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ENVIRONMENT, GROWTH AND BIOMASS PRODUCTION OF SAGO PALM (*Metroxylon sagu* ROTTB.): A CASE STUDY FROM HALMAHERA, PAPUA AND KENDARI

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Abstract

***Abstract*: -** We observed that physical and chemical properties of sago palm growing in three subdistricts of Southeast Sulawesi Province were different with sago growing area in Papua and North Maluku Provinces. Soil texture was loamy to silty loam, BD was 0.598 to 1.360 g/cm^3 and water table was 20 to 150 cm depth. Soil pH was 5.21 to 6.34, available P, total N, and exchangeable K, Ca and Mg was low to very low. C-organic was variable from low to very high. Average of monthly rainfall was 56 to 79 mm month^{-1} in dry season to 200 to 450 mm month^{-1} in wet season, temperature was 15 to 34^{o} C in Southeast Sulawesi Province. Agronomic characteristics indecated that there are three sago types was observed in Southeast Sulawesi Province, more the seven types of sago palm was observed in Sentani Papua Province and five types of sago palm was observed in Noth Maluku Province. The average of trunk fresh weight was 822 kg/palm on spiny type sago to 2093 kg/palm on nonspiny type sago. Plant age of sago palm at harvest time was 6.40 years after trunk form on spiny type sago and 9.75 year after trunk form on nonspiny type sago. We concluded that the diversity and biomass potential of sago palm grown in Sentani Papua Province was higher than sago palm grown in Maba North Maluku and Southeast Sulawesi Provinces.

Key-Words : Agronomic characteristics, Chlorophyll content, Sago palm, Soil properties, Genetic diversity

INTRODUCTION

Sago palm is one of the most important crop in development and cultivation of marginal land in Province of Southeast Sulawesi as reported previously (Pasolon et al., 2011). Centuries ago, sago palm was traditional using as the sources of carbohydrate in many areas of eastern part of Indonesia and Papua New Genia. In Indonesia sago palm mainly growing in Maluku, Seram, Halmahera, Sulawesi, and some parts of Kalimantan and Riau Islands (Ehara et al., 2000). This crop is tradisionally used as staple food for indigenous people those living in that islands.

Earlier studies which conducted in Kendari, the province of Southeast Sulawesi and in Sentani Jayapura, the province of Papua, reported that mature sago palm can produce 140-425 kg starch/palm. The harvest–palm/ha/year in natural sago area was estimated at 22 palms which is equivalent to 3,080-9,350 kg starch/ha/year (Yanagidate et al., 2009; Pasolon et al., 2011). In order to reduce atmospheric CO_2, sago palm has a big potential as shown by average of photosyntetic rate (PR) of sago palm was 17.2 mg CO_2 dm^{-2} h^{-1} (Miyazaki et al., 2007). When leaf area (LA) of sago palam range from 111 to -447 m^2 per palm (Yamamoto et al., 2014), it could be estimated that C fixed of sago palm per year was equivalent to 167.246 to 673.504 kg C/palm/yr, by the following equation (1):

$$C\text{-}fixed = PR \times (LA \times 100) \times PP \times 0.30\ C \times 10^{-6}\ \mathbf{kg} \quad (1)$$

PR = photosynthetic rate, 17.2 mg CO_2 dm^{-1}h^{-1}
PP = photo period, 8 h/day x 365 days/yr,
LA = leaf area, 111 to 447 m^2/palm,

Much amount of C fixed by sago palm was storage in trunk as pith biomass which containing 60 to 70 % starch (Yamamoto et al., 2010). Based on te above estimation, we estimated that C storage in sago palm forest might be higher than C storage in mangrove forest (Ceron-Breton et al., 2014).

We observed that sago palm adapted to variable soil chemical and water regimes (Rembon et al., 2010; Chutimanukul et al., 2014). It also reported that sago palm was salt resistance palm due to mechanism of restriction of an excess influx of Na^+ from the cortex into the stele (Ehara et al., 2008). The same phenomenon was observed on sago palm seeding which can telerated upto 342 mM (2 %) NaCl. This concentration was higher than treatment on *Tetragonia tetragonioides* and Turfgrass (Neves et al., 2008; Beltrao et al., 2009), which categorized as salt tolerant species.

