Proceedings of the Iowa Academy of Science

Volume 56 | Annual Issue Article 26

1949

# Soil Aeration in Relation to Growth of Tomatoes

Herman Wiebe

# Soil Aeration in Relation to Growth of Tomatoes

By HERMAN WIEBE

It is a well known fact that forced aeration is beneficial, even essential for plants growing in solutions. It has also been reported beneficial for soil grown plants on various occasions. However, these reports are usually based on the appearance and yield of the mature plants. Information on the plant responses to aeration throughout the growing period is more limited. Clark and Shive in 1932 found that tomatoes grown in nonaerated nutrient solutions started flowering and fruiting somewhat earlier than the aerated controls, although later the aerated plants gave a much greater yield of fruit. Durell in 1941, also working with tomatoes in solution cultures, reported that at the beginning of fruiting the yield from aerated and nonaerated plants was about the same, but that later the aerated plants greatly surpassed the others in the total yield of fruit. These reports suggest that aeration is not equally beneficial at all stages of growth. It therefore seemed desirable to conduct an experiment with plants growing in soil to find the effect of aeration at early and late stages of the ontogeny of the tomato.

Since some workers have also noted an inter-relationship between aeration and the form of nitrogen supply, it was decided to include the form of nitrogen as another variable. Thus there were four groups of experimental plants, as follows:

$NH_4$ n, received solution containing ammonium nitrogen; not aerated.
$NH_4$ a, received solution containing ammonium nitrogen; aerated.
$NO_3$ n, received solution containing nitrate nitrogen; not aerated.
$NO_3$ a, received solution containing nitrate nitrogen; aerated.

There were 24 plants in each group. Seeds of the Pan American variety of tomato were sown in sand flats on February 20, 1948. On March 9, on the appearance of the first true leaves, the seedlings were transplanted to eight inch clay pots containing a mixture of equal parts sand and loam soil. Two plants were grown in each pot. Uniform aeration was accomplished by forcing air through pumice blocks. Pieces of pumice roughly four centimeters in diameter were fitted with glass tubes. When the pots were filled with soil these blocks were placed near the bottom of the pots and in such a way that the tube projected over the edge of the pot. Air was supplied by a compressed air line, and was bubbled through wash bottles.

These served to humidify the air and allow regulation of the rate of flow. Aeration was continuous, at the rate of about three liters per plant per hour.

In addition to regular watering, the plants were given measured amounts of nutrient solutions once a week. The ammoniacal solution contained the following salts per liter:

286mg $(NH_4)_2SO_4$, 214mg $MgSO_4$,
107mg $CaCl_2$, 143mg Ca $(H_2PO_4)_2$,
107mg $KH_2PO_4$, 107mg $K_2SO_4$.

The nitrate solution contained the following salts per liter:

286mg $Ca(NO_3)_2$, 214mg $MgSO_4$,
107mg $Ca(H_2PO_4)_2$, 72mg $K_2SO_4$,
72mg $KH_2PO_4$.

Microelements were also added to each solution. Each plant received a total of 2.1 liters solution during the experiment. Since larger amounts of certain mineral elements were later recovered from the plants, it is evident that the plants also drew upon the salts contained in the soil.

The plants were grown in a greenhouse, with temperatures at 24° C during the day and 16° C at night. During the warmer days of May and June the temperature occasionally rose to 30° C for brief periods. Weekly measurments were taken of stem height, the number of nodes, leaves, flowers and fruits.

Half of the plants were sampled on April 26, nine weeks after sowing the seed, when the plants were at the height of vegetative enlargement and early anthesis. The remainder were sampled at maturity or mid-fruiting, at the age of 17 weeks. Fresh weights of shoots, fruits, roots and total dry weight were recorded. Three composite samples from each group were preserved for the analysis of carbohydrate and mineral content.

## Results

Plants fertilized with nitrate solution grew faster during the first month than those given ammoniacal solution, and retained this lead until anthesis. (Figure 1.) Within each form of nitrogen treatment the nonaerated plants grew faster during the early vegetative period than aerated plants. During and after anthesis there was little difference in the stem height among plants of the different series, excepting for nonaerated ammoniacal plants. These were somewhat elongated at maturity, while at the same time they had fewer nodes and leaves than the others. Number of nodes, leaves,

