# Why is Calcium, Can Increase the Amount of Mangosteen Fruit (*Garcinia mangostana* L.) Quality?

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**Abstract**. One of the obstacles that exists in the cultivation of mangosteen in Indonesia is the low effectiveness of calcium absorption in mangosteen fruit tissue. Most of the calcium absorbed from the roots will be directly localized to the leaf tissue, because of the nature of calcium which is not mobile and translocation in plant tissues. This results in the possibility of very high levels of yellow. Sap contamination in mangosteen fruit reaches 93% of total production. This study aims to: (1) determine the effect of calcium and calcium in overcoming the yellow sap contamination on mangosteen fruit; (2) Mechanism of absorption and distribution of calcium in mangosteen fruit plants. The study was carried out in the mangosteen garden of the Manggis Karya Mekar Farmer Group, in Cengal Village, Karacak Village, Leuwiliang District, Bogor, Indonesia. The experiment was carried out using factorial randomized block design (RBD) with 3 replications, consisting of the treatment of calcium and boron fertilizer doses as the first factor, consisting of 6 levels, namely: (1.) Control (without calcium and without B ), (2) 2.8 g B / tree / year (6.09 g borate 46 / tree / year), (3) 3.2 kg of calcium dolomite / tree / year (10.67 kg dolomite / tree / year), (4) 3.2 kg of calcite / tree / year calcium (7.11 kg of calcite / tree / year), (5) 3.2 kg of calcium dolomite / tree / year + 2.8 g B / tree / year, and (6) 3.2 kg of calcium calcite / tree / year + 2.8 g B / tree / year. While the second factor is the number of stages of Calcium application and boron in mangosteen per year (T), which consists of 2 levels, namely: (1) Calcium application and boron at the time of the antesis and at the start of the first stage (1 week after the antesis (MSA)). Each time the application is given calcium and boron half of the dose specified. (2) Calcium application and boron at the time of anthesis and at the end of stage I (4 MSA). Each time the application is given calcium and boron half of the dose specified. The results showed that: (1) Application of calcium was able to reduce the contamination of yellow sap on the mangosteen aryl fruit reached 53% and on the rind reached 46% and improved the quality of mangosteen fruit, without calcium produced plants while yellow sap contamination of 91.66% on aryl and 86% on the rind; (2) Calcium is absorbed and distributed by the mangosteen plant through several mechanisms, namely: through xylem in root and continue to the stem and then to pedicel before absorbed into the fruits. The higher Calcium tranlocation to fruits is at the rapid fruit growth.

**Keywords :** xylem, cell wall, pectin, fruits, yellow sap

## 1. Introduction

The main problem in the production of mangosteen fruit in Indonesia is the presence of yellow sap contamination in aryl and mangosteen rind. The presence of yellow sap contamination on the mangosteen fruit will affect the quality of the fruit both the appearance and taste of the mangosteen fruit. Calcium is a nutrient that is not mobile in plant tissues. Calcium translocation from the root to the canopy of the plant is influenced by transpiration, therefore one of the obstacles that arises is the low effectiveness of calcium absorption into the mangosteen fruit tissue. Most of the calcium absorbed from the roots will be directly localized to the leaf tissue, because the nature of calcium which is not mobile in xylem and its translocation in plant tissues is affected by the process of plant transpiration. Leaves as active plant tissues transpire will attract calcium from the roots and become competitors for the fruit. Therefore, an effort is needed to improve the translocation of calcium to the fruit.

Calcium application by spraying directly on the fruit surface can increase the calcium content of the pericarp of the fruit (Clark et al. 1987; Rosen et al. 2006), but this is not practice and less efficient on mangosteen in terms of its application in the field. Calcium application in wrong times through the soil will increase the calcium content in the leaf tissue, but does not increase calcium in the mangosteen rind (Dorly 2009; Depari 2011). This was clarified in the research conducted by Purnama (2014) who obtained results that there was an increase in calcium content in the pericarp of the fruit along with an increase in the calcium fertilizer dose given.

