# The Response of Corn Roots to High Nutrient Concentrations within a Single Root Culture Cell[1]

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## Introduction

In recent years many studies have been made concerning root development around a fertilizer band. The chemical and physical reactions taking place within or adjacent to the band have also been studied. However, little or no attention has been given to the behavior of the few roots which actually strike or penetrate the band where unfavorable conditions of high salt concentrations probably exist.

Results of a study by Lindsay and Stephenson (3) indicate, that the solution leaving a band of monocalcium phosphate monohydrate is highly concentrated and acidic in nature. This solution is believed to have a composition either of a meta-stable triple-point solution with a P content of 3.98 M, a Ca content of 1.44 M, and a pH of 1.48 or that of a triple-point solution with a P content of 4.495 M, a Ca content of 1.34 M, and a pH of 1.01.

From greenhouse experiments with partial root system Duncan and Ohlrogge (1) concluded that the small roots of young corn plants around a fertilizer band are little affected by the salt concentration that might normally exist near the band. Lehr and Brown (2), using several sources of phosphate fertilizers in an experiment with ryegrass and Sudangrass found that there was a consistent development of the roots within the fertilizer sites which included the central region composed essentially of crystalline calcium phosphates. Their petrographic studies have shown the presence of calcium phosphate crystals firmly bound to the root hairs.

Considering the high salt concentration of the solution around the band, it is a striking observation that the roots which come in contact with the fertilizer band survive and function in nutrient absorption.

There are some indications that partial root systems of corn do tolerate osmotic concentrations in soil and vermiculite which are well above the upper limit of tolerance for the whole root system (1). Just as the nutrient uptake from a fertilizer band is in part dependent upon the osmotic properties of the soil and on the solution leaving the band, a better understanding is needed of the reactions of partial root systems. This is particularly true where high nutrient concentrations are involved. Some preliminary results of greenhouse experiments conducted in this area are presented.

## Materials and Methods

Greenhouse experiments were set up to study the response of a portion of a single corn root to different phosphorus concentrations. Small cells

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were constructed for this purpose from 0.006 inch thick Mylar plastic. Each cell consisted of a small cylinder having a diameter and a length of 1.9 and 1.7 inches, respectively. At the bottom and top it was sealed with multiwax[2] impregnated cheese cloth. The top cover was made sufficiently thick so that roots did not penetrate through it. In the center of the top cover a piece of glass tube with a diameter of 0.15 inch and a length of 0.6 inch was inserted for about 0.4 inch inside the cell and sealed in place with parafin. The bottom of this 0.6 inch tube was covered with multiwax impregnated cheese cloth. Thus the cell constituted a closed system preventing moisture exchange with the surrounding medium. By varying the size and the dimension of the cell, the volume of the cell could be changed as well as the length of the root that is exposed to the medium inside the cell. In this experiment, the length of the primary root exposed to the cell medium was approximately 1.3 inches.

Expanded vermiculite (Terralite) was used as the medium inside the cell. This material was chosen because of its high porosity which facilitated straight growth of the root exposed to the medium. On the other hand, this material has the disadvantage of possible reactions with the added fertilizer.

The source of phosphorus was triple-point solution, prepared according to the procedure given by Lindsay and Stephenson (4).

Two series of treatments were used, one with 1/100 M ammonium nitrate and the other without. Each series consisted of 11 treatments with the following dilutions of a triple-point solution: 1.0, 0.5, 0.2, 0.1, 0.09, 0.08, 0.06, 0.05, 0.04, 0.02 and distilled water. The treatments were numbered from 1 to 11 respectively. Six grams of vermiculite were placed in each cell and then saturated with 19 cc of the above indicated solutions.

The experiment was set up in a completely random design with four replications. Tin cans having a diameter of approximately 6 inches and a depth of 7 inches were used. These cans were lined with polyethlene plastic bag and filled with water-soaked vermiculite. Two cells were then placed in each tin can at a depth of about 2 inches. Three-day old corn seedlings of the single cross WF9 x 38-11, which had primary roots with a length of about 1 inch were planted with the first quarter of an inch of the primary root tip trained into the glass tube of the cell, and vermiculite was placed on top of the cell and around the seedling. Through each cell only a single root was trained. This root was able to grow through the wax impregnated cheese cloth without apparently "breaking the seal" of the system. Only seedlings with healthy primary roots which were growing straight downward were used.

The remainder of the root system outside the cell was fertilized with a total of 300 cc Hoagland solution minus phosphorus.