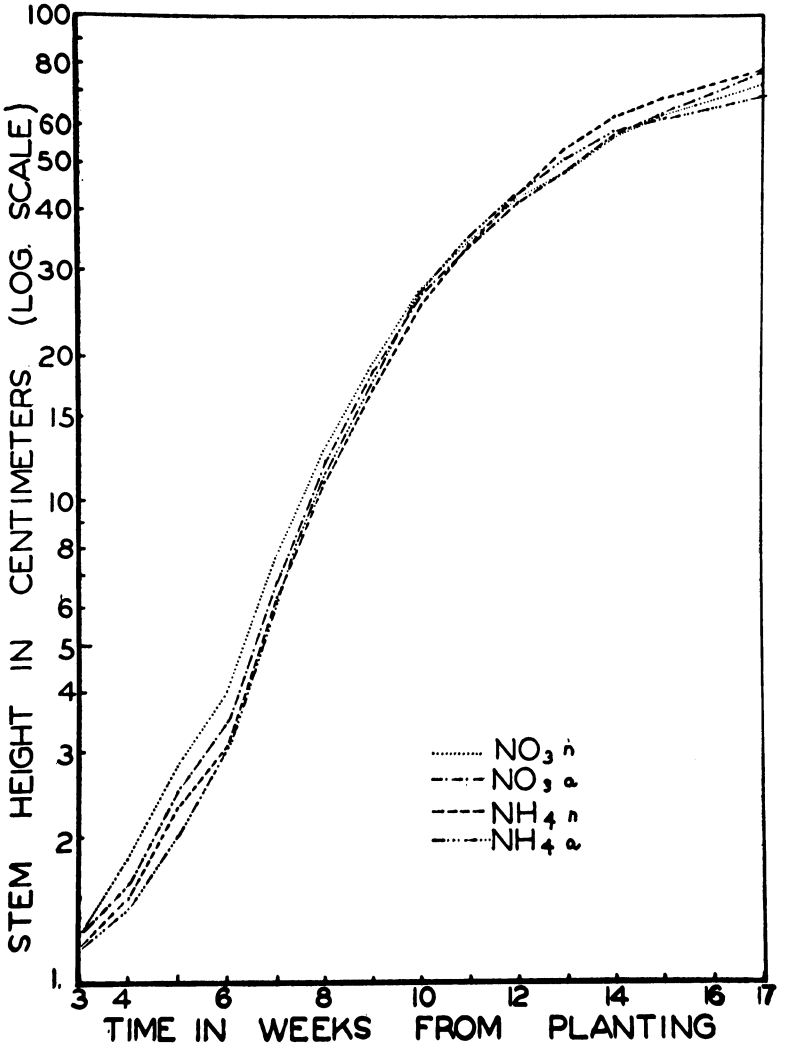


Figure 1. Growth of tomatoes in soil under different forms of nitrogen fertilization (nitrate or ammoniacal) and aeration. "a" indicates aeration; "n" — nonaerated.

and flowers did not vary greatly among the different groups. All plants began flowering at about the same time.

In comparing plants given ammoniacal solution with those given nitrate solution, it must be remembered that these solutions were added to soil which itself contained more than one form of nitrogen. Nitrogen added as solution totaled 130 milligrams per plant, but at least 250 milligrams were recovered per plant by chemical

analysis. Thus a considerable fraction of the total nitrogen, in undetermined form, was supplied by the soil.

Aerated ammonia plants yielded much more fruit than aerated nitrate plants, although the latter had a much higher yield of vegetative tissue and a greater total dry weight. (Table 2; Figures 2 and 3).

**Table 1**

Weights of plants at two stages of their development. Weights are in grams.

| Series | fresh weight | f. w. veg. tops. | f.w. fruits | f. w. roots | Top/ Root | VT/R | dry weight |
|---|---|---|---|---|---|---|---|
| At anthesis, age nine weeks. | | | | | | | |
| $NH_4$ n | 43.6 | 30.3 | — | 13.3 | 2.31 | — | 5.68 |
| $NH_4$ a | 41.5 | 29.7 | — | 12.3 | 2.35 | — | 5.60 |
| $NO_3$ n | 47.3 | 32.8 | — | 14.5 | 2.30 | — | 6.44 |
| $NO_3$ a | 40.5 | 29.3 | — | 10.5 | 2.64 | — | 5.46 |
| At maturity, age seventeen weeks. | | | | | | | |
| $NH_4$ n | 147 | 80.7 | 32.7 | 34.0 | 3.34 | 2.38 | 23.3 |
| $NH_4$ a | 181 | 78.0 | 69.7 | 33.5 | 4.41 | 2.33 | 25.5 |
| $NO_3$ n | 155 | 87.3 | 31.0 | 36.3 | 3.30 | 2.40 | 24.1 |
| $NO_3$ a | 165 | 89.7 | 26.7 | 48.3 | 2.51 | 1.86 | 30.8 |

VT/R — Ratio of stems and leaves (vegetative tops) to roots.
Top/Root — Ratio of stems, leaves and fruit to roots.

At the conclusion of the experiment the pH of the soil extract of $NH_4$ cultures averaged 5.8, with little variation among the different pots. The pH of $NO_3$ cultures was 6.3. This difference suggests the physiological acidity often developed in solution cultures containing ammonium salts as the source of nitrogen.

In comparing aerated and nonaerated nitrate plants at maturity, it was found that the aerated plants consistently had higher fresh and dry weights and lower top root ratios. The converse was true at anthesis, the nonaerated plants being distinctly heavier in terms of both fresh and dry weight at that time. Also the nonaerated plants were taller before anthesis, particularly during the first month.

