
Heat unit, phenology and fruit quality of Salak (*Salacca zalacca* var. *amboinensis*) cv. Gulapasir on different elevation in Tabanan regency-Bali

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Abstract: Each cultivar of zalacca could adapt to elevation, which has close relationship with the plant tolerance to temperature. However, heat unit of zalacca cv. Gulapasir, which are required to reach definite phase if they are grown in Tabanan areas have not known yet. The main objective of the research was to study heat unit, phenology and fruit quality of zalacca cv. Gulapasir planted on different elevation in Tabanan-Bali. The research was designed using Randomized Completely Design (RCD), with one factor as dependent variable along with ten replications. The independent variable was the site altitude of three locations that includes Saribuana village (460 m asl), Pajahan village (570 m asl), and Batungsel village (700 m asl). The phenologic determination of zalacca is based on the heat unit, which is counted using equation $[(T_{max} + T_{min})/2] - T_{base}$, in which T_{max} and T_{min} is daily mean maximum and minimum temperatures, respectively, and T_{base} is the basic temperature. The parameters measured were the emergence of midrib and spatha, the numbers of fruits per bunch, fruit weight, the harvest time, the thickness of the mesocarpium, total soluble solids (TSS), and total acid levels. Data was analyzed by analysis of variance, if the test of variance showed significant difference then it would be followed by LSD test in level 5%. Result of the research showed that different heat unit causes diverse phenology of the zalacca's components, which include the growth of midrib, the emergence of spatha, and the harvest time. Ripe-consumed zalacca was planted in Saribuana(460 m asl) in 7.4 days earlier than zalacca planted in Batungsel, which was 4.2 days earlier than others that were planted in Pajahan. The zalacca cv. Gulapasir were planted at Pajahan (570 m asl) shows the higher quality of fruit such as thickness of the mesocarpium, edible portion, TSS/total acidity ratio, and numbers of fruit then the others two elevation.

Keywords: Zalacca Cv. Gulapasir, Heat unit, Phenology, Quality, Elevation, Tabanan Regency

1. Introduction

Zalacca cv. Gulapasir is an indigenous commodity in Indonesia, which is potential to be developed both for fulfilling the domestic demand and for the export purpose. Specialty of this zalacca cv. Gulapasir is its taste that meets the consumer preference, such as sweet without any sour taste, even though the fruits are immature. This characteristic is ideal to meet the market demand, both domestic and the export purpose [2]. Along with the increasing demand of zalacca, it has been predicted that it will increase and potential to be developed as agribusiness and agroindustry. Besides that, high genetic diversities enable the plant to be developed in order to obtain superior variety [5].

The demand of zalacca cv. Gulapasir has been increased, on the other hand, its prospect keeps decreasing due to unable to compete with *Pondoh* zalacca, and therefore it encourages the government of Karangasem Regency to develop zalacca cv. Gulapasir intensively through growing program in new areas or as replacement of Bali zalacca [16]; [4]. In 1989 population of *Gulapasir* zalacca was about 133 trees [25], in 1992 was 950 trees [27], and in 2007 reached 1.5 million trees [3] or about 25 % of total population that comprised of 5,897,315 in Karangasem Regency [4].

The success of Karangasem Regency in developing *Gulapasir* zalacca has attracted other regions to breed this commodity. If the initial development of such variety was restricted in Karangasem Regency of Bali, however it has

been spread to other regencies in Bali, such as Tabanan, Buleleng, Badung and Bangli [26]. In new development areas, phenology and the heat unit of *Gulapasir* zalacca, which were grown in diverse elevations, have not well-known. Besides that, quality of zalacca in this area was lower than products from the native area, Sibetan Karangasem [22], and therefore this research is important to be conducted as basic in its development.

Appearance of the plant growth and production is affected by the environmental factor particularly microclimate and the endogenous factor, such as carbohydrate content and the growth hormone [6]; [12]. Temperature diversity in tropical areas is due to diverse altitudes above the sea level. The higher the altitude or the growing site, the longer of the plant to live, because the plant requires an amount of heat units to reach definite development level to the harvest time. Temperature has affected on the plant phenology, such as the growth rate and the pattern [8]; [11], has affected the success of pollination [24], influenced both biochemical and physiological process during the fruit development and growth [13]. For zalacca, higher temperature would inhibit development of the fruits and seeds [1], young leaves are easily burnt and dwarf [20]. However, lower temperature would inhibit the flowering time of zalacca [1]; [23], the zalacca would taste sour [20], both fruit weight and mesocarpium are low [15].

