Path coefficient analysis for growth characters of sago palm related to trunk formation at three years after transplanting

D R Sari¹, L Asrul², R Sjahrit², and K Osozawa³

¹Student master in Agrotechnology, Graduate School of Faculty of Agriculture, Universitas Hasanuddin, Makassar, Indonesia
²Department of Agronomy, Faculty of Agriculture, Universitas Hasanuddin, Makassar, Indonesia
³Faculty of Agriculture, Ehime University, Japan

E-mail: dwiratna.sari_92@yahoo.com

Abstract. The trunk formation in sago palm is the most important growth stage as a sign from the start of starch storage activities on the trunk. Generally, sago palm forms trunk at 4-5 years after transplanting. This study aims to characterize and determine the growth character of sago palm that has a direct influence on the character of the sago trunk diameter in a 3-years after transplanting. The characters observed were trunk diameter, petiole length, rachis length, leaf length, tree height, number of suckers, number of leaves, length of leaflets, the width of leaflets, number of right leaflet and number of the left leaflet. The results showed that there were three characters of sago palm growth which were significantly positive in the formation of trunk diameters i.e. the number of leaves, rachis length, and tree height with the total effect values in cross prints respectively 0.746 **, 0.465 * and 0.676 *.

1. Introduction

Sago palm (Metroxylon sagu) is a native Indonesian Palma plant which is claimed as the center of its distribution from Papua[1]. Sago palm can store a large amount of starch in the trunk with a weight of approximately 300 kg (dry wt.)[2]. Sago has a relatively long life cycle of around 11-12 years in Indonesia[3].

Sago palms have enormous potential to be developed both as a source of food and industrial raw materials. The rapid growth of the sago industry, unfortunately, was not matched by the increase in the sago forest area[1]. As discussed by Tarigans[4], Indonesia still relies on natural and semi-cultivated stands to date. Natural sago population growth is feared unable to offset the rate of logging to meet needs.

Various obstacles are faced in making sago forests. Since sago is only for eastern food, price competition, limited processing of products produced, popularity, and long harvest age can influence people to not planting sago.

Four periods of sago growth stage consist of initial growth or cluster (russet) takes 3.75 years, the trunk formation stage takes 4.5 years, the inflorescence stage (flowering) takes 1 year and the seed formation stage takes 1 year[5]. This study used samples of sago plants that had formed trunks at the age of three years after transplanting.

Trunk formation of the sago palm is very important because the sago trunk is a storehouse of starch. Sago's palm experiences very rapid growth until they enter the trunk formation stage. After
that, the sago palm experiences constant growth every month to form flowers. Each growth character of sago palm has a correlation with the formation of sago trunks. Many studies have been conducted on the growth character of sago palm after several years forming the trunk. However, there has been no clear research results regarding the criteria of growth characters as a sign that sago has formed a trunk. For this reason, this study went into the relationship growth character of the sago palm to trunk formation which enters the trunk formation stage at 3 years after transplanting.

2. Materials and methods
The research was conducted in August 2016 at the Sago Cultivation Experiment Field by Hasanuddin University, in Pengkajoang Village, West Malangke District, North Luwu Regency, South Sulawesi. The area has entisol soil type grade sulfaquents, dan hydraquents with flat topography, 3000-3500 mm/year rainfall, has 2 dry months and 7-9 wet months. The average air temperature ranges from 30.6 °C - 31.6 °C in the dry season and 25 °C - 28 °C in the rainy season.

The sago palm used in this study were 10 plants from the collection of UNHAS Sago Cultivation Experiment Field. Currently, the land around the study area is more used for planting corn, chocolate, and patchouli. Sago was grown at a distance of 10 m x 10 m. Between the rows, there was a trench about 1 m wide. There were no fertilization activities or efforts to protect pests and diseases, all we do was land clearing activities.

Data was taken by direct observation through quantitative measurements on the trunk and leaves of the sago palm. The characters observed were trunk diameter, petiole length, rachis length, leaf length, tree height, number of suckers, number of leaves, length of the longest leaflet, width of the widest leaflet, number of right leaflets, and number of left leaflets (illustrated by figure 1).

Figure 1. Illustration of sago palm leaf

In studying the relationship between observed characters, a correlation analysis was conducted. In the final section, a path analysis was carried out to study the magnitude of direct and indirect effects on each growth character on the formation of trunk diameter. The analysis used IBM SPSS Statistics software version 21.

