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Boron deficiency disorders in mango (*Mangifera indica*): field screening, nutrient composition and amelioration by boron application

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ABSTRACT

Internal necrosis (IN) is an emerging physiological anomaly of developing mango fruits due to boron deficiency which may also lead to fruit cracking (FC). Systematic field studies were conducted in six important commercial cultivars, viz 'Dashehari', 'Bombay Green', 'Amrapali', 'Mallika', 'Lucknow Safeda' and 'Chausa' to observe the severity of IN and FC incidence. The studies revealed that out of six cultivars of mango, 'Dashehari' was most sensitive for both the disorders, while cv. 'Chausa' was most tolerant under agro-climatic conditions of Doon Valley, Uttarakhand, India.

The nutrient analysis of leaf and fruit of bearing branches indicated that the IN was caused due to deficiency of boron. The N content in IN affected leaf and fruit was significantly higher in comparison to the normal samples. The high leaf N in 'Dashehari' may be a factor behind low level of leaf B and subsequent IN disorder. Foliar sprays of boron (as disodium octaborate tetrahydrate) @ 0.10% were most effective in increasing the level of B in leaf and fruits (149.64% and 120.14%, respectively) of 'Dashehari' cultivar. In all, foliar application was found to be more effective than soil application in increasing yield and reducing IN and FC disorders. The IN disorder also aggravated the incidence of fruit cracking in 'Dashehari' cultivar.

Key words: Boron, Fruit cracking, Internal fruit necrosis, Mango, Nutritional composition, Varietal screening

Quality production, market value and export of mango (*Mangifera indica* L.) suffer from several limiting factors including nutritional disorders. Among the different nutrients, boron has major role in declining quality as well as yield potential in mango (Raja *et al*. 2005). Deficiency of boron causes several physiological disorders such as internal necrosis (IN) which may lead to fruit cracking. Internal necrosis was identified as a new physiological disorder of developing mango fruits. The first visible symptom was the development of dark green colour on the apical part of the fruit and formation of isolated brown areas of indefinite outline in seed and mesocarp of the rapidly growing fruits. Subsequently affected mesocarpic tissues collapsed and cavities surrounded by corky tissues developed. In some of the fruits, the disorder was limited to seed necrosis, tapering of fruit-tip and fruit cracking. The deficiency of boron and calcium is also believed to be associated with the fruit pitting disorder of mango (Sharma and Singh 2008).

High incidence of fruit drop before maturity has also been a serious concern in mango production (Murti *et al*. 2008). During fruit development, proper supply of B becomes difficult, particularly in areas with acid sandy soils receiving fair amount of rainfall. These conditions are common in Doon valley soils of Uttarakhand. Furthermore, boron is easily leached under such conditions (Mengel and Kirkby 1987). Keeping above facts in mind, the present study was conducted on the varietal screening of boron deficiency related disorders; nutrient status of affected leaf/fruit and effect of soil and foliar application of boron in B-deficient soils of north India.

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MATERIALS AND METHODS

The investigations were carried out at Horticulture Research and Extension Centre (HREC), G B Pant University of Agriculture and Technology, Dhakrani, Dehradun, Uttarakhand, India (elev. 600 m; lat. 28°42' N and long. 77°35'–81°5' E). The details of the different experiments conducted under this study are given as under.

Field screening of mango cultivars

Field screening of different mango cultivars was carried out during 2007 and 2008 for taking an account of physiological disorders, i e internal necrosis (IN) and fruit cracking (FC) in mango orchard of HREC, Dhakrani. The trees selected were of uniform age. In the orchard, six blocks

of each cultivar were marked and five trees in each block were randomly chosen for observations on IN and FC from pea stage to fruit maturity. Each tree represented a replication. Six cultivars, viz 'Dashehari', 'Bombay Green', 'Amrapali', 'Mallika', 'Lucknow Safeda', 'Chausa' were studied for IN and FC incidence. Each tree of different selected cultivars was observed carefully and numbers of damaged fruits were recorded at weekly intervals. Each fruit was cut into two equal halves for observing the incidence of IN. The cracked fruits were recorded by counting the number of normal and cracked fruits to get the incidence of FC. The values of different observations obtained from these trees were averaged to get the mean value. The experiment was conducted for two consecutive years in bearing trees. The data presented are the pooled mean of two years. The statistical analysis of the data was carried out using standard statistical procedures.

