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Effect of Basal Application of Different Sources of Calcium on the Control of Internal Browning of Mauritius Pineapple Under Cold Storage

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ABSTRACT. This experiment was conducted at two locations namely Pallewela and Wagolla in the Gampaha district to investigate the effects of basal application of three calcium fertilizer sources namely lime (CaO), Fused Magnesium Phosphate (FMP) and dolomite for the control of IB development in pineapple cv. Mauritius pineapple. Each source of calcium fertilizer (lime, FMP and dolomite) was applied as a basal dressing at three different doses - 100 kg ha^{-1}, 125 kg ha^{-1} and 150 kg ha^{-1}. A control plot was maintained without calcium fertilizer. Pineapple were planted in a RCBD with three replicates. Fruits at the 5% maturity stage were harvested and uniform size fruits were stored in a cold room at 15°C and 80-85% RH. They were removed at weekly intervals for four weeks and analysed after keeping 72 h at room temperature for IB intensity, ascorbic acid, total soluble solids (TSS), pH, fruit calcium, titratable acidity and the percentage weight loss.

Fruits from all the calcium treatments had significantly low IB development than the control after first and second weeks of cold storage. The fruits harvested from treatments with 125 kg ha^{-1} and 150 kg ha^{-1} of lime had significantly low IB development (< 3 of the scale) up to the fourth week of cold storage. The fruit calcium of these two treatments were also significantly higher than the control during the above period. Ascorbic acid content of all the calcium treatments were significantly higher than the control after the first week. The 125 kg ha^{-1} and 150 kg ha^{-1} of lime treatments had significantly high ascorbic acid content in first three weeks. The percentage weight loss in the above two treatments was significantly lower and TSS values were significantly higher than the control during the first four weeks. Of all the treatments, lime 125 kg ha^{-1} and 150 kg ha^{-1} showed most promising results in reducing IB development and for the other parameters measured. There was no significant difference between these two treatments for the IB development and most of the other parameters. The most suitable source of calcium fertilizer for basal application is lime at 125 kg ha^{-1}.

INTRODUCTION

Internal Browning (IB) development is a serious problem under refrigerated storage of pineapple [*Ananas comosus* (L.) Merr.]. This is the major constraint in export of fresh pineapple from Sri Lanka under refrigerated sea freight. For the expansion of pineapple export it is important to find measures to control this disorder.

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Internal browning which is also known as black heart or endogenous brown spots is a physiological disorder. The initial symptom is the formation of yellow or light brown spots at the base of fruitlets. The spots enlarge and form dark brown tissue masses as the severity of disease increase (Abdullah *et al.*, 1986). Affected fruits show no external symptoms (Sun, 1988).

The ascorbic acid content and total soluble solids (TSS) in affected fruits have been reported to be lower (Hassan and Atan, 1983: Abdullah *et al.*, 1986). Selvarajah and Herath (1997) have reported that, IB developed fruits have high percentage weight loss and high titratable acidity.

According to Wills *et al.* (1989), calcium prevents or delays incidence of physiological disorders. It has been reported that, a high level of calcium (lime-CaO) fertilizer application (150 kg ha^{-1}) is effective for the control of IB for four weeks (Selvarajah *et al.*, 1998).

This experiment was conducted to investigate the effect of basal application of three different sources of calcium fertilizer and to find the most suitable one among them to control IB under cold storage.

MATERIALS AND METHODS

This experiment was conducted at two locations namely Pallewela (Gampaha district) and Wagolla (Gampaha district) on red yellow podzolic soil from January 1999 to March 2001. Pineapple cv. Mauritius was planted in a randomized complete block design with three replicates.

Three sources of calcium fertilizer namely lime (CaO), Fused Magnesium Phosphate (FMP) and dolomite ($CaCO_3$ $MgCO_3$) were applied as basal dressing at three different levels (Table 1) in nine treatments and a control plot was maintained without application of calcium fertilizer. All the other fertilizer requirements (N, P, K) were provided to all the plots in recommended doses.