Twenty eight days after transplanting, the tops were removed and the roots washed. The roots which grew within the cells were harvested separately. The experimental results are presented as root and shoot weights, phosphorus content and reports of visual observations.

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2. Multiwax W-835, a crystalline wax produced by The Sonneborn Chemical and Refining Corporation, Chicago.

## Results and Discussion

Comparing both series (with and without nitrogen), there were no differences in the number of plant roots per treatment that grew into and through the cell. In treatments 7 to 11 of both series, the primary roots in all four replicates grew through the bottom wax layer of the cell with the exception of treatment 11 of the nitrogen series. In the last mentioned treatment, the primary roots in three of the four replicates were killed. Probably toxic concentrations of $NH_4$ arising from ammonium nitrate as a result of high temperature and other prevailing conditions could cause this effect.

In treatments 4, 5, and 6 of both series, the roots penetrated and developed inside the cells. Yet, because of their limited growth they did not grow out through the bottom of the cells. With the nitrogen treatments the portion of the primary roots that developed inside the cell were from ½ to 1½ inches long. Though the roots in treatment number 6 reached a length of 1½ inches, it appeared that they did not have the ability to penetrate through the lower wax layer of the cell. In the no nitrogen series, the primary roots grew to a length of approximately ½ to 1 inch inside the cell.

In treatments 1, 2, and 3 of both series, the primary root tip died. Short healthy appearing lateral roots were observed on the primary root at about 3 mm from the tip by use of 20 power binoculars. These lateral roots, as well as the portion of the primary root behind the tip, were densely covered with root hairs on which salt crystals were observed. Apparently the rapid growing primary root tip was killed as a result of contact with the concentrated medium. The lateral roots which developed later, could tolerate the prevailing conditions probably through a process of adjustment, which may be associated with a slower growth rate.

The nitrogen series showed much more root development inside the cell (Figure 1.). They also had a higher order of root branching. Considering treatments 7 to 10 in both series, the roots in the nitrogen series showed the presence of third- to fourth-order of branching while in the no nitrogen series showed only first order of branching except for treatment 10 which showed second order of branching. The blank treatment (treatment 11) without nitrogen showed a first order of branching and with nitrogen it attained a second order of branching. This is in accordance with the observations of Duncan and Ohlrogge (1).

At lower concentrations of the triple-point solution there was a greater degree of root development when nitrogen was applied. However, there is no apparent explanation for the relatively greater root growth in treatment 7 as compared with treatments 8 and 9 in the nitrogen series. The difference in root growth between treatment 6 and 7 of the nitrogen series and 9 and 10 of the no nitrogen series is distinct and striking. The role of ammonium nitrate in increasing the tolerance of the primary root for lower triple-point dilutions, is not understood and is being studied. It should be mentioned here that the aeration inside the cell might have considerable influence on the root development within the cell.

From a comparison of the total dry weights of the plants (minus the portion of the roots which grew inside the cell) it is apparent that

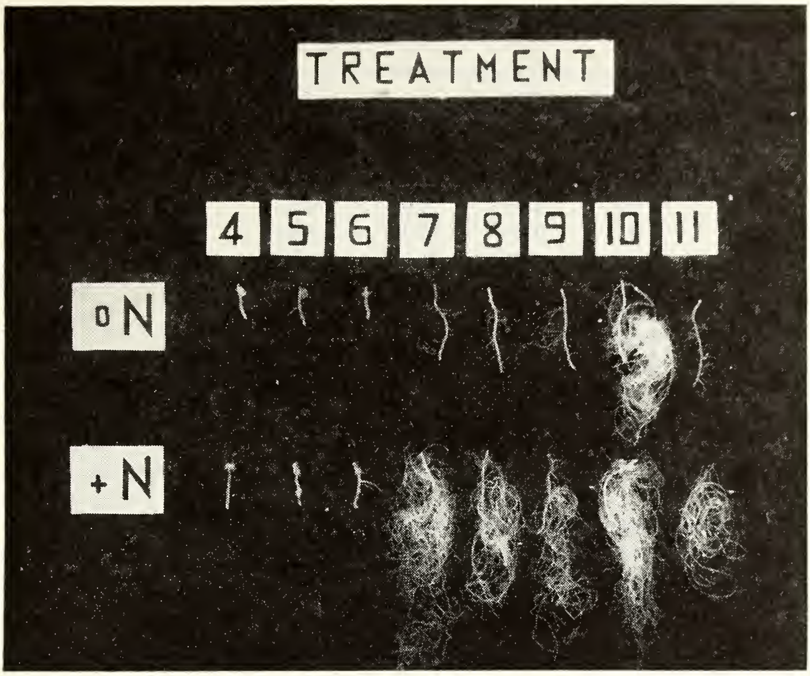


Figure 1

Table 1. Dry weight of root, shoot and total expressed in grams per plant.

