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NUTRIENT DEFICIENCY IN BLACK PEPPER *(PIPER NIGRUM* L.) I. NITROGEN, PHOSPHORUS AND POTASSIUM*

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Black pepper *(Piper nigrum* L.) is one of the most important export oriented spice crops of India which accounts for about 30 percent of the total export earning from spices. Though, Kerala is the native home of pepper and its cultivation is in existence from time immemorial, it is paradoxical to note that the average yield of this valuable spice in the State is very low (0.2 kg/standard) as compared to that of Malaysia (4.0 kg/standard) and Brazil (3.0 kg/standard) which started the pepper cultivation only by the end of 18th century. One of the major reasons attributed for the low productivity and production of pepper in Kerala is undermanuring or imbalanced manuring. In a perennial crop like pepper, development of 'hunger signs' will be of great use to identify the deficiencies in the field and to take appropriate corrective measures in time, which help to maintain the required nutritional status in the plants. But the work on these line is confined to Malaysia only (De Waard, 1969). Therefore, the present investigations were undertaken with an objective of inducing deficiency symptoms of macro and micronutrients under controlled conditions. The present paper deals with only the three macronutrients viz., N, P, and K.

Materials and Methods

To induce the deficiency symptoms in black pepper, sand culture experiment was undertaken in the green house of the Radiotracer Laboratory, College of Horticulture, Vellanikkara, Trichur from December, 1983 to August, 1985. Pure quartz silica sand of 250 mesh obtained from M/s. Usha Minichem Industries, Bangalore was used for the sand culture studies. The sand was first washed with tap water and then kept soaked in dilute hydrochloric acid for 24 hours. Subsequently, the sand was thoroughly washed with tap water and then with deionized water until it became chloride free. Polythene buckets of 20 cm height with a diameter of cm at the top, tapering to 12 cm at the bottom were used for raising the pepper plants the studies. The buckets were rinsed with dilute hydrochloric acid and then washed with deionized water to avoid contamination. The bottom of each bucket was provided with a small drainage hole which was covered with a watch glass duly supported with a thin pad of lead-free glass wool.

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Six-month old rooted cuttings ot the variety Panniyur 1 were used tor the experiment. Acid washed sand was tilled in the buckets (4 kg/bucket) atter giving a thin polythene sheet lining to the inner walls in order to avoid any possible contamination. The rooted cuttings were carefully pulled out ot the polybags and washed thoroughly in tap water to remove the adhering potting mixture. Due precautions were taken to rinse the roots in very dilute hydrochloric acid and to quickly bathe the roots in deionized water. The plants were then planted in the containers at the rate of one plant per pot and irrigated with deionized water. The potted plants were transferred to the concrete benches inside the greenhouse wherein sunlight was allowed to enter at about 60 per cent natural intensity. Air temperature and humidity were non-limiting. The pots were placed on the benches at a spacing of 30 cm x 30 cm and thevines were regularly tied to uncontaminated coir strings which served as supports. The surface of sand was covered with finely perforated black polythene sheet to prevent the growth of algae and to reduce excessive evaporation. During the initial 15 days, the plants were watered with deionized water and thereafter the treatments were imposed.

The treatments given were i) Complete nutrient solution ii) Complete nutrient solution minus nitrogen iii) Complete nutrient solution minus phosphorus iv) Complete nutrient solution minus potassium. Thirty plants were provided under each treatment and thus there were 120 plants in the experiment.

Hewitt's solution with the modifications suggested by De Waard (1969) was used. The composition of the complete nutrient solution was as follows:

Elements	*mg pure element/l*
N	168.00
P	31.00
S	96.00
Ca	160.00
Mg	42.60
K	78.00
Fe (trivalent)	24.21
Mn (bivalent)	0.55
Cu	0.06
Zn	0.10
B	2.00
Mo	0.03

In each treatment where a cation was omitted, Na was introduced as a substitute, in the case of anions, SO_4 was used as the replacing ion. Chemicals of analytical grade were used for the preparation of the solutions.

Every tenth day fresh nutrient solutions were prepared by diluting aliquots of appropriate stock solutions to the desired concentrations. The pH of the final solutions was adjusted 10 5.0 by the addition of concentrated NaOH or HCl.

When the solutions were given at the concentrations suggested by De Ward (1969), salt injury symptoms such as yellowing and drying up ot the leaves were observed in all the treatments. These could be prevented by reducing the concentration of the feeding solution to 50 per cent of recommended dose. Therefore, 50 per cent concentration was applied in the subsequent trials.

Plants were watered every alternate day with 300 ml of the respective nutrient solution. The sand in each pot was cleaned at intervals of ten days to prevent salt accumulation which was followed by the application of fresh nutrient solution.

The aerial portion of the plants under each treatment was carefully watched every day for the appearance of any symptom and the dates of appearance of symptoms suspected to be due to deficiency were recorded. Colour photographs were also taken even in the suspected cases. The symptoms were confirmed when at least three plants developed similar symptoms under a particular treatment. Based on the intensity, the deficiency was categorised into four stages during the development of symptoms. They are (i) 'initial', (ii) 'medium', (iii) 'severe' and (iv) 'very severe'.

Two plants were removed at random from each treatment at an interval of one month starting from two months after the application of the treatments. After the tenth month, the sample size was reduced to one per treatment because of the limited availability of experimental plants. These plants were used for the determination of dry matter as well as macro and micronutrient content.

Individual plant observations on length of vine, internodal length, number of leaves, leaf area index and dry matter content were recorded at monthly intervals starting from the second month after the application of the treatments. The plants under each treatment were uprooted at random and separated into root, shoot and leaf portions. Their dry weights were recorded separately after drying in a cross flow air oven at 70°C + 2°C till constant weights were obtained.

