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Effect of Calcium and Potassium Fertilizer Applied at the Time of Planting on the Control of Internal Browning under Cold Storage of Mauritius Pineapple

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ABSTRACT. *Pineapple [Ananas comosus (L.) Merr.] is a major fruit crop grown in Sri Lanka both for the local market and for export. The development of internal browning (IB) under the cold storage during sea shipment is a major problem faced by pineapple exporters. This experiment was conducted to find the effect of pre-harvest application of different levels of calcium (CaO) and potassium (MOP) fertilizer as basal dressing for the control of IB development. The field experiments were carried out at two different locations in a randomized complete block design with three replicates. At the time of planting three levels of calcium fertilizer (CaO - 100 kg ha^{-1}, 125 kg ha^{-1}, 150 kg ha^{-1}) and three levels of potassium fertilizer (MOP - 55 kg ha^{-1}, 110 kg ha^{-1}, 220 kg ha^{-1}) combinations were applied in nine different treatments. All other fertilizer requirements were provided to all the treatments at recommended levels. Immediately after harvest the fruits were stored in a cold room (15^{0}C and 80-85% RH). They were analysed for the fruit calcium and potassium contents, intensity of IB development, total soluble solids (TSS), ascorbic acid, percentage weight loss, pH and titratable acidity for four weeks at weekly intervals. Fruits were kept 72 h at room temperature before the above analysis.*

Results showed that, the IB development in fruits harvested from all the calcium and potassium treated plots were significantly lower than the control up to the fourth week of cold storage. Fruit calcium and potassium contents were higher in all the treatments compared with control and a significant effect could be observed with increased calcium and potassium levels for the variations of percentage weight loss, TSS, acidity and ascorbic acid contents. Calcium 150 kg ha^{-1} and potassium 220 $kg^{-1}ha$ treatment showed significantly high fruit calcium and potassium contents, low percentage weight loss and high TSS values up to the third week of cold storage. Also they were relatively high in ascorbic acid content and low in titratable acidity. It is concluded that, application of calcium and potassium fertilizer as a basal dressing could increase the fruit calcium and potassium contents, hence could reduce IB development in all the treatments compared to control. Application of calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} is best for the control of IB.

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INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merr.] is an important fruit crop grown in Sri Lanka both for the local market and for export. The main cultivar grown in Sri Lanka is Mauritius. Fresh pineapple is mainly exported under refrigerated conditions by sea freight. The storage potential of fruits is crucial for the long term shipment.

Internal browning (IB) which is also known as indigenous brown spot or black heart development is a major problem in the export of fresh pineapple under refrigerated conditions. This is a physiological disorder which cannot be identified externally. It affects the quality of fruits and reduces the market value due to off flavour and off colour.

It has been reported that, IB is induced by polyphenol oxidase activity (Ploetz *et al.*, 1994). Low ascorbic acid and total soluble solid contents were observed in affected fruits (Selvarajah *et al.*, 1998; Hassan and Atan, 1983). It has also been reported that, affected fruits show higher percentage weight loss and higher titratable acidity (Selvarajah and Herath, 1997).

It is stated that, increase in calcium levels in fruits can decrease the economical losses of fruits by reducing various storage disorders (Marschner, 1995). In pineapple, higher level of fertilizer calcium application (150 kg ha^{-1}) was effective for the control of IB for four weeks (Selvarajah *et al.*, 1998). According to past experiments, Nanayakkara *et al.* (1997) have shown that there is a significant effect over the decrease of IB by increasing fruit potassium ion concentration.

This study was conducted to investigate the effect of different combinations of pre-harvest calcium and potassium fertilizer applications for the control of IB and improve the quality of pineapple under cold storage conditions.

MATERIALS AND METHODS

The experiment was conducted at two different locations namely Giriulla (Kurunegala district) and Pallewela (Gampaha district) on red-yellow podzolic soil from September 1998 to April 2000. Pineapple *cv.* Mauritius was planted in a randomized complete block design with three replicates.

Each site had nine treatments with different calcium (CaO) and potassium (MOP) levels (Table 1) applied as basal dressing and a control which was not provided with calcium or potassium. All the experimental plots received other fertilizers (except MOP) in recommended doses.

Freshly harvested pineapple fruits of 5% ripe stage were immediately transported to the laboratory and sorted according to size. Uniform sized fruits, 120 per replicate (12 fruits from each treatment) were selected and stored in a cold room at 15°C temperature and 80-85% RH conditions. Fruits were removed from the cold room at weekly intervals (9 fruits per treatment) for 4 weeks and kept for 72 h at room temperature.

Table 1. Calcium and potassium fertilizer combinations.

Treatment	Amount of calcium kg ha^{-1}	Amount of potassium kg ha^{-1}
C1 K1	100	55
C1 K2	100	110
C1 K3	100	220
C2 K1	125	55
C2 K2	125	110
C2 K3	125	220
C3 K1	150	55
C3 K2	150	110
C3 K3	150	220
Control	No calcium	No potassium

Determination of internal browning intensity

A visual determination was done using a scale ranging from 0-5 (Teisson, 1979), after cutting fruits longitudinally into two halves.

