SYMPTOMS OF MINERAL DEFICIENCIES (MAJOR ELEMENTS) IN ADZUKI BEAN PLANTS (*PHASEOLUS RADIATUS* L. VAR. *AUREA* PRAIN)

by

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INSUFFICIENT supply of any essential mineral element to plants always results in deficiency symptoms. Although the signs of deficiency of a given element in plants are similar in a general way, they frequently differ among different species[1,2,3]. It is therefore valuable to study the symptoms of deficiency for each species individually.

The Adzuki (Azuki) bean plant is an economic species in Taiwan as well as in other regions of the Far East. From year to year we use this familiar plant as experimental material for research and for training of our students. It is hoped that this paper will be helpful to students who are studying plant physiology in this university, and for agriculturists who are concerned with the problems of the cultivation of this bean.

MATERIALS AND METHODS

1. Preparation of plant material. Seeds of Adzuki bean were soaked in tap water for few hours and then seeded on wet tissue paper in aluminum pans (November 21, 1961). These pans were incubated in the dark at 35°C. After germination, healthy seedlings were selected and transplanted to new pans and moved to natural light condition along the corridor of second floor of Biology Building of National Taiwan University. Supplemental illumination by both incandescent and fluorescent (white, day light type) light was given.

2. Culture technique. Each seedling which had a pair of expanded first leaves (simple leaves) was planted in 250 ml tap water in a 1/4 liter capacity brownish glass container as shown in figure 1 (December 2, 1961). 165 plants were set out and maintained in the

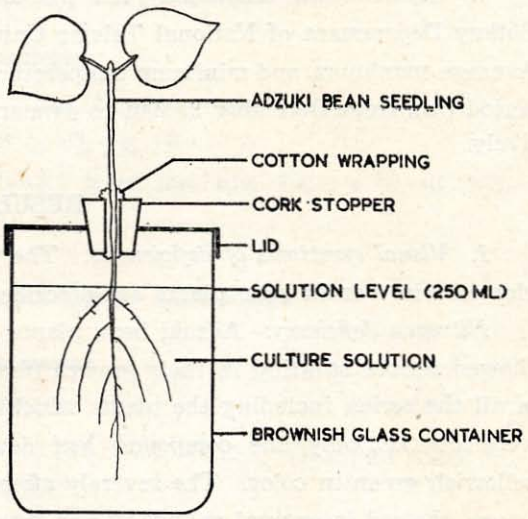

Fig. 1. Culture method used in the present experiment.

green house.

3. Composition of nutrient media. One week after transplanting to tap water (*i.e.*, on December 9, 1961), the tap water in all culture containers was replaced with various kinds of nutrient media which had the following compositions (table 1). Culture media were renewed at weekly interval.

Table 1. Composition of nutrient media*

Stock solutions	Dist. water	Tap water	Full	-K	-P	-Ca	-N	-Mg	-S	-Fe
					ml					
Dist. water	250	—	235	228.5	218.5	230	17.5	227	235	236
Tap water	—	250	—	—	—	—	—	—	—	—
1/4 M $Ca(NO_3)_2 \cdot 4H_2O$	—	—	5	7.5	7.5	—	—	5	5	5
1/4 M KNO_3	—	—	5	—	—	15	—	5	5	5
1/4 M $MgSO_4 \cdot 7H_2O$	—	—	2	2	2	2	0.5	—	—	2
1/4 M KH_2PO_4	—	—	1	—	—	1	—	1	1	1
1/20 M $Ca(H_2PO_4)_2 \cdot H_2O$	—	—	—	10	—	—	10	—	—	—
1/2 M K_2SO_4	—	—	—	—	20	—	20	10	—	—
1/100 M $CaSO_4 \cdot 2H_2O$	—	—	—	—	—	—	200	—	—	—
1/4 M $Mg(NO_3)_2 \cdot 6H_2O$	—	—	—	—	—	—	—	—	2	—
Trace elements soln.**	—	—	1	1	1	1	1	1	1	1
0.125% FeEDTA***	—	—	1	1	1	1	1	1	1	—

* The composition of Hoagland's solution on which this experiment is based is: distilled water, 1 liter; $Ca(NO_3)_2 \cdot 4H_2O$, 1.18 grams; KNO_3, 0.51 grams; $MgSO_4 \cdot 7H_2O$, 0.49 grams; KH_2PO_4, 0.14 grams; FeEDTA, 0.005 grams. The necessary trace elements are added to this.

