THE ABSORPTION AND MOBILITY OF ROOT AND FOLIAR APPLIED CALCIUM, SULFUR, ZINC AND IRON BY TOMATO SEEDLINGS AS INFLUENCED BY GIBBERELLIN TREATMENTS

CHING-CHING CHEN[1]

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Introduction

One criterion of the effectiveness of fertilizers supplied to the plants is the degree at which the applied nutrients are absorbed by the plant translocated to other plant parts. Two distinct but not easily separated processes, absorption and transport or mobility are involved. Transport of root absorbed nutrients occurs via the xylem, while transport of foliar absorbed nutrients undoubtedly occurs via the phloem. It is apparent that the absorption, and subsquent transports of nutrients by root and foliar applications are not necessary the same. The extent of distribution (mobility, xylem and phloem transport) of each element in the plant is an important consideration both in root and foliar applications of fertilizer to satisfy nutrient needs of plants, in assaying the capacity of meristems to initiate "internal starvation" and "keying-out" nutritional deficiencies. Symptoms of malnutrition may arise from lack of mobility as well as lack of initial absorption.

Only in a few instances and with a limited number of the essential elements have rates of foliar absorption and transport been reported. As with most of the agricultural researches isotopic labeling offers a unique approach to studies of nutrient absorption, transport (export) from leaves and roots, and mobility. The rates of absorption, by tomato plants, of radioactive zinc, iron, calcium, and their subsequent mobilities and partitioning within plant parts, with special reference to the effect of gibberellin are herein presented.

Materials and Methods

A Roma tomato variety was selected as experimental plant because of its uniformity both in germination and growth. Seeds were germinated in coarse

(1) Professor and Head, Department of Horticulture, National Taiwan University.

sand in the greenhouse. After emergence of the seeds and after one transplanting in the sands, the seedling were transfered to solution cultures. Half-strength Hoagland solution was used in about 500 ml in each jar for each plant. Two days later, four groups of plants, with 15 plants in one group, received 0, 20–21, 100–105, 200–210, μg/plant of gibberellin by droplet applications to the growing point. Three more days later, all plants received the following isotope treatments:

(A) For root applications: isotopes with total activity of 10 μc were added to the nutrient solution.

(B) For foliar applications: isotope solutions with an activity of 5 μc/ml were painted on one of the healthy leaves, usually the second leaf from the base of the plant.

The radioactive isotopes, their physical and chemical characteristics and the pH of the treating solutions used are listed in Table 1. Solutions of each were prepared with the appropriate carrier at concentrations non-injurious to leaf surfaces, and at pH levels previously determined favorable for rapid uptake by Bukovac and Wittwer (1957).

Table 1. *Treating Solutions of Various Isotopes*

Isotopes	Chemical Form	pH value of Treating Solution
Ca-45	$CaCl_2$	3.0
Fe-55-59	$FeCl_3$	2.0
S-35	SO_4	3.0
Zn-65	$ZnCl_2$	3.0

At various intervals (6, 24, 48, 96, 120 hours) after treatment three plants from each of the gibberellin treatments were harvested. One of the intact plant specimens was then dried, exposed to X-ray film and autoradiogram prepared according to methods outlined by Wittwer and Lundahl. The remainder plants were sectionized or partitioned as follows:

(A) For root application of radioisotopes, the roots, stem, and leaves.

(B) For foliar application of radioisotopes, the treated leaf, non-treated leaves plus stem, and roots.

The plant parts were cut into small segments placed in 50-ml beakers, dried at 70°C for 48 hours in an oven and the dried samples were ground and wet digested with concentrated nitric acid and hydrogen peroxide, evaporated to dryness, and then assayed for radioactivity using end-window G–M tube, gas-flow or scintillation counters and standard scaler circuit. Self-absorption was found negligible for all isotopes in using the proper types of counter.