This experiment purposed to identify the physiological, agronomic characters and potential biaomass production of natural sago palm growing in eastern part of Indonesia: Southeast Sulawesi, Sentani Papua and East Halmahera Provinces, with the following activities: (1). Study of soil physics and chemical properties, (2). Measuring and identification of sago palm characteristic, (3). Measuring of soil water pH and salt content in the sago growing area, and (4) exploring of farmer oppinion on sago palm's foods, local name of sago palm, trunk diameter, chlorophyl content.

MATERIAL AND METHODS

The map of experimental location shown in Fig. 1: experiment 1 in Province of Southeast Sulwesi, Experiment 2 in around lake of Sentani near JayapuraProvince of Papua and experiment 3 in Maba City, East Halmahera Regency.

1 Side Description

1.1 Experiment 1

This experiment was conducted in three side of sago palm forest namely Abeli subdistrict of Kendari City (S = 04^o 00' 25.4" , E= 122^o 38' 15.8") with altitude 15 m above sea level, Abeli Sawa subdistrict (S = 03^o 57' 21.0" , E = 122^o 26' 52.5 ") with altitude 22 m above sea level and Andepali subdistrict (S = 04^o 00' 48.1" , E = 122^o 22' 56.5") with altitude 147 m above sea level, Regency of Konawe, Province of Southeast Sulawesi.

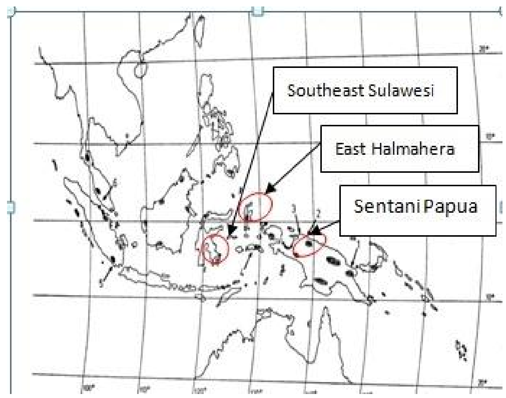

Fig. 1 Map and location of experiments

The position of Abeli subdistrict was 200 m from sea side and water table was 150 cm depth. Abeli Sawa was temporary flooded in the rainy season, with water table was 32 cm depth. Andepali subdistrict was mountain side, ground water level was 67 cm depth. Soil bulk density was range from 0.40 g cm^{-3} (Abeli Sawa), 1.25 g cm^{-3} (Andepali) to 1.47 g cm^{-3} (Abeli). Soil texture was loam and silt loam in Abeli, sandy clay loam in Abeli Sawa and loam to silt loam at Andepali (Brady and Weill. 1996).

Monthly rainfall in around location was 56 to 79 mm $month^{-1}$ in dry season (June to September) and 200 to 450 mm $month^{-1}$ at wet season (October to April). Minimum temperature was 15 to 22^o C and maximum temperature was 31 to 34^o C, respectively (Pasolon et al., 2011.

1.2 Experiment 2

The experiment was conducted at Koya, Yabaso, Yahim and Ifar Besar subdistricts which located in around Lake Sentani near

Jayapura, Province of Papua. The averange of soil bulk density was 0.598 g cm^{-3} with ground water level was range from 15 to 40 cm depth in Koya, Yabaso, and Yahim and and 150 cm at Ifar Besar. Soil textur was loam and silt loam (Widjono et al., 2000; Rembon et al., 2010;).

1.3 Experiment 3

The experiment was conducted in around Maba City, Regency of East Halmahera, Province of North Maluku. Experimental location was was 100 m from sea side. The area was frequently flooded at rainy seasons with ground water level was 0 to 40 cm depth, respectively. Soil water pH was range from 7.6 to 7.78 and NaCl content was 0.05 %.

2 Sampling

2.1 Soil Sampling and analyses

Ground water level measured in the field by using soil auger and meter tape. Soil sample for laboratory analyses collected by using soil auger at 0 to 30 cm depth. Soil bulk density (BD) was collected using cylindrical metal ring sampler (7.5 cm length by diameter 5.5 cm) at at two soil depths: 0 to 15 and 15 to 30 cm depth (Rembin et al., 2010). Colected soil sample with metal ring sampler then oven dry at 100^{o} C for 24 hours upto constant weight. Soil BD measured by the following equation (2) (Brady and Weil, 1996):

$$BD = \frac{W}{V} \qquad (2)$$

BD : bulk density (g/cm^3),
W : weight of oven dry soil (g),
V : volume of cylindrical metal ring (cm^3)

Methods for soil preparation and laboratory analyses as explained in previous report (Rembon et al., 2010).