3. Results and discussion
The research location has entisol soil type grade sulfaquents, dan hydraquents, with average rainfall of 3000-3500 mm per year. The optimum rainfall for sago is 2000 mm per year [7]. Sago palms can grow in various types of undeveloped soils, such as sulfaquents (sulfidic soil), hidraquents (waterlogged), tropaquents (tropical climate), fluvaquents (alluvial), and psammaquents (sandy soils)[8]. Based on these data, the research location was considered appropriate for sago growth. Sago palms planted begin to form trunks at the age of three years after transplanting. Flach[9] mentions that there are also sago plants that have a longer growth period, stem formation more than 4.5 years and a life cycle of more than 16 years depending on the type and condition of the environment. Observations from ten samples of sago palm that form trunk at 3 years after transplanting are presented in table 1.
The size of the sago palm diameter ranged from 48.5 cm - 60.1 cm, while height of tree was 900 - 1100 cm. In line with results of research by Flach[3], the sago trunk diameter without midrib ranged from 35-60 cm with a height of 6-16 m depending on the variety and environmental conditions.

Sago palm that has formed trunks, there is sago palm that has no suckers. The amount of fresh green leaves owned by this group ranged from 16-26 strands. In contrast to the previous study of sago plants, the plantation showed the number of green leaves found in sago palm before the trunk formation stage reached 9-12 strands for 1 year after transplanting sago suckers and experienced a little afterward until trunk formation[10]. Whereas the sago palm in the trunk formation stage has 10-20 living leaves[11].

The length of petiole in trunk formation stages was from 1.8 m to 3.1 m. It is shorter than the length of the petiole during the rosette stages. The petiole is still experiencing elongation until the end of the trunk formation stage[12]. In this study, petiole length ranged from 140 - 188 cm; while the rachis measured 230 - 392 cm.

The size of leaflets in this study had about 110.4 - 164.0 cm and a width of around 7.0 - 9.3 cm. There were 82 - 138 leaflets on each leaf. The number of leaflets during trunk formation ranged from 140 to 180 leaflets[10]. Flach[9] states that trunk formation begins when a certain leaf size is reached. The size of the leaves was almost constant after entering the stage of trunk formation until the flower bud formation. During the rosette period, before the trunk was formed, sago leaves were smaller than the size of the adult leaves. Leaf production speed was faster when the trunk had been formed.

Correlation analysis is intended to find out how strong the relationship between one or several variables with another variable[13]. Correlation methods can measure the strength of the relationship between two variables whose relationship characters are symmetrical or reciprocal. The correlation
The correlation coefficient between the growth characters of sago palm towards the formation of trunk diameter is presented in Table 2.

**Table 2. Correlation Coefficients between Observation Variables**

| Variable | X1   | X2   | X3   | X4   | X5   | X6   | X7   | X8   |
|----------|------|------|------|------|------|------|------|------|
| X2       | 0.509* |      |      |      |      |      |      |      |
| X3       | 0.211 | 0.551* |      |      |      |      |      |      |
| X4       | 0.228 | 0.379 | 0.176 |      |      |      |      |      |
| X5       | 0.111 | 0.299 | 0.013 | 0.462* |      |      |      |      |
| X6       | 0.382 | 0.418 | 0.117 | 0.281 | 0.211 |      |      |      |
| X7       | -0.323 | 0.163 | 0.143 | -0.104 | -0.472* | -0.056 |      |      |
| X8       | 0.028 | 0.271 | -0.044 | 0.038 | 0.210 | 0.240 | 0.170 |      |
| Y        | 0.746** | 0.465* | 0.175 | 0.323 | 0.283 | 0.676** | -0.401 | 0.188 |

Information: (X1= number of leaves; X2= rachis length; X3= length of longest leaflets; X4= width of widest leaflets; X5= number of leaflets; X6= tree height; X7= petiole length; X8= number of suckers; Y= Trunk diameter; ns= not significant; **= significant at level 1%; *= significant at level 5%).

The character of the trunk diameter of the sago palm shows a really positive relationship with the number of leaves, rachis length, and tree height with the correlation coefficient values of 0.746 **; 0.465 * and 0.676 *. However, the trunk diameter character shows a positive relationship but not significant with leaf length (0.175), leaflets width (0.323), number of leaflets (0.283), number of suckers (0.188), and a negative relationship to character petiole length (-0.401). It means that every increase in characters that has a real positive direct effect will increase the size of the trunk diameter while characters that have a real negative direct effect (leaf width) will decrease the size of the trunk diameter.

