CALCIUM SPRAY REDUCES YELLOW LATEX ON MANGOSTEEN FRUITS (*Garcinia mangostana* L.)

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A B S T R A C T

Yellow latex is the main problem in the mangosteen agribusiness because it is a factor that lowers fruit quality. The objective of this research was to study the effect of fruit spray using various forms of calcium namely $CaCl_2$, $Ca(OH)_2$, and $Ca(NO_3)_2$ on the incidence of yellow latex spots, and the physical and chemical properties of a "Leuwiliang subdistrict" mangosteen population. Application of the three forms of calcium in the first year ineffectively reduced yellow latex spots both on the outer part of the fruit and in the aril. $CaCl_2$ application at various doses in the second year effectively reduced yellow latex spots either on the outer part of fruit or in the fruit aril, but the effect was insignificant between the different $CaCl_2$ dosages used. Calcium content in the exo-, meso- and endocarp of the fruit in the first year was significantly different and in several calcium spray treatments was higher than the control (without calcium spray). In the second year, the calcium content of the pericarp with 22.5 g/l $CaCl_2$ was higher than the control treatment but insignificantly different to other $CaCl_2$ spray treatments. The physical and chemical properties of mangosteen fruit following fruit spray treatment in the first and second year were significantly different.

Key words: yellow latex spot, dosage, effective, weeks after anthesis (WAA)

INTRODUCTION

Mangosteen is a highly appreciated fruit commodity on the international market; however the availability of a high quality product that meets export standards accounts for only 30-50% of the total national Indonesian production (Suyanti et al., 1997). One of the criteria of fruit quality to be exported is that they must be unblemished by yellow latex on the outer part of the fruit or in the aril (Directorate General of Horticulture, 2007). At present, yellow latex is the main problem in mangosteen agribusiness since it not only damages the appearance and cleanliness of the outer part of fruit but also makes the aril bitter. The absence of yellow latex is one of the criteria for exporting mangosteen fruit to East Asian countries (Taiwan, Japan and Korea) and Middle Eastern countries (United Arab Emirates, Saudi Arabia and Kuwait). The yellow latex found in arils is exuded because of damage to the epithelial cell walls of yellow latex secretory ducts in the endocarp and not because of a bacterial exudate (Dorly et al., 2008). It has not been possible to prove the cause of yellow latex secretory duct damage as it was assumed to be related to the low calcium (Ca) content in mangosteen fruit (Dorly et al., 2008). Ca is different from other nutrients because it is transported to the fruit in small amounts compared to the amount transported to the leaves (White and Broadley, 2003). Although Ca is available in the soil, Ca deficiency is a problem in natural habitats because Ca concentrations in the shoots range between 0.1% and 5% dry weight (Marschner, 1995). Calcium content in the soil in Leuwiliang subdistrict is 0.87 meq/100 g (Liferdi, 2007), which is considered to be very low. To improve the Ca transfer to fruit, Ca was directly sprayed onto the fruit in this experiment.

Ca is related to physiological disorders in fruits and vegetables (Harker and Venis, 1991; Sharma and Singh, 2009). A low Ca content in pericarp cells is related to fruit cracking in lychee (*Litchi chinensis*) (Kanwar et al., 1972; Huang et al., 2005), sweet cherry (*Prunus avium*) (Brown et al., 1995; Fernández and Florez, 1998), and tomato (*Lycopersicon esculentum*) (Astuti, 2002).

Ca enters the fruit through the cuticle, lenticel, trichome base, and stomata (Bangerth, 1979; Huang et al., 2005; Saure, 2005). It is very difficult, however, for Ca to penetrate into the fruit because the cuticle is very thick and there are few stomata (Pomper and Grusak, 2004; Huang et al., 2005) Therefore, in our experiment, various forms of Ca were applied (calcium chloride – $CaCl_2$, calcium hydroxide – $Ca(OH)_2$, and calcium nitrate – $Ca(NO_3)_2$). Different spraying frequencies in the first year and the application of various doses of $CaCl_2$ in the second year were used to overcome the difficulties mentioned by Pomper and Grusak, 2004. The application of $CaCl_2$ in the second year was based on the result of the first year, in which the dilution level in

water was much higher compared with the other calcium formulae. We applied Ca to mangosteen fruit which were grown in soil with a very low Ca content. In addition to an external supply of Ca compounds to supplement Ca deficiency, Ca was also supplied to reduce the risk of yellow latex duct damage. This was done so that the incidence of yellow latex on mangosteen fruit could be reduced or eliminated. The effect of Ca on the physical and chemical properties of mangosteen fruit was also studied.

MATERIAL AND METHODS

Research was conducted from September 2006 to March 2007 and from October 2007 to April 2008 at a mangosteen production centre in Leuwiliang subdistrict, Bogor, Indonesia. Analyses of physical and chemical properties of fruit were conducted at the Centre for Tropical Fruit Studies (PKBT), Bogor Agricultural University while Ca content in the pericarp was determined in the Laboratory of Soil Science, Bogor Agricultural University.

