KFRI Research Report No. 249 *ISSN 0970- 8103*

DIAGNOSIS OF MICRONUTRIENT DEFICIENCIES IN TEAK SEEDLINGS

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February 2003

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(FINAL REPORT OF THE PROJECT KFRI 307/98)

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ABSTRACT OF PROJECT PROPOSAL

1.	Project No	:	KFRI 307/98
2.	Title of the project	:	Diagnosis of micronutrient deficiencies in teak seedlings
3.	Objective	:	To determine the deficiency symptoms of micronutrients in teak seedlings
4.	Duration	:	3 years
5.	Funding Agency	:	Kerala Forest Department (Development)
6.	Investigator	:	M.P. Sujatha

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ACKNOWLEDGEMENTS

I express my sincere gratitude to Dr. K.S.S.Nair, former Director, KFRI, Dr. J.K. Sharma, Director and Dr. R. Gnanaharan, Research Coordinator for their kind support and constant encouragements; Dr. M. Balasundaram for kind cooperation in the glasshouse study; Dr. S. Sankar for timely advice and editorial scrutiny; Dr. K.V. Sankaran for kind help in micronutrient analyses; Mr. K.C. Chacko and Dr. M. Balagopalan for editorial scrutiny; Dr. Thomas P. Thomas for timely suggestions; Sri. Subhash Kuriakose for photography and cover page designing; Smt. M.S. Indira, Smt. K. Remadevi, Smt. V.S. Samitha and Smt. V.S. Manju for laboratory assistance; Sri. M.K. Sivaraman for assistance in raising seedlings and Smt. P.K. Sughada Devi for word processing.

Financial assistance given by the Kerala Forest Department under Forest Development Fund is also gratefully acknowledged.

ABSTRACT

A study was conducted to diagnose the deficiency symptoms of Fe, Cu, Zn, Mn, Mo and B in teak seedlings using sand culture. Two month old seedlings were planted in acid washed white quartz sand and provided with nutrient solution deficient in Fe, Cu, Zn, Mn, Mo and B to identify the deficiency symptoms of respective nutrients. Symptoms due to Fe deficiency were observed 55 days after planting followed by Zn, Mn, Mo, Cu and B. The deficiency of Fe resulted in interveinal yellowing of new leaves followed by necrosis, inward curling and cupping of leaves and appearance of rusty patches on lower leaves. Appearance of yellow patches on margins of lower leaves, interveinal yellowing and vein clearing of lower leaves, appearance of small and wrinkled new leaves and necrosis of chlorotic leaves were the characteristic symptoms of Cu deficiency. The Zn deficient plants expressed chlorosis of midrib and veins followed by necrosis and premature shedding of affected leaves and emergence of large and drooping new leaves. During the early stage of Mn deficiency, chlorotic spots appeared on younger leaves while at later stage they were confined only to older leaves. Yellowing of leaf tip and margins of new leaves followed by necrosis, production of bluish green new leaves, interveinal yellowing and absence of tip in new leaves were the characteristic symptoms of Mo deficiency. In B deficient plants, clustering and brittling of new leaves, blotching and premature shedding of lower leaves and emergence of slendering and tapering leaves were the characteristic symptoms.

Deficiency of micronutrients also resulted in the retardation of plant growth. The reduction in height at severe stage of deficiency was more in Mo and Cu deficient plants and minimum in B deficient plants. Similarly, there was a drastic reduction in the number of healthy leaves due to the deficiency of all micronutrients, the more reduction in Fe deficient plants and minimum with B. Shortened internodes, production of long abnormal leaves and termination of apical growth were also observed. There was a reduction in the content of nutrients due to the deficiency of respective nutrients and in most cases they were decreasing with advancement of deficiency.

Trials to rectify the deficiency symptoms revealed that recovery was fast and easy if the respective nutrients were applied at the early stage of deficiency. Foliar spray of 0.3% Fe SO_4, 1% Bordeaux mixture, 0.1% Zn SO_4, 0.1% $MnSO_4$, 0.1% MoO_3 and 0.05 % boric acid were found effective in rectifying the deficiency of Fe, Cu, Zn, Mn, Mo and B respectively.`

