ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.08 pp 511-518, 2016

Comparative Studies on Different Agroecosystem Base on Soil Physicochemical Properties to Development of Sago Palm on Dryland

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Abstract : Sago palm (*Metroxylon sagu* Rottb) is a key staple food for residents in eastern Indonesia and the second staple food after rice so that it becomes favorite local food. Development and utilization of sago is very strategic to support and ensure the food security in Indonesia. The development of sago in Indonesia faces serious problems due to the narrowing areas of sago planting and declining of its production potency. Development of sago palm should be directed to be conducted on dry land. Although the dry land is not the native habitat of sago palm, but it is abundant compared to the limited wetland. Therefore, it is necessary to characterize the effect of different environmental conditions on sago planting, mainly concerning the relation of soil physical and chemical properties to the growth, production potential, and quality of produced sago starch. The research results showed that (1) sago plant has a better growth on wetland than on dry land, (2) despite the dry land is less suitable for the cultivation of sago, but if nutrients required by sago plants are available, then the sago plants can be grown on dry land, (3) Therefore, to obtain high growth and production on dry land, the addition of organic matter is needed.
Key words : Sago, Starch, Dry land, Wetlands, Staple food.

Introduction

Sago is one of carbohydrate producing plants that is used as the staple food for most of Indonesian, especially for those in East Indonesia[1,2,3]. Sago palm has a potential to accumulate large amount of carbohydrates that could reach 25 tons per hectare. Rice, corn, wheat and potatoes accumulate carbohydrates to only 6.0 tons, 5.5 tons, 5.0 tons and 2.5 tons per hectare, respectively[4,5,6].

Development and utilization of sago is very strategic to support and ensure the food security in Indonesia. Moreover, sago plants are well-known to be resistant to climate change, drought, flood, pests and diseases. Besides, sago is also able to suppress methane emissions and absorb carbon dioxide, and in turns reducing the greenhouse effect [7,8]. Sago has become an important raw material for industrial[9], such as *acetone-butanol-ethanol* fermentation substrate[10], degradable plastics[11,12], liquid sugar industry[13], food flavoring[14], and even used for new energy sources such as bio-ethanol[15]. Sago starch is also used in medical industry, cosmetic, paper, ethanol, and textile. Moreover, the waste of sago management can be used as livestock food[16] and being played important role as a source of farm and non-farm income generation of poor rural communities [17].

Potential of Indonesian sago is estimated to reach one million hectare, equivalent to 5.1-8.1 million tons per year of dry sago starch. Approximately 90% of Indonesia sago area is in the Papua region. Despite it has many uses and advantages, sago cultivation faces serious problems due to the narrowing areas of sago planting and declining of its production potency[18,19]. Sago planting areas, outside Papua region, are declining each year, due to land conversions to settlements, rice fields or expansion of industrial crops such as oil palm. The decrease also occurs because of the extractive nature of sago management and harvesting, in which sago is being harvested without any cultivation or replanting efforts[20].

Another problem encountered in the cultivation of sago is increasing number of narrowing of wetlands, the original habitat of sago palm. This land is usually in the form of swamps or stagnant land located along the river. The narrowing of wetlands occurs not only due to conversion of land use, but also caused by changes in climate patterns and water use planning. Wetlands that were originally flooded then underwent drying process and turned into dry land permanently.

Even though sago is a local food, it is quite strategic in strengthening food security in Southeast Sulawesi. In fact there is an obvious tendency of shrinking planting areas year by year as a result of land conversions. As a result, planted sago area in Southeast Sulawesi originally reached 13,706 ha but it is currently only about 5,912 ha available [21]. The decrease was due to an extractive cultivation of sago and more limited wetlands available. This is an obvious threat and in needs of preservation and conservation efforts to prevent sago palm from extinction.

Conservation and expansion of sago palm should be directed to be conducted on dry land[20]. Although the dry land is not the native habitat of sago palm, but it is abundant compared to the limited wetlands. Therefore, it is necessary to characterize the effect of different environmental conditions on sago planting, mainly concerning the relation of soil physical and chemical properties to the growth, production potential, and quality of produced sago starch.

Experimental

Research was conducted on sago field plantation located in Kendari Peninsula at Angata District South Konawe (04˚09'59S 122˚07'42E), Soropia District Konawe (03˚54'16S 122˚35'21E), and Abeli District Kendari (04˚00'07S 122˚26'36E) Southeast Sulawesi Indonesia[21]. Observations were made on the physical and chemical soil properties that included soil texture, soil pH, organic matter content, nitrogen (N) content, phosphorus (P), potassium (K), cation exchange capacity (CEC), calcium (Ca), sodium (Na) and magnesium (Mg). Soil analysis was performed at the Soil Science Laboratory, Faculty of Agriculture, Bogor Agricultural University (IPB) Indonesia. Observed sago planting parameters included sago vegetation conditions and sago starch production.

