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The Agroecosystem of Salak Gulapasir (*Salacca zalacca* var. amboinensis) in New Development Areas in Bali

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Abstract. This research was aimed to identify the agro ecosystem characteristics of salak Gulapasir (*Salacca zalacca* var. amboinensis) and the environmental factors affecting the yields and quality of the fruit. The research was conducted at Sub-district of Slemadeg Barat, and Sub-district of Pupuan, Survey was conducted in each location within the agro ecosystem zone of 400-500 m above sea level (asl), 501 – 600 m asl, 601-700 m asl and 701-800 m asl. Yields and quality of fruit from each area, was analysed using Randomized Complete Block Design (RCBD) with four replications. The analysis of ground water balance contents in each area was done using Thornthwaite and Mather methods (1957). The measurement of the physical and chemical characteristics of the soil was in accordance with the data required for the agroecosystem analysis. The results of the studies indicated that the monthly rain fall over a period of 10 years according to Oldeman method that the zones between 400-500 m asl and that of 501 – 600 m asl were classified as C2 agro climate zone, the zones between 601 – 700 m asl were categorized as B2, and the ones between 701 – 800 m asl belongs to B1. The results of the analysis of soil water contents indicate that the 400 – 500 m asl zones experience the highest water deficit (125.82 mm/year) while within the 701-800 m asl zones there was annual water surplus. The studies indicated that different agroecosystem zones truly affect yields and quality of fruit. The highest weight and quality of fruits are produced within the 501-600 m asl zones.

Keywords: *Salak Gulapasir, new area, development, agroecosystem.*

1. Introduction

There are a number of varieties for Salak Bali, depending on fruit characters (forms, aroma, taste and skin colour) or locations where the fruits are cultivated (Darmadi et al., 2002; Sumantra et al., 2016). Until today, there are two varieties of Salak Bali, i.e. according to the Decree of the Indonesian Minister of Agriculture on Salak Bali (SK.No.585/Kpts/TP.240/7/94) and Salak Gulapasir (SK.No.584/Kpts/TP.240/7/94). Salak Gulapasir has high quality because its sweet taste even the fruits are still young, thick flesh and the price is four times of Salak Bali. This fruit is considered ideal to meet both the domestic market and export (Anonymous, 2004) and also as agro-industry and agro-tourism (Sumantra et al., 2017 and Sumantra and Anik Yuesti 2018).

The success of Karangasem in developing Salak Gulapasir inspired other areas not only in Bali but also from other island to cultivate this commodity. When initially it started in Karangasem, it has now been spread out to Tabanan, Buleleng, Badung and Bangli. From these four areas, Tabanan has the biggest area of plantation mainly in the sub-district of Pupuan and West Slemadeg (Sumantra et al., 2016; Sumantra et al., 2012).

A problem faced by farmers in the new areas of development especially in Tabanan is low yields and quality resulting in low selling prices. The results of initial studies show that the weight of individual fruit

^{1}, bunches^{-1}, total number of individual fruit^{-1} and volume of bunches^{-1} are 39.91 g^{-1}, 779.85 gram^{-1}, 35,6 ml respectively or more equals 7.11 %, 31.64%, 24.43% and 25% if compared to Salak Gulapasir from Sibetan, Karangasem. The skin colour of Salak Gulapasir from Tabanan tend to be brownish black while the ones from Sibetan tend to be blackish brown. Another problem faced by farmers in the new areas is traditional method cultivation. There is no intensive method of fertilizing while water supplies mainly depends on the rain fall (Ashari, 2002; Sukewijaya et al., 2009). As a result the quality is rather low and fails to meet the criteria of good quality fruit with relevance to its form, size, taste and flesh thickness (Sumantra and Labek 2015).

The cause of low quality of Salak Gulapasir in the new areas have not been known whether it is due to the effects of agroecosystem factors or plant genetic factor because the breeding of Salak Gulapasir is conducted generatively as well as due to cultivation technology itself (Sumantra and Labek 2012). The performance and produce are influenced by environmental factors particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status and growth hormone (Bernier et al., 1985; Kinet et al., 1985; Leopold & Kriedemann, 1975). Climate affects almost all aspects of farming activities. The need for accurate climate information is getting more strategic to support agricultural activities. Therefore, one way of handling salak quality is by undertaking serious studies on a number of factors such as land and climate as well as to adjust agricultural patterns in accordance with local climate condition. The adjustment should be based on identification, understanding or accurate interpretation of land and climate in each agroecosystem location. Therefore, in identifying locations with their specifically local climate suitable for salak cultivation requires comprehensive interpretation of land and climate.

