloride solution had been applied to the rooting medium. The foliar fertilized plants did not seem to respond until several days after the applications terminated, however, the plants appeared to be a darker green color. In spite of the fact that there was a delayed response in terms of growth, the foliar fertilized plants developed more rapidly than those plants to which the material had been applied to the rooting medium. One replication of the plants as they appeared at the termination of the test may be seen in Figure 8. The corn was harvested August 20.

The data in Tables 15 and 16 indicate that there is no significant difference between foliar applied and irrigation solution applied potassium when both were used in equal amounts and at the same time. These treatments while less effective than that supplying a high concentration of potassium in culture solution (100 ppm) did produce a significant increase in dry matter when compared to those plants which did not receive potassium.

Figure 8. Comparative growth of corn that (1) received no potassium, (2) 62 ml. of potassium chloride solution applied to foliage, (3) 62 ml. of potassium chloride solution added to culture solution, and (4) 100 ppm potassium initially supplied in the culture solution.

Table 15. Dry Weight of Corn Receiving No Potassium, Potassium Chloride Solution Applied to Foliage, Potassium Chloride Solution Applied to Rooting Medium, and an Initial 100 ppm Potassium in Culture Solution (Tops).

Replication	Minus K (Treatment A)	K Applied to Foliage (Treatment B)	K Applied to Rooting Medium (Treatment C)	An Initial 100 ppm K in Culture Solution (Treatment D)
	Grams	Grams	Grams	Grams
1	7.5	21.7	20.2	44.1
2	7.5	15.9	19.2	40.5
3	7.5	18.1	25.9	43.2
4	6.4	14.7	17.2	49.6
5	10.1	17.2	16.7	56.5
6	7.7	18.0	23.0	55.9
Total	46.7	105.6	122.2	289.8
Mean	7.7	17.6	20.3	48.3

L.S.D. (.05) = 4.90

Table 16. Apparent Dry Root Weight of Corn that Received No Potassium, Potassium Chloride Solution Applied to Foliage, Potassium Chloride Solution Applied to Rooting Medium, and an Initial 100 ppm Potassium in Culture Solution.

Replication	Minus K (Treatment A)	K Applied to Foliage (Treatment B)	K Applied to Rooting Medium (Treatment C)	An Initial 100 ppm K in Culture (Treatment D)
	Grams	Grams	Grams	Grams
1	1.0	3.8	2.8	7.5
2	0.9	2.5	2.6	7.8
3	0.7	2.8	3.6	7.7
4	0.8	2.5	2.3	10.4
5	1.0	2.5	2.2	10.9
6	0.9	3.3	3.7	14.8
Total	5.3	17.4	17.2	59.1
Mean	0.88	2.90	2.86	9.68

Since there is evidence that potassium as well as phosphorus may be fixed by the soil particles and thus made unavilable to the plant, it may be assumed that foliar fertilization may have an advantage when plants grow in soil. In order to test the validity of this hypothesis, a soil was selected from a check plot of a lime experiment that was known to be low in potash (0.18 m.e. exchangeable K per 100 gms. of soil). An experiment consisting of the following treatments was devised with four replications of each: (A) No potash added, (B) KCL solution applied to foliage, (C) Same amount of KCl solution used in Treatment B applied to soil.

Applications at the rate of 2½ tons of lime and 600 pounds of superphosphate per acre of air dry soil were added to the 12 kilograms of soil of each pot. The lime and phosphorus were added separately to each replication of the three treatments to ensure uniformity. Nitrogen was added in solution as 32% ammonium nitrate at a rate of 300 pounds per acre several days after emergence.

Eight kernels of corn were planted in each of the 12 pots on May 18, 1953. The corn was up to a good stand by May 21. An average of 60 milliliters of solution containing 5 gms. of KCl per 1. was added to each replication of Treatments B and C between June 17 and June 28. The solution was applied to the foliage in the same manner as in the preceding test. The potassium chloride solution used in Treatment C was diluted to 100 ml before it was applied to the soil of each pot in order that it could be distributed fairly uniformly over the surface.

