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IMPACT OF BORON AND CALCIUM ON INTERNAL BROWNING OF BANANA

S.D.R. WANNIARACHCHI, C.D. WICKRAMASINGHE, C.K.D. WELLALA and M.S. KARUNATILEKE
Fruit Crops Research and Development Centre, Kananwila, Horana, Sri Lanka

ABSTRACT

Internal Browning (IB) is a severe problem in banana (*Musa acuminata*), especially in varieties 'Kolikuttu' and 'Ambul', in almost all banana growing areas in the country. In this disorder, brown colored flecks could be seen all over the flesh thus, adversely affecting the quality of banana. A series of experiments was carried out at the Fruit Crops Research and Development Centre, Horana, Sri Lanka, during 2006 to 2008 with the objective of developing control measures for this disorder using the variety 'Kolikuttu'. Crops were tested in dry and wet soil conditions to study the effect of moisture on IB and also with different methods of application of boron and calcium to minimize the problem. Incidence of browning disorder was recorded at harvest. Occurrence of IB was observed in almost every crop cycle with varying intensity. The problem could also be seen in crops grown in both wet and dry soils and the severity was high with decreasing soil moisture conditions. Results revealed that foliar application of boron as 0.5 % Borax or calcium as 0.5 % calcium nitrate at 3, 5 and 7 months after planting reduced the IB disorder in banana up to 80 %.

KEYWORDS: Banana, Boron, Calcium, Internal Browning, Nutrient deficiencies

INTRODUCTION

Banana has an ever increasing demand due to its high consumer preference. Continuous supply of fruits of good quality is important to maintain this demand unaffected. Internal Browning (IB) is a problem in banana that has been observed for a long time affecting the fruit quality severely. In this disorder, brown coloured flecks could be observed all over the flesh of the fruit concentrated more towards the nipple end. These flecks extend up to the outer tissues of the flesh but not to the peel. In some fruits they are observed only in the outermost tissues, just under the peel. Therefore, the affected fruit cannot be identified by external appearance easily. A partial fruit filling above the flower end could also be seen in several fruits.

This disorder could be observed in almost all banana varieties grown areas in Sri Lanka. However, it is commonly found in the low country wet zone. The banana varieties 'Kolikuttu' and 'Ambul' are mostly affected, where the symptoms are obvious in both main crop and ratoon crops. To-date, no pathogen or pest has been found in the affected fruits. Moisture stress and nutrient deficiencies were suspected to be the causal factors for this disorder. Fernando and Alwis (2005) reported that 75 % depletion of water created browning suggesting that it was a problem related to low moisture conditions.

In contrary, the condition was prevalent in banana grown with supplementary irrigation throughout the crop in the dry zone (Weerasinghe *et al.*, 2001), indicating that occurrence of IB could be due to reasons other than the water stress.

The presence of amber colored gummy deposits in banana was associated with boron (B) deficiency (Shorrocks, 1984). Brown color deposits in the flesh of boron deficient banana fruits was also reported by Cull (1995). Tisdale et al (1990) and Marschner (1998) reported that calcium (Ca) and boron have similar functions in plants. A typical symptom of Ca deficiency is the disintegration of cell walls and the collapse of the affected tissues, which could result in discoloration in the storage tissues (Marschner, 1998). Basal application of Ca at double the recommended dosage has helped complete recovery of pineapple plants from the IB disorder (Selvarajah *et al.*, 1998). However, soil application of Ca has not been successful in recovering the IB in banana (Weerasinghe, 2005).

Investigations have not been carried out hitherto, in developing effective methods for controlling IB in banana in Sri Lanka. Therefore, experiments were conducted at the Fruit Crops Research and Development Centre, Horana, Sri Lanka, in order to study the effect of water availability on the disorder and to develop methods of application of Ca and B to control IB of banana.

MATERIALS AND METHODS

Four separate experiments were conducted in a sequential order as described below.