2.2 Sago Palm Sampling

Measurement and identification of sago palm charactertics was determined as follows:
In Experiment 1: we selected three mature palms of sago Molat from each side. Total sample was nine palms. In Experiment 2: we selected eight palms. Each palm was representative from seven types sago palms, with local namely: Rondo, Manno Hongleu, Manno Kecil, Panne, Wanni, Folo and Osokulu (Widjono et al., 2010). The selected mature palms then cut down using a chainsaw. Total plant length, trunk length, leaf scars and leaf number measured after trunk was clean. Sampling process and measurement of trunk length and trunk weight as explain in previous report (Yamamoto et al., 2010; Pasolon et al., 2015). In Experiment 3: we observed five types of sago palms: Bawet, Gigemin, Wagam, Silva and Salime. The measurements was conducted as follows:

- Trunk diameter at breast height or 130 cm from soil surface of mature palm was measured by using meter tape. The diameter was calculated by a simple formula (3):

$$TDBH = \frac{TC}{\pi} \qquad (3)$$

TDBH : trunk diameter at breast height (cm)
TC : trunk circle (cm)
π : 3.14

- Trunk volume of sago palm measrured calculation with equation (4):

$$TV = \pi \, x \, r \, x \, t \qquad (4)$$

TV : trunk volume (m^3),
r : radial (½ x TDBH) (cm)
t : trunk length (m)

The age of sago palm was calculated by equation (5) [16]:

$$P.\,A = \frac{(LS+FL)}{12} \qquad (5)$$

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P.A : palm age (yr)
LS :No. leaf scars
FL :No. functional leaves

- Chlorophyll content of the middle leaflet was taken from the mature leaf of sago sucker. The Chlorophyll content then measured by Chlorophyll Meter SPAD-502 (Minolta Co. Ltd., Japan) [5].
- Soil water was collected from five sides where sago palm grow. Soil water pH was measured by Compact pH Meter Twin pH (Horiba, Ltd, Japan).
- NaCl concentration (%), was measured by Compact Salt Meter, Model C-121, and NaCl ions (ppm) was determined by Compact Ion Meter model C-122 (Horiba, Ltd., Japan).

Identification of sago types was conducted based on the several characters:

- Local name
- Spines: yes or no,
- Petiol and rachis color at the mature stage
- Trunk performance: length and size
- Leaflet: color, density, size and thicknes
- Palm age at harvest time.

RESULT AND DISCUSSION

1. Farmer Interviewe

All respondenits agree that starch from sago palm is used as an alternative food by ppeoples with high income family but as main food by the poor family. The sago consumption has decreased from 2002 when the central goverment introduced rice subsidy for poor family. Recently, most of familis still consume sago starch as supplementary food.

2. Chemical Properties of Soil

In Tabel 1 we shown that soil properties at two region of sago palm garden was quitly different mainly on C-orgnic and CEC properties. C-organik and CEC was high content in sago garden of Southeast Sulawesi than in Sentani Papua. Soil properties at Southeast Sulawesi have significantly correlationsip with sago palm grown in this area.

Table 1. Average of soil chemical properties at sago garden in Southeast Sulawesi and Sentani Papua

Location	Parameters	Values
Southeast Sulawesi	pH (H_2O)	5.21
	C-organik (%)	10.07
	Total -N (%)	0.44
	Bray-2 P (ppm)	2,33
	CEC (me/100 g)	26.89
	Exch. K (me/100 g)	0.29
	Ca (me/100 g)	3,38
	Mg (me /100 g)	0,39
Sentani, Papua	pH (H_2O)	6.34
	C-organik (%)	4.64
	Total -N (%)	0.39
	Bray-2 P (ppm)	2.55
	CEC (me/100 g)	17.31
	Exch. K (me/100 g)	0.36
	Ca (me/100 g)	4.91
	Mg (me /100 g)	0.53

This phenomenon was not observed in Sentani Papua. In Maba area, soil water pH was 7.6 to 7.78 and there is no a significantly difference of soil pH at 20 cm and 40 cm depth. NaCl content at 20 cm to 40 cm depth was 0.05 %, as shown in Table 2.