When observed several times during the course of the treatments and also at the termination, there was no obvious difference in any of the three treatments from the viewpoint of growth and appearance.

The corn was harvested July 7. The dry weight of each replication of the three treatments is given in Table 17.

It is obvious that little response, in terms of growth, was received from the addition of the potassium chloride solution to the soil. The solution had a slight deleterious effect when applied to the foliage. On the other hand, it is interesting to note (Table 18) that there was approximately a 7 per cent increase in the potassium content of the corn tissue of both Treatments B and C over Check, Treatment A.

The lack of response of corn grown in soil to foliar applications of potassium chloride was considered to be due to the fact that the soil supplied sufficient potassium for the plant. In an attempt to overcome this problem, the soil of an Alfalfa-Trefoil experiment that received liberal applications of phosphorus but no potassium was selected. An analysis showed that the exchangeable potassium content of this soil was 0.16 m.e. per 100 grams of soil.

The test consisted of four replications of the following eight treatments: (A) No potash added to soil nor foliage; (AA) No potash added to soil but four applications of potassium chloride solution applied to foliage; (B) 50 pounds per acre of 60 per cent potassium chloride added to soil (BB) 50 pounds per acre of 60 per cent potassium chloride added to soil plus four applications of potassium chloride solution applied to foliage; (C) 150 pounds per acre of 60 per cent

potassium chloride added to soil; (CC) 150 pounds per acre of 60 per cent potassium chloride applied to soil plus four applications of potassium chloride solution applied to foliage; (D) 300 pounds per acre of 60 per cent potassium chloride added to soil; (DD) 300 pounds per acre of 60 per cent potassium chloride added to soil plus four applications of potassium chloride solution applied to foliage.

Table 17. Dry Weight of Corn that Received No Potassium, Potassium Chloride Solution Applied to Foliage, and Potassium Chloride Solution Applied to Soil.

Replication	No K Added (Treatment A)	K Applied to Foliage (Treatment B)	K Applied to Soil (Treatment C)
	Grams	Grams	Grams
1	47.0	44.5	50.5
2	44.1	31.1	46.3
3	40.4	41.1	45.7
4	43.4	43.4	38.1
Total	174.9	160.1	180.6
Mean	43.72	40.02	45.15

L.S.D. (.05) = 8.07

Table 18. Per Cent of Potassium in Tissue of Corn that Received No Potassium, Potassium Chloride Solution Applied to Foliage and Potassium Chloride Solution Applied to Soil.

Replication	No K Added (Treatment A)	K Applied to Foliage (Treatment B)	K Applied to Soil (Treatment C)
	Pct.	Pct.	Pct.
1	1.22	1.32	1.34
2	1.24	1.32	1.34
3	1.22	1.32	1.32
4	1.22	1.32	1.34
Total	4.90	5.28	5.34
Mean	1.22	1.32	1.33

Eight kernels of corn were planted in each 3 gallon glazed pot on July 15, 1953. The plants were up to a good stand by July 19 and were thinned to 5 plants per pot on July 21. Enough potassium chloride was added in solution to supply the desired amount immediately after the thinning operation.

The corn was sprayed with potassium chloride solution (5 gms./l.) July 30, July 31, August 3 and August 4. A small hand sprayer was utilized. The corn was harvested August 12, washed thoroughly, dried, weighed and ground for analysis.

The dry weight of each treatment is given in Table 19. A statistical analysis of the data (Table 20) indicate that there is no significant difference at the 5 per cent level. Even though there was no significant response in terms of growth as measured by dry weight, there was a progressive increase in the potassium content of the tissue (Table 21) as the rate applied to the soil was increased. The spray applications also resulted in a slightly higher potassium content than the unsprayed plants. On the basis of the rather widely accepted principle suggested by Macy (8), the data seem to indicate that there was a "luxury consumption" of potassium.

Table 19. Dry Weight of Corn That Received Different Rates of Soil and Foliar Applied Potassium.

