International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

The Growth and Yield of Taro (*Colocasia esculenta* (L.) Schott) var. *Antiquorum* in Diverse Sizes of Tuber and Numbers of Leaf

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Abstract: ***Objectives of the research were to study the sizes of tuber and numbers of leaf that must be left to increase the growth and yield of taro. The research was conducted at the field in Karang pandan Village, Rejoso Subdistrict, Pasuruan Regency, from October 2012 – July 2013. The research used a Randomized Complete Design (RCD), which was constructed in factorial that comprised of 2 factors. The first factor is the tuber sizes (U) : (U_1) size of the germ tuber 30 – 49 g, (U_2) size of the germ tuber 50 – 69 g, and (U_3) size of the germ tuber 70 – 89 g. The second factor is the left leaves (D) : (D_0) control (the leaves are not pruned), (D_1) numbers of the left leaves, 2 leaves plant^{-1}, (D_2) numbers of the left leaves, 3 leaves plant^{-1}, (D_3) numbers of the left leaves, 4 leaves plant^{-1}. Results of the research showed no significant interaction between the tuber size and numbers of leaf, however, size of the germ tuber and number of the left leaves have significant effect on all of the observed parameters, except RGR (Relative Growth Rate) and NAR (Net Assimilation Rate (NAR) on the germ tuber size and RGR, NAR and Dision Index (DI) on number of leaf. Size 70-89 g produces fresh weight of tuber 22.53 ton ha^{-1}, while the plants, which do not prune the leaves, will produces fresh weight of tuber 23.43 ton ha^{-1}.***

Keywords: Taro, tuber size, number of leaf, yield

1.Introduction

Taro (*Colocasia esculenta* (L.) Schott var. *Antiquorum* belongs to the root crops that can be utilized as local food sources, which is healthy and safe to be consumed due to low carbohydrate content (22.25), reduction sugar (0.87) and starch (20.03%), which contain in the tuber (Suminarti, 2009). The taro tuber can be consumed directly, by steaming or being processed into flour that can be made as instant foods for baby and the old (Onwueme, 1977). The increasing social awareness for the fulfilment of local food sources, which is healthy and safe, has caused the increasing demand for taro tubers. High demand of taro tubers has not been able to be fulfilled due to low production of taro tubers in the farmer level, 6 ton ha^{-1} (Goenaga and Chardon, 1995), meanwhile, the potential yield has reached 20.7 ton ha^{-1} (Onwueme, 1977). Based on result of the survey, the increasing demand of taro tubers has reached 44% (in Asia) and 10% in Malang (Brilliantono, 2006 and Suminarti, 2009).

In general, taro plants are planted in the yard or dry land cultivation by low management due to quality of the germ tubers have small size (< 20 g) and they are highly heterogeneous, therefore the yields are low as well. It requires some efforts to increase the yield of taro tubers per ground area unit and time, as well as determination of tuber size that must be concerned. It reminds that the tuber size will determine the next development and yield of the crops. Small tubers have different content of food reserves in comparison with the bigger ones, meanwhile the germination of the plant is highly affected by the amount of energy in the tuber as reflected by the amount of the food reserves in the tuber. Besides that, low yield of the tuber was also caused by low resistance of the plant toward high humidity. Under high humidity condition, not only due to high rainfalls but also high shade of the plant, it has caused the plant to be sensitive to pest and disease infections. In order to anticipate the pest and disease infections, pruning the leaf is required, particularly in the lower part as the parasite leaf. Pruning the leaf is intended to provide an opportunity for the assimilate allocation to the productive parts, as the formed leaf or to the sink part, where assimilates are stored. The amount of the contributed assimilates, which are going to be distributed to the plant in relation to the pruned leaves, is highly determined by the amount of the remain leaves, so that determination for numbers of leaf that conformed to the growth yield of the taro should be done.

2.Material and Method

The research was conducted at the field in Karang pandan Village, Rejoso Subdistrict, Pasuruan Regency, started from October 2012 – July 2013, at the altitude of 4 m asl (above sea level), rainfall is about 179.26 mm year^{-1}, daily temperature ranges 22.8 – 28.6, humidity is 60-80% in alluvial soil. Instruments of the research used soil cultivator, sprayer, watering can, analytic scales, oven, meter, phosphate (SP-36 36% P_2O_5), cattle droppings, Dithane M-45, Sidametrin and Mastecx. The research applied a Randomized Complete Design (RCD), which was constructed in factorial that comprised of 2 factors by 3 replications. The first factor is the tuber sizes (U) : (U_1) size of the germ tuber 30 – 49 g (small), (U_2) size of the germ tuber 50 – 69 g (medium), and (U_3) size of the germ tuber 70 – 89 g (big). The second factor is the left leaves/ the remained leaves (D) : (D_0) control (the leaves are not pruned), (D_1) numbers of the left/remained leaves, 2 leaves plant^{-1}, (D_2) numbers of the left leaves, 3 leaves plant^{-1}, (D_3)