Other studies indicate the relationship between boron content and increased absorption and function of calcium in reducing the contamination of yellow sap on mangosteen fruit. Saribu (2011) showed that the application of calcium together with boron through the soil decreased the yellow sap contamination in aryl up to 0%. Similar results are shown in research conducted by Pechkeo et al. (2007) and Kurniadinata (2016b) that the application of calcium and boron to the mangosteen fruit can increase the calcium content of the pericarp and reduce the potential for yellow sap contamination in the mangosteen fruit. However, it is not yet clear whether the link between boron in supporting calcium uptake and translocation to the mangosteen fruit tissue and its influence on different sources of calcium on the decrease of yellow sap contamination in pericarp and aryl mangosteen. Therefore, it is necessary to obtain calcium absorption and translocation mechanisms and the most effective and efficient application of calcium and boron techniques, to increase calcium absorption in fruit tissue and reduce the contamination of yellow sap on mangosteen fruit. This study aims to: (1) determine the effect of calcium and calcium sources in overcoming yellow sap contamination on mangosteen fruit; (2) knowing the mechanism of absorption and translocation of calcium in mangosteen.

## 2. Materials and Methods

### *2.1. Place and time*

The study was conducted in the mangosteen garden of the Manggis Karya Mekar Farmer Group, in Cengal Village, Karacak Village, Leuwiliang, Bogor, Indonesia. The research location is located at an altitude of 390-398 m above sea level (ASL). Leuwiliang mangosteen garden is dominated by productive mangosteen plants that are more than 20 years old. This garden is located at an altitude of 390-398 m ASL, with 6-30% wavy and sloping topography, high podsolic soil type with high clay texture and pH ranging from 4.30-5.50. Soil chemical analysis and plant tissue were carried out at the

Laboratory of the Soil Research Institute, Bogor and the quality of fruit at the Post Harvest Laboratory of the Faculty of Agriculture, Bogor Agricultural University.

2.2. *Material*

The plant material used is mangosteen plants aged approximately 20 years and has been producing. The selection of sample plants is based on good and relatively uniform plant growth conditions. The level of uniformity was assessed based on the condition of the trees in the garden, which is based on similarity in stem diameter, crown size, plant height and suitability of maintenance history, with a view to reducing the diversity of plant conditions.

2.3. *Research methods*

The experiment was carried out using factorial randomized block design (RBD) with 3 replications, consisting of the treatment of calcium and boron fertilizer doses as the first factor, consisting of 6 levels, namely:

1) Control (without calcium and without B)
2) 2.8 g B / tree / year (6.09 g borate 46 / tree / year)
3) 3.2 kg of calcium dolomite / tree / year (10.67 kg dolomite / tree / year)
4) 3.2 kg of calcium calcite / tree / year (7.11 kg of calcite / tree / year)
5) 3.2 kg of calcium dolomite / tree / year + 2.8 g B / tree / year
6) 3.2 kg of calcium calcite / tree / year + 2.8 g B / tree / year

While the second factor was the number of stages of Calcium application and boron in mangosteen per year (T), which consists of 2 levels, namely:

1) Calcium and boron application at the time of the antesis and at the start of the first stage (1 week after the antesis (WAA)). Each time the application is given calcium and boron half of the dose specified.
2) Calcium and boron application at the time of anthesis and at the end of stage I (4 WAA). Each time the application was given calcium and boron half of the dose specified.

Each treatment level consists of one plant so that 36 adult mangosteen plants are needed (approximately 20 years of age and have fruited) that are relatively uniform in the experimental location. The calcium sourced from Dolomite (CaMg (CO3) 2) and Calcite (CaCO3), while boron sourced from Borat 46 fertilizer.

*2.4. Fruit labeling*

Fruit labeling was carried out on 100 flowers / trees. Labeling aims to determine the fruits to be used during observation.

2.5. *Harvesting*

Fruit harvested at 112 days after anthesis.