Nutrient composition of mango cv. 'Dashehari'

Owing to the severity of the IN and FC problem in 'Dashehari' cultivar, the status of nutrients in different plant parts of normal and IN affected trees were worked out. The mature leaf and fruit samples were collected in the first week of June for two consecutive years in 2007 and 2008 from fruit bearing shoots of 'Dashehari'. The leaf sampling procedure as described by Koo and Young (1972) was followed. Tissue concentration of nitrogen was determined by Kjeldhal's methods, phosphorous by vanadomolybdate method (Jackson 1973) and potassium by flame photometer (Chapman and Pratt 1961). The concentration of zinc, iron, manganese and copper were determined with the help of atomic absorption spectrophotometry. The content of boron was estimated by Azomethine-H method (Wolf 1971).

Effect of boron application in mango cv. 'Dashehari'

This experiment was carried out during 2008 and 2009 with 30-year-old 'Dashehari' trees as this cultivar is susceptible to IN and FC disorders. Representative soil samples were collected from drip line area of trees from experimental orchard on 15 December 2007 prior to start of the experiment. The *p*H of the soil was determined in 1:2.5 soil water extract, organic carbon by Walkley and Black's titrimetric method and boron was estimated by Azomethine-H method (Wolf 1971). Boron treatment was done through soil application as well as foliar sprays. There were seven treatments replicated four times in randomized block design. The treatments were: T_1- control, T_2- soil application of boron @ 25 g/tree, T_3- soil application @ 50 g/tree, T_4- soil application @ 75 g/tree, T_5- foliar sprays of boron @ 0.05%/tree, T_6- foliar sprays @ 0.075%/tree and T_7- foliar sprays @ 0.10%/tree. Boron was applied through disodium octaborate tetrahydrate containing 20% boron. The soil application was given each year once during second week of December in 20 cm deep trenches, 200 cm away from the main trunk. The first of three foliar sprays were given at pea stage, in third week of April, followed by second and third sprays at 15 days intervals. The incidence of IN on each tree was recorded by counting the number of necrotic and healthy fruits in June as described earlier. Fruit yield was also recorded. The tissue concentration of boron in leaf and fruit was determined by Azomethine-H method (Wolf 1971).

RESULTS AND DISCUSSION

Field screening of mango cultivars

The field screening results had divulged that among the selected cultivars, the IN was significantly higher in 'Dashehari' (20.16%) and 'Mallika' (20.11%), followed by 'Lucknow Safeda' (16.38%) and 'Amrapali' (16.07%), while 'Chausa' (3.41%) was least affected as shown in Table 1. The susceptibility of 'Dashehari' and 'Bombay Green' to IN may be because of their higher boron requirement than other cultivars. They observed inverse linear relationship between B contents in the leaf and fruit with per cent fruit necrosis. Saran and Kumar (2008) also concluded that the susceptibility of 'Dashehari' cultivar to IN might to be due to its high boron requirement.

Fruit cracking is a serious economic problem in many fruit crops and the severity of damage varies with the cultivar. Mango crop is also affected by FC disorder (Saran *et al.* 2008). In case of FC disorder, maximum incidence was observed in 'Dashehari' (4.12%), followed by 'Lucknow Safeda' (0.80%), 'Amrapali' (0.73%) and 'Bombay Green' (0.64%), while least incidence was observed in 'Chausa' (0.20%). Thus the field screening studies revealed that out of six cultivars of mango, 'Dashehari' was most susceptible to both the physiological disorders while cv. 'Chausa' was most tolerant. The symptom of IN and FC in 'Dashehari' cultivar are shown in Figs 1, 2. The maximum incidence was found in 'Dashehari' (4.12%), while least incidence was observed in 'Chausa' (0.20%). The high incidence of IN in 'Dashehari' probably also induces and aggravates the incidence of FC in this cultivar.

