APPLICATION OF K, Ca, and Mg ON PEEL THICKNESS AND FRUIT CRACKING INCIDENCE OF CITRUS

Hardiyanto*
Indonesian Center for Horticultural Research and Development, Bogor, Indonesia

Friyanti Devy Nirmala
Indonesian Citrus and Subtropical Fruits Research Institute, Batu, Indonesia

*E-mail: hardiyanto85@yahoo.com

ABSTRACT
Citrus cv. Terigas (Citrus reticulata) genetically has a fragile fruit peel that occurs from young up to mature stage which causing farmers to suffer detrimental lost in production. The addition of K, Mg, and Ca can reduce the number of damaged fruit. This research was conducted at the Tekung Experimental Field, Indonesian Citrus and Subtropical Fruits Research Institute (ICSFRI) in January - October 2017, using 4-year-old Mandarin cv. Terigas and Tangerine cv. Pontianak citrus plants. The aims of this study was to evaluate the effect of K, Ca and Mg fertilizers on nutrient uptake in plants, fruit development, and the percentage of cracking fruit on Mandarin cv. Terigas (Citrus reticulata) and Tangerine cv. Pontianak (C. reticulata Blanco.). The experiment was carried out in a Nested Design. The 1st factor was the application of K, Ca and Mg through foliar spray, consisted of P1 (Control/without fertilizing), P2 (recommended fertilization), P3 (P2 + 3 g l⁻¹ K + 1 g l⁻¹ Ca + 1 g l⁻¹ Mg), P4 (P2 + 6 g l⁻¹ K + 2 g l⁻¹ Ca + 2 g l⁻¹ Mg), and P5 (P2 + 6 g l⁻¹ KNO₃). The second one was the variety, Mandarin cv. Terigas and Tangerine cv. Pontianak as a control. The treatment was repeated 3 times with a unit treatment of 5 plants. Observations were made on macro nutrient uptake on leaves and fruit skin, development of fruit size, number of cracking fruit/plant, size of fruit diameter, and thickness of fruit peel. The results showed that the cracking incidence of Terigas fruits was caused by the thinning of the fruit peels, where the thinner the peel of the fruit, the more fruit would be cracked (Y = 20.501 to 9, 9702 X, R² = 67.5%), while the thickness of the skin was not influenced by nutrients absorbed in the fruit peel. Treatment P2 to P5 was able to suppress fruit cracking on Terigas Mandarin between 22 - 56.1% at age of 22 weeks and 14.9 - 42.6% at age of 26 weeks after flowering. Moreover, P3 can prevent 50% of cracking fruit/plant less than the control (P1). All treatments did not significantly affect on the thickness of peel fruit of Tangerine cv. Pontianak. This activity has an impact on increasing the quantity and quality production of Mandarin cv. Terigas.

KEY WORDS
Fruit cracking, Mandarin cv. Terigas, Tangerine cv. Pontianak, fruit peel.

Fruit cracking incidence is one of disorders that can be caused by either abiotic factors, the rootstock used (El-Sayed, 2016), or other physiological disorders (Agusti et al., 2002). Genetically, this damage is likely caused by the fruit skin which is relatively thinner than others. Garcia-Luis et al. (2001) added that fruit anatomy developed distinctively between susceptible and resistant varieties to fruit cracking.

The occurrence of fruit cracking was caused by disturbances during the development of the skin and fruit pulp. In the cell enlargement phase, if the fruit's skin develops more slowly than the fruit pulp, this process would occur. Although the albedo part ('spongy') can adjust to this process, but this is not the case for more rigid parts of the flavado, hence fruit tend to cracks. The phenomenon of those cracking in citrus is different from other plants (Sheikh & Manjula, 2012), because its fruit has a unique morphology (Cronje et al., 2013). Citrus fruit consists of pulp and skin composed of an internal layer (mesocarp) with white
colour (albedo) and an external layer/flavedo (exocarp). The pressure that occurs due to the rapid expansion of the pulp when the fruit develops will trigger the formation of cracks in the flavedo and it is the beginning of the breaking of fruit on the stylar, which is the weakest part of the skin of the citrus fruit. In addition, nutritional imbalance, low Ca and K and high P, conditions of hot and humid air, irregular irrigation, and plants with heavy fruit can also trigger fruit cracking incidence in some citrus varieties starting at the time they begin to develop. Fruit in young trees tends to be more susceptible to cracking than older plants (Goodwin, 2008; Cronje et al., 2013).

Studies showed that field flooding during the dry season followed by fertilizer application was able to improve the quality of Terigas Mandarin fruit, including reduced broken fruit, increased fruit diameter (grade), reduced acid levels (%), and increased fruit sugar levels (Purba et al., 2016). The application of organic fertilizer + inorganic fertilizers + mulch + (Ca and B) accompanied by flooding ditches can reduce the number of broken fruit to 19.4%. This is in accordance with the opinion of Goodwin (2008), that damaged fruit can be reduced by maintaining optimal environmental conditions for plant growth, including watering and adequate nutritional intake. The condition of deficiency of K elements will cause thin fruit skin which will encourage breakage on the fruit. The use of mulch and compost will also maintain the degree of moisture in the soil, while the application of slow release fertilizers will be enough to help provide food intake evenly.