The dried leaves were ground in a Wiley-mill to particles of 40 mesh size and chemically analysed for the macro and micronutrients following the standard methods.

Nitrogen was estimated by adopting the method suggested by Snell and Snell (1967). Diacid extract prepared as per method standardised by Johnson and Uirich (1959) was used for the analysis of P and K. Phosphorus was determined colorimetrically by the vanadomolybdo-phosphoric yellow colour method (Jackson, 1958). Flame photometer (EEL make) was made use of for the estimation of K.

Results and Discussion

Foliar symptoms

The plants which received complete nutrient treatment exhibited a vigorous vegetative growth with dark green leaves throughout the period of investigations. There were no deficiency symptoms.

Nitrogen deficiency

The initial symptom of N deficiency appeared during the fourth month after treatment, on the older leaves as pale green colouration of the entire laminae. The growth and general health of the plant, however, were not affected at this stage (initial stage).

One month after the occurrence of the initial symptom, the older leaves became uniformlyyellow (medium stage). The yellowing gradually spread over to the younger leaves and by the sixth month, the symptoms attained a severe nature (severe stage). During this stage, the leaf including the petiole turned deep yellow or orange yellow (Plate 1). All the leaves on the plant exhibited discolouration, but the intensity was low towards the growing point. Concurrent with the development of the symptoms, growth retardation and reduction in leaf size were also observed (Plate 2) The leaf tips and margins at the lower end became necrotic and brown in colour which gradually spread towards inside and proximal end.

By eight months after treatment, the whole lamina became necrotic and brown (Plate 3). The completely necrotic leaves were held attached to the vine for about five to ten days and then dropped (very severe stage). The growth was completely stunted and ultimately the entire vine was stripped off except a few immature leaves at the growing point.

The chlorotic symptoms are natural since 70 per cent of leaf N is present in chloroplast (Stocking and Ongun, 1962). The symptom expression was simlar to that explained by De Waard (1 969)for pepper. However, De Waard did not observe differences in intensity of chlorosis based either on age or position of leaf. The present study clearly indicated that the early symptoms appeared on the older leaves and it spread to the younger leaves only when the intensity of deficiency was high. This is expected because of the mobilisation of N from older leaves to the younger ones where metabolic activities are more. It is well established that N is highly mobile in plants. The results obtained by Gauch (1 972) fully agree with the above observations. The studies conducted by other workers on perennial crops like coffee (Cooli *et al.*, 1958), citrus (Reuther *et al.*, 1958 and Jones and Embleton, 1959) and avacado (Jones, 1975) also agree with the present findings.

Phosphorus deficiency

The initial symptom of P deficiency was developed only ten months after the treatment. Bright green to bluish green colour of the older leaves was the first symptom. However, at this stage (initial stage) the symptom was not conspicuous, to be used as a tool for diagnosis of P deficiency. There was practically no change for the initial symptoms for the next two months. Thereafter, the older leaves turned bronze green without any other prominent changes (medium stage). After one month, the leaf tips and margins developed necrosis (severe stage). Stunted growth was also observed during this stage.

The necrosis spread to the inner portion of the laminae and the necrotic areas on the older leaves showed burnt appearance (Plate 4, very severe stage). This stage was closely preceded days after) by the severe stage. The laminae of the older leaves exhibited a downward curving at the margins where necrosis has occurred and later dropped off. No new growth was produced and the vines presented a wilted appearance with drooping of the very few leaves that remained on the vine.

The purple colour of the leaves can be attributed to the formation of anthocyanin pigments due to P deficiency (Gauch, 1972). De Waard (1969) also reported similar symptoms of P deficiency; except that he could not observe necrotic symptoms. This may probably be due to the fact that they appear only at the later stages. The leaves with burnt areas were also reported by Haas (1936) in lemon and orange, due to P deficiency. The symptoms observed during the present investigations were in full agreement with those explained by Bingham (1975) in tree crops and bushes, Wallace (1953) in apple, Lineberry and Burkhart (1943) in strawberry and Hoagland and Chandler (1932) in peach.

Potassium deficiency

Visual symptoms of K deficiency was first manifested during the fifth month after treatment. The symptom was characterised by the necrosis of the older leaf tips. Unlike in the case of N deficiency, the necrotic area was black in colour (initial stage). The necroric spot which appeared at the tip of the lamina gradually progressed towards proximal end and covered about one tenth of the leaf (Plate 5). The necrosis appeared at the leaf margins. The symptom gradually, spread to the upper leaves also (medium stage).

The symptoms attained severity when the necrotic area occupied about one-third portion of the leaf lamina (severe stage). The marginal necrosis which appeared during the medium stage developed inward to the centre of the lamina. During this stage, the leaves in the lower half of the vine were affected. The affected leaves were otherwise healthy but for the necrotic area.

Within one month after the beginning of the preceding stage, about two-thirds of the laminae of the older leaves became necrotic (very severe stage). The symptoms progressed upward and covered approximately lower two-thirds of the leaves on the vine. The proximal portion of the lamina remained green in colour. The border which demarcated the healthy and necrotic areas was charcoal black in colour which faded to ash coloured necrotic area and green coloured healthy area via. pale yellow or orange (Plate 5). The affected leaves even with the very severe symptoms showed no tendency for abscission.

