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NUTRIENT DEFICIENCY IN BLACK PEPPER *(PIPER NIGRUM* L.)

2. CALCIUM, MAGNESIUM AND SULPHUR

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Though the importance of secondary nutrients in the nutrition of pepper has been established by several workers (De Waard, 1969; Sim, 1971 and Sankar, 1985), information on the effect of deficiency of these nutrients on pepper is very meagre. However, De Waard (1969) in Malaysia has described the deficiency of Ca and Mg in pepper. The investigations reported herein form a part of the studies carried out to induce macro and micronutrient deficiency symptoms in pepper and an account of the deficiency symptoms of N, P and K has already been reported (Nybe and Nair, 1986).

Materials and Methods

Sand culture experiment was undertaken at the College of Horticulture. Vellanikkara, Trichur, Kerala from 1983 to 1986 to induce the nutrient deficiency symptoms. The materials and methods described by Nybe and Nair (1986) were followed except for the treatments. The treatments given were as follows. (1) Complete nutrient solution (2) Complete nutrient solution minus Ca (3) Complete nutrient solution minus Mg, and (4) Complete nutrient solution minus S.

Results and Discussion

Calcium deficiency

Calcium deficiency symptoms were manifested only after one year of growth of the vine. The initial symptom appeared as tiny brown necrotic pinhead spots over chlorotic area near the leaf margins (initial stage). The symptom was first observed on immature leaves followed by mature ones. One and a half months after the occurrence of the initial symptom, the necrotic spots enlarged and were surrounded by yellow halo. The chlorotic area spread towards the distal end of the leaf (medium stage). Fifteen days after, the affected leaves developed interveinal chlorosis and die-back of vine tips (severe stage). Thereafter black necrotic areas near the leaf margins were developed. This did not spread towards the centre of the leaf blade. The proximal portion of the lamina remained pale green in colour with occasional scattered brown necrotic spots. The affected leaves were shed and finally only the immature leaves remained attached to the plant (very severe stage).

The symptoms expressed were similar to those explained by De Waard (1969) in black pepper. Chapman (1975) described the Ca deficiency symptoms in a number of other perennial crops which are in agreement with the present findings.

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Calcium being immobile within the plant, its deficiency symptoms first appear on the younger leaves. Chlorotic symptoms may be due to the inhibition of N metabolism when Ca is deficient in the plant (Paulsen and Harper, 1968). Since Ca is essential for imparting mechanical strength to tissues, the deficiency of Ca may result in shedding of the leaves (Rasmussen, 1967).

The data on the effect of Ca deficiency on vegetative characters are furnished in Table 1. It could be observed that as far as the vegetative growth is concerned, the influence of Ca was comparatively less. There was reduction in shoot growth which ranged between 7.1 cm (initial) and 32 cm (very severe) as compared with healthy plants. The degree of reduction was only two percent during initial stage which gradually reached six per cent within three months. The reduction in number of leaves was only one to two per cent from that of the healthy vines. The reduction in internodal length ranged from 0.1 to 0.4 cm (from initial to very severe stage). This corresponds to two per cent and eight per cent respectively. There was no pronounced reduction in leaf area index However, a reduction by four per cent was observed during the very severe stage of deficiency.

The results revealed that Ca has got a very pronounced effect on root growth in pepper. The reduction in root growth ranged between 0.3 g and 4.6 g from initial to very severe stage as compared with control plants. The magnitude of reduction reached 61 per cent at very severe stage which was only seven percent during the initial stage. The dry matter content of shoot and leaves recorded a reduction by 7 per cent and one per cent respectively during very severe stage. However, the reduction in dry matter content ot leaves was much higher (7%) during the initial stage. The decrease in total dry matter content varied from 9.4 to 14.0 g (from initial to very severe stage) which corresponds to five percent and six percent respectively. The deficiency of Ca affected the crop growth only at a later stage i. e., 15.5 months after treatment.