Observations of sago vegetation conditions, rate of growth and production of sago starch were made on sago trees that had reached ripe-harvest levels. Signs for harvestable sago trees are, among others, having heart or flower buds. The harvestable sago trees were cut-down and cleared of old stem-barks, and finally they were extracted. Observed vegetative parameters were trunk length, bark thickness, trunk diameter, petiole length, leaf length and leaflet width. The approximate age of sago trees was calculated by the Flach method[4]. Generative variables included flowering stage and starch production. The observed data were then analyzed using analysis of variance. Duncan's Multiple Range Test (DMRT) at 95% confidence level was performed to see the effect of different soil conditions on vegetative and generative components.

Results and Discussion

1. Physical and Chemical Soil Properties.

The results showed that there were differences in the physical and chemical soil properties at three sago field planting in Kendari Peninsula which included Angata, Soropia and Abeli. Physical and chemical soil properties in Abeli were generally better than those in Angata and Soropia (Table 1).

Table 1 indicates that the characteristics of the soil in the three areas of sago planting are quite diverse, both for wetland and dry land agroecosystem. The level of soil acidity in these locations was in the category of acidic soil with pH ranging from 4.6 to 5.1, except in Abeli area with neutral soil pH to slightly alkaline (7.2 to 7.8). The acidity of soil affects the solubility and availability of nutrients, as well as to the decomposition of soil minerals, organic matter and the formation of clay minerals.

Table 1. The difference of soil physical and chemical properties in three locations of sago field planting in Kendari Peninsula

Soil condition	Sago Field Planting					
	Soropia		Angata		Abeli	
	Wetland	Dryland	Wetland	Dryland	Wetland	Dryland
pH H_2O (1:1)	4.8 A	5.1 A	4.9 A	4.6 A	7.2 N	7.8 SA
C organic (%)	0.65 VL	0.82 VL	1.65 L	0.57 VL	2.94 M	1.47 L
N total (%)	0.06 VL	0.07 VL	0.12 L	0.06 VL	0.21 M	0.11 L
Available-P (ppm)	1.7 VL	2.0 VL	3.2 VL	2.4 VL	6.1 VL	7.11 VL
Ca (cmol kg^{-1})	4.58 L	5.31 L	3.39 L	3.61 L	9.33 M	10.15 H
Mg (cmol kg^{-1})	6.39 H	5.94 H	7.22 H	6.54 H	12.74 VL	13.19 VH
K (cmol kg^{-1})	0.64 H	0.72 H	0.61 H	0.72 H	1.26 VH	1.67 VH
Na (cmol kg^{-1})	0.63 M	0.61 M	0.57 M	0.54 M	0.81 H	0.84 H
CEC (cmol kg^{-1})	25.34 H	26.29 H	25.72 H	23.64 M	24.62 H	25.82 H

Remarks : A=Acid, N=Neutral, SA=Slightly Alkaline, VL=Very Low, L=Low, VH= Very High, H= High, M=Medium

Based on data in Table 1, it appears that the content of P, Ca¸ Mg and K in Abeli was higher than the other two locations, Soropia and Angata. The content of Na and CEC in Abeli was also higher than those in Soropia and Angata. Overall the P content in soils on all three locations was so low that causes a deficiency for the plants. The low level of P is associated with lower pH, because it is fixed by acid cations such as Al and Fe[22,23,24,25]. P deficiency will cause a drag on the growth of the root system, leaves and stems[26,27,28]. The physical and chemical soil properties are key factors in the mobility and accessibility of heavy metals in the soil and plants[29].

Phosphorus is one of the essential macronutrients for growth and development of plants[30,31]. P deficiency symptoms include growth retardation, small and curly leaves, reduced numbers of flowers and tillers [32,33]. The function of P in the soil to the plants is as a builder substance and bound in organic compounds [34]. High level of Fe in acid soils causing fixation of P by Fe (Fe-P) and Al (Al-P) to form insoluble compounds [35,36,37,38,39] that can inhibit the growth and production of sago plants both on wetlands as well as on dry land.

The content of exchangeable Ca, Mg, K, and Na of soils in the sago field plantation varies from low to very high. Table 1 show that the entire complex adsorption is dominated by Mg^{+2}, followed by Ca^{+2}, K^+ and Na^+. Cations K^+, Ca^{+2} and Mg^{+2}, are antagonism to each other, so that the necessary balance of certain nutrients to minimize the antagonist effect of three cations. So that needs to optimally balance K, Ca and Mg in the land using *basic cation saturation ratio* (BCSR) concept[40]. It suggests that the composition of cations in the soil that is good for plant growth is 5% K^+, 65% Ca^{+2}, Mg^{+2} 10% and 20% H^+. Further, for cocoa crops in Ivory Coast[41] suggested that the optimum ratio of K/Ca/Mg was 8/68/24. Furthermore, revealed the optimum ratio of K/Ca/Mg for oil palm plantation[42] was at 10/60/30. The study of BCSR on sago palm is, in fact, not well established. Therefore the characteristic of nutrient on oil palm are employed to explain the growth ability of sago palm, because of similar characteristic when grown[43].