DIAGNOSIS OF MICRONUTRIENT DEFICIENCY SYMPTOMS IN TEAK SEEDLINGS

INTRODUCTION

Production of healthy and vigorous seedlings in forest nurseries demands balanced supply of both macro and micro nutrients. Compared to macronutrients, the requirement of micronutrients by the plants is very small, but their deficiency usually lead to abnormal or retarded growth. Micronutrient deficiencies commonly occur due to varied reasons like increased use of NPK fertilisers generally devoid of micronutrients, intensive cultivation coupled with lack of replenishments, repeated cultivation of same species in the same field, changes in environmental conditions such as rains, soil moisture, micro flora of soil, shade, pH, interaction between different nutrients etc. In forest nurseries, seedlings are produced every year and substantial amount of soil is removed with each harvest leading to the depletion of site fertility. Failure to recoup the fertility or replenishment with NPK fertilisers devoid of micronutrients often result in micronutrient deficiencies. Since micronutrients especially Fe, Cu, Mn and Zn play a major role in building up chloroplasts and help in photosynthetic activities, their deficiency will hinder normal photosynthesis and leaves may show various symptoms of deficiency. B is involved in cell division, cell growth and membrane function and hence its deficiency usually hinders the apical growth. The major role of Mo is associated with the action of nitrate reductase and so its deficiency disturbs nitrogen metabolism.

Micronutrient constraints emanating from their deficiencies have been assessed in various plant species through visual symptoms, soil and plant tests. The diagnostic methods and threshold values for micronutrients varies with different soil-crop situation and they are being used successfully in pinpointing micronutrient related constraints to high productivity. Among the various diagnostic methods, the easiest way to diagnose the nutrient deficiency at field level is through visual symptoms. In agricultural crops, visual symptoms are expressed in foliage, fruits, seeds etc. but in forest species, foliar symptoms are the only possible tool for diagnosis at field level.

Teak being one of the high valued timbers of Kerala, large number of seedlings are produced and supplied every year for establishment of plantations. But, recently it has come to the notice that most of the nursery managers find it difficult to diagnose the nutrient disorders often occurring in the nurseries and apply appropriate remedial measures. Hence this study mainly aimed at diagnosing the symptoms of micro nutrient deficiencies in teak seedlings and prescribing appropriate remedial measures to aid the forest managers at field level.

REVIEW OF LITERATURE

The importance of micronutrients in the normal life process and the expression of various types of symptoms under conditions of their deficiency have been subjected to detailed studies in various agricultural crops (Deward, 1969; Bunt, 1976; Smith and scudder, 1981; Nene *et al*.,1994; Tandon, 1995). Usually the visual symptoms expressed due to the deficiency of a particular element varies with plant species. So also, depending upon the mobility of the deficient element in the plant, the position of leaves on which the symptom initially appear varies. Among the essential micronutrients, Fe and B are relatively immobile within the plant and hence the deficiency symptoms are first expressed in young and expanding leaves while the symptoms of relatively mobile Cu, Mn, Mo and Zn are expressed on matured leaves (Dell *et al*., 1995). According to Broschat(1984) micronutrient deficiencies were almost indistinguishable from one another in five species of palm grown as foliage plants and it took 6-15 months for the symptoms to be expressed. In Kerala, detailed studies on the deficiency of micronutrients in nutmeg (Philip, 1986), cashew (Gopikumar and Aravindakshan, 1988), clove (Nazeem *et al.*, 1993) have been reported. The studies pertaining to the visual symptoms commonly encountered in various forest species due to the deficiency of Fe, Cu, Mn, Zn, Mo and B are described in the following paragraphs.

The widespread symptom of Fe deficiency in green plants is the characteristic interveinal chlorosis of young leaves in which the area between the veins become yellow and the veins remain green (Chapman 1975). Extensive chlorosis followed by bud rot in *Araucaria klinkii* and *A. cunninghamii* was due to the deficiency of Fe induced by high soil pH (Baseden, 1960). Dell *et al.* (1995) reported yellow expanding leaves with narrow green veins as characteristic symptom of Fe deficiency in *Eucalyptus globulla* and *E. urophylla.*

Growth characteristics and leaf symptomatology of acute Zn deficiency are well so defined with some crops that supplementary leaf and/or soil analysis tests are unnecessary. However, mild deficiencies in many crops cannot be identified. Excessive Zn often produces Fe chlorosis (Chapman, 1975). The characteristic deficiency of Zn in the seedlings of teak is shortening and curling of leaves with unequal leaf margins and blades and the seedling appears as a creeper due to the tendering of the stem. But in

Eucalyptus hybrid, the leaves become small and narrow and assume sickle shape (Kamala *et al.*, 1986). According to Dell *et al.*(1995), in *E. grandis, E. pellita and E. urophylla* deficiency of Zn leads to interveinal chlorosis of expanding leaves, development of purple areas on the leaves, leaf stunting, leaf rolling, crowding of leaves near the apex and leaf tip necrosis. Gopikumar *et al.*(2001) observed the deficiency of Zn in teak seedlings as development of chlorotic patches on lower leaves, small clustered leaves, development of necrotic patches on leaves and later burnt appearance.

