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Research Article

Yield response of ten varieties of sweet potato (*Ipomoea batatas* L.) cultivated on dryland in rainy season

Akbar Saitama[1*], Agung Nugroho[2], Eko Widaryanto[2]

[1] Postgraduate Program, Faculty of Agriculture, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia
[2] Department of Agronomy, Faculty of Agriculture, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia

*corresponding author: akbar.saitama@ymail.com

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Abstract: Sweet potato is a tuber commodity and one of alternative crops in Indonesia. The demand of sweet potato in Indonesia continues to increase. However, the supply of sweet potatoes for consumption estimated is 2020 in Indonesia will be deficit. Low production of sweet potato is basically due to the decrease of land area as cultivation production and also sweet potatoes have a low yield when planted in rainy season. Based on the high utilization of sweet potato make demand for this commodities continues to increase.Therefore, several strategies to increase crop yields of sweet potato needs to be done. This study aimed to elucidate various sweet potato varieties that can cultivated on dry land in the rainy season. This study was conducted from November 2016 until March 2017 using a randomized block design with treatments of ten varieties of sweet potato consisting of (V1) Papua Solossa variety, (V2) Jago variety, (V3) Kidal variety, (V4) Antin-1variety, (V5) Sari variety, (V6) Sawentar variety, (V7) Beta-2variety, (V8) Antin-2variety, (V9) Antin-3 variety, (V10) Beta-1variety. The results showed different responses of each variety.The vegetative growth was high as shown by the LAI value of 7.23 at 90 days after planting. In conclusion, the sweet potato leaves had to be prune to boost the agronomic yield. Yields of ten varieties of sweet potato crops ranged from 8.86 to 44.76 t/ha. Some varieties such as Sari, Papua Salosa and Beta-2 varieties showed high yield although they were planted in moorland conditions in the rainy season.

Keywords: *dry land, rainy season, sweet potato, varieties, yield*

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Introduction

Sweet potato as a food commodity, shows its position increase to fulfill national food sufficiency. This is not only due to the nutrient contents, minerals and vitamins, but also the high utilization of the tuber varieties. Sweet potato tubers can be directly processed into various food forms and they can be processed for industrial raw materials such as flour, sugar syrup, cosmetic ingredients, ethanol and alcohol (Warhamni, 2013). Production of sweet potato nationally continued to decrease from 2011 to 2016 while the reduction in production had reached 50,000 ton per year. Otherwise, the productivity of sweet potato in 2011 increased from 12 t/ha to 17 t/ ha in 2016. Based on this data, sweet potato cultivation has problems related to constriction of field production that can be seen from the production decline. Sweet potato harvest area in the world for the last five years showed a decrease of 1.14% per year with an average harvest area of 11.54 million hectares. The potential of some varieties of sweet potato actually is more than the national average productivity where the high yield of varieties sweet potato production can reach over 30 t/ha. The high utilization and reduced production of these tubers caused demand for sweet potato continues to increase. Kementan RI (2016) stated the demand for root crops from 2011 to 2016 continued to increase approximately 200,000 ton per years and demand for sweet potato nationally from 2017 to 2020 will increase around 4.88% each year. Therefore, several strategies to increase sweet potato yield needs to be done.

Crop production is influenced by genetic and environmental factors (Gonggo et al., 2008). Production on the sweet potato highly depends on the varieties and environmental conditions such as soil conditions, precipitation and solar radiation (Tsuno and Fujise, 1965). One of the matters that led to the low production of formation sweet potato tuber is due to high growth on plant vegetative hence soil conditions and heavy rainfall (Mwololo et al., 2012). In the dry season, sweet potato crops can be planted in paddy fields by using surface irrigation, while in the rainy season sweet potato will be well cultivated on moorland with rain fed irrigation systems although the sweet potato will have high vegetative phase so that the tuber formation will be obstructed (Dukuh, 2011).

Laurie et al. (2013), Sweet potatoes have a high varieties, which each varieties have different morphological characteristics such as leaves, stems and tubers. The productivity of each varieties will be different even in the same environmental conditions. Therefore, the selection of suitable sweet potato varieties, that to be planted based on environmental conditions is very important (Trustinah dan Iswanto, 2014).