Three forms of Ca spray treatment – $CaCl_2$, $Ca(OH)_2$, $Ca(NO_3)_2$ and various doses of $CaCl_2$ (5, 15, 22.5, and 30 g/l) on selected fruit of 30-years-old mangosteen trees. Fruit labelling was carried out on 20 flowers per tree to determine which fruits would be sprayed with Ca. Fruits were harvested at approximately the 16th week after anthesis (WAA).

During the first year of experiment, fruit were sprayed with the three forms of Ca. Huang et al. (2005) showed that the application of $CaCl_2$ with a Ca-chelating agent, citric acid, and the auxin α-naphthalene acetic acid (NAA) were more effective than $CaCl_2$ alone, on lowering the cracking rate in lychee fruit. Therefore, a total of 13 Ca fruit spray treatments were applied either alone or in combination with citric acid and NAA:

1. the control,
2. $CaCl_2$ 22.5 g/l,
3. $CaCl_2$ 22.5 g/l + NAA 40 mg/l,
4. $CaCl_2$ 22.5 g/l + citric acid 5.7 g/l,
5. $CaCl_2$ 22.5 g/l + NAA 40 mg/l + citric acid 5.7 g/l,
6. $Ca(OH)_2$ 12.33 g/l,
7. $Ca(OH)_2$ 12.33 g/l + NAA 40 mg/l,
8. $Ca(OH)_2$ 12.33 g/l + citric acid 5.7 g/l,
9. $Ca(OH)_2$ 12.33 g/l + NAA 40 mg/l + citric acid 5.7 g/l,
10. $Ca(NO_3)_2$ 35.757 g/l,
11. $Ca(NO_3)_2$ 35.757 g/l + NAA 40 mg/l,
12. $Ca(NO_3)_2$ 35.757 g/l + citric acid 5.7 g/l,
13. $Ca(NO_3)_2$ 35.757 g/l + NAA 40 mg/l + citric acid 5.7 g/l.

In contrast to the first year, the second year fruit was sprayed with various doses of $CaCl_2$:

1. the control,
2. $CaCl_2$ 5 g/l + citric acid 5 g/l,
3. $CaCl_2$ 15 g/l + citric acid 5 g/l,
4. $CaCl_2$ 22.5 g/l + citric acid 5 g/l,
5. $CaCl_2$ 30 g/l + citric acid 5 g/l.

Ca was diluted with 1 l of water, then 0.5 ml/l (v/v) of a surfactant (Prostiker) was added. Ca was sprayed (approx. 10 ml/fruit) with a hand sprayer directly on the fruit

until it was thoroughly wet at the 2nd, 4th, 6th, 8th and 10th WAA in the first year and at the 2nd, 4th, 6th, 8th, 10th, 12th, 14th WAA in the second year. The different treatments in the second year were to guarantee the supply of Ca close to harvesting time so that the risk of yellow latex secretory duct damage would be reduced or eliminated. The experiment was arranged in a completely randomized block design with three replicates (plants) in each treatment.

The major parameter measured was yellow latex score (YLS) on the outer part of the fruit and aril of mangosteen fruit. The scores on the skin and aril of fruit were obtained by using a modification of the Kartika method (2004) as follows:

On the outer part of fruit:

- Score 1: no yellow latex spots;
- Score 2: 1-5 yellow latex spots on the outer part of fruit;
- Score 3: 6-10 yellow latex spots on the outer part of fruit;
- Score 4: three-fourth part of the outer part of fruit was full of yellow latex spots;
- Score 5: the whole outer part of fruit was full of yellow latex spots.
- In the aril:
- Score 1: no yellow latex spots;
- Score 2: one-fourth of the aril was full of yellow latex spots;
- Score 3: half of the aril was full of yellow latex spots;
- Score 4: three-fourths of the aril was full of yellow latex spots;
- Score 5: the whole aril was full of yellow latex spots.

Ca content in the pericarp was determined with an atomic absorption spectrophotometer (Perkin Elmer, Model 1100B). Analyses of fruit Ca content were conducted by using five fruit samples taken compositely from the same tree; each treatment with three replication trees per treatment. Calcium content was measured in the exo-, meso- and endocarp in the first year. In the second year Ca content in the fruit was measured in the pericarp only. Fruit, fruit skin, aril and seed weight of mangosteen were assessed with an analytical balance. Transversal and longitudinal diameters and skin thickness were measured by callipers (Mitutoyo, Japan). Pericarp hardness level was measured by a penetrometer (FDK160, Wagner, made in Germany). The edible portion was stated as a percentage and could be estimated by the following formula:

$$\frac{aril\ weight\ (g) \times 100\%}{fruit\ weight\ (g)}$$

Total soluble solid (TSS; ^{o}Brix) was measured using a refractometer (PAL-1, Atago, Tokyo Tech). Titratable acidity (TTA; %) was measured using the following method: Distilled water was added to 10 g of crushed fruit in the measuring flask until the volume reached 100 ml, then it was filtered. A few drops (approx. 2-3 ml) of phenolphthalein indicator were added into 25 ml of filtrate, then titrated with 0.1 N NaOH until a pink, stable colour formed. TTA was calculated based on the amount of organic acid i.e. citric acid in accordance with AOAC (2007). The TSS/TTA ratio was determined.