2.6. *Observation*

The variables observed are:

*2.6.1. Contamination of yellow sap on aryl.*

a. Percentage of polluted fruit per tree. Calculated based on the percentage of polluted fruit on the number of fruit samples (100 fruits) per tree.
b. Percentage of contaminated touring per fruit. Calculated based on the percentage of polluted fruit segment on the number of heads per fruit (taken from the average of all polluted samples per tree).

c. Measurement of contamination of sap guning on aril. Measurements were made using scoring which refers to the modified Kartika (2004), as listed in Table 1.

Table 1. Scores of yellow sap contamination on aryl

| Yellow sap contamination score on Aril | Information |
|---|---|
| Score 1 | **Very Good**, white aril is clean, there is no yellow sap between the aril and the rind and the fruit |
| Score 2 | **Good,** white aryl, there are 1-2 stains (small patches) of yellow sap on one end of the aryl, but do not give a bitter taste |
| Score 3 | **Good enough,** there are several stains (spots) of yellow sap at one end of the tip or between the fingers and contaminate the aril |
| Score 4 | **Bad,** there are stains / lumps of yellow sap both at the end of the tip, between the inside or in the fruit vessels which causes the fruit to taste bitter |
| Score 5 | **Very Bad,** there are large stains / lumps both in the fruit segment, between the inside and in the fruit vessels which cause the fruit to taste bitter, the aryl color becomes clear |

*2.6.2. Contamination of yellow sap on the Rind.*

a. Percentage of polluted fruit per tree. Calculated based on the percentage of polluted fruit on the number of fruit samples (100 fruits) per tree.

b. Measurement of contamination of yellow sap on mangosteen rind. Measurements were made using scoring which refers to the modified Kartika (2004), as listed in Table 2.

Table 2. Scores of yellow sap on the Rind

| Scores of yellow sap on the rind | Information |
|---|---|
| Score 1 | **Very Good,** smooth rind without visible yellow sap |
| Score 2 | **Good,** smooth rind with 1-5 small lumps of yellow sap that dries without affecting the color of the fruit |
| Score 3 | **Good enough,** smooth rind with 6-10 small drops of yellow sap that dries out and does not affect the color of the fruit |
| Score 4 | **Bad,** dirty rind due to medium / large lumps of yellow sap, there are 1-2 traces of yellowing that form yellow lines on the surface of the fruit |
| Score 5 | **Very Bad,** dirty rind because there are more than 1 large lump of yellow sap, there are many yellow lines on the surface of the fruit, and the color of the fruit becomes dull. |

*2.6.3. Fruit quality components*

Observations on the components of mangosteen fruit quality were carried out on the variables:Fresh fruit weight (g), Fruit rind hardness (kg / $cm^2$ / sec), Transverse diameter (cm) and Longitudinal diameter (cm).

*2.6.4. Time to develop young roots.*

Observations are made by making a vertical cut from the ground surface to a depth of 0.30 m. Cut length is 0.30 m. so that vertical and transverse pieces are formed in the 0.30 m x 0.30 m land profile. The cut is 1.5 m from the mangosteen tree trunk (under the canopy).

*2.6.5. The presence of a kaspari tape.*

Observations were carried out microscopically on young root and old roots tissue of mangosteen. The roots are cut transversely as thin as possible, cleaned using 70% alcohol, then observed the presence of a cassava tape.

## 3. Research Result

*3.1. Application of Calcium and Boron*

Application of calcium and boron proved to be able to reduce the percentage of fruit contaminated with yellow sap on aryl, yellow sap contamination scores on aryl, and the percentage of polluted fruit segment, both in the first year and in the second year of the experiment (Table 3). In the first year, the application of dolomite + boron was able to reduce the percentage of fruit contaminated with yellow sap on aryl to be 53%, much lower when compared to without calcium and boron (control) which produced yellow sap contamination in aryl by 91.66%. Lower contamination score scores were also found in dolomite + boron treatment of 1.68, while control showed a contamination score of 3.01.
In the second year, the application of dolomite + boron reduced the percentage of fruit contaminated with yellow sap on aril to 31.66%, not significantly different from the application of dolomite (36.33%) and calcite + boron (33.00%), but significantly different from the control (62.66%). Whereas the percentage of polluted jellies per fruit, dolomite + boron application was significantly different from the control but not significantly different from other applications, both in the first and second year.