Gauch (1940) observed that Ca deficiency symptoms first appeared in the roots making the root tips slimy and black. Rios and Pearson (1964) also emphasized the importance of Ca for the growth and development of roots. Calcium being a major component of the middle lamella of cell walls, it imparts rigidity to cell wall and is necessary for growth and development (Uhrstrom, 1969).

The data on the foliar nutrient concentration at different stages of Ca deficiency are furnished in Table 2. Results indicated that there was an appreciable reduction in foliar Ca content of plants receiving minus Ca treatment. The Ca content of the healthy vines ranged between 2.25 percent and 2.30 per cent whereas that of Ca deficient vines decreased with the increase in the severity of deficiency During the initial stage, the actual foliar content of Ca was 1.51 per cent which was 32 per cent lower than the normal value. The extent of reduction was increased upto 65 per cent (actual foliar Ca content was 0.8%) in a period of three

Table 1

Effect of deficiency of calcium on vegetative characters

Stages of calcium deficiency	Months after treatment	Length of vine (cm)	No. Of leaves	Inter-node length (cm)	Leaf area index (cm^2)	Dry matter production (g)			
						Root	Shoot	Leaves	Total
Initial	14	438.9	81.5	5.2	85.0	4.2	95.3	90.3	189.8
		(2)	0)	(2)	(1)	(7)	(3)	(7)	(5)
Complete*	14	446.0	82.1	5.3	85.6	4.5	98.1	96.6	199.2
Medium	15.5	460.3	91.3	5.0	84.2	4.5	100.2	988	203.5
		(3)	(2)	(0)	(1)	(24)	(5)	O)	(4)
Complete*	15.5	475.5	93.0	5.0	85.0	5.9	105.6	99.6	211.1
Severe	16	471.6	93.8	4.8	83.1	3.9	103.7	99.1	206.7
		(4)	O)	(4)	(1)	(40)	(5)	(2)	(4)
Complete*	16	490.8	95.0	5.0	83.8	6.5	108.9	101.0	216.4
Very severe	17	480.4	94.3	4.8	82.4	3.0	105.6	100.1	208.7
		(6)	O)	(8)	(4)	(61)	(7)	(1)	(6)
Complete*	17	512.4	95.6	5·2	85.4	7.6	113.7	101.4	222.7

Plant receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

Table 2

Foliar composition of nutrients at different stages of calcium deficiency

Stages of calcium deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	14	300	0.293	3.20	1.51	1.502	0.215	201	89	121	71	50
		(-9)	(-2)	(+3)	(-32)	(+1)	(-2)	(-2)	(+1)	(-3)	(+1)	(-2)
Complete*	14	330	0.300	3.12	2.25	1.480	0.219	205	88	125	70	51
Medium	15.5	3.20	0.309	3.51	1.01	1.689	0.220	210	87	126	65	48
		(-5)	(-0.6)	(+15)	(-56)	(+11)	(-2)	(+1)	(-4)	(-4)	(-4)	(-4)
Complete*	15.5	3.37	0.311	3.05	230	1.513	0.225	208	91	131	68	50
Severe	16	3.08	0.318	3.68	0.93	1.750	0.211	212	90	125	70	49
		(-8)	(+4)	(+19)	(-59)	(+16)	(-5)	(+1)	(0)	(-2)	(-3)	(+2)
Complete*	16	3.35	0.305	3.10	2.31	1.500	0.221	210	90	128	72	48
Very severe	17	3.21	0.315	3.72	0.80	1.816	0.215	211	88	129	71	50
		(-2)	(+2)	(+18)	(-65)	(+21)	(-1)	(-2)	(-2)	(-1)	(-1)	(-2)
Complete*	17	3.29	0310	3.14	2.30	1.491	0.218	215	90	130	72	51

Hants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

months which corresponded to the very severe stage. The reduction in Ca content was also accompanied by a rise in leaf K and Mg by 18 and 21 per cent respectively. No marked variation was observed in the foliar concentration of other nutrients.