The work of De Waard (1969) on pepper also agrees with the present findings. Potassium being highly mobile within the plant, the deficiency symptom can naturally be expected on the older leaves first. Ulrich and Ohki (1975) described

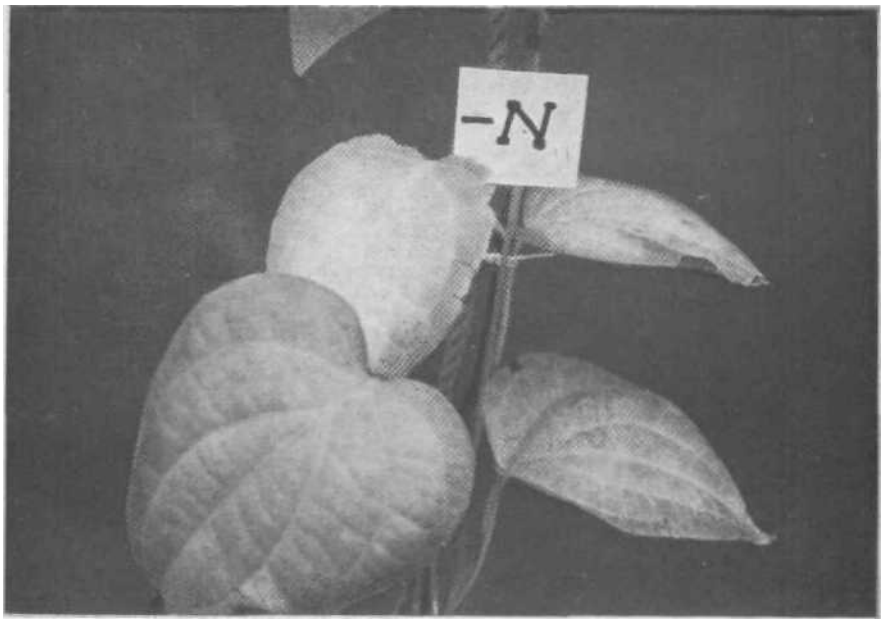

Plate 1 Leaves showing N deficiency

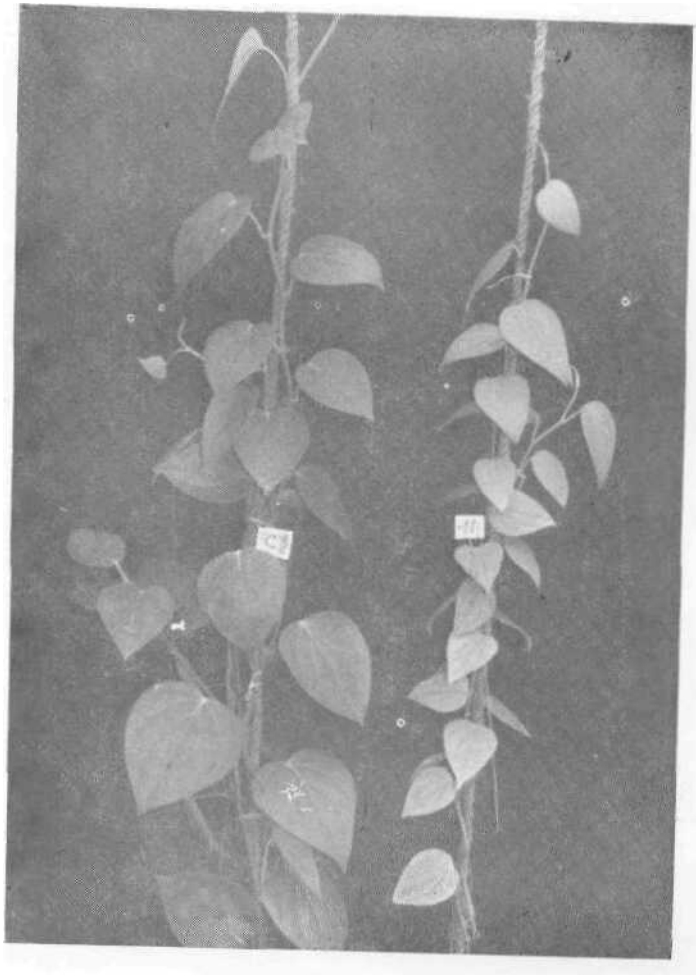

Plate 2 Nitrogen deficient plant with reduced leaf size as compared to healthy plant