Table 3. Fertilization of calcium and boron in mangosteen, on the percentage of fruits contaminated with yellow sap on aryl.tree$^{-1}$, percentage of polluted segment and yellow sap contamination scores on aril for two years.

| Application of calcium and boron | Yellow sap contamination on aril | | | | | |
|---|---|---|---|---|---|---|
| | Contaminated fruit.tree$^{-1}$ (%) | | Contaminated fruit segment (%) | | Score (1-5) | |
| | Year 1 | Year 2 | Year 1 | Year 2 | Year 1 | Year 2 |
| Control | 91.66 a | 62.66a | 30.4 a | 33.3 a | 2.96a | 3.01a |
| Boron | 85.00 a | 57.66a | 26.5 ab | 26.7 b | 2.45b | 2.45b |
| Dolomite | 63.33 b | 36.33c | 19.3 c | 18.3 c | 1.81d | 1.88c |
| Calcite | 66.66 b | 42.33b | 24.2 bc | 20.9 c | 1.95cd | 1.80cd |
| Dolomite + boron | 53.33 c | 31.66c | 18.7 c | 17.3 c | 1.80d | 1.68d |
| Calcite + boron | 68.33 b | 33.00c | 22.2 bc | 21.8 c | 2.05c | 1.81c |

Note: Scoring data were tested using the Kruskal Wallis rank test. The contamination score is based on a score of 1-5 with a value of 1 (best / without contamination) up to a score of 5 (worst / has the highest contamination score). The numbers followed by the same letter in the yellow sap score column showed no difference significantly based on Dunn's test of 5%, in the column%

of contaminated fruit per tree and% of contaminated fruit segment per fruit showed no significant difference based on 5% DMRT test.

The application of calcium and boron was also able to reduce the percentage of fruit contaminated with yellow sap on the rind and the yellow sap contamination score on the rind during the two-year trial (Table 4). The application of dolomite + boron reduced the percentage of yellow sap contamination on the rind to 76.66% in the first year, while the control produced 88.33%. In the second year of the experiment, application of dolomite + boron decreased the percentage of yellow sap contamination on the rind to 46.33%, while the control was still above 85%. Likewise in the yellow sap contamination score on the rind, the application of dolomite + boron showed lower sap contamination scores compared to the control, and was not significantly different from other applications of calcium and boron.

Table 4. Fertilization of calcium and boron in mangosteen, on the percentage of fruit contaminated with yellow sap on the rind. tree$^{-1}$ and yellow sap contamination score on fruit rind for two years.

| Application of calcium and boron | Yellow sap contamination on Rind | | | |
|---|---|---|---|---|
| | Contaminated fruit. tree$^{-1}$ (%) | | Score (1-5) | |
| | Year 1 | Year 2 | Year 1 | Year 2 |
| Control | 88.33a | 86.00a | 3.01a | 3.00a |
| Boron | 86.66ab | 73.00b | 2.73b | 2.58b |
| Dolomite | 83.33ab | 52.00cd | 2.26c | 2.13c |
| Calcite | 85.00ab | 57.00c | 2.20c | 2.18c |
| Dolomite + boron | 76.66bc | 46.33d | 2.11c | 2.08c |
| Calcite + boron | 71.66c | 50.00d | 2.11c | 2.15c |

Note: Scoring data were tested using the Kruskal Wallis rank test. The contamination score is based on a score of 1-5 with a value of 1 (best / without contamination) up to a score of 5 (worst / has the highest contamination score). The numbers followed by the same letter in the yellow sap score column showed no difference significantly based on Dunn's test of 5%, in the column% of contaminated fruit per tree and% of contaminated fruit segment per fruit showed no significant difference based on 5% DMRT test.