To provide an explanation of the correlation of the relationship model above, path analysis was carried out. Information obtained from path analysis can be used as an alternative to determining the character of effective selection [13]. Thus, the direct and indirect effects given by each growth character can be shown in figure 2.
Photosynthesis in strongly supports plant growth and plants to obtain sunlight among competition from other plants. Miyazaki palm which is 3 years old after transplanting. Tree height is very closely related to the effort of sago leaflets, $X_6=$ tree height; $X_7=$ petiole length; $X_8=$ number of leaflets; $X_1=$ number of leaves $X_2=$ rachis length; $X_3=$ length of longest leaflets; $X_4=$ width of widest leaflets; $X_5=$ number of suckers; $Y=$ Trunk diameter; ns= not significant; *= significant at level 1%; **= significant at level 5%

Table 3. Direct and indirect effects, and correlation coefficient values between growth character and trunk diameter

| Character | Direct effect | Indirect effect through | Total effect |
|-----------|--------------|-------------------------|--------------|
|           | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 |              |
| X1        | 0.445* |   | 0.020 | 0.009 | 0.017 | -0.007 | 0.165 | 0.093 | 0.003 | 0.746** |
| X2        | 0.039 | 0.039 | 0.025 | 0.028 | -0.019 | 0.181 | -0.047 | 0.033 |        | 0.465*  |
| X3        | 0.045* | 0.045 | 0.094 |   | 0.021 | -0.001 | 0.051 | -0.041 | -0.005 | 0.175** |
| X4        | 0.073* | 0.073 | 0.101 | 0.015 |   | -0.03 | 0.121 | 0.03 | 0.005 | 0.323** |
| X5        | -0.065** | -0.065 | 0.049 | 0.012 | 0.001 |   | 0.091 | 0.136 | 0.026 | 0.283** |
| X6        | 0.432* | 0.432 | 0.17 | 0.016 | 0.005 | 0.021 |   | 0.016 | 0.03 | 0.676** |
| X7        | -0.289** | -0.289 | -0.144 | 0.006 | 0.006 | -0.008 | 0.031 |   | -0.021 | -0.401** |
| X8        | 0.123** | 0.123 | 0.012 | 0.011 | -0.002 | 0.003 | -0.014 | 0.104 |   | 0.188** |

Based on figure 2, the height of the tree has a direct influence on the trunk formation of the sago palm which is 3 years old after transplanting. Tree height is very closely related to the effort of sago plants to obtain sunlight among competition from other plants. Miyazaki[14] states that sunlight strongly supports plant growth and development because the sun acts as energy for photosynthesis. Photosynthesis in the form of carbohydrates is needed by the plants in filling starch in the trunk.

Figure 2. Track diagram of character growth and trunk diameter

(X1= number of leaves X2= rachis length; X3= length of longest leaflets; X4= width of widest leaflets; X5= number of leaflets, X6= tree height; X7= petiole length; X8= number of suckers; Y= Trunk diameter; ns= not significant; *= significant at level 1%; **= significant at level 5%)
Information: (X1= number of leaves X2= rachis length; X3= length of longest leaflet; X4= width of widest leaflet; X5= number of leaflets, X6= tree height; X7= petiole length; X8= number of suckers; Y= Trunk diameter; ns= not significant; **= significant at level 1%; *= significant at level 5%).

Based on table 3, only tree height gives a real direct effect on trunk formation. However, by calculating the indirect effects given by each growth character observed, a number of leaves, rachis length, and tree height are important characters that give total influence on the trunk formation of diameter size. The number of leaves is the most potential characters as character selection because it is a place where photosynthesis occurs to produce photosynthetic substrates for plant growth[15][2]. Flach[9] states that trunk formation in sago palm has to do with the size of certain leaves. The size of the leaves is almost constant after entering the trunk formation stage until the flower bud formation. Increasing the number of leaves occurs to produce a larger leaf area for photosynthesis to produce photosynthate substrates for plant growth[16]. Yamamoto[17] stated that rachis is the main part of the leaf that supports the leaf strands and has the task of placing leaf strands in such a position that they can get as much sunlight as possible. It is also very closely related to tree height which has an important meaning in estimating the yield of the sago palm.