According to El-Tanany et al. (2011), spraying K, Ca and Mg on leaves once to three times also increases the number of fruit set per branch and the number of fruit/plant. In addition, this treatment also increases the speed of fruit development, significantly reducing the broken fruit and increasing the quality of WNO sweet orange fruits. Also added by El-Rahman et al. (2012), that K applied in the form of 4-6 % KNO₃ significantly increases skin thickness thereby reducing the incidence of cracking, increases fruit size, and production, while the combination of KNO₃ 5% + 2.4 D 20 ppm sprayed 60 days after flower blooms will increase fruit size (Boman & Hebb, 1998; Rattanpal et al., 2005; Vijay et al., 2016). Improvement of irrigation management, mulching, manure application, as well as other inorganic additions can reduce fruit cracking on lemon (Sandhu & Bal, 2013).

Fruit cracking can also be reduced by other growth regulator applications. The addition of Zn and NAA during the enlargement phase of Shatangju citrus will encourage an increase in IAA, GA₃ and tryptophan at the beginning of the development of the skin, thus inducing cell growth and division, reducing the variation in skin hardness and reduce cracking on the albedo which will reduce broken fruit (Li et al., 2016).

The justification of the research is that in less optimal conditions of citrus plants, the fruits of Terigas Mandarin tend to crack. On the other hand, the addition of K, Mg, and Ca by foliar spray on them would be reducing the number of damaged fruit. The aim of this study was to evaluate the effect of foliar spray of K, Ca and Mg fertilizer on nutrient uptake in plants, fruit development, fruit peel thickness, and percentage of fruit cracking in Terigas Mandarin (Citrus reticulata) with Pontianak Tangerine (C. reticulata Blanco) as a control variety.

MATERIALS AND METHODS OF RESEARCH

The study was conducted at KP. Tlekung, ICSFRI from January to October 2017, using 4-year-old Terigas Mandarin and Pontianak Tangerine plants as a control.

| Block I | Block II | Block III |
|---------|----------|-----------|
| P 5 V 1 | P 3 V 1  | P 4 V 1  |
| P 3 V 1 | P 2 V 1  | P 1 V 1  |
| P 2 V 1 | P 1 V 1  | P 3 V 1  |
| P 4 V 1 | P 5 V 1  | P 2 V 1  |
| P 1 V 1 | P 4 V 1  | P 5 V 1  |

| Block I | Block II | Block III |
|---------|----------|-----------|
| P 1 V 2 | P 2 V 2  | P 5 V 2  |
| P 5 V 2 | P 3 V 2  | P 1 V 2  |
| P 3 V 2 | P 4 V 2  | P 2 V 2  |
| P 2 V 2 | P 1 V 2  | P 4 V 2  |
| P 4 V 2 | P 5 V 2  | P 3 V 2  |

Note: V1 = Terigas Mandarin; V2 = Pontianak Tangerine

Figure 1 – The layout of the treatments
Experiment was done by adding minerals K, Ca and Mg by spraying on the leaves of plants. The treatment consisted of 2 factors, first factor was the treatment of spraying (P) and II was citrus varieties (V), with each treatment consisted of 5 plants and repeated 3 times (Figure 1). Experiments were carried out in a nested design, with models: \( Y_{ijk} = \mu + B_k + R_{ij} + A_j + AB_{ij} + \epsilon_{ijk} \).

The spray dosage treatment was as follows:
- P1: Control, plants were not fertilized;
- P2: Fertilization treatment according to field standards (1 kg/plant of Ponska and ZA);
- P3: P2 + Fertilizer K 3 gram/l + Fertilizer Ca 1 gram/l + Fertilizer Mg 1 gram/l (sprayed in January, February and March 2017);
- P4: P2 + Fertilizer K 6 gram/l + Fertilizer Ca 2 gram/l + Fertilizer Mg 2 gram/l (sprayed in January, February and March 2017);
- P5: P2 + KNO₃ 6 gram/l (sprayed in January, February and March 2017).

Observation Parameters:
- The content of macro nutrient on leaves and fruit peels. Analysis on macro nutrient uptake was carried out at the Soil Analysis Laboratory, Faculty of Agriculture, Univ. Brawijaya Malang, East Java-Indonesia. Analysis of N, P, K, Ca, and Mg leaves was carried out 20 days after the final treatment;
- Fruit size. Observation on development of fruit size was carried out by measuring the diameter of the fruit in 20 samples/plant. Fruit samples were determined on branches in the direction of 4 winds, 5 fruits/branches. Fruit development measurement is the increase in the average size of the diameter (fruit diameter in \((n + 1)\) month – fruit diameter in \(n\) month);
- Number of fruit cracking that is observed every month;
- At harvest time: fruit diameter, fruit skin thickness (transversal fruit cut, thickness);
- Statistical analysis. Data collected was analysed by ANOVA using Minitab 16 program.