Experiment 1. Effect of soil moisture on IB of banana grown in pots

The experiment was carried out to study the effect of water on IB, as the information available on this aspect was contradictory (Fernando and Alwis, 2005; Weerasinghe *et al.*, 2005). Steel barrels (60 cm diameter x 75 cm height) were used as pots. The barrels were filled up to six inches below the brim with equal volumes (175 litres) of 1:1 sand to soil mixture. Banana (*Musa acuminate* Colla.) suckers of 60 cm in height and 8 cm in basal diameter of the variety 'Kolikuttu' were planted in these barrels (1 plant per barrel). Recommended cultural practices including fertilizer without organic manure were applied to all pots.

Two months after establishment of the plants, two treatments, namely dry and wet conditions were imposed with 4 plants per treatment. The plants in the wet soil treatment were maintained at near field capacity by watering every other day and mulching. Plants in dry soil treatment were kept at below

50 % of field capacity by supplying minimum quantity of water once in 2 weeks. To keep the rain water away, the soil in pots in the dry treatment were covered with polythene supported by wooden frames placed on the barrel, and water was allowed to flow outside the barrel. The yield was taken at full maturity at 14 weeks after flowering (WAF). All fingers were cut longitudinally to two halves to examine browning symptoms. Fruits with any degree of browning were counted as affected ones. Data were analyzed statistically by using pooled t-test.

Experiment 2. Effect of soil and foliar application of calcium and boron on IB of banana grown in pots

This experiment was also carried out in pots similar to that of the experiment 1. Pots were used to limit the soil volume to supply limited quantity of nutrients and to control the water supply to induce deficiency symptoms. Seven treatments consisted of soil and foliar application of Ca and B separately and their combinations were tested in an observational experiment on variety 'Kolikuttu'. Four plants were included in one treatment. All the soil treatments were given before planting and the foliar treatments at 2 month intervals. The plant height and the girth at 30 cm above the ground level were measured monthly. The yield and the number of fruits with brown flecks were taken at full maturity, 14 WAF. Browning was examined as in experiment 1. Percentage of fruits with browning symptoms, and increase of height and girth during a six month period were calculated.

Experiment 3. Effect of foliar application of calcium and boron on IB of banana.

The experiment was carried out in the field as an observational study on the banana variety 'Kolikuttu'. Four plants were included in one treatment. The five treatments consisted of the control (T_1), 0.5 % calcium nitrate (T_2), 0.5 % borax (T_3), a combination of T_2 and T_3 (T_4), and 0.5 % urea (T_5). Urea was included in treatments 5 and 3 to compensate the effect of N supplied with calcium nitrate in treatments 2 and 4. The treatments were sprayed with a surfactant on banana plants at 2 month intervals, on to both first and second crop. All cultural practices were adopted as recommended by the Department of Agriculture, Sri Lanka, but without organic manure. The crop was raised under rainfed conditions. The number of fruits with browning symptoms and the yield parameters were measured at full maturity 14 WAF. Severity of IB was recorded using a 0-4 point scale (Devanathan and Ramanujam, 1995), where 0 = browning free, 1 = 0-25 %, 2 = 26-50 %, 3 = 51-75 %, and 4 = 76-100 %.

The percentage browning index (PBI) was computed using the formula

$$PBI = \frac{\text{Sum of numerical ratings} \times 100}{\text{Total number of fruits assessed} \times \text{maximum rating}}$$

Experiment 4. Effect of time of application of foliar sprays of boron and calcium on IB of banana