Statistical analysis

Trials were established a completely randomized block design with 3 replicates plants per treatment and analyses were conducted using SPSS version 15.0 for Windows. Analysis of variance was performed with the general linear model (GLM) procedure. In the case of statistical significances, results were compared by Duncan's Multiple Range Test ($p \leq 0.05$).

RESULTS

Figure 1 shows mangosteen fruit skin and aril with and without yellow latex spots. Data in Table 1 show that various Ca treatments, with or without citric acid and NAA, in the first year of experiment, did not effectively reduce YLS both on the outer part of the fruit and in the aril. Compared to the control, spray treatments with various forms of Ca did not reduce YLS in the aril. However, after calcium treatment, YLS on the outer part tended to be reduced (Tab. 1).

YLS in the aril was lower in the $CaCl_2$ + NAA and $Ca(OH)_2$ + NAA spray treatments, and was not significantly different from other treatments except for $CaCl_2$ + citric acid and $Ca(NO_3)_2$ + citric acid.

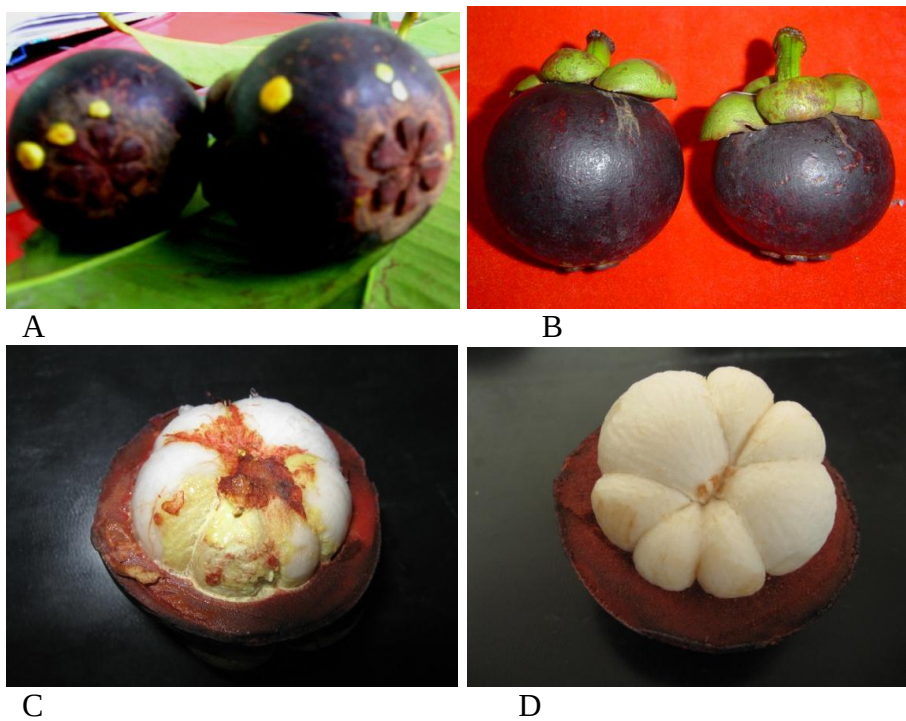

Figure 1. Fruit skin (A & B) and aril (C & D) with yellow latex spot and without yellow latex spot respectively on mangosteen fruit

Table 1. The effect of various calcium sprays on the yellow latex score in the first year

Treatment	Yellow latex score (1-5)	
	outer part of fruit skin	Aril
Control (1)	1.81 ± 0.36	1.21 ± 0.02 ab
$CaCl_2$ (2)	1.57 ± 0.04	1.16 ± 1.14 ab
$CaCl_2$ + citric acid (3)	1.58 ± 0.01	1.46 ± 0.48 a
$CaCl_2$ + NAA (4)	1.42 ± 0.25	1.02 ± 0.04 b
$CaCl_2$ + citric acid + NAA (5)	1.42 ± 0.18	1.17 ± 0.15 ab
$Ca(OH)_2$ (6)	1.55 ± 0.35	1.23 ± 0.10 ab
$Ca(OH)_2$ + citric acid (7)	1.77 ± 0.31	1.15 ± 0.17 ab
$Ca(OH)_2$ + NAA (8)	1.51 ± 0.26	1.09 ± 0.11 b
$Ca(OH)_2$ + citric acid + NAA (9)	1.52 ± 0.27	1.16 ± 0.14 ab
$Ca(NO_3)_2$ (10)	1.70 ± 0.18	1.15 ± 0.13 ab
$Ca(NO_3)_2$ + citric acid (11)	1.69 ± 0.34	1.44 ± 0.20 a
$Ca(NO_3)_2$ + NAA (12)	1.62 ± 0.14	1.35 ± 0.14 ab
$Ca(NO_3)_2$ + citric acid + NAA (13)	1.43 ± 0.11	1.19 ± 0.17 ab

