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The study of shoot pruning time on growth and yield of three varieties of sweet potato (*Ipomoea batatas* L.) in rainy season

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This study aims to knows the response and get the right time of shoot pruning on 3 varieties of sweet potato. The study was conducted in Landungsari Village, Dau District, Malang Regency, from January to May 2018. The treatment design used was a Split plot design with 3 replications, by placing varieties as the main plot consists of 3 levels, namely the Beta-1 variety (V1), Sari variety (V2) and Antin-3 variety (V3). Shoot pruning as a sub plot consists of 4 levels, namely without pruning (P0), shoot pruning 45 DAP (P45), shoot pruning 65 DAP (P65), and shoot pruning 85 DAP (P85). Observation data were analyzed by the F test at level 5%, if there were interactions followed by Honestly Significant Difference test at level 5%. The results showed that the shoot pruning 45 and 65 DAP significantly increased the vegetative growth of Beta-1 variety, but could not increase tuber yield. While shoot pruning 45 DAP on Sari variety can increase yield of tuber by 7.96 tons ha^{-1}. Likewise, on Antin-3 variety shoot pruning 45 and 65 DAP can increases tuber yields by 7.97 tons ha^{-1} and 7.71 tons ha^{-1} respectively.

Keywords: ***Sweet potato, Varieties, Shoot pruning, Beta-1, Sari, Antin-3***

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is one of commodities of carbohydrates source after rice, corn, and cassava. Therefore, sweet potato has the potential to be developed as an alternative food source so as to reduce dependence on rice, especially in supporting food diversification programs. In addition, the nutrient content such as protein, fat, carotene, vitamins A and C and minerals Ca and Fe in sweet potatoes, it was makes sweet potato not only used as food, but also widely used as industrial raw materials such as flour, sugar, syrup, food coloring, noodles, cosmetics, mono sodium glutamate, ethanol and alcohol (Nedunchezhiyan et al., 2012). Along with the high of sweet potato utilization and the increasing number of people, the demand for sweet potato is increasing. The demand of sweet potato from 2011 until 2016 continues to increase, which is around 200,000 tons per year and the estimate of national sweet potato demand from 2017 until 2020 will increase about 4.88% annually (Ministry of Agriculture, 2016). However, the increased in demand of sweet potato was not followed by an increased in production and harvested area.

Sweet potato is the plants that have high morphological diversity. One of them is a variety, where each variety has morphological characters such as stems, leaves and tubers that are different, and has different responses to environmental conditions, so that it will affect its production (Laurie et al., 2013). However, sweet potato plants have a character of growth, namely the high growth of leaves and stems, especially if planted in rainy season. Photosynthesis per unit

area of leaves in sweet potato plants is indeed high when viewed from the number of leaves, but when viewed from the composition of the leaves that overshadow each other, and the location of young leaves that are in the upper position of the leaves that have been fully develope resulting it less efficient in absorbing sunlight because the penetration of light entering the plant canopy is low, so the total assimilat produced by plants are low (Rahajeng, 2015). Furthermore Jayanti *et al.* (2016), explained that the available assimilat will be distributed to various organs in plants. If see the character of sweet potato growth which dominated by the vegetative phase, will be very litle of carbohydrates available for the development of tubers.

One of the agronomic actions that can be done to control vegetative growth in sweet potato plants is pruning (Esmaielpour et al., 2011). Pruning is an act of reducing plant organs (tendrils/stems) which aims to control elongation of tendrils, adventitious root formation and growth rate of leaves, so that the level of asymylate translocation competition to economical parts decreases. Kumar et al., (2010) explained that pruning not only can reduce excessive vegetative growth, but also can increase the physico-chemical quality of economic results in plants. The effect of pruning on growth and crop yield depends on time, especially sweet potato plants because it is very related to the growth phase which correlates with the time of tuber formation (Aniekwe, 2014). Suminarti (2016) further added that the effect of pruning on yields depends on the number of leaves trimmed, the position of leaves on the stem, the frequency of pruning, the time of pruning and the period of plant growth. The purpose of this study was to knows the response and get the right time of pruning on 3 sweet potato varieties.