Scale	Description
0	Good flesh with no discolouration
0.5	Formation of watery spots with yellow or light brown colour at the base of fruitlets
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

Determination of fruit flesh calcium, potassium and ascorbic acid contents

The peal and core of the fruits were removed and the flesh was blended thoroughly. Fruit flesh calcium and potassium contents were measured using flame photometer technique. Ascorbic acid content was determined by titrating against 2, 6 dichloro-phenol indophenol according to Askar and Treptow (1993).

Determination of total soluble solids (TSS) and pH

The TSS of fruit juice was determined by a hand refractometer. The pH of fruit juice was determined by a pH metre.

Determination of Percentage Weight Loss

Each fruit was weighed before storage (initial weight) and before the final analysis (final weight). The percentage weight loss was calculated by the following formula.

$$Percentage\ weight\ loss = \frac{(Initial\ weight\ - final\ weight)}{Initial\ weight} * 100$$

Determination of Titratable Acidity

The titratable acidity of fruit juice was determined by titrating with 0.1 N sodium hydroxide using phenolphthalein as the indicator. Titratable acidity was calculated as amount of citric acid using the following formula.

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

RESULTS

Results showed that internal browning development in all the treatments was significantly lower than the control up to the fourth week of cold storage. There was no IB development during the first week in all the treatments (Fig. 1).

Fruit calcium and potassium contents in all the treatments were relatively higher than the control up to the fourth week of cold storage. Treatments of calcium 150 kg ha^{-1} with potassium 110 kg ha^{-1} and calcium 150 kg ha^{-1} with potassium 220 kg ha^{-1} had significantly high fruit calcium contents up to the third week. Also the fruits harvested from calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} (highest calcium and potassium doses) had significantly high potassium content up to the third week of cold storage. Table 2 indicates the fruit calcium and potassium contents after three weeks of cold storage.

The total soluble solids did not differ significantly between treatments and control after one week of cold room storage. After second and third week of cold storage, pineapples from calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} treatment had significantly higher TSS values and it varied from 13.36% to 13.33% from first week to the third week. Also a relatively high level of TSS could be observed after the fourth week of cold storage in this treatment. The fruits from calcium 150 kg ha^{-1} and potassium 110 kg ha^{-1} applied plots also were having significantly high TSS after the third week of cold storage (Table

3). The reduction of TSS values from the first week up to the fourth week is much higher in all the other treatments and the control.

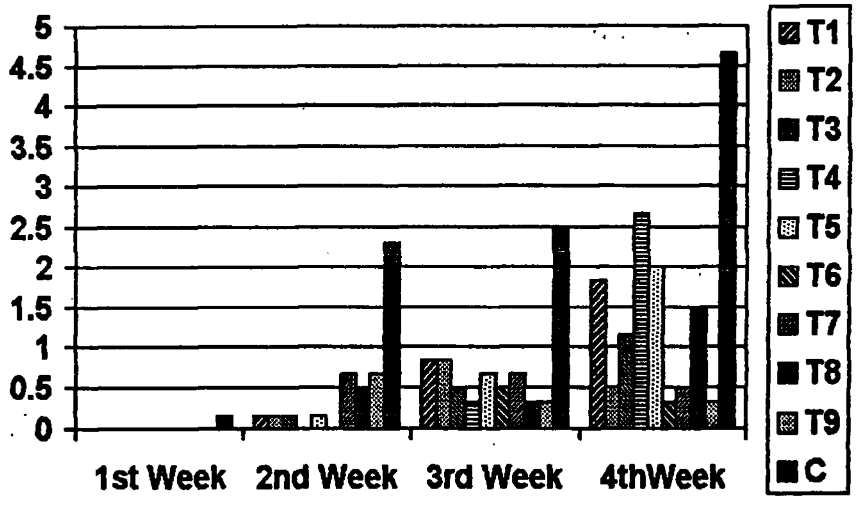

Fig. 1. Effect of calcium and potassium on IB intensity of pineapple stored at 15°C.
[Note: T1 = C1 K1, T2 = C1 K2, T3 = C1 K3, T4 = C2 K1, T5 = C2 K2, T6 = C2 K3, T7 = C3 K1, T8 = C3 K2, T9 = C3 K3, C = control]

Table 2. Fruit calcium and potassium contents after three weeks of cold storage at 15°C.

Treatment	Calcium (ppm)	Potassium (ppm)
C1 K1	48.00 b	1266.7 bcd
C1 K2	53.00 b	1293.3 abcd
C1 K3	79.33 ab	1346.7 abcd
C2 K1	62.33 b	1563.3 ab
C2 K2	50.33 b	1496.7 abc
C2 K3	49.33 b	1330.0 abcd
C3 K1	84.67 ab	1220.0 cd
C3 K2	116.67 a	1616.7 a
C3 K3	117.33 a	1500.0 abc
Control	46.33 b	1060.0 d

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

Ascorbic acid values were relatively higher in all the treatments than the control up to the fourth week of cold room storage. The ascorbic acid contents of the fruits harvested from calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} plots were highest after the third week of cold storage. Ascorbic acid was reduced in all the treatments and the control with prolonged storage time.