Replication	No K Added	No K Added to Soil but Corn Sprayed	50 lb./A 60% KCl Added to Soil	50 lb./A 60% KCl Added to Soil and Corn Sprayed	150 lb./A 60% KCl Added to Soil	150 lb/A 60% KCl Added to Soil and Corn Sprayed	300 lb./A 60% KCl Added to Soil	300 lb./A 60% KCl Added to Soil and Corn Sprayed
	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams
1	25.2	25.4	24.5	23.0	26.1	26.9	33.2	28.1
2	23.7	25.5	30.0	26.8	25.4	24.0	27.3	29.2
3	24.8	25.0	20.9	24.0	26.0	24.2	24.0	24.5
4	23.0	25.8	26.9	23.9	23.4	25.4	28.4	27.9
Total	96.7	101.7	102.3	97.7	100.9	100.5	112.9	109.7
Mean	24.17	25.42	25.57	24.42	25.22	25.12	28.22	27.42

Table 20. Summary of Analysis of Dry Weight of Corn that Received Different Potassium Rates Applied to Soil and Foliar Applications of Potassium.

Source	Sum of Squares	d.f.	Mean Square	F	$F_{.05}$
Treatments	55.80	7	7.97	1.77	2.59
Replications	29.44	3	9.81	2.18	3.07
Discrepance	94.36	21	4.49		

Table 21. Per Cent of Potassium in Tissue of Corn That Received Different Rates of Soil and Foliar Applied Potassium.

Replication	No K Added	No K Added to Soil But Corn Sprayed	50 lb./A. 60% KCl Added to Soil	50 lb./A. 60% KCl Added to Soil and Corn Sprayed	150 lb./A. 60% KCl Added to Soil	150 lb/A. 60% KCl Added to Soil and Corn Sprayed	300 lb./A. 60% KCl Added to Soil	300 lb./A. 60% KCl Added to Soil and Corn Sprayed
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1	1.23	1.36	1.47	1.68	2.00	2.28	2.54	2.81
2	1.19	1.24	1.23	1.47	1.82	2.24	2.68	2.74
3	1.08	1.23	1.37	1.47	1.66	2.08	2.64	2.69
4	1.04	1.17	1.32	1.50	1.80	2.12	2.48	2.74
Total	4.54	5.00	5.39	6.12	7.28	8.72	10.34	10.98
Mean	1.13	1.25	1.34	1.53	1.82	2.18	2.58	2.74

The Response of Corn to Several Forms of Foliar Applied Phosphorus and Nitrogen

An experiment, employing gravel culture, was carried out to compare the response of corn to several forms of foliar applied nitrogen and phosphorus. The concentrations of the solutions from the selected nitrogen carriers were adjusted so that a given volume of the different solutions would supply an equivalent amount of nitrogen. In a similar manner, the solutions made from the compounds that were used as a source of phosphorus were adjusted so that a given volume would supply an equivalent amount of phosphorus. The compounds and the concentrations used in the nitrogen and phosphorus treatments were as follows:

Phosphorus Treatments: (A) No phosphorus;

(B) 8 gms. KH_2PO_4 per liter

(C) 7.5 gms. $Ca(H_2PO_4)_2.H_2O$ per liter

(D) 7.9 gms. $(NH_4)_2HPO_4$ per liter

Nitrogen Treatments: (A) No nitrogen

(B) 3 gms. NH_4NO_3 per liter

(C) 4.7 gms. $(NH_4)_2SO_4$ per liter

(D) 4.7 gms. $(NH_4)_2HPO_4$ per liter

All of the nitrogen treatments received an initial 5 ppm nitrogen in the culture solution.

The corn wasplanted in gravel culture on June 9. The appropriate culture solution was added June 18. The treatments started July 6 and terminated July 11 and July 15 for the phosphorus and nitrogen series

respectively. During this time a total of 65 milliliters of the phosphorus solutions and 50 milliliters of the nitrogen solutions was applied to each replication of the respective treatments. The volume of the funnel of the corn plant in which the solution was placed determined the volume applied at one application but the same total volume for each treatment and replication was attained within a 24 hour period.

