

# Fruit Scar Incidence and Its Effect on Guava 'Kristal' Fruit Quality (*Psidium guajava* L.) at Low- and Middle-altitude Orchards in Bogor, Indonesia

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## Abstract

Information on scar incidence and its effect on fruit quality of 'Kristal' guava (*Psidium guajava* L.) grown on different altitudes is currently limited. The aim of this study was to evaluate the fruit scar incidence and fruit quality of 'Kristal' guava var. grown on low- and middle-altitude orchards. The research was conducted by collecting 50 samples of fruit harvested from each orchard from January to June 2019. Fruit quality evaluation was carried out at Postharvest Laboratory, Department of the Agronomy and Horticulture, IPB University, whereas scarring pest observation was conducted at Insect Biosystematics Laboratory, Department of Plant Protection, IPB University. Our results showed that the low-altitude orchard produced more fruits with medium, high, and very high scar intensity, while the middle-altitude orchard produced more fruits with low and very low scar intensity. Fruit scar was caused by fruit scarring pests, especially thrips and mites. Fruit tissue damage only occurred on the epidermis of fruit pericarps where the tissue turned brownish and thickened. Additionally, there was no expansion of the damage into the pulp. The peel damage did not affect the fruit taste as indicated in the level of total soluble solids (TSS), titratable acidity (TA), TSS/TA ratio, vitamin C, and total flavonoids content. Fruit external quality was varied in response to altitude, where middle-altitude orchard produced heavier, larger and harder fruits than low-altitude orchards. Present findings determine the best growth site and adjustment of pest control to maintain fruit quality.

Keywords: altitude, fruit damage, mites, thrips, total soluble solid, titratable acidity, vitamin C.

## Introduction

Guava (*Psidium guajava* L.) of the Family Myrtaceae is one of the common fruit trees cultivated in Indonesia. Guava cultivar 'Kristal', a variety introduced by the Taiwan Engineering Mission, was released in Indonesia by the Agriculture Ministry under the Agriculture Minister Decree No. 540/Kpts/SR.120/9/2007 (Balitbu, 2009). Compared to other varieties of guava, guava 'Kristal' has thick flesh (2.1-3.2 cm), fewer seeds, slightly flattened in shape, has crispy pulp texture, and sweet taste. It is relatively a short plant with height of 2 -2.5 meters (Ditbenih, 2007). The vitamin C content of guava 'Kristal', which ranges from 121.30 to 146.18 mg.100 g<sup>-1</sup>, is four times higher than that of oranges (Romalasari et al., 2017) or pomelo, which ranges from 38.5 to 48.2 mg.100 g<sup>-1</sup> (Susanto et al., 2011). Its fruit characteristics, nutrition, and vitamin values, make guava 'Kristal' a highly preferred popular fruit among consumers in Indonesia (Hartati et al., 2020; Guntarti and Hutami, 2019; Susanto et al. 2019).

Despite the valuable fruit characteristics of 'Kristal' its external appearance due to peel damage makes it unattractive to buyers in the local market. The presence of brown scar spots and other fruit peel damage results in low fruit smoothness, thereby significantly reducing its market price. Fruit scar incidences cause a significant decrease of farmers' income by 38.93 % per kg in case of mangosteen (Farded, 2012) and 30% per kg in case of mandarin (Kementan, 2014).

Currently, there is limited information regarding scar incidence in guava and its economic effects to fruit farmers. In addition to improper handling, fruit scar is caused mainly by pests. Environmental conditions in different growing altitudes highly influence

pest development and subsequently fruit quality. Different altitudes affect microclimates that support the development of scarring-pests. The role of temperature, humidity, and rainfall in pests population development has been previously studied by Meena et al. (2013), Laranjeira et al. (2015) and Reyes et al. (2020). Widyastuti (2019) highlighted that growing location is one factor that could affect fruit quality in 'Kristal' guava. The different altitude of growing location could result in the development of different pests. The objective of this study was to evaluate the scar incidence and guava 'Kristal' fruits harvested from low- and middle-altitude orchards.

