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Analysis of Phenotypic Variability and Correlation on Sugar Content Contributing Phenotypes of Salak (*Salacca sumatrana Reinw var.Sidempuan.*) under Various Altitudes

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***Abstract*— *Salak (Salacca edulis), commonly known as snake fruit, is one of Indonesia's local fruit preference with a promising commercial prospect for the development of horticultural product. This fruit is a superior fruit commodity of Padang Sidempuan which has been recognized nationally. A significant change of geographical altitudes from lowland to highland supported the salak growth when planted in South Tapanuli. This study was aimed to evaluate the phenotypic variability as well as its correlation of salak planted in three different subdistricts of South Tapanuli representing low, mid and highlands. Sampling was conducted using purposive sampling method where 30 accessions of salak were collected from all those three subdistricts in South Tapanuli. Both qualitative and quantitative traits were statistically analyzed and evaluated for its phylogenetic using NTSYS 2.02. According to the phylogenetic analysis, 37 morphological traits resulted in a similarity coefficient ranging from 0.34-0.68. Of all accessions tested, two accessions (MC4 and MC5) were closely clustered with a coefficient of 0.68. Moreover, 7 traits were positively correlated to sugar content, including plant height,number of fruit bunch, length and width of leaflet, number of leaf, fruit weight and flesh thickness.*

***Keywords*— snake fruit, germplasm, characterization, sugar content, correlation.**

I. INTRODUCTION

Salak (*Salacca edulis*) is one of preferred fruit due to its fruit texture and taste as well as its high nutritional value. This fruit is also potential to be commercialized as the fruit itself can be processed into various food products with promising economical value. The plant can be found in most regions in Indonesia, either being cultivated purposefully or being wildly grown. Herwin (2000) mentioned that salak cultivar was categorized based on its flesh texture, peel color, scent and flesh flavor. The difference related these parameters occurred not only among different production center, but also among plant cultivated in the same area or region. This condition indicated a broad genetic diversity due to its high variability on various phenotypes, such as fruit shape, size and peel color.

Several previous studies had characterized the morphology and variability of salak cultivated in some areas in South Tapanuli. However, the correlation analysis of sugar content-related traits of this plant were still less reported. Correlation among traits is defined as the degree of linkage or connection between one certain trait with other traits. Estimation of both genotype and phenotype correlations are required in the planning and evaluation of certain plant breeding program.

Compared to salak cultivated in other regions in Indonesia, salak cultivar originating from Padang Sidempuan is known for its high sugar and water contents. Due to these unique features, salak was found to be a potential source for bioethanol (Fatima, 2013). Regarding the region of its cultivation, South Tapanuli is one of the regencies in Sumatera Utara categorized as perhumid zone whose the regional topography consists of numerous valleys and hills. These geographical features result in steep slopes with highly different altitude among areas. According to Agriculture Office (1996), such a slope topography was suitable for salak cultivation as it provided a good drainage. A striking change of altitude from lowland to highland serves a favorable environment for salak cultivation due to its shallow rooting system which is sensitive towards drought and water flooding.

This present study was aimed to evaluate the phenotypic variability and correlation of sugar content-contributing traits of salak found in several areas of South Tapanuli representing different level of altitude. The results of this study provide the useful information regarding the level of variability on the phenotypes of salak planted in different areas of South Tapanuli. These data can be used as a reference for the determination of an appropriate breeding program of salak, thus enable the development of superior varieties of salak in the future.

II. MATERIALS AND METHODS

This research was carried out using the survey method where the samples were purposively collected. This research was conducted from April to June 2017 in local salak farms located in three subdistricts of South Tapanuli which represented different altitudes. Subdistrict South Angkola (200-400 m asl) represented low land, while subdistrict West Angkola (400-800 m asl) and subdistrict Marancar (800-1100 m asl) represented mid and highlands.All collected samples were observed carefully to identify both qualitative and quantitative data. Analysis of these data were proccessed using NTSys 2.02 before being subjected into variability and similarity analysis.

Phenotypic variability among samples wasdetermined using this following formula:

$$S^2 = \frac{\sum[(xi - \dot{x})^2]}{n-1}$$

where *S2* was symbolized variability, *xi* was first observation value,$\dot{x}$ was average of observation values and *n* was number of samples observed.