3 Characteristics of Sago

The characteristics of sago palm in three main regions of sago palm in Eastern part of were described based on the following characters.

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Tabel 2. Chemical properties of soial water pH in sago growing area, Maba East Halmahera

No	Sago type	pH		NaCl (%)	
		20 cm	40 cm	20 cm	40 cm
1	Bawet	7.2	7.9	0.07	0.07
2	Gigemin	7.7	7.9	0.07	0.05
3	Wangam	7.7	7.4	0.07	0.08
4	Silva	7.8	7.6	0.02	0.01
5	Salime	7.4	7.9	0.03	0.03
Average		7.6	7.7	0.05	0.05

3.1 Type and Morphology

Traditional farmer has documented three ecotypes of sago palm in Southeast Sulawesi Region, namely: Sagu Rotan, Sagu Rui and Sagu Molat(Yamamoto et al., 2010), in this report we described only one ecotype (Sagu Molat) and shown in Table 3.

Table 3. Agronomic characteristics of sago Molat grown in Southeast Sulawesi Province

Agronomic Characters	Subdistrict: Abeli	A.Sawa	Andepal
Plant length (m)	18.0	21.0	21.3
Trunk length (m)	9.23	9.50	12.06
Trunk diameter (m)	0.49	0.58	0.53
Trunk weight (kg)	1422	1984	1877
No.leaf scars (a)	65	78	94
No.**f**unctional **le**aves (b)	21	21	14
(a+b)	86	99	108
No.leaflet (no./leaf)	176	176	163
Plant age (yr)[1]	7.17	8.25	9.0
Plant Stage[2]	Flw.I	Flw.I	Flw. I

[1]Estimated palm age: calculated by eaquation (5). [2]Flw.I: flower initiation, Flw: flowering, Bolt.: bolting stages.

In Sentani Papua we observed there are many potential of sago palm grown in around Sentani lake. Some of them are; Rondo, Manno Hongleu, Manno Kecil, Osokulu, Wanni and Follo. In this report we reported only eigh palms which grouped in Non spiny type: palm (P.) no. 4 (Folo), P.5 (Osokulu), P.7 (Wani) and P.9 (Pane) as shown in Table 4. For spiny type sago palm: P.6 and P.13 (Rondo) and P.10 and P.11 (Manno) as shown in Table 4. In Maba City, we observed five ecotypes: Bawet, Gigemin, Wagam, Silva and Salime. The morphology and agronomic characters of each sago type we described in Table 5.

In Sentani Papua Province we described six ecotypes of indigenous sago palms. Local farmer identified that there are two groups of sago palm growing there: Spiny and nonspiny types, with agronomic characters as shown in Table 4.

Table 4. Agronomic characteristics of sago palm grown in Sentani, Papua Province

Agronomic characters	A. Non spiny type: Pane P.9	Wani P.7	Folo P.4	Osokulu P.5
Plant length (m)	19.35	21.80	17.45	21.5
Trunk length (m)	8.20	12.40	7.70	11.40
Trunk diameter (**m**)	0.68	0.47	0.49	0.5
Trunk weight (kg)	2544	2246	1351	2230
No.leaf scars (a)	93	110	82	92
No.funct. leaves (b)	27	19	14	27
(a+b)	120	129	96	119
No.leaflet (no./leaf)	177	134	142	157
Plant age (yr)[1]	10	11	8	10
Plant Stage[2]	Flw.I	Flw.	Flw.	Bolt

Agronomic characters	B. Spiny type: Rondo Manno P.6	Rondo P.13	Manno P.10	P.11
Plant length (m)	14.7	14.92	19.30	13.35
Trunk length (m)	3.70	5.10	8.40	5.63
Trunk diameter (m)	0.44	0.42	0.54	0.42
Trunk weight (kg)	545	630	1447	664
No.leaf scars (a)	63	40	83	61
No. funct. leaves (b)	15	14	25	21
(a+b)	78	54	108	82
No.leaflet (no./leaf)	166	174	141	126
Plant age (yr)[1]	5.25	4.50	9.0	6.83
Plant Stage[2]	Bolt.	Flw.I	Bolt.	Frut.