## Material and Methods

### Sampling

The research was conducted in two orchards in Bogor, Indonesia namely Cikarawang low-altitude orchard (6° 55" south latitude, 106° 74" east longitude, ± 192 m above sea level) and Sukajadi middle-altitude orchard (6° 64" south latitude, 106° 72" east longitude, ± 532 m above sea level) from January to June 2019. 'Kristal' guava trees with relatively uniform growth performance (5 years after planting) were identified as sample sources. Ten guava trees from each orchard were selected for this study. Flowers on each tree were tagged and maintained until fruit development. A total of 100 fruit samples, representing 50 fruits from each orchard or 5 fruits per tree were used for this study. These samples were used for assessing the external and internal characteristics and overall quality of the harvested fruits.

Uniformity among identified sampling trees was maintained since the beginning of the experiment by pruning (i) the tertiary branches, which left four pairs of leaves, and (ii) the unhealthy twigs or branches that were attacked by pests or disease. Fertilizer composed of nitrogen-phosphor-potassium (NPK) and manure was provided after pruning. This was done by applying approximately 20 kg per plant of goat manure once after pruning, and 200 g NPK (16-16-16) per plant twice after pruning, and after flowers bloomed. The fertilizers were buried in a circle under the plant canopy with 30 cm depth and 1 m away from the main stem of the plant. The fruits were bagged using transparent plastic and foam net four weeks after anthesis and remained covered until harvest. Fruits were harvested at 14 weeks after anthesis, as indicated by the fruit color change to yellowish-green. Once harvested, the fruits were packed with cardboard and separated within by a foam net. They were transported to the Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty

of Agriculture, IPB, to examine external and internal characteristics and overall quality.

The variables measured in the present experiment were fruit scar incidence, external and internal quality of fruit. Fruit scar incidence was observed to measure scar intensity, fruit smoothness, and fruit-scarring pest. The scar intensity value was obtained from the ratio of the scar area to the total surface area of the fruit peel. The observation was done by peeling the fruit peel thoroughly, laying down the fruit peel on a flat surface, and then taking a picture of the fruit peel for further processing by ImageJ software. The fruit scar intensity was grouped into: very low (0-2.5 %), low (>2.5-5.0 %), medium (>5.0-7,5 %), high fruit scar (>7.5-10 %), and very high (>10%). The scar fruit was measured in 50 fruit samples from each orchard, and it was expressed in percentage. The thickness of fruit peel damage was compared by observing a vertically sliced fruit peel under an electric trinocular microscope (Olympus trinocular BX51, 4x magnification).

The pest in scar fruit was observed at Insect Biosystematics Laboratory, Department of Plant Protection, IPB University by collecting the pest in fruit, then keeping it in a test tube filled with 70 % alcohol as fixative. Observation was done using a compound microscope (Olympus, 10x magnification). The pest were identified by the identification taxonomic keys of Thysanoptera (Sartiami, 2008) and mites (Dina and Santoso, 2017).

The external fruit quality consisted of fresh fruit weight, fruit diameter, and fruit softness. Fruit weight was measured by using digital analytic. Fruit diameter was observed by measuring the widest diameter of fruit by vernier caliper. Fruit softness was assessed at the tip, middle, and base of the fruit using a penetrometer. The penetration time was 5 seconds, with a total load of 50 g and expressed in units of mm 50 g<sup>-1</sup>.5s<sup>-1</sup>.

The internal fruit quality consisted of total soluble solids (TSS), titratable acidity (TA), vitamin C, total flavonoids, and fruit pigment content. TSS was measured by dropping juice of blended fruit on a lens of refractometer (PAL-1 Atago). TA was measured using 0.1 N NaOH titration with phenolphthalein indicator (Sadler and Murphy, 2010). Vitamin C content was measured using the Iodine titration method (Rahman et al. 2015). Fruit pigment content was observed in the fruit peel following a modified method by Sims and Gamon (2002), and total flavonoid was analyzed following Do et al. (2014).