*3.2. Application time of calcium and boron*

When the application of calcium and boron had an effect on the percentage of fruit contaminated with yellow sap on aril in the second year of the experiment, it did not give an effect on the decrease in the yellow sap contamination score in aril in the same year. When the application of calcium and boron only affects the yellow sap contamination score in the first year of application. Whereas in the percentage of contaminated fruit segment, calcium and boron application time did not give effect both in the first year and the second year of the experiment (Table 5).

Table 5. Time for fertilizing calcium and boron in mangosteen, on the percentage of fruit contaminated with yellow sap on aryl.tree$^{-1}$, yellow sap contamination score on aryl and the percentage of polluted fruit segment for two years.

| Application of calcium and boron | Yellow sap contamination on aril | | | | | |
|---|---|---|---|---|---|---|
| | Contaminated fruit.tree$^{-1}$ (%) | | Contaminated fruit segment (%) | | Score (1-5) | |
| | Year 1 | Year 2 | Year 1 | Year 2 | Year 1 | Year 2 |
| Anthesis + 1 WAA | 70.00 | 42.33 b | 0.23 | 0.22 | 2.08b | 2.10 |
| Anthesis + 4 WAA | 72.77 | 45.55 a | 0.23 | 0.23 | 2.25a | 2.11 |

Note: Scoring data were tested using the Kruskal Wallis rank test. The contamination score is based on a score of 1-5 with a value of 1 (best / without contamination) up to a score of 5 (worst / has the highest contamination score). The numbers followed by the same letter in the yellow sap score column showed no difference significantly based on Dunn's test of 5%, in the column% of contaminated fruit per tree and% of contaminated fruit segment per fruit showed no significant difference based on 5% DMRT test.

When the application of calcium and boron does not give an effect on the decrease in the percentage of yellow sap contamination on the rind both in the first and second year. However, the application time of calcium and boron has an effect on the yellow sap contamination score on the rind in the first year of application, whereas in the second year it does not give effect. Application of calcium and boron at the time of antesis + 4 WAA gave the worst yellow sap contamination score compared to the application at the antesis + 1 WAA (Table 6).

Table 6. Time for fertilizing calcium and boron in mangosteen, on the percentage of fruit contaminated with yellow sap on the rind.tree$^{-1}$ and yellow sap contamination score on fruit rind for two years..

| Application of calcium and boron | Yellow sap contamination on Rind | | | |
|---|---|---|---|---|
| | Contaminated fruit.tree$^{-1}$ (%) | | Score (1-5) | |
| | Year 1 | Year 2 | Year 1 | Year 2 |
| Anthesis + 1 WAA | 82.22 | 60.77 | 2.35b | 2.37 |
| Anthesis + 4 WAA | 81.66 | 60.66 | 2.46a | 2.33 |

Note: Scoring data were tested using the Kruskal Wallis rank test. The contamination score is based on a score of 1-5 with a value of 1 (best / without contamination) up to a score of 5 (worst / has the highest contamination score). The numbers followed by the same letter in the yellow sap score column showed no difference significantly based on Dunn's test of 5%, in the column% of contaminated fruit per tree and% of contaminated fruit segment per fruit showed no significant difference based on 5% DMRT test.

In the second year, the application of calcium and boron at the time of antesis + 1 WAA was able to reduce the percentage of fruit contaminated with yellow sap on fruit aryl better than the application of calcium and boron at the time of antesis + 4 WAA. It is suspected that calcium and boron applications can meet calcium and boron requirements after two years of application to support fruit growth and development at a later stage. Whereas in the first year, the application time can only reduce the yellow pollutant sap score on aryl and fruit rinds, with the application when antesis + 1 WAA decreases the yellow sap contamination score lower than the application time at antesis + 4 WAA.

