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NUTRIENT DEFICIENCY IN BLACK PEPPER *(PIPER NIGRUM* L.)
3. IRON, MANGANESE AND COPPER

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Though black pepper remains as the most important spice crop of India, research information regarding the mineral nutrition of this crop remain very scarce. What little work that has been done is confined to macronutrients alone. But in a perennial crop like pepper, micronutrients are also very important for keeping the plant healthy and productive. De Waard (1969) has described the deficiency symptoms of macronutrients except S in pepper. However, no work has been done in India or elsewhere regarding the 'hunger signs' in pepper due to the deficiency of micronutrients. This necessitated the present investigations which were undertaken to induce deficiency of Fe, Mn and Cu. The present paper forms a part of the main study which deals with macro and micronutrients.

Materials and Methods

The investigations were conducted in the College of Horticulture, Vellanikkara from 1983 to 1985. The materials and methods adopted with regard to the preparation of sand, pots, planting materials, planting, preparation of nutrient solutions, description of deficiency symptoms, observations on growth parameters and chemical analyses have been described in detail in the first paper of this series by Nybe and Nair (1986). The treatments given were the following: (1) Complete nutrient solution (2) Complete nutrient solution minus Fe (3) Complete nutrient solution minus Mn; and (4)Complete nutrient solution minus Cu.

Results and Discussion

Iron deficiency

The effect of Fe deficiency was first noticed on the top two to three immature leaves during the fourth month of treatment. Interveinal chlorosis with green band along the veins, the symptom typical to Fe deficiency in many other crops was observed in pepper also (initial stage). This interveinal chlorosis gradually intensified (medium stage).

Three months after the initial symptom was expressed, chlorosis spread to another eight to ten lower leaves also. During this stage, green colour was absent in the finest veins of the chlorotic leaves. But the green bands along the major veins were present (severe stage). However, growth retardation and premature leaf fall could be observed. The symptoms remained as such without further progress even after five months (very severe stage).

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Though not a part of chlorophyll, Fe- is essential for chlorophyll synthesis (Bogorad, 1956). Therefore, chlorotic symptoms may be expected when Fe is deficient within the plant, Appearance of deficiency symptoms on the younger leaves may be because Fe is immobile within the plant system. The general symptoms characteristic of Fe deficiency reported by Gauch (1972) and Wallihan (1975) also agree with the present findings.

The results pertaining to the effect of Fe deficiency on vegetative growth are presented in Table 1. It could be seen from the table that the reduction in growth of shoot varied from 4.3 to 101 cm (from initial to very severe stage) as compared to healthy plants. The extent of reduction was six per cent at initial stage which increased to 37 per cent in about five months time (severe stage). The number of leaves produced decreased by 17 percent during initial stage and 33 per cent during very severe stage. The actual reduction in the number of leaves ranged between 2.4 and 18.3 during a period of nine months (from initial to very severe stage). The reduction in internodal length varied from 0.1 to 0.5 cm within a period of four (initial) to nine months (very severe) which amounted to two per cent and ten per cent respectively. The leaf area index also showed a slight reduction by five per cent at very severe stage.

The reducfion in growth may be expected since Fe is actively involved in photosynthesis (Betts and Hewitt, 1986). It also influences growth by its involvement in nitrate and nitrite reduction processes (Joy and Hageman, 1966).

From the data presented in Table 2 it could be observed that the visual symptoms of Fe deficiency was associated with a steep reduction in the foliar concentration of that element. The quantum of reduction ranged between 29 ppm and 131 ppm from initial to very severe stage. During the initial stage of deficiency the extent of decrease was 24 per cent which increased to 68 per cent in about five months (very severe stage), The influence of Fe on the leaf content of other nutrients was negligible.

Iron deficiency was the one which was recovered within the shortest period. The deficiency at the medium stage could be corrected within a week and that at the severe stage in two weeks after the application of Fe. The leaf concentration of the element has increased to 102 ppm and 98 ppm in recovered vines.

Manganese deficiency

Interveinal chlorosis of the younger leaves was the first visual symptom of Mn deficiency. The symptom was observed six months after treatment (initial stage). The vein clearing progressed much and the symptom spread to the middle whorl leaves also. The condition was observed about one month after the beginning of the initial symptoms (medium stage).