**RESULTS AND DISCUSSION**

_Nutrients content in the leaves and fruit peels of _Terigas _Mandarin and _Pontianak _Tangerine. In general, the average content of N, P, and Ca absorbed in the leaf level was higher than in the peel of its fruit, whereas K and Mg were not significantly different (Table 1).

| Organ       | % absorption of nutrients |
|-------------|---------------------------|
| N           | P       | K       | Ca      | Mg      |
| Leave       | 2.979   | 0.175   | 0.823   | 3.014   | 0.279   |
| Peel        | 1.273   | 0.092   | 0.778   | 0.882   | 0.300   |
| T Test (5%) | **      | **      | ns      | **      | ns      |

*Note: ns = not significant different based on T test 5%.*

Coetzee (2007a) mentioned that the total N content on citrus cv. Valencia Late Orange (VLO) ranged from 700 - 900 g/plant, with a composition of 40% and 20% for leaves and fruit respectively; 30 % in buds, branches, stems; and the rest (10%) in the roots. Moreover, Dalal _et al._ (2017) reported that the maximum N content in leaves reached 2.51% after foliar application of 3% KNO₃, and this level was not significantly different compared to other treatments. Higher nutrient levels in the leaves are assumed to be due to differences in the way they are absorbed. According to Coetzee (2007a), Ca is absorbed by plants and then translocated passively to leaves and fruit through water flow. The process of transpiration of young leaves is much higher than that of young fruit, so that the flow of water and Ca that are carried will be even higher. The accumulated calcium cannot move to other tissues. This causes the Ca levels to be high after the application of foliar spray. The remaining calcium that is not used by plants will be deposited in the form of calcium oxalate which is not soluble
in water. Calcium absorbed in the fruit skin will affect the quality of the fruit (Blanco et al., 2010).

Potassium is mobile and generally enters the plant due to absorption by the roots and transported to meristem tissue. Apart from absorption, nutrient content in a tissue is also caused due to relocation, i.e. from old to young tissue (Coetzee, 2007b). Due to higher mobility and always on the move, the remaining content in the leaf tissue is not higher than before after spraying application. However, the addition of K application will still have an impact on increasing the size of fruit diameter compared to the control treatment, although its absorption efficiency in the field was only ± 25% (Coetzee, 2007c). On the skin of Terigas Mandarin and Pontianak Tangerine fruits, the average nutrient content of N and Ca is relatively higher than the others. Singh et al. (2015) reported that Ca in grapefruit (cv Star Ruby) was higher than other macro nutrients, as the fruits get older. Therefore each of these minerals is absorbed in different patterns (Figure 2).

![Figure 2 – Macro nutrient in the skin of grapefruit (cv Star Ruby) (Source: Singh et al. (2015)]](image)

Based on the correlation analysis, there was no relationship between nutrient uptake in the leaves and the fruit peel (Table 2). The same trends was also reported by Coetzee’s (2007a, b), where differences in the levels of mineral nutrients in the leaves and in the skin of the fruit are caused by the way they are absorbed or relocated.

| Nutrients in the leaves / skin | N    | P    | K    | Ca   | Mg   | Equation                   | R²   |
|-------------------------------|------|------|------|------|------|---------------------------|------|
| N                             | ns   | -    | -    | -    | -    | Y = 2.723 - 0.174 X       | 0.001|
| P                             | -    | ns   | -    | -    | -    | Y = 0.137 + 0.439 X      | 0.024|
| K                             | -    | -    | ns   | -    | -    | Y = 0.570 + 0.249 X      | 0.035|
| Ca                            | -    | -    | -    | ns   | -    | Y = 3.14 - 1.21 X        | 0.06 |
| Mg                            | -    | -    | -    | -    | ns   | Y = 3.55 - 3.28 X        | 0.342|

*Note: ns = not significant at correlation test 5%.*

**Effect of varieties and foliar application of K, Ca and Mg on leaf nutrient content.** The nutrient levels absorbed in the leaves are influenced by interaction of varieties and spraying dosages (Table 3). The levels of N, P, K, and Mg absorbed in the leaves of P1 (control, not fertilized) were in the optimal range. This shows that the 4-year old plants were in optimal condition. Under these conditions, it is suspected that the addition of fertilizer given by spray on the leaves does not have much effect on the increase of absorbed nutrient levels. The application of mineral nutrients through leaves is thought to be directly used by plants for metabolic processes, plant growth and development. This can be seen in the application of treatment P4 where the nutrient content is raised 100% compared to P3, but the nutrient content absorbed in the leaves tends to decrease.
Table 3 – Percentage of N, P, K, Ca, and Mg uptake in leaves

| Treatment | % N, P, K, Ca, and Mg elements uptake in leaves |
|-----------|-------------------------------------------------|
|           | N       | P       | K       | Ca       | Mg       |
| P1 V1     | 2.39 b  | 0.18 abc| 1.11 a  | 3.02 ab  | 0.20 a   |
| P2 V1     | 2.49 ab | 0.20 a  | 0.88 abc| 3.17 ab  | 0.20 a   |
| P3 V1     | 2.66 ab | 0.19 ab | 0.63 abc| 3.08 ab  | 0.25 a   |
| P4 V1     | 2.53 ab | 0.16 abc| 0.59 abc| 2.67 ab  | 0.33 a   |
| P5 V1     | 2.38 b  | 0.15 bc | 0.39 bc | 3.20 ab  | 0.20 a   |
| P1 V2     | 2.51 ab | 0.18 abc| 0.87 abc| 3.41 a   | 0.26 a   |
| P2 V2     | 2.36 b  | 0.20 a  | 1.07 a  | 2.75 b   | 0.32 a   |
| P3 V2     | 2.86 a  | 0.18 abc| 1.04 a  | 2.72 b   | 0.38 a   |
| P4 V2     | 2.28 b  | 0.14 c  | 0.75 abc| 3.14 ab  | 0.32 a   |
| P5 V2     | 2.33 b  | 0.18 abc| 0.9 abc | 2.74 b   | 0.32 a   |

P1: Control, plants are not fertilized;  
P2: Fertilization treatment according to field standards;  
P3: P2 + Fertilizer K 3 g/l + Fertilizer Ca 1 g/l + Fertilizer Mg 1 g/l (sprayed in January, February & March);  
P4: P2 + K fertilizer 6 g/l + Fertilizer Ca 2 g/l + Fertilizer Mg 2 g/l (sprayed in January, February & March);  
P5: P2 + KNO3 6 g/l (sprayed in January, February & March);  
V1: Terigas Mandarin; V2: Pontianak Tangerine.