De Waard (1969) observed 1.12 per cent Ca (33% reduction over normal) in the leaves of pepper at 'intermediate' level of Ca deficiency whereas at the 'complete' deficiency level it was 0.86 per cent (43% reduction over normal). The foliar level of Ca at very severe stage of deficiency under the present investigation was only 0.80 per cent. The considerable loss of Ca might have been compensated by a rise in foliar Mg by 60 per cent.

The results of the recovery studies suggested that correction of Ca deficiency required comparatively longer period of three and five weeks respectively, at the medium and the severe stages. The Ca content of the medium deficient vines at the recovered stage was 1.62 per cent and that at the severe stages after recovery was 1.68 per cent

Magnesium deficiency.

Magnesium deficiency symptom first appeared on the older leaves eleven months after starting the treatments. The symptom observed was pale yellow discolouration of the leaf margins and tips (initial stage). One month after the expression of the initial symptom, oval shaped interveinal chlorotic areas started developing from the leaf tip (medium stage). Gradually, the oval chlorotic area expanded towards the leaf margins. Bands of green tissue along the major veins were seen which tapered gradually towards a sharp junction at the distal end. The major veins remained green whereas the laterals turned yellow (severe stage). Small interveinal necrotic spots appeared on the lamina.

By third month after the expression of the initial symptom, the intensity of deficiency reached very severe stage. The chlorotic area developed upwards towards the leaf base. But the proximal end where the major veins join together to form the mid-rib and the major veins along with a narrow band remained green. The necrotic spots enlarged and coalesced to form necrotic patches followed by defoliation (very severe stage).

Since Mg constitutes 2.7 per cent of the weight of chlorophyll, chlorotic symptoms are generally observed on Mg deficient plants. Unlike Ca, Mg is mobile within the plant system and hence deficiency symptoms first appeared on the older leaves. DeWaard (1969) also described symptoms of Mg deficiency as observed during the present investigations. According to Embleton (1975), the general symptom of Mg deficiency was chlorosis which started from the leaf margins and tips and progressed inward interveinally. The results of the studies conducted in other perennial crops such as cacao (Hewitt and Bull, 1956), rubber (Boynton and Erickson, 1954), citrus and grapes (Tanaka, 1960) also agree with the present findings.

The data on the influence of Mg on vegetative growth are presented in Table 3. Reduction in growth of shoot was observed which ranged between 5.4cm and 59.1 cm from initial to very severe stage as compared with healthy vine. The reduction was only one per cent during the initial stage which reached 13 per cent within a period of three months (very severe stage). The number of leaves and leaf area index showed a reduction by seven per cent at very severe stage (14 months after treatment.) The reduction in number of leaves ranged from 1.4 to 5.9 and that of leaf area index from 1 1 to 6.4 cm^2 from initial to very severe stage as compared with healthy vines. The internodal length was not much affected by Mg deficiency. However, a decrease by four per cent was recorded during the very severe stage.

With respect to the dry matter of roots, the rate of reduction was higher (9%) during initial stage as compared with severe or very severe stages (2% and 7%). The dry matter of shoot and leaves recorded a reduction by one per cent (1.1 g) and two per cent (1 2 g) respectively during the initial stage which increased to 3 per cent (12.4 g) and 25 per cent (13.8 g) respectively within a period of three months (very severe stage). The total dry matter content showed a reduction which amounted to two per cent at the initial stage and 15 per cent at the very severe stage As evidenced by the total dry matter content, stunted growth was observed from the thirteenth month onwards. However, complete arrest of growth was not observed. The reduction observed in the vegetative growth could well be explained as due to the reduced photosynthesis resulting from Mg deficiency.

The results pertaining to the foliar nutrient composition as influenced by Mg deficiency are presented in Table 4.

Deficiency of Mg concurred with a fall in the foliar concentration of Mg by 39 per cent during the initial stage which was increased upto 78 per cent within a period of three months (very severe stage). The actual content of Mg increased from 0.913 to 0.330 per cent from initial to very severe stage. The concentrations of Mg in the healthy vines during the corresponding periods were 1.5 per cent and 1.48 per cent respectively.