Fruits of quarter ripened stage (5% maturity) were harvested in the morning and transported to the laboratory of the Department of Agricultural Biology. They were sorted according to size and uniformity. From each treatment 36 fruits were selected representing three replicates. They were stored in a cold room of 15°C temperature and 80-85% RH and removed at weekly intervals (nine fruits per treatment) for four weeks and analysed after keeping for 72 h at room temperature.

Determination of IB intensity

Fruits were cut into two halves longitudinally and the IB intensity was determined using the following visual scale modified from Teisson (1979).

Scale	Description
0	Good flesh with no discolouration
0.5	Formation of watery spots at the base of fruitlets, yellow or light brown in colour
1	10% of flesh discoloured
2	25% of flesh discoloured
3	50% of flesh discoloured
4	75% of flesh discoloured
5	100% of flesh discoloured

Table 1. Amounts of different sources of calcium fertilizer applied as basal dressing.

Treatment	Amount of calcium fertilizer kg ha^{-1}
C1	100
C2	125
C3	150
F1	100
F2	125
F3	150
D1	100
D2	125
D3	150
Control	Nil

C = lime F = FMP D = dolomite

Determination of ascorbic acid content, total soluble solids (TSS) and pH

After the removal of core and peel of fruits, fruit juice was extracted from the flesh and the ascorbic acid content was determined by titrating with 2, 6 dichlorophenol indophenol according to Askar and Treptow (1993).

The TSS and pH of fruit juice were measured by a hand refractometer and a digital pH metre (TOA pH metre HM - 20 S) respectively.

Determination of percentage weight loss, fruit flesh calcium content and titratable acidity

Weight of each fruit before cold storage (initial weight) and before the final analyses (final weight) was measured. The percentage weight loss was calculated using the following formula.

$$\textit{Percentage weight loss} = \frac{(\textit{Initial weight} - \textit{Final weight})}{\textit{Initial weight}} \times 100$$

The calcium content of the fruit juice extracted from well blended fruit flesh was determined by the flame photometer (JENWAY PFP7).

The titratable acidity was determined by titrating fruit juice with 0.1 N sodium hydroxide using phenolphthalin as the indicator. Titratable acidity was calculated using the following formula.

$$\textit{Percentage of acid} = \frac{\textit{Titre} \times \textit{Normality of alkali} \times \textit{meq. wt. of acid}}{\textit{Volume of the sample}} \times 100$$

Statistical analyses

Qualitative parameters were analysed by Friedman test using the MINITAB statistical program. Quantitative parameters were analyzed for analyses of variance (ANOVA) and Duncan Multiple Range Test (DMRT) using Statistical Analyses System (SAS) statistical software package.

RESULTS

Results showed that, fruits from all the calcium treatments were significantly lower ($p<0.05$) than control in IB development after first and second weeks of cold storage and this was below 1 of the scale. After third and fourth weeks of cold storage, the fruits from treatments which had lime 125 kg ha^{-1} and 150 kg ha^{-1} were significantly low ($p<0.05$) in IB development than the control. These two treatments had IB<3 of the scale after the fourth week. The IB level of control fruits was > 4 after the fourth week (Fig. 1).

The percentage weight loss was significantly lower ($p<0.05$) than the control in all the calcium treatments after third and fourth weeks of cold storage. Fruits from the treatments with lime 125 kg ha^{-1} and 150 kg ha^{-1} showed significantly low percentage ($p<0.05$) weight loss after second, third and fourth weeks ranging from 4.69-8.97%. Compared to that, control fruits had a high level of weight loss ranging from 8.18-21.22% from second to fourth weeks. Fruits from the treatment with FMP 150 kg ha^{-1} also had significantly low ($p<0.05$) percentage weight loss than the control after second and third weeks of cold storage (Table 2).