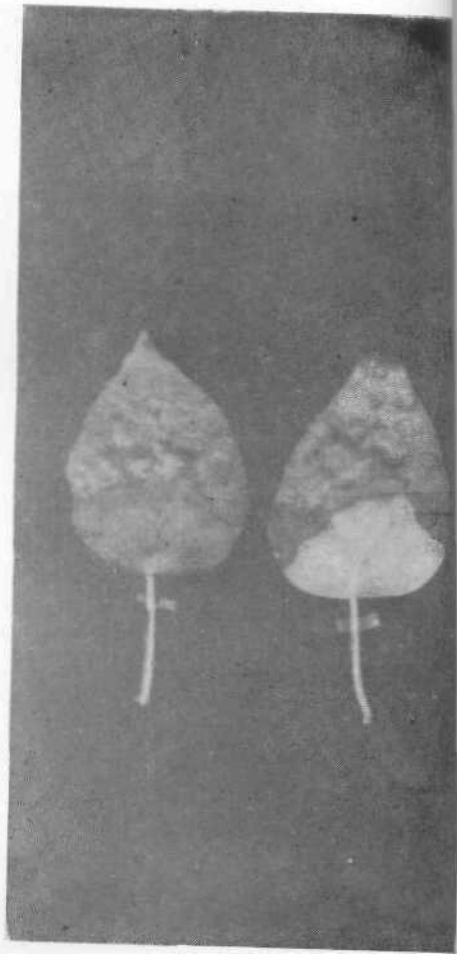

Plate 3 Leaves showing very severe stage of N deficiency

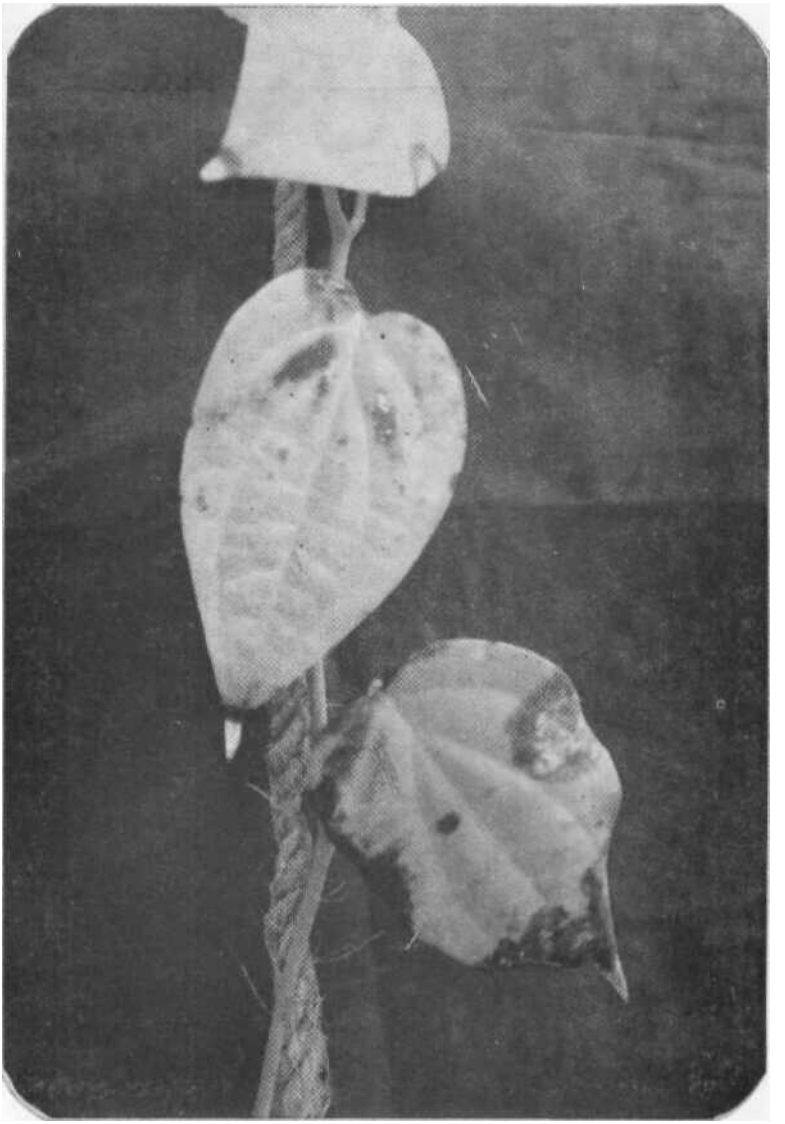

Plate 4

Leaves showing very severe stage of P deficiency

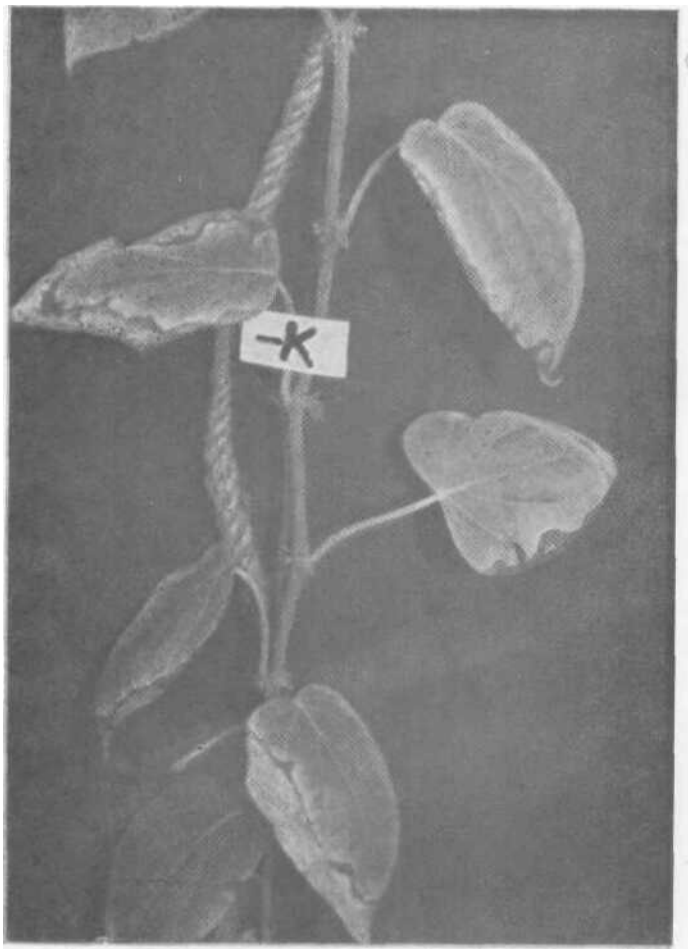

Plate 5

Leaves showing deficiency

the general symptom of K deficiency in perennial crops as tip and marginal scorch of the recently matured leaves. The K deficiency symptoms described by Purseglove (1977) in pepper also agree with the results of the present investigation.

Effect of nutrient deficiencies on vegetative growth and development

Nitrogen deficiency

It could be observed from Table 1 that there was reduction in shoot growth of N deficient plants which ranged between 5.7 cm and 1 33.0 cm from initial to very severe stage as compared to healthy ones. The extent of reduction was 8 per cent during the initial stage which increased up to 56 percent within four months (very severe stage). The reduction in number of leaves varied from 1.4 to 25.6 from initial to very severe stage which corresponded to 10 per cent and 53 per cent respectively. The omission of N resulted in decreased internodal length which ranged between 0.1 cm and 1 cm from initial to very severe stage as compared to plants which received complete nutrient treatment. During the initial stage the magnitude of reduction from the healthy vine was 2 per cent and that during very severe stage was 20 percent. The leaf area index showed a decreasing trend with the advancement of deficiency. The reduction ranged from 22.4 to 53.7 cm^2 within eight months period (from initial to very severe stage). During the severe stages it registered a reduction by 63 percent which was only 29 per cent in the initial stage.

