

Magnesium Deficiency in Cotton

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INTRODUCTION

THE importance of magnesium for plant growth has been appreciated since 1906 when Willstater showed this element to be an integral part of the chlorophyll molecule. This element is essential for growth and reproduction of all plants (5, 10) and for most plants it ranks third to fifth in abundance among the essential nutrient elements. The magnesium content in most crop plants varies between 0.2 and 0.6 per cent of the dry weight (2), and oily seeds like cotton and flax contain more of this element than starch containing seeds of cereals (2, 14, 16).

This communication reports the effect of magnesium deficiency on growth of cotton recorded during the course of an investigation on some aspects of mineral nutrition of the plant which is reported elsewhere (15).

MATERIALS AND METHODS

Six-day-old seedlings of the variety "Deltapine 15" were transplanted to 6-liter plastic pots containing a nutrient solution of the following composition :—

<i>Salt</i>	<i>Millimolar Concentration</i>
$\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$	5
KNO_3	3
$(\text{NH}_4)_2\text{SO}_4$	2
K_2HPO_4	1
$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$	2

The above solution was supplemented with micronutrient elements as follows :—

Fe 2.0 ppm, Mn 0.5 ppm, Zn 0.05 ppm, Cu 0.03 ppm, B 0.5 ppm and Mo 0.04 ppm.

The nutrient solutions in the pots were aerated from a central source. The pH of the solutions was checked daily and adjusted if necessary by the addition of dilute HNO_3 or NH_4OH to maintain the pH range 5.0 to 6.0. Solutions were changed at weekly intervals.

Thirty days after transplanting magnesium was omitted from the nutrient solution in some pots in order to induce magnesium deficiency in the plants. Plants in other pots continued to receive the full complement of nutrients.

At the early and more advanced stages of the development of magnesium deficiency symptoms, chlorophyll and carotenoid pigments in leaves were determined according to the method of Loomis and Shull (12). Leaf blades from the uppermost fully-expanded leaf on the main stem were selected for this purpose. Optical densities of the chlorophylls and carotenoids were determined at 660 and 425m μ respectively using a Bausch and Lomb "Spectronic 20" colorimeter.

Plants were harvested at 60 and 85 days after treatment. They were separated into several parts and dried to constant weight in a forced-draft oven and dry weights recorded. The dried plant material was finely ground and suitable aliquots were ashed in a muffle furnace at 500° C. The ash was dissolved in 5 per cent HCl and the resulting solution analysed for magnesium, potassium, calcium and sodium using a Beckman DU Spectrophotometer with a flame attachment.

RESULTS

Visual deficiency symptoms

Incipient magnesium deficiency symptoms were observed twelve days after plants were deprived of this element. These plants exhibited an interveinal chlorosis on the recently matured leaves which gradually turned reddish-brown in colour during the next three to four weeks. With time these areas spread and coalesced.

Growth and development

Magnesium deficient plants were retarded in growth and remained stunted while those receiving adequate amounts of the element grew vigorously and remained healthy. The former were characterised by their shorter internodes, fewer and smaller leaves and by the retardation of leaf and root production. At seventy days of age