The scoring of this variability was characterized according to the criteria proposed by Pinaria (1995). A phenotype with broad variability would reveal the value of variability which is two-fold higher than the value of standard deviation, vice versa. The determination of standard deviation value was performed using this following formula:

$$Standard\ deviation\ (SD) = \sqrt{S^2}$$

Similarity analysis was aimed to assess the possible genetic relationship among samples. Additionally, correlation analysis was also performed using simple correlation coefficient proposed by Pearson through this following formula:

$$r = \frac{\sum(Xi - X)(Yi - Y)}{\sqrt{\sum((Xi - X)^2(\mathrm{Yi} - \mathrm{Y})^2)}}$$

If the value of calculated *r* is lower than the value of table *r*, it means no correlation among traits, vice versa. If the table is unavailable, hence T-test could be performed using this following formula:

$$calculated\ t = \frac{r}{SE\ (r)}$$

$$SE = \frac{\sqrt{1 - r^2}}{n-2}$$

If the value of calculated *t* is lower than value of table *t*, it means no correlation.

III. RESULTS AND DISCUSSIONS

Field Observation of Salak Morphology

Salak grown in three subdistricts of Tapanuli conferred different characteristic in most of morphological parameters observed (Table 1). Several parameters showed a prominent difference, such as gap among lower leaflets, number of fruit bunch and fruit weight. It indicated that the different geographical topography of these three subdistricts influenced the morphological performance of salak. Plant phenotypes were affected by both genetic and environmental (Murti et al., 2002; Mufida, 2011). Different altitude provided different climate and soil conditions, thus the quality of plant growth would depend on its compatibility with the growing location (Aydin, 2004). In addition, the performance of a morphological parameter could also depend on the performance of other parameters. For instance, the increase of fruit weight was in line with the increase of fruit age. The older the fruit age, the heavier the fruit weight (Santosa and Fauzia, 2011).

Phenotypic Variability of Salak Grown at Different Altitudes

There were 21 quantitative and 16 qualitative traits analyzed for its phenotypic variability among 30 accessions of salak. Regarding the quantitative phenotypes, the variability among those three different subdistricts in South Tapanuli showed a broad variability (Table 2). Unlike quantitative phenotypes, variability of 16 qualitative phenotypes varied according to the phenotype. Nine phenotypes showed a narrow variability, while the remaining phenotypes showed a broad one (Table 3). These results suggested that different geographical altitude altered the developed morphological characters of salak in each subdistrict, thus broadened its phenotypic variability. It also implied that the genetic of these salak plants was possibly highly variable. Moreover, this high phenotypic variability might be associated withits propagation method where salak plant in Padang Sidempuan was mostly propagated generatively through seed.

Variability is defined as the diversity among the characters or phenotype of an individual plant in each population. The variability of a population could be measured through its phenotypes and genetic variability. Phenotypic variability is measurable and clearly observed for certain characters. Unlike phenotypic variability, genetic variability requires special methods and tool to measure as it is invisible. A population showing broad phenotypic variability is not always showing a broad variability on its genetic aspect due to the influence of environmental factors on the performance of a phenotype. Genetic variability is resulted from gene interaction within the population (Crowder, 1983).Differ from phenotypic variability, a broad genetic variability would lead to broad phenotypic variability due to the effect of genetic-environment interaction (Swasti, 2006; Putri et al., 2017).

Based on the field observation in three subdistricts of South Tapanuli, salak grown in South and West Angkola exhibited well-developed growth with tall stems, green-colored leaves, large-sized fruit compared to the one in Marancar. It indicated that salak plant preferred the agroclimate condition in low and midland, such as found in West and South Angkola. Salak plant grown in high land (Marancar) showed shorter and smaller stem with more yellowish leaves and smaller fruit.

Table 2. Phenotypic variability of salak grown in three subdistricts of Padang Sidempuan based on the quantitative phenotypes. Salak favored a growing condition at 0 to 700 m asl and the best growth was commonly achieved when it was grown at 0 to 400 m asl. Higher altitude up to 900 m asl was still tolerable, but the growth would be troubled if the altitude was more than 900 m asl. This growth inhibition might result in the difficulty of fruit formation and development (Agrotani, 2016).

