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Responses of taro plant (*Colocasia esculenta* L. Schott) to cormel size as planting material, NPK application and aphid infestation

Lakitan, B.[1,2,*], Ria, R. P.[1], Putri, H. H.[1], Achadi, T.[1] and Herlinda, S.[2,3]

[1]College of Agriculture, Universitas Sriwijaya, Inderalaya 30662, Indonesia; [2]Research Center for Sub-optimal Lands, Universitas Sriwijaya, Palembang 30139, Indonesia; [3]Department of Plant Pests and Diseases, College of Agriculture, Universitas Sriwijaya, Indralaya 30662, Indonesia.

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Abstract The strong correlation amongst pairs of cormel morphological traits was found between cormel weight with diameter (r = 0.9068) and with length (r = 0.8659). Thus, cormel weight was used as main indicator of cormel size. Taro plant consists of one mother plant and many suckers. Cormel weight consistently exhibited positive effects on number of suckers and base diameter, length and width of the largest leaf, length and diameter of petiole measured consecutively at 3 WAP, 5 WAP, and 7 WAP. However, Increased in number of suckers did not affect growth of mother plant as indicated by constant number and size of leaves produced by the mother plant. Response of taro plant to NPK application was monitored every 2 days based on SPAD value. If the NPK was applied at 4 WAP, during early vegetative phase, it took 12 days before SPAD value dropped back to pretreated condition but if it was applied at 12 DAP, during tuber development phase, it only needed 6 days. This finding suggests that more frequent NPK application is needed by taro plant for enhancing tuber growth. Aphids can seriously damage the taro plant. Aphids attacked leaves at all dimensions, but serious damage (score = 4) mostly observed in older leaves. Cormel size positively affects growth traits yet did not affect number of leaves and leaf water content. It is recommended for farmers to use larger cormel size for taro cultivation.

Keywords: Aphid attack; Cormel size; Morphological trait; Response to fertilizer; Tuber yield

Introduction

Taro plant, *Colocasia esculent*a (L.) Schott is high productivity, easy to grow, and good quality carbohydrate/starch source. Farmers are hesitant to cultivate due to low price and the industry demand has not eager to use it as raw material due to its high oxalate content in both tuber and shoot. Total oxalate content in the leaves of taro ranged from 433.8 to 856.1 mg/100 g wet matter

[*] **Corresponding Author:** Lakitan, B.; **Email:** blakitan60@unsri.ac.id

(WM); while the soluble oxalate ranged from 28% to 41% and insoluble oxalate ranged from 59% to 72% (Thanh *et al.*, 2017). However, Kizhakedathil *et al.* (2020) recently found that 98.3% of total undesirable oxalates can be removed under optimal conditions using microbial oxalate oxidase without altering the desirable properties of taro starch.

Almost all parts of taro can be used including taro peels which contains many starch residues; therefore, this taro waste could be used as raw materials for producing bioethanol (Wu *et al.,* 2016). Taro starch is suitable for use in producing floating pellets for fish feed (De Cruz *et al.,* 2015; Kamarudin *et al.,* 2018). Moreover, enzyme-treated taro leaves can be used as prebiotic in animal feed (Saenphoom *et al.,* 2016).

Taro can be grown conventionally or organically cultivated. Both elite and local varieties responded equally well to organic management (Suja *et al.,* 2017). Challenge in cultivation of organic taro is to avoid this plant from phytophagous insects and pathogenic microorganisms. Taro leaf blight caused by *Phytophthora colocasiae* could be a serious problem during rainy season (Abdulai *et al.,* 2020). Aphids' attack should also be anticipated (Rhainds and Messing, 2005).

The continuously maintained soil moisture and crop water requirement were necessary for achieving optimum yield (Mabhaudhi *et al.,* 2013; Lakitan *et al.,* 2019). Pruning by leaving 6 leaves increased number of tubers and productivity of Taro. While the best harvest times to optimize productivity of taro was at age of 7 to 8 months (Ramadan *et al.,* 2018).

The common planting materials used in taro cultivation are cormels, a small and healthy corm collected from the previous harvest. Normally the sizes of collected cormel is not uniform. The research findings were designed to evaluate the correlation between cormel size and morphological traits in taro plant, response of taro plants to periodic NPK fertilizer application and severity of aphid's attack to taro plant.

Materials and methods

The used planting materials were small cormels of green taro (*Colocasia esculenta* (L.) Schott) from the previous harvest, ranging from 3.61 to 68.59 g in weight, 16.68 to 69.04 mm in length and 12.96 to 41.33 mm in diameter. Length and diameter were measured using digital caliper (Taffware SH20). The cormels were planted in 25-cm upper diameter pots, filled with soil-manure mix at the ratio of 2:1 v/v.