Potassium is absorbed by plants in the form of K^+ ions. The potassium serves to accelerate the formation of carbohydrates, strengthening the plant body, and increasing resistance to pests and plant diseases and drought[44,45,46,47]. Water relations, photosynthesis, assimilate transport and enzyme activation can be all impacted by potassium[48]. Potassium increases crop yield and improves quality[49,50]. Potassium is easily soluble, easily washed and easily fixed, so that the levels of K in wetlands tend to be lower than on dry land. In addition, the higher levels of potassium in dry land was also affected by the soil conditions that generally contain more minerals[51,52], in which K is donated from the weathering of minerals that releases K ions and much available to plants. The main source of K for plants growing under natural conditions also comes from the weathering of K minerals and organic K-sources such as compost and plant residues[53].

Calcium is absorbed by plants from the soil in ionic form Ca^{+2}, an essential element for the growth of the plants and fruit development, and it is important in the resistance of the plants to diseases due to with base in the protection of the cell wall[54]. Calcium is a cation which can contribute to the reduction of the effects of soil acidity. The low content of Ca in the soil of sago planting is closely associated with low soil pH. Calcium exchange capacity in soils is dependent on the clay content in the soil. Table 1 shows that the higher the CEC (the higher the clay content), the higher the soil Ca levels. In wetlands, Ca along with H^+ is dominant on the complex cation adsorption, while on dry land loss of Ca is so real that liming is highly recommended.

Magnesium is taken by plants in the form of ions Mg^{+2}, which acts as a constituent of chlorophyll. The state of Mg ions in the ground is almost the same with K, adsorbed by plants in a form that can be exchanged or in a water-soluble form, so that the absorption is dependent upon the amount available and the amount that can be exchanged. Table 1 show that the levels of Mg in the soil were high to very high, so it did not become an inhibiting factor for the development of sago both on wetlands and dry land.

Cation exchange capacity (CEC) in soils at the sago locations was overall in a high category (23.64 to 26.29 cmol kg^{-1}). These conditions will determine the potential for soil fertility. Cation exchange capacity indicates the ability of soil to adsorb and exchange cations by the negative charge, which in the soil mainly comes from humus and mineral colloidal clay. CEC magnitude is influenced by the soil nature and characteristics such as soil pH, soil texture (clay number), the type of clay mineral, soil organic matter, liming and fertilizing.

Sago plants can grow on a various soil conditions, either on drylands, on seasonally flooded wetlands, or on wetlands flooded throughout the year. Sago plants also have wide adaptability and tolerant to various soil acidity conditions. Sago plants in Southeast Sulawesi generally are grown in lowlands. The characteristics of lowlands are highly influenced by the characteristics of surrounding soil and the condition of the parent material. Results of the study revealed that the soil physicochemical characters under sago growing areas were varied depending on the position which affected by the surroundings soil types[48].

2. Growth and Production of Sago

The results showed that the average growth of the sago vegetative and generative characters in Abeli, Angata and Soropia varied both for wetlands and dry land, as shown in Table 2. In general, the growth of vegetative and generative characters of sago palm in Abeli was higher than those of in Soropia and Angata. Production of sago starch is determined not only by the rate of starch content in the pith of the stem, but it is also depended on trunk length and trunk diameter. The highest sago palm production in Abeli is directly correlated to the trunk length and trunk diameter, both in wetlands and dry land.

Sago production on dry land is generally lower than the sago production on wetlands. Percentage reduction of sago on dry land can reach 30%. Sago production on dry land in Abeli, although lower than the sago production on wetlands, but is still higher if compare to the sago production on wetlands in two other locations. This indicates that the production of sago, even on dry land, can be improved as long as the required nutrients are available. In addition, it was also because of nutrient content in the dry land in Abeli was relatively high and did not had too much difference from nutrients contained in the wetlands.

