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Effects of Ammonium and Nitrate Nutrition on Floral Initiation of Tomato Plants

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There has been extensive work on the relationship of temperature, photoperiod and nitrogen supply to the time required to bring a plant from the vegetative to the reproductive phase. This investigation was designed to ascertain whether any differences existed between the time required for the initiation of the first floral primordia in tomato plants when treated with a nutrient solution containing all available nitrogen in the ammoniacal form as compared to a nutrient solution where all available nitrogen was in the nitrate form.

Methods

Seeds of tomato plants, Pan American variety, were planted in sterile sand on June 27, 1951. These seeds were covered to a depth of approximately one-eighth inch and allowed to germinate under greenhouse conditions. Plants which germinated earlier or later than this date were removed from the sand flat in order to keep the experimental plants as uniform as possible. The seedlings were watered daily with distilled water and weekly with nutrient solution. Those plants which were to be used in the ammoniacal (NH_4) series were treated with the nutrient solution containing all available nitrogen in the ammonium form and likewise those to be used in the nitrate (NO_3) series were treated with a nutrient solution where all available nitrogen was in the nitrate form (Table 1).

Table 1
NUTRIENT SOLUTION
Grams per 10 L.

Compound	NO_3 Solution	NH_4 Solution	Concentration (%) NO_3	NH_4
KNO_3	0.143		0.00143	
$Ca(NO_3)_2$	0.571		0.00571	
$(NH_4)_2SO_4$		0.553		0.00553
$CaSO_4$		0.474		0.00474
KH_2PO_4	0.143	0.143	0.00143	0.00143
$MgSO_4$	0.143	0.143	0.00143	0.00143
KOH		0.079		0.00079
Total	1.000	1.392	0.01000	0.01392

*Micro elements were added.

On July 18, 1951 ten plants were transplanted into each of four glazed earthenware jars of two gallon capacity. Two of these jars were filled with inert quartz gravel (G) and the remaining two were filled with pumice (P) one-half inch in diameter. The jars containing pumice were capped with one inch of quartz gravel to prevent algal growth. One jar filled with gravel and one jar filled with pumice was supplied with a modified Knop's solution with all available nitrogen as nitrate. The remaining two jars were supplied with a nutrient solution where all available nitrogen was in the ammoniacal form (Table 1).

The nutrient solution was changed once a week and between changes distilled water was added when needed. The pH of the nutrient solution was adjusted to 6.2 when added. Continuous aeration was employed through-out the experiment. Each week the pH of the residual nutrient solution, number of nodes, appearance of the apical meristem and the general condition of the plants were noted. At each period of observation three plants were utilized in dissecting the meristem, except during the last period where only one plant was available.

Results

Gravel NH_4 Series

The tomato plants in this series were comparable to those of the other three series during the early portion of the experiment. At

Fig. 1. Appearance of plants at the age of 76 days. Legend: G indicates gravel substrate; P, pumice subtrate; NH_4, all available nitrogen as ammonium; and NO_3, all available nitrogen as nitrate.

the end of 76 days, when the experiment was terminated, the plants in this series had become dwarfed, spindly and the lower leaves were chlorotic and fired. The total height attained by this plant was 5.9 cm. (Fig. 1 and 4).

The first nine nodes or leaf primordia were initiated at the rate of approximately one every three days. The following primordia required an interval of approximately eleven days to initiate. After the ninth node was initiated, the plants in this series appeared to be retarded in growth and development (Fig. 3). At the age of 46 days no floral primordia could be observed, however, at 76 days the single remaining plant had initiated the floral primordia at the eleventh node (Fig. 2 and 3).

The shape of the vegetative apex was relatively flat or slightly convex (Fig. 2). No observations were made in this series during the transition of the apical meristem from the vegetative to the reproductive phase.

The shift in pH of the residual nutrient solution was abrupt at first from 6.2 to 4.4 and remained low, showing a slight rise to 4.6 at the termination of the experiment (Fig. 5).

Gravel NO_3 Series

The plants in this series attained a total height of 44.8 cm. and showed no adverse effects of experimental treatment, as the plants of the G-NH_4 series (Fig. 1 and 4). The first fourteen nodes were initiated at the rate of approximately one every three days. The initiation of the following nodes required a period of five days. The floral primordia appeared at the eleventh node. (Fig. 2 and 3).