In *Eucalyptus* hybrid, deficiency of Fe and Zn usually leads to yellow leaves often with pink to red coloured spots followed by reduction in size and die back of affected shoots (Dhanda, 1983).

According to Chapman(1975) the symptoms of Cu deficiency are not so specific and the terminal growth of most plants are the first to be affected, with dieback of twigs or growing points, a common symptom. Rosetting of terminal leaves often precedes dieback. Benzian and Warren(1955) reported the development of needle tip- burn on sitka spruce seedlings and black discolouration of the leaves of *Populus x robusta* cutting due to the deficiency of Cu. In the seedlings of *Tectona grandis* stunted growth, shortening of leaves, appearance of yellow patches on the leaves and whitish yellow leaf tips and margins were observed due to the deficiency of Cu. Kamala *et al*. (1986) reported that in *Swietenia mahogany*, Cu deficiency leads to light green young leaves with marginal necrosis as well as leaf curling. In *Eucalyptus* hybrid, the leaves become soft textured and curling of leaf margin was seen. Curling of tip of younger leaves, appearance of chlorotic spots followed by blackening of leaves in teak seedlings, chlorosis and curling of leaves in mahogany and *Eucalyptus* hybrid were also observed by them. But Dell *et al.*(1995) noticed pendulous habit of lateral branches, twisted, cupped or recurved expanding leaves, irregular margin, dieback of shoot apex and shedding of axillary buds in *Eucalyptus globulus* and *Eucalyptus urophylla* due to the deficiency of Cu.

Mn deficiency symptoms on many plants are well defined, but it is easy to confuse symptoms of Mn with Zn or Fe deficiency (Chapman, 1975). Yellowing of younger leaves and curling of leaf tip in teak, curling of younger leaves, and chlorotic tips and yellow spots on the leaves of mahogany and uneven development of leaf blade and leaf tip chlorosis and curling are the symptoms due to the deficiency of Mn (Kamala *et al.*, 1986). The deficiency of Mn leads to interveinal chlorosis of expanding leaves, leaf tip necrosis, recurved lateral branches in *E. globulus*; development of yellowing first in the expanding leaves and its further spread to younger and older leaves in *E grandis* and interveinal chlorosis followed by white necrotic spots in *E. urophylla* (Dell *et al*., 1995*).*

In general, the deficiency of B in plants leads to rosetting and dieback of terminal shoots, thickening, brittleness, curling, wrinkling, wilting and chlorotic spotting of leaves and thickened, corky, cracked, crosshatched and water soaked dead areas in petioles or stems (Chapman, 1975). According to Kolari(1979), the deficiency of B in *Pinus sylvestris* results in dieback. Occurrence of dieback without earlier visual symptoms in scots pine was mainly due to the deficiency of micronutrients, especially B (Silfverberg, 1979). Acute micronutrient deficiency, especially B caused isolated occurrences of severe dieback and/or swelling and discolouration of leading shoots of Douglasfir (*Pseudotsuga menziesii*) in British Columbia (Carter and Klinka, 1986). Kamala *et al.*(1986) reported the occurrence of leaf tip blackening and its further spread to half of the leaf in teak seedlings. They also could notice chlorotic spots and yellow spots in mahogany and red or pink patches on the leaves of *Eucalyptus* hybrid. According to Dell *et al*.(1995), the first signs of deficiency in *E. globulus* are leaf rolling and weeping branches. In severely deficient trees, all the branches prostrate because the stems do not have enough lignin in the wood to support the foliage and the shoots die back from the growing points. The remaining upper nodes become enlarged and bear multiple, short-leaved shoots in *E. deglupta*, *E. grandis* and *E. urophylla).* In *E. robusta* and *E. urophylla,* the leaves are often brittle and have raised corky tissue associated with the veins.

Often the first and most obvious symptoms of Mo deficiency symptoms are similar to those of uncomplicated nitrogen deficiency. In addition to the nitrogen deficiency symptoms, marginal scorching and rolling or cupping are the characteristic Mo deficiency symptoms (Chapman, 1975). The Mo deficient teak seedlings assume the appearance of creeper while in the seedlings of eucalypts hybrid, leaves become twisted and midrib and veins get thickened (Kamala *et al.*, 1986). In *E. grandis* and *E. urophylla,* the deficiency symptoms (interveinal chlorosis) of Mo resemble the early symptoms of N deficiency, but unlike those of N deficiency, they appear first in young leaves (Dell *et al*., 1995). Gopikumar *et al*.(2001) could notice considerable reduction in the size of terminal leaves and they were narrow in appearance.