Results and Discussion

It is obvious that plants roots and foliage absorbed nutrients at greatly varying rates, (Figures 1–8 and Tables 2, 3). In some cases, foliage absorbed nutrients much more rapid than the roots did, for instance in the cases of calcium and sulfur, this is in agreement with most investigators with different crops. On the other hand, some elements such as zinc and iron, were absorbed at a less rapid rate in foliar applications than in root applications (Tables 2, 3), the reason for this was not known, since the exact mechanism of the absorption of these elements by plant cells is still not clear. As to various isotopes, some elements were absorbed faster than others, this was the case for both root and foliar applications. Furthermore, some elements were absorbed more than others in leaf application while they were absorbed lesser in root application than others, distinct example for this situation is presented in Tables 2, 3. Radiosulfur when applied to the foliage of tomato seedlings, after the absorption period of 120 hours, an activity of 12,200 cpm was recovered in all plant parts, while only 3,554 cpm was recovered for radiocalcium. In the case of root application, the reverse was true when an activity of 1,476 cpm was recovered for calcium and only 674 cpm for sulfur. The reason for this differential absorption was not known. However, it is thought, although there is no apparent evidence, that when two ions of same valence it seems there is a more favorable absorption for cations than anions in root absorption, since cations such as zinc, and calcium held the same trend in being absorbed more favorable by roots as compared with the absorption of these elements by the leaves (Tables 2 and 3).

Table 2. *Absorption and Translocation of Root Applied Isotopes by Tomato Seedlings as Influenced by Gibberellin (Absorption Period: 120 Hours)*

Gibberellin treatment	% Absorption & Translocation								Total Absorption (CPM)			
	Treated Roots				Non-treated Leaves & Stem							
	Ca^{45}	S^{35}	Zn^{65}	Fe^{55}	Ca^{45}	S^{35}	Zn^{65}	Fe^{55}	Ca^{45}	S^{35}	Zn^{65}	Fe^{55}
Checks	7.4	19.8	42.1	81.1	92.6	80.2	57.9	19.9	1,467	674	6,987	150
21μg	13.0	23.5	32.6	85.7	87.0	76.5	67.4	14.3	1,252	537	5,348	20
105μg	15.5	21.7	31.5	86.3	84.5	78.3	68.5	13.7	1,041	633	5,652	39
210μg	18.8	25.2	46.4	89.1	81.2	74.9	53.6	10.9	1,793	511	3,434	66

Time is another important factor for root and foliar absorption of nutrients and the subsequent transport of nutrients within the plant. Practically in all cases, rapid absorption and translocation of the applied isotopes occured within

Table 3. *Absorption and Translocation of Foliar Applied Isotopes by Tomato Seedlings as Influenced by Gibberellin (Absorption Period: 120 Hours)*

Gibberellin treatment	% Absorption & Translocation								Total Absorption (CPM)			
	Treated Leaf				Non-treated Leaves, Stem and Roots							
	Ca^{45}	S^{35}	Zn^{65}	Fe^{55}	Ca^{45}	S^{35}	Zn^{65}	Fe^{55}	Ca^{45}	S^{35}	Zn^{65}	Fe^{55}
Checks	97.6	96.6	68.2	80.3	2.4	3.4	31.8	19.7	3,078	12,200	38	38
21μg	98.8	97.1	90.9	82.9	1.2	2.9	9.1	17.1	2,718	7,251	198	24
105μg	99.3	97.9	98.4	87.5	0.7	2.1	1.6	12.5	2,200	7,171	90	17
210μg	99.2	97.4	96.1	88.7	0.8	2.6	3.9	11.3	1,901	8,959	228	13

48 hours after treatments were made, with the exception of the root application of radioiron in which the major portion of iron was absorbed 96 hours after treatments were made (Figures 1–8). If comparison of root absorption of calcium and iron is being made, it is easily seen that plant roots absorbed much more calcium than iron in a given period of time (Tables 2 and 3). Also, the absorption of iron was much slower than the absorption of calcium by the roots (Figures 5 and 8). This is thought to have two reasons, firstly, the plant requires more calcium than iron for its normal growth, secondly, root cells absorb and accumulate divalent cations more and faster than trivalent cations. Since the iron used in this experiment was in a form of Ferric chloride ($FeCl_3$), the uptake of the trivalent iron was accordingly at a less rapid rate.

Generally speaking, foliar absorption of calcium and sulfur is much more efficient than root absorption in terms of percent absorption. However, the subsequent translocation of the absorbed elements is not necessary the case. According to the autoradiograms shown in this report (Photo 1–21), The mobility or phloem transport of calcium is much lower than the rest of the elements studied. Bukovac and Wittwer proposed that calcium, not exported from the leaf and is considered immobile, chlorine and sulfur are readily absorbed by the leaf and are highly mobile, while zinc and iron are intermediate in their mobility or phloem export. From the gross autoradiogram studies the results of this experiment confirm previous reports by various investigators.

As to the effects of gibberellin on the nutrient absorption by plant cells. There was no significant difference between the gibberellin treated and non-treated plants. However, a trend that gibberellin depressed the absorption and subsequent translocation of nutrient did exist, and this depression was progressively noticeable as the amount of gibberellin increased (Tables 2–3).