MATERIALS AND METHODS

This study was carried out in rainy season, from January to May 2018 in Landungsari Village, Sub District of DAU, Malang, East Java, Indonesia, at an altitude 540 m above sea level with average rainfall 3000 mm per year and daily temperature 26 ^{0}C. The treatment design used in this study was Split Plot Design (SPT), with placing the varietas as main plot consisting of 3 levels, namely the Beta-1 variety (V1), Sari variety (V2) and Antin-3 variety (V3). While the time of pruning as sub plots consists of 4 levels, namely without pruning or control (P0), pruning 45 DAP (P45), pruning 65 DAP (P65), and pruning 85 DAP (P85). From the two factors, obtained 12 combination treatments and 3 repetition, so obtained 36 treatment units. 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 yield obtained from calculating the beds of tile. Harvest bed tile consistedof 6 plants, with area of harvest bed was 160 cm x 90 cm = 1.44 m^2. Calculation of the yield used the following formula:

$$\text{Yield (t ha}^{-1}) = \frac{10000}{\text{Scale of sampling plot}} x \text{ yield of sampling plot}$$

The data of the observations were analyzed by the F test at the level of 5%. If there is an interaction, it will be continued Honestly Significant Difference (HSD) Test at level 5% (Gomez and Gomez, 1995).

RESULTS AND DISCUSSION

Leaf Area

Based on the data in Table 1 shows that on various varieties at the ages of 100 DAP, lower leaf area was obtained at 85 DAP pruning and caused a decrease in leaf area for each variety, on Beta-1 variety of 4124.16 cm^2 (38.49%), the Sari variety was 2219.96 cm^2 (41.94%) and in the Antin-3 variety was 3497.45 cm^2 (45.35%). This is quite reasonable because the plants are only 15 days after being pruning, of course, many branches and leaves are discarded, while for recovery of plants, needed of time, so that the number of branches and leaves of plants that pruned 85 DAP less than plants that are not pruned, pemangkasan 45 and 65 DAP. As we know, branches are a place the growth of leaves, so the number of branches certainly will positively correlate to the number of leaves and leaf area. In accordance with the opinion of Riodevriza (2010), which states that the growth of shoots or branches of a plant will be directly proportional to the growth of the leaves. If seen from the response of the three varieties to the time of pruning 45 DAP, it appears that for the Beta-1 variety, plants that were pruned 45 DAP the leaf area increased by 2202.13 cm^2 (17.05%). Whereas on Sari and Antin-3 varieties there was no increase in leaf area in plants which have been pruning 45 DAP.

The area of leaves is one indicator of plant growth which is quite important, because it is a picture of plant capacity in carrying out photosynthesis.

Table 1; Average of Leaf Area of 3 Varieties of Sweet Potato at the age 100 DAP

Treatments	Shoot Pruning Time (DAP)							
	Control		45		65		85	
Varieties:	Leaf Area (cm^2 $plant^{-1}$)							
Beta-1	10714,29	b	12916,42	c	11170,85	bc	6590,13	a
	C		C		B		B	
Sari	5293,08	b	5130,68	b	4840,48	ab	3073,22	a
	A		A		A		A	
Antin-3	7712,15	b	7649,76	b	5935,39	b	4214,70	a
	B		B		B		A	
HSD (5%) = 1815,50								
CV a= 12,80%					CV b=11,07%			

Information: Numbers followed by the same lowercase letter in the same row or the same uppercase letter in the same column show not significant different based on the HSD test at level 5%. DAP = days after planting, CV = coefficient of variance

According to Peksen (2007), leaf area illustrates the correlation of physiological characteristics that are important to determine the overall contribution of each part of the canopy to fruit quality and crop production. According to Suminarti (2016), the high number and area of leaves on sweet potato plants caused the light received by the leaf lamina to be low, especially the leaves at the bottom, because the composition of the leaves shading each other. This causes a reduction in photosynthesis, so that the resulting asymylate is low. The ability of plant leaf area to intercept solar radiation and the maximum photosynthetic rate is a very determine factor PGR (plant growth rate) Madhu and Hatfield (2016), in addition, the environmental conditions in which plants grow greatly influence the PGR of sweet potato, corelated to solar radiation received by plants and the ability of plants to use them optimally to produce photosynthate (Ravi and Saravanan, 2012).