The corn was observed during an after the termination of the treatments. In regard to the phosphorus treatments, at no time did there appear to be any consistent difference in Treatments B, C and D. All of them responded rapidly to the treatments and were superior in terms of growth to Treatment A, which was characterized by the phosphorus deficiency symptoms described previously.

There was no apparent difference in any of the treatments of the nitrogen series.

The corn was harvested July 22. The dry weight of the tops for the phosphorus treatments is given in Table 22.

The data (Table 23) indicate that there is no highly significant difference in the dry top weight resulting from the foliar application of the several phosphorus carriers used in the test; the application of any one carrier produced a significant increase in dry matter when compared with the untreated corn. The dry weight of the roots of the phosphorus treatments is given in Table 24.

The dry weight of the tops for the nitrogen treatments is given in Table 25. An analysis of the dry weight of tops (Table 26)

indicates that there is no significant difference between the treatment means at the 5 per cent level. The dry weight of the roots of the nitrogen treatments is given in Table 27.

An examination of previous data involving foliar fertilization with urea indicates that the response is much greater when no nitrogen is applied to the rooting medium as a starter. The slight but insignificant response obtained in this test further supports this point of view.

Table 22. Dry Top Weight of Corn that Received Different Foliar Applied Phosphorus Compounds.

Replication	Treatment A (Check)	Treatment B (KH_2PO_4)	Treatment C ($Ca(H_2PO_4)_2\ H_2O$	Treatment D ($(NH_4)_2\ HPO_4$
	Grams	Grams	Grams	Grams
1	19.2	55.5	45.0	37.9
2	17.7	47.4	40.2	44.2
3	18.0	36.5	39.0	31.5
4	20.0	67.4	48.0	39.2
5	22.9	46.9	47.0	46.9
6	21.4	43.5	55.0	71.0
Total	119.2	297.2	274.2	270.7
Mean	19.86	49.53	45.70	45.1

L.S.D. (.05) = 10.42

Table 23. Summary of Analysis of Dry Weight of Corn Receiving Different Foliar Applied Phosphorus Compounds (Top).

Analysis of Variance

Source	Sum of Squares	d. f.	Mean Square	F
Treatments	3329.36	3	1109.78	15.44**
Replications	630.59	5	126.11	1.75
Discrepance	1077.75	15	71.85	

**Significant at 1 per cent level.

Table 24. Apparent Dry Root Weight of Corn that Received Different Foliar Applied Phosphorus Compounds.

Replication	Treatment A (Check)	Treatment B (KH_2PO_4)	Treatment C $Ca(H_2PO_4)_2\ H_2O$	Treatment D $(NH_4)_2\ HPO_4$
	Grams	Grams	Grams	Grams
1	7.1	12.3	11.3	10.2
2	4.0	10.2	9.5	10.5
3	7.1	9.3	10.0	7.7
4	5.4	11.1	8.9	11.0
5	9.0	13.1	7.3	7.5
6	10.0	11.1	12.3	14.0
Total	42.6	67.1	59.3	60.9
Mean	7.1	11.18	9.88	10.16

Table 25. Dry Top Weight of Corn That Received Different Foliar Applied Nitrogen Compounds.

Replication	Treatment A (Check)	Treatment B (NH_4NO_3)	Treatment C $(NH_4)_2SO_4$	Treatment D $(NH_4)_2$ HPO_4
	Grams	Grams	Grams	Grams
1	17.2	15.9	16.5	17.2
2	16.3	18.5	18.2	19.1
3	13.2	20.9	15.3	18.8
4	15.0	17.0	16.5	14.5
5	16.1	16.3	17.2	17.2
6	14.1	16.2	17.4	15.5
Total	91.9	104.8	101.1	102.3
Mean	15.31	17.46	16.85	17.05

Table 26. Summary of Analysis of Dry Weight of Corn Receiving Different Foliar Applied Nitrogen Compounds (Top).