Each cultivar of zalacca could adapt to elevation, which has close relationship with the plant tolerance to temperature [20]. However, both heat unit and quality of the *Gulapasir* zalacca, which are required to reach definite phase if they are grown in new areas, have not known yet. This information is really important because determination of the harvest time has only applied time unit in days. It is considered that this method is unsuitable due to diversity of daily mean temperature as a result of different elevation and seasons [8]. Such diversity will cause number of days of the plant could reach diverse period of growth and maturity as well. Some research showed accumulation of heat unit after the flowers bloom, could explain diversity of the fruit growth in different location [7].

Objectives of the research were to study heat unit, phenology and fruit quality of *Gulapasir* zalacca, which were grown in diverse altitude in new development areas in Bali, therefore result of this research can be used as information sources in developing and improving quality of the fruits in new development areas at Tabanan regency.

2. Material and Method

2.1. Material and Study area

The research conducted from March 2012 – September 2012 in three different locations in new development areas in Tabanan-Bali that included Saribuana Village, which locates in latitude of 08°20'15.6" South Latitude and 115°02'26.4" East Longitude. The altitude is 460 m asl, average temperature is 23.80 °C, mean humidity is 86.78%.

Texture of the soil is dusty loam, high C-organic content, low NPK, pH 5.46.

Pajahan Village lies in latitude of 08°20'08.6" South Latitude, 114°59'17.4" East Longitude. The altitude is 570 m asl, average temperature is 22.21 °C, humidity is 87.96%. Texture of the soil is dusty loam, high C-organic content, low NPK, pH 5.75.

Batungsel Village locates in latitude of 08°20'15.6" South Latitude and 115°02'26.4" East Longitude, the altitude is 700 m asl, average temperature is 21.53 °C. Texture of the soil is dusty loam that having high C-organic content, low medium N content in the soil and low PK contents, pH 5.65.

Gulapasir zalacca used as object of the research is the plant that has already produced fruits, 8 years of age. Selecting samples of each location was performed and then followed by observation and measurement in order to find out the heat units accumulated by the zalacca plants. The samples were based on homogenous of morphology, age, and the applied cultivation. The related cultivation is directed to plants, which only midrib pruning, as well as removing the weeds. During the research, the plants were not given any fertilizer and water, but rainfall only, as used to be applied by the farmer. Midrib of the selected plant were just left for about 13 midrib.

2.2. Methodology

The research is designed using Randomized Completely Design (RCD) by one factor as dependent variable with ten replications. The dependant variable is the altitude of three locations, which includes Sarinbuana (460 m asl), Pajahan (570 m asl) and Batungsel (700 m asl) Villages. The heat units accumulated by the plants were calculated by equation as followed:

$$\sum \text{Heat unit (HU)} = \sum_{i=1}^n (T_i - T_{\text{base}}) \quad (1)$$

where: i = day 1, 2, 3.....n,

T_i = daily mean temperature $(T_{\text{max}} + T_{\text{min}})/2$,

T_{base} = basic temperature of the plant 15 °C [9].

Phenology and heat unit during the emergence of midrib and spatha are counted by adding the daily accumulated heat units until new midrib and spatha are formed. Ripe-consumed fruits are obtained by calculating the accumulated heat units starting from the blooming to ripe-consumed fruits. Characteristics of ripe-consumed fruits are the color change from dark brown to light brown, reducing thorns on the fruit skin and they are not sharp anymore, and in general, during the stage, the fruits are easily fallen when they are shaken until the fruits are ready to be harvested.

The fruit qualities from these three-observed locations include numbers of fruits per bunch, which are calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree are weighed after the fruits were removed from the bunch. Thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically.