NPK fertilizer at ratio of 16:16:16 was initially applied at 5 g/plant. SPAD values were measured every 2 days starting from the day of NPK fertilizer was applied until 20 days after the application. Chlorophyll meter (Konica Minolta SPAD-502Plus) was used for measuring the SPAD value. Reapplication of the NPK was done after significant drop of the SPAD value had been observed. Leaf damage due to aphids (*Aphis gossypii*) attack was also monitored and recorded, using score 1 to 5 based on severity of physical damage (Figure 1).

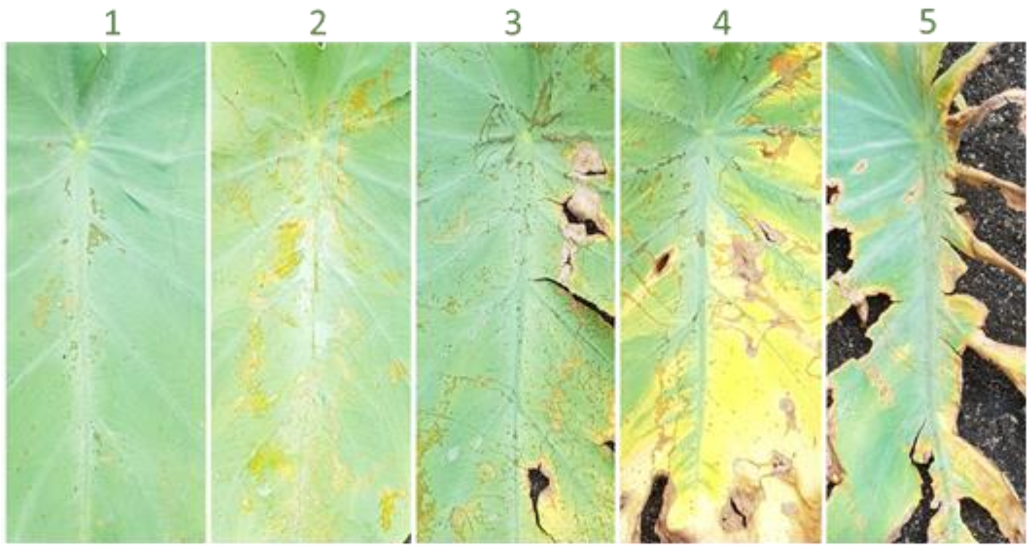

Figure 1. Damage score on leaf of Colocasia esculenta plant attacked by black aphids (*Aphis gossypii*): Score 1 = the least damaged; 5 = the most damaged; Meanwhile 0 = healthy, not attacked; 6 = leaf death, fully dried (not shown)

Parameters were weekly measured using non-destructive procedure, including the number of suckers, number of mother plant's leaves, stem base diameter, length of petiole, petiole diameter at upper-end, length and width of the largest leaf. Data on morphological traits were measured on 3, 5, 6, 7, 8, and 9 weeks after planting (WAP). During the first 5 weeks, growth of the green taro was relatively slow, exponential rapid growth started after 5 WAP. Destructive sampling procedure was conducted at 9 WAP which allowed for measurements of more additional parameters, including total and average weight of suckers, leaf fresh and dry weight and tuber fresh weight. Also, for calculating secondary parameters including leaf water content, ratio of leaf/total fresh weight, and ratio of tuber/total fresh weight.

This experiment was arranged according to the split plot design. Days of the NPK fertilizer application were assigned as the main plots with 3 treatment levels, i.e., unfertilized control, applied at 4 WAP (at early vegetative phase), and applied at 12 WAP (during tuber development phase). Cormel sizes were assigned as the subplots consisted of 3 grades, i.e., large varied from 23.09 to 68.59 g; medium varied from 12.00 to 22.92 g; and small varied from 3.61 to 11.93 g. Each treatment combination consisted of 5 replications. Significant differences among treatment effects on selected traits were tested based on analysis of variance (ANOVA) procedure. Mean comparison was using the least significant difference at $p<0.05$. The relationship among the morphological traits was analyzed using regression and correlation procedures. Severity of aphid attacks was proxied using score based on level of physical damage.

Results

Effects of planted cormel size on morphology of green taro plant

Cormel size can be described based on its fresh weight, diameter, or length. Among these three indicators, cormel fresh weight was strongly correlated with both cormel diameter and length (Figure 2). Shape of cormel is also irregular. Therefore, this study used cormel fresh weight as main indicator for cormel size.