The Ca content of the Mg deficient vines increased with the advancement of deficiency. The concentration of Ca was 2.2 per cent during the initial stage of Mg deficiency which was increased upto 2.68 per cent at the very severe stage. The magnitude of increase over the healthly vine was 7 per cent and 19 per cent during the corresponding periods. Though K content also registered an increasing trend, the extent of increase was only up to 3 per cent. No appreciable variation was observed with respect to the foliar content of other nutrients due to Mg deficiency.

According to DeWaard (1969), Mg deficiency symptoms manifested when the foliar level of Mg fell below 0.23 per cent. He further observed that the deficiency of Mg depressed the leaf concentration of the element by 60 to 68 per

Table 3

Effect of deficiency of magnesium on vegetative characters

Stages of magnesium deficiency	Months after treatment	Length of vine (cm)	No. of leaves	Inter-nodal length (cm)	Leaf area index (cm^2)	Dry matter production (g)			
						Root	Shoot	Leaves	Total
Initial	11	360.2	65.2	5.2	76.1	3.2	80.0	68.8	152.0
		(1)	(2)	(2)	(1)	(9)	O)	(2)	(2)
Complete*	11	365.6	66.8	5.3	77.2	3.5	81.1	70.0	154.6
Medium	12	372.6	67.1	5.5	75.7	3.6	82.6	69.3	155.5
		(4)	(4)	(0)	(3)	(8)	(6)	(4)	(5)
Complete*	12	388.7	70.1	5.5	78.0	3.9	87.8	72.5	164.2
Severe	13	380.3	74.7	5.3	76.3	4.0	84.4	70.5	164.9
		O)	(4)	(2)	(2)	(2)	(9)	(5)	(3)
Complete*	13	416.7	77 5	54	77.6	4.1	92.3	74.3	170.7
Very severe	14	386.9	76.2	5.4	79.2	4.2	85.7	72.8	168.7
		(13)	(7)	(4)	(7)	(7)	(13)	(25)	(15)
Complete*	14	446.0	82.1	5.6	85.6	4.5	98.1	96.6	199.2

Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

Table 4

Foliar composition of nutrients at different stages of magnesium deficiency

Stages of magnesium deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	11	3.20	0.310	3.16	2.20	0.913	0.200	195	89	125	66	50
		(-0.3)	(+3)	(+2)	(+7)	(1-39)	(-5)	(+1)	(+2)	(0)	(-3)	(-2)
Complete*	11	3.21	0.300	3.10	2.05	1.500	0.210	193	87	125	68	51
Medium	12	3.11	0.299	3.09	2.35	0.675	0.211	190	85	126	69	48
		(-4)	(-3)	(+ 0.3)	(+8)	(-55)	(-2)	(-3)	(-2)	(+1)	(-1)	(-4)
Complete*	12	3.24	0.300	3.00	2.18	1.500	0.215	195	87	125	70	50
Severe	13	3.08	0.286	3.05	2.51	0.531	0.220	197	86	124	71	51
		(-8)	(-8)	(+0.3)	(+12)	(-65)	(+5)	(-1)	(0)	(-2)	(+1)	(+4)
Complete*	13	3.33	0.310	3.04	2.25	1.501	0.219	198	86	127	70	49
Very severe	14	3.20	0.295	3.22	2.68	0.330	0.218	200	85	121	68	50
		(-3)	(-2)	(+3)	(+19)	(–78)	(-0.4)	(-2)	(-3)	(-3)	(-3)	(-2)
Complete*	14	3.30	0.300	3.12	2.25	1.480	0.219	205	88	125	70	51

Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage reduction from normal value