Based on the range of nutrients absorbed in the leaves, all nutrients found in Terigas Mandarin and Pontianak Tangerine were in the optimal level category. The optimal K and P levels in the leaves of citrus plants ranged between 0.10% - 0.16% and 1.0% - 1.5%. The same trend was also reported by Conell (2018) (Table 4).

Table 4 – Optimal nutrient content in citrus leaves

| Nutrients absorbed in the leaves | % nutrient uptake |
|---------------------------------|-------------------|
|                                 | Deficiency        | Optimal          |
| N                               | <2.2              | 2.4 - 2.6        |
| P                               | <0.09             | 0.12 - 0.16      |
| K                               | <0.40             | 0.70 - 1.09      |
| Ca                              | <1.6              | 3.0 - 5.5        |
| Mg                              | <0.16             | 0.26 - 0.6       |

Source: Conell, 2018.

Table 5 – The influence of foliar application of K, Ca, Mg on the average of N content in the skin of Terigas Mandarin and Pontianak Tangerine

| Treatment | % N on fruit peels |
|-----------|-------------------|
| P1V1      | 1.400 a           |
| P2V1      | 1.323 b           |
| P3V1      | 1.350 ab          |
| P4V1      | 1.307 b           |
| P5V1      | 1.327 b           |
| P1V2      | 1.140 d           |
| P2V2      | 1.310 b           |
| P3V2      | 1.230 c           |
| P4V2      | 1.040 e           |
| P5V2      | 1.300 b           |

P1: Control, plants are not fertilized;  
P2: Fertilization treatment according to field standards;  
P3: P2 + Fertilizer K 3 g/l + Fertilizer Ca 1 g/l + Fertilizer Mg 1 g/l (sprayed in January, February & March);  
P4: P2 + K fertilizer 6 g/l + Fertilizer Ca 2 g/l + Fertilizer Mg 2 g/l (sprayed in January, February & March);  
P5: P2 + KNO3 6 g/l (sprayed in January, February & March);  
V1: Terigas Mandarin; V2: Pontianak Tangerine.

Effect of varieties and foliar application of K, Ca and Mg on nutrient levels in fruit peels.  
The interaction of application and varieties had significantly different on N absorption. The N uptake was highest in the treatment of the combination of P1V1 and P3V1 namely 1.40 and
1.35%, but P3V1 was not significantly different from the 3 other treatment combinations in Terigas Mandarin; whereas in the combination of nutrient addition treatment in Pontianak Tangerine, N uptake in fruit peels tends to be lower than all treatments in Terigas Mandarin (Table 5). This difference in absorption ability may be related to the genetic traits of the plant.

The highest N level on fruit skin was in P1V1 treatment due to better absorption than other treatments. Suspected in P1V1 (control plants, without fertilization) the vegetative growth of the plants was slower than other plants because of lack of nutrient intake relatively. This condition causes the process of N uptake in the fruit skin to be better because there is no competition with the same process in the leaves, which then increases the N levels in the fruit skin.

N and Ca absorption was significantly affected by varieties. In Terigas Mandarin, the N content was high but Ca was lower than Pontianak Tangerine (Figure 3). This character is thought to be due to the genetic nature of each variety (Boaretto et al., 2015) thus affecting the vulnerability of Terigas Mandarin to break compared to other varieties. According to Juan & Jiezhang (2017), Ca nutrient plays an important role in cell wall metabolism, and can reduce the occurrence of degradation by the hydrolase enzyme which encourages a reduction in the process of fruit skin cracking. The degradation of Ca in fruit peels may also be caused by high N uptake in plants, and causes very active vegetative growth, resulting in high absorption of water and Ca in the leaves. With such conditions, fruit is no longer able to compete with leaves in the absorption process of Ca (Coetze, 2007d).

Furthermore, the implementation of P2 up to P5 had a significant effect on the levels of N and Mg absorbed in the fruit skin, where treatment P4 caused the percentage of N and Mg absorbed levels to be lower than others (Figure 4).

Figure 3 – The percentage of total N (a) and Ca (b) on the skin of the fruit Terigas Mandarin and Pontianak Tangerine

Figure 4 – Average N and Mg uptake on fruit peel by treatment P1-P5

Decreasing absorption of N and Mg through the application of foliar spray (P4) is assumed to be due to the addition of K, Ca, and Mg with a dose that is raised 100%
compared to P3 in plants that are just 4 years old. Thus, it will encourage a higher vegetative growth, resulting in uptake of N, Mg, and more water to the leaf. Meanwhile, uptake in fruit peels will be reduced as occurs in other nutrient minerals (Coetzee, 2007 a).