Phenotypic Similarity of Salak Grown at Different Altitudes

As seen in Fig. 1, all accessions were highly separated among each other suggesting that salak plants found in Padang Sidempuan were not closely related. This result was also in line with the result of phenotypic variability analysis as most phenotypes observed were broadly diverse. This analysis also showed that those 30 accessions exhibited similarity coefficient ranging from 34-68%based on 21 phenotypes.

Similarity analysis was commonly conducted according to both qualitative and quantitative data. This analysis was purposed to assess the relationship distance and phylogenetic among individuals from the same genus or species (Swasti et al., 2007). The higher the similarity among individuals, the closer the relationship. Supporting this statement, Syukur (2012) proposed that the higher the value of similarity coefficient, the higher the similarity level between the compared individuals.

Correlation Analysis of Salak Sugar Content-Contributing Phenotypes

Salak is known for its high sugar content, thus this commodity has a promising potency to be utilized as an alternative source of bioethanol. However, this trait is greatly influenced by environmental factor, especially the altitude. As seen in Table 4, most of salak accessions from those three subdistricts in South Tapanuli conferred high sugar content ranging from 15-20 °Bx (Brix).

Regarding the difference of altitudes where these salak accessions were found, it seemed that different altitude did not give much significant effect on the sugar content of salak grown in all locations observed (Table 4).

Moreover, although the altitude difference was significantly different, but the climate (temperature and light intensity) and soil (pH) conditions did not differ very much among those three subdistricts representing low, mid and highlands (Table 4).Sugar content in a plant part is greatly affected by the climate condition. Geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity and rainfall. These climatic elements are generally depended on the altitude, latitude position, distance from the sea, topography, soil condition and vegetation. Besides the environmental factor, the appearance or performance of a certain phenotype could be affected by the appearance or performance of other phenotypes. In this case, the sugar content of salak plant from those three areas showed low correlation with several phenotypes in other plant parts, such as fruit and leaf. As seen in Table 5, significant correlation was shown in the interaction of sugar content-number of leaf (0.805) and sugar content-number of fruit bunch (-0.667). However, some phenotypes exhibited no correlation at all with the performance of sugar content-contributing phenotypes.

Table 5 also showed that the correlation between sugar content-contributing phenotype and other morphological phenotypes were varied among locations. It indicated that different geographical topography affected the performance of those morphological phenotypes, hence its effect on the sugar content-contributing phenotype was also varied. It also implied that the performance of the sugar content-contributing phenotypes was quite dependent on the vegetative growth of salak. Value of correlation coefficient is commonly used to determine the level of resemblance in the variability among parent plants and its progenies. This value is useful as a refere

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IV. FIGURES AND TABLES

Table.1. Difference of morphological characteristics of salak grown in three different altitudes in South Tapanuli.

Morphological Parameters	Location of Sample Collection		
	South Angkola (low land)	West Angkola (mid land)	Marancar (high land)
Plant height (m)	4.54	5.55	5.26
Stem color		Brown	
Leaves			
Gap among upper leaflets (cm)	3.95	3.48	2.71
Gap among middle leaflets (cm)	6.56	7.56	7.57
Gap among lower leaflets (cm)	9.31	14.54	13.43
Main color of leaf buds	Brown (8 accessions)	Brown (9 accessions)	Brown
Color of leaf upper surface		Green	
Color of leaf bottom surface		Gray	
Leaf color		Grayish green	
Inflorescence			
Position of inflorescence		Positioned in leaf axil (axillary)	
Color of flower bundle		Brown	
Inflorescence color		Pink	
Duration of flower anthesis		3-4 days	
Fruit			
Number of fruit bunch per plant	4	1	
Fruit weight (g)	113	30	
Flesh color		Yellowish white with red spots	

Table.2: Phenotypic variability of salak grown in three subdistricts of Padang Sidempuan based on the quantitative phenotypes