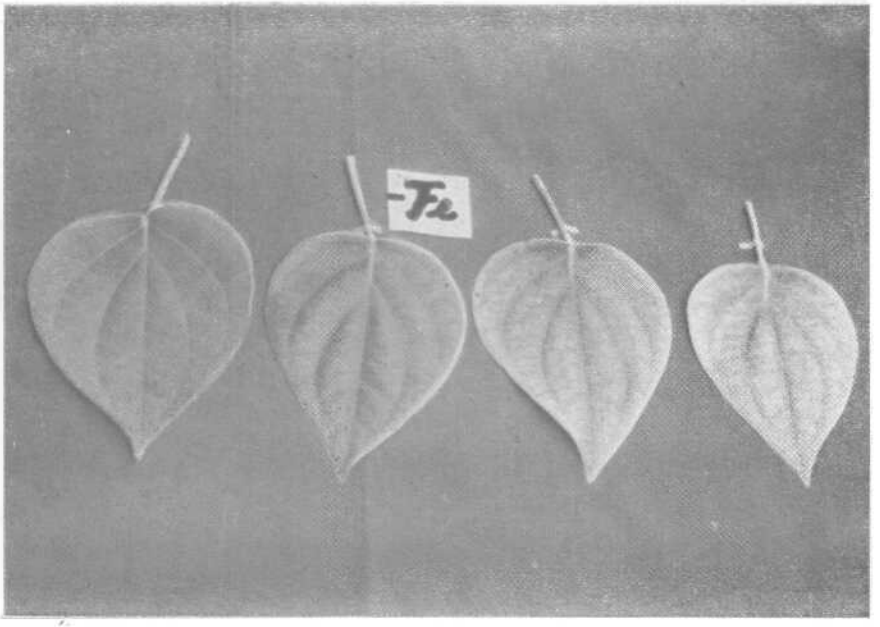

Fig. 1 Leaves showing different stages of iron deficiency symptoms

Table 1

Effect of deficiency of iron on vegetative characters

Stages of iron 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	4	70.1	11.5	5.5	75.5	1.2	21.5	18.2	40.9
		(6)	(17)	(2)	O)	(8)	(10)	(7)	(9)
Complete*	4	74.4	13.9	5.4	762	1.3	238	19.6	44.7
Medium	5	96.3	17.8	5.4	77.3	1.5	22.3	20.1	43.9
		(9)	(27)	(26)	(7)	(17)	(32)	(26)	(29)
Complete*	5	105.4	24.5	4.3	83.0	1.8	32.6	27.3	61.7
Severe	7	162.3	35 3	4.6	81.4	2.6	36.5	39.9	79.0
		(18)	(13)	(4)	(5)	(4)	(33)	(19)	(26)
Complete*	7	196.8	40.7	4.8	85.9	2-7	54.8	49.1	106.8
Very severe	9	175 2	37.0	4.7	80.2	3.0	39,6	40.2	82.8
		(37)	(33)	(10)	(5)	(6)	(39)	(31)	(35)
Complete*	9	276.2	55.3	5.2	84.6	3.2	649	58.4	126.5

* Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

Table 2

Foliar composition of nutrients at different stages of iron deficiency

Stages of iron deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	4	3.22	0.281	2.87	1.61	1.193	0.190	94	74	103	58	49
		(+7)	(+0.4)	(-3)	(-4)	(-8)	(-3)	(-24)	(—1)	(-1)	(-5)	(+2)
Complete*	4	3.01	0.280	2.96	1.68	1.301	0.195	123	75	104	61	48
Medium	5	3.19	0.285	2.91	1.92	1.285	0.200	88	76	122	66	51
		(+2)	(-2)	(-1)	(-7)	(-9)	(-5)	(-31)	(-3)	(-2)	(-3)	(+2)
Complete*	5	3.12	0.291	2.95	2.06	1.405	0.210	128	78	125	68	50
Severe	7	3.20	0.296	2.98	2.00	1.369	0.210	75	83	126	70	50
		(-1)	(-7)	(+4)	(-6)	(-5)	(+5)	(-53)	(-3)	(+0.8)	(+11	(0)
Complete*	7	3.24	0.298	2.87	2.12	1.448	0.200	158	86	125	63	50
Very severe	9	3.30	0.229	3.00	2.086	1.481	0.215	61	85	125	71	51
		(+0.3)	(-2)	(-3)	(-6)	(-2)	(-0.5)	(-68)	(0)	(-3)	(+3)	(+4)
Complete	9	3.29	0.304	3.10	2.18	1.506	0.215	192	85	129	69	49

* Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

The chlorotic area covered almost complete of the interveinal portion making the major veins and laterals more prominent. The pale yellow colour of the chlorotic area changed to bronze yellow (severe stage). Within a period of four months very severe symptoms such as abscission of the affected leaves and growth retardation were exhibited by the plant (very severe stage). The major difference from Fe deficiency was that the green bands along the major veins were absent in this case.

