SOME MINERAL DEFICIENCY SYMPTOMS IN PLANTS

JOHN SKOK

University of Chicago, Chicago, Illinois

In addition to carbon, hydrogen, and oxygen, plants need a number of mineral elements for normal growth and development. If any of these essential elements are not available to the plant, certain disturbances and usually characteristic deficiency symptoms result (1, 2, 4, 5, 7, 9, 10, 11, 14, 15, 17, 19). These essential elements are applied in the form of nutrient solutions made up of various salts (3, 6, 8, 12, 13, 16, 18). By choosing various combinations of salts any one of the elements may be absent in these solutions and such solutions are used to study deficiency symptoms.

In these experiments some mineral deficiency symptoms of three flowering plants were studied. The following plants were used: *Petunia hybridia*, var. Rosy Morn; *Salvia splendens*, var. Scarlet Dragoon; and *Phlox drummondii*. The plants were grown in clean quartz sand in two-gallon glazed earthenware pots. Nine series of each of the four plants were grown, consisting of one series which received a complete nutrient and eight series each lacking a different element. The eight deficiencies were: nitrogen, calcium, potassium, phosphorus, magnesium, sulphur, boron, and iron. The nutrient solutions were made up with distilled water and Merck's reagent quality chemicals as indicated in Table 1.

DEFICIENCY SYMPTOMS

The Complete Nutrient Plants.—The plants in this series were green, vigorous, and made good growth in general. All produced many flowers.

Nitrogen Deficiency.—The minus nitrogen plants were all stunted, spindling, pale in color, and very hard rather than succulent. The lower leaves particularly were yellow and finally dried and fell off. All the leaves were much reduced in both size and number. One Petunia plant in the nitrogen deficient series produced a flower and it bloomed eight days earlier than did the plants of the complete nutrient series. The top-root ratio of the minus nitrogen plants was much smaller than that of the complete nutrient plants.

Calcium Deficiency.—The calcium deficiency symptoms were the most severe of all the deficiency symptoms. Petunia

TABLE 1.—COMPOSITION OF NUTRIENT SOLUTIONS

	Constituents of Solutions
Complete Nutrient	$Ca(NO_3)_2$ .....0.006 molar KH_2PO_4 .....0.0045 molar $MgSO_4$ .....0.045 molar B .....0.5 p.p.m. added as H_3BO_3 Fe .....0.5 p.p.m. added as ferric citrate Mn .....0.5 p.p.m. added as $MnCl_2$ Cu .....0.125 p.p.m. added as $CuCl_2$ Zn .....0.5 p.p.m. added as $ZnCl_2$
Minus Nitrogen	$CaCl_2$ Substituted for $Ca(NO_3)_2$
Minus Calcium	$NaNO_3$ Substituted for $Ca(NO_3)_2$
Minus Potassium	NaH_2PO_4 Substituted for KH_2PO_4
Minus Phosphorus	KCl Substituted for KH_2PO_4
Minus Magnesium	Na_2SO_4 Substituted for $MgSO_4$
Minus Sulphur	$MgCl_2$ Substituted for $MgSO_4$
Minus Boron	H_3BO_3 Omitted
Minus Iron	Ferric Citrate Omitted

and Phlox showed definite symptoms five days after calcium was withheld and Salvia a few days later. The plants were stunted and pale and made no additional growth after the symptoms became evident. The top portions of the plants were affected first. The upper leaves became grayish-yellow in color and the veins turned brown. Later the veins and portions of the stems at the leaf axes became dark brown and black, and the growing tips died. Finally the entire plant including the lower leaves turned grayish-yellow and unless small amounts of calcium were added the plants died very soon. None of the minus calcium plants produced flowers unless calcium was finally added. The roots of the minus calcium plants were very dark brown in color and poorly developed.

Potassium Deficiency.—The potassium deficiency symptoms appeared about ten to twelve days after potassium was withheld. The plants were stunted and pale. The lower leaves of Petunia were wilted and some had cream colored spots which became dry giving the leaves a mottled appearance. Later all the leaves became very chlorotic and wilted. The dry leaves were light brown in color. The leaves of Salvia did not become extremely chlorotic but they were wrinkled and curled and severely scorched. The lower leaves were affected first and finally most of them fell off. The dry leaves of Salvia were also light brown in color. The leaves of Phlox were rather chlorotic and the tips of particularly the lower leaves were yellow and brown.

Phosphorus Deficiency.—All the phosphorus deficient plants were spindling, stiff, and had a very characteristic dull bluish-green color. As the deficiency symptoms progressed the leaves turned to a dull yellowish-green color. In Petunia only the first or second lower leaves became dry and fell, but in Salvia all the leaves were burned at the tips and all the lower leaves up to the fourth or fifth nodes from the bottom had dried and fallen off. The leaves were not wrinkled as they were in potassium deficient plants. The dry leaves of both Petunia and Salvia deficient in phosphorus were very dark brown in color.