** Trace elements stock solution: $MnCl_2 \cdot 4H_2O$, 1.81 grams; H_3BO_3, 2.86 grams; $ZnSO_4 \cdot 7H_2O$, 0.22 grams; $CuSO_4 \cdot 5H_2O$, 0.08 grams; $H_2MoO_4 \cdot H_2O$, 0.09 grams; distilled water, 4 liters.

*** A solution of an iron complex of ethylenediaminetetra-acetic acid.

4. Experimental conditions. All plants were grown in a green house of the Botany Department of National Taiwan University under natural day light and length. Average maximum and minimum temperatures of green house during this experimental period (*i.e.*, from December 2, 1961 to January 12, 1962) were 21.6°C and 15.4°C respectively.

RESULTS

1. Visual symptoms of deficiencies. The visual symptoms of various major mineral elements in Adzuki bean plants are described in the following paragraphs:

Nitrogen deficiency: Adzuki bean plants grown in a minus nitrogen culture media showed serious stunting in their growth (figure 7). They made the smallest growth of all the series, including the plants which were grown in distilled water. Leaves were few (*i.e.*, only one compound leaf developed). They were smaller, and pale yellowish green in color. The severely affected leaves, which were usually the older leaves, showed intervenal yellowing and dried to light brown from the tip and margin of the leaves (figures 7, 10-H, and 11).

Phosphorous deficiency: The plants grown in minus phosphorous nutrient media were the only of the series of plants which did not show chlorosis. The plants were as green in color as normal plants (figures 8, and 10–J). Defoliation, starting from the old leaves, was premature (*i.e.*, the defoliated leaves remained more or less green in color) (figure 8). One of the distinct symptoms of phosphorous deficiency in Adzuki bean is the development of reddish pigment at the base of the midrib of the affected leaflets (figures 9, and 10–J). The growth of shoots was poor.

Potassium deficiency: The symptoms of potassium deficiency appeared earliest among all experimental series, indicating that potassium was the most important macro-element. The deficiency symptoms induced by minus potassium always appeared first on the older leaves and gradually extended toward the younger leaves (figure 6). Necrosis appeared on veins of affected leaves in the early stages of deficiency. In the later stages, necrosis also occurred on intervenal mesophyll tissues of the blades (figure 12) and on petioles. The outstanding symptoms of severely affected leaves was the burning, or scorching. The browning, followed by scorching, began from the tip and margin of the affected blade (figure 10–I). The leaves finally died and defoliated at the base of their petioles. The growth was restricted.

Calcium deficiency: Since the calcium is known as one of the less mobile elements in plant body, the symptoms induced by the shortage of calcium appear first at the growing point and gradually extend toward the older leaves (figure 2). The death of the growing point was an outstanding characteristic (figure 2). The affected blades first showed intervenal chlorosis, followed by brown-spotting, and then died from the tip and margin of the blades (figure 10–B). They were twisted or distorted (*i.e.*, the tip were hooked and the margin curled), and finally defoliated at the base of the petiolules (figure 2). The old leaves were almost normal, but the blades were slightly rolled on the lower surface (figure 2).

Magnesium deficiency: Unlike calcium deficiency, the symptoms resulting in minus magnesium cultures appeared first on the older leaves (figure 4). The affected blades showed intervenal chlorosis and necrosis (spotting), followed by collapse and death of the mesophyll tissues (figures 10–F, 10–G, and 13). But unlike calcium deficiency, the margin and tip of the affected blades often remain green in color, although necrosis did occur sometimes on the margin but in smaller areas (figures 4, 10–F, and 10–G). Affected blades were distorted (figure 4).