numbers of the left leaves, 4 leaves plant^{-1}. As a whole, there are 12 combinations of treatment. Data collection in relation to the growth observation was taken at 90, 130, and 165 dap, by 2 sample plants for each combination of the treatment. Observation on the growth and yield was done by uncovering the plants (destructive), and observation on the yield (harvest) was conducted at the age of 8 months. Components of the growth and yield on the observed plants at the ages of 95, 130, and 165 dap, include : leaf area, total dry weight of the plant, number and fresh weight of the tuber, the yield components (at the harvest time) include : number of tuber, fresh weight of the tuber, yield of the tuber (ton ha^{-1}) and tuber classes. Analysis of the plant growth includes : Leaf Area Index (LAI), Relative Growth Rate (RGR), Net Assimilation Rate (NAR), and Division Index (DI). Data analysis uses analysis of variance (F-test) at the level p = 0.05 and if any significant effect occurred, it will be followed by SSD test at the level of p = 0.05.

Table 1: Leaf area plant^{-1} at all ages of observation due to the treatment on sizes of tuber for seed and numbers of leaf

Treatment	Leaf area (cm^2)/age of observation (dap)		
	95	130	165
Size of tuber for seed			
30 - 49 g (small)	2294.77	3250.39 a	1441.71 a
50 - 69 g (medium)	2400.25	3491.31 b	1625.57 b
70 - 89 g (big)	2474.97	3622.50 c	1798.62 c
SSD 5%	Insig	60.24	49.47
Number of leaf			
Control	254.21 d	3691.64 d	1831.29 d
2 leaves	2200.44 a	3082.99 a	1331.77 a
3 leaves	2353.55 b	3460.40 b	1562.82 b
4 leaves	2464.79 c	3583.89 c	1761.99 c
SSD 5%	61.74	80.32	65.96

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%, insig = insignificant, dap = days after planting

3.Result and Discussion

Treatment of the germ tuber size and number of leaf showed no significant interaction toward all components of the growth and yield, as well as the yield at the harvest time and analysis of the growth,

3.1 The Effect of Tuber Size

Size of the germ tuber has significant effect on leaf area at the age of 130 and 165 dap (Table 1). At the age of 130 dap, the plant has optimal growth of leaf area (peak), but at the age of 165 dap, the growth of leaf area has decreased. The bigger the size of the germ tuber is, the higher the leaf area will be resulted. Treatment of big germ tuber (70-89 g) has provided the highest leaf area due to such tuber has the greatest food reserves, so that it would be able to grow well from the early growth to the end. Research by Putra, Herlina and Wardiyati (2006) showed that the treatment of size on potato germ > 60–90 g produced the highest yield on parameter of the development of the plant height, number of branches, number of leaf, and leaf area. According to Enyi (1967), the growth of shoots highly depends on the size of tuber. Soetopo (1985) suggested that big germ contain more food reserves. Meanwhile, Goldsworthy (1992) stated that big tuber would produce higher yield and growth. Sitompul and Guritno (1995) stated that one of factors, which determine quality of planting material, is the amount of food reserves contained in the material.

The highest leaf area on the treatment of big tuber germ (70-89 g) has been able to intercept the highest light in comparison with two other treatments. More light that can be intercepted, more photosynthates can be produced. It has been proven that total dry weight of the plant resulted by the big tuber germ (70-89 g) is the highest. Result of the research by Hossain *et al.* (2004) showed that biomass of curcuma is highly affected by the size of the rhizome germ. Higher biomass has been obtained from the application of the biggest size (30-50 g) of the rhizome germs.

During the research, the big tuber germs (70-89 g) have produced the highest total dry weight of the plants, but it does not mean that they have different RGR. It shows that the growth rates of the plants, in forming the biomass per initial weight, are identical on three treatments of the tuber size. Leaf Area Index (LAI), as a result of the tuber treatment, has shown very significant effect at the age of 130 and 165 dap, and the highest is for the big size of germ (70-89 g). Soemono *et al.* (1984) stated that the highest LAI (1.03) was resulted by the big size of *suweg* germ (150 g) at the age of 40 dap. LAI values (Table 3) on all treatments < 1 to all ages of the observation.