## 4. Discussion

The quality of mangosteen fruit is related to the presence of yellow sap on the rind and fruit aryl. The more contamination that occurs, the lower the quality of the fruit. The results of this study indicate a decrease in the percentage of fruit contaminated with yellow sap and yellow sap contamination scores on aryl and rind, since the first year of the experiment. This has become an indicator that calcium is the main important element in the decline. The combination of calcium application (both from dolomite or calcite) and boron proved to be able to reduce the percentage of polluted fruit on aryl and rind as well as yellow sap contamination scores on aryl and rind, both in the first year and in the second year of the experiment. It is suspected that with the application of calcium, there is an increase in uptake and tranlocation of calcium into the fruit tissue. In addition to calcium, a combination of calcium and boron will guarantee the supply of boron to fruit growth and development. Boron has the same function in increasing cell wall strength as well as calcium (Hu et al. 1996). Therefore boron is thought to support the function of calcium in increasing the strength of the wall of the yellow epithelial cell channel epithelial cells.

The combination of calcium and boron will increase the resistance of the cell wall channel to the risk of rupture when there is pressure on the channel. Limpun-Udom (2001) in his study found that calcium and boron content in the normal mangosteen rind which was not contaminated with yellow sap was higher than the fruit that experienced yellow sap contamination. Lim et al. (2001) added that boron has an important function in supporting calcium function in plant tissues especially as one of the constituent components of cell walls. The presence of boron elements will support increased resistance and rigidity of the yellow sap channel cell wall. Marschner (1995) and O'Neill et al. (2004) that just like calcium, boron functions as a constituent of cell walls, functioning to improve the stability and firmness of cell wall structures and improve plasma membrane integrity. Furthermore Kobayashi et al. (1996) on the results of their study reported that boron as boric acid bound together with two rhamnogaladuronan II (RG II) chains forms a boron-polysaccharide complex. These two Rhamnogaladuronan II molecules are linked to each other by boric acid to form a boron-polysaccharide complex. Application of calcium both sourced from dolomite and calcite with boron will ensure the availability of calcium and boron during fruit growth and development and support the formation and development of cell walls in the phase of fruit growth and development in the generative phase of the plant. The presence of pressure on the fruit endocarp due to the rapid growth of seeds and aryl, causing the yellow sap channel to be susceptible to damage. The presence of calcium from both dolomite and calcite and boron will increase the cell wall strength of the yellow sap canal so it is not easily broken. Both dolomite and calcite have a relatively similar effect in reducing the score of yellow sap contamination both on aryl and mangosteen rind. This shows that the two sources of calcium can be used to overcome the contamination of yellow sap on the mangosteen fruit. However, Boron's ability to reduce the percentage of fruit contaminated with yellow sap and contamination scores has not been as large as the decrease obtained with calcium application.

Calcium requirements for plants occur when entering the generative stage, especially during anthesis (Pechkeo et al. 2007, Hu et al. 1996). In this stage, fruit plants will absorb all the nutrients needed for the growth and development of flowers and fruit. The nature of the toxic boron element causes boron cannot be applied excessively. Marshner (1995) states that boron is toxic to plants at different levels, this difference is related to the function of boron and the need for boron. Boron is mainly absorbed maximally during cell wall synthesis, especially at the time of lignin formation and as a constituent of cell walls. For mangosteen plants, Martias (2012) in his study found that optimum leaf boron content (86.5 ppm) eliminated yellow sap contamination to a minimum (2.86%), but increased boron leaves up to 130 ppm caused yellow sap contamination to increase by 40.7%. From the results of this study it can be seen that the application of boron can reduce yellow sap contamination but in certain amounts boron can act as toxic for plants.

Several studies have shown that calcium can increase the tolerance level of plants to the toxic properties of boron. As stated by Tisdale et al. (1985) in his research that there is a relationship between calcium and boron on plants. When calcium is in sufficient quantities, plants will become more tolerant of the presence of boron. The presence of calcium is known to be able to increase the tolerance level of plants against boron poisoning by regulating boron transport in plant cells, and protecting cells from the entry of boron into plant cells in excess amounts. This will improve the efficiency of the function of boron as one of the constituents of the cell wall and is able to improve the quality of fruit, and this function is closely related to the presence of calcium.