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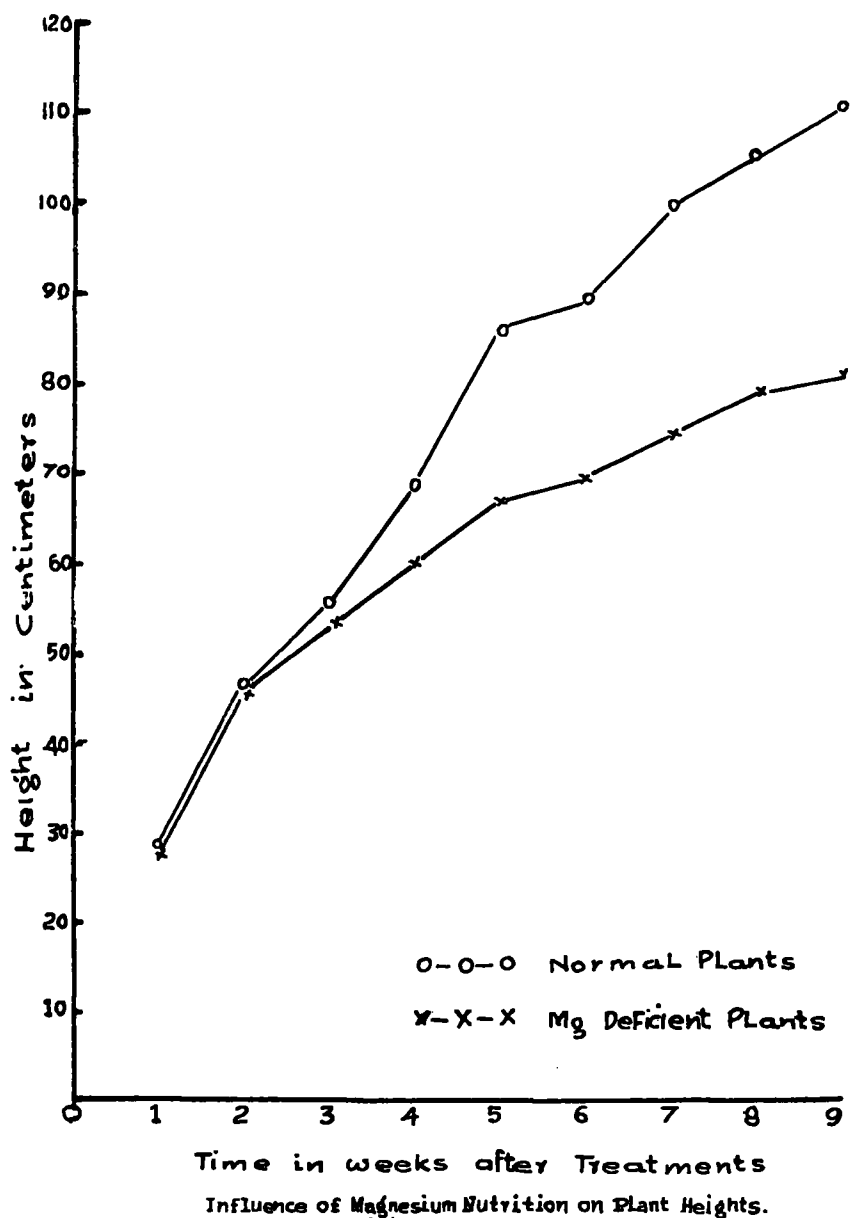


Figure 1

(40 days after treatments) magnesium deficient plants displayed obvious chronic nutritional deficiency symptoms and morbidity but remained alive throughout the experiment. Figure I shows the retardation in plant height due to inadequate supplies of magnesium, while the data in table I clearly indicate the depressing effect of magnesium deficiency on dry weight of plants. Plants from which magnesium was withdrawn shed almost all of their flower buds.

Chemical analysis

The effect of magnesium nutrition on the relative contents of chlorophyll and carotenoid pigments in the leaves is presented in table II. The cation composition of the various tissues of 60 and 85-day-old cotton plants receiving adequate and deficiency levels of magnesium is presented in table III.

DISCUSSION

Growth and development

Absence of magnesium after the first 30 days in the nutrient medium produced smaller stunted plants as compared to those in the control treatments.

Magnesium-deficient plants were approximately 28 percent shorter than plants receiving adequate magnesium. The data on dry weight yield (table 1) further emphasizes the importance of magnesium for growth of cotton plants.

TABLE I.—Dry Weights of 60 and 85-day-old plants as influenced by Magnesium nutrition (gms.)

<i>Age (days)</i>	<i>60</i>				<i>85</i>			
	<i>Normal Plants</i>		<i>Magnesium Deficient Plants</i>		<i>Normal Plants</i>		<i>Magnesium Deficient Plants</i>	
<i>Tissues</i>								
Leaves	..	11.60	..	11.50	..	43.76	..	16.39
Stems	..	8.90	..	6.20	..	45.97	..	8.09
Roots	..	3.20	..	2.80	..	11.20	..	2.90
Squares	..	—	..	—	..	8.37	..	0.12
Total	..	23.70	..	20.00	..	109.30	..	27.50

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TABLE II.—Relative Chlorophyll and Carotenoid contents in leaves of cotton plants as influenced by Magnesium nutrition (figures in optical density)

Age of Plants (days)	Chlorophyll				Carotenoid			
	Normal		Magnesium		Normal		Magnesium	
	Plants		Deficient Plants		Plants		Deficient Plants	
47	..	0.232	..	0.142	..	0.878	..	0.640
78	..	0.224	..	0.104	..	0.324	..	0.186

The most marked effect of limiting magnesium during the first 30 days of treatment (60 day old plant) was on stem growth. The weight of stems in magnesium deficient plants was approximately 70 per cent. that of normal plants while those of roots and leaves were only about 88 and 99 per cent. respectively. The total dry weight of magnesium deficient plants was approximately 18 per cent. less than that of normal plants at the first harvest.