Analysis of Variance

Source	Sum of Squares	d. f.	Mean Square	F	$F_{.05}$
Treatments	15.85	3	5.28	2.17	3.29
Replications	14.34	5	2.86	1.17	2.90
Discrepance	36.46	15	2.43		

Table 27. Apparent Dry Root Weight of Corn that Received Different Foliar Applied Nitrogen Compounds.

Replication	Treatment A (Check)	Treatment B (NH_4NO_3)	Treatment C ($(NH_4)_2SO_4$)	Treatment D ($(NH_4)_2\ HPO_4$)
	Grams	Grams	Grams	Grams
1	6.8	8.2	8.5	12.3
2	7.7	9.7	6.0	8.5
3	5.6	7.6	6.1	8.7
4	8.0	9.6	8.2	5.5
5	8.3	7.5	7.0	6.6
6	7.4	6.7	5.8	6.1
Total	43.8	49.3	41.6	47.7
Mean	7.30	8.21	6.93	7.95

SUMMARY AND CONCLUSIONS

Greenhouse pot experiments utilizing gravel cultures and soil were conducted to determine the response of corn to foliar application of nitrogen, phosphorus and potassium salts in aqueous solution.

The fertilizer materials were applied to the foliage as a spray and also by pipetting a known quantity of solution into the funnel of the growing tip formed by the leaf blades. This technique made possible the comparison of a given amount of an element applied to the foliage with the same amount applied to the rooting medium.

Corn responded, but inconsistently, to the foliar application of urea solution when an initial 5 ppm nitrogen was supplied in the culture solution. A greater response was received when no nitrogen was initially supplied in the culture solution but there was no significant difference in the dry weight when the same volume of urea solution was applied to the foliage or to the rooting medium. The former resulted in a slightly higher nitrogen content of the corn tissue.

No significant response resulted from the foliar application of ammonium nitrate, ammonium sulfate or ammonium phosphate when used as a source of nitrogen and an initial 5 ppm nitrogen was supplied in the culture solution.

The foliar application of a potassium chloride solution was effective in promoting a significant increase in the dry weight of corn when grown in gravel culture. However, there was no significant difference in the response when the same volume of potassium

chloride solution was applied to foliage or to rooting medium.

When corn was grown in soil it did not increase in growth, when foliar or soil application of potassium chloride solution were used. An increase in the per cent of potassium of the corn tissue resulted from both but the plants which received the foliar application were slightly higher.

The foliar application of monobasic potassium phosphate when used as a source of phosphorus was effective in promoting a significant increase in the dry weight of corn when grown in either gravel culture or soil.

When the corn was grown in gravel culture, it responded slightly more, but insignificantly, when the monobasic potassium phosphate solution was added to the rooting medium. This may have been due to a slight burning from the foliar application of the material. No significant difference in dry weight resulted from the two methods of application when the corn was grown in soil. The phosphorus content of the foliar fertilized plants was slightly greater than the check when grown in either gravel culture or soil. The foliar fertilized plants contained slightly more phosphorus than those that had received the phosphorus in the culture solution or soil.

When the two methods of application were compared by using radioactive phosphorus, the relative amount in the tissue samples of the plants that received the material applied to foliage or roots increased with time, but the amount at any given time was greater when

applied to the rooting medium.

A significant increase in the dry weight of corn resulted from foliar applied solutions of monobasic potassium phosphate calcium phosphate and ammonium phosphate when the solutions contained equivalent amounts of phosphorus. However, there was no significant difference in the response of corn to the three compounds.

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I, Winfred Thomas, was born in Geneva, Texas, June 6, 1920. I received my secondary school education in the public schools of the city of Dallas, Texas. My undergraduate training was obtained at Prairie View College, from which I received the degree of Bachelor of Science in 1943. I received the degree Master of Science from Cornell University in 1947. I received an appointment as Research Assistant at the Ohio Agricultural Experiment Station, where I specialized in the Department of Agronomy. I held this position for approximately two years while completing the requirements for the degree Doctor of Philosophy.