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STUDIES ON THE DEFICIENCY OF IRON ON POTATO WHEN GROWN IN NUTRIENT SOLUTION

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Effect of iron in a Fe-free nutrient solution on potatoes was studied at the American University of Beirut, Lebanon. Potato tubers were first germinated in sand culture and then transplanted in a jar containing Fe-free nutrient solution.

A pale leaf colour without any specific pattern developed in the youngest growing parts of the plant during the 2nd week of plant growth. The deficiency symptoms then progressed rapidly with the age of the plants. Consequently the whole plant became chlorotic at 5th week of growth. The upper parts of the plant exhibited white colouration at sixth week after transplanting. The lower portion of the plant, however, maintained a light green colour. The roots had a yellow colour, thick structure and did not develop root hairs.

All the essential nutrient elements except N and P were found in smaller quantities in the upper rather than the lower portions of the plant. Potassium was found evenly distributed in all parts of the plant.

INTRODUCTION

Plants require 16 nutrient elements for their normal growth, each of which is as essential as is any of the others, and each has a specific physiological function within the plant. Moreover, the deficiency of any of these elements causes peculiar visual abnormal symptoms on leaves, stem and roots. Crops can be raised in the absence of soil by giving them, in artificial form, the nutrients which they usually draw from the soil, through their roots. The soil-less culture (water-culture or hydrophonic culture) has some advantages, the most important of which is the diagnosis of visual symptoms, caused by the deficiency of one or many of the macro- or micronutrient elements in the solution [7].

Visual symptoms of nutrient deficiencies are helpful in diagnosing what is wrong with plants. However, it represents the advanced stage of the deficiency in many cases. Deficiency of certain elements appear first at the same place for all species of plants. Symptoms of disease, insect attacks and physiological disturbance can often be misinterpreted as nutrient deficiency symptoms. Often only leaf chemical analysis will give the proper interpretation, as to whether, or not a deficiency exists [2].

Iron deficiecny or chlorosis, is believed to be caused by imbalance of metallic ions, such as copper and manganese, excessive amounts of phosphorus in soils, a combination of high pH, high lime, high levels of HCO_3^- in the rooting medium [9]. Halen *et al.* [4] observed iron-deficiency symptoms on the upper young leaves. These leaves became chlorotic and progressively their margin turned necrotic. In severe cases the leaves turned completely white and as a result there was cessation of growth. They stated that Fe participated in the oxidation–reduction reactions in the plants which in turn regulates the synthesis of sugars and proteins, lack of Fe in the nutrient medium of the plant leads to abnormal plant development.

Thomas [8] found that iron seems necessary for the synthesis of chlorophyll. Moreover, he noted that the best known role of iron in plant metabolism was its function in the prosthetic group of the cytochrome system and other oxidation–reduction enzymes such as catalase and peroxidase also contain Fe as an active group. Welkie and Miller [10] reported that a deficiency of Fe interferes with the utilization of the riboflavin as a prosthetic group of flavoprotein enzymes. Tisdale and Nelson [9] reported that the amount of iron in relation to the amounts of other elements in many instances is as important and more so than the absolute quantities of this element present in tissues.

In view of the significance of the iron in the nutrition of the plants these investigation were carried out on potatoes grown in Fe-free nutrient solution at the School of Agriculture, American University of Beirut, Lebanon, during the year, 1976 for the development and description of

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Fe-deficiency symptoms as well as to study the effect of this element in the nutrient balance of the plant.

MATERIALS AND METHODS

A water culture experiment with no iron was conducted on potatoes in the Glass House of the School of Agriculture, American University of Beirut, Lebanon, during 1976 for the development and description of the Fe deficiency symptoms as well as to study the effect of this element in the nutrient balance of the plant. One wide-necked, glazed earthen jar of five-litre capacity was thoroughly cleaned and sterilized. The pot was enclosed with cellophane bags from inside as well as outside after painting it black and three holes were left out. In the central hole were placed two seedlings of potatoes, raised on sand-culture in the laboratory. The roots of the seedling were dipped in the nutrient solution containing 50 ml each of solution 1, 2 and 3 and 5 ml of solution 4.

The potato seedlings were held in place by sticking to erected rod in the jar. Through the other two holes were passed two glass delivery tuber for daily bubbling of air through the nutrient solution, in order to supply oxygen to the roots and to supply distilled water or change the nutrient solution, when deemed necessary. The delivery tubers were supported by wooden sticks and the holes were plugged with cotton wool. The jar was placed in the Glass-house of the School of Agriculture, American University of Beirut, Lebanon.

The vorious salts used for making the nutrient solutions and the ratios of the macro- and microelements employed are given in Tables 1 and 2.

The nutrient solution was changed at 10-day interval and added 50 ml each of macro- and 5 ml of microelement stock solutions each time. The plants were grown from 6 March to 18 April and observations on plant height, leaf length and Fe-deficiency symptoms were recorded from time to time during the growing stages of the plants. The plants were harvested in the 3rd week of April and noted the state of Fe-deficiency symptoms, plant height, root length and condition of growth. The stalks were separated from the roots and divided into upper(1/3) portion and lower(2/3) portion of the plants. Oven-dry weight of stalks and roots were taken after drying at 70^{o} for 24 hr.

After grinding, the samples taken of stalks were extracted in accordance with the method given by Piper [6] for Na, Mg, Ca, K, Cu, Zn, Mn and Fe determination. The extracts were read on atomic absorption spectrophotometer.