**Effect of varieties and foliar application of K, Ca and Mg on fruit growth.** In general the interaction of varieties with the application of K, Ca, Mg through leaves had significantly different. Fruit size increased in the 2\textsuperscript{nd} (March) to the 5\textsuperscript{th} month (June), it was in accordance with the development of its diameter. In the combination of the spraying treatment of K, Ca, and Mg in the Pontianak Tangerine produced a larger size than that of Terigas Mandarin (Table 6).

Table 6 – The influence of foliar application of K, Ca, Mg on the increment fruit diameter from March to June 2017

| Treatment | Increment of fruit diameter (cm) | Total increment (Feb to Jun) |
|-----------|----------------------------------|-----------------------------|
|           | March                            | April | May      | June     | June   |
| P1V1      | 4.8 e                            | 4.9 ab | 4.1 a    | 1.9 b    | 15.6 e |
| P2V1      | 4.8 e                            | 4.9 ab | 4.0 a    | 3.6 a    | 17.3 de|
| P3V1      | 5.4 e                            | 5.0 ab | 4.2 a    | 3.2 ab   | 17.5 de|
| P4V1      | 6.1 de                           | 4.9 ab | 4.8 a    | 2.8 ab   | 18.6 bcde|
| P5V1      | 5.9 de                           | 5.1 ab | 4.7 a    | 2.3 ab   | 18.2 cde|
| P1V2      | 15.0 a                           | 4.8 ab | 4.9 a    | 2.6 ab   | 25.9 a |
| P2V2      | 8.1 CD                           | 7.7 a  | 4.4 a    | 2.4 ab   | 22.5 ab|
| P3V2      | 10.5 bc                          | 5.8 ab | 4.2 a    | 2.2 ab   | 22.9 ab|
| P4V2      | 11.0 b                           | 4.9 ab | 4.9 a    | 2.1 ab   | 22.7 abc|
| P5V2      | 10.2 bc                          | 4.0 b  | 3.9 a    | 2.4 ab   | 20.9 bcd|

P1: Control, plants are not fertilized;  
P2: Fertilization treatment according to field standards;  
P3: P2 + Fertilizer K 3 g/l + Fertilizer Ca 1 g/l + Fertilizer Mg 1 g/l (sprayed in January, February & March);  
P4: P2 + K fertilizer 6 g/l + Fertilizer Ca 2 g/l + Fertilizer Mg 2 g/l (sprayed in January, February & March);  
P5: P2 + KNO\textsubscript{3} 6 g/l (sprayed in January, February & March);  
V1: Terigas Mandarin; V2: Pontianak Tangerine.

At the beginning of the treatment or observation (in February 2017), the fruit size ranged from 29-34 mm and 24-33 mm for Terigas Mandarin and Pontianak Tangerine, respectively. The increment of fruit diameter on Pontianak Tangerine was higher than that of Terigas Mandarin, so the average fruit diameter at the end of the observation (June) was also higher, 52.5 mm and 48.6 mm respectively (Figure 5).

![Graph showing the development and increment of fruit diameter](image)

**Note:** PT = Pontianak Tangerine; TM = Terigas Mandarin

Figure 5 – Development and increment of fruit diameter

Difference in the pattern of fruit development is most likely due to genetic factors. This is clearly showed in P1V1 (control, Terigas Mandarin) and P1V2 (control, Pontianak) these were 15.6 and 25.9 mm, respectively. Bermejo & Cano (2012) reported that differences in the nutritional content and physic of citrus fruits were influenced by genetic characteristics,
environment, cultivation methods and use of rootstock. In the development of citrus fruit, there are 3 phases that are much related, namely cell division, cell development and ripening (Verreynne, 2010; Farooq et al., 2011). In the second phase, rapid fruit growth occurs which influenced greatly by environmental factors. In sweet oranges, phase I is achieved in the first 2 months of growth, phase II at 2-6 months, while the next phase until harvest time is above the age of 6 months (Farooq et al., 2011); whereas in lime, from phase II to phase III occurs for 8 weeks (Elsadig & Suleiman, 2013). This also occurs in Terigas Mandarin and Kitamani Tangerine as presented in Figure 5, in which the diameter increases very quickly in March until May 2017 (phase II) and followed by a slowdown in phase III (June 2017).

In Terigas Mandarin, the treatment of P4 and P5 encourages the increase in fruit diameter better than the control (P1). The response is probably due to the addition of P, K, and Ca which is applied through the leaves right at the fruit development phase (Phase II, i.e. January to March). This is in accordance with a study conducted by El-Tanany et al. (2011) and Dalal et al. (2017) on Washington Navel Orange (WNO), Kinnow Mandarin and sweet oranges cv. Jaffa. Number of fruit/branches as well as fruit diameter increased when the nutrient had added through foliar spraying. Application of K through foliar spray causes an increase in photosynthesis, so that protein synthesis, carbohydrate metabolism, and enzyme activation also increase in developing fruits (Hasanuzzaman et al., 2018). Besides influencing photosynthesis, K also causes cell wall formation (Yadav et al., 2014). Nevertheless, according to Morgan et al. (2005), the P element in plants does not correlate with the quality, size and thickness of fruit peels, whereas, K is very influential. Low level of K will significantly inhibit the development of fruit, therefore the plant will produce a smaller size of fruit and thinner fruit skin, encouraging cracks on the skin. Fruit diameter of Pontianak Tangerine (P1) was better than P5 treatment, this suggests that these varieties do not respond to the addition of P, K, and Ca in phase II.

