Boron Deficiency in Mango (*Mangifera indica* L.): A Cause Delineation Study in Acidic Soils of Maharashtra, India

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Boron deficiency is a major production constraint of Mango cv Alphonso in western coast, Maharashtra, India. The soils are sandy-loam, light, acidic in reaction and receive high annual precipitation of above 2,500 mm. The leaf and soil B status was low with an average of 23 and 0.25 mg kg^{-1} respectively. About 60% of the orchards were found to be deficient in B. The B adsorption study using Langmuir adsorption isotherm revealed that the adsorption capacity of B by these soils was low with an average adsorption maxima (*b*) of 16.62 μg g^{-1} and bonding energy constant (*K*) of 0.09 mL μg^{-1} making soil B susceptible to leaching. The Mango leaf N status was in excess range, which aggravated B deficiency through growth dilution. A significant negative correlation was observed between leaf B and leaf N (statistically significant at 1% level (p=0.01)). The free Al status of the soils was found to be fairly high, and its detrimental effect on root growth was observed which led to inefficient absorption of limited soil B by roots. The climatic conditions of Konkan like high humidity, high temperature and long sunshine hours also favored widespread incidence of B deficiency, low yield and poor quality. The response of Mango cv Alphonso to the B application was found to be more in foliar than in soil application.

Key Words: **acidic soils, boron deficiency, mango.**

Mango (*Mangifera indica* L.) is the most important fruit crop of India with an area of 1.3 Mha but with low productivity of 5 to 6 t ha^{-1}. Among Indian varieties, Alphonso grown in West coast of Maharashtra (Konkan), cultivated in about 0.13 Mha is well known for its quality. But of late the productivity of Alphonso in Konkan has drastically declined to 3 – 4 t ha^{-1} due to poor fruit set, internal breakdown exhibited as spongy tissue, a sour mass of tissue in the flesh and visible only when cut opened. The widespread occurrence of B deficiency has been identified as one of the important causes of poor yield and quality of Alphonso Mango of this region (Edward Raja and Anil Kumar 2003). Since several soil and climate factors were suspected to aggravate B deficiency, a study was undertaken to identify all the causes to work out sustainable correction.

MATERIALS AND METHODS

To establish the causes of widespread B deficiency, a survey of orchards of Alphonso variety of mango was undertaken in 2001 and 2002 in Sindudurgh District, in Konkan region of Maharashtra. Ten composite leaf (4–6 month old) and surface soil samples in the 0–15 cm layer from active root zone in each of the six taluks (regions) were collected. The leaf samples were washed with water, detergent solution, rinsed with 0.1 M HCl and distilled water, oven dried, powdered and analyzed for B by dry ashing (Gaines and Mitchell 1979), and colorimetry using Azomethine-H. Nitrogen was analyzed by Kjeldahl method and in the wet ash samples, K was estimated by flame photometry and Zn and Mn by atomic absorption spectrophotometry. The air dried soil samples were analyzed for pH, EC, organic carbon (OC), Fe and Al oxides, Hydroxy Al compounds and exchangeable Al (Black 1965; Jackson 1976) and hot water soluble B by modified Azomethine-H method (Parker and Gardner 1981).

The B adsorption characteristics of the surface soil samples were carried out by adopting the method of Mondal et al. (1993). The B equilibrium concentration used for the study was 0–60 μg g^{-1} and adsorption was studied by using the well known Langmuir adsorption isotherm equation. $C/S=(1/Kb)+(C/b)$ where C=equilibrium concentration, S=amount absorbed, B=adsorption maxima and K=a constant related to bonding energy.

Two representative soil profiles, one representing majority of orchards which were severely B deficient and another representing healthy orchards, were examined for physico-chemical properties to relate them to causes of B deficiency.

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Field experiments were carried out in 2003–2004 at Kankavli, Konkan Maharashtra to study the response of Mango cv Alphonso to B following completely randomized design. The treatments consisted of foliar application of Solubor at 0.1% twice during October and December and soil application of Borax at 125 g tree^{-1} and 250 g tree^{-1} in July. The statistical analysis of the data was carried out using standard statistical procedures.

RESULTS AND DISCUSSION

B status in soil and leaf

The results of survey indicated low B in soil (hot water soluble) and leaf in all regions. In soil B concentration varied from 0.19 to 0.31 mg kg^{-1} with a mean of 0.25 mg kg^{-1} (Table 1) and in leaf the values ranged between 13 to 33 mg kg^{-1} with a mean of 23 mg kg^{-1} (Table 4). Whereas 0.5 mg kg^{-1} is the critical level of B in soil for most of the crops (Mengel and Kirkby 1987) and 50 to 100 mg kg^{-1} B in leaf is the satisfactory range for mango (Agarwala et al. 1988), 65% of orchards were found to be deficient in B based on the above standards. Trees were also exhibiting visible symptoms of B deficiency like irregular leaf lamina, necrotic leaf tips with poor fruit set.