Low concentration of chlorophyll may be expected in the case of Mn deficiency due either to the reduction in number or disorganization of chloroplasts (Homann, 1967). The results of the work carried out by Labanauskas (1975) on citrus also corroborate with the present findings.

The extent of reduction of vegetative growth as a result of omission of Mn from the growing medium is presented in Table 3. No pronounced influence on vegetative growth could be observed by Mn deficiency. However, the length of vine showed a decrease by four to ten per cent in a period of ten months (from initial to very severe stage). The reduction in length was 6.1 cm during the initial stage which was increased to 31.7 cm in about four months (very severe). The number of leaves and leaf area index were reduced by five per cent during the initial stage. However, the maximum reduction observed was during the severe stage in both cases (12% and 7% respectively). The internodal length also registered seven per cent reduction in a period of ten months as compared to healthy vines.

The dry matter of root, shoot and leaf recorded a reduction by 14 per cent, 16 per cent and 11 per cent respectively during the very severe stage. During the initial stage there was no reduction in root growth whereas the dry matter of shoot and leaves registered a decrease by ten per cent and two per cent respectively. The total dry matter content also showed a reduction by 14 per cent during the very shvere stage. The quantum of reduction was as much as 5.5 to 20.6 g during a period of ten months (initial to very severe). Eventhough the rate of growth was much reduced, complete arrest of growth could not be observed upto ten months after treatment. The reduction in vegetative growth is quite natural since Mn is essentialfor chlorophyll synthesis.

The data relating to the foliar composition of nutrients at different stages of Mn deficiency are presented in Table 4. There was reduction in foliar Mn content, the amount of reduction being 30 ppm and 56 ppm during initial and very severe stages respectively. The rate of reduction has increased with the severity of deficiency and reached 66 percent (29 ppm) by the tenth month which was only 36 per cent (54 ppm) during the initial stage. A slight reduction in Fe content was also observed which amounted to 14 per cent (161 ppm) at the severe stage and eight per cent (175 ppm) during the very severe stage.

Table 3

Effect of deficiency of manganese on vegetative characters

Stages of manganese 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	6	150.1	33.1	4.5	82.4	2.5	40.5	39.1	82.1
		(4)	(5)	(0)	(5)	(0)	(10)	(2)	(6)
Complete*	6	156.2	34.8	4.5	86.8	2.5	45.1	40.0	87.6
Medium	7	185.6	38,4	4.7	81.6	2.5	51.6	44.2	98.3
		(6)	(6)	(2)	(5)	(7)	(6)	(10)	(8)
Complete*	7	196.8	40.7	4.8	85.9	2.7	54.8	42.1	106.6
Severe	8	208.6	43.0	4.8	80.2	2.8	562	51.8	1108
		(12)	(12)	(2)	(7)	(10)	(11)	(9)	(10)
Complete*	8	236.0	48.6	4.9	85.9	3.1	62.9	56.8	122.8
Very severe	10	300.2	55.4	5.0	77.5	3.0	62.8	60.2	126.0
		(10)	(9)	(7)	(6)	(14)	(16)	(11)	(14)
Complete*	10	331.9	61.2	5.4	82.4	3.5	75.1	68.0	146.6

* Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

Application of full nutrient solution could correct Mn deficiency completely The time taken for recovery of vine at the medium stage was two weeks and that at the severe stage was three weeks. The concentrations of the nutrient of the recovered vines were 75 ppm (medium) and 68 ppm (severe).

Copper deficiency

As in the case of Fe and Mn deficiencies, the first symptom manifested was interveinal chlorosis of young leaves. The symptom was expressed at the later stage of growth i. e., about one year after treatment (initial stage).

Gradually, yellow chlorotic area spread to the entire interveinal portion. The fine veins turned chlorotic and the green colour of the major veins and laterals faded to pale green (medium stage).