The data presented in Table 1 revealed that the dry matter production was adversely affected by N deficiency. The range of reduction in dry weight of roots from initial to very severe stage as compared to healthy plants was 0.1 to 1.2 g. The extent of reduction was 8 per cent and 39 per cent respectively, during the initial and very severe stages. The dry weight of shoot also "registered a reduction by 8 to 49 per cent during a period of four months. The quantity reduced was 2.0 to 30.9 g within eight months period (from initial to very severe stage). With regard to the dry matter of leaves, the reduction from healthy plants ranged from 4.2 to 31.6 g during a period of eight months. The magnitude of reduction was 21 per cent during the initial stage which increased up to 56 per cent within four months. There was increase in growth, of course at lower rate, up to sixth month even though visual deficiency symptoms were manifested by the fourth month. The reduction in total dry matter content ranged between 14 per cent (initial) and 51 per cent (very severe) within a period of four months. The growth was completely arrested after six months as evidenced by the total dry matter production. The reduction in vegetative growth is quite natural since N is involved in all the processes associated with protoplasm, enzymic reactions and photosynthesis (Gauch, 1972 and Jones, 1975).

Phosphorus deficiency

Absence of P adversely affected all the growth parameters except internodal length and leaf area index (Table 2), The growth of shoot was reduced by 61.9 to 118.8 cm during a period of 13.5 months. The amount of reduction was 19 per

Table 1

Effect of deficiency of nitrogen on vegetative characters

Stages of nitrogen deficiency	Months after treat-ment	Length (cm)	No. of leaves	Internodal length (cm)	Leaf area index (cm^2)	Dry matter production (g)			
						Root	Shoot	Leaves	Total
Initial	4	68.7	12.5	5.3	53.8	1.2	21.8	15.4	38.4
		(8)	(10)	(2)	(29)	(8)	(8)	(21)	(14)
Complete*	4	74.4	13.9	5.4	76.2	1.3	23.8	19.6	44.6
Medium	5	95.9	21.2	4.2	44.3	1.6	30.6	25.1	57.3
		(9)	(13)	(21)	(47)	(11)	(6)	(8)	(7)
Complete*	5	105.4	24.5	5.3	83.0	1.8	32.6	27.3	61.7
Severe	6	101.5	23.0	3.9	32.2	1.6	32.1	25.5	59.2
		(35)	(34)	(13)	(63)	(36)	(29)	(36)	(32)
Complete*	6	156.2	34.8	4.5	86.8	2.5	45.1	40.0	87.6
Very severe	8	103.0	23.0	3.9	32.2	1.9	32.0	25.2	59.1
		(56)	(53)	(20)	(63)	(39)	(49)	(56)	(51)
Complete*	8	236.0	48.6	4.9	85.9	3.1	62.9	56.8	122.8

Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

Table 1

Effect of deficiency of nitrogen on vegetative characters

Stages of nitrogen deficiency	Months after treat-ment	Length (cm)	No. of leaves	Internodal length (cm)	Leaf area index (cm^2)	Dry matter production (g)			
						Root	Shoot	Leaves	Total
Initial	4	68.7	12.5	5.3	53.8	1.2	21.8	15.4	38.4
		(8)	(10)	(2)	(29)	(8)	(8)	(21)	(14)
Complete*	4	74.4	13.9	5.4	76.2	1.3	23.8	19.6	44.6
Medium	5	95.9	21.2	4.2	44.3	1.6	30.6	25.1	57.3
		(9)	(13)	(21)	(47)	(11)	(6)	(8)	(7)
Complete*	5	105.4	24.5	5.3	83.0	1.8	32.6	27.3	61.7
Severe	6	101.5	23.0	3.9	322	1.6	32.1	25.5	59.2
		(35)	(34)	(13)	(63)	(36)	(29)	(36)	(32)
Complete*	6	156.2	34.8	4.5	86.8	2.5	45.1	40.0	87.6
Very severe	8	103.0	23.0	3.9	32.2	1.9	32.0	25.2	59.1
		(56)	(53)	(20)	(63)	(39)	(49)	(56)	(51)
Complete*	8	236.0	48.6	4.9	85.9	3.1	62.9	56.8	122.8

Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

Table 2

Effect of deficiency of phosphorus on vegetative characters

Stages of phosphorus 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	10	270.0	50.0	5.3	80.3	3.0	60.0	52.0	115.0
		(-19)	(-18)	(-2)	(-3)	(—14)	(-20)	(-24)	(-22)
Complete *	10	331.9	61.2	5.4	82.4	3.5	75.1	68.0	146.6
Medium	12	312.5	54.2	5.6	81.5	2.5	69.2	55.0	126.7
		(-20)	(-23)	(+2)	(+5)	(-36)	(-21)	(-24)	(—23)
Complete *	12	388.7	70.1	5,5	78.0	3.9	87.8	72.5	164.2
Severe	13	316.5	55.0	5.6	80.6	2.4	70.0	53.0	125.4
		(-24)	(-29)	(+4)	(+4)	(-41)	(-24)	(-29)	(-27)
Complete *	13	416.7	77.5	5.4	77.6	4.1	92.3	74.3	170.7
Very severe	13.5	318.2	55.0	5.7	78.2	2.2	70.6	53.0	125.8
		(-27)	(-32)	(+4)	(-2)	(-45)	(-26)	(-30)	(-28)
Complete *	13.5	437.0	81.0	5.5	79.8	4.0	95.0	75.8	174.8