Sulfur deficiency: The symptom of sulfur deficiency was observed on young leaves (figure 5). The affected leaves showed 'mosaic' chlorosis, *i.e.*, yellowing occurred between veinlets in mosaic pattern, scattering on the whole surface of the blades (figures 10–C, and 15). No abnormality could be observed in older leaves (figure 5).

Iron deficiency: The outstanding symptom resulting from iron deficiency was the striking yellowing of the younger leaves, known as 'general chlorosis', *i.e.*, yellowing or whiting occurring homogeneously all over the blades, but not in the

intervenal pattern (figures 3, 10–D, 10–E, and 16). The youngest leaf was the most severely affected leaf and was almost completely bleached. The older leaves, on the contrary, were normal (figure 3).

Full nutrient culture: The plants growing in the full nutrient media (*i.e.,* complete Hoagland's mineral nutrient solution) showed normal growth and development. The growth of both shoots and roots was the best among all series. The plants were thick, sound and green. At the end of culture (January 31, 1962), floral primordia were developed only in this series of plants (figure 1–C).

Distilled water and tap water: The growth of plants in distilled water and tap water was poor. The plants were stunted and thin. The leaves were few, small and pale green in color. On the whole, they looked like nitrogen deficiency. But unlike nitrogen deficient plants, they did not show any abnormal developement, such as dying of tissues, throughout the experiment. The growth of the plants in tap water were slightly better than those in distilled water. (figures 1–A and 1–B).

2. A key to deficiency symptoms. As described above, the shortage in each element resulted in its characteristic symptoms which could be clearly distinguished from others. The distinctions among these deficiency symptoms can be seen more clearly and easily with a key. The table 2 is the key to symptoms of the seven major mineral elements in Adzuki bean plants. This key may be used for diagnosis of mineral deficiency in Adzuki bean plants. The conclusions obtained should be checked by reference to the detailed descriptions and the colored illustrations in the text.

Table 2. Key to symptoms of nutrient deficiency (major mineral elements) in Adzuki bean plants

Symptoms	Element deficient
A. Symptoms appear first on young leaves.	
B. Affected leaves show a distorted development	Ca
BB. Affected leaves do not show a distorted development.	
C. Chlorosis intervenal in "mosaic"	S
CC. Chlorosis general, *i.e.* the entire leaf tissues become yellow or white in color	Fe
AA. Symptoms appear first on old leaves.	
B. Affected leaves show chlorosis or mottling.	
C. Affected leaves show mottling and scorching; necrosis occurs on both veins and mesophyll tissues and die from tip and margin of the blades.	K
CC. Affected blades show chlorosis.	
D. Affected leaves become pale green, drying to light brown or white in color from tip and margin of the blades.	N
DD. Affected leaves show prominent intervenal chlorosis; necrosis occurs on mesophyll tissues and die from mesophyll tissues	Mg
BB. Affected leaves do not show chlorosis; plants are as green as normal; reddish pigment appears at the base of the main vein of each affected leaflets	P

In the diagnosing process by visual method with the key, it is helpful to consider the correlation between the position of appearance of symptoms on plants and the mobility of the element which is lacking. Since magnesium, potassium, phosphorous and nitrogen are mobile elements in plant bodies, the symptoms always appear first on the basal (or older) parts of the shoots and progressively extend toward the tips or younger parts of the shoots. Iron, calcium and sulfur are less or non mobile elements, so then symptoms develop from younger regions and progress downward toward the older leaves.

SUMMARY

Deficiency symptoms of seven major mineral nutrient elements (namely: nitrogen, phosphorous, potassium, calcium, magnesium, iron, and sulfur) in Adzuki bean plants (*Phaseolus radiatus* L. var. *aurea* Prain) were described.