4. Conclusion
Path analysis showed that there were three growth characters of sago palm which were significantly positive in the formation of trunk diameter, namely the number of leaves, rachis length, and tree height with the total effect values in cross-prints respectively 0.746 **; 0.465 * and 0.676*.

References
[1] Abbas B, Bintoro MH, Sudarsono, Surahman M, Ehara H. 2009. Genetic relationship of sago palm (Metroxylon sagu Rottb.) in Indonesia based on RAPD markers. Biodiversitas 10(4) : 168-174.
[2] Ehara, H. 2009. Potency of Sago Palm as Carbohydrate Resource for strengthening the Food Security Program. Indonesia Journal of Agronomy 37(3) : 209 – 219.
[3] Flach M. 1977. Yield Potential of The Sago Palm and Its Realization. In: Sago ’76: Papers of The 1st International Sago Symposium “The Equatorial Swamp as a Natural Resources”. (Tan, K. Ed.) University of Malaya (Kuala Lumpur)
[4] Tarigans, D. D. 2001. Sagu Memantapkan Swasembada Pangan. Warta Penelitian dan Pengembangan Pertanian 23: 1-3. (in Indonesian)
[5] Flach. 1983. The Sago Palm, FAO Plant Production and Protection Paper 47, FAO (Rome).
[6] Nakamura, S., Y. Nitta, Y. Goto. 2004. Leaf Characteristics and Shape of Sago Palm (Metroxylon sagu Rottb.) For Developing A Method of Estimating Leaf Area. Plant Production Science 7: 198-203
[7] Okazaki M, Kimura SD. 2015. Ecology of the sago palm. In: The sago palm, the food and environmental challenges of the 21st century. The Society of Sago Palm Studies, Kyoto University Press, pp 41–60
[8] Notohadiprawiro T, Louhenapessy JE. 1992. Potensi sagudalampengenekamanbahanpanganpokokditinjauariharpersyaratanlanahan. Prosiding Simposium Sagu Nasional. Fakulas Pertanian Universitas Pattimura. Ambon. Hal, pp 99–106 (in Indonesian)
[9] Flach M. 1997 Sago palm. Metroxylon sagu Rottb. Promoting the Conservation and use of underutilized and neglected crops. 13. Rome, Italy (IT) : Institute of Plant Genetics and Crop Plant Research, Gatersleben/ International Plant Genetic Resources Institute. Pg 12-20.
[10] Yamamoto, Y., T. Yoshida, A. Miyazaki, F.S. Jong, Y. B. Pasolon, H. Matsumubun. 2005 Studies on Starch Productivity and The Related Characters of The Sago Palm (Metroxylon Sagu Rottb.) Varieties In Irian Jaya, Indonesia. Proceedings of The 14th Conference of The Society of Sago Palm Studies, 8-13.
[11] SSPS (The Society of Sago Palm Studies). 2015 *The Sago Palm: The Food and Environmental Challenges of The 21st Century.* Kyoto University Press

[12] Nakamura S, Watanabe M, Goto Y. 2015 *Leaf formation and development. In: Sago palm: the food and environmental changes of the 21st century.* Kyoto University Press and Trans Pacific Press, pp 104–109

[13] Abdurahman, Maman, Muhidin, Sambas & Somantri, Ating. 2012 *Dasar-Dasar Metode Statistika Untuk Penelitian.* Bandung: CV. Pustaka Setia. (in Indonesian)

[14] Miyazaki A, Yamamoto Y, Omori K. 2007 *Leaf photosynthetic rate in sago palms (Metroxylon sagu Rottb.) grown under field conditions in Indonesia.* Japan J Trop Agric 51:54–58

[15] Tenda, E.T., Miftahorrachman. 2014 *Hubungan Karakter Vegetatif Dengan Produksi Sagu Baruq (Arenga macrocarpa Becc.) Asal Kabupaten Sangihe.* JurnalLittri 20 (4), Desember 2014, Hlm 203-210. ISSN 0853-8212. (in Indonesian)

[16] Ehara, H. 2018 Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. ISBN 978-981-105269-9 (eBook)

[17] Yamamoto Y, Omori K, Nitta Y. 2014 *Changes of leaf characters in sago palm (Metroxylon sagu Rottb.) after trunk formation.* Trop Agric Devel 58:43–50