This research aimed to identify agroecosystem characteristics of Salak Gulapasir in new development areas as well as factors affecting its yields and quality. The results of the studies can be used to determine accurate cultivation techniques (fertilising, water management and shade trees), to improve product competitiveness and to preserve land caring capacity.

2. Methodology

The agro ecosystem studies of Salak Gulapasir was conducted in new area of development in some villages in Tabanan district such as Kebon Jero, Anggesari, Munduk Temu, Pajahan, Bangsing and Sarinbuana, during harvest season of December-April 2015. The objects under studies were Salak Gulapasir trees approximately aged 8 years, located in Salak development centre in the sub-district of West Slemadeg and Pupuan in Tabanan within the agroecological zones of 400 – 800 m asl. The agroecosystem locations were determined using purposive sampling techniques in 16 locations each for 16 salak trees. The equipment used to conduct the studies are 60 CSX GPS maps, thermometer, hygrometer, Light photometer, soil moisture tester, borer, spade, hoe, rope, measuring tape, scale, oven and laboratory equipment for soil and fruit quality analysis.

The research used survey methods, including collection of secondary data, field observation to identify agroecosystem boundaries, sample observation, soil and plant organ sampling and laboratory analysis. In order to know the difference of fruit yields and quality in each agroecosystem zone, study were used single factor Randomized Completely Block design with 4 replications. On basis of area spread, the agroecosystem zones of Salak Gulapasir were divided into 4 zones, i.e., 400 – 500 m asl; 501 – 600 m asl; 601 – 700 m asl; and 701 – 800 m asl.

The analysis of land water balance used Thornthwaite and Mather analysis method (1957). Analysis on climate condition was the average of monthly temperature and the data on the average of monthly rain fall during the normal period of 2001 – 2010 from the 4 post in the research areas. In calculating the water balance the following input data were required: rain fall (R), potential evapotranspiration (ETP), ground water contents in the field capacity (FC), ground water contents at permanent wilting point (PWP). The ETP value was calculated using the following equation.

$$ETP = 1{,}6\ F\ (10\ T/I)^{a}$$

Notes:

I = Heat accumulation index in one year = $(T/5)^{1.54}$

T = Average temperature (°C)

F = Length of day lights

a = value determination: $a = 675 \times 10^{-9} \times I^3 - 771 \times 10^{-7} \times I^2 + 1792 \times 10^{-5} \times I + 0.49239$

The steps of calculating area water balance using Thornthwaite dan Mather method (1957) are as follows:

a. Filling in the column for average of monthly rain fall (R).
b. Filling in the column for potential evapotranspiration (ETP).
c. Filling in the R-ETP column. This value is required to determine the period of water deficit and surpluses.
d. The negative value of the above steps is accumulated every month known as the accumulation of potential water loss (APWL) which is the total amount of lack of rain fall for Filling in the column for average and is entered the right column.
e. Filling in the column for ground water contents (GWC), where ground water contents can be at the maximum level during a certain period where R-ETP has negative value. If the R-ETP value is negative, the gournd water contents is then determined based on Soil Moisture Retention Table which depends on the value of field capacity of the researched areas.
f. Filling in the dKAT column (change of ground water contents). The change of ground water contents is the difference of ground water content between one period and the one before ($KA_{Ti} - KA_{Ti-1}$). The positive dKAT value shows an increase in ground water contents.
g. Filling in Actual Evapotranspirational column (ETA), when the water fall reaches or surpasses the potential evapotranspirational value then ETA = ETP. If the rain fall is lower than the potential evapotranspiration, the lands begins to dry out and that ETA is smaller that ETP, which in this condition the value of ETA = R + dKAT.
h. Filling in the deficit column with the formula ETP – ETA. Deficit means that the decrease of water contents required for potential evapotranspirational. Therefore, water deficit is the difference between the potential evapotranspirational value with the actual value (ETP – ETA). The deficit value is the total amount of water to be added to fulfill the need of potential evapotranspiration.
i. Filling in the surplus column with R-ETP-dKAT. Aftter the ground water deposit reaches the Field Capacity (FC), the rain fall surplus is calculated as the value of rain fall minus potential evapotranspiration and change of ground water contents.