After the first week of cold storage ascorbic acid content of fruits from all the calcium treatments were significantly higher than the control ranging from 12.80-28.80 mg/100 ml (Control = 2.38 mg/100 ml). The treatments with 100 kg ha^{-1}, 125 kg ha^{-1} and 150 kg ha^{-1} lime had significantly high ascorbic acid content than control after first, second and third weeks of cold storage ranging from 24.8-2.18 mg/100 ml. In the control fruits, the ascorbic acid values were 2.38-0.94 mg/100 ml from first to the third week. Fruits from the treatment of 150 kg ha^{-1} FMP also had significantly high ascorbic acid content after first and second week ranging from 28.80-15.44 mg/100 ml (Table 2).

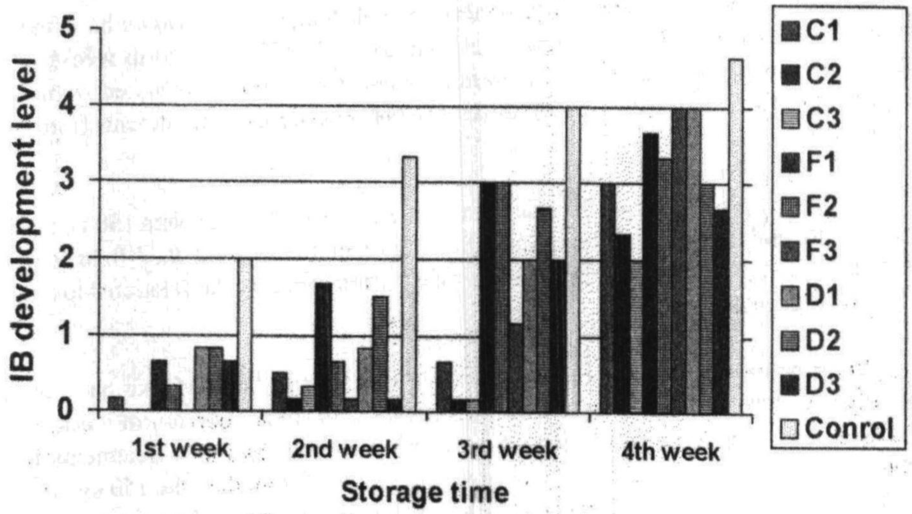

Fig. 1. Development of IB in pineapple for four weeks of cold storage at 15°C.

Table 2. Ascorbic acid, TSS, % weight loss and fruit calcium content after three weeks of cold storage at 15°C.

Treatment	Ascorbic acid (mg/100 ml)	TSS %	% Weight loss	Fruit calcium (mg/l)
C1	2.18 bc	12.60 bc	8.54 bc	46.18 ab
C2	2.72 b	13.26 ab	7.66 c	48.75 a
C3	4.44 a	14.93 a	7.45 c	49.38 a
F1	2.25 bc	11.16 c	8.58 bc	45.70 ab
F2	1.62 bcd	11.26 bc	8.02 bc	44.06 ab
F3	1.51 cd	12.73 bc	9.37 bc	45.35 ab
D1	2.01 bcd	12.40 bc	9.25 bc	45.95 ab
D2	1.55 bcd	12.66 bc	8.93 bc	46.51 ab
D3	1.77 bcd	11.53 bc	10.34 b	44.22 ab
Control	0.94 d	8.96 d	13.21 a	41.38 b

* In each column the mean values denoted by the same letters are not significantly different by Duncan's Multiple range test at p=0.05. Each value represents mean of nine fruits.

Fruits from all the calcium treatments had significantly high total soluble solid (TSS) contents after the first and third week of cold storage. The treatments with 125 kg ha^{-1} and 150 kg ha^{-1} lime had significantly high TSS content ranging from 15.96-13.26% than the control after first, second, third and fourth weeks. The TSS contents were not significantly different between these two treatments (Table 2).

Fruit calcium content of the treatments of 125 kg ha^{-1} and 150 kg ha^{-1} lime were significantly higher than the control after first, second, third and fourth weeks of cold storage. They varied from 54.44-42.98 mg/l while the control fruits varied from 42.84-33.09 mg/l. There was no significant difference between these two treatments from first to the fourth week.

Pineapple fruits from the calcium treatments with 100 kg ha^{-1} and 150 kg ha^{-1} lime had significantly low titratable acidity than control ranging from 0.53-0.36 g/100 ml (Control = 0.75-0.54) after third and fourth week. There was no clear relationship between pH and IB development.

