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Short Communication: 'Crystal' guava fruit quality in response to altitude variation of growing location

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Abstract. *Widyastuti RAD, Budiarto R, Warganegara HA, Timotiwu PB, Listiana I, Yanfika H. 2022. Short Communication: 'Crystal' guava fruit quality in response to altitude variation of growing location. Biodiversitas 23: 1546-1552.* 'Crystal' guava is a popular fruit with high demand due to its delicious taste and super nutritious content. This study aimed to analyze the fruit production and quality of 'Crystal' guava in response to different altitudes of growing location, i.e., highland and lowland in the tropics. Ten individual guava trees were maintained in a nested design by small-scale farmers in both lowland (Brajaselebah orchard, 25 m asl) and highland (Gunung Batu orchard, 1000 m asl). The result showed that the altitude of the growing location affected the plant production and fruit quality of 'Crystal' guava. Although there was no significant difference in vegetative and generative shoot numbers among the two growing locations, there was a tendency for a dominant generative shoot in highland. Lowland orchards produced a significantly heavier fruit compared to highland orchards. 'Crystal' guava tree was able to produce 41 to 46 fruits per tree with a total fruit production of about 8.69 to 9.21 kg per tree. The significantly lower incidence of fruit smoothness in lowland compared to highland was affected by a significantly higher incidence of fruit scars in the lowland. Guava fruit from the lowland had a significantly higher TSS, while fruit from the highland contained a significantly higher vitamin C than lowland.

Keywords: Generative shoot, orchard, TA, TSS, vitamin C

INTRODUCTION

Guava is a popular fruit worldwide due to its delicious taste and super nutritious content, i.e., rich in natural fiber, vitamin C and antioxidant compounds (Guntarti and Hutami 2019; Hartati et al. 2020; Jiménez-Escrig et al. 2001; Susanto et al. 2019). An earlier study reported the range of nutritional content of eight guava varieties during three years of observation, i.e., 0.76-1.85% protein, 0.35-0.85% mineral matter, 136.5-220.4 mg per 100 g vitamin C and 4.33-6.36% total sugar (Adrees et al. 2010). In addition to fruit, this plant's leaf, flower, root, and stem bark are also beneficial for traditional medicine (Dange et al. 2020; Joseph and Priya 2011; Nahdi et al. 2006; Olatunde et al. 2018;) however, this practice is still less popular. The demand for guava fruit is potentially increasing due to the trend of healthy lifestyles in modern and urban society. One of the popular guava varieties in Indonesia is 'Crystal' guava. The 'Crystal' guava contains few seeds (or even seedless in some cases), a large edible portion (97-98 %), crispy and sweet fruit flesh, rich in vitamin C (18.73 mg 100 g^{-1}) (Ministry of Agriculture 2007). Therefore, there is a need to improve the quantity and quality of guava production, especially the 'Crystal' variety.

From an agronomist's point of view, the quantity and quality of fruit production are highly influenced by genotype, cultural practices, and growing location (Efendi and Budiarto 2022). Genetic background determines the potential yield of guava since different varieties may have different potential yields and fruit quality. An earlier study reported the variation of plant morphology among interspecific and intraspecific varieties due to distinct genetic backgrounds (Budiarto et al. 2021a).

Culture practices are an intervention of humans in the agroecosystem to improve the yield and quality of guava fruit. Numerous studies have reported dealing with the incorporation of several agricultural inputs into the ecosystem, such as the regulation of source and sink balance through strangulation (Widyastuti 2019a) and pruning (Bhagawati et al. 2015; Susanto et al. 2019), flower bud thinning (Suman and Bhatnagar 2019), bending and defoliation (Budiarto et al. 2018), root pruning (Budiarto et al. 2019a), shading (Budiarto et al. 2019b; Budiarto et al. 2022), bagging (Widyastuti et al. 2022), application of organic fertilizer (Goswami et al. 2015; Trivedi et al. 2012), mineral fertilizer and biofertilizer (Shukla et al. 2014).

In terms of growing location, former studies showed that land altitude affects the quality of pineapple guava (Parra-Coronado et al. 2018), Columbian guava (Solarte et al. 2014) and figs (Trad et al. 2013). The variation of land altitude, microclimate and soil nutritional status is reported to be the main reason behind the influence of growing

location on plant production (Efendi et al. 2021). Additionally, the temperature is also reported as a limiting factor in the highland area (Lio and Dewi 2018). Among several fruit quality variables, previous studies have reported the difference in vitamin C and fruit appearance (scar incidence of the fruit peel) in response to different altitudes of growing location, i.e., lowland versus medium-land (Musyarofah et al. 2020; Musyarofah et al. 2021). Since vitamin C is a popular and essential nutrient for maintaining human body health (Cruz-Rus et al. 2012), evaluating this nutrient in guava is also important to reveal.