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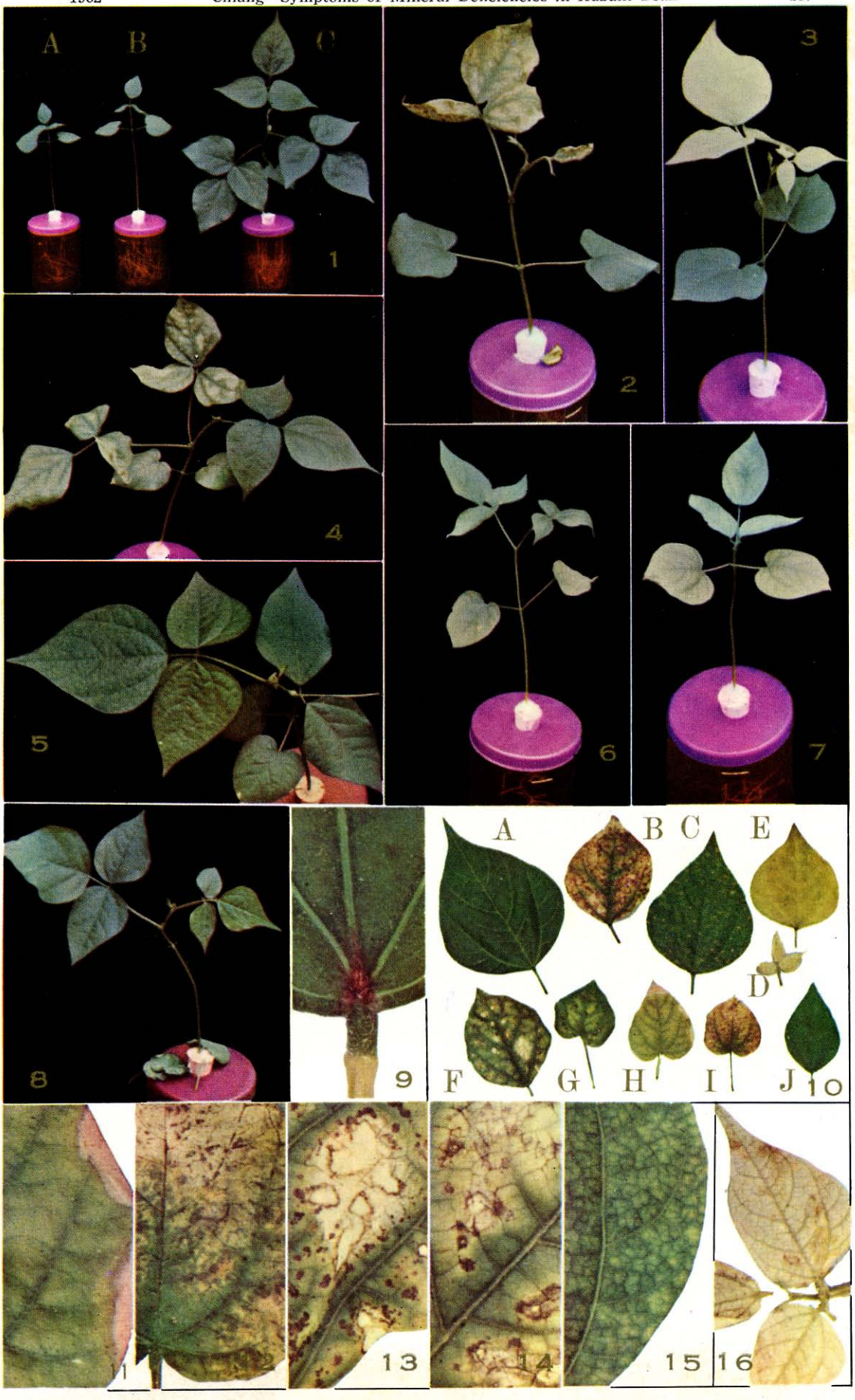
Plate I

Deficiency symptoms and figures in the plate:

Culture media	Numbers of figures
Minus Ca	2, 10-B, 14
Minus S	5, 10-C, 15
Minus Fe	3, 10-D, 10-E, 16
Minus N	7, 10-H, 11
Minus K	6, 10-I, 12
Minus Mg	4, 10-F, 10-G, 13
Minus P	8, 9, 10-J
Distilled water	1-A
Tap water	1-B
Full nutrient	1-C


A
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