Leaf area index

Average of leaf area index (LAI) on various varieties due to pruning at age 100 DAP is presented in Table 2. On Beta-1 varieties, pruning 45 and 65 DAP caused an increase in plant LAI of respectively 1.70 (24.34%) and 1,59 (23.13%). Whereas in Sari varieties, LAI of plants that were pruned 45 and 65 DAP were not significantly different from plants that were not pruned, even the treatment of pruning 85 DAP could reduce LAI 1.39 (31.56%). The same pattern occurs in the Antin-3 variety, where LAI of crop which has been pruned at 85 DAP decreased by 1.43 (28.57%).

Leaf area index is the ratio between leaf area per plant with the area land which shaded. According to Belehu (2003), LAI strongly determines the growth rate of sweet potato plants from the initial phase of growth until enter the end of the vegetative phase, but after the vegetative phase ends PGR is no longer affected by LAI. Sitompul (2016), said that most plants at the beginning of growth for several weeks after planting have LAI less than 1, then increase rapidly to reach the maximum level in the middle of the growth period, and then occur a decrease in LAI at the end of the plant growth period. The results of this study indicate that maximum LAI occurs at the age of 100 DAP, after which it decreases. Generally, in sweet potato plants the increase in LAI is not always followed by increased production, because LAI that is too high caused photosynthate translocation from the source to the sink to be not optimal because photosynthate accumulates in vegetative organs, especially leaves (Isa et al., 2015).

In Table 2, it can be seen that LAI on Beta-1 varieties which were pruned 45 and 65 DAP reached 6.98 and 6.87. According to Tsuno and Fujise (1963), the optimum LAI for sweet potato plants ranged from 3-4. The high value of LAI in Beta-1 varieties is thought to be due to the wider size of leaves and the larger number of leaves. LAI of a plant besides being influenced by the type of plant itself also influenced by the leaf area (Cristifori et al., 2011). This is supported by the opinion of Hue et al. (2012), which states leaf area will affect the LAI value. The results of this study also showed that LAI was positively correlated with the number of leaves, number of branches and leaf area. Suminarti (2016) said that the value of LAI greatly determines the penetration of light entering the canopy of plants. The greater the LAI of a plant, the lower the penetration of light into the canopy of plants, its make the light received by canopy on the lower is low, this effected in reduced photosynthetic activity.

Table 2; Average Leaf Area Index of 3 Varieties of Sweet Potato at the age 100 DAP

Treatment	Shoot Pruning Time (DAP)							
	Control		45		65		85	
Varieties:								
Beta-1	5,28	a	6,98	b	6,87	b	5,25	a
	A		B		B		B	
Sari	4,40	b	4,80	b	4,15	ab	3,01	a
	A		A		A		A	
Antin-3	5,01	b	5,21	b	4,67	ab	3,58	a
	A		A		A		A	
HSD (5%) = 1,15								
CV a= 12,01					CV b=10,05			

Information: Numbers followed by the same lowercase letter in the same row or the same uppercase letter in the same column show that they are not different based on the HSD test at level 5%, DAP = days after planting, CV = coefficient of variance

Table 3; Average of Dry Weight Total of Plant on 3 Varieties of Sweet Potato at age 100 DAP

Treatments	Shoot Pruning Time (DAP)							
	Control		45		65		85	
Varieties:	Dry Weight of Plant (g plant^{-1})							
Beta-1	181,30	a	171,27	a	165,30	a	174,53	a
	A		A		A		B	
Sari	163,20	a	205,97	b	168,30	ab	141,57	a
	A		A		A		AB	
Antin-3	167,00	ab	206,63	b	173,63	ab	133,90	a
	A		A		A		A	
HSD (5%) = 39,90								
CVa= 11,52%					CVb= 10,10%			

Information: Numbers followed by the same lowercase letter in the same row or the same uppercase letter in the same column show that they are not different based on the HSD test at level 5%, DAP = days after planting, CV = coefficient of variance