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05. NAA = 1-naphthalene acetic acid

Table 2. The effect of various doses of calcium spray on the yellow latex score in the second year

Treatment	Yellow latex score (1-5)	
	outer part of fruit	Aril
Control	4.25 ± 0.31 a	2.52 ± 0.30 a
$CaCl_2$ (5 g/l) + citric acid (5 g/l)	2.97± 0.16 b	1.60 ± 0.48 b
$CaCl_2$ (15 g/l) + citric acid (5 g/l)	2.79 ± 0.58 b	1.27 ± 0.29 b
$CaCl_2$ (22.5 g/l) + citric acid (5 g/l))	3.07 ± 0.40 b	1.19 ± 0.18 b
$CaCl_2$ (30 g/l) + citric acid (5 g/l)	2.34 ± 0.72 b	1.36 ± 0.31 b

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05

Application of $CaCl_2$ was done at various doses and was combined with citric acid. The spray on the fruit was repeated at the 2^{nd}, 4^{th}, 6^{th}, 8^{th}, 10^{th}, 12^{th}, 14^{th} WAA in the second year. Such an application effectively reduced the incidence of yellow latex both on the outer part of the fruit and in the aril. However, there were no significant differences among the various doses of $CaCl_2$ (Tab. 2). Data presented in Tables 1 and 2 indicate that for unsprayed fruit (the control) the incidence of YLS in the second year of the experiment was much higher than in the first season.

Calcium content of pericarp

Ca content in the exo-, meso- and endocarp in the first year was significantly different (Tab. 3). The highest Ca content in the exocarp was found following the $Ca(OH)_2$ + NAA and

$Ca(OH)_2$ + citric acid + NAA treatments. The highest Ca content in the mesocarp was also found after treatment with $Ca(OH)_2$ + NAA whereas the highest Ca content in the endocarp was found in the $Ca(NO_3)_2$ + citric acid + NAA treatment. The highest Ca content in the exo- and mesocarp after treatment with $Ca(OH)_2$ + NAA was assumed to be related to the low YLS in the aril.

In the second year, the Ca content in the pericarp of the 22.5 g $CaCl_2$ treatment was higher than in the control, but insignificantly different from the other levels of $CaCl_2$ spray (Tab. 4). In general, the calcium content in the control fruits was lower in the second year compared to the control fruits in the first year of the experiment.

Table 3. The effect of various calcium fruit spraying on calcium content in mangosteen pericarp in the first year

Treatment	Calcium content in pericarp [%]		
	exocarp	mesocarp	endocarp
Control (1)	0.42 ± 0.12 b	0.36 ± 0.09 bc	0.39 ± 0.08 bc
$CaCl_2$ (2)	0.36 ± 0.09 c	0.33 ± 0.13 cde	0.30± 0.10 ef
$CaCl_2$ + citric acid (3)	0.29 ± 0.10 e	0.24 ± 0.03 f	0.26± 0.04 f
$CaCl_2$ + NAA (4)	0.35 ± 0.12 cd	0.34 ± 0.17 bcd	0.39 ± 0.13 bc
$CaCl_2$ + citric acid + NAA (5)	0.44 ± 0.12 ab	0.32 ± 0.14 cde	0.37 ± 0.15 cd
$Ca(OH)_2$ (6)	0.33 ± 0.12 cde	0.31 ± 0.09 cde	0.30 ± 0.12 ef
$Ca(OH)_2$ + citric acid (7)	0.35 ± 0.08 cde	0.30 ± 0.09 cdef	0.34 ± 0.12 cde
$Ca(OH)_2$ + NAA (8)	0.49 ± 0.05 a	0.44 ± 0.04 a	0.42 ± 0.13 ab
$Ca(OH)_2$ + citric acid + NAA (9)	0.48 ± 0.09 a	0.32 ± 0.10 cde	0.32 ± 0.07 de
$Ca(NO_3)_2$ (10)	0.35 ± 0.09 cd	0.28 ± 0.09 def	0.32 ± 0.10 e
$Ca(NO_3)_2$ + citric acid (11)	0.31 ± 0.10 cde	0.40 ± 0.10 ab	0.39 ± 0.10 bc
$Ca(NO_3)_2$ + NAA (12)	0.29 ± 0.08 e	0.29 ± 0.09 cdef	0.30 ± 0.11 ef
$Ca(NO_3)_2$ + citric acid + NAA (13)	0.30 ± 0.08de	0.27± 0.08 ef	0.46± 0.11 a

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05. NAA = 1-naphthalene acetic acid