The qualitative data were analyzed descriptively. Quantitative data obtained from all the assessments undertaken were statistically analyzed using the

Minitab program. The Student's t-test was carried out at the  $\alpha = 5\%$  to compare the mean value between two locations on all observed variables.

## Result and Discussion

### Fruit Scar Incidence

The differences of growing altitude significantly affected fruit scar intensity and smoothness. In guava 'Kristal', the scar intensity was significantly higher (nearly 2x higher) in the low-altitude orchard than in the middle-altitude. The percentage of fruit smoothness was significantly lower in the low-altitude orchard than in the middle one (Table 1).

Five fruit scar intensity and appearance groups were observed in the low- and middle-altitude orchards (Table 2). The low scar intensity was observed by the minor and thin brownish scars, while the high scar intensity was observed as the large brownish scars or spots that have potentially spread over the entire fruit peel. Fruits with high scar intensity were not always marked with deep brown spots. The fruits with low scar intensity might have deeper damage thickness because damage was only concentrated in one part and did not spread throughout the fruit.

Fruit scar intensity and appearance varied in response to the different altitudes of the growing location (Table 2). Fruits with low and very low intensity were more prevalent in the middle-altitude than in the low-altitude orchard. There were no fruits found with very high scar intensity. Fruits with medium, high, and very high scar intensities are more abundant at the low-altitude compared with the middle-altitude orchard, i.e., 5x, 6x, and 10x respectively. This demonstrates that fruit scar incidence is more severe in the low-altitude orchard.

Scar damage was only found on the epidermis of the guava fruit pericarp. A scar was observed as brown spot in certain part of fruit epidermis as the effect of necrosis. This damage did not spread into deeper fruit tissue, thereby resulting in an undamaged flesh of the fruit and acceptable quality (Figure 1C and 1D). The depth of tissue damage in the present study only varied in ranges from 0.054-0.215 mm. Hoy (2011) stated that the depth of tissue damage was not affected by the scar intensity but related to mites and thrips feeding activities, influenced by pest population density, stylet length, and feeding time. In addition, Childers and Rodrigues (2011), the scar damage in citrus was also more severe during the dry season due to the rapid development of mites.

Table 1. Guava 'Kristal' fruit scar intensity and fruit smoothness from low- and middle- altitude orchards

Orchard	Scar intensity (%)	Fruit smoothness (%)
Low-altitude	5.08	94.92
Middle-altitude	2.77	97.23
Student's T-test	**	**



















Note : \* = significant at  $\alpha = 5\%$ , \*\* = significant at  $\alpha = 1\%$ , ns = not significant.

Our findings indicate that altitude influences fruit scar incidence and the level of pest attack that caused fruit scarring. During the study period, the average of monthly ambient temperature, rainfall, and relative humidity in the low-altitude orchard was 27.48 °C, 368 mm, and 78%, respectively, and 26.7 °C, 384 mm, and 79%, respectively for the middle-altitude orchard (BMKG Dramaga, 2019). The higher scar incidence could be attributed to the rapid development of fruit scarring pests, including thrips (Thysanoptera: Thrips) and mites (Tenuipalpidae: *Brevipalpus*) that were observed in this study (Figure 2). Previous results by Sarwar (2006) also attributed the incidence of fruit scar on guava as the effect of *Selenothrips rubrocinctus* and *Brevipalpus phoenics*. These pests can damage the fruits, in the form of scars, and associate with other pests to create more severe fruit damage.

The pest infestation is influenced by temperature (Meena et al. 2013), relative humidity (Steiner et al., 2011), and daylength (Laranjeira et al., 2015). Reyes et al. (2020) reported a weaker correlation between relative humidity and the infestation and thrips population. The temperature in the low-altitude orchard was higher (27.2 °C) than the middle-altitude orchard (26.7°C). The higher temperature increased the pest growth and pest population, leading to a shorter pest life cycle in citrus (Laranjeira et al., 2015). The development period of mites (*Tetranychus urticae*) in strawberry at 20°C and 25°C was shorter than 15°C (Kaur and Zalom, 2017). In the case of thrips (*Thrips nigropilosus*) from *Chrysanthemum morifolium*, they need 21 days to fully develop at 20°C, whereas at 30°C, thrips only need 11 days (Ganaha-Kikumura and Kijima, 2016). It signifies that temperature affects the rate of pest development. Mite and thrip populations increase during the fruit development stage, leading to a more severe fruit scar incidence.