There is a relationship between fruit development with calcium requirements available in the soil, namely the increase in calcium absorption into the fruit tissue during fruit development. The increase occurs following the fruit development stage, mainly occurs in the early stages of fruit development and then decreases as the level of fruit maturity increases. Mentioned by Tomala et al. (1989) that calcium absorption into fruit tissues occurs continuously and fluctuates in the process of fruit development. This statement is in accordance with Faust (1989), Wilkinson and Perring (1961), Ford and Quinlan (1979), Fuhr and Wieneke (1974), Hu et al. (1996), Pechkeo et al. (2007) and Wilsdorf (2011) which states that in general the absorption of calcium by fruit occurs during the initial stages of fruit growth and development. Rapid absorption of calcium and boron by plants mainly occurs at the beginning of fruit growth and development, which is dittrlokasikan via xylem to the fruit. Increasing the size of the mangosteen fruit causes the fruit to be susceptible to yellow sap contamination in aryl and fruit rinds due to pressure due to fruit development. The pressure occurs due to the difference in the growth rate between aryl and seeds to the rind of the fruit. This insistence has the potential to cause rupture of the yellow sap channel in the pericarp tissue of the fruit which then pollutes the aryl (Poerwanto et al. 2010).

The application of calcium and boron through rooting at the time of anthesis can meet calcium requirements, especially in the fast stadia of fruit development, ie at 1-4 WAA. Stage 1 of fruit growth becomes critical time for Ca up to support fruit growth and development. Poovarodom (2009) explained that the mangosteen fruit consists of three fruit development stages namely I 1-4 WAA stage, stage II 5-13 WAA, and stage III 14-15 WAA. Therefore, the application of calcium and boron which is done twice during antesis + 1 WAA is thought to be able to increase absorption and translocation of calcium to fruit tissue through xylem compared to the application at antesis + 4 WAA (Figure 1).

Application of calcium and boron at the time of antesis + 4 WAA is thought to be less effective in increasing uptake and translocation of calcium and boron into the fruit tissue. This is because when 4 WAA the need for calcium and boron for the growth and development of fruit is not as high as the requirement at the antesis + 1 WAA. Explained by Rigney and Wills (1981) and Poovarodom (2009) that during the development of the mangosteen fruit, calcium needs in the cell wall will increase but will then decrease before cooking.