Similar trends in dry weight depression were observed in 85-day-old plants which were grown under conditions of magnesium deficiency for 55 days. Here too the largest depression in dry weight was in the stems while that of roots and leaves was comparatively less. The adverse effects of limiting magnesium supplies on the reproductive phase of growth is seen in the relatively small weight of squares in deficient plants as compared with those of normal plants. The total dry weight of magnesium deficient plants was approximately 25 per cent. the weight of plants grown in the complete solution. Thus the depression in dry weight which was approximately 18 per cent at the earlier harvest increased to almost 75 per cent. at the later harvest.

Chemical Analysis

(a) Chlorophyll and carotenoid pigments.

In plants, magnesium exists in at least three states : in combination with protoplasm, in specific linkage in the chlorophyll molecule, and in the free or inorganic form in the cell sap (16).

The influence of magnesium in maintaining high levels of chloroplast pigments in leaf tissue is obvious from the data in table II.

This is as expected because of the essential nature of this element in the structure of the chlorophyll molecule. A noteworthy observation however is that an inadequate supply of magnesium resulted in a decrease in the carotenoid pigments as well although this element does not enter into the structure of these compounds. Explanation for this may be found in the work of Hinkle and Eisenmenger (8) who found that one part of carotene and two parts of xanthophyll were lost for each twenty parts of chlorophyll.

The work of several investigators has shown that chlorophyll magnesium is only a small proportion of the total content of this element in leaves (3, 9), and that magnesium plays an important role in photosynthesis apart from its role in the formation of chlorophyll (6). But, because magnesium functions in a multiplicity of enzyme-systems (4, 7, 11, 13) its absence should probably affect other metabolic processes in addition to chlorophyll synthesis and photosynthesis. The marked depression in dry weight of plants starved of this element may thus be the effect of magnesium deficiency in reducing photosynthesis and in inhibiting other metabolic processes in cotton plants.

(b) Cation composition

The data on cation composition of plants as influenced by treatments is presented in table III.

Table III.—Distribution of cations in cotton plants as influenced by treatments
(% dry matter)

Age and Tissues	Normal Plants				Magnesium Deficient Plants			
	Magne- sium	Potas- sium	Cal- cium	Sodium	Magne- sium	Potas- sium	Cal- cium	Sodium
60 DAY-OLD PLANTS								
Leaf	0.811	3.38	1.51	0.18	0.19	3.35	1.64	0.21
Stem	1.360	10.85	0.46	0.08	0.05	4.74	0.99	0.13
Root	0.410	7.46	0.30	0.07	0.10	3.65	0.58	0.09
85 DAY-OLD PLANTS								
Old Leaf	1.04	3.85	1.49	0.75	0.17	4.43	1.96	0.71
New Leaf	1.00	2.29	1.40	0.15	0.20	3.90	2.03	0.12
Old Stem	0.42	2.72	0.78	0.10	0.13	2.23	1.24	0.15
New Stem	0.72	6.76	1.09	0.13	0.29	3.60	2.52	0.25
Root	0.53	3.27	0.67	0.11	0.46	3.45	0.86	0.15

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As expected the amount of magnesium per unit of dry weight in all tissues was considerably lower in plants from magnesium deficient solutions as compared with those from complete nutrient solutions. Under conditions of magnesium deficiency there was lesser accumulation of potassium in the stems. This was most marked at 60 days, and in the new stems at 85 days. Probably associated with this was a corresponding increase in potassium concentrations in the leaves of magnesium deficient plants. The concentration of calcium in all tissues of plants deficient in magnesium was higher than in corresponding tissues of plants receiving adequate magnesium. This may be explained on the basis of the concept of the cation equivalency in plants (1), especially since both elements concerned are divalent. Magnesium deficient plants generally tended to accumulate more sodium in their tissues as compared with those receiving adequate amounts of the element. This sodium was from traces found as impurities in the nutrient solutions.

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