The external product appearance becomes one of several considerations for the customer before buying a certain product. In terms of leaf-based products, such as kaffir lime leaves, the desired product criteria are green, clean, fresh, pest-disease free and scar-free (Budiarto et al. 2021b). The external peel color plays an important role in fruit-based products in determining customer preference. Postharvest treatments such as degreening and precooling are introduced to improve the orange color formation in the external peel color of local tangerine (Efendi et al. 2022). Fruit bagging is applied in guava to impede the incidence of fruit scars on the guava peel due to consumer concern (Widyastuti et al. 2022). In addition, previous studies have identified the fruit scar incidence and its effect on 'Crystal' guava fruit quality at medium and lowland orchards (Musyarofah et al. 2020; Musyarofah et al. 2021). However, there has been limited research reporting the evaluation of production and quality of 'Crystal' guava in the highland compared to the lowland orchard. Therefore, this study aimed to analyze the fruit production and quality of 'Crystal' guava in response to different altitudes of growing location, i.e., highland and lowland in the tropics.

MATERIALS AND METHODS

Study area

This study was held from March to August 2021 in Lampung Province, Indonesia. The experimental design used was a nested design, with a variation of altitude as the treatment. The Gunung Batu orchard was located at 1000 m above sea level (asl); thus, it was determined as the representative of highland growing location, while the Brajaselebah orchard was located at 25 m asl, as the representative of lowland growing location. The harvesting season of 'Crystal' guava fruit was predominantly found in the period of March to May and September to November (Widyastuti et al. 2019b). The present study was only observed the fruit quality harvested in the period of March to May 2021.

Procedures

There were ten plants selected as replications in every growing location, with consideration of uniformity in terms of plant age (2 years old), plant canopy size (1-1.5 m in diameter), plant height (1.5 m), and plant damage-free condition. Both orchards were managed by the small-scale farmer (less than 0.1 ha of production area). Local farmers used the following general culture practices and also a previous report by Musyarofah et al. (2020): monthly weed control, three times a year pruning, annual application of organic fertilizer (20 kg per tree), three times a year application of inorganic fertilizer (250 g NPK), and pest control in the form of pesticide application (if there is significant damage).

Measured variables were the number of vegetative shoots, generative shoots, total shoots, fruit production, fruit number, fruit diameter, fruit weight, fruit smoothness, fruit scar incidence, total soluble solid (TSS), titratable acidity (TA), TSS/TA ratio, and vitamin C. The numbers of vegetative, generative, and total shoots were observed simultaneously in the same plant from June to August 2021 using a digital hand counter. Unlike generative shoots, vegetative shoots did not have a flower in the shoot tip. The number of total shoots accumulated both vegetative and generative shoots. Fruit production, fruit number, fruit weight and fruit diameter were also measured simultaneously and expressed in kg per tree, fruits per tree, g and cm, respectively.

Both fruit smoothness and fruit scar incidence were assessed concurrently by the image processing approach. The peel of guava fruit was removed carefully, laid out on white paper and then photographed. The taken picture was then processed in ImageJ to calculate the proportion of scar (if present) compared to the entire fruit peel area, known as fruit scar incidence (%). In contrast, the fruit smoothness (%) was calculated by comparing the no scar area to the entire fruit peel (Musyarofah et al. 2021).

The total soluble solids (TSS) were measured using a hand refractometer and expressed in the ^{0}Brix unit. The juice was generally dropped on an angled prism, which sealed the daylight plate and then inspected through the eyepiece. The NaOH titration method was used to measure the titratable acid (TA), and the result was expressed in percent. The sample was prepared from blended guava fruit to make juice. Approximately 10 ml of guava juice was mixed with 100 ml of distilled water, and then 10 ml of that final solution was transferred to a new tube. Three drops of phenolphthalein were added to that tube before being titrated by 0.1 N NaOH. The titration was terminated when pink color was detected in the sample.