**Effect of varieties and foliar application of K, Ca and Mg on total number of cracking fruit.** The incidence of fruit cracking only occurs in Terigas Mandarin which started in May (± 22 weeks after the flower blooms) or in phase II fruit development (Figure 6). According to Lin & Chen (2017), the occurrence of cracking in citrus fruit is a gradual process. Initially the fruit will develop normally, where the skin of the fruit develops normally, attaches to the inside, and the oil gland has a normal shape and arrangement. In stage II, there is an increase in the volume of fruit flesh, resulting in progressive changes in the form of fruit. In susceptible varieties, these developments led to the fruit skin become thin and encourage the occurrence of cracks on the skin (Cronje et al. 2013).

![Figure 6 – Normal (a) and cracking fruit of Terigas Mandarin](image)

In Terigas Mandarin, the average number of cracking fruits per plant was not significantly different between controls (P1) and other treatments. However, the treatment P1 tends to produce more damaged fruit, whereas with the addition of nutrient application by foliar spray (P2 to P5) can suppress the level of damage on observed fruit/plant between 22 to 56.1% at the age of 22 weeks, and 14.9 to 42, 6% at the age of 26 weeks after the flowers bloom (May and June) (Table 7).
Table 7 – The influence of foliar application of K, Ca, Mg on the average number of cracking fruit/plant on Terigas Mandarin

| Treatment | Number of cracking fruit/plants | May | June | Total |
|-----------|---------------------------------|-----|------|-------|
| P1        |                                 | 4.1 a | 4.7 a | 8.8 a |
| P2        |                                 | 2.8 a | 4.0 a | 6.8 a |
| P3        |                                 | 1.8 a | 2.7 a | 4.4 a |
| P4        |                                 | 2.3 a | 2.8 a | 5.1 a |
| P5        |                                 | 3.2 a | 3.8 a | 6.9 a |

P1: Control, plants are not fertilized;  
P2: Fertilization treatment according to field standards;  
P3: P2 + Fertilizer K 3 g/l + Fertilizer Ca 1 g/l + Fertilizer Mg 1 g/l (sprayed in January, February & March);  
P4: P2 + K fertilizer 6 g/l + Fertilizer Ca 2 g/l + Fertilizer Mg 2 g/l (sprayed in January, February & March;  
P5: P2 + KNO₂ 6 g/l (sprayed in January, February & March;  
V1: Terigas Mandarin; V2: Pontianak Tangerine.

In treatment P3, the level of total fruit damage can be reduced to 50% compared to the control. This is in line with the results of the study El-Tanany et al. (2011) in WNO citrus plants on which he applied K, Ca, and Mg nutrients once, two, and three times with a concentration of 300 ppm K + 100 ppm Ca + 20 ppm Mg, resulting in a reduction in the percentage of broken fruit compared to controls along with the thickness increase in the skin of the fruit.

Effect of varieties and foliar application of K, Ca and Mg on fruit skin thickness. The treatment of varieties, the application of K, Ca, and Mg through leaves and their combinations did not significantly affect the skin thickness of the intact fruit. The average thickness of Terigas Mandarin and Pontianak Tangerine was 2.24 and 2.27 mm in May and 2.12 and 2.05 mm in June, respectively (Table 8).

Table 8 – The influence of foliar application of K, Ca, Mg on the average skin thickness of Terigas Mandarin and Pontianak Tangerine intact fruit

| Treatment | Fruit skin condition | Skin thickness (mm) | May | June |
|-----------|----------------------|---------------------|-----|------|
| P1        | Terigas Mandarin (intact) | 2.17 a | 2.04 a |
| P2        | 2.34 a | 2.27 a |
| P3        | 2.22 a | 2.06 a |
| P4        | 2.19 a | 2.12 a |
| P5        | 2.29 a | 2.06 a |
| Average   | 2.24 a | 2.11 |
| P1        | Pontianak Tangerine | 2.22 a | 2.00 a |
| P2        | 2.32 a | 2.32 a |
| P3        | 2.10 a | 1.76 a |
| P4        | 2.43 a | 2.13 a |
| P5        | 2.33 a | 2.09 a |
| Average   | 2.27 | 2.05 |

The development of fruit skin thickness in the two varieties is in accordance with the phase of growth and development which is differently intervals for each variety. According to Lu et al. (2017), in Satsuma Mandarin the development of fruit is characterized by the increase of diameter size along with the thickening of fruit skin until the age of 30 days. Then with increasing age, the size of the fruit increases but the thickness of the skin decreases until the ripening phase.