In previous studies by the author (1961), it was found that gibberellin retard root development to a fairly great extend in terms of dry weight and root length.

Fig 1 Absorption-translocation curve for foliar application of Ca-45

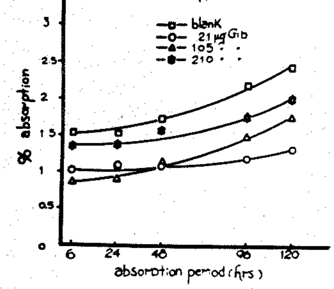


Fig 2 Absorption-translocation curve for foliar application of S-35

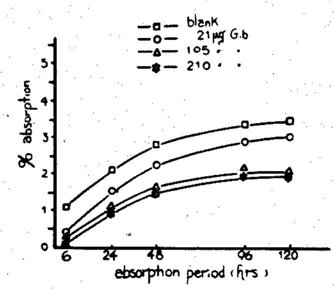


Fig 3 Absorption-translocation curve for foliar application of Zn-65

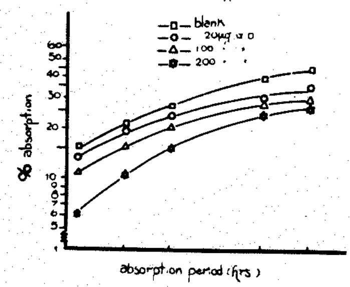


Fig 4 Absorption-translocation curve for foliar application of Fe-55

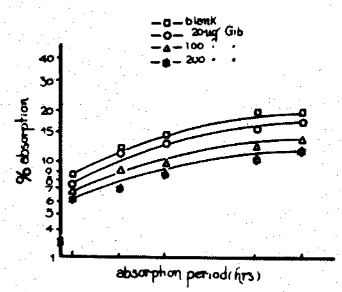


Fig 5 Absorption-translocation curve for root application of Ca-45

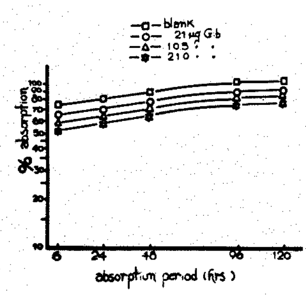


Fig 6 Absorption-translocation curve for root application of S-35

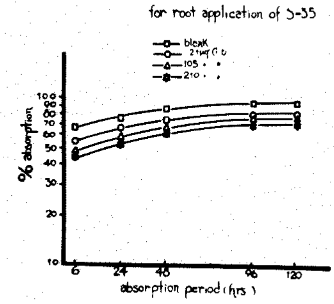


Fig 7 Absorption-translocation curve for root application of Zn-65

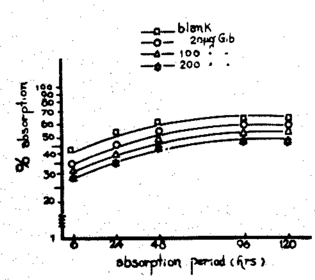
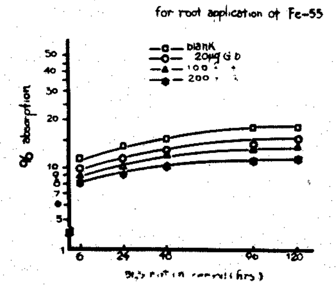
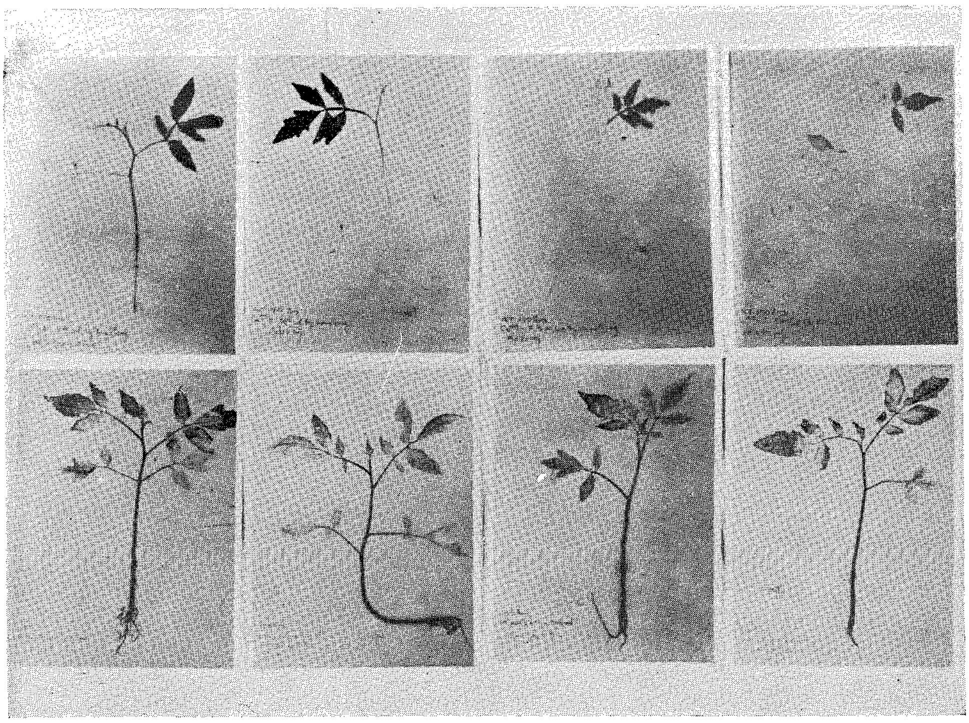