The ratio of TSS and TA was also one of the measured chemical quality variables of 'Crystal' guava fruit in this study and was obtained simply by dividing the result of TSS by TA. The last chemical quality variable was vitamin C, which was analyzed by the iodine 0.01 N titration method and expressed in mg 100 g^{-1}, following the previous report (Suntornsuk et al. 2002) with a slight modification. As much as 25 g, the fruit was juiced and then filtered. A total of 10 ml filtered juice was then diluted with distilled water into 100 ml. Afterward, 10 ml of diluted filtered juice was transferred to a new Erlenmeyer flask, and 2 ml of the starch indicator was added to erlenmeyer prior to being titrated with 0.01 N iodine. The titration was terminated when the dark blue color was detected in the solution.

Data analysis

Obtained data were processed using analysis of variance (ANOVA). If there was a significant finding, the test was continued with the Least Significant Difference (LSD) test at α 5% level. All statistical analysis was run in STAR version 2.0.1.

RESULTS AND DISCUSSION

The results showed no significant differences in the number of vegetative, generative, and total shoots in response to different altitudes of growing location (Figure 1A, 1B, 1C). The total shoots in the entire 'Crystal' guava tree were 80.80 shoots in lowland and 82.80 shoots in highland (Figure 1C). In the lowland, the number of vegetative shoots was 60.20 shoots (Figure 1A), while the rest for about 20.60 shoots was the generative ones (Figure 1B). In highland, the number of vegetative and generative shoots was 56.20 shoots (Figure 1A) and 26.60 shoots (Figure 1B), respectively. Thus, there was a tendency for a higher number of generative shoots and a lower number of vegetative shoots found in highland rather than lowland. Culture practice such as pruning was previously reported to enhance the number of shoots in 'Crystal' guava (Widyastuti et al. 2019c). The reason behind the stimulation of shoot growth in the pruned tree is the increase of sunlight exposure in pruned trees rather than unpruned ones (Budiarto et al. 2019b). Both lowland and highland orchards were actually treated with pruning. However, the variation of severity level between both orchards might differ, leading to the variance of new emerging shoots number. The severity level of pruning is previously reported to relate to the number of new emerging shoots in guava and citrus (Bhagawati et al. 2015; Budiarto 2018; Susanto et al. 2019).

Plant production was represented by fruit diameter, fruit weight, fruit number, and fruit production per individual tree. Fruit size was quantitatively represented by individual fruit diameter and fruit weight. The result showed no significant variation of fruit diameter in response to the growing location's altitude, although smaller fruit still tended to originate from highland rather than lowland (Figure 2A). An earlier study also reported the variation of 'Crystal' fruit diameter in the range of 7-8 cm (Musyarofah et al. 2020). The improvement of fruit diameter was possible to achieve through the intensification strategy, as the previous study reported the success of increasing 10% and 17% of fruit diameter on both low and medium-land, respectively (Musyarofah et al. 2020). The rate of fruit diameter enlargement of 'Crystal' guava was reported to be 0.4 cm per week (Widyastuti et al. 2019a).