The occurrence of broken fruit in Terigas Mandarin began in May, with an average number per sample of 2.8 and 3.6 in May and June, respectively. The thickness of the fruit peel was not significantly affected by all treatments. The thickness of fruit peel on normal fruit is higher than that of broken fruit, both in May and June observations, whereas for control (P1), the fruit skin tends to be thinner than other treatments (Figure 7).
Based on macro nutrient uptake on the leaves and skin of the fruit above, it appears that the levels are classified as optimal. According to Cronje et al. (2013), if the crop has absorbed nutrient levels optimally but the incidence of broken fruit is still happening, then this shows that nutrient factors are not a single factor in the damage, but there are still many factors that influence it. Moreover, the decreasing pattern of average fruit skin thickness is not followed by the absorption pattern of the fruit (Figure 8). According to Cronje et al. (2013) depletion of fruit peels when fruit develops is because the environmental conditions are not optimal, including nutrient imbalance, low Ca and K and high P. If the nutrients in the fruit peel do not significantly affect the thickness of the fruit skin, it is suspected that the occurrence of thinning on the fruit skin is much influenced by the genetic characteristics of the plant itself. The application of Ca to plants should increase levels of Ca $^{2+}$ in the cell wall of the skin and prevent degradation of pectin, cellulose and hemicellulose, reduce arabinose and galactose, and increase levels of water-soluble pectin on the cell wall (Blanco et al., 2010). However, according to Morgan (2005), the level of Ca present in the skin of Hamlin’s sweet orange fruit has no correlation with the quality, juice content and skin thickness of the fruit.

The thinner fruit skin formed, the higher and more significant the number of cracking fruit as indicated by the regression equation $Y = 20, 501-9, 702 X$ (R2 = 67.5%). According to Cronje et al. (2013), one of the causes of cracking in citrus fruit is because the skin is not thick enough to be able to withstand the pressure caused by the rapid expansion of the pulp in the fruit development phase. With the decrease of the Terigas Mandarin skin thickness in June (Table 7), the number of broken fruit also increased compared to the previous month (May).
CONCLUSION

The incidence of fruit cracking in Terigas Mandarin is caused by the decrease of fruit skin with the equation $Y = 20.501 - 9.702 X$ ($R^2 = 67.5\%$), however the thickness of the fruit skin does not correlate significantly with nutrient content in the fruit skin. Likewise, nutrient levels in fruit peel also do not correlate with nutrient levels in leaves.

Cracking of fruit in Terigas Mandarin is caused more by genetic traits; it is more sensitive than control variety (Pontianak Tangerine)

P3 treatment is able to prevent 50% of cracking fruit per plant sample compared to treatment P1 (control).