On the basis of soil analysis, a Red Yellow Podsolic soil with low soil fertility was selected for the experiment. Plots were separated by drains to allow excess water to flow out. Organic manure was added at the rate of 5 kg/hole as the soil was infertile. Banana variety 'Kolikuttu' was planted in a randomized complete block design (RCBD) with three replicates. Fertilizer application was done according to the recommendation of the Department of Agriculture, Sri Lanka. Crop was raised under rainfed conditions. Foliar sprays of boron as 0.5 % Borax and calcium as 0.5 % calcium nitrate, with surfactant, were given at 1 month intervals and 3, 5, 7 months after planting (MAP) according to the treatments, commencing at 3 MAP. Water was sprayed for the control treatment. Plant height and girth were measured at flowering, increase in height and girth in 6 months, and the weight and number of fruits, and incidence of browning were measured at full maturity at 14 WAF. Severity of IB was recorded using the formula described under experiment 3. Angular transformation was used for PBI values and all the data were subjected to Analysis of Variance (ANOVA) and mean differences were determined by the Duncan's Multiple Range Test (DMRT) at p= 0.05 using MStat Statistical package.

RESULTS AND DISCUSSION

Experiment 1. Effect of soil moisture on IB of banana grown in pots.

The results showed that browning symptoms were observed under both dry and wet conditions in soil (Table 1). However, in the wet soil condition, number of affected fruits was significantly lower than that of dry soil. This confirms that the problem was not directly due to water deficit but certain other factors aggravating the disorder when there is a moisture stress. This could be due to the insufficient levels of B or Ca in soil as suggested by Shorrocks (1984) and Selvarajah *et al.* (1998). Tisdale *et al.* (1990) stated that B and Ca deficiencies are associated with dry weather and low soil moisture, thus impairing the ability of plants to extract these two nutrients from soil due to lack of moisture in the root zone. Even though the nutrient levels in soil are high, low soil moisture impairs transport of B and Ca to absorbing root surface as both of these nutrients are moved to the plant roots by mass flow (Tisdale *et al* 1990). The IB, which occurs only at or below 75% of soil water depletion

level (Fernando and Alwis, 2005), might be due to unavailability of B or Ca caused by less moisture.

Table 1. Yield and browning symptoms of banana grown in wet and dry soil conditions.

Treatment	*Mean Yield (g/clump)*	*% fruits with browning symptoms*
Wet soil	4441± 591.39*a	17.25± 2.87*a
Dry soil	2625± 439.65*a	43.00±11. 61*b

*Standard Error. Mean values followed by the same letter are not significant at p=0.05

The observation of browning symptoms in supplementary irrigated conditions as reported by Weerasinghe *et al.* (2001) might also be due to unavailability of these nutrients under such conditions. There are several factors affecting the boron availability to plants. In addition to low content of B in soil (Tisdale *et al.*, 1990), un-dissociated boric acid and borate anions in the soil solution are relatively free to move in soil water and can be quickly leached from soil (Tisdale *et al.*, 1990).

Experiment 2. Effect of soil and foliar application of boron and calcium on IB of banana grown in pots

In the control treatment (T4), in which plants were not treated with Ca or B, browning was observed in all hands (Table 2).

Table 2. Growth measurements and browning symptoms of banana with boron and calcium treatments.

Treatment	*% increase in height in 6 months*	*% increase in girth in 6 months*	**Mean yield g/clump*	*% fruits with browning symptoms*
T_1. 4kg lime + 0g borax (soil)	13.5	8.8	4270±337	0
T_2. 0 lime + 5g borax (soil)	15.0	10.0	4017±564	0
T_3. 4 kg lime + 5g borax (soil)	2.0	8.8	5478±252	0
T_4. 0 lime + 0 borax (control)	2.2	8.1	3018±235	45
T_5. Calcium nitrate 0.5% foliar spray	18.9	13.6	4930±155	0
T_6. Borax 0.5 % foliar spray	20.7	16.1	4212±140	0
T_7. Calcium nitrate 0.5% + borax 0.5% foliar spray	11.5	9.1	5280±195	0

*mean of 4 plants ± SE

All fingers of the first hand and a few fingers of other hands were affected. No browning was observed in plants treated with either Ca or B, as soil or foliar application. However, in plants treated with borax as a soil application, boron toxicity symptoms were visible. All plants of this treatment

showed marginal leaf scorching. This shows that even a small quantity of borax (5g/ plant) was toxic to banana plants when grown in pots. Das and Mohan (1993) found that leaf spray applications of micronutrients to be much effective than soil application for fruit trees. In addition, micronutrients are required by plants in very small quantities. This practice prevents possible toxic effects and leaching of applied nutrients. Hence, the treatments of the next experiment were confined to foliar applications.