The purpose of this study was to evaluate the yield response of ten varieties of sweet potato grown in moorland during the rainy season, to conclude the recommendation of which varieties that suitable to land and environmental conditions and determine the actions of management for moorland cultivation in the rainy season.

Materials and Methods

This research was conducted on October 2016 until January 2017 which located in Agrotechnopark Brawijaya University, Jatikerto Village, Sub district Kromengan, Malang, East Java at altitude of 303 meters above sea level. The average rainfall of the area ranges from 100 to 1600 mm per year with temperature of 16 to 31^{o}C. This research used a factorial randomized block design with ten treatments consisting of : (V1) Papua Solossa variety, (V2) Jago variety, (V3) Kidal variety, (V4) Antin-1 variety, (V5) Sari variety, (V6) Sawentar variety, (V7) Beta-2 variety, (V8) Antin-2 variety, (V9) Antin-3 variety, (V10) Beta-1 variety. Each treatment in this study was repeated three times. Length of total plot was 355 cm, height 40 cm, width 40 cm, and the distance between rows 30 cm. The stages of this research were land preparation, planting, irrigation, fertilization (Urea, SP36 and KCL), reversal stem, shoots pruning, weeding, soil piling up and harvesting. This research observations consisted of leaf area, leaf area index (LAI), total plant dry weight and harvest yield. The LAI was calculated using Regazzoni et al. (2014) formula of LAI =LA/GA, where LAI = Leaf area index, LA = Leaf Area, GA = Ground Area. Ground area is shaded of leaf area. The yield obtained from calculating the beds of tile. Harvest bed tile consisted of 6 plants, with area of harvest bed was 210 cm x 60 cm= 1.26 m^2. Calculation of the yield used the following formula: Yield (t/ha) = [(10000/scale of sampling plot) x yield of sampling plot].

Results and Discussion

Soil condition

The research was located at the Agro Techno Park Brawijaya University, Jatikerto village, Kromengan, East Java. Before being used for this research, land area was planted with long green bean. Land was dry land (moor), which rely to rain-fed irrigation for water sources. The study was conducted from November 2016 to March 2017 as the months are classified for rainy season. Based on the soil analysis, soil of the study area is classified as a sandy clay loam texture soil with pH 6,8, C-organic 1.67%, total N 0.18%, C/N 9, P 11.27 mg/kg, K 0.65 me/100g and base saturation of 82%.

Leaf area

Leaf area becomes a parameter that is directly related to the plant growth parameters. The observations of plant leaf area on this study were presented in Table 3. Sweet potato leaf area on the age of 45 days after planting (DAP) ranged from 408.75cm^2 to 1118.81 cm^2 (Table 1). The results of leaf area observation at 90 DAP gained sweet potato leaf area that ranged from 5948.83cm^2 to 12419.25 cm^2. The leaf areas of Sari and Beta-2 varieties of 5948.83 cm^{2}and 7982.69 cm2, respectively, at 90 DAP were not significantly different. Leaf area at 120 DAP ranged from 3953.21 cm^2 to 9982.71 cm^2.

Results of the study indicated that each varietiy showed different performance on leaf area. Each of the varieties grown had different leaf characteristics. Variety testing is part of genetic studies that will show responses in physiological and agronomic environment. Leaf area is a determinant factor of sweet potato plant to adapt on the environmental conditions. The sweet potato varieties planted on dry land (moor) in rainy seasons showed the leaf area growth continuously. Persistent leaves growth constantly feared will make the process of tuber formation in sweet potato crops were not happen (Dubois et al., 2013). Isa et al., (2015) stated if the vegetative growth was very high and no pruning treatment, sweet potato tubers would be difficult to form and obstruct the process of tuber formation. The low production occurs due to the growth phase is dominated by sweet potato vegetative growth of the upper leaves and stems are excessive along with the lack of tuber formation.