Plants receiving complete nutrients

Figures given in parenthesis indicate percentage variation from healthy vines

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Table 3

Effect of deficiency of potassium on vegetative characters

Stage of potassium 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	5	102.0	24.0	5.1	80.0	1.5	31.8	28.0	61.3
		(3)	(2)	(4)	(4)	(17)	(2)	(3)	(1)
Complete*	5	105.4	24.5	5.3	83.0	1.0	32.6	27.3	61.7
Medium	5.5	125.3	27.8	45	84.1	1.7	35.1	30.1	66.9
		(4)	(4)	(0)	(1)	(15)	(6)	(6)	(6)
Complete*	5.5	130.1	29.0	4.5	85.0	2.0	37.5	320	71.5
Severe	6	138.8	30.5	4.5	85.2	2.2	42.0	35.3	79.5
		(11)	(12)	(0)	(2)	(12)	(7)	(12)	(9)
Complete*	6	156.2	34.8	4.5	86.8	2.5	45.1	40.0	87.6
Very severe	7	175.6	38.0	4.6	85.0	2.4	46.8	45.5	94.7
		(11)	(7)	(4)	(1)	(11)	(15)	(7)	(11)
Complete*	7	196.8	40.7	4.8	85.9	2.7	54.8	49.1	106.6

Plants receiving complete nutrients

Figures given in parenthesis indicate percentage reduction from healthy vines

The degree of reduction in respect of dry matter content was also very low. The quantum of reduction in dry weight of roots was 0.3 g in all the four stages of deficiency. The rate of reduction has actually decreased from initial to very severe stage (17 to 11 %). The magnitude of reduction in the case of dry weight of shoot ranged from 2 to 15 percent within a period of two months (from initial to very severe stsge). Maximum reduction in dry matter content of leaves was noticed during severe stage (6th month) and thereafter, the rate of reduction has decreased to 7 per cent. The total dry matter content also showed a steady decrease from 1 to 11 per cent within a period of two months of deficiency. In terms of quantity, the reduction ranged between 0.4 g and 11.9 g during a period of seven months, it is of interest to note that even at very severe stage of deficiency, growth progressed uninhibited, through the rate was reduced.

Potassium being involved in translocation, the deficiency of K will result in decreased translocation of photosynthates from leaves to other portions (Hartt, 1969). Potassium is also found to be necessary for glycolysis, oxidative phosphorylation, photophosphorylation and for adenine synthesis (Evans and Sorger, 1966). Therefore, K deficiency may inhibit starch synthesis which could be the result of reduced energy supply. The reduced vegetative growth was due to the above reasons.

Effect of nutrient deficiencies on the foliar composition

Nitrogen deficiency

There was a gradual decrease in foliar N level with increasing severity of the deficiency (Table 4). Nitrogen level in the leaves of healthy plants was found to be 3.01 to 3.30 percent while it decreased in deficient plants. During the initial stage of deficiency, the actual foliar content of N was 2.45 percent (—19%). Further drop to 1.56 per cent (—53%) in foliar level occurred within a period of four months.

The concentrations of other nutrients were also affected by N deficiency at varying magnitude. Pronounced decrease could be observed in the case of Mg and Fe which recorded a reduction by 23 per cent (1.201%) and 36 per cent (121 ppm) respectively, at the very severe stage. The extent of reduction during the initial stage was 21 percent (1.030%) in Mg and percent (121 ppm) in respect of Fe. The elements P, Zn and B have also registered a slight decrease by per cent and 12 per cent during initial and very severe stages, respectively.

Working with the same crop, De Waard (1969) observed that less than 2.70 percent N in leaf exhibited N deficiency symptoms. Chapman (1949) reported less than 2.00 per cent N in N deficient leaves of citrus. The variation in N content between the present study and that of De waard (1969) is possible due to the differences in variety, soil and climate. According to De Waard (1969) the reduction in foliar N during complete deficiency stage amounted to 25 percent coupled with a reduction in Mg content by 18 per cent and increase in foliar P by 44 per cent. The N and P antagonism was reported by Bessis (1967) also in a

number of other perennial crops. The positive correlation of N with Mg and Fe may be due to the involvement of these elements in the chlorophyll synthesis. Iron also functions in nitrate and nitrite reductions (Betts and Hewitt, 1966 and Joy and Hangeman, 1966).

Phosphorus deficiency

Phosphorus deficiency was associated with a decrease in foliar content of P amounting to 33 per cent in the initial stage which increased up to 65 per cent in a period of three and a half months (Table 5). Initial symptoms of P deficiency occurred when the leaf concentration of P was reduced to 0.2 per cent. During the course of development of deficiency, the P content continued to reduce and reached 0.11 percent at the very severe stage. The P content of the healthy vines varied between 0.299 percent and 0.310 percent during a period of 13.5 months. Omission of P from the growing medium could not influence the foliar concentration of other nutrients to a considerable extent.

According to De Waard (1969) also, omission of P was reflected by the reduction of foliar P by 43 percent and no influence of P on the foliar levels of other nutritients could be observed. However, the level of P in the leaves showing 'intermediate level' of deficiency was much lower than that observed during the present investigation which may be attributed to the variations in the experimental condition and the genotype. In citrus and grapes the plants which showed P deficiency contained less than 0.1 percent foliar P (Bingham and Martin, 195 and Bergmen *et al.* 1958).

Potassium deficiency

Deficiency of K was associated with a depression in leaf K content (Table 6) The percentage of K during the initial stage of deficiency was [illegible] per cent at against the normal value of 2.95 per cent during the corresponding period. Right from the initiation of deficiency the K content went on decreasing and registered a value as low as 1 per cent (normal value was 2.87% during the very severe stage. The extent of reduction was 29 per cent at the initial stage which was increased up to 65 per cent within a period of two months.