Table 4;Average Diameter of Tuber of 3 Varieties of Sweet Potato at Harvest Time

Treatments	Shoot Pruning Time (DAP)							
	Control		45		65		85	
Varieties:	Diameter of Tuber (cm)							
Beta-1	7,18	a	5,99	a	6,10	a	6,83	a
	B		A		AB		A	
Sari	6,54	a	8,73	b	7,65	ab	6,80	a
	B		B		B		A	
Antin-3	4,31	a	5,98	b	5,97	b	5,29	ab
	A		A		A		A	
HSD (5%) = 1,58								
CVa= 14,35%					CVb=10,64%			

Information: Numbers followed by the same lowercase letter in the same row or the same uppercase letter in the same column show that they are not different based on the HSD test at level 5%, DAP = days after planting, CV = coefficient of variance

Dry weight total of plant

At the age of 100 DAP for Beta-1 varieties, there was no significant difference on total dry weight of plants trimmed with controls. While for Sari varieties, the total dry weight of the crop that was pruning by 45 DAP increased by 42.27 grams (20.76%). On Antin-3 variety, the total dry weight of the plants that was pruned 45 DAP was higher 72.73 grams (35.20%) compared the plants which was pruned 85 DAP, but the results of both were not significantly different from controls and pruning 65 DAP.

The amount of assimilation produced by a plant can be seen from its biomass, because the greater the assimilation produced, the greater the dry weight produced. The dry weight of a plant is determined by the optimal photosynthesis, if the results of photosynthesis increase, the dry weight also increases. Sanoussi et al., (2016), stated that at the beginning of the growth of sweet potato plants, the partition highest of dry weight was located on the zone of above ground, namely on

stems and leaves, but with increasing age the partitions of plant dry weight would be focused on tuber, and at time harvesting partition tuber can reach 90% of the total dry weight of plants. This causes when the observation age of 60 and 80 DAP of plants which pruned 45 and 65 DAP the dry weight is lower than the control, because the partition of photosynthate is larger to the canopy tissue of plants, especially stems and leaves have been reduced as effect of pruning. Results of research Madhu and Hatfield (2016), showed that at age 44 HST partitioned of dry matter which focused on leaves reached 55%, at stem 35% and at 10% root. Whereas at the time before harvesting in the process of filling the tuber partitions the dry weight of tubers can reach 45.9% of the total of dry weight of the plant.

Diameter of Tuber

On Beta-1 variety, the diameter of tuber produced by various shoot pruning times was not significantly different. Whereas on Sari varieties, the diameter of tuber which was prunned by 45 HST increased by 2.19 cm (25.06%). In Antin-3 varieties, shoots pruning of 45 HST and 65 HST can significantly increase tuber diameter by 1.67 cm (27.87%) and 1.65 cm (27.71%), respectively.

As we knowed the purpose of pruning is to inhibit the growth of excessive vegetative organs so that the formation of tubers begins immediately. However, on Beta-1 varieties, after shoots pruned cause growth of leaves and branches was higher, especially for plants that pruned at ages 45 and 65 DAP. Zhu and Jiang (2014), explained that the formation of dry matter is the result of three processes, namely the process of photosynthetic buildup, photosynthate reduction due to photosynthate respiration and distribution to the part of the need. The growth of vegetative organs, especially the leaves and branches which high on Beta-1 varieties which are pruned, is cause low the assimilate which distribution to the tuber, so that the shoot pruning cannot increase the diameter and weight of the tuber on the Beta-1 variety. This is in accordance with the opinion of Isa et al., (2015), which states that the tuber formation process in sweet potato plants will be disrupted if the vegetative growth is high. Whereas in Sari and Antin-3 varieties showed a different response, where after pruned the growth of vegetative organs was lower than the control plants. This is thought to result in faster tuber formation and assimilate proportions between tendrils and tubers being balanced, so that the diameter and weight of tuber which produced by the Sari variety that were pruned 45 DAP and Antin-3 varieties that were pruning 45 and 65 DAP higher than control plants.