The fruit taste is determined by the acidity level and sugary content of the fruit. Total acidity be measured by *tytrimetry*, in which 10 g of the fruits are weighed and dissolved in mortar. Then it is put into the flask that having 250 ml capacity and add water until the calibration mark and filtered. The filtrate obtained was taken as 25 ml, and then titrated by 0.1 N NaOH solution using phenolphthalein indicators. The result is calculated as percentage of tartrate acid by equation :

$$A = \frac{\text{ml NaOH} \times \text{N NaOH} \times \text{P} \times \text{BM}}{\text{Y} \times 1000 \times 2} \times 100 \% \quad (2)$$

where: A = percentage of total acidity

P = amount of dilution

BM = weight of tartrate acid molecules

Y = weight of the sample (g)

Total dissolved solid substrate (TSS). The measurement is taken on the zalacca juice using hand refractometer (Bellingham and Stanley Ltd., London) under temperature of 20°C. In order to know the fruit taste (sour and sweet tastes), values of the total dissolved solid substrate (TSS) is compared with total acidity, therefore the sugary and acidity ratio of the fruit could be determined.

Daily temperature is measured every day. The obtained daily temperature will be converted into heat unit. Soil analysis is conducted to find out chemical and physical characteristics of the soil. Sample of the soil was taken from the soil under the plant by composite in 0 – 40 cm depth. The chemical analysis was done on total N (Kjeldahl method), the available P (Olsen and Bray method), total K (HCL 25 % method), C organic, pH, KTK.

Data was analyzed by analysis of variance [21], if the test of variance showed significant difference then it would be followed by LSD test in level 5%. Relationship between heat unit and the plant phenology will be analyzed by regression. Data is presented in Table and Figure.

3. Result and Discussion

3.1. The Growth of New Midrib

Different altitudes has significant effect on growth and development of zalacca. *Gulapasir* zalacca is grown in area at the altitude of 460-700 m asl, the growth of new midrib emerges during 40.42 – 44.32 days by heat units range between 129.00 – 289.47 degree days (DD) (Table 1). Result of the regression analysis showed a linear model : $Y = -0.383x + 549.01$ ($R^2 = 0.87$) between altitude and the heat unit since the emergence of midrib. This value means that rise altitude where the plants grown from 460 m to 700 m asl has reduced the heat unit value from 380.03 DD to 289.47 DD. On the other hand, there is positive relation $Y = 0.017x + 32.751$ ($R^2 = 0.97$) between altitude where the plants grown and time when the midrib emerges. The higher alti altitude, from 460 m to 700 m, it takes longer for the midrib to emerge, from 40.42 days to 44.32 days.

3.2. The Emerge of New Spatha

Along with the growth of the midrib, the spatha starts to emerge at the back part of the midrib base. The emergence of new spatha at the third or the fourth midrib from the growing point depends on the altitude and condition of the plant. The emergence of new spatha ranges 129.00 - 145.10 days that requires heat units for about 1233.62 DD – 1047.90 DD. There is a linear relation between altitude where the plants grown and the heat unit $Y = -0.7804x + 1573.4$ ($R^2 = 0.824$). This value means that the height location of the growing land, the less heat required to form the spatha. On the contrary, the emergence of spatha shows positive relationship with equation of $Y = 0.0168x + 32.751$ ($R^2 = 0.974$). It means that the lower the location of the spatha emergence early in comparison with the higher location (Table 1).

3.3. The Harvest Time of Zalacca

The harvest of zalacca in Tabanan area is different and depends on location and the altitude. For zalacca, which is grown in altitude of 460 m, the harvest time lasts from the first week to the second week in August; in altitude of 570 m, the harvest time lasts from the third week to the fourth week in August; in altitude of 700 m, the harvest time lasts from the fourth week of August to the first week of September. In altitude of 460 m, it takes 167 days for the fruits to be harvested; in altitude of 570 m, it takes 171 days, and; in altitude of 700 m, it takes 174 days (Table 1). The regression analysis shows negative and significant relationship between altitude and the heat unit to achieve the harvest: $Y = -1.424x + 2129$ ($R^2 = 0.81$). On the contrary, for the harvest time, it shows that the higher the place where the plants grown, it takes much longer for the zalacca plants to ripe-consumed $Y = 0.03x + 152.0$ ($R^2 = 0.976$).