Phenotypes	Mean	S²*	SD**	2 SD	Variability Spectrum
Plant height (m)	307.33	8.29	0.86	0.74	
Leaflets					
Gap among leaflets (cm)					
Upper	278.67	7.17	0.62	0.38	
Middle	532.33	39.97	0.95	0.90	
Lower	426	126.03	2.27	5.17	
Number of leaflets per leaf	761	896.89	6.65	44.28	
Leaflet length (cm)	547	1790.36	7.06	49.88	
Leaflet width (cm)	347.1	932.86	4.79	22.94	
Leaves					
Leaf length	58.63	5.51	0.53	0.28	
Number of leaf	87.73	29.43	1.24	1.53	
Spines					Broad
Spine length	91.3	44.26	1.46	2.14	
Spine width	135.77	22.57	1.11	1.24	
Female inflorescence					
Length of flower bundle	345.67	678.674	6.12	37.45	
Female inflorescence panicle	28.33	10.39	0.75	0.56	
Length of female inflorescence panicle	266	2040.19	9.69	93.98	
Length of female inflorescence	170.67	738.50	6.11	37.30	
Anthesis of female inflorescence	033.33	3.44	0.43	0.182	

Fruits				
Number of fruit bunch	13.58	35.98	3.32	6.63
Fruit weight (g)	313.99	16858.70	78.27	156.54
Flesh thickness	7.81	473.05	0.97	1.95
Seed size	5.17	4.36	3.79	7.575
Seed weight	32.94	107.45	6.05	12.10

Table.3: Phenotypic variability of salak grown in three subdistricts of Padang Sidempuan based on the qualitative phenotypes.

Phenotypes	Range	Mean	S^{2*}	SD**	2 SD	Variability Spectrum
Stem color	Dark brown	Dark brown	0	0	0	Narrow
Leaves						
Main color of leaf bud	Brown, yellow	Brown	0	0	0	
Color of leaf upper surface	Green, dark green	Green	0	0	0	Narrow
Color of leaf bottom surface	Gray, light gray	Gray	0	0	0	
Leaf color	Green, grayish green	Grayish green	188.55	1.44	2.89	Broad
Spines						
Spine color	Black, grayish black	Black	0	0	0	
Spine position on leaf	Single, clustered into 3	Clustered into 3	0	0	0	Narrow
Spine density	Dense, quite dense	Dense	10.15	1.00	2.00	Broad
Inflorescences						
Inflorescence color	Pink	Pink	0	0	0	
Inflorescence position	Leaf axil	Leaf axil	0	0	0	Narrow
Flower bundle	Brown	Brown	0	0	0	
Fruits						
Fruit shape	Round, spherical round	Spherical round	191.34	1.36	2.73	
Peel color	Brown	Brown	56.42	2.36	4.72	
Flesh color			27.12	1.75	3.50	Broad
Seed shape			15.81	1.21	2.43	
Seed color			24.77	1.12	2.25	