Magnesium Deficiency. — Magnesium deficiency symptoms were evident within ten days after magnesium was withheld. At first the plants were only slightly stunted but the leaves were very chlorotic. The leaf discolorations varied from pale green to almost white. The veins and the areas just next to the veins usually retained a light green color. The Petunias were the most chlorotic of the magnesium deficient plants. The leaves of Salvia became dry rather than extremely chlorotic and finally all but the very uppermost leaves dropped.

Sulphur Deficiency.—The sulphur deficiency symptoms, although apparent, were not as pronounced as the others described. The sulphur deficient plants were less vigorous and bushy than the control plants and were lighter in color. The leaves were pale in general but no pronounced chlorosis or drying took place. In Petunia the lower leaves were

TABLE 2.—PETUNIA

	Average for one plant, Grams				% Dry weight entire plant	% Dry weight tops	% Dry weight roots	Wet top-root ratio	Dry top-root ratio
	Wet top weight	Wet root weight	Dry top weight	Dry root weight					
C	233.00	3.54	21.56	0.53	9.33	9.25	14.97	65.81	40.67
—N	0.47	0.23	0.12	0.06	25.71	25.53	26.08	2.04	2.00
—Ca	.....	.....	0.61	0.12	.....	.....	.....	.....	5.08
—K	3.15	0.39	0.71	0.06	21.75	22.54	15.38	8.07	11.83
—P	2.77	0.58	0.50	0.10	17.91	18.01	17.24	4.77	5.00
—Mg	.....	.....	0.38	0.07	.....	.....	.....	.....	5.43
—S	124.00	17.75	10.63	3.05	9.65	8.57	17.18	6.98	3.48
—B	4.60	0.57	0.44	0.07	9.86	9.56	12.28	8.07	6.28
—Fe	232.00	7.98	22.83	1.31	10.05	9.83	16.41	29.07	17.42

TABLE 3.—SALVIA

	Average for one plant, Grams				% Dry weight entire plant	% Dry weight tops	% Dry weight roots	Wet top-root ratio	Dry top-root ratio
	Wet top weight	Wet root weight	Dry top weight	Dry root weight					
C	176.00	61.00	28.81	6.47	14.04	15.23	10.60	2.88	4.14
—N	0.64	0.39	0.06	0.07	12.62	9.37	17.94	1.64	0.85
—Ca	6.79	4.95	1.07	0.60	14.22	15.75	12.12	1.37	1.78
—K	3.08	2.75	0.31	0.26	9.77	10.06	9.45	1.12	1.19
—P	1.02	1.90	0.17	0.16	11.30	16.66	8.42	0.53	1.06
—Mg	0.78	1.17	0.12	0.14	13.33	15.38	11.96	0.66	0.85
—S	67.00	30.00	9.47	2.66	12.50	14.13	8.86	2.25	3.56
—B	21.80	8.35	3.06	0.97	13.36	14.03	11.61	2.61	3.15
—Fe	105.00	47.00	6.94	5.60	8.25	6.60	11.91	2.23	1.23

affected more than the upper ones. Several flowers were produced by all plants. The total dry weight of the top portion of the sulphur deficient Petunia plants was about half that of the control plants, but the total root weight was almost six times greater than that of the control plants. The root weight of the sulphur deficient Salvia plants was less than half that of the control plants.

Boron Deficiency. — The symptoms caused by boron deficiency were very striking in all the plants. They were evident from eight to ten days after boron was withheld. Petunia and Phlox grew only 3 to 8 cm. in height, and produced no flower buds. In a very short time the central leaves and the growing tip became yellowish-brown to bronze in color and terminal growth stopped. Several lateral buds appeared, but before long they were similarly affected and also stopped growing. This resulted in a short greatly fasciated plant. Several boron deficient Petunia and Phlox plants died before the experiment was finished.

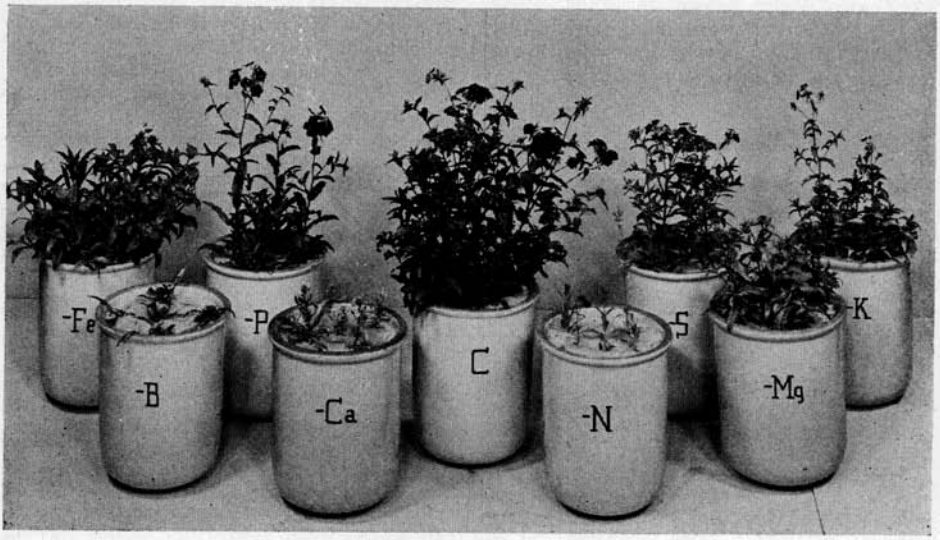

Fig. 1.—Photograph showing mineral deficiences in phlox series.