The shape of the vegetative apex was relatively flat up to the ninth node, then it became deeply humped by the tenth node and the floral primordia was initiated at the eleventh node. After this period, the vegetative apex remained highly domed (Fig. 2).

At the time of, or immediately following the initiation of the floral primordia, there was an increased growth in the elongation and diameter of the stem and foliar development. No lateral bud development was observable prior to floral initiation. The shift in pH of the residual nutrient was gradual at first rising from 6.2 to 6.8 and following floral initiation dropped to 6.0. By the end of the experiment the pH rose to 6.2 (Fig. 5).

Pumice NH_4 Series

There was little difference in the appearance of the plants in this series as compared to those of the G-NO_3 series. The total height attained by the plants in this series was 49.8 cm. (Fig. 1 and 4).

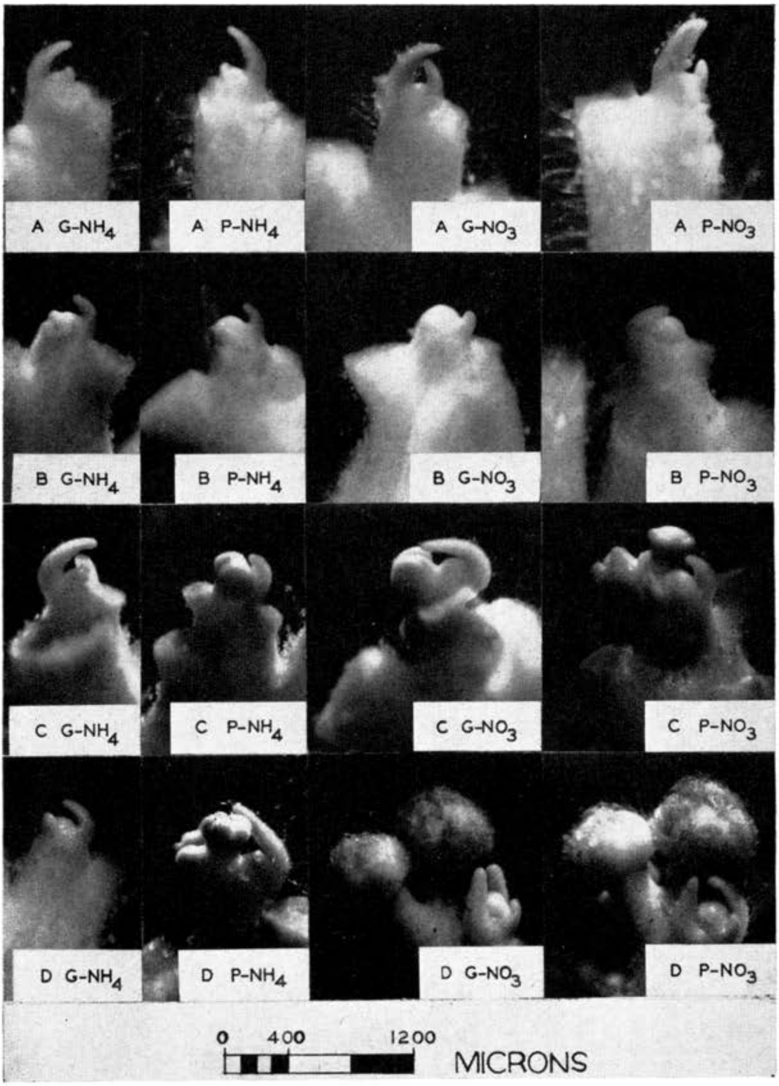

Fig. 2. Nodal initiation. Legend: A, B, C, and D indicate age of plants; G, gravel substrate; P, pumice substrate; NH_4, all available nitrogen as ammonium, and NO_3, all available nitrogen as nitrate.