Nutrient composition of mango cv. 'Dashehari'

There was significant difference in normal and IN affected

Table 1 Field screening of different mango cultivars for internal necrosis (IN) and fruit cracking (FC)

Cultivar	Sample size (no.)	Necrotic fruits (no.)	Cracked fruits (no.)	I N (%)	F C (%)
'Dashehari'	3 809	768	157	20.16	4.12
'Bombay Green'	2 381	270	16	11.25	0.64
'Amrapali'	3 115	507	23	16.07	0.73
'Mallika'	2 442	489	13	20.11	0.53
'Lucknow Safeda'	3 075	472	2	16.38	0.80
'Chausa'	4 443	156	7	3.41	0.20
CD (*P*=0.05)				3.26	0.35

Fig 1 Internal necrosis in 'Dashehari'

Fig 2 Fruit cracking in 'Dashehari'

samples of leaf and fruit for N content in bearing branch of 'Dashehari'. The N content in normal leaf (0.93%) and fruit (0.59%) was significantly lower than those of IN affected samples of leaf (1.16%) and fruit (0.66%) as shown in Table 2. The N content in IN affected leaf and fruit was higher in comparison to the normal samples. Recent reports have indicated that excess N application leads to B deficiency through crop growth dilution in mango (Raja *et al*. 2005). Therefore, the high leaf N in 'Dashehari' may be responsible for low level of leaf B and subsequent IN disorder.

The P content of leaf and fruit were at par in normal and IN affected samples. K content in leaf was not affected by IN. However, K content in fruit of normal samples (0.59%) was lower as compared to fruit of IN affected samples (0.64%).

Significant amount of Zn was noticed in IN affected samples of leaf (29.92 mg/kg) as compared to normal samples (20.21 mg/kg), while fruit (15.66 mg/kg) of normal samples contained significantly higher amount of Zn as compared to IN affected samples of fruit (12.12 mg/kg). Fe content in leaf was significantly reduced in IN affected samples in comparison to normal samples. However, it significantly increased in fruits of IN affected samples. There was no significant difference in the Mn and Cu content of leaf and fruit in normal and IN affected samples.

The B content in normal samples of leaf (86.16 mg/kg) and fruit (32.17 mg/kg) were significantly higher in comparison to IN affected samples of leaf (38.95 mg/kg) and fruit (20.64 mg/kg). Thus IN affected trees had low concentrations of B in leaf and fruit indicating that deficiency of only B is responsible for IN in 'Dashehari' mango.

Effect of boron application in mango cv. 'Dashehari'

The soil analysis data of the experimental field are presented in Table 3. With increasing soil depth, the *p*H and organic carbon decreased coupled with reduction in available boron. The soil was slightly acidic and considering 0.5 mg/kg as the critical level of B in soil for most of the crops (Mengel and Kirkby 1987), the experimental soil was deficient in B.

The untreated trees of 'Dashehari' showed highest incidence of IN and FC as shown in Table 4. The soil application of boron @ 25 g, 50 g and 75 g to each tree decreased IN to 5.87%, 3.53% and 3.48%, respectively. The foliar application of boron @ 0.05%, 0.075% and 0.10% decreased IN to 4.39%, 3.74% and 2.92%, respectively. The response of mango towards foliar B application was more in comparison to soil application as also reported by Raja *et al*. (2005).

In case of FC, soil application of boron @ 25 g, 50 g and 75 g/tree decreased incidence to 2.02%, 1.01%, 1.05%, respectively, whereas foliar application of boron @ 0.05%, 0.075% and 0.10% decreased incidence to 0.90%, 0.75% and 0.47%, respectively. The incidence of IN (2.92%) and FC (0.47%) were lowest when trees were sprayed with 0.10% boron. The ameliorative effect of B in reducing the incidence of fruit cracking is well recognized (Davis *et al*. 2003). The cracking in apple was completely eliminated by B containing

Table 2 Nutrient status in different plant parts of normal and internal necrosis (IN) affected trees of mango cv. 'Dashehari'

Plant part/samples		Average nutrient concentration in bearing branch							
		N	P	K	Zn	Fe	Mn	Cu	B
		(%)			(mg/kg)				
Leaf	Normal	0.93	0.27	0.31	20.21	389.93	306.91	7.28	86.16
	IN affected	1.16	0.28	0.33	29.92	226.48	308.96	6.48	38.95
Fruit	Normal	0.59	0.22	0.59	15.66	320.27	102.65	5.45	32.17
	IN affected	0.66	0.21	0.64	12.12	436.80	103.03	5.40	20.64
CD (*P*=0.05)		0.06	0.03	0.03	1.93	43.85	11.57	0.89	6.54

Table 3 Some chemical properties of orchard soil of experimental site

Soil depth (cm)	*p*H	Available boron (mg/kg)	Organic carbon (%)
0–25	6.6	0.44	0.71
25–50	6.2	0.40	0.54
50–75	5.9	0.34	0.48