When all treatments were compared, the 125 kg ha^{-1} and 150 kg ha^{-1} lime had significantly low IB development than the control from first to the fourth week of cold storage. Also there was no significant difference between these two treatments for IB development and most of the other parameters measured. Fruits from the 150 kg ha^{-1} FMP treatment had significantly low IB development for first and second weeks and also had significantly high ascorbic acid content, TSS content and significantly low percentage weight loss than control during that period.

DISCUSSION

Results showed that, the application of all the sources of calcium fertilizer is effective for the control of IB for two weeks at cold room temperature of 15°C. However the lime application at 125 kg ha^{-1} and 150 kg ha^{-1} could significantly reduce IB than the control from first to the fourth week. The fruit calcium content of these two treatments also was significantly higher than control from first to the fourth week. According to these results it is clear that the application of any one of these sources of calcium fertilizer is able to control IB development for at least two weeks under cold storage. However application of lime has a clear effect in the control than the other two sources.

According to Marschner (1995), increased fruit calcium level can be effective in preventing or decreasing storage disorders. As Richardson and Hyslop (1985) stated, calcium in plants involved in the structure of cell walls, membranes and the activity of enzymes. Wills *et al.* (1989) stated that, calcium binds with pectic substances in the middle lamella and with the membranes for strengthening structural components of cells, and also prevent or delay enzyme reactions that cause browning symptoms.

After the first week of cold storage, fruits from all the calcium treatments showed significantly high ascorbic acid content. However, lime treatments showed significantly high ascorbic acid level from first to the third week. Internal browning affected fruits had low levels of ascorbic acid and the values in all the treatments and control fruits reduced with the prolonged storage. Similar results have been reported in earlier studies by Abdulla *et al.* (1986) and Hassan and Atan (1983).

Richardson and Hyslop (1985) have stated that, oxidases such as peroxidase and phenolase catalyse destruction of ascorbic acid. According to Arya (1993), L-ascorbic acid oxidize to dehydro-L-ascorbic acid by oxidative enzymes like polyphenol oxidase and peroxidase. A high level of polyphenol oxidase (Martinez and Whitaker, 1995) and peroxidase (Selvarajah *et al.*, 1998) activity have been observed in IB affected fruits. This may be the reason for having reduced ascorbic acid content in IB affected fruits.

In fruits of calcium treatments there was a low level of percentage weight loss. Fruits of 125 kg ha^{-1} and 150 kg ha^{-1} lime showed clearly a low percentage weight loss from second to fourth week than the other treatments. Low moisture loss is desirable because loss of weight causes a wilted appearance and reduction of market value (Wills *et al.*, 1989). The TSS content of 125 kg ha^{-1} and 150 kg ha^{-1} lime treatments were significantly high from first to the fourth week. Low IB affected fruits had high TSS values. Similar relationships have been reported in previous studies too (Abdulla *et al.*, 1986; Selvarajah *et al.*, 1998).

Of all the calcium treatments application of lime at 125 kg ha^{-1} and 150 kg ha^{-1} showed the most promising results. These two treatments had IB<3 of the scale after the fourth week. Also, FMP 150 kg ha^{-1} treatment had significantly low IB in the first and second weeks of cold storage with significantly high ascorbic acid up to the second week, and significantly low percentage weight loss after second and third weeks of cold storage.

According to the results, the application of lime has better performance on the control of IB in Mauritius pineapple than the other two calcium sources. This may be because lime contains relatively high calcium content (34.5%) than the other two treatments (FMP=30%, dolomite=15%).

CONCLUSIONS

According to the results, basal application of lime at the rate of 125 kg ha^{-1} and 150 kg ha^{-1} is most effective for the control of IB development under cold storage. Between these two treatments the IB development and other parameters measured showed no significant difference. Hence the most suitable dose of lime for basal application is 125 kg ha^{-1} other than the application of a high dose of lime as 150 kg ha^{-1} when consider the effects on soil conditions and the cost of fertilizer.

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