Series A, age 22 days; number of nodes 7 in each.
Series B, age 32 days; number of nodes 9 in G-NH_4, 10 in P-NH_4, and 11 in both G-NO_3 and P-NO_3.
Series C, age 39 days; number of nodes 9 in G-NH_4, 13 in P-NH_4, and 14 in both G-NO_3 and P-NO_3.
Series D, age 46 days; number of nodes 9 in G-NH_4, 14 in P-NH_4, and 15 in both G-NO_3 and P-NO_3.

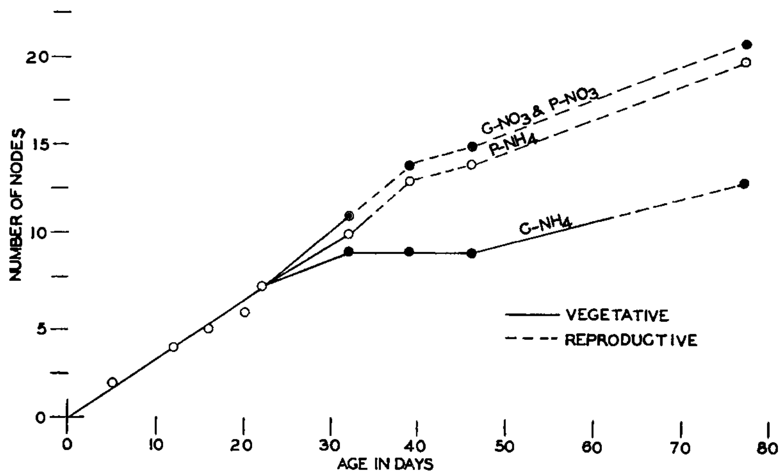

Fig. 3. Rate of node initiation in the various series.

The first ten nodes were initiated at the rate of approximately one every three days. Primordia following this period required five days to appear. The first floral primordia appeared at the eleventh node (Fig. 2 and 3). The transition of the plant from the vegetative to the reproductive phase and conditions following the transition were essentially the same as those described for the $G\text{-}NO_3$ series. The shift in pH of the residual nutrient solution was

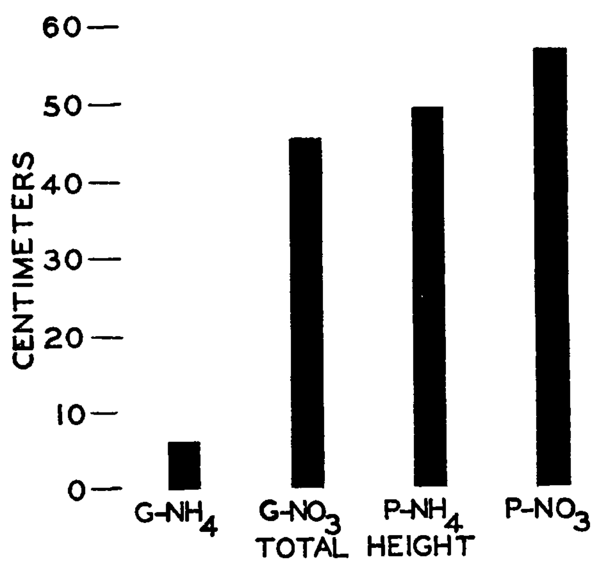

Fig. 4. Total height of plants at the age of 76 days.

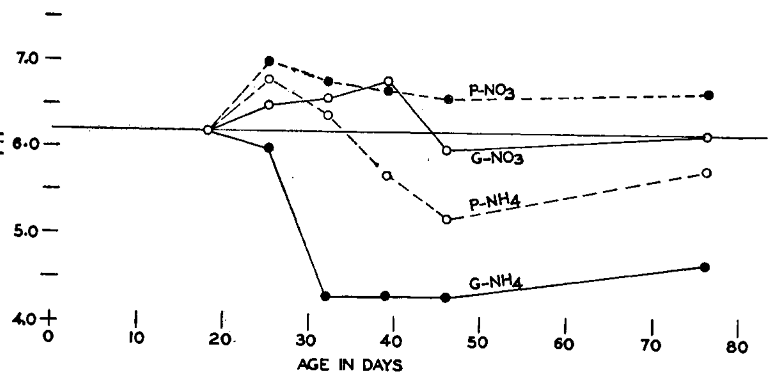

Fig. 5. The shift in pH of residual nutrient solutions.

abrupt, at first rising from 6.2 to 6.8 then dropping to 5.2. By the end of the experiment the pH rose to 5.8 (Fig. 5).