The deficiency symptoms of B, Cu, Mn, Mo, Fe and Zn in deciduous and coniferous forest trees (Kolari, 1979), *Eucalyptus* (Dell *et al*., 1995 and Kamala *et al.*,1986) and in the seedlings of sandal, teak, mahogany (Kamala *et al.*,1986) have been studied in detail. Angadi *et al.*(1988) reported that reduction in leaf area, decrease in chlorophyll activity and photosynthetic efficiency of the leaves of cassia, eucalypts, mahogany, neem, rosewood, sandal and teak suffering under deficiency of Cu, Zn, Mn, Mo and B could be taken as a diagnostic factor to identify the deficiency symptoms. Lime induced chlorosis due to the deficiency of Fe, Cu, Zn and Mn in *E. teriticornis* has been reported by Kaul *et al.*(1982) from India. Yellowing and dieback in *E. tereticornis* in N. India was associated with micronutrient deficiencies (Seghal, 1984).

MATERIALS AND METHODS

Deficiency symptoms of various micronutrients (Fe, Cu, Zn, Mn, B and Mo) in teak seedlings were induced artificially through sand culture. For this, 1000 kg of white quartz sand, collected from Usha Minechem Industries, Bangalore were washed thoroughly with tap water followed by dilute HCl. After that they were made chloride free using deionised water and kept in plastic pots. In between, teak seeds were sown in the nursery during February 2000 and the germinated seedlings were transplanted to polythene bags containing potting mixture. After a period of two months, the seedlings were uprooted; roots were washed thoroughly with deionised water and then transplanted to the pots containing washed white quartz sand (Plate 1). The pots with the seedlings were kept under glasshouse condition and arranged in seven groups, each group containing 10 pots. The plants were supplied with 50 ml of deionised water twice a day during the first four days and after that once a day regularly.

Modified Hoagland No. 2 nutrient solutions containing all the micro and macro nutrient solutions were prepared separately (Table 1). After a period of two weeks, nutrient solutions deficient in Zn, Fe, Cu, Mn, Mo and B respectively were supplied to the first six groups @ 50 ml/pot twice a week for the first 30 days and after that on alternate days and on other days they were fed with deionised water only. Two ml of $FeSO_4$ was added

Table 1. Composition of modified Hoagland No.2 solution

	Compound	Concentration of stock solution, M	Vol. of stock solution per litre of final solution, ml
Macronutrient	KNO_3	1.0	6
	$Ca(NO_3)_2$	1.0	4
	$NH_4H_2PO_4$	1.0	2
	$MgSO_4.7H_2O$	1.0	1
Micronutrient	Compound	Concentration of stock solution, M	Vol. of stock solution per litre of final solution, ml
	KCl	50	1
	H_3BO_3	25	
	$MnSO_4.H_2O$	2.0	
	$ZnSO_4.7H_2O$	2.0	
	$CuSO_4.5H_20$	0.5	
	H_2MoO_4	0.5	
	$FeSO_4$	20	-

separately to all the plants except those, which were labelled as –Fe. The pots in the seventh group were kept as control.

All the plants were observed regularly. Details on the expression of deficiency symptoms specific to each nutrient and further development of the symptoms were recorded. Necessary photographs of these symptoms were also taken.

Plate 1. General view of the teak seedlings grown in white quartz sand

Remedial measures to correct the deficiencies were tried in five replications of each nutrient and in the rest of the pots, recording of foliar symptoms were continued until the completion of the experiment. The white sand in the pots was discarded. Repeated the trial during the next year also with 10 replications for each treatment. Young foliar samples of plants showing the deficiency symptoms of nutrients were collected and oven dried. The oven dried plant samples were powdered and digested using sulphuric acid, salicylic acid and hydrogen peroxide mixture. Care was taken to avoid contamination during the processing of plant samples. Micronutrients in the digested samples were determined using Varian atomic absorption spectrometer.

RESULTS AND DISCUSSION

a. Appearance of deficiency symptoms

The plants, which were not supplied with specific nutrients, started to express the deficiency symptoms of the nutrient concerned within a couple of weeks. Some of the symptoms viz., retarded growth, shortening of internodes, production of long leaves etc. was common in most cases. But there were some characteristic symptoms with respect to each nutrient based on which the deficient nutrient could be diagnosed, details of which are discussed in the following paragraphs.

Fe deficiency

Among the six nutrients under study, the plants, which were not supplied with Fe, started to express the symptoms first. After 55 days of planting the seedlings in the white quartz sand, yellow chlorotic spots were appeared in the interveinal area of the newly emerged leaves. As the plant grew, the intensity of yellow colour also increased. Gradually the entire leaf became yellow and the green colour was restricted only to the veins (Plate 2a). This particular pattern of leaf, with green veins and yellow interveinal area (interveinal chlorosis), expressed by the newly opened leaves was found to be a characteristic symptom of Fe deficiency. The interveinal chlorosis of young emerging leaves due to the deficiency of Fe has been reported in various agricultural crops (Chapman, 1975) and eucalyptus (Dell *et al.*, 1995). Later, most of the leaves of the plant became yellow ((Plate 2b) and at the acute stage, the yellow leaves became necrotic (Plate 2c) and the whole leaves died off.