Fig 8 Absorption-translocation curve for root application of Fe-55



Photoes 1-8 Autoradiograms showing the absorption and translocation of foliar and root applied Ca-45 to tomato seedlings, 120 hours following application of the radioisotopes.

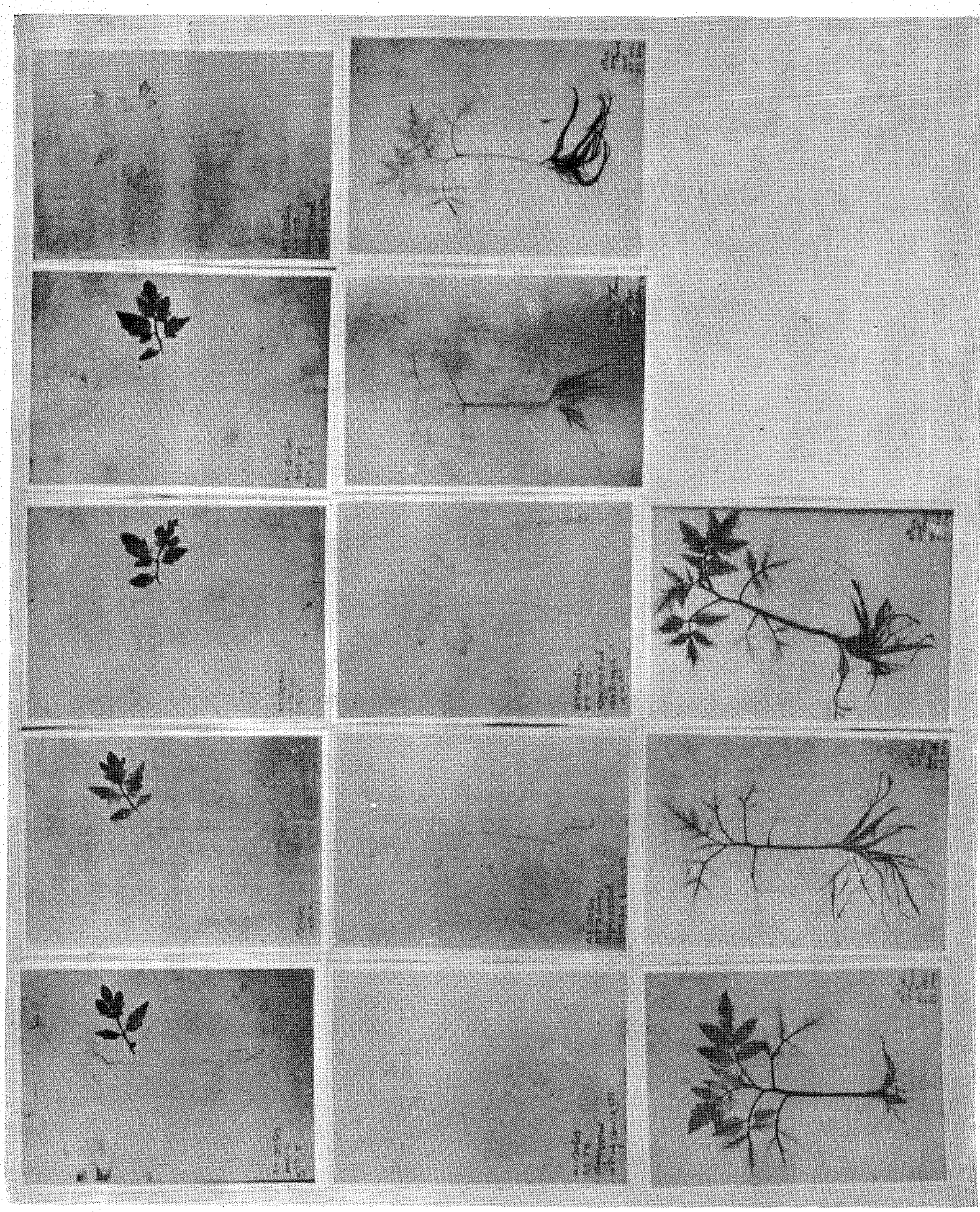


A B C D

Photoes 1-4 (upper left to right) foliar application.
Photoes 5-8 (lower left to right) root application.
A, B, C, D representing gibberellin treatments 0, 21, 105 and 210μg. respectively.

Photoes 9-21 Autoradiograms showing the absorption and translocation of foliar and root applied S-35 to tomato seedlings, 120 hours following application of the radioisotope, and autoradiograms showing the absorption and translocation of root applied Zn-65 of tomato seedlings at various absorption periods.

Order of photoes: left to right and upper to lower rows.



Photoes 9-12 foliar application of S-35, 13-16, root application of S-35, 17-21, root application of Zn-65 at 6, 24, 48, 96 and 120 hours intervals following applications.

Since greater absorption is expected only when the plant has a well developed root system, the low absorption and translocation rates were expected. The development of the root system for the plants in this experiment was not noticeably retarded by gibberellin, this is due to the fact that the plants were harvested only 5 days after the gibberellin treatments were made, it was not long enough for the plant to show any response caused by gibberellin.

Summary

1. Absorption and subsequent translocation of root and foliar applied zinc, iron, calcium, and sulfur by tomato seedlings were thoroughly studied in this investigation.

2. It is found that plant roots and foliage absorb nutrients at greatly varying rates.