Table 4. The effect of various dosages of calcium fruit spraying on calcium content in mangosteen pericarp in the second year

Treatment	Calcium content in pericarp [%]
Control	0.16 ± 0.02 b
$CaCl_2$ (5 g/l) + citric acid (5 g/l)	0.24 ± 0.02 ab
$CaCl_2$ (15 g/l) + citric acid (5 g/l)	0.17 ± 0.03 ab
$CaCl_2$ (22.5 g/l) + citric acid (5 g/l)	0.25 ± 0.06 a
$CaCl_2$ (30 g/l) + citric acid (5 g/l)	0.23 ± 0.06 ab

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05

Table 5. The effect of various calcium sprayings on fruit diameter, and fruit and seed weight of mangosteen in the first year

Treatment	Transversal diameter [cm]	Longitudinal diameter [cm]	Fruit weight [g]	Seed weight [g]
Control (1)	5.64 ± 0.23 ab	5.23 ± 0.28 ab	87.04 ± 10.97 ab	1.50 ± 0.14 abc
$CaCl_2$ (2)	5.51 ± 0.13 abc	5.11 ± 0.07 abc	83.17 ± 7.31 abc	1.54 ± 0.46 abc
$CaCl_2$ + citric acid (3)	5.74 ± 0.19 a	5.41 ± 0.06 a	93.82 ± 9.22 a	1.19 ± 0.34 bc
$CaCl_2$ + NAA (4)	5.51 ± 0.30 abc	5.20 ±0.24 ab	83.24 ± 14.95 abc	1.71 ± 0.68 abc
$CaCl_2$ + citric acid + NAA (5)	5.36 ± 0.25 bcd	5.10 ± 0.25 abc	72.71 ± 13.11 bc	1.29 ± 0.32 bc
$Ca(OH)_2$ (6)	5.55 ± 0.14 abc	5.27 ± 0.14 ab	87.31 ± 6.80 ab	1.88 ± 0.32 ab
$Ca(OH)_2$ + citric acid (7)	5.44 ± 0.14 abc	5.10 ± 0.21 abc	78.46 ± 9.79 abc	1.03 ± 0.09 c
$Ca(OH)_2$ + NAA (8)	5.12 ± 0.14 d	4.76 ± 0.25 c	66.50 ± 8.45 c	1.31 ± 0.18 bc
$Ca(OH)_2$ + citric acid + NAA (9)	5.36 ± 0.07 bcd	4.99 ± 0.18 bc	79.91 ± 4.17 abc	1.91 ± 0.15 ab
$Ca(NO_3)_2$ (10)	5.45 ± 0.13 abc	5.14 ± 0.26 abc	73.89 ± 6.73 bc	2.22 ± 0.50 a
$Ca(NO_3)_2$ + citric acid (11)	5.54 ± 0.13 abc	5.24 ± 0.09 ab	87.64 ± 2.22 ab	1.73 ± 0.26 abc
$Ca(NO_3)_2$ + NAA (12)	5.31 ± 0.19 cd	4.94 ± 0.21 bc	73.42 ± 10.00 bc	1.52 ± 0.13 abc
$Ca(NO_3)_2$ + citric acid + NAA (13)	5.44 ± 0.10 abc	4.97 ± 0.11 bc	79.20 ± 0.46 abc	1.64 ± 0.64 abc

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05
NAA = 1-naphthalene acetic acid

Table 6. The effect of various dosages of calcium spraying on the diameter, fruit weight and pericarp hardness of mangosteen in the second year

Treatment	Transversal diameter [cm]	Fruit weight [g]	Pericarp hardness [kgf]
Control	5.95 ± 0.04 a	114.51 ± 6.99 a	0.75 ± 0.03 a
$CaCl_2$ (5 g/l) + citric acid (5 g/l)	5.54 ± 0.15 bc	94.90 ± 7.80 bc	0.71±0.03 ab
$CaCl_2$ (15 g/l) + citric acid (5 g/l)	5.98 ± 0.14 a	115.03 ± 5.55 a	0.68 ± 0.04 b
$CaCl_2$ (22.5 g/l) + citric acid (5 g/l)	5.74 ± 0.19 ab	105.34 ± 10.82 ab	0.69 ± 0.05 b
$CaCl_2$ (30 g/l) + citric acid (5 g/l)	5.31 ± 0.18 c	82.34 ± 5.73 c	0.7 ± 0.04 ab

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05

Table 7. The effect of various calcium fruit spraying on skin thickness, pericarp hardness and edible portion in the first year