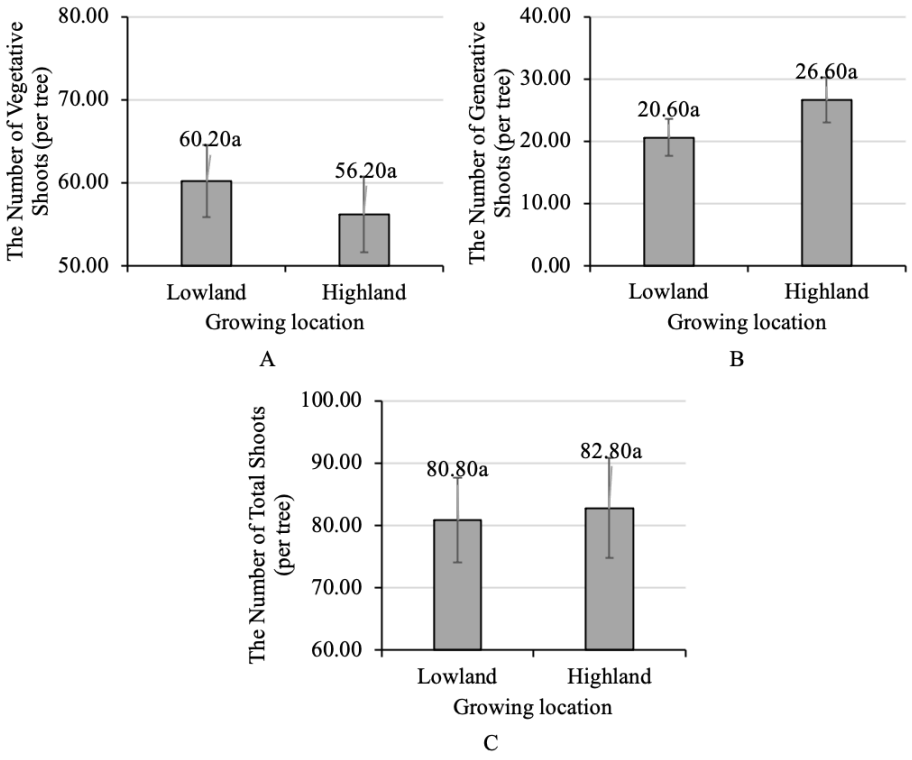

Figure 1. The number of generative shoots (A), vegetative shoots (B) and total shoots (C) on 'Crystal' guava tree in different growing locations. Note: the different alphabet above the rectangular bar is significantly different based on the LSD test at α 5%; the error bar represents the standard deviation

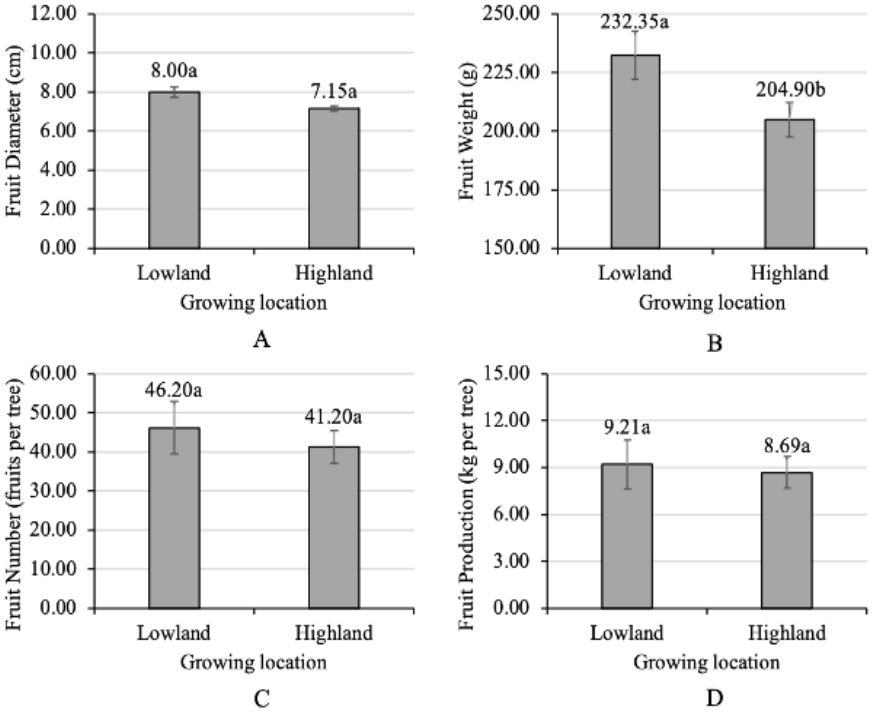

Figure 2. Plant production of 'Crystal' guava tree in different growing locations, as indicated by fruit diameter (A), fruit weight (B), fruit number (C) and fruit production (D). Note: the different alphabet above the rectangular bar is significantly different based on the LSD test at α 5%; the error bar represents the standard deviation

In contrast to fruit diameter, fruit weight was significantly affected by the altitude of the growing location. Lowland orchards produced significantly heavier fruits (232.35 g) than highland orchards (204.90 g) (Figure 2B). On average, there was an improvement of fruit weight by about 13% in lowland compared to highland. Compared to the highland of Sukabumi, the lowland of Lampung was reported to have greater flowering and fruiting responses of 'Crystal' guava that were associated with different microclimates between both locations (Widyastuti et al. 2019b). In the present study, all observed fruits weighed more than 200 g each, irrespective of the land altitude of the orchard. This finding was in agreement with a previous study that achieved an individual fruit weight in the range of 220-230 g (Widyastuti et al. 2019c). Fruit weight is an important fruit quality variable because consumers of 'Crystal' guava in Indonesia prefer to buy a large fruit, as indicated by the weight of more than 200 g, rather than a smaller one, especially for any fruit designed to meet supermarket demand (Musyarofah et al. 2020).