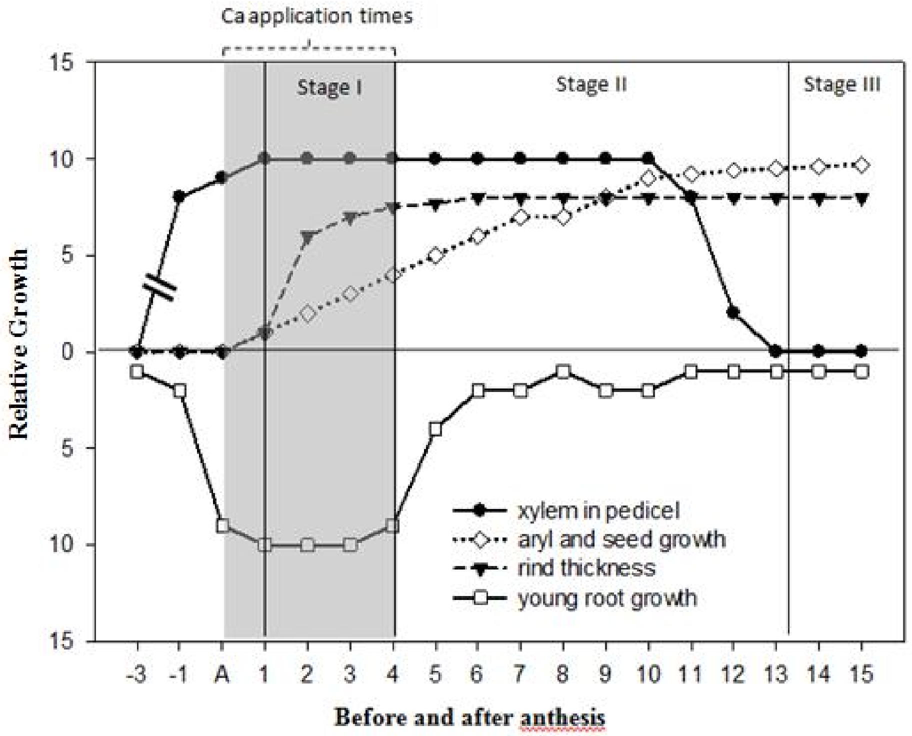


**Figure 1.** Relationship model of calcium absorbed and translocation based on young root growth, fruit growth, and xylem condition in pedicel. X axis ([-] = Weeks before anthesis; [A] = anthesis; [+] = weeks after anthesis). Y axis (xylem, aryl and seed, rin, and young root growth (not to scale). (source : Kurniadinata *et al.* 2017)

The category of fast fruit growth in mangosteen occurs at 1-4 WAA. At this time the elements of calcium and boron will be tranlocated to fruit tissue in large quantities because the fruit becomes a strong sink against various nutrients (Marschner 1995). In this stage the flow of calcium and boron translocation that was previously dominant towards the leaves will move towards the fruit. Application of calcium and boron at the time of antesis + 4 WAA will be less effective than the application of calcium and boron during antesis + 1 WAA because during the second application at 4 MSA, the need for calcium and boron is not as much as at 1 MSA. However, the application of calcium and boron at the time of the second year of application showed no significant difference to the decrease in contamination of yellow sap on aryl and mangosteen rind. The time difference between 1 WAA and 4 WAA is still not able to show the effect of calcium application in reducing the yellow sap contamination clearly. The time interval between 1WAA and 4 WAA is thought to be too close to determine the effect of calcium application time on the removal of yellow sap contamination on mangosteen fruit. 1st Class, 1-4 1-4, is the most important time for calcium and boron for plants. The application of calcium and boron at the time of anthesis plays an important role in fulfilling calcium and boron needs to reduce yellow sap contamination. In addition, the number and level of different fruit growth and development stages in one plant is thought to affect the absorption and translocation rates of calcium and boron to the mangosteen fruit.

$Ca^{2+}$ absorbed in root especially in root elongation zone, located between the root meristem and root differentiation zone (Kurniadinata et.al 2017). At anthesis and Stage I, plants also initiates new roots (Marschner, 1995). Hidayat (2002) explained that the mangosteen rapid root growth occurred before bud break due to an increased need of assimilates to perform high rate of cell division. Development of new roots is an important factor in the mechanism of Ca uptake and translocation from the root to the xylem since $Ca^{2+}$ is mainly absorbed by young root tissue (Himelrick and McDuffie 1983, Marschner 1995). $Ca^{2+}$ can easily pass through endodermis of young roots. Ca translocation is more limited in older roots with well-formed casparian strips; casparian strip will shield the cells and block $Ca^{2+}$ translocation into the xylem.

The experiments showed that anthesis is the best time for Ca application. At this stage, fruits become the strong sink, xylem tissues function optimally, and young roots are already formed and functioning. Application of Ca can be repeated at 4 WAA. Twice application of Ca at anthesis and 4 WAA will increase availability and uptake of Ca into fruit. $Ca^{2+}$ that has been absorbed by young roots since anthesis and 4 WAA will be translocated into the fruit tissues throughout the growth and fruit development stage (Figure 1). The results of this study have provided important information to increase the quality of mangosteen by reducing yellow sap incidence.

## 5. Conclution

From this experiment it can be concluded that:

1. Application of calcium was able to reduce the contamination of yellow sap on the mangosteen aryl fruit reached 53% and on the rind reached 46% and improved the quality of mangosteen fruit, without calcium produced plants while yellow sap contamination of 91.66% on aryl and 86% on the rind;
2. Calcium is absorbed and distributed by the mangosteen plant through several mechanisms, namely: through xylem in root and continue to the stem and then to pedicel before absorbed into the fruits. The higher Calcium tranlocation to fruits is at the rapid fruit growth.

## References


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