Treatment	Skin thickness [cm]	Pericarp hardness [kgf]	Edible portion [%]
Control (1)	0.71 ± 0.05 a	1.52 ± 0.19 ab	31.81 ± 0.67 abcd
$CaCl_2$ (2)	0.65 ± 0.17 abc	1.56 ± 0.06 ab	31.62 ± 0.23 abcd
$CaCl_2$ + citric acid (3)	0.67 ± 0.10 abc	1.75 ± 0.34 a	32.07 ± 0.52 abcd
$CaCl_2$ + NAA (4)	0.67 ± 0.06 abc	1.56 ± 0.07 ab	29.97 ± 1.78 cd
$CaCl_2$ + citric acid + NAA (5)	0.65 ± 0.11 abc	1.64 ± 0.14 ab	31.08 ± 1.60 bcd
$Ca(OH)_2$ (6)	0.71 ± 0.01 a	1.41 ± 0.16 b	29.73 ± 2.25 d
$Ca(OH)_2$ + citric acid (7)	0.70 ± 0.01 ab	1.75 ± 0.13 a	33.19 ± 2.24 ab
$Ca(OH)_2$ + NAA (8)	0.61 ± 0.03 c	1.60 ± 0.01 ab	29.99 ± 0.26 cd
$Ca(OH)_2$ + citric acid + NAA (9)	0.61 ± 0.02 c	1.43 ± 0.04 b	31.94 ± 1.11abcd
$Ca(NO_3)_2$ (10)	0.58 ± 0.05 c	1.47 ±0.11 b	33.85 ± 0.81a
$Ca(NO_3)_2$ + citric acid (11)	0.63 ± 0.04 abc	1.57 ± 0.06 ab	33.28 ± 0.68 ab
$Ca(NO_3)_2$ + NAA (12)	0.62 ± 0.06 bc	1.62 ± 0.19 ab	32.03 ± 1.44 abcd
$Ca(NO_3)_2$ + citric acid + NAA (13)	0.61 ± 0.03 c	1.64 ± 0.12 ab	32.45 ± 1.31abc

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05. NAA = naphthalene acetic acid

Physical properties of mangosteen fruit

Measurements in the first year of experiment (Tab. 5) indicated that all of the various Ca spray treatments affected the transversal and longitudinal diameter, fruit and seed weight. Compared with the control, spray treatments of various forms of Ca alone, did not increase significantly either the fruit transversal or longitudinal diameter, fruit or seed weight.

Measurements in the second year (Tab. 6) show that spray treatment of various doses of $CaCl_2$ affected the transversal diameter, weight and pericarp hardness. The highest transversal diameter and fruit weight were

found when fruit was sprayed with 15 g $CaCl_2$. These parameters were significantly different from fruit sprayed with 5 and 30 g/l but were not significantly different from the control (unsprayed fruits).

Table 7 shows that fruit sprayed with various forms of Ca in the first year affected skin thickness, pericarp hardness and the edible portion. The thickest skin (0.71 cm) was found in the control treatment and fruit sprayed with $Ca(OH)_2$ and significantly different from treatments 8, 9, 10, 12 and 13. The highest pericarp hardness (1.75 kgf) was found on fruits sprayed with $CaCl_2$ + citric acid and $Ca(OH)_2$ + citric acid but it was insignificantly different from the control and treatments 2, 4, 5, 8, 11, 12 and 13. The highest edible portion was found in fruits treated with $Ca(NO_3)_2$. The lowest edible portion was found in fruits treated with $Ca(OH)_2$.

Total soluble solids content and titratable acidity of mangosteen fruit

TSS of fruits was affected by the form of Ca applied in the first year. The highest TSS was found in fruit sprayed with $CaCl_2$ + citric acid + NAA, even though it was insignificantly different from the control and other Ca spray treatments, except for $Ca(OH)_2$ + citric acid (Tab. 8). TTA was slightly affected by the treatments. Only differences in TTA of fruits treated with $CaCl_2$ + NAA and $Ca(NO_3)_2$ + NAA were statistically significant. However, the TSS/TTA ratio was insignificantly different in all treatments (Tab. 8). Even though TSS and TTA differed significantly among treatments the differences in the TSS/TTA ratio were insignificant (Tab. 8). This implies that fruit spray treatments did not affect mangosteen TTA and TSS content.

Table 8. The effect of various calcium sprayings on the total soluble solid (TSS), total titrated acids (TTA), and TSS/TTA ratio in the first year