Harvest Yields

The crop yields in this study showed that on Beta-1 variety there were no significant differences of yields between plants that were pruning at various ages with control plants. Whereas for Sari varieties, plants that which were pruned 45 DAP the yield increased 7.96 tons ha^{-1} (24.91%), while for the plants which pruned 65 and 85 DAP, the yields not increase the significantly. While for Antin-3 variety, plants that were pruned 45 and 65 DAP of crop yield increased by 7.97 tons ha^{-1} (41.44%) and 7.71 tons ha^{-1} (40.09%), respectively (Figure 1)

The high of yields of the Sari variety which were pruned 45 DAP and Antin-3 variety which were pruning 45 and 65 DAP were thought to be due to the size of the tuber and the weight of the tuber produced was high. This indicates that diameter and weight of tuber are very influential and positively correlated with crop yields. According to Suminarti (2016), the high of vegetative growth on sweet potato plants will have an impact on the postponement of the generative phase because of the longer vegetative phase, this will affect the initiation (formation) of tubers, so that the tubers formed are relatively smaller in size. In addition, pruning is done when the plant enters the filling and enlargement phase of the tuber, causing some of the assimilates to form the tuber to be overhauled back into energy for growth, so that the assimilates stored as tubers are reduced. This is thought to have caused the Sari variety which was pruned 65 and 85 DAP, and the Antin-3 variety which was pruned by 85 DAP, the diameter and weight of the tuber produced was not significant different from the control. This is possible because at the age of 65 DAP until 85 DAP has entered the filling and enlargement phase of the tuber, so that shoot pruning cannot increase the diameter and weight of the tuber significantly.

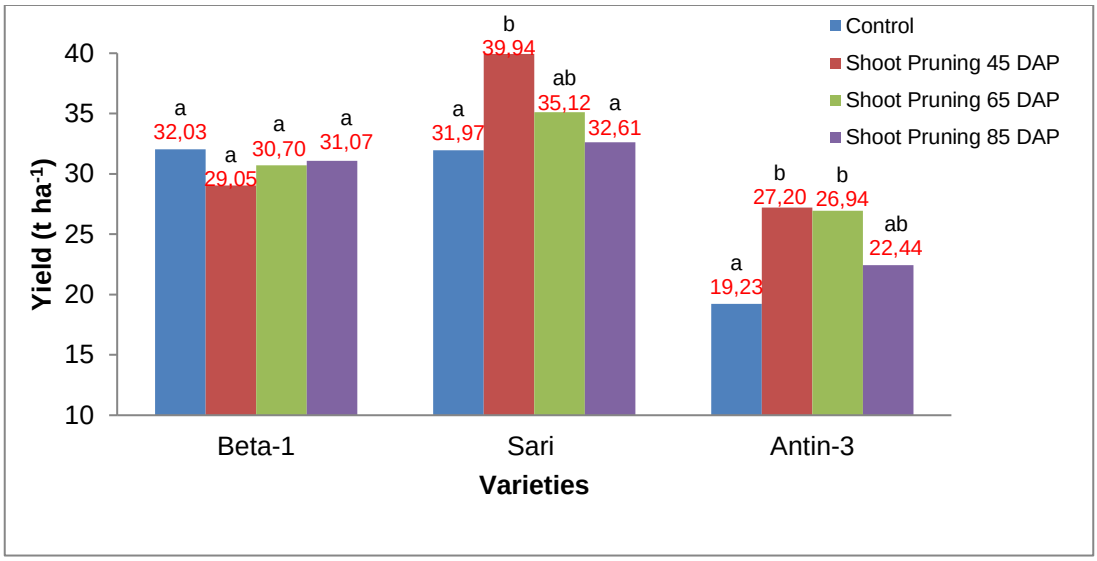

Figure 1; Yields of three Sweet Potato varieties repectively on various shoot pruning times

CONCLUSION

Shoot pruning 45 and 65 DAP causes high the growth of vegetative organs on Beta-1 varieties, but cannot increase the tuber yields. Whereas in Sari variety, shoot pruning 45 DAP increases tuber yield by 7.96 tons ha^{-1}. For Antin-3 variety, shoot pruning 45 and 65 DAP increased the tuber yield by 7.97 tons ha^{-1} and 7.71 tons ha^{-1} respectively.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All the authors have contributed on this article. M contributed to designed and performed the experiments, data collection, data analysis and wrote the manuscript, EW contributed to determinated of research treatment, field survey and reviewed the manuscript, NES contributed to experimental designed and determination of research treatment.

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