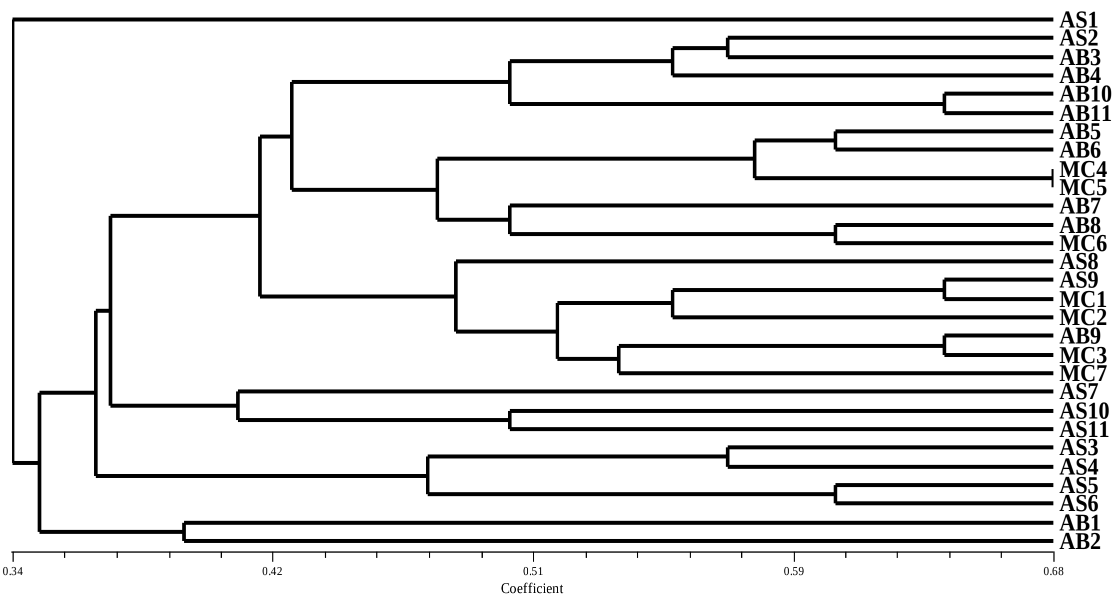

Fig.1: Dendogram of similarity based on quantitative and qualitative phenotypes of all salak accessions. AS, accessions from South Angkola; AB, accessions from South Angkola; MC, accessions from Marancar

Table.4: Effect of the environmental condition differences in the sugar content of salak grown in different locations.

Location/Accession	Sugar content (°Bx)	Altitude (m asl)	Soil pH	Temperature (°C)	Light intensity (%)
South Angkola					
AS1	20.0	218	6.2	29.3	69
AS2	19.0	221	6.2	29.3	66
AS3	18.0	356	5.0	31.0	68
AS4	20.0	355	5.0	32.0	68
AS5	17.0	363	5.3	30.0	69
AS6	18.0	365	5.4	30.0	69
AS7	18.4	350	6.0	27.0	68
AS8	16.3	351	6.1	28.0	70
AS9	17.1	406	6.5	29.0	68
AS10	19.1	400	6.1	29.0	67
AS11	18.3	420	6.1	29.0	74
West Angkola					
AB1	16.1	516	6.0	29.0	66
AB2	14.4	515	6.1	28.0	64
AB3	19.0	731	6.2	28.0	67
AB4	19.1	732	6.3	28.0	67
AB5	16.0	613	6.2	30.0	69
AB6	18.2	615	6.1	31.0	71
AB7	17.0	650	6.5	27.0	68
AB8	15.2	650	6.5	28.0	70
AB9	16.0	671	6.1	29.0	68
AB10	14.3	669	6.1	29.0	67
AB11	17.2	672	6.1	29.0	74
Marancar					
MC1	16.2	965	6.0	29.0	66
MC2	14.4	966	6.1	28.0	64
MC3	19.0	970	6.2	28.0	67
MC4	19.1	971	6.3	28.0	67
MC5	16.0	985	6.2	30.0	69
MC6	18.2	986	6.1	31.0	71
MC7	17.0	990	6.5	27.0	68
MC8	15.2	988	6.5	28.0	70

Table.5: Correlation between sugar content-contributing phenotype and other morphological phenotypes of salak grown in three subdistricts of South Tapanuli

Phenotypes	Correlation coefficient with sugar content-contributing phenotype in each location		
	South Angkola	**West Angkola**	**Marancar**
Plant height	0.344	0.229	-0.071
Number of fruit bunch	-0.667*	0.201	0.073
Leaflet length	0.255	0.385	0.391
Leaflet width	0.023	0.567	-0.345
Number of leaf	-0.152	-0.100	0.805*
Fruit weight	0.255	0.385	0.391
Flesh thickness	0.491	-0.314	0.089
Peel color	0	0	0
Flesh color	0	0	0

Fruit shape	0	0	0
Seed shape	0	0	0
Fruit color	0	0	0
Seed color	0	0	0

V. CONCLUSION

Based on the results obtained, the variability coefficient among salak accessions from those three subdistricts resulted in 34-68%, suggesting that salak diversity in South Tapanuli (Padang Sidempuan) was considered as broad spectrum variability. Regarding its sugar content, the difference of geographical topography where all those accessions were found did not affect the sugar content as it had been naturally high sugar content. Most accessions in all locations conferred more than 15 °Bx sugar content.

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