Table 1. Leaf area of ten sweet potato varieties

Varieties	**Leaf Area (cm²/plant)**					
	45 DAP		**90 DAP**		**120 DAP**	
Papua Salosa	1133.56	b	10793.04	b	5874,98	bc
Jago	698.92	ab	12002.09	b	7677,84	de
Kidal	1051.07	b	10676.85	b	7057,46	cd
Antin-1	1035.76	b	11758.55	b	7392,03	cd
Sari	408.75	a	5948.83	a	3953,21	a
Sawentar	1118.81	b	10769.71	b	7172,18	cd
Beta-2	493.47	a	7982.69	a	4498,00	ab
Antin-2	970.56	b	11996.67	b	9982,71	f
Antin-3	1103.35	b	12419.25	b	9310,04	ef
Beta-1	983.60	b	12070.13	b	9316,76	ef
LSD 5%	467.53		2460.11		1736.61	
CV (%)	30.29		13.48		14.01	

Description: Numbers followed by the same letter at the same column show no significant different in LSD test at 5% level. DAP: days after planting.

Therefore, photosynthate left is only few for tubers development. If vegetative and reproductive phases are in balance, the accumulation of photosynthate will be balance as well. The plants with moderate vegetative growth will have many tubers. In this research, shoot pruning at 90 DAP decreased leaf area from 90 to120 days after planting. Pruning was aimed to reduce leaf buds or young leaves to stop the growth of plant leaves. According to Van An and Lindberg (2003), the effect of shoot pruning on sweet potato plant is to reduce the leaf growththerefore, the assimilates will be distributed to generative organs while in sweet potato, it will distributed to the tubers.

Leaf area index

Leaf Area Index (LAI) observations on the study are displayed in Table 2. Leaf area index at 45dapobservation had value between 1.2 and 3.62 per plant. The leaf area index of sweet potato observed at 90 DAP had values between 4.40 and 7.23 per plant, at the age of 120 DAP had values between 3.15 and 4.67 per plant. LAI value of Beta-2 variety was 3.15 per plant, the results were not significantly different from the Sari, Sawentar, Jago and Kidal varieties. Beta-2 variety had lower LAI value of 31.43% than that of Papua Salosa variety. Otherwise, the difference LAI of Beta-2 of 35.87%was lower than Antin-1 variety. Beta-2 variety had lower LAI ranging from 41.90 to 48.25% when compared to Antin-3, Antin-2 and Beta-1 varieties. Papua Salosa, Jago, Kidal, Antin-1, Antin-2, Antin-3 and Beta-1 varieties had leaf area indexes that were not significantly different from 3.81 until 4.67 per plant. Antin-2 and Beta-1 varieties having higher LAI value up to 32.55% compared to other varieties.

LAI differences in sweet potato plants is influenced by the main factor, which is each varieties of sweet potato have different morphological characters, especially the shape and size of the leaves that could affect LAI in sweet potatoes (Tsialtas et al., 2008), Sweet potato have optimum LAI around 3 to 4 (Tsuno and Fujise, 1963).The leaf area index (LAI) at 90 DAP was high and almost reach more than 7. High LAI will cause the difficulty in generative organs formation. It is caused the photosyntathe are focused in formation of vegetative organs, especially on leaves. High LAI were affected by some factors such as; the high of leaf area and number of leaves, therefore it will be found many overlapping leaves. Agata and Takeda (1982), high LAI on sweet potato plant will not impact positively on tuber formation.

Table 2. Leaf area index of ten sweet potato varieties

Varieties	**Leaf Area Index Observations Period (DAP)**					
	45		**90**		**120**	
Papua Salosa	2.36	abc	7.13	bc	4,14	bcd
Jago	1.43	a	5.89	b	3,91	abcd
Kidal	2.16	ab	6.61	bc	3,81	abcd
Antin-1	2.85	bc	7.14	bc	4,28	cd
Sari	1.20	a	4.43	a	3,28	ab
Sawentar	2.74	bc	7.23	c	3,65	abc
Beta-2	1.31	a	4.40	a	3,15	a
Antin-2	3.29	bc	6.91	bc	4,66	d
Antin-3	3.62	c	6.80	bc	4,47	cd
Beta-1	2.87	bc	7.06	bc	4,67	d
LSD 5%	1.26		1.32		0.91	
CV (%)	30.92		12.07		13.39	

Description: Numbers followed by the same letter at the same column show no significant different in LSD test at 5% level. DAP: days after planting.

