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Absorption of Nutrient Ions by the Tomato Plant at Various Stages of Development

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Absorption of Nutrient Ions by the Tomato Plant at Various Stages of Development[1]

By Wayne J. McIlrath

In studies with herbaceous annuals, it has often been observed that characteristic changes in metabolism and rate of growth are closely associated with certain stages in the development cycle (Loehwing, 1942, 1948, 1951; Murneek, 1937; Wittwer, 1943). Of particular interest have been changes accompanying synapsis and syngamy. One of the changes following these stages appears to be a marked acceleration in the rate of inorganic ion uptake from the substrate. Such accelerations have been shown to follow floral initiation and formation of the embryo in several plants including barley (Burd, 1919), corn (Hornberger, 1882; Jones and Huston, 1914), cotton (Olson and Bledsoe, 1942) and tobacco (Vladescu, 1934). Although it has been reported that the largest increment in nutrient absorption by the tomato plant occurs during flowering and fruiting (Hester, 1938; Hester et al., 1951), this plant has apparently not been examined critically to determine whether two maxima are present within this period of stimulated uptake.

This investigation was initiated to determine whether the rate of ion absorption by the tomato plant was correlated with particular stages in development.

Material and Methods

Seeds of tomato, variety Pan America, were planted in quartz sand and the sand watered with dilute nutrient solution. On February 9, 24 days after the seeds were sown, seedlings of a uniform height of 4.5 cm. were selected and transplanted in two-gallon glazed stone jars of quartz gravel and two liters of nutrient solution. The following millimolar concentrations of salts constituted the macronutrient content of the nutrient solutions: 0.70 KNO_3, 0.52 KH_2PO_4, 0.59 $MgSO_4$, and 1.73 $Ca(NO_3)_2$. Trace quantities of boron, copper, iron, maganese and zinc were also added. At the end of the fourth week the millimolar concentrations of all macronutrient salts were doubled. The initial pH of the solution was adjusted to 6.4. Compressed air was utilized to aerate the cultures.

Additional solution or distilled water was added during the week as required to maintain nutrient ions and sufficient substrate moisture. At the end of each week the residual nutrient solution was drained from the jars and replaced with solution

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containing the salt concentrations indicated above. The ion content of the residual solution was determined utilizing the methods of Wolf and Ichisaka (1947). Ion uptake of the plants was calculated as the difference between nutrient added and that recovered in the residue.

To check the validity of this method of determining ion absorption, plants were harvested at several developmental stages and analyzed for the elements being studied. The plant material was killed at a temperature of 100° C, dried to a constant weight at 80° C in a forced-draft oven and ground to 40 mesh in a Wiley mill. Chemical analyses for calcium, magnesium, phosphorus and potassium were made by the methods of Wolf and Ichisaka (1947) and nitrogen by a modification of that of Koch and McMeekin (1924).

In determination of the absorbing efficiency of the roots, the dry weights of these organs were determined after drying as indicated above. Stem height measurements were made at weekly intervals throughout the study. To facilitate making these measurements the plants were kept pruned to a single axis.

Data and Discussion

Comparison of absorption of nutrients by the plants as indicated by plant analysis with that shown by measurement of ions lost from the nutrient solution revealed that values obtained by the two techniques were essentially the same. Thus it would appear that the method utilized in this study gave a valid index of ion absorption.

Examination of the data on nutrient uptake by the tomato plants during their development cycle showed that there were two distinct periods of accelerated absorption (Fig. 1). One of these followed the floral primordia stage and the second was at the time of and subsequent to anthesis. The floral primordia stage in this case was that time at which the flower buds of the first inflorescence were macroscopically visible, while the anthesis phase represented the time at which several flowers of this inflorescence reached full bloom. Because critical microscopic examination was not made of the reproductive structures, the exact cytological status represented by each of these two stages is not known. It can probably be assumed, however, that these stages closely approximate the phases of synapsis and syngamy of other workers (Loehwing, 1942; Murneek, 1937; Wittwer, 1943).

Although several workers have observed excretion of ions from plants at certain developmental stages (See Loehwing, 1942, 1951), this phenomenon was not observed in this experiment. There were, however, definite indications of a reduced rate of uptake of calcium and magnesium slightly prior to the floral primordia stage. A similar reduction in absorption of phosphorus occurred

slightly later, but no such response was observed for nitrogen and potassium.

The stimulated absorption subsequent to floral initiation was of about a week's duration. This was followed by a period in which there was little increase in uptake rate. At anthesis the rate of absorption was again accelerated and this rate continued to increase over a period of about two weeks. After this it was maintained at a high, fairly uniform rate through the time of fruit enlargement (Fig. 1). These periods of high ion absorption by the plant correlate well with reports of the effectiveness of fertilizer placement just preceding or during the flowering phase (Loehwing, 1942).