Table 2. Differences in vegetative and productive growth of sago palm in three locations of sago field planting in Kendari Peninsula

Vegetative and Generative Growth	Sago Field Planting					
	Soropia		Angata		Abeli Dalam	
	Dryland (D)	Wetland (W)	Dryland (D)	Wetland (W)	Dryland (D)	Wetland (W)
Trunk length (m)	5.5	7.5	7.2	8.2	7.2	9.7
Bark thickness (cm)	1.3	1.7	1.1	1.4	1.5	2.0
Trunk diameter (cm)	45.2	49.3	43.8	48.3	52.5	58.6
Petiole length (m)	7.2	7.6	8.3	8.4	8.8	9.9
Leaf length (cm)	132.5	143.2	147.5	153.0	158.6	167.8
Leaflet width (cm)	8.5	9.1	8.7	10.0	11.5	12.7
Flowering stage (year)	8.5	9.6	8.9	10.5	10.8	13.4
Starch production (kg per trunk)	133.1	198.0	203.1	255.0	240.7	362.0

Note : Figures followed by the same index in the same row, are not significantly different at Duncan's Multiple Range Test (DMRT)

Based on Table 1 and Table 2, it appears that the physical and chemical properties of soil will determine the magnitude of the potential growth and production of sago plantation. It appears that the condition of soil fertility is directly proportional to the level of potential growth and production of sago plants.

The potential growth of sago palm in Abeli was higher if compare to the potential growth and production of sago palm in Angata and Soropia, as a result of the higher soil nutrient content in Abeli. The growth and the production of sago palm in Angata were higher than those in Soropia, because the physical and chemical soil properties in Angata were better than the ones in Soropia. Differences in soil physical and chemical properties will determine the potential growth and production of sago plantation.

Based on the data of soil characteristics between agroecosystems of wetlands and dry land at the three locations of sago field plantation, it showed an inconsistent pattern of variation. In Soropia and Abeli region showed that soil characteristics in dry land is better than that in the wetlands. In contrast, in Angata, a soil characteristic in the wetlands agroecosystem is better than that on the dry land. This phenomenon occurs because sago palm areas are generally located in lowlands, formed from the deposition from surrounding areas so that characteristics of the soil are strongly influenced by the initial material originally present in the vicinity.

The growth and production of sago in wetlands tend to be better than those of on dry land[52,55,56]. However, there was a tendency that the average of growth and production of sago, in the region of Abeli was much higher than those in Soropia and Angata. This condition shows that even though sago prefers a wet condition, but if the soil chemical characteristics are high, available and balanced, then sago plants can still grow and produce well. In Soropia and Angata, the growth and production were caused by the differences in fertility in wet and dry land. Chemical conditions in wetlands and dry land in Abeli were not too much different thus the growth and production were also not significantly different. Hence, actually sago can be cultivated on dry land as long as required nutrients are available and not merely because of flooded or unflooded.

Sago plant has a better growth on wetland than on dry land[57], this is due to the wetlands, despite having a low pH, has higher Mg content to meet the needs of the plant. On the condition of wet soil, acidic soil pH will be neutralized by water. The growth of sago palm on wetlands and dry land in Abeli was generally similar, because they had relatively similar soil fertility and the soil pH was neutral so that the availability of nutrients was high or nutrients became more readily available. The high content of Mg led to better plant growth. C-organic content was higher in wetlands. Apparently sago plants require fertile soils, pH neutral, enough Mg, Ca and organic matter contents.

The high soil pH in Abeli had better effect on the growth and production of sago palm. The increase in soil pH will increase nutrient availability for plants, which in turn will increase the growth and production of sago. The soil pH affected the growth and development of plant[58]. The indirect effect is through the solubility and availability of nutrients, such as changes in P concentrations. Soil acidity also has effects on the decomposition of soil minerals, organic matter and also the formation of clay minerals.

The content of soil organic C and total N on the sago plantings was varied, ranging from very low, low to moderate. This was caused by the low contribution of organic materials from the surrounding areas. Additionally anaerobic conditions in wetland sago planting that were constantly flooded causing slow decomposition so that C and N produced were also low. Organic material serves to bind metal ions such as Al, Fe and Mn to form complex compounds or chelates, thus protecting the plants from their toxic. Addition of organic materials can also help increasing the absorption and cation exchange capacity (CEC) through colloidal organic (humus) produced during decomposition[59,60]. Therefore, the addition of soil organic matter is important, especially for the development of sago palm on dry land, so that the ability of soil to hold nutrients and water is improved, considering the sago plant is a species that requires a lot of water during growth.

Conclusion

In conclusion, the physical and chemical properties of the soil were directly proportional to the potential growth and crop production of sago. This is indicated by the growth potential and the sago production potential in Abeli, which was higher than those in Angata and Soropia. Similarly, the potential of growth and the potential of sago production in Angata were higher than the ones in Soropia.

In general, the growth and production of sago on the wetlands were better than the sago production on dry land. The research results showed that despite the dry land is less suitable for the cultivation of sago, but if nutrients required by sago plants are available, then the sago plants can be grown on dry land. Therefore, to obtain high growth and production on dry land, the addition of organic matter is needed.

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