Concomitant with the decrease in K content, pronounced increase in foliar Ca and Mg levels were observed. The increase in Ca content was as much as 25 per cent (2.65%) and that of Mg was 24 per cent (1.80%). The actual content of Ca in leaves during the initial stage was 2 per cent (3% less than normal) which increased up to 2.65 per cent within a period of two months. The Mg content of the K deficient vines ranged between 1.418 per cent and 1.800 per cent during a period of seven months. Potassium failed to establish any profound influence on the concentration of other macro and micronutrients.

According to De Waard (1969) the depression in the leaf concentration of K due to K deficiency was 40 per cent. The antagonistic effect of K with Ca

Table 4

Foliar composition of nutrients at different stages of nitrogen deficiency

Stages of nitrogen deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	4	2.45	0.285	2.95	1.57	1.030	0.163	121	72	95	55	46
		(-19)	(+2)	(-0.3)	(-7)	(-21)	(-16)	(-2)	(-4)	(-9)	(-10)	(-4)
Complete*	4	3.01	0.280	2.96	1.68	1.301	0.195	123	75	104	61	48
Medium	5	2.20	0.302	2.95	2.04	1.303	0.188	125	75	122	65	50
		(-29)	(+4)	(0)	(-1)	(-7)	(-10)	(-2)	(-4)	(-2)	(-4)	(0)
Complete*	5	3.12	0.291	2.95	2.06	1.405	0.210	128	78	125	68	50
Severe	6	2.01	0.325	2.89	2.04	1.278	0.199	135	78	120	63	46
		(-38)	(+9)	(0)	(-4)	(-12)	(-6)	(-13)	(-7)	(-2)	(-3)	(-6)
Complete*	6	325	0.297	289	2.12	1.451	0.212	156	84	123	65	49
Very severe	8	1.56	0.331	2 90	2.11	1.201	0.200	121	79	122	61	45
		(-53)	(+10)	(-3)	(-5)	(-23)	(-7)	(-36)	(-7)	(-5)	[-10)	(-12)
Complete*	8	3.30	0.301	3.00	2.23	1.568	0.215	188	85	128	68	51

Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

Table 5

Foliar composition of nutrients at different stages of phosphorus deficiency

Stages of phosphorus deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	10	325	0.200	2.98	2.11	1.453	0.200	188	83	118	65	48
		(-2)	(-33)	(-1)	(-4)	(—2)	(-2)	<~1)	(-2)	(-2)	(-4)	(0)
Complete*	10	3.30	0.299	3.00	2.20	1.482	0204	190	85	121	68	48
Medium	12	3.31	0.178	3 01	2.21	1.498	0210	196	85	122	71	51
		(+2)	(-41)	(-2)	(—1)	(-0.1)	(-2)	(+ 0.5)	(-2)	(-2)	(+1)	(+2)
Complete*	12	3.24	0.300	3.08	2.18	1.500	0.215	195	87	125	70	50
Severe	13	3.30	0.115	3.00	2.09	1.512	0.213	199	82	125	70	48
		(-1)	(-63)	(-1)	(-7)	(—1)	(-3)	(+0.5)	(-5)	(-2)	(0)	(-2)
Complete*	13	3 33	0.310	3.04	2.25	1.501	0.219	198	86	127	70	49
Very severe	13.5	3.31	0.110	3.02	2.11	1.500	0.211	200	85	125	72	49
		(-1)	(-65)	(-1)	(-6)	(-0.5)	(-4)	(-1)	(-2)	(-1)	(+1)	(-2)
Complete*	13.5	3.35	0.310	3.06	2.25	1.493	0.220	203	87	126	71	50

· Plants receiving complete nutrients

given in parenthesis indicate the percentage variation from normal value

Table 6

Foliar composition of nutrients at different stages of potassium deficiency

Stage of potassium deficiency	Months after treatment	Macronutrients (%)						Micronutrients (ppm)				
		N	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
Initial	5	3.11	0.290	2.10	2.OO	1.418	0.200	125	76	121	69	45
		(-0.3)	(-0.3)	(-029)	(-3)	(+1)	(-5)	(-2)	(-3)	(-3)	(+1)	(-10)
Complete*	5	3.12	0.291	2.95	2.06	1.405	0.210	128	78	125	68	50
Medium	5.5	3.00	0.293	1 .50	2.25	1.632	0.213	150	81	122	63	49
		(-3)	(-1)	(-48)	(+ 13)	(+17)	(+1)	(+ 1)	(+1)	(-1)	(-2)	(-2)
Complete*	5.5	3.10	0.295	2.90	2.00	1.411	0.210	149	80	123	64	50
Severe	6	3.18	0.291	1 .20	248	1.713	0.211	156	80	121	66	51
		(-2)	(-2)	(-58)	(+ 17)	(+18)	(-0.5)	(0)	(-5)	(-2)	(+2)	(+4)
Complete*	6	3.25	0.297	2.89	2.12	1.451	0.212	156	84	123	65	49
Very severe	7	3.21	3.295	1.OO	2.65	1.800	0.210	160	85	124	62	50
		(-1)	(-1)	(-65)	(+ 25)	(+24)	(+5)	(+1)	(-1)	(-1)	(-2)	(0)
Complete*	7	3.24	0.298	2.87	2.12	1.448	0.200	158	86	125	63	50

Plants receiving complete nutrients

Figures given in parenthesis indicate the percentage variation from normal value

(+36%) and Mg (+ 27%) was also observed by De Waard. The foliar level of K observed by De Waard below which deficiency symptoms were manifested was 2.0 per cent which was closely related with the present finding.

Recovery studies

When the deficiency symptoms were visually confirmed, one plant each from the medium and the severe stages was given full nutrient solution and observed for recovery. When the plants were recovered of the visual deficiency symptoms it was confirmed by foliar analysis for the nutrient in question. In the case of K deficiency, the recovery of the affected leaves was not possible, the new growth, however, was free from the deficiency.