The observation and measurement of physical land characteristics in the field is an accordance with the needs of the data to perform an agro ecosystem analysis for salak. The data includes drainage system, rock condition and threat of flooding and land texture (Djaenudin *et al*., 2000).

The land fertility is determined through an analysis of soil sample taken from the different plots of composite salak plantations. The composite land sample from 8-10 drilling point, taken from each agroecosystem sub-zone is considered to have similar characteristics representing an area of 1 - 5 ha. There are three steps to determine the status of land fertility: (1) land surveys, (2) analysis of soil sample, and (3) interpretation of the results of soil analysis. The soil sampling technique was conducted using drill to 0 - 40 cm deep. The soil sample was analysed in the laboratory by calculating the percentage of sand, dust and clay using straw method; soil pH, organic materials used Black and Walky methods, salinity level used conduct meter, CEC used NH4OAc method, and macronutrient level: N total used Kyedall method; P2O5 and K2O used Bray I methods.

The observation and measurement of Salak plantation in the field was as follows: bunch weight^{-1}, individual fruit weight^{-1} and total fruits in a bunch^{-1}. The fruit quality as follows:fruit volume, flesh thickness, contents of sugar, and acid content.

3. Results and Discussion

3.1. Characteristics of Climate and Land

The average annual rainfall indicates that the 400-500 m asl zones can be classified as the C2 agroclimatic zone according to Oldeman classification characterized by 6 months of wet and 3 months of dry climate. The average of annual rainfall is 2466.66 mm, with the highest rainfall was in December (369.55 mm) and the lowest in July (43.71 mm). The average temperature is 23.39 °C with the highest temperature of 24.41°C in March and the lowest in August (22.25°C) with humidity between 84.96 – 90.92%.

The 501-600 m asl zones are categorized as C2 agro climatic type with an average annual rainfall of 2564.96 mm, the highest rainfall being in December (380.87 mm) and the lowest in August (38.51 mm). The average temperature is 22.42 °C with highest in February (23.70°C) and the lowest in Agustus (21.26°C) and humidity between 87 and 91.5 %.

The 601-700 m zones are categorized as B2 agro climatic type with 9 months of wet and 3 months of dry climate. The average annual^{-1} rainfall is 2887.83 mm with the highest rainfall in November (449 mm) and the lowest in July (57.7 mm). The average temperature is 21.61°C, the highest being in March (22.47°C) and the lowest in August (20.5°C) and humidity between 84 and 92 %.

The 700 – 800 m zones categorized as B1 agroclimatic type with 9 months of wet and 1 month of dry climate. The average annual^{-1} rainfall is 4207.63 mm with the highest rainfall in January (701.49 mm) and the lowest in July (87.96 mm). The average temperature is 21.43 °C, the highest being in February (22.77 °C) and the lowest in August (20.33°C) and humidity between 86 and 93%.

In the 400-700 m zones the land is categorized as Typic Eutrudepts formed by the main Tufa, lava sediment of mountain of Buyan,Beratan and Batur. Typic Hapludand category of land is found at 700-800 m formed by main Tufa, lava sediment of buyan, beratan and batur.

Table 1 shows the physical characteristics of land affecting root growth of the plant which include texture, drainage system and root depth. At the depth of 80-100 cm the land contains clay and dust. There are no rocks visible on the surface with a slope between 1 and 8%. The other quality including nutrient retention such as CEC, alkali saturation, c-organic is considered high to very high (Table 1), soil pH is considered acidic (5.61 – 5.84).

The result of soil analysis regarding the contents of N, P and K shows that the total N contents is low in the four different locations, P contents is very low in the 400 – 500 m, 600 – 700 m, and 700 – 800 m asl zones., and it is low in the 500 – 600 m zones. The K contents is low in the 400 – 500 m and 700 – 800 m asl zones while it is average in the 500 – 600 m and 600 – 700 m asl zones (Table 1).