B adsorption

Soils of all the six regions obeyed the Langmuir sorption isotherm, and the adsorption maxima (b) value for B in the soils of different regions ranged from 3.86 to 23.58 μg g^{-1} with an average of 16.62 μg g^{-1} and bonding energy constant (K) ranged from 0.04 to 0.124 mL μg^{-1} with an average of 0.090 mL μg^{-1}. The Konkan region receives high annual precipitation in short duration thus soil B is subjected to severe leaching loss since the low B adsorption values indicate the inability of these soils to retain B against the strong leaching action of high rainfall. The reasons for low adsorption capacity of these soils could be attributed to many other factors

Table 1. Physico-chemical properties of the surface soils (0–15 cm) of different regions in Konkan, India.

Regions	pH (1:2.5)	OC (%)	Clay (%)	CEC (cmol(+) kg^{-1} soil)	Fe oxides (%)	Al oxides (%)	Hydroxy Al (cmol(+) kg^{-1} soil)	Exch. Al (cmol(+) kg^{-1} soil)	Hot water soluble B (mg kg^{-1})
1	4.35	0.49	15.4	8.3	0.38	0.46	14.31	8.61	0.21
2	5.65	0.66	8.9	13.5	0.48	0.36	13.96	3.29	0.19
3	6.32	0.58	10.8	7.6	0.55	0.55	18.82	5.36	0.29
4	4.20	0.79	16.5	10.9	0.56	0.68	15.96	4.28	0.26
5	4.85	0.72	20.8	11.9	0.62	1.06	20.79	3.59	0.31
6	5.36	0.61	18.5	14.6	0.63	0.86	16.82	4.48	0.24
Mean	5.12	0.64	15.15	11.1	0.54	0.66	16.77	4.93	0.25

Table 2. Physico- chemical properties of representative soil profile from B deficient mango orchards, Konkan.

Depth (cm)	Horizon	Clay (%)	Texture	pH (1:2.5 water)	OC (%)	Bases (cmol(+) kg^{-1} soil)	CEC (cmol(+) kg^{-1} soil)	Acidity: Exch. H (cmol(+) kg^{-1} soil)	Acidity: Exch. Al (cmol(+) kg^{-1} soil)	Root abundance by number and size[a] (avrg. m^{-2})
0–15	Ap	16.3	Sl	4.9	0.57	5.74	8.1	0.17	0.42	>1,000 Fine
15–40	2A2	7.5	S	5.2	0.28	1.06	3.9	0.08	0.38	500–600 Medium
40–74	2BW1	20.2	Scl	5.8	0.27	1.24	2.8	0.07	0.17	10–15 Coarse
74–108	2BW2	17.2	Sl	5.6	0.26	2.33	4.2	0.09	0.23	Nil
108–145	2BC	19.0	S	5.8	0.20	5.81	6.9	0.09	0.27	Nil

[a]Fine=1–2 mm, Medium=2–5 mm, Coarse=5–10 mm.

Table 3. Physico-chemical properties of representative soil profile of healthy orchard without B deficiency in Konkan.

Depth (cm)	Horizon	Clay (%)	Texture	pH (1:2.5 water)	OC (%)	Bases (cmol(+) kg^{-1} soil)	CEC (cmol(+) kg^{-1} soil)	Acidity: Exch. H (cmol(+) kg^{-1} soil)	Acidity: Exch. Al (cmol(+) kg^{-1} soil)	Root abundance by number and size[a] (avrg. m^{-2})
0–15	Ap	35.6	Sc	5.4	0.81	5.74	21.8	0.05	0.03	>1,000 Very Fine
15–40	2A2	36.1	Sc	6.0	0.74	1.06	16.93	0.03	0.01	500–600 Fine
40–74	2BW1	27.2	Scl	6.2	0.33	1.24	15.46	0.01	0.02	>100 Medium
74–108	2BW2	30.7	Sc	6.4	0.24	2.33	11.39	0.00	0.00	50–60 Coarse
108–145	2BC	24.6	Sl	6.5	0.14	5.81	8.50	0.00	0.00	<50 Coarse

[a]Very Fine=1 mm, Fine=1–2 mm, Medium=2–5 mm, Coarse=5–10 mm.

Table 4. Leaf nutrient status of mango of different regions, Konkan, Maharashtra.

Region	N	P	K	Zn	B	Mn
	(%)			(mg kg^{-1})		
1	1.86	0.09	0.65	25	20	265
2	1.76	0.07	0.98	29	26	369
3	1.62	0.10	1.00	20	33	307
4	1.94	0.11	0.75	18	13	401
5	1.83	0.09	0.70	21	21	389
6	1.79	0.11	0.30	14	27	510
Mean	1.80	0.09	0.73	21	23	373

like low organic matter, low pH and low clay content and predominance of 1:1 type and oxide clay minerals.

B uptake and Al toxicity

The Al fractionation (Table 1) in soil showed a higher range of free Al in these soils. In profile where B deficiency was severe, less root proliferation was observed with no root activity in lower horizons (Table 2). Thickened root tips and lateral roots were observed in upper surface with reduced fine branching, whereas in the profile of healthy trees, the root proliferation was seen throughout the profile with more fine roots in surface (Table 3) and root inhibiting nature of Al is well known. Low K (0.73%) in leaf (Table 4) was observed but 0.77–1.73% K is the optimum range for Alphonso Mango (Raghupathi and Bhargava 1999) and it has been proved by Matsumoto and Yamaya (1984) that Al toxicity causes low K uptake due to disturbance to membranes.