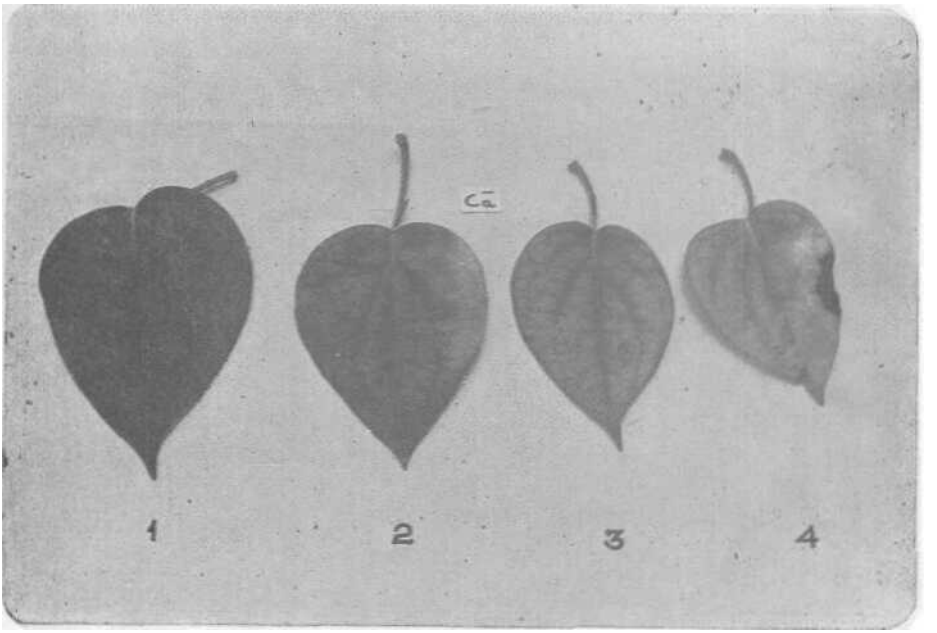
Table 5

Effect of deficiency of sulphur on vegetative characters

Stages of sulphur deficiency	Months after treatment	Length of vine (cm)	No. of leaves	Internodal length (cm)	Leaf area index (cm^2)	Dry matter production (g)			
						Root	Shoot	Leaves	Total
Initial	3	45.2	85	5.3	71.3	1.0	10.1	9.3	20.4
		(13)	(12)	(0)	(6)	(9)	(17)	(21)	(18)
Complete*	3	51.8	9.7	5.3	75.9	1.1	12.1	11.8	25.0
Medium	4	51.0	9.0	5.3	68.5	1.1	11.3	9.5	21.9
		(31)	(35)	(2)	(10)	(15)	(53)	(52)	(51)
Complete*	4	74.4	13.9	5.4	76.2	1.3	23.8	19.6	44.7
Severe	4.5	55.0	9.0	5.3	68.5	1.1	12.2	9.6	22.9
		(40)	(54)	(5)	(14)	(27)	(56)	(57)	(55)
Complete*	4.5	90.6	197	5.6	79.4	1.5	27.5	22.2	51.2
Very severe	5	55.0	9.0	5.3	68.5	1.3	12.2	9.6	23.1
		(48)	(63)	(0)	(17)	(28)	(63)	(65)	(63)
Complete*	5	105.4	24.5	5.3	83.0	1.8	32.6	27.3	61.7

Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines



lg Calcium deficiency sympton with increasing severity

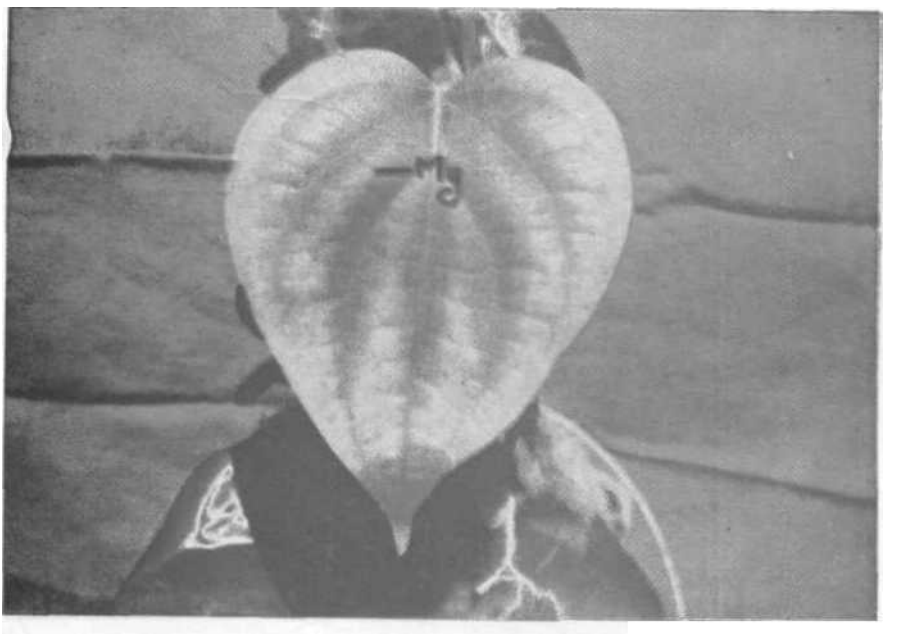


Fig. 2 Foliar symptoms of magnesium

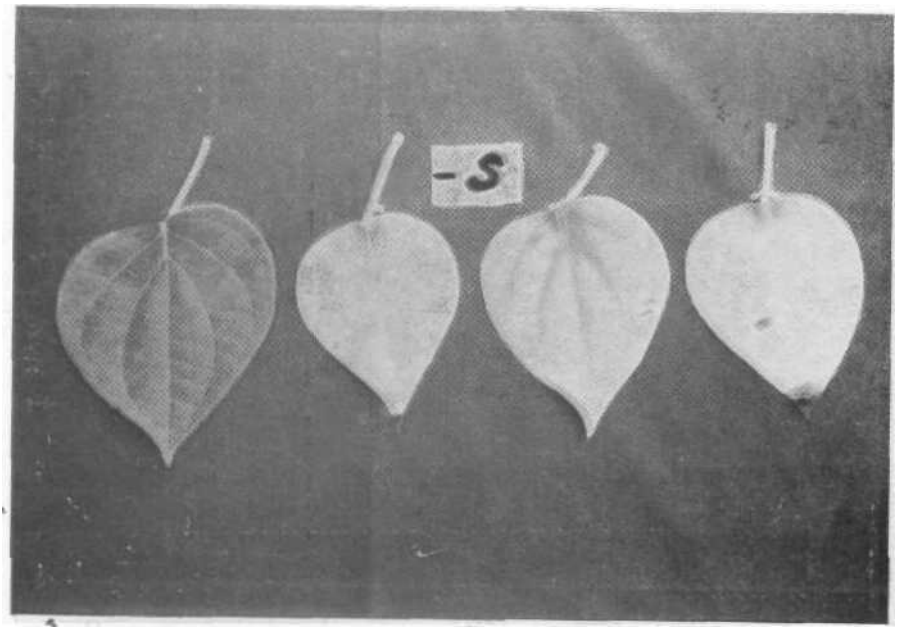


Fig. 3 Sulphur deficiency symptoms with increasing severity

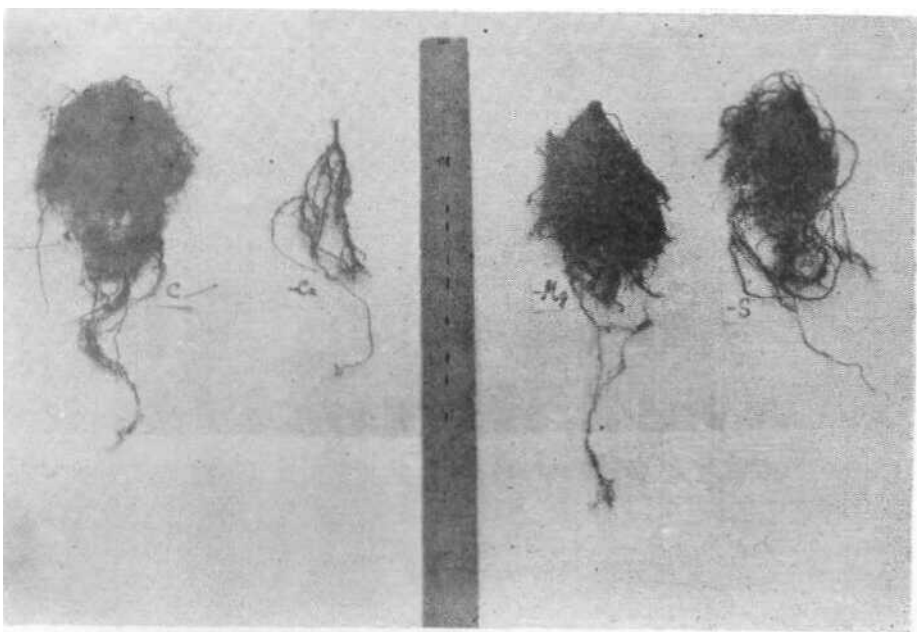


Fig. 4 Root development as influenced by the deficiency of calcium, magnesium and sulphur (in comparison with the control)

Table 6

Foliar composition of nutrients at different stages of sulphur deficiency

Stages of sulphur deficiency	Months after treat-ment	Micronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	3	2 61	0.275	2.69	1.52	1.088	0.121	120	70	100	58	43
		(+2)	(+4)	(-3)	(+1)	(-2)	(-33)	(+0.8)	(-1)	(+5)	(+5)	(+5)
Complete*	3	2.56	0.265	2.78	1.50	1.111	0.180	119	71	95	55	41
Medium	4	2.95	0.381	2.80	1.71	1.291	0.088	121	74	108	62	47
		(-2)	(+0.4)	(-5)	(+2)	(-0.8)	(-55)	(-2)	(-1)	(+4)	(+2)	(-2)
Complete*	4	3.01	0.280	2.96	1.68	1.301	0.195	123	75	104	61	48
Severe	4.5	3.00	0.283	2.91	1.85	1.395	0.063	123	76	115	63	50
		(-4)	(-0.7)	(-1)	(-6)	(-0.4)	(-70)	(-2)	(-3)	(+5)	(-3)	(+2)
Complete*	4.5	3.11	0.285	2.94	1.97	1.400	0.210	125	78	110	65	49
Very severe	5	3.03	0.290	2.90	2.00	1.412	0.040	126	77	122	65	51
		(-3)	(-0.3)	(-2)	(-3)	(+0.5)	(-80)	(-2)	(-1)	(-2)	(-4)	(+2)
Complete*	5	3.12	0.291	2.95	2.06	1,405	0.210	128	78	125	68	50

*Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

cent, accompanied by a rise in the leaf Ca by 17 to 33 percent. Antagonistic effect between Mg and Ca has also been reported by Emmert (1961).

It was revealed that Mg deficiency at the medium and the severe stages could be rectified in two and three weeks respectively, after application of Mg. The Mg contents of the recovered vines were 1.21 per cent (medium) and 1.09 per cent (severe).