3. Some elements were absorbed faster than others, this is true both for root and foliar applications.

4. Some elements were absorbed more than others in leaf application while they were absorbed lesser in root application than others.

5. Practically in all cases, rapid absorption and translocation of the applied isotopes occured within 48 hours after treatments were made, with the exception of the root application of radioiron in which the major portion of iron was absorbed 96 hours after treatments were made.

6. Trivalent iron was absorbed and translocated at a much less rapid rate than the divalent calcium ions.

7. Foliar absorption of calcium and sulfur is much more efficient than root absorption in terms of percent absorption, but the subsequent translocation of the absorbed nutrients is not necessary the case.

8. From the gross autoradiograms studies, the distribution of nutrients within the plant confirm previous reports by various investigators.

9. A trend that gibberellin depresses nutrient absorption and subsequent translocation exists although significant difference between treated and non-treated plants was not found.

Gibberellin 對蕃茄幼苗葉面及根羣施用鈣、硫、鋅及鐵吸收與運移影響

陳 慶 京[1]

(一) 本試驗係以番茄幼苗爲試材，研究鈣，硫，鋅，鐵等元素，施用於根羣或葉面之吸收及轉運情形。

(二) 植物經根羣或葉面吸收及運移營養素，各不同元素間之吸收及運移率，差別頗大。

(三) 不論施用於根羣抑或葉面，各不同元素間之吸收速率亦頗多差別。

(四) 有些元素施用於葉面時，其吸收率嘗較其他元素爲多，但如施用於根羣時，則又較其他元素爲少。

(五) 除鐵元素外，於各次試驗中，各元素均於施用後 48 小時內卽迅行吸收及轉運，但前者之吸收及轉運，則大部份均延至施用後 96 小時。

(六) 三價鐵之吸收及轉運速率，遠較二價之鈣素爲遲緩。

(七) 如以百分率計之，葉面施用營養素之吸收率，遠較根羣施用者爲有效，但其隨後之轉運率，則並不盡然。

(八) 由調查性放射圖像之觀察，各營養素於植物體中之分佈情形，尙能重證前人研究結果。

(九) gibberellin 對植物吸收及轉運營養素之影響，於各次試驗中，處理植株與非處理植株間，雖無顯著差異，但 gibberellins 有抑制植物吸收及轉運營養素之趨勢則似爲可見。

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[1] 國立臺灣大學農學院教授兼園藝系主任