Dry weight

Total dry weight of the sweet potato that was observed at 45 dap ranged from14.85 to 44.40 g per plant. Dry weights of the sweet potato that was observed at 90 dap 72.28 to 115,03 g per plant. Total partition of plant dry weight at 90 DAP (which entered the generative phase of 10 varieties that focused on the stem ranged from 41.12 to 46.18% (Figure 1). The partition of leaf dry weight ranged from 34.15 to 37.10%.The partition of root dry weight at 90 DAP compared to that of 30 DAP increased from 18.03 to 23.30%. Sweet potato crop was harvested when the plant was entering 120 DAP. Total plant dry weight at 120 DAP was on average range from 168.10 until 409.04 g per plant. The percentage of plants partition at harvest time (120 DAP) showed that the partitioning dry weight in the leaves ranged from 2.53 to 21.23% (Figure 2). Partitions on stem ranged from 5.55 to 34.50%, and partitions on root and tuber ranged from 44.28 to 91.92% (Figure 2).

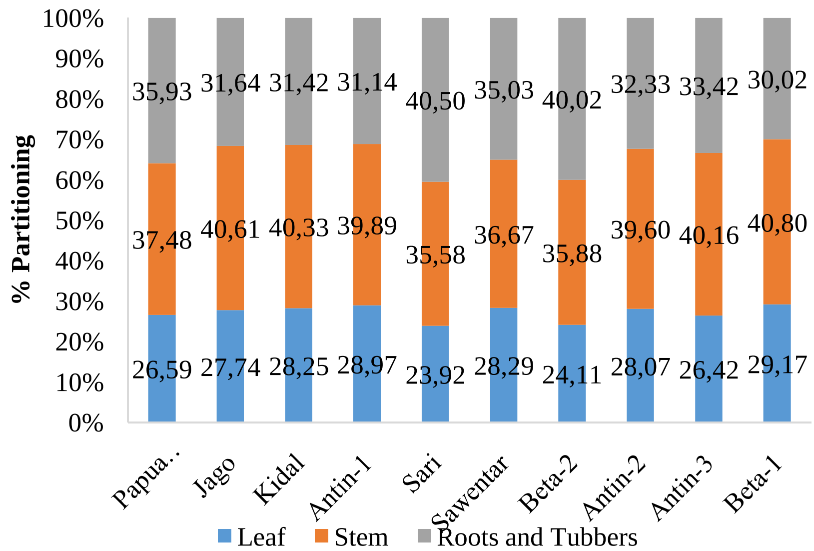

Figure 1. Partitioning dry weight of ten sweet potato varieties at 90 days after planting

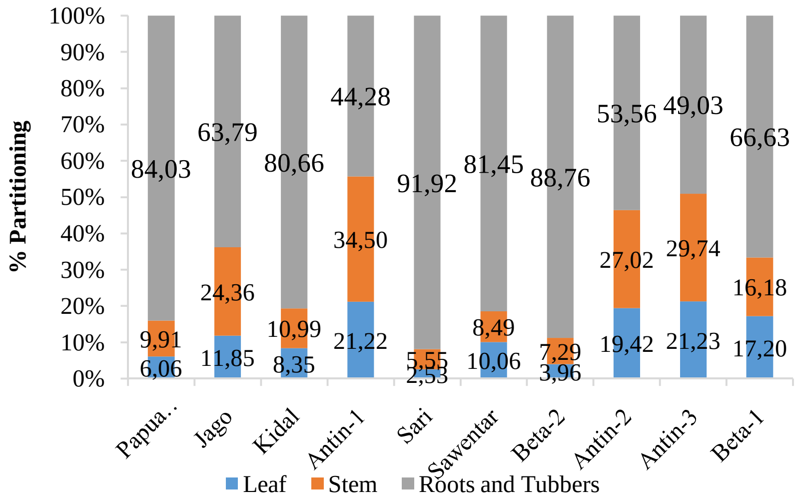

Figure 2. Partitioning dry weight of ten sweet potato varieties at 120 days after planting