Experiment 3. Effect of foliar application of boron and calcium on IB of banana

In the first crop, there was no browning associated with any treatment (Table 3). This might be due to the available nutrients at the initial stages in the soil in sufficient amounts for a good crop growth, and the soil moisture condition was favorable to absorb these nutrients to avoid IB symptoms. In the second crop, a considerable level of PBI was observed in treatments 1 and 5, which were not supplied with Ca or B.

Table 3. Effect of foliar sprayed treatments on the performance of banana

Treatment	*First Crop*		*Second Crop*	
	*Mean Yield (kg/clump)**	*PBI %*	*Mean Yield (kg/clump)**	*PBI %*
T_1 Water	7.6 ± 0.41	0	9.02 ± 0.73	30.2
T_2 Calcium nitrate	9.5 ± 0.53	0	11.03 ± 0.36	1.20
T_3 Borax 0.5% + Urea 0.5%	7.9 ± 0.42	0	10.37 ± 0.35	3.8
T_4 Calcium nitrate 0.5% + Borax 0.5%	8.7 ± 0.82	0	10.83 ± 0.52	3.4
T_5 Urea 0.5%	9.3 ± 0.49	0	9.75 ± 0.23	35.0

*mean of 4 plants ± SE

These symptoms may be a result of insufficient levels of B or Ca, as a low number of fruits with symptoms were observed in the presence of Ca or B or combinations of these two nutrients. This shows that in these treatments, foliar sprays had been effective in supplying the required Ca and B nutrients to the plants. Difficulty in supplying Ca to banana plants through soil, which was experienced by Weerasinghe (2005) could be overcome by this application technique.

Experiment 4. Effect of time of application of foliar sprays of boron and calcium on IB of banana

According to the analysis, the soil at the experimental site was infertile (Table 4). Only phosphorus was at the optimum level. Calcium was below the critical level (1.3 meq/100g) and B was very low (0.01ppm).

Table 4. Soil characteristics at the site of experiment 4 compared with optimum values

Soil character	*Values*	*Optimum values of soil*
Texture	Sandy loam	Loam
pH	5.4	5-6.5
EC (µS/cm)	0.06	<0.8
CEC (meq/100g)	2	>10
O.M (%)	0.8	5
N (µg/g)	18	Vary
P_2O_5 (µg/g)	52	48
S (µg/g)	4	40
B (µg/g)	**0.01**	**0.8**
Cu (µg/g)	1.1	3
Mn (µg/g)	2.5	12
Fe (µg/g)	203	30
Zn (µg/g)	1.7	4
Ca (meq/100g)	**1.3**	**3.5**
Mg (meq/100g)	0.38	1.5
K (meq/100g)	0.13	0.4

1. Analysis done on an air dry basis; 2. pH and EC ratio 1:2.5 mixture-water; 3. Ca and Mg extracted with 1 N KCl, ratio 1:10 mixture- solution; 4. K,P,Mn,Zn,Cu and Fe extracted with $NaHCO_3$ (modified Olsen), Ratio mixture 1:10; 5 .S and B extracted with $Ca(H_2PO_5)_5, H_2O$, Ratio mixture 1:10; 6. K, Mg , Ca, Cu, Fe ,& Zn tested using automatic absorption spectrometry; 7. B, S and NH4-N tested using UV visible spectrophotometry (Analyzed at CIC Laboratory, Palwehera)

The results on yield parameters and PBI values are presented in Table 5. Among the yield parameters measured, number of fruits and weight of a fruit were not significantly affected by the treatments.