Table 2: Total dry weight plant^{-1} at all ages of observation due to the treatment on sizes of tuber for seed and numbers of leaf

Treatment	Total dry weight of plant (g)/age of observation (dap)		
	95	130	165
Size of tuber for seed			
30 - 49 g (small)	121.70 a	201.96 a	211.75 a
50 - 69 g (medium)	140.51 b	215.75 b	232.71 b
70 - 89 g (big)	150.13 c	236.80 c	250.02 c
SSD 5%	3.86	6.20	4.63
Number of leaf			
Control	149.23 c	251.80 d	273.51 d
2 leaves	122.32 a	187.88 a	194.85 a
3 leaves	136.60 b	210.47 b	218.49 b
4 leaves	141.63 b	222.53 c	239.13 c
SSD 5%	5.15	8.27	6.18

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%, dap = days after planting

According to Sitompul and Guritno (1995), value of LAI < 1 shows that the leaves are not shade one to another. However the tuber treatment does not show any different values of NAR. It shows that the ability to increase total dry weight of the plant per leaf area unit among those three treatments is identical. RGR values relate to NAR and the increasing as well as the decreasing NAR of the plant will affect the subsequent RGR values of the plant. At 95 dap; the division index (DI) value is the highest for the treatment of big germ tuber (70-89 g), Table 4. It shows higher yield of the photosynthesis on the big germ tuber (70-89 g), so that more assimilates can be stored in the tuber, and of course, it will increase the tuber weight

Table 3: Leaf area index plant^{-1} at all ages of observation due to the treatment on sizes of tuber for seed and numbers of leaf

Treatment	*Leaf area index/age of observation (dap)*		
	95	*130*	*165*
Size of tuber for seed			
30 - 49 g (small)	0.41	0.58 a	0.26 a
50 - 69 g (medium)	0.43	0.62 b	0.29 b
70 - 89 g (big)	0.44	0.64 c	0.32 c
SSD 5%	insig	0.011	0.01
Number of leaf			
Control	0.45 c	0.66 d	0.33 d
2 leaves	0.39 a	0.55 a	0.24 a
3 leaves	0.42 b	0.62 b	0.28 b
4 leaves	0.44 c	0.64 c	0.31 c
SSD 5%	0.011	0.014	0.01

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%, dap = days after planting

Table 4: Index/Coefficient of division due to the effect of tuber sizes for seed and numbers of leaf

Treatment	*Observation at the age of 95 dap*
	Index /Coefficient of Division
Size of tuber for seed	
30 - 49 g (small)	0.64 a
50 - 69 g (medium)	0.67 b
70 - 89 g (big)	0.72 c
SSD 5%	0.012
Number of leaf	
Control	0.69
2 leaves	0.67
3 leaves	0.68
4 leaves	0.68
SSD 5%	insig

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%, insig = insignificant, dap = days after planting

Research by Pangaribuan (2000) showed that the big size of the tuber germ (46-60 g) produced the greatest number of potato tuber and the lowest for the small size < 20 g. More photosynthates contain in the big tuber germ, so that more assimilates will be stored as well; therefore, it will increase the tuber weight. There was very significant connection between number of tuber and fresh weight of the tuber at the harvest time (0.99**). It showed that the greater numbers of the tuber that have been produced will increase the carbohydrates, which are going to be allocated to the tuber, so that it will increase weight of the resulted fresh tubers. Big tuber germs produce the highest yield of tuber and fresh weight of the tuber, so that the yield of tuber ha^{-1} has also resulted on the big germ tuber (70-89 g). Sukarman *et al.* (2001) showed that treatment using an intact-parent wild ginger rhizome, 220.5 g, and the parent rhizome was cut into two pieces (109.7) and the obtained rhizome yield was 27.2 and 24.2 ton ha^{-1} higher than if the parent rhizome was cut into four pieces (54.36 g), 8 pieces (27.2 g), and the yield were 18.2 and 14.7 ton ha^{-1}

Table 5: Numbers of tuber plant^{-1} and fresh weight of tuber plant^{-1} at the harvest time due to the effect of tuber sizes for seed and numbers of leaf

Treatment	Number of tuber	Fresh weight of tuber (g)
Size of tuber for seed		
30 - 49 g (small)	25.62 a	1243.58 a
50 - 69 g (medium)	29.27 b	1349.00 b
70 - 89 g (big)	31.63 c	1396.68 c
SSD 5%	0.45	28.79
Number of leaf		
Control	29.89 c	1452.96 d
2 leaves	27.13 a	1174.78 a
3 leaves	28.47 b	1306.37 b
4 leaves	29.87 c	1384.89 c
SSD 5%	0.61	38.38