Sulphur deficiency

The earliest visual deficiency symptom was expressed by the element S. The initial symptom appeared during the third month of the treatment as pale green to silvery white discolouration of the younger three to four leaves. There was a specific gardation with regard to the intensity of discolouration, the youngest leaf being the most intensely coloured (initial stage). A month after the initial symptom was manifested, the colour of the affected leaves turned uniform yellow. By this time, the discolouration spread to few more lower leaves also. The growth gradually retarded (medium stage).

The next stage was characterized by the appearance of multitude of tiny necrotic spots on the lamina of the affected leaves. The terminal bud failed to develop and complete stunting of growth was observed. The leaf tip turned black and necrotic. Black round necrotic areas were also seen on the lamina (severe stage).

The necrotic area progressed from the distal end to the proximal end involving about one-third to two-third portion of the lamina. The affected leaves were shed prematurily. Die-back of the vine tip was also noticed. The symptoms progressed from the tip to the base of the vine and ultimately only the basal fully matured four or five leaves remained attached to the plant (very severe stage).

The early symptoms were similar to those of N deficiency except that here the younger leaves were chlorotic rather than the older ones. This is because unlike N, S is immobile within the plant. According to Gauch (1972), a general overall yellowing of the younger leaves occurred due to S deficiency. The S deficiency symptoms described by Storey and Leach (1933) in tea also agreed with the present findings.