In the early plant growth phase of sweet potato, plant dry weight partitioning focused on shoot zone. This partition occured until 90 dap and the condition of partition of plant dry weight was not significantly different. When vegetative phase occurred, plant dry weight was going to focus on the stem (tendril) and leaves. Partitioning photosynthate is mostly going to the plant canopy, especially stem tissue. It causes photosynthate quantity for root growth in root tissue becomes small. This conditions cause dry weight of canopy and stem become high while root dry weight becomes small. Dry weight of canopy is determined by the growth rate of stems, and the stem growth rate is positively affected by the rate of leaf initiation (Clough and Miltthorpe, 1975). Dry weight of stem is influenced by number of leaves that formed. Sanoussi et al., (2016) stated that partition of sweet potato crop dry weight at the vegetative growth would show the highest on the leaves and stems, when generative phase, the partition of the dry weight would be highest on tubers. On the harvest time, partition of sweet potato tuber could reach 90% of the total plant dry weight. A study conducted by Madhu and Hatfield (2016), showed that dry weight partitioning at the age of 44 dap could reach 55% on the leaves, 35% on the stems, and 10% on the root. While the plants in the process of tubers fillings before harvest partition. The tuber dry weight could reach 45.9% of the total plant dry weight

Table 3. Total dry weight of ten sweet potato varieties

Varieties	**Dry Weight (g/plant)**					
	45 DAP		**90 DAP**		**120 DAP**	
Papua Salosa	35.17	cd	92.73	abc	374,06	de
Jago	28.22	bc	95.43	bc	202,50	ab
Kidal	38.82	cd	102.72	c	303,27	cd
Antin-1	41.66	d	98.61	c	168,10	a
Sari	15.99	ab	72.28	a	409,04	e
Sawentar	39.36	cd	74.83	ab	263,04	bc
Beta-2	14.85	a	99.45	c	320,25	cd
Antin-2	38.65	cd	104.46	c	187,52	ab
Antin-3	34.43	cd	110.17	c	153,54	a
Beta-1	44.40	d	115.03	c	248,38	bc
LSD 5%	13.50		22.68		77.05	
CV (%)	22.95		13.69		17.08	

Description: Numbers followed by the same letter at the same column show no significant different in LSD test at 5% level. DAP: days after planting.

Harvest yield

The harvest yield of ten varieties of sweet potato in the study showed that Antin-1, Antin-3, Antin-2, Jago, Beta-1, Sawentar, Kidal, Beta-2, Papua Salosa, and Sari varieties could produce 8.86, 8.96, 11.96, 15.38, 19.70, 24.51, 29.12, 33.84, 37,42, and 44.76 t/ha, respectively (Figure 3). The yield of Antin-1 variety was not significantly different with yields of Antin-2, Antin-3 and Jago varieties. Antin-1variety had 122.35% lower productivity compared to Beta-1 variety, 187.92% lower than Sawentar variety, 228.67% lower than Kidal variety, 281.94% lower than Beta-2 variety, 322.35% lower than Papua Salosa variety, and 405.19% lower than Sari variety. Sari and Papua Salosa varieties were not significantly different. Sari variety had four times higher productivity compared with Antin-1, Antin-2 and Antin- 3 varieties.