Therefore, the zalacca plants in Saribuana are harvested more early 7.4 days in comparison with in Batungsel (700 m), 4.2 days early, in comparison with in Pajahan (570 m). Different time of each development phase of the plants in each location is determined by the heat units, which are accumulated everyday. During the growth and development cycles of the plant in dry season, from March to the second week of September, in which the heat units in Batungsel is 1285.72 DD, in Pajahan is 1355.75 DD, and in Saribuana is 1635.12 DD. Different accumulated heat units are affected by daily mean temperature. In Saribuana, the highest daily mean temperature is 23.80°C, Pajahan 22.21°C and Batungsel 21.53°C (Fig. 1). The highly varied of temperature effected the rainfall difference in three locations. The increased temperature at Saribuana become the rainfall lower (44 mm on March – 205 mm on September), but on the other hand at Pajahan and Batungsel on the same month were 50 mm – 321 mm and 57.7 mm – 337.20 mm respectively (Fig. 1).

The harvest time has negative correlation with temperature ($r = -0.99$ **). It means that lower temperature takes longer time to harvest. Low temperature in altitude of

700 m will affect other climatic components particularly humidity and rainfalls. It is shown by correlation of humidity and rainfall as well as the harvest time, which are significant by the values of ($r = 0.98^{**}$) and ($r = 0.88^{**}$), respectively.

Factors have affected quality of the fruit, but the most dominant is climate, particularly the temperature [19]. Daily mean temperature in different altitude affects the seedling time, flowering and producing fruits. The higher the altitude, the longer time that must be taken for seedling, flowering, and producing fruits [14].

3.4. The Quality of Zalacca Fruit

Altitude has significant effect on numbers of fruit and percentage of the fruit-consumed and no significant effect on the fruit weight (Table 2). Table 2 presents that zalacca plants, which are grown in altitude of 570 m, result the highest yield for numbers of fruit and part of the fruit-consumed, 15.90 zalaccas and 72.27%, respectively;

but these have no significant difference in comparison with zalacca, which are grown in altitude of 460 m asl. The fruit parts that can be consumed refer to thickness of the mesocarpium and weight of the fruit. Thicker mesocarpium will result heavier fruit weight.

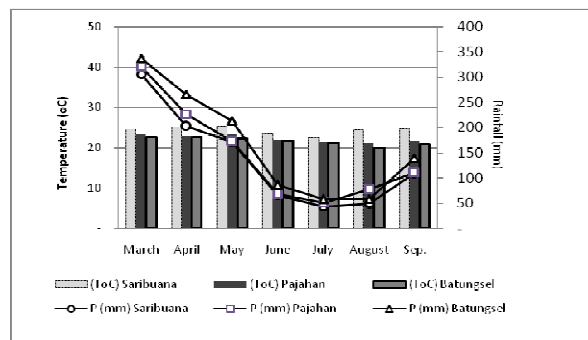


Figure 1. The average of rainfall and temperature in different elevation in Tabanan

Table 1. Phenology and heat unit of zalacca in different elevation in Tabanan

Location	Emergence of midrib (days after pruning)	Amount of heat unit in emergence of midrib (DD)	Emergence of spatha (days after pruning)	Amount of heat unit in emergence of spatha (DD)	Harvest time (days after blooming)	Amount of heat unit during harvest time (DD)
Saribuana(460 m)	40.42±2.21 b	380.03±10.23 a	129.00±5.51 b	1233.62±45.3 a	166.60±3.16 b	1510.73±9.52 a
Pajahan (570 m)	42.66±1.77 a	311.49±9.48 b	139.70±5.67 a	1080.75±35.9 b	170.80±6.69 a	1227.58±11.69 b
Batungsel (700 m)	44.32±2.49 a	289.47±10.03 c	145.10±9.48 a	1047.90±58.5 b	174.00±6.83 a	1171.45±15.57 b
LSD 5%	1.95	15.83	6.44	42.87	5.26	15.48

Notes : Numbers followed by the same letter in the same column have no significant difference in LSD level of 5%.