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%

The plants, which are not pruned, produce the highest leaf area due to more leaves remain. Leaf area is determined by the numbers of leaf and the individual area of each leaf; however, more leaves mean higher leaf area (Table 1). Result of the research by Arafat (2007) showed that the mungbean plant without any defoliation will produce the highest leaf area; meanwhile, the lowest leaf area is resulted from the plant that has been defoliated, 6 leaves. According to Sitompul and Guritno (1995), formation and development of leaf, stem, root, and tuber are highly affected by the yield of photosynthesis. Individual leaf area and total leaf area affect on the resulted biomass or photosynthate due to the higher the leaf area, the greater the light that can be intercepted by the leaf. Light is used to produce energy (ATP and $NADPH_2$), which will be used to reduce CO_2 into sugar. The more the light is, the more photosynthate (sugar) can be produced. On number of leaf treatment, the plants, The treatment on number of leaf affects on leaf area and total dry weight of the plant, but it does not affect on RGR. It shows that the growth rates, to form biomass, are identical for all treatments. It shows very significant correlation between leaf area index and RGR on the whole ages of observation (r = 0.96**, r = 0.98** and r = 0.92**). The identical results were found on NAR, which showed no significant difference among those treatments. It shows very significant correlation between LAI and NAR (r = 0.99**,r =0.97** and (r = 0.88*). It describes that the increasing values of NAR is affected by the increasing leaf area index. However, the highest weight of tuber is derived from the plant that has unpruned leaves. It shows that such plant has more carbohydrates that are used for the tuber enlargement. The highest fresh weight plant^{-1} on the unpruned plant is identical as the yield of plant ha^{-1} that has been achieved by the same treatment. There is very significant correlation (r=0.91**) between leaf area and number of tuber, as well as between number of tuber and fresh weight of tuber during the harvest time (r = 0.98**). It shows that the increasing leaf area will increase the photosynthate, therefore, it will increase number of tuber and fresh weight of the tuber as well. Besides that, high fresh weight of the tuber is as a result of the unpruned plant produces the highest tuber size >70 g, even though the tuber size is 50 – 69 g and < 50 g, which is not different from other treatment.

Table 6: Yield of tuber ha^{-1} at the harvest time due to the effect of tuber sizes for seed and numbers of leaf

Treatment	*Yield of tuber ha^{-1} (ton)*
Size of tuber for seed	
30 - 49 g (small)	20.06 a

50 - 69 g (medium)	21.76 b
70 - 89 g (big)	22.53 c
SSD 5%	0.46
Number of leaf	
Control	23.43 d
2 leaves	18.95 a
3 leaves	21.07 b
4 leaves	22.34 c
SSD 5%	0.62

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%

Table 7: The tuber classes at the harvest time due to the tuber size and number of leaf

Treatment	Tuber class		
	>70 g	50-70 g	<50 g
Size of tuber for seed			
30 - 49 g (small)	1.15 a	1.60 a	22.87 a
50 - 69 g (medium)	1.65 b	2.02 b	25.60 b
70 - 89 g (big)	1.68 b	2.78 c	27.42 c
SSD 5%	0.11	0.13	0.36
Number of leaf			
Control	2.02 c	2.22	25.64
2 leaves	1.16 a	1.96	24.36
3 leaves	1.36 b	2.16	24.96
3 leaves	1.44 b	2.20	26.22
SSD 5%	0.15	insig	insig

Notes: Numbers followed by the same letter in the same column show insignificant difference based on SSD at the level of 5%, insig = insignificant

4.Conclusion

1) Different sizes of germ tuber and number of leaf do not show significant interaction toward all components of growth and yield of the taro plants.
2) The use of medium size of germ tuber (50-69 g) has resulted higher yield and growth of the small size of the germ tubers (30-49 g) and the highest yield has been obtained from the big germ tubers (70-89 g), which produces fresh weight of tuber 1396.68 g plant^{-1} or 22.53 ton ha^{-1}, 3.54% higher than the medium size of germ tuber (50-69 g) and 12.31% higher than the small size germ tuber (30-49 g).
3) Plant that has 4 leaves shows lower yield and growth in comparison with the plant, which is not pruned, and higher than the plants that have 3 and 2 leaves. The plant that is not pruned will produce fresh weight of tuber 1384.89 g plant^{-1} or 23.43 ton ha^{-1}, 4.69% higher than the plant that has 4 leaves, 11.20% higher than the plant that has 3 leaves, and 23.64% higher than the plant that has 2 leaves.

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