[1,2]Same an explanation in Table 2

3. 2 Chlorophyll Content (SPAD)

Chlorophyll content (SPAD) as shown in Fig. 2 indicated that SPAD for Wagam, Gigemin were less then 60 and the SPAD value for the other palm was higher then 60. The small SPAD of Wangam and Gigemin indicated that chlorophyll content of this sago type was small and this may related to the yellowish of petiole, rachis and leaflet as shown Table 5.

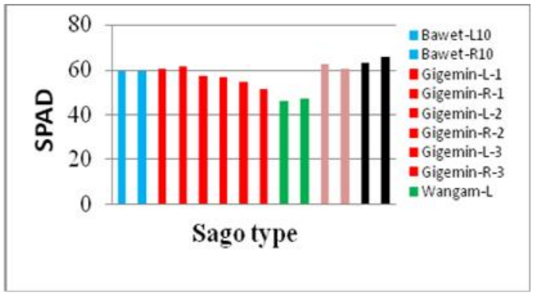

Fig. 2. Chlorophyll content in leaflet of sago palm, Grown in Maba, East Halmahera

Fig. 2 shown that there was no diferent of chlorophyll content in left and right side leaflet. Salime and Silva types containing higher amount of chlorophyll as compared with the other sago type in Maba Subdistrict. We observed that trunk length, trunk weight and leaf scars of nonspiny types was higher than spiny types as shwon in Table 4.

Table 5. Morphological of sago palm grown in Maba, East Halmaheta

No.	Local name	Main characteristics*
1	Bawet	Molat type, spineless, darkis petiole near to mature
2	Gigemin	Tuni type, spine, tall trunk, dense of spine, produced seed and soft leaflet
3	Wagam	Molat type, spineless, yellowish of petiole, rachis and leaflet
4	Silva	Molat type, spineless, big trunk, leaflet sparse, wide and hard
5	Salime	Rotan type, spine, short trunk, early maturity

*Molat, Tuni and Rotan as explain in (Yamamoto et al., 2010).

Biomass production in trunk of sago plams was higher on nospiny types (e.g 2093 kg/palm in Sentani, 1761 kg/palm in Southeast Sulawesi) if compering with spiny type in Sentani (822 kg/palm). How ever, growing period (palm age at harvest time) was shorter in spiny type (4.5 to 9.0 years) than non spiny types (8.0 to 11 years) as shown in Table 4. Based on the plant age, sago Rondo and Manno was shorter therefore, those palms categorized as early maturity sago palm and non spiny types was categorized as late maturity sago palm.

3.3 Trunk Diameter

Trunk diameter at breast height (DBH) of sago palm in Maba was varied from 35 to 47 cm as shown in Fig. 3. Trunk diameter at DBH and height are the important indicator for the trunk volume and the potential of starch production.

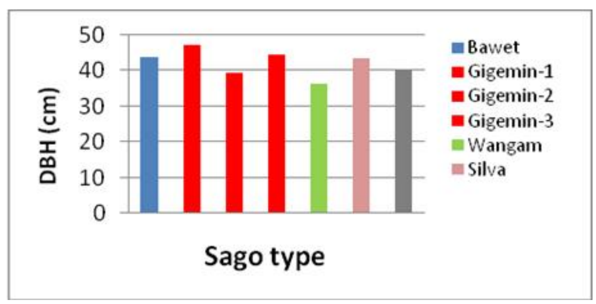

Fig. 3. Trunk diameter of sago palm

CONCLUSION

Based on the above results, we concluded that there are two groups of sago palm growing in eastern part of Indonesia: Spiny and non spiny types. Each sago type consist of different ecotypes. Based on trunk fresh weight we concluded that spiny type sago produced lower biomass than nonspiny type, how ever, harvesting time of spiny type sago was shorter than nonspiny

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type sago. In developing of sago palm plantation mixed of spiny and nonspiny type sago may be one of the strategy to improve biomass production of natural sago plantation in the future. Since sago palm was adapted to variable of climatic, soil physics and chemicals, it could be recommended to use sago palm plantation in combating hungger and poverty in many regions of humid tropical countries.

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