The results of S deficiency on growth parameters are presented in Table 5. The reduction in shoot growth varied between 6.6cm (initial) and 50.4 cm (very severe) during a period of five months as compared with plants under complete nutrient treatment. The degree of reduction was as much as 13 per cent during initial stage which increased to 48 per cent in about two months. The number of leaves also showed a great reduction amounting to 12 percent and 63 percent during initial and very severe stages respectively. The reduction in number ranged

from 1.2 to 15.5 within a period of five months (very severe stage). There was not much variation in the case of internodal length except a slight reduction by five per cent at severe stage of deficiency. The leaf area index also showed a notable decrease by six per cent during initial stage which gradually increased to 17 percent within two months.

The total dry matter as well as the dry matter of roots, shoots and leaves recorded a considerable decrease as compared to healthy vines. The dry weight of roots was reduced by nine per cent during initial stage and 28 per cent during very severe stage. The reduction in dry weight of shoot ranged between 2.0 g (initial) and 20 4 g (very severe) during a period of five months as compared to plants under complete nutrient treatment. The reduction was 17 per cent during the initial stage and 63 per cent at very severe stage. The dry matter content of leaves recorded 21 per cent reduction during the initial stage which increased upto 65 per cent in about two months The quantum of reduction varied from 2.5 g to 17.7 g during a period of five months (from initial to very severe stage). The total dry matter content was reduced by 63 per cent within a period of five months (at very severe stage). The absence of S affected the plant growth within a short period of three months after treatment. As compared with Ca and Mg. the element S manifested the earliest deficiency symptoms. The growth was completely arrested by fourth month due to S deficiency.

Sulphur being a constituent of the aminoacids found in plants, the deficiency of the element will definitely inhibit protein synthesis which in turn will affect the growth and development. The conspicuous reduction in length of vines and number of leaves may be due to the die-back of the vine tips.

The data on the influence of the element S on the concentration of foliar nutrients are furnished in Table 6. There was a high degree of reduction in the foliar S content due to the omission of S from the growing medium. The extent of decrease was to the tune of 33 per cent during the initial stage which was increased upto 80 per cent within a period of two months. The actual S content of the deficient vines varied from 0.121 to 0.04 per cent and that of healthy vine from 0.18 to 0.21 per cent during a period of five months (from initial to very severe stage). The influence of S on the foliar level of other nutrients was found to be very meagre.

The severe stage of S deficiency could not be corrected by giving S whereas the deficiency at the medium stage was recovered in about two weeks. The foliar S concentration of the recovered vine was 0 150 percent.

Summary

Studies conducted to induce deficiency symptoms of Ca, Mg and S in pepper revealed that the deficiency symptoms were first manifested on the younger leaves except in the case of Mg. Calcium deficiency symptoms appeared as tiny

brown necrotic spots on chlorotic area near margins which later enlarged to form black necrotic areas. Visible symptom of Mg deficiency was oval interveinal chlorotic area followed by black necrotic patches. Sulphur deficiency was manifested as uniform yellowing with brown necrotic spots. The reduction in shoot growth and leaf area index was maximum in the case of deficiency of S (48% and 17%) whereas the effect of Ca and Mg deficiency on vegetative growth was comparatively low. However, the deficiency of Ca resulted in a marked reduction in root growth which extended upto 61 per cent. The growth of the vine was completely arrested at a very early stage of 4.5 months after treatment due to S deficiency whereas no cessation of growth occurred in the case of deficiencies of Ca and Mg. Concurrent with the manifestation of deficiency symptoms, there was a reduction in the foliar levels of the concerned elements. Initial symptoms of deficiency were manifested when the foliar level was reduced to 1.51 per cent in the case of Ca, 0.913 per cent in Mg and 0.121 per cent in S. Antagonistic effects among K, Ca and Mg were also observed. The deficiency symptoms could be recovered by the application of the nutrient element which was deficient.

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