REFERENCES

1. Agusti, M, Martinez-Fuentes, A & Mesejo, C, 2002, Citrus fruit quality. Physiological basis and techniques of improvement. Agrociencia, Vol V1, no. 2, pp. 1-16
2. Bermejo, A & Cano, A, 2012, Analysis of Nutritional Constituents in Twenty Citrus Cultivars from the Mediterranean Area at Different Stages of Ripening. Food and Nutrition Sciences, Vol. 3, pp. 639-650. http://dx.doi.org/10.4236/fns.2012.35088 Published Online May 2012 (http://www.SciRP.org/journal/fns)
3. Blanco, A, Victoria, F, Jesús, V, 2010. Improving the performance of calcium-containing spray formulations to limit the incidence of bitter pit in apple (Malus × domestica Borkh). Sci Hortic, Vol. 127.; pp. 23–28.
4. Boaretto, RM, Mattos Junior, D, Quaggio, JA, Cantarella, H & Trivelin, PCO, 2015, Nitrogen-15 uptake and distribution in two citrus species, https://www.researchgate.net/publication/268422398
5. Boman, BJ & Hebb, JW, 1998, Postbloom and summer foliar K effects on Grapefruit size. Proc. Fla. State Hort. Soc. 111, pp. 128 – 135.
6. Coetzee, JGK, 2007a. Chapter 4: Potassium. 2007 Citrus Research International (Pty) Ltd. pp. 24-28
7. Coetzee, JGK, 2007b. Chapter 2: Nitrogen. 2007 Citrus Research International (Pty) Ltd. pp. 5-18
8. Coetzee, JGK, 2007c. Chapter 5: Calcium. 2007 Citrus Research International (Pty) Ltd. pp. 29-31
9. Coetzee, JGK, 2007d Chapter 25: Foliar sprays. Citrus Research International (Pty) Ltd. pp. 91-96
10. Conell, J, 2018. Citrus Nutrition. University of California, Cooperative Extension, Agriculture & Natural Resources Central Valley Region. (http://www.cebutte.ucanr.edu/files/43255.pdf. [Diakses 2 Agustus 2018].
11. Cronje, PJR, Stander, OPJ & Theron, KL, 2013, Fruit Splitting in Citrus, Horticultural Reviews, Vol. 41, First Edition in Janick, J.(edit), John Wiley & Sons, Inc. pp. 177-200
12. Dalal, RPS, Vijay & Beniwal, BS, 2017, Influence of Foliar Sprays of Different Potassium Fertilizers on Quality and Leaf Mineral Composition of Sweet Orange (Citrus sinensis) cv. Jaffa, Int. J. Pure App. Biosci. Vol. 5, no. 5, pp. 587-594. doi: http://dx.doi.org/10.18782/2320-7051.3095
13. El-Rahman, A, Hoda, AGF, Mohamed, M & Ensherah, AHT, 2012, Effect of GA3 and Potassium Nitrate in Different Dates on Fruit Set, Yield and Splitting of Washington Navel Orange. Nature and Science, Vol. 10, no. 1, pp. 148–157.
14. El-Sayed, SA, 2016, Some Factors Affecting Orange Fruit Splitting of Washington Navel Orange Under Kafr Elsheikh Conditions. A- The Effect Of Rootstock, J. Plant Production, Mansoura Univ., vol. 7, no. 3, pp. 343 -349.
15. El-Tanany, MM., Messih, MNA & Shama, MA, 2011, Effect of Foliar Application with Potassium, Calcium and Magnesium on Yield, Fruit Quality and Mineral Composition of Washington Navel Orange Trees. Alexandria Science Exchange Journal, Vol. 32, no. 1), pp. 65 – 75.
16. Elsadig, EH & Suleiman, AS, 2013 Development of Lime Fruit (Citrus aurantifolia) in Northern Gezira State, Sudan, Journal of Agriculture and Biodiversity Research, vol. X, no. X, pp. xx-xx. http://www.onlineresearchjournals.org/JABR
17. Farooq, Rab, A, Khan, N & Rahman, H, 2011, Fruit Growth and Development in Three Cultivars of Citrus: Orange, Kinnow And Feutrall’s Early, Fuuast J. Biol., Vol. 1, no. 2, pp. 145-147.
18. Garcia-Luis, A, Duarte, AMM, Kanduser, M & and Guardiola, JL, 2001, The anatomy of the fruit in relation to the propensity of citrus species to split. Scientia Horticulturae Vol. 87, pp. 33 – 52.
19. Goodwin, CMG, 2008, Disorders Citrus Fruit Splitting. Texas AgriLife Extension Service. 2 pp.
20. Hasanuzzaman, Bhuyan, MMHMB, Nahar, Hossain, MdS, Al Mahmud, J, Hossen, MdS, Masud, AAC, Mouri & Masayuki Fujita, M, 2018, Potassium: A Vital Regulator of Plant Responses and Tolerance to Abiotic Stresses. Agronomy, Vol. 8, No. 31; doi:10.3390/agronomy8030031.
21. Li, J & Chen, J, 2017, Citrus Fruit-Cracking: Causes and Occurrence, Horticultural Plant Journal, Vol. 3, no. 6, pp. 255-260.
22. Li, J, Liang, C, Liu, X, Huai, B, Chen, J, Yao, Q, Qin, Y, Liu, Z, Luo, X, 2016, Effect of Zn and NAA co-treatment on the occurrence of creasing fruit and the peel development of ‘Shatangju’ mandarin, Scientia Horticulturae 201, pp. 230–237
23. Lu X-P, Li F-F, Xiong J, Cao X-J, Ma X-C, Zhang Z-M, Cao S-Y & Xie S-X, 2017, Transcriptome and Metabolome Analyses Provide Insights into the Occurrence of Peel Roughing Disorder on Satsuma Mandarin (Citrus unshiu Marc.) Fruit. Front. Plant Sci. 8:1907. doi: 10.3389/fpls.2017.01907
24. Morgan, KTM, Rouse, RE, Roka, FM, Futch, SH & M. Zekri, M, 2005, Leaf and fruit mineral content and peel thickness of ‘Hamlin’ orange. Proc. Fla. State. Hort. Soc. 118, pp. 19-21.
25. Purba, T, Zuhran, M & Supriyanto, A 2016, Perbaikan Mutu Buah Jeruk Keprok Terigas Melalui Teknologi Pengelolaan Air dan Pemupukan di Kabupaten Sambas, Kalimantan Barat, Informatika Pertanian, vol. 25, no.1, pp. 1 - 8
26. Rattanpal, HS, Rani, Shobha, Kumar, A & Dhaliwal, HS, Effect of potassium and 2,4-D sprays on physical parameters of Kinnow fruits. Haryana J. Hortic., Vol. 34, no. 3-4, pp. 222-223.
27. Sandu, S. & Bal, JS, 2013, Quality improvement in lemon (Citrus limon (L.) Burm.) through integrated management of fruit cracking. African Journal of Agricultural Research, Vol. 8, no. 7, pp. 3552-3557.
28. Sheikh, MK & Manjula, N 2012, Effect of chemicals on control of fruit cracking in pomegranate (Punica granatum L.) var. Ganesh, In: Melgarejo P. (ed.), Valero D. (ed.). II International Symposium on the Pomegranate. Zaragoza: CIHEAM / Universidad Miguel Hernández, 2012. p. 133-135 (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 103)
29. Singh, S, Gil, PPP, Aulakh, PS & Singh, S, 2015, Changes of minerals in fruit peel and pulp of grapefruit (C. paradisi Macf.) cv. Star Ruby during fruit development. Res. on Crops, Vol. 16, no. 4, pp. 669-674.
30. Verreynne, S, 2010, Fruit Size and Crop Load Prediction, Citrus Research International Vol. II, Chapter 5: Crop manipulation, p 1-6
31. Vijay, Dalal, RPS, Beniwal, BS & Saini, H, 2016, Impact of foliar application of potassium and its spray schedule on yield and quality of sweet orange (Citrus sinensis) cv. Jaffa. Journal of Applied and Natural Science, Vol. 8, no. 4, pp. 1893-1898.
32. Yadav, D, Singh, SP, & Singh, S, 2014, Effect of foliar application of potassium compounds on yield and quality of ber (Zizyphus mauritiana) cv. Banarasi Karaka. International Journal of Research in Applied, natural and social sciences, Vol. 2, pp. 89-92.