Pumice NO_3 Series

The plants in this series in respect to general appearance, the rate of nodal initiation, the point at which the first floral primordia appeared and the transition from the vegetative to the reproductive phase was very much like that of the plants in the G-NO_3 series (Fig. 1, 2 and 3). The total height of the plants in this series was 57.3 cm. (Fig. 4).

The shift in the residual nutrient solution was abrupt, at first rising from 6.2 to 7.0, gradually decreasing to 6.6 and rising to 6.7 by the end of the experiment (Fig. 5).

Discussion

It is clearly indicated that the tomato plants in the G-NH_4 series were retarded in their floral development as compared to the remaining three series (Fig. 2 and 3). The critical point in the development seemed to lie between the seventh and ninth nodes, just prior to the floral initiation at the eleventh node. The rate of node formation in all series was comparable until the ninth node, then the rate of formation decreased in all series. The greatest decrease was exhibited in the G-NH_4 series with a smaller decrease, however, the same in the remaining series (Fig. 3).

The appearance of the floral primordia at the eleventh node was specific in all series irrespective to the plastochron. The plastochron is the period between the initiation of two successive primordia.

The shape of the apical meristem during the vegetative phase was relatively flat in all series up to the time just prior to the initiation of the first floral primordia. At this time the meristem became highly dome shaped and the vegetative apex appeared to remain dome shaped even after the initiation of the floral primordia (Fig. 2). During this period of early floral initiation, it was noted that the stem diameter and elongation, and foliar development was increased markedly. This suggests that the condition of the apical meristem reflects the metabolic activities of the plant as a whole (2 and 3).

The growth and development of the tomato plants in the series P-NH_4, G-NO_3 and P-NO_3 were comparable and did not exhibit any adverse effects of the type of nutrition supplied. However, the plants grown in the G-NH_4 series were retarded in growth and development, and did show a toxic effect to the type of nutrition supplied. These plants in the latter series became dwarfed, spindly and the lower leaves were fired and chlorotic (Fig. 1, 2, 3 and 4). The difference in growth and development in the various series was probably due to the availability of the various ions in the nutrient solution and the assimilation of these ions by the root system as affected by the pH of the solution.

It has been shown that essential ions are less available to plants at a low pH as compared to a higher pH (6) and that the assimilation of the ammonium ion is greater at a higher pH than at a lower pH, whereas the nitrate ion is assimilated more readily at lower than higher pH range (1).

The plants grown on the pumice substrate were larger than those grown on gravel substrate. This may be accounted for by the fact that the pH was generally higher in the pumice series and that pumice due to its composition may have been the source of added nutrition (4).

The shift in pH in the ammoniacal series and nitrate series of the residual nutrient solution was probably due to the uptake of the respective nitrogen ions present in the solution by the tomato plants (5). In general the pH of the residual nutrient solution in the pumice series remained higher than in the gravel series. Likewise there was less fluctuation of the pH in the pumice series indicating that there is an ionic exchange between the substrate and the nutrient solution and that pumice acts as a buffer system in preventing a sudden shifts in pH (Fig. 5).

Conclusions

Floral initiation was retarded in tomato plants grown in a nutrient solution where all of the available nitrogen was in the ammonioniacal form on a gravel substrate.

Floral initiation was not significantly retarded in tomato plants grown in a nutrient solution containing all available nitrogen as ammonium on a pumice substrate, nor in plants grown in solutions where all available nitrogen was in the nitrate form on either gravel or pumice substrates.

The first floral primordia in tomato plants is initiated at the eleventh node irrespective of the plastochron. The apical meristem is relatively flat during the vegetative phase as compared to its dome shape during the reproductive phase. There is a direct correlation between the initiation of the first floral primordia and the increased elongation and diameter of the stem as well as increased foliar development.

Pumice was found to be a better substrate on which to grow tomato plants and also acted as a buffer system in preventing abrupt shifts in pH as compared to the gravel substrate.

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