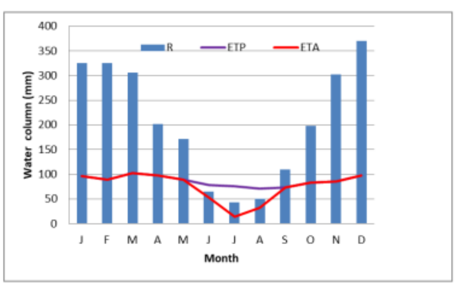
Table 1. Characteristics of salak land in various agroecosystem

No.	Measurement	Agroecosytem Zone (m asl)			
		400-500	501-600	601-700	701-800
1	Average annual temperature (t) (in °C)	23.82 (s1)	22.75 (s1)	22.12 (s1)	21.49 (s2)
	Water availability (w) - Rainfall (in mm)	2369.86 (s2)	2439.20 (s2)	2865.6 (s2)	4070.4 (s3)
2	Roots growth media (r)				
	- Drainage system	Good	Good	Good	Good
	- Bulk density (g.cm^{-3})	0.995	0,952	0.980	0.880
	Land texture				
	- Sand	25.53	22.63	36.10	34.41
	- Dust	50.76	51.71	42.74	47.84
	- Clay	23.61	25.66	21.15	14.93
	Notes:	clay dusty	Clay dusty	Clay dusty	Clay dusty
	- Soil depth (in cm)	87 (s1)	87 (s1)	100 (s1)	100 (s1)
3	Nutrient retention (f)				
	-CEC (me/100 g)	27.20 (h)	33.65 (h)	34.87 (h)	37.13 (h)
	-Base saturation (%)	70.66 (vh)	71.11 (vh)	70.75 (vh)	70.57 (vh
	-pH (H_2O)	5.76 (ra) (s2)	5.61 (ra) (s2)	5.84 (ra) (s2)	5.70 (ra) (s2)
	-C-organic (%)	3.28 (h)	3.26 (h)	4.24 (h)	4.44 (h)
4	Nutrient availability (n)				
	-N total (%)	0.185 (l)	0.182 (l)	0.165 (l)	0.182 (l)
	-P_2O_5 (ppm)	8.64 (vl)	10.24 (l)	8.47 (vl)	8.75 (vl)
	-K_2O (ppm)	11.01 (l)	24.52 (m)	20.15 (m)	14.10 (l)
5	Salinity (c)				
	-Salinity (mmhos/cm)	1.19 (r) (s1)	0.96 (sr)(s1)	1.20 (r) (s1)	1.22 (r) (s1)

Notes: h: high; vh: very high; ra: rather acid; l : low; vl : very low; m : medium; s1 : very relevant; s2 : quite relevant; s3: marginally relevant (Djaenudin *et al.*, 2000)

3.2. Water Availability

The results of water content analysis in each zone show a significant difference during surplus and deficit periods. The 601-700 and 701-800 m zones have longer surplus period compared to the zone 400-500 and 501-600 m zones. The results of analysis show that the higher the zones the shorter the deficit period. In the 701-800 zones water surplus happens through the year. The deficit period in the 400-500 m zones takes place in June, July and August with a total deficit of 125,81 mm. The deficit period in the 501-600 m zones happens in June, July and August with a total deficit of 93.84 mm, while in the 601-700 m zones the deficit period is in July and August with a total of deficit of 56.9 mm. The low water deficit is due to low Evapotranspiration (ETP) (Figure 1-4).



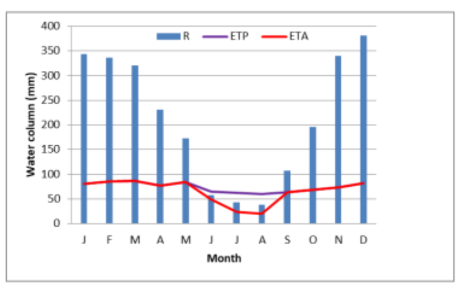


Fig. 1. Rain fall, ETP, ETA zone 400-501 m asl. Fig.2.Rain fall,ETP and ETA zone 501-600 m asl.