Table 3. Intensity of IB, ascorbic acid, TSS, percentage weight loss and acidity after three weeks of cold storage at 15°C.

Treatment	IB (0 - 5)	Ascorbic Acid (mg/100 ml)	TSS %	Percentage Weight Loss	Acidity (g/100 ml)
C1 K1	0.8 b	16.45 ab	13.80 a	3.92 d	0.98 bcd
C1 K2	0.8 b	18.91 ab	11.43 b	9.87 ab	0.91 d
C1 K3	0.5 b	20.08 a	12.60 ab	9.09 ab	0.97 cd
C2 K1	0.3 b	20.60 a	12.76 ab	5.11 cd	1.11 a
C2 K2	0.6 b	19.57 a	12.73 ab	7.56 abc	0.99 bcd
C2 K3	0.5 b	18.55 ab	13.10 ab	9.07 ab	1.07 abc
C3 K1	0.6 b	20.70 a	13.26 ab	8.25 abc	1.09 ab
C3 K2	0.3 b	19.88 a	13.26 ab	6.95 bcd	1.06 abc
C3 K3	0.3 b	21.00 a	13.33 ab	6.51 bcd	1.05 abc
Control	2.5 a	11 78 b	9.06 c	10.82 a	1.10 a

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

Percentage weight loss was significantly lower than the control up to the third week of cold storage in the calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} treatment. The values varied from 4.78% to 6.51% from the first week to the third week of cold storage. The control fruits had the highest percentage weight loss compared to all the treated fruits varying from 7.01% to 15.36% during that period.

The titratable acidity values of all the treatments were lower than the control after the first week. A relatively low titratable acid content was observed in calcium 150 kg ha^{-1} with potassium 55 kg ha^{-1} and calcium 150 kg ha^{-1} with potassium 220 kg ha^{-1} treatments. There was no clear relationship between pH values and the development of internal browning.

Compared with all the treatments the pineapple fruits harvested from plants treated with calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} (highest calcium and potassium doses) at the time of planting had lowest IB development (below 0.5 in the scale) up to the fourth week of cold storage. The fruit calcium and potassium contents of this treatment were significantly higher than the control up to the third week. Also relatively high TSS values, relatively low titratable acid content up to the fourth week of cold storage and high ascorbic acid content and low percentage weight loss up to the third week could be observed in this treatment. Control fruits had the highest IB development, lowest TSS values, lowest ascorbic acid contents and highest percentage weight loss compared to all the treatments up to the fourth week of cold storage.

DISCUSSION

The results of this study indicate that the application of calcium and potassium fertilizer as basal dressing had a significant effect over the control of internal browning induced in Mauritius pineapple up to the fourth week of cold storage. The fruit calcium and potassium contents could be increased by the application of calcium and potassium fertilizer at the time of planting.

Increased calcium content of fruits is able to control IB probably because calcium binds with pectic substances in the middle lamella and with membranes and hence strengthening structural components of the cell. As Wills *et al.* (1989) stated, the strengthening of cell components may prevent or delay the loss of cell compartmentation and the enzyme reactions that cause browning symptoms. It also helps to maintain normal metabolism in fruits.

Potassium plays a major role in stomatal regulation which leads to control of water loss. Potassium ions are important for the maintenance of solute potential in vacuoles causing retention of high tissue water content. According to Nanayakkara *et al.* (1997), internal browning in pineapple could be controlled to some extent by spraying potassium sulphate on to the fruits four weeks before harvest.

Ascorbic acid contents were relatively higher in all the treatments than the control. Ascorbic acid is a browning inhibitor (Wills *et al.*, 1989). In the IB developed fruits the ascorbic acid contents were relatively lower. It is known that, L-ascorbic acid is easily oxidized to dehydro-L-ascorbic acid by the enzyme ascorbic acid oxidase or by other oxidative enzymes like polyphenoloxidase, peroxidase (Arya, 1993). It has been reported that there is a high level of polyphenoloxidase (Martinez and Whitaker, 1995) and peroxidase (Selvarajah *et al.*, 1998) activity in the IB developed fruits than the unaffected fruits. This may be the reason that ascorbic acid content of control fruits is lower considerably than in all the treatments.

Relatively lower percentage water loss could be observed in the fruits of calcium and potassium treatments. According to Marschner (1995), potassium maintain high tissue water content. Low moisture loss is desirable because according to Wills *et al.* (1989) even the reduction of only 5% of weight may cause perishables to appear wilted leading to direct loss of marketing value. In this study pineapple fruits less affected with IB have shown low percentage weight loss.

CONCLUSIONS

Results showed that, the application of calcium and potassium fertilizer at the time of planting could increase fruit calcium and potassium content and it could reduce the incidence of IB up to the fourth week of cold storage (15°C and 80-85% RH) in all the treatments compared to the control without calcium or potassium. Basal application of calcium 150 kg ha^{-1} and potassium 220 kg ha^{-1} showed the most pleasing results.

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