Table 2 shows that zalacca, which is grown in altitude of 570 m, results heavier weight even though it has not shown any difference based on the statistical test. In accordance with this research [15], reported that thickness of the mesocarpium and weight of the fruit are affected by environment where the plants grown and altitude of the growing land. *Gondok* and *Gulapasir* cultivars, which are grown in medium altitude (400 – <650 m asl) show heavier weight and thicker mesocarpium than plants, which are grown in lowland (250 - <400 m asl) and upland (> 650 m asl).

The plants, which are grown in Pajahan (570 m) and Saribuana (460 m), has resulted better quality of the fruits in comparison with the yield from Batungsel (700 m dpl). The quality is shown by thickness of the mesocarpium, TSS, and higher ratio of sugar and acid contents (Table 2).

Weight of fruit and quality component of the fruit have not shown linear pattern along with higher location of the growing land, such as the calculation of heat unit, which is required by the plants. The heat unit in this research is just used to determine the growth phase particularly during the optimum harvest in order to obtain maximum yield of the fruits. However, the increasing temperature will accelerate biochemical process of photosynthesis and development of the plant, and on the other side, the respiration process will run fast as well [18]. Therefore, more assimilates will be

reorganized to produce energy for physiological process. Therefore, zalacca that is grown in altitude of 460 m will produce lighter fruit than plant which is grown in altitude of 570 m asl. Result of this research is parallel with findings in which Bali's zalacca that is grown in altitude of 501-600 m asl has produced the greatest number of fruits and heavier fruit weight per tree in comparison with plants which are grown in altitude less than 500 m asl and above 600 m asl [17]. Furthermore Bali's zalacca, which is grown in altitude below 300 m asl will grow miserably and have drying leaves, and when it is grown in altitude of > 600 m asl, the fruits taste more sour [20]. The orange plants, which are grown under higher daily temperature will be mature early, bigger size of the fruit, and lower acidity content of the fruits [10].

Flowering and the fruit yield are affected by the environmental factors particularly microclimate and the endogenous factor of the plant, such as carbohydrate content, nutrient status and growing hormone [6]. Temperature has affected on phenology of the plant, such as pattern and the growth rate [8]; [11], affects the success of pollination [24], affects both biochemical and physiological processes during the growth and development of the fruits [13] In zalacca, higher temperature would inhibit the development of fruit and seed as well [1]. However, lower temperature would inhibit the blooming of zalacca [23], both fruit weight and mesocarpium are low [15].

Table 2. The effect of altitude on numbers of fruit, weight of fruit, thickness of Gulapisir's mesocarpium, TSS and total acidity

Location	Number of fruits bunch ⁻¹	Weight of fruit ⁻¹ (g)	Weight of fruit tree ⁻¹ (g)	Edible portion (%)	Thickness of mesocarpium (cm)	TSS (% Brix)	Total acid (%)	Ratio TSS and acidity
Saribuana (460 m)	15.70± 1.49a	38.29±2.59	621.72±50.61	70.41± 1.38a	0.61± 0.09ab	16.90± 0.08a	0.59± 0.08c	28.87± 4.20a
Pajahan (570 m)	15.90± 0.73a	39.12±3.07	662.03±61.70	72.27± 3.04a	0.64± 0.07a	16.92± 0.09a	0.77± 0.09b	22.36± 3.06b
Batungsel (700 m)	14.50± 0.85b	37.60±2.07	617.15±72.70	67.88± 1.55b	0.57± 0.07b	16.27± 0.35 b	0.93± 0.09a	17.54± 1.71b
LSD 5%	1.00	ns	ns	1.87	0.05	0.35	0.15	5.05

Notes : Numbers followed by the same letter in the same column have no significant difference in LSD level of 5%.

4. Conclusions

Results of the research conclude that:

1. Different heat unit causes diverse phenology of the zalacca, such as midrib development, the emergence of spatha, and the harvest time. Ripe-consumed zalacca in Saribuana (460 m asl.) was grown in 7.4 days earlier than zalacca grown in Batungsel (700 m asl.), which was 4.2 days earlier than others that were planted in Pajahan (570 m asl.).
2. Different heat unit causes different quality of Gulapisir zalacca. Gulapisir zalacca, which is grown 570 m asl, would result higher quality of fruit that include thickness of the mesocarpium, edible portion, TSS/total acid ratio, and numbers of fruit then the others two elevation.

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