Pest development is also influenced by rainfall intensity. This was demonstrated in a previous study where pest development was negatively correlated

Table 2. The percentage and appearance of guava 'Kristal' fruits with scar at low and middle altitude orchards

Level	Fruit scar intensity (%)	Percentage of scarred fruit (%)		Scar fruit appearance			
		Low-altitude	Middle-altitude	Low-altitude		Middle-altitude	
Very low	0-2.5	30	60				
Low	>2.5-5.0	28	34				
Medium	>5-7.5	20	4				
High	>7.5-10.0	12	2				
Very high	>10.0	10	0			None	
Total		100	100				

Note: The total measured fruit is 50, or 100 % fruits from each orchard.

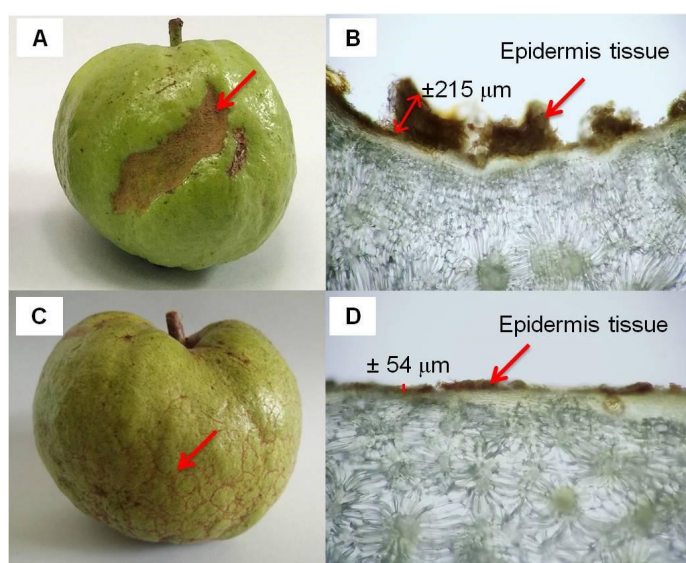


Figure 1. A guava "Kristal" fruit showing severe epidermal scars (>10% scar intensity) (A) and a cross-section of the fruit epidermis (B) from a low-altitude orchard; a fruit showing fine scars (<2.5% scar intensity) (C) and a cross-section of the fruit epidermis (D) from a middle-altitude orchard.



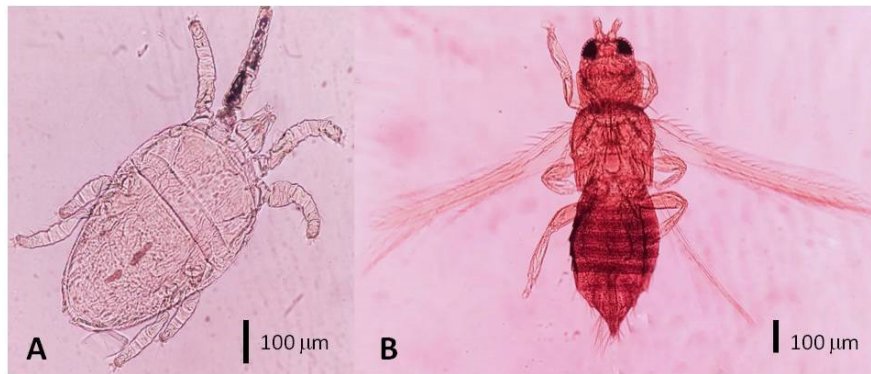


Figure 2. Fruit scarring pests *Brevipalpus* mites (A) and thrips (B) under 100x magnification.

with rainfall intensity in growing locations (Ghoshal et al., 2011). Higher rainfall intensity leads to the decline of mite populations due to rainfall leaching. During our period of study, rainfall intensity in the middle-altitude orchard (Sukajadi) was at 384 mm per month, while in the low-altitude orchard (Cikarawang) was at 368 mm per month. The differences in rainfall intensity could be due to the decline in mite and thrip populations and infestations in middle-altitude orchard.