'Crystal' guava was able to produce 41.2 fruits per tree in highland to 46.2 fruits per tree in lowland (Figure 2C) with the total fruit weight per tree of about 8.69 kg per tree and 9.21 kg per tree in highland and lowland, respectively (Figure 2D). The number of fruits per tree was highly influenced by the percentage of fruit set. Fruit set is the proportion of harvested fruit compared to the entire flower emergent. The fruit set in 'Crystal' guava was reported to be 60% (Widyastuti et al. 2019c). The harvested fruit was determined at 122-142 days after the opening flower or anthesis (Patel et al. 2015). An earlier study by Widyastuti et al. (2019b) reported that there were two periods of guava harvesting seasons both in lowland and highland, i.e., March to May and September to November. However, the present study was only observed the fruit quality harvested in the period of March to May 2021.

Fruit's external appearance is one of the considerable factors in the buyer's point of view. Buyers prefer to purchase fruit with a high level of fruit smoothness in its peel. The damage to avocado fruit peel could be caused by thrips, such as *Frankliniella occidentalis* (Pergande), *Haplothrips bedfordi* (Jacot-Guillarmod), *Haplothrips gowdeyi* (Franklin), *Megalurothripss jostedti* (Trybom), *Scirtothrip saurantii* (Faure), *Thrips pusillus* (Bagnall), *Thrips gowdeyi* (Bagnall) and *Thrips tenellus* (Trybom) (Bara and Laing 2019), leading to the presence of scar incidence and reducing the fruit smoothness. In terms of guava, several fruit scarring pests were reported by earlier studies, i.e., Thysanoptera thrips, Brevipalpus mites (Musyarofah et al. 2021); *Selenothrips rubrocinctus* and *Brevipalpus phoenics* (Sarwar 2006). In the present study, there was a significantly lower level of fruit smoothness in lowland, i.e., 94.89% compared to highland, i.e., 97.42% (Figure 3A), as the effect of the significantly higher fruit scar incidence in lowland, i.e., 5.11% compared to highland, 2.58% (Figure 3B).

It was likely that fruit scar incidence was associated with the altitude of the growing location. This finding was consistent with an earlier study (Musyarofah et al. 2021) which found that scar intensity was higher in the lowland

than medium ones. A previous study by Laranjeira et al. (2015) revealed the effect of relative humidity, temperature and rainfall on pest development. The lower the temperature, the higher the relative humidity, the lower the pest development. The incidence of fruit scars also varied among growing seasons (Azain et al. 2019), when a severe incidence was more displayed in the dry season than the rainy ones (Childers and Rodrigues 2011). Eco-friendly pest population control could take the form of different colored methyl eugenol-based traps that was reported to be an effective way to control fruit flies (Bajaj and Singh 2018; Bajaj and Singh 2020) and also the use of fruit bagging technique for control the fruit scarring pest (Romalasari et al. 2017; Sharma et al. 2020).

Aside from external quality, internal fruit quality was also an important variable to be observed. Four important variables in terms of the internal quality of guava fruit were total soluble solids (TSS), titratable acidity (TA), TSS/TA, and vitamin C. The result showed a significantly higher TSS of guava fruit harvested from lowland, i.e., 9.81 ^{0}Brix, rather than fruit from highland, i.e., 8.29 ^{0}Brix (Figure 4A). This finding was in accordance with a former study (Solarte et al. 2014). The TSS was previously reported to be significantly affected not only by altitude but also pre-harvest pruning (Adhikari and Kandel 2015) and fruit maturation stage (Mubarok et al. 2021). However, the TA seemed to have no significant difference in response to different growing altitudes (Figure 4B). The TA in the present experiment varied from 0.40-0.47%, and it was similar to the previous study (Musyarofah et al. 2021), i.e., 0.40%. The ratio of TSS to TA is an important variable related to the fruit taste and then consumer acceptance level (Musyarofah et al. 2020). Most Indonesians love to eat dominantly sweet fruit rather than sour ones. Thus, the higher ratio TSS/TA in the lowland, i.e., 24.78, rather than the highland, i.e., 17.83 (Figure 4C), might be more favorable.

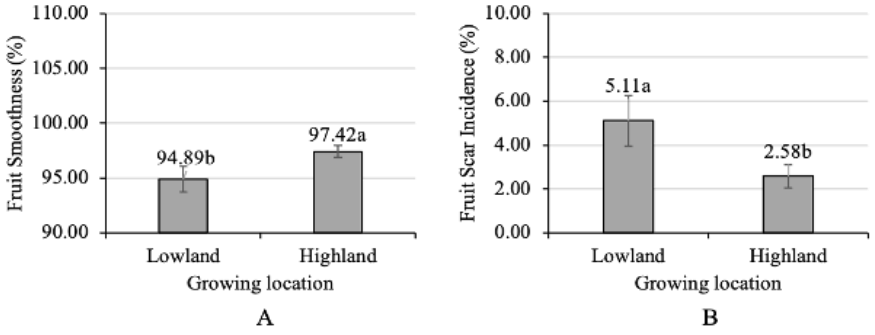

Figure 3. Fruit smoothness (A) and fruit scar incidence (B) in different 'Crystal' guava growing locations. Note: the different alphabet above the rectangular bar is significantly different based on the LSD test at α 5%; the error bar represents the standard deviation

