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

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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 Tlekung 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 Ist 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} KNO_3). 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, R^2 = 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 flavedo, 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 the 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 % KNO_3 significantly increases skin thickness thereby reducing the incidence of cracking, increases fruit size, and production, while the combination of KNO_3 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, GA_3 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: $Y_{ijk} = \mu + B_k + R(B) + A_j + AB_{ij} + \varepsilon_{ijk}$.

The spray dosage treatment was as follows:

P 1: 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 + KNO_3 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).

Table 1 – T test for percentage of nutrient uptake in fruit peel and citrus leaves of Terigas Mandarin and Pontianak Tangerine

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% KNO_3, 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).

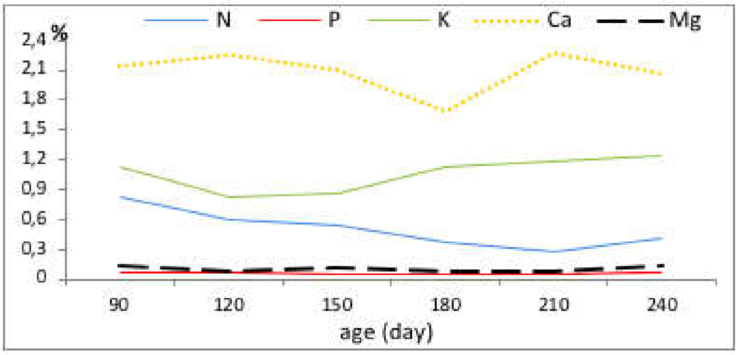


Figure 2 – Macro nutrient in the skin of grapefruit (cv Star Ruby) (Source: Singh *et al.* (2015)

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 (2007 a, 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.

Table 2 – Correlation between macro nutrient uptake in leaves and on fruit peels

Nutrients in the leaves / skin	N	P	K	Ca	Mg	Equation	R^2
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 V 1	2.39 b	0.18 abc	1.11 a	3.02 ab	0.20 a
P2 V 1	2.49 ab	0.20 a	0.88 abc	3.17 ab	0.20 a
P3 V 1	2.66 ab	0.19 ab	0.63 abc	3.08 ab	0.25 a
P4 V 1	2.53 ab	0.16 abc	0.59 abc	2.87 ab	0.33 a
P5 V 1	2.38 b	0.15 bc	0.39 bc	3.20 ab	0.20 a
P1 V 2	2.51 ab	0.18 abc	0.87 abc	3.41 a	0.26 a
P2 V 2	2.36 b	0.20 a	1.07 a	2.75 b	0.32 a
P3 V 2	2.86 a	0.18 abc	1.04 a	2.72 b	0.38 a
P4 V 2	2.28 b	0.14 c	0.75 abc	3.14 ab	0.32 a
P5 V 2	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 + KNO_3 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

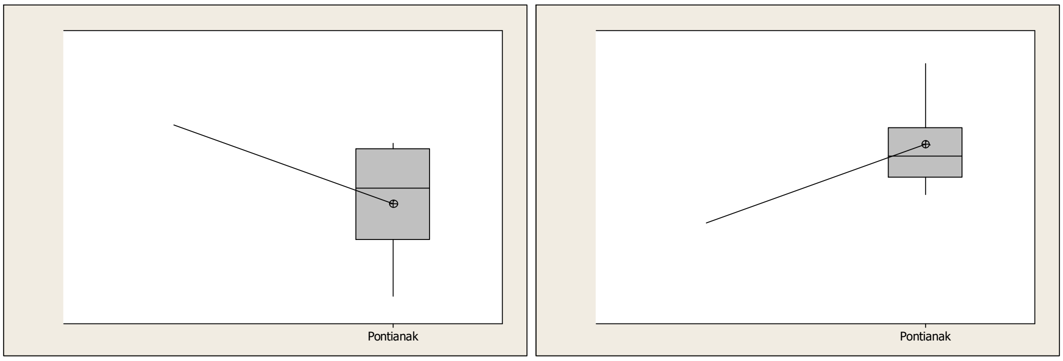
P1: Control, plants are not fertilized;
P2: Fertilization treatment according to field standards;
P3: P2 + Fertilizer K 3 g/l + Fertilizer Ca 1 g/l + Fertilizer Mg 1 g/l (sprayed in January, February & March);
P4: P2 + K fertilizer 6 g/l + Fertilizer Ca 2 g/l + Fertilizer Mg 2 g/l (sprayed in January, February & March;
P5: P2 + KNO_3 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 aplication and varieties had significanty difference 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 & Jiezhong (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 (Coetzee, 2007d).