Another characteristic symptom observed due to the deficiency of Fe was cupping of leaves (Plate 2d). The margins of the leaves especially the upper and immediate below started to curl outwardly and attained the shape of a cup. Development of rusty patches on older leaves (Plate 2e) and the formation of multistems were also noticed in Fe deficient plants.

a.Interveinal yellowing of new leaves -early stage

b. Yellowing of entire leaves- advanced stage

c. Necrosis starting from the base of the leaf – severe stage

d. Cupping and inward rolling of leaves

e. Rusty patches on lower leaves

Plate 2. Foliar symptoms due to the deficiency of Fe

Cu deficiency

The plants, which were not supplied with Cu, expressed deficiency symptoms 84 days after planting. During the early stages of deficiency, yellow patches appeared on the margins of older leaves. Kamala *et al*.(1986) also could observe the development of yellow patches on the leaves of teak seedlings due to the deficiency of Cu. Later, the veins and veinlets of matured leaves became green and very clear (vein clearing) and the interveinal area remained yellow as in Fe deficient leaves (Plate 2c). As the plant growth advanced, the entire leaf became chlorotic. Gradually necrosis developed from tip of the leaves (Plate 3d) as observed by Benzian and Warren(1995) in Sitka spruce seedlings and the whole leaf became necrotic. In between, white chlorotic mottling appeared on younger leaves and the affected leaves lost their softness and they became crisp. Some of the leaves produced were oblong in shape. In the advanced stage of deficiency, the new leaves formed were wrinkled in shape (Plate 3e) and the growth of leaves was found arrested. Chapman (1975) also reported the retardation of terminal growth due to the deficiency of Cu.

Zn deficiency

The plants, which were not receiving Zn expressed the symptoms 64 days after planting. The affected young leaves lost their softness and became crisp as in Cu deficient plants. The veins and veinlets of recently matured leaves became more prominent (Plate 4a). Gradually, white chlorotic spots appeared on the midrib and veins of the leaves (Plate 4b) unlike in Fe deficient leaves wherein the interveinal area get discoloured. Later whole leaf became chlorotic and necrosis started from the tip of the leaf (Plate 4c). Development of bronze coloured spots was also observed (Plate 4d) on lower leaves and later they merged together to form patches. Necrotic patches and burnt appearance on the leaves of Zn deficient teak seedlings were observed by Gopikumar *et al*.(2001). At the acute stage, margins of older leaves became necrotic and premature leaf shedding occurred. In some cases the newly formed leaves were extra ordinary big in size and these leaves were found drooping (Plate 4e).

a. Yellow patches on lower leaves – early stage

b. Yellow patches restricted to leaf margins

c. Interveinal yellowing and vein clearing in lower leaves

d. Chlorosis of entire leaf followed by necrosis starting from leaf tip

e. Small and wrinkled new leaves

Plate 3. Foliar symptoms due to the deficiency of Cu

a. Chlorosis of new leaves- early stage

b. Chlorosis of midrib and veins and appearance of light brown spots – mid stage

c. Chlorosis of entire leaf followed by necrosis starting from leaf tip and margins

d. Necrosis followed by immature shedding of leaves - severe stage

e. Large and drooping new leaves

Plate 4. Foliar symptoms due to the deficiency of Zn

Mn deficiency

After 65 days of planting, the disintegration of chloroplasts of young matured leaves occurred in plants, which were not supplied with Mn. Later these leaves became completely chlorotic (Plate 5a). As the deficiency progressed, the whole leaves turned chlorotic (Plate 5b). But at later stage, lower leaves remained chlorotic and the upper leaves became green (Plate 5c). Similar observations were recorded by Kamala *et al.*(1986).

Mo deficiency

The plants which were not supplied with Mo, developed yellow patches on the tip and upper margin of the older leaves after 65 days of planting (Plate 6a & 6b). Later, these patches gradually spread to the margins of the leaves and became necrotic (Plate 6c). Marginal scorching due to the deficiency of Mo was also reported by Chapman (1975). In some plants the leaves became bluish green in colour (Plate 6d). As in Cu deficient plants, the newly matured leaves expressed vein-clearing symptoms and the interveinal area remained green (Plate 6e). The characteristic symptom observed in Mo deficient plants was the absence of leaf tip and the reduction in the size of leaf lamina towards the base similating the whiptail in cauliflower (Plate 6e&6f).