Table 1. Preparation of major elements stock solution (500 ml)

Solution	Elements	Concn (ppm)	Nutrient (g/51)	Nutrient (g/500 ml) (stock solution)	Salt (g/500 ml)	Salt used	Stock solution (ml/51)
1	Nitrogen	150	0.750	7.50	11.46	NH_4NO_3	
	Calcium	100	0.500	5.00	29.45	$Ca(NO_3)_2 4H_2O$	50
2	Phosphorus	83	0.415	4.15	18.22	KH_2PO_4	50
	Potassium	105	0.525	5.25			
3	Magnesium	25	0.125	1.25	12.67	$MgSO_4 7H_2O$	50
	Sulfur	33	0.165	1.65			

Table 2 Preparation of trace-elements stocks solution (50 ml)

Solution	Element	Concn (ppm)	Nutrient (g/5 l)	Nutrient (g/50 ml)	Salt (g/50 ml)	Salt used	Stock solution (ml/5 l)
	Manganese	1.00	0.0050	0.050	0.180	$MnCl_2 4H_2O$	
	Boron	0.50	0.0025	0.025	0.143	H_3BO_3	
4	Copper	0.30	0.0015	0.015	0.059	$CuSO_4.5H_2O$	5 ml
	Zinc	0.50	0.0025	0.025	0.052	$ZnCl_2$	
	Molybdenum	0.05	0.0002	0.0025	0.0063	$NaMoO_4.2H_2O$	

Nitrogen was estimated by kjeldahl method and P calorimetrically as given in A.O.A.C. [1].

Observations on the development of Fe-deficiency symptoms were recorded every week after transplantation of the seedlings.

First Week. The plants maintained a green colour, showing no sign of any deficiency.

Second Week. A pale leaf colour without any specific pattern developed in the youngest growing parts of the plant.

Third Week. Yellowing between the veins of the leaves with a sharp distinction between the green veins and the yellow areas started. Deficiency symptoms progressed rapidly and within the same week the leaves developed a chlorosis which covered the whole area between the veins in the youngest growing parts of the plant.

Fourth Week. The leaves on the youngest growing parts of the plant became yellowish white and their margin turned necrotic and curled upwards.

Fifth Week. The whole plant became chlorotic.

Sixth Week. The youngest growing parts of the plant exhibited white colouration with cessation of growth. The lower parts of the plant maintained comparatively a light green colour. The colour of the roots was yellow and thick in structure and did not develope root hairs.

RESULTS AND DISCUSSION

The effects of Fe-less nutrient solution on the growth and chemical compositions of the plant is shown in Tables 3 and 4 respectively. Data in Table 3 indicate that plant height and leaf length at different positions increased consistently with the age of the plants. However, the upper leaves (apical portion of the plant) did not increase in length as that of lower leaves. Table 4 shows that the upper deficient (1/3) portion of the plant was low in Ca, Mg, Zn, Cu, Mn and Fe as compared with the lower(2/3) portion of the plant.

These studies showed that plants supplied with less-iron nutrient solutions continued to gain height and increased in leaf length at different stalk positions with the age of the plants. However, the pace of growth slowed down at the advanced stages of growth. The apical leaves in young growing parts of the plant showed less increase in length with the age of plant as compared with the lower leaves. This decrease in pace of growth at the young growing parts of the plants can be attributed to the decrease in transportation of iron from lower parts of the plant to the upper young growing portions of the plant. This is reasonable in view of Berger [2] studies who reported that when the supply of iron is limited, it is accumulated at the lower

Table 3. Plant height and leaf length at different stalk positions with the age of the plant.

Days after transplantation	Plant No.	Plant height	Leaf position		
			Bottom	Middle	Top
15	1	27	13	15	11
	2	23	14	14	12
21	1	35	16	16	12
	2	33	18	15	13
30	1	56	19	16	13
	2	53	20	17	15
45	1	65	23	17	13
	2	60	22	17	15

Table 4. Chemical composition of plant grown in Fe-less nutrient solution.

Plant portion	Oven dry wt (g)	Percentage									
		N	P	K	Ca	Mg	Na	Zn	Cu	Mn	Fe
Upper (1/3)	9.13	5.65	0.19	4.35	0.85	0.51	0.007	0.0076	0.0061	0.0075	0.0007
Lower (2/3)	13.35	3.40	0.10	4.35	1.60	0.77	0.005	0.0120	0.0110	0.0235	0.0025

parts of the plant and does not move up due to its less mobile nature and the new growth of plants, therefore, cannot depend on export of Fe–from older tissues. Since iron participates in the oxidation–reduction reactions in the plants as observed by Thomas [8] which in turn regulates the synthesis of sugars and proteins, lack of iron in the nutrient solution of the plant leads to abnormal plant development.

The concentration of Ca, Mg, Zn, Cu, Mn, and Fe tended to increase with the age of the plant body as observed in these stuides is reasonable in view of the findings of Bradford and Harding [3] and Mukherjic [5]. The distribution of potassium remained uniform the upper and lower portions of the plant which is supported by Berger's [2] work who reported that potassium evenly distributes between the upper and lower portions of the plants when its supply is adequate. High contents of N and P of chlorotic tissues may have resulted from a decrease in the content of oxiding enzymes (catalase and peroxidase) causing a reduction in the amount of organic acids, thus allowing excessive amounts of P to enter the cell vacuole and hence more nitrogen uptake. In general except N and P and the essential nutrient elements were found in smaller quantities in the upper rather than the lower portion of plant.

These studies showed that potatoes are good indicators of iron deficiency. Potato plants supplied with Fe-less nutrient solution developed chlorosis in the youngest growing parts of the plants and consequently the whole plant became chlorotic. In the advanced stages of growth, the upper parts of the plant exhibited white colouration and as a result cessation of growth.

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