Among plants given ammoniacal solution the most noticeable effect of aeration was a great increase in the yield of fruit. Fresh and dry weights were generally greater and vegetative top root ratios lower among the aerated plants at maturity. At anthesis however, it was again noticed that nonaerated plants produced a greater yield of vegetative material. This difference in yield at

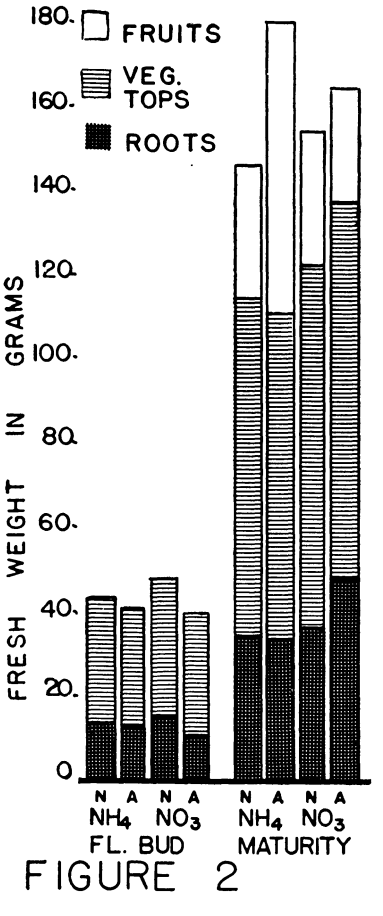


FIGURE 2

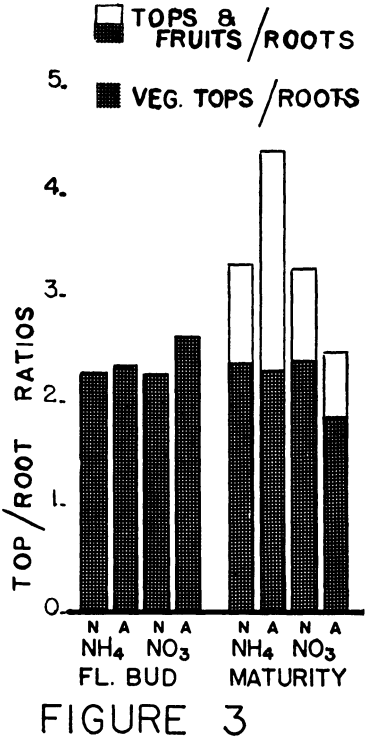


FIGURE 3

Figure 2. Fresh weights, in grams, at flower bud or early anthesis and maturity, of roots, stems, and fruits of soil-grown tomatoes under different forms of nitrogen fertilization and of aeration.

Figure 3. Ratios of vegetative tops to roots, and of vegetative tops and fruits to roots at early anthesis and maturity.

anthesis, which is shown in Figure 2 where each value is based on the average of twelve plants, was even more pronounced when the weights of each plant were compared. Only 15 percent of the aerated plants were as large at anthesis as the smallest of the non-aerated plants.

The detrimental effect of aeration during vegetative growth was primarily on the roots. At anthesis they weighed less among non-aerated plants, and the top/root ratio was higher among these plants. By maturity aeration had become beneficial, aerated plants

having heavier roots and lower vegetative top/root ratios than the corresponding nonaerated plants. The total top/root ratio was high among aerated ammoniacal plants because of the greater yield of fruit. These results agree well with those of Clark and Shive, 1932, and of Durell, 1941. Both found that nonaerated tomatoes in solution cultures came to fruit sooner than aerated ones. We might conclude that the earliest and highest yields could be obtained by beginning forced aeration at the height of vegetative growth rather than early in the growth of the plants. Another experiment in which the plants were sampled at several stages during vegetative growth should yield valuable information.

## Summary

Tomato plants growing in soil were fertilized with either ammoniacal or nitrate salts. Half of the plants in each group received forced aeration.

1. Forced aeration was detrimental during early vegetative growth, but decidedly beneficial after anthesis. The influence of aeration seemed to be exerted primarily on the roots.
2. Plants fertilized with nitrate salts made better vegetative growth, while those fertilized with ammoniacal solution gave a greater yield of fruit.
3. Soil of cultures fertilized with ammoniacal solution was more acid at the conclusion of the experiment than soil of cultures given nitrate solution.

I wish to express my appreciation to Professor Walter F. Loehwing for suggesting this study and for his kindly interest and assistance throughout the progress of the work.

### Literature Cited

1. Clark, H. S., and Shive, J. W. Influence of continuous aeration on the growth of tomato plants in nutrient solutions. Soil Science 34:37-42. 1932.
2. Durell, Wm. D. Effect of aeration on the growth of tomatoes in nutrient solutions. Plant Physiology 16:327-341. 1941.