Table 5. Yield measurements and PBI values at harvest in experiment 4

Treatment	*Total Wt of fruits (g/cl)*	*Number of fruits*	*Wt /fruit (g)*	*PBI (%)*	*% reduction of PBI over the control*
T1 – Control	5077 b	75.0 a	110.5 a	37.1 a	-
T2 - 0.5% Calcium nitrate 3,5 7 MAP	8396 a	73.7 a	111.4 a	2.05 c	94.0
T3 - 0.5% Calcium nitrate monthly	7424 ab	63.3 a	112.6 a	0.84 c	98.0
T4 - 0.5 % Borax 3,5,7 MAP	9721 a	93.0 a	121.0 a	5.90 bc	84.0
T5 - 0.5% Borax monthly	7888 a	73.0 a	108.7 a	3.55 bc	90.0
T6 - 0.5% Cal.nitrate+ 0.5% Borax 3,5,7MAP	7939 a	68.7 a	116.0 a	19.4 ab	48.0
T7 - 0.5% Cal.nitrate+ 0.5% Borax monthly	7882 a	62.7 a	102.3 a	7.35 bc	80.0
CV %	17.8	18.2	16.8	14.7	

Within a column, mean values followed by the same letter are not significantly different at p=0.05

However, the total weight of fruits of the control treatment and 0.5 % calcium nitrate at one month intervals were significantly low ($p>0.05$). A significantly higher PBI value was recorded in the untreated control (T_1). All other treatments of boron and calcium gave low values for PBI. The mean % reduction of PBI over the control was 80 %. Cull (1995), describing the deficiency symptoms of banana, stated that the amber-colored deposits throughout the pulp, in the center or just under the skin are related to boron deficiency. The symptoms observed in the present study were very much similar to those described by Cull (1995). Shorrocks (1984) explained the brown colored flecks observed in boron deficient fruits are due to the breakdown of the walls of parenchyma cells caused by reduction of lignifications, which is associated with phenol accumulation. With reference to calcium nutrition in plants, Marschner (1998) stated that a typical symptom of calcium deficiency is the disintegration of cell walls and the collapse of the affected tissues. This also might cause discolored patches in fruits. These findings show that both calcium and boron deficiencies induce browning symptoms. Tisdale *et al.* (1990) reported that certain deficiency symptoms were similar for both calcium and boron. Shear (1975) stated that 'bitter pit', which occurs in Ca deficient apples, can sometimes be effectively reduced by B sprays, probably due to that B is required for proper uptake as well as transportation of Ca in plants (Shorrocks, 1994). Ramon *et al.* (1990) also reported impaired shoot transport of Ca in boron deficient plants.

There was no difference between foliar application of the nutrients at 3, 5, 7 MAP, and monthly application. Kumar and Jeyakumar (2001) sprayed several nutrient applications at 3, 5 and 7 MAP for banana and obtained the highest growth and yield responses. Use of micronutrients as foliar applications at 3, 5 and 7 MAP for banana has been reported to be more efficient (Das and Mohan, 1993; Ghanta and Mitra, 1993). All nutrient applications for banana should be completed before flowering for efficient utilization (Cull, 1995). Therefore, application of boron or calcium at 3, 5 and 7 MAP is acceptable for supplying those two nutrients for banana. However, 100 % reduction of the problem could not be obtained with treatments imposed in the present experiment. There must be a more efficient way of supplying these nutrients for the total recovery the problem. Hanson, (1991) showed that recovery of problems related to quality of some fruits could be obtained by spraying relevant nutrients during fruit development. This method has to be tested to reduce the problem further.

CONCLUSIONS

Internal browning (IB) of banana is a disorder that occurs due to the deficiency of boron or calcium, and aggravated under moisture deficit conditions. The problem could be reduced to about 80 % by foliar treatment of boron as 0.5 % borax or calcium as 0.5 % calcium nitrate, applied at 3, 5, and

7 months after planting. Further research on more efficient and practical methods of application of these two nutrients need to be conducted.

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