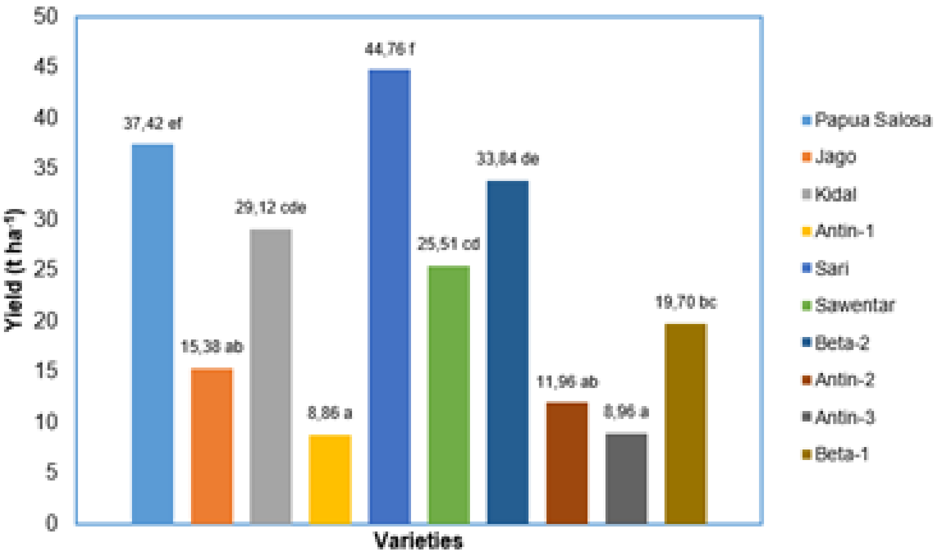

Figure 3. Yields of ten sweet potato varieties

This study was conducted in the rainy season with dry land category (moor), which is known that if sweet potato is planted in the rainy season it will have a long vegetative phase (Dukuh, 2011) The number of tubers per plant is potential sink. There is a relationship between the number of tubers per plant with a total weight of tubers, the more number of tubers per plant, the lower weight of the tuber. This suggests that assimilates (source) translocated to tuber (sink) formation were limited because parts of assimilate were translocated to the stem. Translocation of assimilates is mostly shipped to the tuber. The amount of assimilates transported and stored as a backup food determines the weight of tubers per plant. Small amount of assimilates will make tuber weight per plant smaller, whereas if the number of assimilates is high, it will increase the weight of tubers per plant. Low yield in tuber plant production is caused by the plant itself which is dominated by vegetative growth. This makes leaves and stems are growing excessively and lacking of tuber formation because there are few carbohydrate left for tuber formation (Panggabean et al., 2014). If vegetative and reproductive phases are in balance, usage and accumulation are in balance as well, practically assimilates that are used and stored will be in balance (Zhu and Jiang, 2014). Plants having moderate vegetative growth will have many roots. Modification of plant growth physiologically is one effort to overcome the low production of sweet potato by controlling vegetative growth. There are morphologically modification efforts through agronomic ways such as the use of growth regulators to maintaining the balance of vegetative and generative growth,so the utilization assimilate by vegetative could be in control and most assimilates could be distributed into the sink (Rahmiana et al., 2015). Agronomic maintenance such as reversal plant canopy, pruning leaves and shoots are effective in modifying plant morphology (Esmaielpour et al., 2011). In this study, reversal plant canopy of sweet potato and shoots pruning were done at 90 DAP. The purpose of the reversal was to form the tubers. The influence of leaf reduction on growth and yield of crops depends on the missing leaf area, leaves posisiton on the stems, and crop-growing period. Shoot pruning on sweet potato that was done at 90 dappositively affected the tuber formation on the ten varieties of sweet potato. Dukuh (2011) stated that shoot pruning at 12 weeks after planting significantly affected the tuber formation, especially the quality and quantity of sweet potato tubers.Timing of shoot pruning influence plant growth, especially the sweet potato crop (Aniekwe, 2014). When shoot pruning occurs on the vegetative phase it will increase the vegetative organs, whereas if shoot pruning occurs in late vegetative phase it will accelerate the formation of generative organs that in sweet potato it will be distributed to the tubers (Nedunchezhiyan et al.,2012). Sulkan et al. (2014) stated that the formation of sweet potato tubers was influenced by formation of the roots on sweet potato crop. Tuber formation begins when the leaves begin to decline, in other words the growth rate of leaves need to be inhibited. When the sweet potato crop is planted in the rainy season it will accelerate the process of formation sweet potato tubers.

Conclusion

The response of each of ten sweet potato varieties planted in dry land (moor) and rainy season conditions showed differences. Some varieties showed high responsive to the environment with the components shown in vegetative growth observations such as stems and leaves. This was proved by the high vegetative growth at 90 days after planting. Leaf area index (LAI) on sweet potato had the optimum value when entered 90 dap, LAI of Sawentar variety showed value of 7.23, while varieties with limited LAI response were Sari and Beta-2 varieties. To inhibit the growth rate of vegetative organs, after 90 dap sweet potato leaves need to be pruned. Sari and Papua Salosa varieties had high yields. Shoot pruning needs to be done to reduce the vegetative growth of sweet potato planted in the rainy season. Therefore, further studies are required to establish ideal treatments about shoot pruning in sweet potato.

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