Table 4 Effect of boron application on the incidence of internal necrosis and fruit cracking in mango cv. 'Dashehari'

Treatment	I N (%)	F C (%)	Yield (kg/tree)
T_1, control	17.32	3.84	169.55
T_2, soil application (25 g/tree)	5.87**	2.02**	185.93*
T_3, soil application (50 g/tree)	3.53**	1.01**	203.81**
T_4, soil application (75 g/tree)	3.48**	1.05**	200.43**
T_5, foliar sprays (0.05%)	4.39**	0.90**	193.23**
T_6, foliar sprays (0.075%)	3.74**	0.75**	207.48**
T_7, foliar sprays (0.10%)	2.92**	0.47**	215.58**
CD (*P*=0.05)	1.35	0.33	12.85
CD (*P*=0.01)	1.84	0.45	17.49

*P=0.05, **P=0.01

sprays. This might be due to the effects of B on membranes and cell walls. It is also well documented that B helps in maintaining membrane stability.

The maximum yield was obtained with the foliar application of boron @ 0.10% (215.58 kg/tree), followed by foliar application of boron @ 0.075% (207.48 kg/tree) as presented in Table 4. The application of boron through foliar spray was significantly more effective than soil application. The application of boron through foliar spray was more effective due to better intake of boron by leaf cuticle, as compared to root uptake. The foliar application of boron is reported to improve fruit set and subsequent fruit yield (Ebeed and El-Migeed 2005).

Boron content was significantly higher in leaf samples as compared to fruit samples (Fig 3). The concentration of boron in leaf and fruit samples significantly increased with all the treatments of boron. The maximum increase in leaf B concentration was found with foliar application of boron @ 0.10% (T_7) which was 120.14% higher than the control (T_1), followed by foliar application @0.075% (90.17%) and soil application @ 75 g (77.70%). In case of fruit, maximum B content was observed with foliar spray of boron @ 0.10% and 0.075% which was 149.64% and 102.92%, respectively, followed by soil application @ 75 g/tree (88.32%). In mango leaf, 50 to 100 mg/kg B is the satisfactory range and leaf B above the concentration of 50 mg/kg is considered adequate (Littlemore *et al*. 1991). The results revealed that the foliar application of boron @ 0.10% were most effective for controlling above disorders and for maintaining the adequate

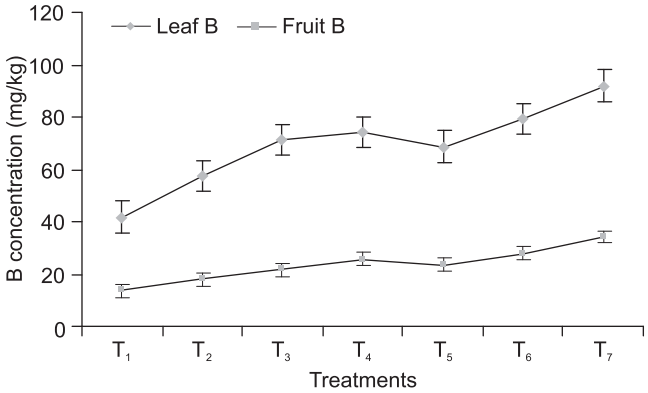

Fig 3 Effect of B application on the concentration of B in leaf and fruit of mango cv. 'Dashehari'. Vertical bars show standard error

level of B in leaf and fruits of 'Dashehari'. There may be several factors responsible for the low response of soil application of boron. In case of soil application, losses due to leaching in acid sandy soils receiving fair amount of rainfall is common (Mengel and Kirkby 1987). It is well known that most of the feeding roots in case of mango are confined to 75 cm soil depth. Moreover, 75% of mango root activity is confined to surface layer of 0–47.3 cm depth. In the present study, the level of boron observed at the soil depth of 0–75 cm was below the critical level.

We observed that among the screened commercial cultivars, 'Dashehari' was most sensitive to IN and FC. The high leaf N in 'Dashehari' may be a factor behind low level of leaf B and subsequent IN disorder. The practice of imbalanced application of nitrogenous fertilizers may also induce B deficiency through crop growth dilution. The ameliorative effect of B application (as disodium octaborate tetrahydrate) through foliar sprays is more effective than soil application. Therefore, balanced application of macronutrients along with proper B management is imperative for quality production in B deficient acidic soils of mango-growing regions of the world.

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