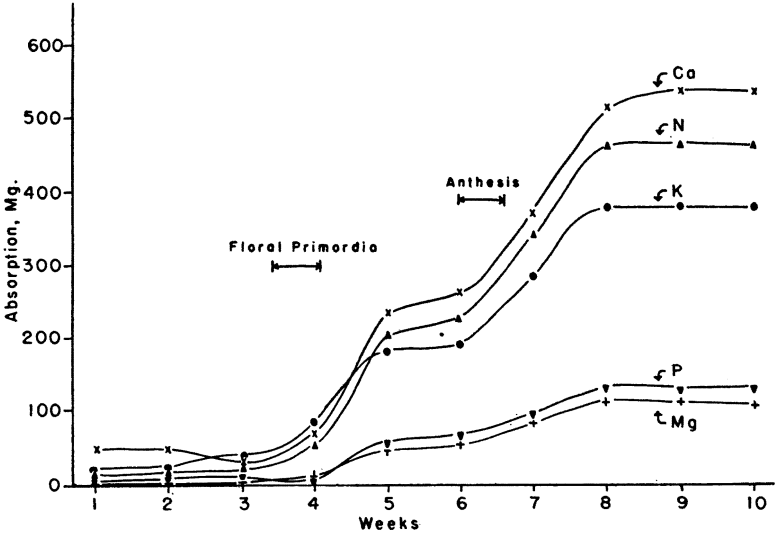

Fig. 1. Mean weekly uptake of calcium, magnesium, nitrogen, phosphorus and potassium in milligrams per plant.

The pattern of absorption was, in general, similar for all the elements checked, though the absolute quantities of each element taken up varied greatly (Fig. 1). The results of this study were in agreement with those of Hester (1938) who observed that the nutrients absorbed by the tomato in the greatest quantities were calcium, nitrogen and potassium. In terms of absolute amounts, the highest initial intake of any element was calcium. Hester (1938) observed a similar high initial uptake of this element. As has been observed in other investigations with tomato (Hester, 1938; Hester et al., 1951), it was found in this study that the greatest absorption of ions was during the fruiting stage. In general, however, the greatest efficiency of the roots in absorbing ions appeared to be in the vegetative stage of development (Table

Table 1
Ion Absorbing Efficiency of the Roots of the Tomato Plant at Various Stages of Development

Days after transplanting	Developmental stage	Milligrams/week*/gram dry weight roots				
		Ca	Mg	N	P	K
19	Vegetative	660	24	434	180	722
27	Floral primordia	352	38	263	30	426
46	Anthesis	60	13	52	15	44
59	Fruit enlargement†	70	14	60	17	50
82	Fruit maturity‡	56	11	51	14	42

*For week preceding harvest
†Mean diameter of fruit of first inflorescence 3.1 centimeters
‡Fruit of first inflorescence maturing

1). The ion absorbing efficiency of the roots continued to fall until the plants reached anthesis. Subsequent to this, during the fruit enlargement stage, there was a slight improvement in the root absorbing efficiency but this gave way to a further reduction during fruit maturation.

The trends in growth of the plant, as indicated by stem elongation, showed some similarity to those of nutrient uptake although the influence of reproductive stages upon growth were less pronounced (Figs. 1 and 2). At the floral primordia stage, for example, the slight decline in absorption of calcium, magnesium and phosphorus was accompanied by a reduction in the rate of stem growth. Following the floral primordia and anthesis stages there was an accelerated rate of stem growth as well as in ion uptake.

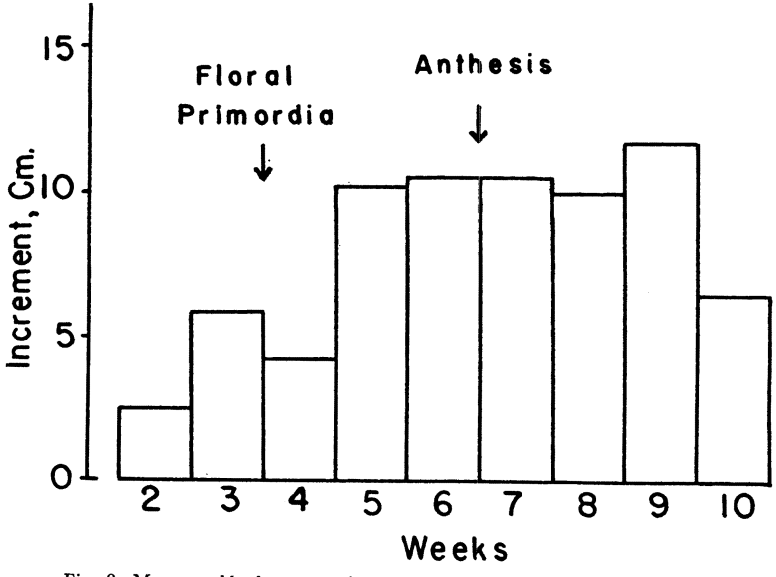

Fig. 2. Mean weekly increment in stem height per plant in centimeters.

Although the increase in ion absorption subsequent to the fourth week could possibly be credited to the increased nutrient solution concentration, this appears to be only a remote possibility. The jar residues prior to this time still contained relatively high concentrations of ions indicating that absorption up to this time was not limited by an inadequate nutrient supply. It is also possible that abrupt changes in environmental factors such as light intensity and temperature may induce changes in plant metabolism and thereby affect ion uptake and growth. Since no such changes occurred during the course of this study, it is unlikely that the periods of rapid absorption can be attributed to more favorable environmental conditions.

Summary

This investigation was undertaken to determine whether the rate of absorption of calcium, magnesium, nitrogen, phosphorus and potassium from the substrate was correlated with particular developmental stages of the tomato plant. Plants were grown in quartz gravel culture and the uptake of elements was determined by the loss of ions from the nutrient solution.

It was found that two distinct periods of accelerated absorption of all ions occurred during the developmental cycle. One followed the appearance of macroscopic floral buds while the second occurred at the time of and subsequent to anthesis. A slight reduction in the rate of uptake of calcium and magnesium was noted at about the time of floral initiation and a similar reduction was noted for phosphorus at the time of the floral primordia stage. The greatest total quantity of ions were absorbed during the fruiting stage with calcium, nitrogen and potassium being taken up in the greatest amounts.

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