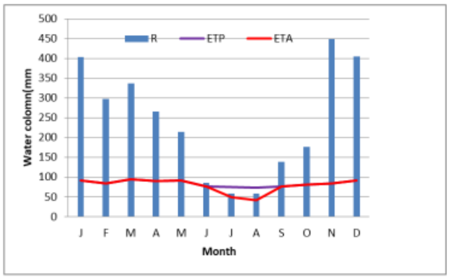


Fig. 3. Rain fall, ETP,ETA zone 601-700 m asl.

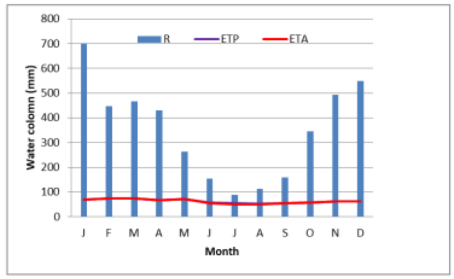


Fig.4.Rain fall,ETP and ETA zone 700-800 m asl.

Naturally, the flowers of salak Gulapasir trees appear three to four times per year (Sumantra et.al. 2014). Flowering and pollination of fruit crops is influenced by environmental factors, particularly the microclimate such as temperature, humidity, light intensity and rainfall (Sumantra et.al., 2012). Rai et. al. (2010) found that fruit yield in Gulapasir salak trees has a positive correlation with humidity, but a negative correlation with sunlight intensity. It means that the plants only need portion of sunlight. In fact, they need 50-70% sunlight (Sukawijaya et.al., 2019). Therefore, sunlight reduction is essential in Gulapasir salak tree plantation. The shade trees and salak trees together will form a certain agro-ecosystem in the area.

Our inventory on types of shade trees in Gulapasir salak tree farming system in the new development area in Bali found that each agro-ecosystem zone has different types of shade trees. The plant species was commonly used as building material and for land conservation such as Sengon (*Albisia falcate*), Suren (*Toona sureni* Merr) and Gempinis (*Melia azedarach* L.) largely dominate the zone 600-800 m asl. Commercial fruits like Mangosteen (*Garcinia mangostana* L.), Durian (*Durio zibethinus* Murr), and jackfruit (*Artocarpus heterophylla* L.) as shade trees were found in the zone 400-600 m asl. Crop species used in industry such as clove (*Eugenia aromatic* OK) was found in the zone 501-800 m asl. The different in crop species in the agro-ecosystems are strongly influenced by ecological conditions, its economic benefits and its purpose of natural resources conservation.

The results of the research showed that there were different light intercepts, humidity and temperature under salak trees. The 501-600 m zone shows that the percentage of light intercepts is the highest (80.23%) and the lowest is in the 400-500 m zone (77.73%). The temperature and humidity shows the opposite, i.e. the highs the agroecosystem zone of 400-500 to 700-800 m the temperature is lower and the humidity is higher (Table 2).

Table 2. Average sunlight intensity, temperature and humidity under salak trees in difference agro ecosystem zones

No	Parameter	Zone agroecosystem (m asl)			
		400-500	501-600	601-700	701-800
1	Sunlight intensity				
	Above salak trees (lux meter)	375.83	398.66	391.75	392.66
	Under salak trees (lux meter)	85.63	78.73	78.25	78.33
	Sunlight intercepts (%)	77.73	80.23	79.31	79.98
2	Temperature under the tree (°C)	28.14	26.24	24.28	24.13
3	RH under the tree (%)	75.33	79.12	88.45	89.50

3.3. Yields of Salak Gulapasir

Salak Gulapasir grow in the 400 – 800 m asl zone can normally bear fruits but they different in quantity (Table 3). The fruits weight in the 501 – 600 m asl zone is 1.76 kg tree^{-1}, while in the 400 – 500 m asl and 700 – 800 m asl zones is only 1.22 kg and 1.42 kg $^{tree-1}$ respectively. The high weight is found in the 501-600 m asl zone with more fruits in every bunch^{-1}, higher fruit weight^{-1}, higher bunch weigth^{-1}.