| Series | Plant part | Treatment Number | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| O N | Shoot | 0.51 | 0.44 | 0.44 | 0.63 | 0.50 | 0.61 | 0.68 | 0.64 | 0.63 | 0.74 | 0.40 |
| | Root | 0.41 | 0.42 | 0.39 | 0.45 | 0.39 | 0.48 | 0.48 | 0.49 | 0.50 | 0.60 | 0.36 |
| | Total | 0.92 | 0.86 | 0.83 | 1.08 | 0.89 | 1.09 | 1.16 | 1.13 | 1.13 | 1.34 | 0.76 |
| + N | Shoot | 0.46 | 0.46 | 0.45 | 0.53 | 0.64 | 0.64 | 0.68 | 0.72 | 0.76 | 0.70 | 0.40 |
| | Root | 0.41 | 0.41 | 0.40 | 0.51 | 0.53 | 0.53 | 0.52 | 0.58 | 0.57 | 0.55 | 0.36 |
| | Total | 0.87 | 0.87 | 0.85 | 1.04 | 1.17 | 1.17 | 1.20 | 1.30 | 1.33 | 1.25 | 0.76 |

applied phosphorus enhanced plant growth. Though root development within the cell was limited under the conditions of treatments 1, 2, and 3, there was a marked yield response to phosphorus.

In the case of treatments 6 through 9, there was a marked yield response to nitrogen. This response was greatest for treatment 9. In the no nitrogen series, the maximum response was shown in treatment 10.

The phosphrous content of roots and shoots seemed to be correlated with the extent of root development within the cells. The greater the amount of root development the higher the phosphorus content. Phosphorus content for all treatments exceeded that of the blank (Table 2.).

Table 2. The phosphorus concentration in shoot and roots, and the total amount of phosphorus per plant.

| Treatment Number | + N % P Shoot | Root | Total P in mg/plant | O N % P Shoot | Root | Total P in mg/plant |
|---|---|---|---|---|---|---|
| 1. | 0.05 | 0.04 | 0.79 | 0.05 | 0.02 | 0.68 |
| 2. | 0.04 | 0.05 | 0.69 | 0.05 | 0.02 | 0.60 |
| 3. | 0.06 | 0.03 | 0.98 | 0.06 | 0.02 | 0.69 |
| 4. | 0.07 | 0.04 | 1.14 | 0.06 | 0.02 | 0.92 |
| 5. | 0.08 | 0.04 | 1.46 | 0.05 | 0.02 | 0.66 |
| 6. | 0.08 | 0.03 | 1.34 | 0.06 | 0.02 | 0.92 |
| 7. | 0.50 | 0.15 | 8.30 | 0.08 | 0.02 | 1.27 |
| 8. | 0.33 | 0.11 | 6.02 | 0.10 | 0.03 | 1.58 |
| 9. | 0.26 | 0.09 | 5.07 | 0.11 | 0.04 | 1.77 |
| 10. | 0.37 | 0.14 | 6.71 | 0.25 | 0.07 | 4.74 |
| 11. | 0.04 | 0.03 | 0.54 | 0.05 | 0.02 | 0.54 |

This uptake was quite striking even where there was little root development (treatments 1, 2, and 3). Perhaps passive absorption of phosphorus by the damaged primary root tip was involved here. Likewise, contact exchange between root hairs and salt crystals could have been involved.

The higher phosphorus uptake at higher phosphorus concentrations in the presence of nitrogen indicates that nitrogen increased the tolerance of roots to this environment. Thus, it appears that not only the total salt concentration but also complementary nutrients effect root growth and function. Treatments 7, 8, and 10 of the nitrogen series showed a P concentration of above 0.3 percent which represents luxury consumption. There seems to be no logical explanation for the phosphorus content maximum under the conditions of treatment 7 where nitrogen was applied.

## Summary and Conclusions

A growth cell for single corn root was devised to study the response of single corn roots to different nutrient concentrations.

The primary roots of young corn plants showed little or no root development in a vermiculite media containing a phosphorus solution approaching the concentration of a triple-point solution.

The presence of small amounts of ammonium nitrate mixed with triple-point solution, increased the tolerance of the primary corn root to lower dilutions of the triple-point solution.

A small portion of the primary corn root in contact with the appropriate media can supply the phosphorus needed by the young corn plant.

## Literature Cited

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