#### Fruit External Quality

The different growing locations significantly affected the fruit weight. The middle-altitude orchard produced heavier fruit than the low-altitude orchard (Table 3). The higher fruit weight from the middle-altitude orchard was directly proportional with the broader fruit diameter compared with fruit from low-altitude orchard. Middle-altitude fruits were harvested slightly longer than low-altitude fruits by two weeks. Low altitude fruits were harvested 12 weeks after anthesis, while middle-altitude fruits were harvested 14 weeks after anthesis. The more prolonged harvest of guava 'Kristal' fruits in middle-altitude caused dry matter accumulation variations during fruit ripening. Budiarto et al. (2019) reported that the increasing dry matter accumulation in citrus could be affected by the lower environmental temperature. In addition, Guerrero-Chavez et al. (2015) reported that the lower temperature, the more prolonged ripening periods, and dry matter accumulation caused the increase of strawberry fruit weight. A previous study by Widyastuti (2019) observed the flowering and harvesting periods in middle-altitude to be two weeks longer than those in low altitude. Higher temperature accelerated the flowering and harvesting period, while lower rainfall reduced the risk of fallen flowers, and increased the production of flowers and fruits of guava 'Kristal'.

In terms of softness, fruits from the low-altitude orchard were significantly softer compared with the middle-altitude ones (Table 3). The higher fruit softness in low-altitude orchard could be attributed to high

temperature, resulting in accelerated fruit ripening. The higher temperature activated Polygalacturonase (PG) enzyme to hydrolyze the fruit cell wall. The higher PG level along fruit ripening triggered fruit softening incidence (Parra-Coronado et al., 2018). Jain et al. (2003) stated that fruit softening incidence is also influenced by altering cell wall components of fruit flesh during the ripening period. The decline of the content of hemicellulose, cellulose, lignin, and pectin cause fruit to soften. Feng et al. (2021) explained that guava fruits softening could be caused by both starch and cell wall degradation. In case of guava, most genes involved in starch degradation and genes related to cell wall degradation that encoding  $\beta$ -galactosidase, polygalacturonase and pectate lyase showed an increased expression as the fruit getting ripe, implied the presence of fruit softening incidence during the ripening process.

The different growing altitudes did not significantly affect the content of fruit pigments, i.e., chlorophyll a, chlorophyll b, carotenoid, and total chlorophyll. Chlorophyll pigment content is one of the fruit maturity indicators. A reduction of total chlorophyll, chlorophyll a, and chlorophyll b usually occurs during the maturity process whereas the carotene content increases (Jain et al., 2003). A significantly higher amount of anthocyanins (36.38%) was detected on fruits from the middle-altitude compared to the fruits from the lower altitude (Table 4). The differences in anthocyanin content could be due to the differences in environmental temperatures. The higher temperature at low-altitude inhibited anthocyanin biosynthesis as indicated by the low expression of anthocyanin genes and related enzyme activity in grapes and apples (Lin-Wang et al., 2011; Liang et al., 2014). In addition, increasing anthocyanin content in the middle-altitude fruit is a form of plant adaptation mechanism to higher altitude and lower temperature (Liu et al., 2020).