Table 3. Average fruits per bunch, number of fruits per tree, fruit weight per bunch, and fruit weight per tree in different agroecosystem zone

Agroecosystem zone (m asl)	Total Fruits		Fruit weight		
	Bunch^{-1}	Harvest-tree^{-1}	Fruit^{-1} (g)	Bunch^{-1} (g)	Tree^{-1} (kg)
400 – 500	17.90 b	1.74 a	34.94 b	688.78 b	1.22 b
501 – 600	21.89 a	1.99 a	42.86 a	857.38 a	1.76 a
601 – 700	19.95 ab	1.62 a	39.75 ab	791.21 ab	1.53 ab
701 - 800	18.20 b	1.74 a	37.54 b	675.12 b	1.42 ab
LSD 5 %	2.82	-	3.74	119.95	0.48
CV (%)	8.55	8.38	5.45	9.50	8.96

Notes: In the same column, the numbers followed by the same letter was not significant difference at LSD 5%.

The results of the research was in line with the studies taken by Sumantra et al. (2014), Purnomo and Sudaryono (1994) that the presentation of fruit weight, flesh weight and flesh thickness is affected by the area and altitude. Cultivar Gulapasir grown in the medium area 500 -600 m asl, demonstrates higher weight and size compared with other altitude, taste of salaks is sour if they are grow in more than 600 m asl (Sumantra et al., 2014).

The 501- 600 m asl zone is an ideal zone to grow salaks. In this zone the environmental factors including climate is much better that the other zones. This can be seen from the nutrient availability especially P and K which higher than the other zones. This nutrient availability affects the process of translocation, photosynthesis, flower development and fruit formation (Gardner et al., 1991). On the other hand, in the 501-600 zone there is a higher sunlight intercepts (80.23%) compared to the one in 400-500, 601-700 and 701-800 m zones with a sunlight intercept value of 77.73%, 79,31% and 79.98% respectively. A high intercept value means that sunlight is optimally used to perform photosynthesis which is a positive impact on flower development. This condition will affect the establish and fruits development (21.89 fruit bunch^{-1}). The high intercepts value in 501-600 m zone is also related to the role of the shade plants of 10 $^{m-2}$ with 13 different species. The result of this study are in line with the findings of Sumantra et al. (2014) that the salak Gula Pasir cultivar grown in 400 – 600 m asl shows higher grade of fruit and flesh if compared with in high land > 600 m asl. It's means at an altitude of 400-600 m asl. is an ideal agroecosystem condition for zalacca plants. But the limiting factors are lack of rain water especially in June, July and August and it is necessary to supply adequate water during the dry season.

4. Conclusion

The results of the research can be concluded as follows:

1. Every agroecosystem zone shows different periods of water surplus and deficit. In the 601-700 and 701-800 m zones there is longer period of water surpluses compared to the 400-600 m zones. In the 400-600 m zones the deficit period was in June, July and August with a total deficit of 125.81 mm (400-500 m) and 93.84 mm (501-600 m).
2. Agroecosystem zone has a real effect on the yields of Salak Gulapasir. The 500-600 m zones are the most ideal zones to obtain a high quality yields of Salak Gulapasir.
3. Limiting factors of salak Gulapasir in the new areas depend on the agroecosystem zones. In the 400-600 m zones the limiting factors are lack of rain water (June, July, August), level of soil pH,

nutrient status especially NPK. In the 701-800 m zones the limiting factors are soil pH, nutrient status, too high rain falls and too low temperature.

Salak Gulapasir cultivation can sustain in the new areas it is necessary to improve and modify the environment as follows:

1. It is necessary to perform intensive care of the plants by regulating the number of midribs and intense shading to produce an ideal condition for sunlight intercept (80.23%).
2. It is necessary to build a drainage system in high rain fall zones to stimulate perfect root growth and plants physiological process.
3. The improvement of soil chemical characteristics such as pH and availability of adequate nutrients with add of limestone and using both organic and anorganic fertilizers.
4. It is necessary to supply adequate water during the dry season especially in the months of water deficit in June, July, August. It is during these months the plants develop their fruit for "Gadu season" and develop their flowers for major harvest.

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