Treatment	TSS [^{o}Brix]	TTA [%]	TSS/TTA ratio
Control (1)	19.64 ± 0.28 ab	0.23 ± 0.03 ab	85.32 ± 9.28
$CaCl_2$ (2)	19.90 ± 0.79 ab	0.23 ± 0.02 ab	86.63 ± 9.43
$CaCl_2$ + citric acid (3)	20.15 ± 0.87 ab	0.23 ± 0.02 ab	84.45 ± 3.33
$CaCl_2$ + NAA (4)	19.66 ± 0.24 ab	0.24 ± 0.02 a	81.87 ± 7.65
$CaCl_2$ + citric acid + NAA (5)	20.49 ± 1.82 a	0.22 ± 0.02 ab	91.16 ± 4.37
$Ca(OH)_2$ (6)	19.68 ± 0.04 ab	0.23 ± 0.01 ab	85.08 ± 5.45
$Ca(OH)_2$ + citric acid (7)	18.25 ± 0.17 b	0.23 ± 0.02 ab	81.24 ± 7.39
$Ca(OH)_2$ + NAA (8)	20.26 ± 0.90 a	0.23 ± 0.00 ab	88.70 ± 2.91
$Ca(OH)_2$ + citric acid + NAA (9)	19.94 ± 0.68 ab	0.23 ± 0.01 ab	84.56 ± 5.14
$Ca(NO_3)_2$ (10)	20.32 ± 1.40 a	0.23 ± 0.01 ab	89.42 ± 8.58
$Ca(NO_3)_2$ + citric acid (11)	19.55 ± 0.43 ab	0.21 ± 0.00 b	94.36 ± 2.70
$Ca(NO_3)_2$ + NAA (12)	20.49 ± 1.44 a	0.23 ± 0.00 ab	90.99 ± 4.71
$Ca(NO_3)_2$ + citric acid + NAA (13)	19.58 ± 0.80 ab	0.23 ± 0.02 ab	87.16 ± 10.21

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05. NAA = 1-naphthalene acetic acid

Table 9. The effect of various dosages of calcium spraying on the total soluble solid (TSS), total titrated acids (TTA), and TSS/TTA ratio in the second year

Treatment	TSS [^{o}Brix]	TTA [%]	TSS/TTA ratio
Control	18.57 ± 1.18 b	0.61 ± 0.01 b	30.60 ± 1.70 b
$CaCl_2$ (5 g/l) + citric acid (5 g/l)	19.82 ± 0.52 a	0.65 ± 0.01 ab	30.35 ± 1.20 b
$CaCl_2$ (15 g/l) + citric acid (5 g/l)	19.41 ± 0.63 ab	0.69 ± 0.04 a	28.34 ± 2.17 b
$CaCl_2$ (22.5 g/l) + citric acid (5 g/l)	19.06 ± 0.39 ab	0.55 ± 0.02 c	34.66 ± 0.94 a
$CaCl_2$ (30 g/l) + citric acid (5 g/l)	19.38 ± 0.32 ab	0.63 ± 0.02 b	30.78 ± 1.19 b

Values (mean ± SD) within a column followed by different letters indicate significant differences according to Duncan's Multiple Range Test at p = 0.05

Table 9 shows that fruit spray treatment in various doses of $CaCl_2$ in the second year significantly affected TSS, TTA, and the TSS/TTA ratio. In addition, $CaCl_2$ treatments raised the TSS value compared with the control. The lowest TTA value (0.55%) was found for fruit treated with 22.5 g/l $CaCl_2$ (Tab. 9) while in the same treatment the TSS/TTA ratio was highest and significantly different from the control and other doses of $CaCl_2$.

DISCUSSION

Applications of various forms of Ca, namely $CaCl_2$, $Ca(OH)_2$ and $Ca(NO_3)_2$ with or without citric acid and NAA in the first year, ineffectively reduced yellow latex both on the outer part of fruit, and in the aril. The response of fruit to the form of Ca in reducing fruit damage was not the same. Callan (1986) reported that $Ca(OH)_2$ was more effective than $CaCl_2$ in reducing the rate of fruit cracking on sweet cherry; Huang et al. (2005) reported that $Ca(NO_3)_2$ solution was more effective in reducing fruit cracking on lychee than $CaCl_2$. In our study, the effectiveness of various forms of Ca in the reduction of YLS was almost the same.

The addition of NAA reduced the YLS in the aril (except for $Ca(NO_3)_2$ and did so more than citric acid. NAA is capable of increasing the transport and accumulation of Ca in fruit (Marcelle and Clijsters, 1978). The addition of NAA significantly increased the calcium content in exocarp, mesocarp and endocarp compared to the treatment without NAA (except for $Ca(NO_3)_2$. Nevertheless, the addition of Ca with a chelating agent, was better than Ca alone. Brown et al. (1995) noted that the addition of Ca with citric acid could reduce fruit cracking in sweet cherry. Huang et al. (2005) reported that the addition of citric acid and NAA to $CaCl_2$ could reduce fruit cracking on lychee compared with $CaCl_2$ alone. Yamamato et al. (1992) noted that a spray with a combination of calcium nitrate and NAA, more effectively reduced cracking than did either reagent as a single spray in sweet cherry fruits.

In our experiment, Ca was applied directly on the fruit because if

it had been applied through the leaves it would not guarantee an increase of Ca in the fruit. This is related to the immobile characteristic of Ca which has a very small possibility of being transported through the phloem (Bangerth, 1979; White and Broadley, 2003). A non-ionic surfactant was added to the Ca application and served to facilitate easy Ca penetration into the pericarp. Kraemer et al. (2009) reported that the addition of a surfactant increased the penetration of Ca into tomato fruit. The cell wall is composed primarily of cellulose, pectin, hemicellulose and lignin, whereas cuticular, cutin, suberin, and wax compounds are cell wall components of the fruit exocarp (Dickison, 2000). Ca was transported by apoplast diffusion, namely through the cell wall and intercellular space, into the pericarp (Glenn et al., 1985; Saure, 2005). The dynamic factors affecting the path or absorption of Ca into fruit are not entirely understood yet (Saure, 2005). Saure (2005) reported that Ca concentration in apple fruit can change during fruit development and is not uniform throughout the parts of the whole fruit. In the mature fruit, the highest Ca concentration in apple fruit was found in the skin, and the lowest in the fruit flesh.