Though amounts of exchangeable Al is not so high (0.42 cmol(+) kg^{-1} soil) compared to other acidic soils, Al toxicity effect has been exacerbated due to the low organic carbon (0.64%) in these soils (Table 1). Several studies have shown that organic matter present in soil can alleviate Al toxicity considerably and under low organic matter levels even the low exchangeable Al concentration can affect the plant roots severely (Shuman et al. 1991). Moreover, 75% of mango root activity is confined to surface layer of 0–47.3 cm depth (Bojappa and Singh 1974) and the presence of even moderate concentration of exchangeable Al in the top layers would affect the roots considerably. In addition, the climatic conditions of Konkan, Maharashtra (Fig. 1) favors intense vegetative growth leading to wider shoot to root ratio which also might increase the sensitivity of mango roots to Al toxicity.

Metabolic requirement of B influenced by N

The farmer's practice of imbalanced application of inorganic NPK fertilizers (@ 1.5 kg N : 0.5 kg P_2O_5 : 0.5 kg K_2O tree^{-1} year^{-1}) is also another major cause of B deficiency in this region. The average N content in leaf was 1.80% and 45% of the orchards had leaf N status in excess range (Table 4). The optimum N for Alphonso Mango is 0.78–1.15% (Raghupathi and Bhargava 1999). A significant negative correlation was obtained for leaf N and B ($r=-0.6585$, statistically significant at 1% level ($p=0.01$)). It is well established that excess N application leads to nutrient deficiencies through crop dilution effect.

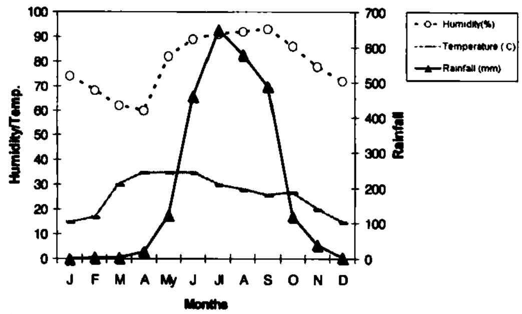

Fig. 1. Mean weather changes of Konkan, Maharashtra.

Table 5. Response of Alphonso Mango to B application in Konkan, Maharashtra.

Treatment	Leaf B concentration (mg kg^{-1})	Yield (t ha^{-1})	Percent fruit set (increase over control)
Solubor spray at 0.1%	67*	7.8*	25–30
Soil application of Borax (125 g tree^{-1})	32	6.1	10–15
Soil application of Borax (250 g tree^{-1})	35	6.3	10–15
Control	20	5.6	–

* Significant statistically at 5% level ($p=0.05$).

Climatic conditions aggravating B deficiency

Though a clear cut study to know the effect of climate on B deficiency was not done, the climatic conditions of Konkan Maharashtra region were suspected to induce B deficiency by increasing the metabolic requirement and limiting the uptake. The high humidity (60–80%) throughout the year in Konkan, Maharashtra (Fig.1) has contributed to the lower uptake since B translocation is influenced by transpiration. The long hours of sunlight (mean of 14.5 h d^{-1}) and high mean temperature (25°C) (Fig.1) throughout the year has also ensured vigorous vegetative growth and high B requirement but the reserve in the soil is low due to leaching and low organic matter status. High light intensity and longer days (Tanaka 1966) and high humidity are not ideal for B uptake when the soil B status is low. The soil moisture is one more factor, which plays a role in limiting effective B absorption by plants since B is mostly taken up by mass flow but dry soil profile conditions prevail for longer period in Konkan (December to May), as a result uptake of B is severely affected.

Response of mango to B application

Field response studies were conducted at Kankavli, Konkan in B deficient orchards (leaf B <25 mg kg^{-1}) to study response and evaluate different methods of B application. Correction of B by foliar application of Solubor performed better than soil application of Borax

(Table 5) and in the leaf, concentration increased significantly to 67 mg kg^{-1}. Moreover, B application by foliar spray increased fruit set by 25–30% over control and resulted in early flowering. The average yield after correction was 7.8 t ha^{-1} compared to only 5.6 t ha^{-1} in no B (control) and the trees, which did not flower for last 3–4 years, flowered after application of B through foliar spray. In control the deficiency symptoms prevailed and a leaf B concentration of 20 mg kg^{-1} was observed.

Conclusion

Our study concludes that the inherent low B status of these soils is due to heavy leaching loss and low adsorption capacity of these soils. The Al toxicity has affected the root growth affecting the efficiency of absorption. The excess application of N has led to high B requirement and deficiency thereof through crop dilution. The climatic conditions have ensured vigorous vegetative growth and high metabolic requirement further inducing the deficiency, as the available B is already low in these soils. A sustainable correction has to address all these factors. Mango cv Alphonso was more responsive to the foliar application of B than soil application.

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