B deficiency

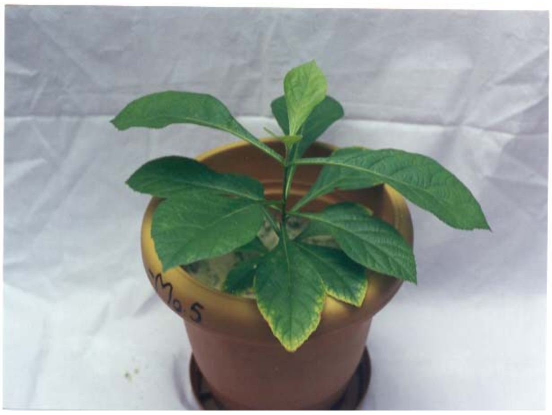
B was the last in the series in the expression of the deficiency symptoms by the teak seedlings and the symptoms appeared only six months after planting. The new leaves developed were small in size and they were found clustering on the top (Plate 7a & 7b). Both the upper and lower leaves were very brittle. All the leaves were yellow in colour and at the acute stage leaves became necrotic (Plate 7c) leading to premature leaf fall. Chapman(1975) also reported rosetting, brittleness and die back of shoots due to the deficiency of B. The B deficient plants produced multistems and the leaves were slendering and tapering (Plate 7d).

a. Chlorotic spots on young leaves – early stage

b. Chlorotic spots on entire leaves – mid stage

c. Chlorotic spots on lower leaves- advanced stage

Plate 5. Foliar symptoms due to the deficiency of Mn

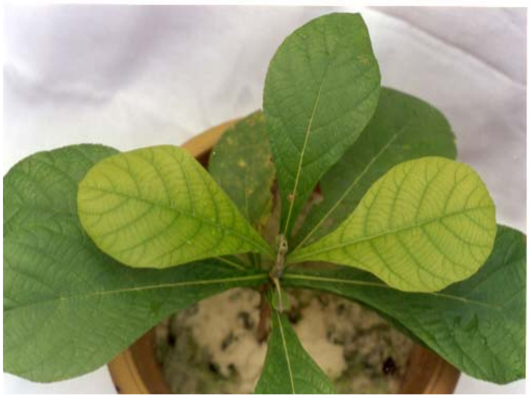


a. Yellowing of leaf tip and
margins of lower leaves – early stage

b. Yellowing of leaf tip and margins of lower
leaves – closer view

c. Necrosis of lower leaf starting from leaf tip

d. New leaves with bluish green colour



e. Interveinal yellowing and absence of tip in
new leaves

f. Comparison on the shape of Mo deficient (left)
and Cu deficient (right) leaves

Plate 6. Foliar symptoms due to the deficiency of Mo

a. Clustering and brittling of new leaves

b. Clustering of new leaves- A closer view

c. Blotching of lower leaves followed by shedding

d. Slendering and tapering leaves and production of multiple shoots

Plate 7. Foliar symptoms due to the deficiency of B

It was also noticed that when all the micro nutrients were deficient, leaves developed interveinal yellowing and this was more intense than that observed in Fe deficient plants (Plate 8).

Plate 8. Interveinal yellowing of new leaves when all the micronutrients were deficient

b. Growth performance

Growth of plants in all the pots were monitored regularly and the growth parameters mainly the height and total number of healthy leaves were recorded during three and six months after planting. Total biomass, which is also a measure of growth was not taken into consideration since in some cases the deficiency of nutrients lead to the development of large abnormal sized leaves which may lead to some erratic results. Compared to control, deficiency of all the nutrients resulted in drastic retardation in the growth of plants (Plate 9a to 9f). As revealed in the Plates 10a, 10b, 10c and 10d the deficiency of Fe, Cu, Mn and Mo respectively led to the shortening of internodes and clustering of branches. Similarly, development of long leaves (Plate 11a to 11d) were seen due to the deficiency of Cu, Zn, Mn and Mo.

There was considerable reduction in the height of the plants (Table 2) due to the deficiency of micronutrients when compared with control. The reduction in height varied between 18 and 45% during three months after planting and it increased to 20-52% six months after planting. Among the nutrients, Mo and Cu caused more growth reduction and B the least at early stage. Similar observations were recorded six months after planting also.