The aim of repeated sprayings is to raise the Ca concentration in the pericarp. Huang et al. (2005) reported that the repeated application of 20 mmol l^{-1} $CaCl_2$, namely at the 4^{th}, 6^{th} and 8^{th} WAA on lychee, effectively reduced fruit cracking as compared to the control. In tomato, $CaCl_2$ sprayed 2-3 times at preharvest could raise the Ca content in tomato fruit from 0.843 mg/g in the control to 0.907 mg/g after 2 applications and 0.977 mg/g after 3 applications (Astuti, 2002). Chen and Wei (2004) reported that spraying 0.8% $CaCl_2$ solution three times on the surface of young apple fruits of 'Red Fuji' and 'Starkrimson' cultivars during the early stage of fruit development increased the Ca contents in all forms. Furthermore, Marschner (1995) suggested that because of Ca immobility, repeated spray applications to fruit would be more effective.

In the second year, fruit sprayed with various doses of $CaCl_2$ had elevated Ca content in the pericarp compared with the control (statistically proved only for treatment with 22.5 g/l). In tomato fruit, $CaCl_2$ preharvest spray raised the Ca content (Astuti, 2002) while in lychee fruit, a fruit cracking-resistant variety showed a higher Ca content than the susceptible variety (Huang et al., 2005).

Spraying with different forms of Ca in the first year did not increase the physical and chemical properties (TSS and TTA) of mangosteen fruit. Callan (1986) also reported that the application of various forms of Ca on sweet cherry did not affect fruit quality. In contrast, the chemical properties of mangosteen fruit sprayed with various doses of Ca in the second year increased compared with the control. The TSS value at 5 g/l $CaCl_2$ was significantly higher than the control while the highest TSS/TTA ratio was found with the 22.5 g/l $CaCl_2$ treatment. Callan (1986) re-

ported that Ca spray on sweet cherry fruit raised TSS compared with the control. The highest TSS value (19.82 °Brix) was found at 5 g/l $CaCl_2$ even though it was insignificant from the 15-30 g/l $CaCl_2$ doses. The results of our experiment show that the application of various forms of Ca as a spray on mangosteen fruit could reduce the incidence of yellow latex. It may be very difficult to apply such a method in a commercial mangosteen plantation because skilful workers would be required.

CONCLUSION

The appearance of yellow latex spots is related to the calcium content in mangosteen pericarp. The treatment of fruits during the vegetative period with calcium chloride could be an effective way to reduce the incidence of yellow latex spots in mangosteen fruits.

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WPŁYW OPRYSKIWANIA WAPNIEM NA REDUKCJĘ ŻÓŁTEGO LATEKSU POJAWIAJĄCEGO SIĘ NA OWOCACH MANGOSTANU (*Garcinia mangostana* L.)

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S T R E S Z C Z E N I E

Głównym problem przemysłu rolnego związanego z produkcją mangostanu jest pojawiający się żółty lateks (mleczko kauczukowe), który obniża jakość owoców. Celem badań było określenie wpływu opryskiwania wapniem w postaci $CaCl_2$, $Ca(OH)_2$ i $Ca(NO_3)_2$ na liczbę żółtych lateksowych plam oraz na właściwości fizyczne i chemiczne mangostanu uprawianego w podokręgu Leuwiliang. W pierwszym roku opryskiwanie wapniem we wszystkich postaciach miało niewielki wpływ na redukcję plam, pojawiających się zarówno na zewnątrz owoców, jak i w osnówce. Zastosowanie $CaCl_2$ w różnych dawkach w drugim roku znacznie zmniejszyło liczbę plam na zewnątrz i w osnówce, niezależnie od dawki. Zawartość wapnia w egzo-, mezo- i endokarpie owoców w pierwszym roku różniła się znacznie i po zastosowaniu niektórych dawek była wyższa niż w grupie kontrolnej, w której nie zastosowano wapnia. W drugim roku zawartość wapnia w owocni po zastosowaniu 22,5 g/l $CaCl_2$ była wyższa niż w grupie kontrolnej. Nie zaobserwowano jednak znacznych różnic w jej zawartości po zastosowaniu $CaCl_2$ w innych dawkach. Właściwości fizyczne i chemiczne opryskiwanych owoców mangostanu znacznie różniły się w pierwszym i drugim roku uprawy.

Słowa kluczowe: żółta lateksowa plama, dawka, skuteczność, tygodnie po kwitnieniu (WAA)