(a) (b)

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

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 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 leave. Meanwhile, uptake in fruit peels will be reduced as occurs in other nutrient minerals (Coetzee, 2007 a).

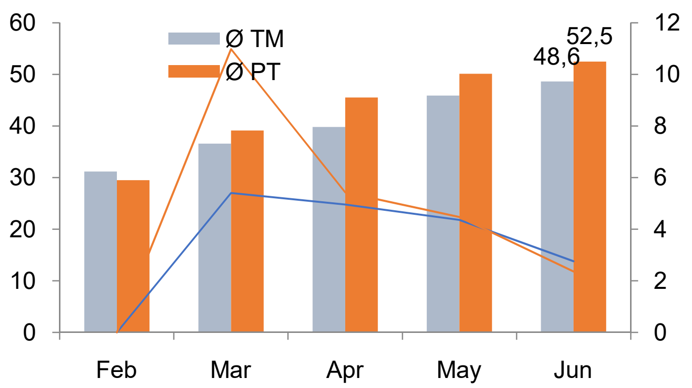
Effect of varieties and foliar application of K, Ca and Mg on fruit growth. In general the interaction of varieties with the application of K, Ca, Mg through leaves had significantly different. Fruit size increased in the 2nd (March) to the 5th month (June), it was in accordance with the development 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 fom 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_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).



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. Aplication 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).

(a) (b)

Figure 6 – Normal (a) and cracking fruit of Terigas Mandarin

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 + KNO_3 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		2.2 4	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).

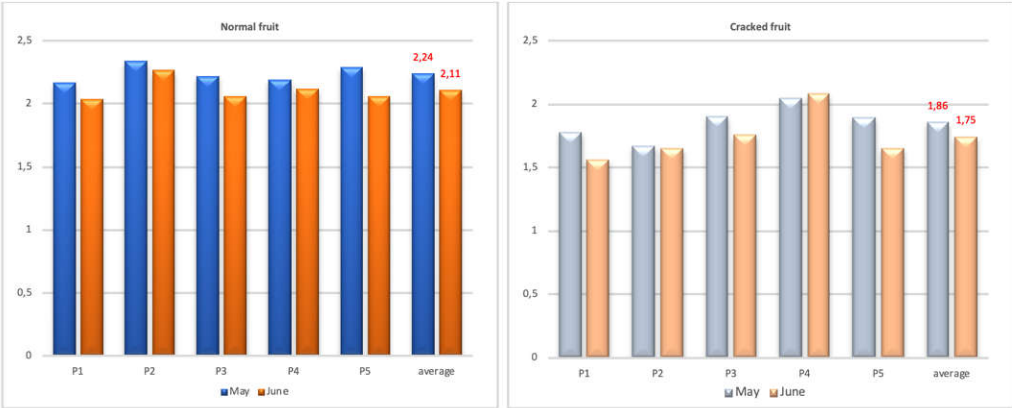


Figure 7 – The thickness of normal and broken fruit skin on Terigas Mandarin

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.

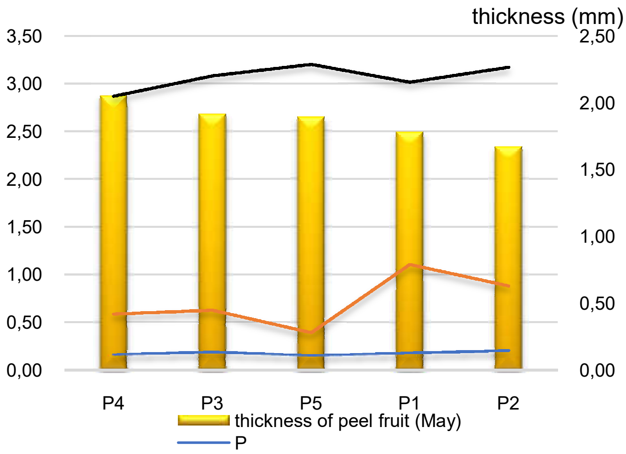


Figure 8 – Pattern of absorption of Ca, K, and P on the fruit peel Terigas Mandarin (P1 to P5)

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 (R2 = 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).

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