Table 2 Growth of teak seedlings due to the deficiency of micronutrients

Treatment	At the time of planting		Three months after planting				Six months after planting				
	Ht. (cm)	No. of leaves	Height		Healthy leaves		Height		Healthy leaves		Dry root weight (g)
			cm	% reduction	No.	% reduction	cm	% reduction	No.	% reduction	
Cont-rol	2.6	6	42.2	-	13	-	62.3	-	16	-	12.64
Fe	2.5	6	28.4	33	4	69.2	33.6	46	2	87.5	13.82
-Cu	1.9	5	24.3	42	8	38.5	35.4	43	3	81.3	7.79
-Zn	2.6	5	26.1	38	8	38.5	32.8	47	3	81.3	14.45
-Mn	2.6	6	27.3	35	10	23.1	35.9	42	2	87.5	10.92
-Mo	2.6	6	23.1	45	10	23.1	29.6	52	3	81.3	12.92
- B	2.6	6	34.8	18	13	--	49.6	20	2	87.5	10.22

n=10

Similarly, the number of healthy leaves in B deficient plants were on par with control during three months after planting. During this stage Fe deficient plants had less number of healthy leaves; 69.2% less than control. The reduction in healthy leaves over control was 38.5% in Cu and Zn deficient plants and 23.1% in Mn and Mo deficient plants. But at the severe stage of deficiency, the number of healthy leaves were 87.5% less in Fe, Mn, and B deficient plants and 81.5% less in Cu, Zn and Mo deficient plants than control.

As shown in Plate 12, the growth of root system was considerably affected when all the micronutrients were not supplied. But, when each nutrient was considered individually, only the deficiency of Cu resulted in retardation of root growth (Table 2).

Thus it was observed that even though the reduction in plant growth due to the deficiency of micronutrients was less during the early stage, it was severe at advanced stage.

Plate a. Control with Fe deficient plant

Plate b. Control with Cu deficient plant

Plate c. Control with Zn deficient plant

Plate d. Control with Mn deficient plant

Plate e. Control with Mo deficient plant

Plate f. Control with B deficient plant

Plate 9. Comparative growth performance of teak seedlings deficient in micronutrients

Plate a. Fe deficient plant

Plate b. Cu deficient plant

Plate c. Mn deficient plant

Plate d. Mo deficient plant

Plate 10. Shortening of internodes due to the deficiency of micronutrients

Plate a. Cu deficient plant

Plate b. Zn deficient plant

Plate c. Mn deficient plant

Plate d. Mo deficient plant

Plate 11. Production of long abnormal leaves due to the deficiency of micronutrients

Plate 12. Retardation of root growth due to the deficiency of micronutrients

c. Foliar content of nutrients

The content of Fe, Cu, Zn and Mn in the young leaves of the plants showing the deficiency symptoms of Fe, Cu, Zn, Mn, B and Mo were determined at both early and severe stages of deficiencies.(Table 3). In all the cases except Cu, there was a drastic reduction in the content of nutrients with the advancement of the deficiency.

During the early stage of Fe deficiency, the foliar content of Fe ranged from 288-322 ppm while at later stages it decreased to 160-205 ppm. Higher accumulation of Fe in the foliage was observed at the early stage of B deficiency (1165 ppm) and advanced stage of Cu (439-844 ppm) and Zn (532-1163 ppm) deficiencies. The optimum content of Fe recorded in the healthy plants was in the range 379-502 ppm and 326-416 ppm during three and six months after planting respectively.

Compared to Fe, the content of Cu in the plants was very low and the healthy plants contained 18-19 ppm and 12-14 ppm during three and six month after planting respectively. The content of Cu in the Cu deficient plants was 9-10 ppm at early stage of deficiency and it came down to 7-8 ppm at advanced stage of deficiency. Relatively higher accumulation of Cu (37-38 ppm) was noticed at the advanced stage of Mo deficiency.

With respect to Zn, the healthy plants contained relatively higher content of Zn than Cu, but far below that of Fe. As observed in the case of Fe and Cu, the foliar content of Zn decreased with increase in the stage of growth. Data reveal that plants started to express the deficiency symptoms of Zn when its content in the foliage decreased from 56-77 ppm to 44-63 ppm and at severe stage of deficiency it dropped to 21-23 ppm.

In the case of Mn, the healthy plants at three months after planting contained 170- 186 ppm and it was found decreasing to 146-152 ppm at six months after planting. As revealed by the data, plants started to express the deficiency symptoms when its content dropped to 42 ppm and at severe cases it again reduced to 27-36 ppm. An extraordinary accumulation of Mn in the foliage was noted due to the deficiency of Mo.