The leaves of the Petunia plants were small but thick and very brittle. They were very deformed often being curled, rolled, and stubby, and had an oily or greasy appearance. The leaves of Phlox and Salvia did not have this oily appearance. The Salvia plants had small discolored leaves but did not develop the fasciated condition as was found in Petunia and Phlox. The growing tips in all Salvia plants died, but the lateral shoots usually made considerable growth before they stopped growing. Several flower buds were produced by these lateral shoots, but the flowers were very small and poorly developed. The roots of both Petunia and Salvia were very poorly developed, coarse, and dark in color. The extremities of the roots were blunt or bulbous rather than fibrous.

Iron Deficiency.—Petunia and Salvia showed only very slight iron deficiency symptoms. Petunia was not affected in growth or general vigorousness but had a few chlorotic leaves. Salvia made less total growth when deficient in iron but the plants were not chlorotic. The sand used in these experiments contained impurities of iron which apparently was available to the plants. The iron deficient Phlox plants were grown in sand from which the iron had been removed by several treatments with hydrochloric and nitric acid. The acid treated sand was carefully leached with distilled water to remove all traces of soluble iron and acid. Phlox grown in this iron free sand were stunted and very chlorotic. The chlorotic leaves were in some cases mottled and in others very light in general. The newer leaves were particularly light. The veins of even the more chlorotic leaves usually retained their green color. No drying or leaf destruction took place in these plants.

Fresh and dry weights of the top- and root-portions of Petunia and Salvia were taken at the time of harvest. These with other data are shown in tables 2 and 3. A photograph of the Phlox series is shown in fig. 1.

LITERATURE CITED

1. Brenchley, Winifred, E. The essential nature of certain minor elements for plant nutrition. Bot. Rev. 2:173-196. 1936.
2. Gregory, F. G., Mineral nutrition of plants. Ann. Rev. Biochem. 6:557-578. 1937.
3. Hoagland, D. R. and Arnon, D. I., The water-culture method for growing plants without soil. Cal. Agr. Expt. Sta. Circular 347. 1939.
4. Jacks, G. V. and Scherbatoff, H., Soil deficiencies and plant diseases. Imperial Bureau of Soil Sci. Tech. Com. No. 31. 1934.
5. Laurie, Alex, and Wagner, Arnold., Deficiency symptoms of greenhouse flowering crops. Ohio Agr. Expt. Sta. Bull. 611. 1940.
6. Livingston, B. E. and Tottingham, W. E., A new three salt nutrient solution for plant culture. Am. Jour. Bot. 5:337-346. 1918.
7. Mazé, P., The role of special elements (boron, copper, zinc, mangonese, etc.) in plant nutrition. Ann. Rev. Biochem. 5:525-538. 1936.
8. McCall, A. G., Physiological balance of nutrient solutions for plants in sand cultures. Soil Sci. 2:205-253. 1916.
9. McMurtrey, J. E. Jr., Distinctive effects of deficiency of certain essential elements on the growth of tobacco plants in solution cultures. U. S. D. A. Tech. Bull. 340. 1933.
10. ....., Distinctive plant symptoms caused by any one of the chemical elements essential for normal development. Bot. Rev. 4:183-203. 1938.
11. Post, Kenneth, Effects of mineral-nutrient deficiencies and excesses upon the vegetative growth and flowering of sweet peas. Cornell Agr. Expt. Sta. Bull. 745. 1940.
12. Shive, J. W., A study of pnysiological balance in nutrient media. Physiol. Res. 1:327-399. 1915.
13. ....., and Robbins, W. R., Methods of growing plants in solution and sand cultures. N. J. Agr. Expt. Sta. Bull. 636. 1938.
14. ....., and Robbins, W. R. Mineral nutrition of plants. Ann. Rev. Biochem. 8:503-520. 1939.
15. Stewart, F. C., Mineral nutrition in plants. Ann. Rev. Biochem. 4:519-544. 1935.
16. Tottingham, W. E., A quantitative chemical and physiological study of nutrient solutions for plant cultures. Physiol. Res. 1:133-245. 1914.
17. Willis, L. G., Bibliography of references to the literature on the minor elements and their relation to plant and animal nutrition. 3rd ed. Chilean Nitrate Education Bureau, New York. 1939.
18. Withrow, R. B. and Biebel, J. P., Nutrient solution methods of greenhouse crop production. Purdue Agr. Expt. Sta. Circular 232. 1938.
19. Young, R. S., Certain rarer elements in soils and fertilizers, and their role in plant growth. Cornell Agr. Expt. Sta. Mem. 174. 1935.