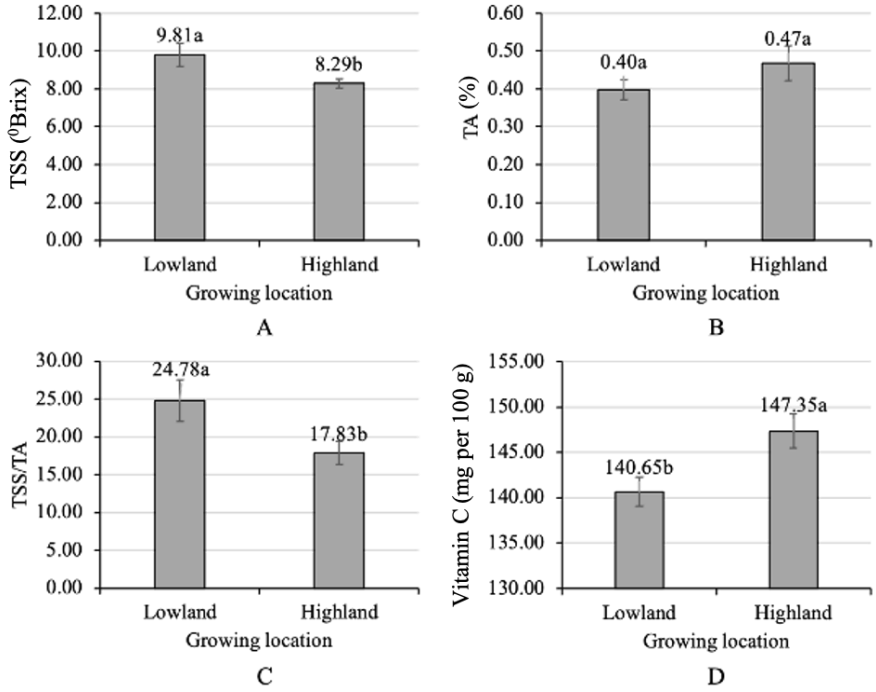

Figure 4. The internal chemical quality of 'Crystal' guava fruits in different growing locations, as indicated by total soluble solid (A), titratable acid (B), the ratio of total soluble solid to titratable acid (C) and vitamin C (D). Note: the different alphabet above the rectangular bar is significantly different based on the LSD test at α 5%; the error bar represents the standard deviation

In terms of vitamin C content, the present experiment revealed that guava fruit from the highland possessed a higher vitamin C for about 147.35 mg per 100 g rather than those from the lowland, at about 140.65 mg per 100 g (Figure 4D), as in agreement with an earlier study (Guntarti and Hutami 2019) who reported the increase of vitamin C at a higher altitude of growing location. The variation of vitamin C in the present experiment was 140-147 mg per 100 g. A previous study reported that vitamin C in 'Crystal' guava originated from the lowland was around 135 mg per 100 g sample (Musyarofah et al. 2021). An earlier report showed the range of vitamin C as 121.30-146.18 mg per 100 g (Romalasari et al. 2017). Aside from location, vitamin C in fruit could also be affected by fruit maturation stages (Gull et al. 2012). In the course of the ripening process, the guava seemed to experience an increase in reduced sugar (Jain et al. 2003) and TSS, with a reduction in TA as well (Soares et al. 2007).

In conclusion, the altitude of the growing location affected the plant production and fruit quality of 'Crystal' guava. Although there was no significant difference in the number of vegetative and generative shoots among the two growing locations, there was a tendency for a dominant generative shoot in the highland. Lowland orchards produced significantly heavier fruit compared to highland orchards. 'Crystal' guava tree was able to produce 41 to 46 fruits per tree with a total fruit weight of about 8.69 to 9.21 kg per tree. The significantly lower incidence of fruit smoothness in lowland compared to highland was affected by a significantly higher incidence of fruit scars in the lowland. Guava fruit from the lowland had a significantly higher TSS, while fruit from the highland contained a significantly higher vitamin C than lowland.

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