Table 3.Content of micronutrients in teak seedlings at slight and severe stages of deficiency

Treatment	Age of the plant	Severity of symptom	Concentration of nutrient, ppm			
			Fe	Cu	Zn	Mn
Control	3 months 6 months	-- --	379-502 326-416	18-19 12-14	56-77 38-50	170-186 146-152
-Fe	2 months 6 months	Slight Severe	288-322 160-205	14-15 13-14	31-34 10-58	201-205 172-349
-Cu	3 months 6 months	Slight Severe	205-314 439-844	9-10 7-8	20-26 80-106	135-139
-Zn	3 months 6 months	Slight Severe	91-326 532-1163	18-19 14-15	44-63 21-23	286-291 141-264
-Mn	3 months 6 months	Slight Severe	260-322 93-288	17-19 16-17	42-48 27-36	262-268 55-173
-B	3 months 6 months	Slight Severe	165-215 114-150	17-18 13-14	42-46 17-22	228-231 230-235
-Mo	3 months 6 months	Slight Severe	152-158 151-153	7-9 37-38	26-28 14-24	157-162 685-706

n=8

However, the results in general showed that the order of abundance of micronutrients in the teak seedlings was Fe>Mn>Zn>Cu and the content of all these nutrients decreased with increase in the age of the plants. During the expression of deficiency symptoms, the content of all the nutrients dropped from their normal level and with advancement of the deficiency the concentration also reduced.

d. Recovery

In order to find out the measures to rectify the symptoms caused by the deficiency of micronutrients, respective nutrients were supplied through soil as well as foliar spray during early and later stages of the deficiency. Results indicated that the plants under early stage of nutrient deficiency could recover their original vigour within few days of the supply while those under severe stage of the deficiency could recoup only in certain cases.

Application of complete Hoagland solution through soil to the Fe deficient plants imparted green colour to the foliage within one month. The trials on foliar application of $FeSO_4$ at different concentrations (1%, 0.55%, 0.3%) were also conducted considering its necessity in cases where soil application was not possible. Foliar spray of 1% $FeSO_4$

caused the death of whole leaves indicating phyto toxicity. Some necrotic spots developed on the leaves when 0.5% $FeSO_4$ was applied. But foliar spray of 0.3% $FeSO_4$ two times a week resulted in the rectification of symptom. At severe stage of deficiency, the affected leaves were not able to recoup, but new green leaves emerged without any symptoms of phyto toxicity. So as a remedial measure of Fe deficiency, a foliar spray of 0.3% $FeSO_4$ twice a week is suggested when soil application is not possible.

In the case of Cu deficient plants, soil application of Hoagland solution resulted in the recovery of deficient plants. Foliar application of $CuSO_4$ even at 0.3% led to phyto toxicity. But the Cu deficient plants recovered by spraying 1% Bordeaux mixture.

As in the case of Fe and Cu, application of complete Hoagland solution through soil rectified the deficiency of Zn, Mn, Mo and B. With regard to the foliar spray, application of 0.2% $ZnSO_4$, 0.2% $MnSO_4$ and 0.2% H_2MoO_4 twice a week could eliminate the deficiency symptoms of respective nutrient, but the new leaves failed to emerge. Same nutrients when applied at 0.1% resulted in the emergence of new flushes in all the cases. Among the above nutrients, recovery through foliar spray at severe stage of deficiency was possible only in the case of Mn. The B deficient plants developed phyto-toxicity on spraying 0.1% boric acid and the recovery was possible only at 0.05% H_3BO_3.

CONCLUSION

The study in general revealed that teak seedlings were able to survive almost about 50 days without any micronutrients and after that they developed symptoms of Fe deficiency followed by the deficiencies of Zn, Mn, Mo, Cu and B. The deficiency of each micronutrient expressed some characteristic symptoms along with common symptoms like growth retardation, shortening of internodes, production of long abnormal and unhealthy leaves, etc. The reduction in height was more in Mo and Cu deficient plants and the minimum in B deficient plants at severe stage deficiency. Similarly, there was a drastic reduction in the number of healthy leaves due to the deficiency of all micronutrients, the more reduction in Fe deficient plants and minimum with B. The content of all nutrients in the foliage also dropped due to the deficiency of respective nutrients and in most cases they were decreasing with advancement of deficiency.

It was also noticed that when all the micronutrients were deficient, leaves developed interveinal yellowing and this was more intense than observed in Fe deficient plants. Even though, the reduction in plant growth due to the deficiency of micronutrients was less during the early stage, it was severe at advanced stage. The results in general showed that the order of abundance of micronutrients in teak seedlings was Fe>Mn>Zn>and Cu and the content of all these nutrients decreased with increase in the age of the plants. During the expression of deficiency symptoms, the content of all the nutrients dropped from their normal level and with advancement of the deficiency their concentration again reduced. The plants under early stage of deficiency could recover their original vigour within few days of the nutrient supply while those under severe stage of the deficiency could do so only in the case of Mn and Fe. Foliar spray of 0.3% Fe SO_4, 1% bordeaux mixture, 0.1% Zn SO_4, $MnSO_4$, 0.1% MoO_3 and 0.05% H_3BO_3 was found effective in rectifying the deficiency of Fe, Cu, Zn, Mn, Mo and B respectively.

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