#### Fruit Internal Quality

There were no significant differences in the fruit

Table 3. External quality of guava 'Kristal' fruits from low- and middle-altitude orchards

Orchard	Fruit weight (g)	Fruit diameter (cm)	Fruit softness (mm.50 g <sup>-1</sup> .5s <sup>-1</sup> )
Low-altitude	144.77	7.01	27.18
Middle-altitude	176.50	7.44	23.62
Student's T-test	**	**	**

Note : values within one column are significantly different at  $\alpha = 5\%$  (\*) or  $1\%$  (\*\*); ns = not significant

Table 4. The peel pigment content of guava 'Kristal' fruits from low- and middle-altitude orchards

Orchard	Chlorophyll A (mg.g <sup>-1</sup> )	Chlorophyll B (mg.g <sup>-1</sup> )	Anthocyanin (mg.g <sup>-1</sup> )	Carotenoid (mg.g <sup>-1</sup> )	Total chlorophyll (mg.g <sup>-1</sup> )
Low-altitude	0.025	0.009	0.006	0.008	0.034
Middle-altitude	0.028	0.010	0.009	0.009	0.038
Student's T-test	ns	ns	*	ns	ns

Note : values within one column are significantly different at  $\alpha = 5\%$  (\*) or  $1\%$  (\*\*); ns = not significant

Table 5. Nutritional quality of guava 'Kristal' fruits from low- and middle-altitude orchards

Orchard	TSS (°Brix)	TA (%)	TSS/TA	Vitamin C (mg.100g <sup>-1</sup> )	Total flavonoid (mg.100g <sup>-1</sup> )
Low-altitude	10.11	0.43	23.58	147.78	88.65
Middle-altitude	9.78	0.44	22.47	148.62	91.11
Student's T-test	ns	ns	ns	ns	ns

Note : values within one column are significantly different at  $\alpha = 5\%$  (\*) or  $1\%$  (\*\*); ns = not significant; TSS= total soluble solid; TA= titratable acidity.

quality as indicated by TSS, TA, TSS/TA ratio vitamin C and total flavonoid, in response to the difference of altitude of growing locations (Table 5). In general, a higher scar intensity in low-altitude fruits did not affect internal fruit quality. Both low- and middle-altitude orchards can produce fruits with relatively equal internal fruit qualities.

Widyastuti (2019) reported that different altitudes of growing location do not affect TSS and TA of 'Kristal' guava. Dolkar et al. (2017) also reported that fruit quality, as indicated by TSS and TA, is not affected by different growing location but is affected by the fruit ripening stage. Musyarofah et al. (2020) found that the ratio of TSS/TA and vitamin C content are influenced more by cultivation practices than by altitude differences.

Fruit scar is one of the main problems in 'Kristal' guava that results in decline of its market price. The presence of fine scar was still allowed in the B grade, while the A grade did not accommodate the presence of scar, implied that there was a decline of price in response to different fruit grade (Pratidina et al., 2015). Several cultural practices could be carried out to minimize fruit scar incidence and protect the fruit smoothness, i.e., fruit bagging, sanitation, and yellow

sticky trap application. The fruit bagging application with perforated polyethylene bags and newspaper bags decrease blemishes or scar and disease attacks (Abbasi et al., 2014). Fruit peel smoothness is maintained up to 85% using a foam net with yellow or red plastic baggings (Romalasari et al., 2017). Tree sanitation in the orchard can be done by regular weeding and discarding the pest-infested parts. The use of sticky yellow traps can attract aphids, whitefly and other flying insects (Haseeb, 2007), thus potentially decline the pest population.

## Conclusion

The fruits of guava 'Kristal' harvested from the low-altitude orchard had significantly higher scar intensity and were less smooth compared to those from the middle-altitude orchard. The low-altitude orchard produced more fruits with a medium, high, and very high scar intensity, while the middle-altitude orchard had more fruits with low and very low scar intensity. Fruit scar was found in the epidermal tissue of fruit pericarp, and it was caused mainly by fruit scarring pests, such as thrips and mites. The infected tissue turned brown and thickened, however, it did not cause damage to the pulp. Fruit scar did not

affect the internal quality of 'Kristal' guava fruits as indicated by levels of TSS, TA, TSS/TA ratio, vitamin C, and flavonoid content. Fruit external quality vary in response to altitude, where middle-altitude orchard produced heavier, larger and harder fruits than low-altitude orchards. The results of our study have provided the baseline information to determine the best growth site for guava, and recommendation of pest control to maintain fruit quality.

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