From Table 7 it could be seen that the medium stage of N deficiency could be recovered by one week whereas it tookthree weeks for the recovery of the severe deficiency symptoms. The N percentages of the recovered vines were 2.73 and 2.60 respectively of the medium and the severe stages.

Table 7

Recovery of nutrient deficiencies

Treatments	Stages of deficiency	Time taken for recovery (weeks)	Foliar nutrient content after recovery (%)
+ N	Medium	1	2.73
	Severe	3	2.60
+ P	Medium	4	0.23
	Severe	Not recovered	
+ K	Medium	2	2.45
	Severe	3	2.28

With regard to the recovery of P deficiency it was observed that once the deficiency has attained the severe stage it was not possible to recover the plants from the malady. But, if P could be supplied at the medium stage, the recovery was observed within a period of four weeks and the P content during the stage was 0.23 per cent.

The plants suffering from K deficiency at the medium and the severe stages could be recovered within two and three weeks respectively. The K contents of the recovered plants were 2.45 and 2.28 per cent respectively.

Summary

Detailed studies were conducted in black pepper (var. Panniyur 1) from 1983 to 1985 at the College of Horticulture, Vellanikkara with a view to induce deficiency symptoms of N, P and K by sand culture. Deficiency symptoms of all the three nutrients studied were first manifested on the older leaves. Symptoms of N deficiency were expressed as uniform yellowing followed by necrosis whereas

purple to bronze yellowing with ash coloured necrotic areas were the symptoms of P deficiency. Potassium deficiency was characterised by tip and marginal necrosis which later progressed to the two-thirds distal portion of the lamina. There was profound reduction in vegetative growth due to deficiency of N and P. The reduction in shoot growth and leaf area index was maximum in the case of deficiency of N *(56%* and 63%) followed by P (32% and 2%). The reduction in root growth was quite high due to deficiency of P (45%) followed by N (39%). The growth of vine was completely arrested at comparatively early stage (6th month after treatment) due to N deficiency followed by P (13th month). There was no cessation of growth in the case of deficiency of K. Visual symptoms of deficiencies concurred with a marked reduction in the foliar levels of the concerned elements. Initial symptoms of deficiency were manifested when the foliar level was reduced to 2.45 per cent in the case of N, 0.20 per cent in P and 2.10 per cent in K. Antagonistic effect of K with Ca and Mg was also observed. The deficiency symptoms could be recovered by the application of the deficient nutrient element.

സംഗ്രഹം

പാക്യജനകം, ഭാവഹം, ക്ഷാരം എന്നീ പോഷണ മൂലകക്കുറവ് കുരുമുളകു ചെടിയെ എങ്ങിനെ ബാധിക്കുന്നുവെന്ന് കണ്ടുപിടിക്കുന്നതിനു വേണ്ടി വെള്ളാനിക്കര ഹോർട്ടിക്കൾച്ചർ കോളേജിൽ ഒരു പരീക്ഷണം നടത്തുകയുണ്ടായി. മേൽപറഞ്ഞ മൂന്നു മൂലകങ്ങളുടെയും കുറവുമൂലമുണ്ടാകുന്ന ബാഹ്യലക്ഷണങ്ങൾ raT^s^aioaQ/I കാണുന്നതു വള്ളിയുടെ അടിഭാഗത്ത് ഇലകളിലാണ്. പാക്യജനകക്കുറവുമൂലം ഇലകൾ ആദ്യം മഞ്ഞനിറമാകുകയും പിന്നീട് ഉണങ്ങി roiosi* വീഴുകയും ചെയ്യുന്നു. പുതുതായി ഉണ്ടാകുന്ന ഇലകൾ വലുപ്പത്തിൽ വളരെ ചെറുതായും കാണപ്പെട്ടു. ഭാവഹത്തിന്റെ കുറവുമൂലം ഇലകൾ ആദ്യം പച്ചപ്പിൽ കലർന്ന മഞ്ഞ നിറമാവുകയും തുടർന്ന് ക്ഷാര നിറത്തിലുള്ള കരിഞ്ഞ പാടുകൾ ഉണ്ടാവുകയും തൽക്ഷണം ഇല കൊഴിയുകയും ചെയ്യുന്നു. ഇലകരിച്ചിലാണ് ക്ഷാരകുറവുമൂലമുണ്ടാകുന്ന പ്രധാന ലക്ഷണം. കരിച്ചിൽ ഇലയുടെ അഗ്രത്തിൽനിന്നും വശങ്ങളിൽനിന്നും തുടങ്ങി അവസാന ഘട്ടമാകുമ്പോഴേയ്ക്കും ഏതാണ്ട് ഇലയുടെ മൂന്നിൽ രണ്ടു ഭാഗത്തേയും ബാധിക്കുന്നു. പോഷണ മൂലകക്കുറവ് ചെടിയുടെ കായിക വളർച്ചയെ പ്രതികൂലമായി ബാധിക്കുന്നതായും കണ്ടു. അവയിൽ ഏറ്റവും പ്രാധാന്യമർഹിക്കുന്നത് പാക്യജനകമാണെന്നും കാണുകയുണ്ടായി. പോഷണക്കുറവുമൂലമുണ്ടാകുന്ന ബാഹ്യലക്ഷണങ്ങൾ കാണുന്നതോടൊപ്പം roisimo ഇലയിലുള്ള അവയുടെ തോത് വളരെയധികം കുറയുന്നതായും മനസ്സിലാക്കാൻ സാധിച്ചു. കുറവുള്ള പോഷണമൂലകം തക്കസമയത്തു നൽകുക വഴി ചെടിയെ പോഷണമൂലക്കുറവുമൂലമുണ്ടാകുന്ന അവസ്ഥയിൽ നിന്നും രക്ഷപ്പെടുത്തുവാൻ സാധിക്കുന്നതാണ്.

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