With a period of fifteen days the entire lamina including veins became chlorotic. Dark brown necrotic spots developed towards the tip and margin of the leaf. Terminal growth was arrested and new growth from the basal portion of the vine was initiated (severe stage). During the next stage the lamina became deep bronze coloured and the necrotic spots coalesced to form large black necrotic areas near the tip and margins (very severe stage). The major veins were conspicuous with the interveinal area by deep orange yellow colour. Inward curling of the necrotic margins was also observed. Shedding of the very severely affected leaves was also observed which led to sparse foliage. The new growth produced also showed the characteristic symptoms.

Since Cu is necessary for the formation of the precursor of chlorophyll, the deficiency of the element may naturally produce chlorotic symptoms. The bronze colouration may be attributed to the accumulation of gum due to non-oxidation of phenols in the absence of Cu (Epstein, 1 978). Reuther and Labanauskas (1975) also observed die-back of the growing point coupled with chlorosis and necrosis of the younger leaves as the general symptoms of Cu deficiency in most of the perennial crops.

The results of the study on the effects of Cu deficiency on vegetative growth are furnished in Table 5. During the initial stage of Cu deficiency there was no marked reduction in vegetative growth. A reduction amounting to ten per cent was observed in the case of shoot growth compared to the plants which received complete nutrients during the very severe stage. The reduction in length of vine ranged between 15.8 cm and 46 0 cm within a period of 15 months (from initial to very severe stage). The reduction in number of leaves was only 0.5 percent during the initial stage which increased to seven percent in about two months (very severe stage). The reduction in internodal length and leaf area index was not so pronounced. However, a reduction by four per cent during the initial stage was observed in the case of internoda! length. The reduction in leaf area index was maximum during medium stage (5%).

Table 4

Foliar composition of nutrients at different stages of manganese deficiency

Stages of manganese deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	6	3.11	0.285	2.92	2.20	1.450	0.200	52	54	121	60	45
		(-4)	(-4)	(+1)	(+4)	(-3)	(-6)	(-3)	(-36)	(-2)	(-8)	(-8)
Complete*	6	3.25	0.297	2.89	2.12	1.451	0.212	156	84	123	65	47
Medium	7	3.26	0.300	2.90	2.20	1.500	0.210	155	40	124	62	48
		(+0.6)	(+0.7)	(+1)	(+4)	(+4)	(+5)	(-2)	(-53)	(-0.8)	(-2)	(-4)
Complete*	7	3.24	0.298	2.87	2.12	1.448	0.200	158	86	125	63	50
Severe	8	3.25	0.200	3.00	2.22	1.513	0.213	161	36	126	65	50
		(-2)	(-0.3)	(0)	(-4)	(-4)	(-1)	(-14)	(-58)	(-2)	(-4)	(-2)
Complete*	8	3,30	0.301	3.00	2.23	1.568	0.215	188	85	128	68	51
Very severe	10	3.20	0.301	2.28	2.20	1.500	0.208	175	29	129	67	50
		(-3)	(+0.7)	(-0.7)	(0)	(+1)	(+2)	(-8)	(-66)	(+7)	(-1)	(+4)
Complete*	10	3.30	0.299	3.00	2.20	1.482	0.204	190	85	121	68	48

* Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

Table 5

Effect of deficiency of copper on vegetative characters

Stages of copper deficiency	Months after treatment	Length of vine (cm)	No. of leaves	Inter-nodal length (cm)	Leaf area index (cm^2)	Dyr matter production (g)			
						Root	Shoot	Leaves	Total
Initial	13	400.9	77.1	5.2	77.0	3.7	88.8	74 2	167.7
		(4)	(0.5)	(4)	(0.8)	(10)	(4)	(0·1)	(2)
Complete*	13	416.7	77.5	5.4	77.6	4.1	92.3	74 3	170.7
Medium	14	417.2	80.2	5.2	80.1	4.0	92.6	91.1	188.4
		(7)	(2)	(2)	(5)	(11)	(6)	(5)	(5)
Complete*	14	446.0	82.1	5.3	85.6	4.5	98.1	96.6	199.2
Severe	14.5	420.0	82 4	5.1	80.5	4.4	93.3	95.8	193.4
		(8)	(4)	(2)	(2)	(14)	(8)	(1)	(5)
Complete*	14.5	455.2	85.4	5.2	82.3	5.1	101.0	97.0	203.1
Very severe	15	420.0	82,4	5.1	81.0	4.7	933	95.8	193.8
		(10)	(7)	(0)	(0.7)	(15)	(10)	(2)	(6)
Complete*	15	466.0	89.0	5.1	81.6	5.5	103.2	98.0	206.0

* Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

Table 6

Foliar composition of nutrients at different stages of copper deficiency

Stages of copper deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	13	2.95 (—11)	0.315 (+2)	3.00 (-1)	2.26 (+0.4)	1.451 (-3)	0.205 (-6)	190 (—4)	88 (+2)	50 (—61)	71 (+1)	45 (+10)
Complete*	13	3.33	0.310	3 04	2.25	1.501	0.219	198	86	127	70	49
Medium	14	3.08 (-7)	0.311 (+4)	3.10 (-0.6)	2.20 (-2)	1.468 (-0.8)	0.215 (-2)	200 (-2)	89 (+1)	46 (-63)	68 (-3)	48 (-6)
Complete*	14	3.30	0.300	3.12	2.25	1.480	0.219	205	88	125	70	51
Severe	14.5	3.10 (-6)	0.299 (+3)	3.09 (+3)	2.11 (-4)	1.500 (+3)	0.211 (-4)	202 (—3)	85 (-6)	37 (-71)	72 (+6)	46 (-4)
Complete*	14.5	3.30	0.289	3 00	2.20	1.450	0.220	208	90	128	68	48
Very severe	15	3 26 (-3)	0.310 (+3)	3.20 (-1)	2.25 (-3)	1.503 (+5)	0.220 (+1)	205 (-2)	87 (-3)	30 (-76)	70 (-I)	49 (-2)
Complete*	15	3.35	0.302	3.24	2.31	1.431	0.218	210	90	126	71	50

* Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

The dry matter of root was reduced by 10 per cent during the initial stage which increased to 15 per cent within two months. The reduction ranged between 0.4 g (initial) and 0.8 g (very severe) during a period of 15 months. The dry matter content of shoot and leaves also got reduced by ten per cent and two per cent respectively during the very severe stage. The results suggested that Cu deficiency could affect the crop growth only at a later stage of 14.5 months after treatment. The involvement of Cu in chlorophyll synthesis and oxidation reduction reactions may be contributing to the reduction in vegetative growth and die-back symptoms.

Table 6 represents the data on the foliar concentration of nutrients at different stages of Cu deficiency. The absence of Cu in the growing medium has highly affected the concentration of that element in the leaf. During the initial stage of deficiency, the foliar content of Cu was 50 ppm which was 61 per cent less than that of the normal vines (127 ppm). The extent of reduction was 76 per cent (30 ppm) at the fifteenth month after treatment. However, there was not much variation in the foliar concentration of other nutrients due to Cu deficiency.

For the recovery of Cu deficiency at the severe stage it took comparatively longer period of one month whereas that at medium stage could be recovered within two weeks. The Cu content of leaf at the recovered stage was 68 ppm and 55 ppm for the medium and the severe stages of deficiencies.

Nybe and Nair (1986 and 1987) have already described the deficiencies of macronutrients in pepper.

Summary

The studies conducted to induce deficiency symptoms of Fe, Mn and Cu in black pepper (var. Panniyur 1) revealed that the deficiency symptoms of the above nutrients were first manifested as interveinal chlorosis of the younger leaves. However, the later symptoms were specific to the concerned nutrients. Iron chlorosis was characterized by the presence of green bands along the major veins whereas bronze yellow colour of the interveinal area was the specific symptom of Mn deficiency. Bronze colour of the entire lamina with necrotic tips and margins were the diagnostic symptoms of Cu deficiency. There was no marked reduction in vegetative growth due to the deficiency of Mn and Cu. However, Fe deficient plants recorded 35 per cent reduction in total dry matter production. The growth of the vine was completely arrested by 7 and 14.5 months respectively after treatment due to Fe and Cu deficiencies. But there was no cessation of growth due to Mn deficiency. Visual symptoms of deficiencies concurred with a marked reduction in the foliar levels of the concerned elements. Deficiency of the element failed to influence the foliar levels of other elements. The deficiency symptoms could be recovered by the application of the deficient nutrient element.

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