The number of suckers per plant was strongly associated with planted cormel size. Larger cormel size used as planting material produced more suckers, measured at 3, 5, and 7 WAP. Meanwhile, the relationship between cormel size and stem base diameter of green taro mother plant was only observed at 3 and 5 WAP. Measurement at 7 WAP exhibited that stem base diameter of taro plant was not significantly (R2 = 0.191) related to planted cormel size (Figure 3). Halted enlargement proses in stem base diameter of mother plant at 7 WAP was assumed to be allied with massive growth of its suckers.

The association between cormel size and length or width of the largest leaf had diminished at 7 DAP. Meanwhile, associations were observed at 3 and 5 DAP (Figure 4). The size of the largest leaf in taro plant represents canopy or plant size since the number of leaves was relatively similar between small and large plants. At 7 DAP and later, roots have been well developed and functional; thus, the plants were no longer dependent on nutrients provided from the planted cormel. Similar trends were observed on the association between planted cormel size with petiole length or diameter at upper end position (Figure 5). Under favorable agroclimatic condition and in healthy plants, leaf size and petiole length were most likely proportional.

Correlation between the number of suckers and the number of leaves in green taro mother plant was observed at 6 WAP (Figure 6). This was a good indication that the increase in the number of suckers did not affect the growth of mother plant. Another research should be conducted to test the direct effect of eliminating all suckers on growth and development of the mother plant.

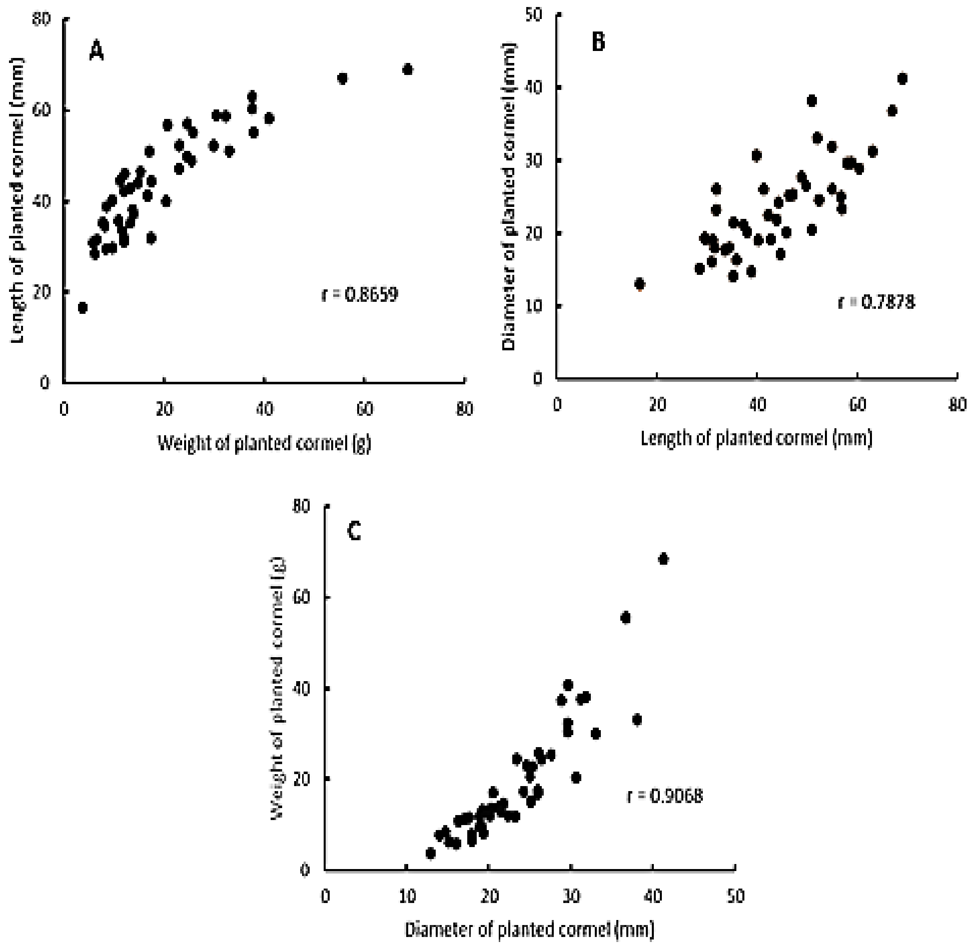

Figure 2. Correlation coefficient between pairs of cormel morphological traits in *Colocasia esculenta*

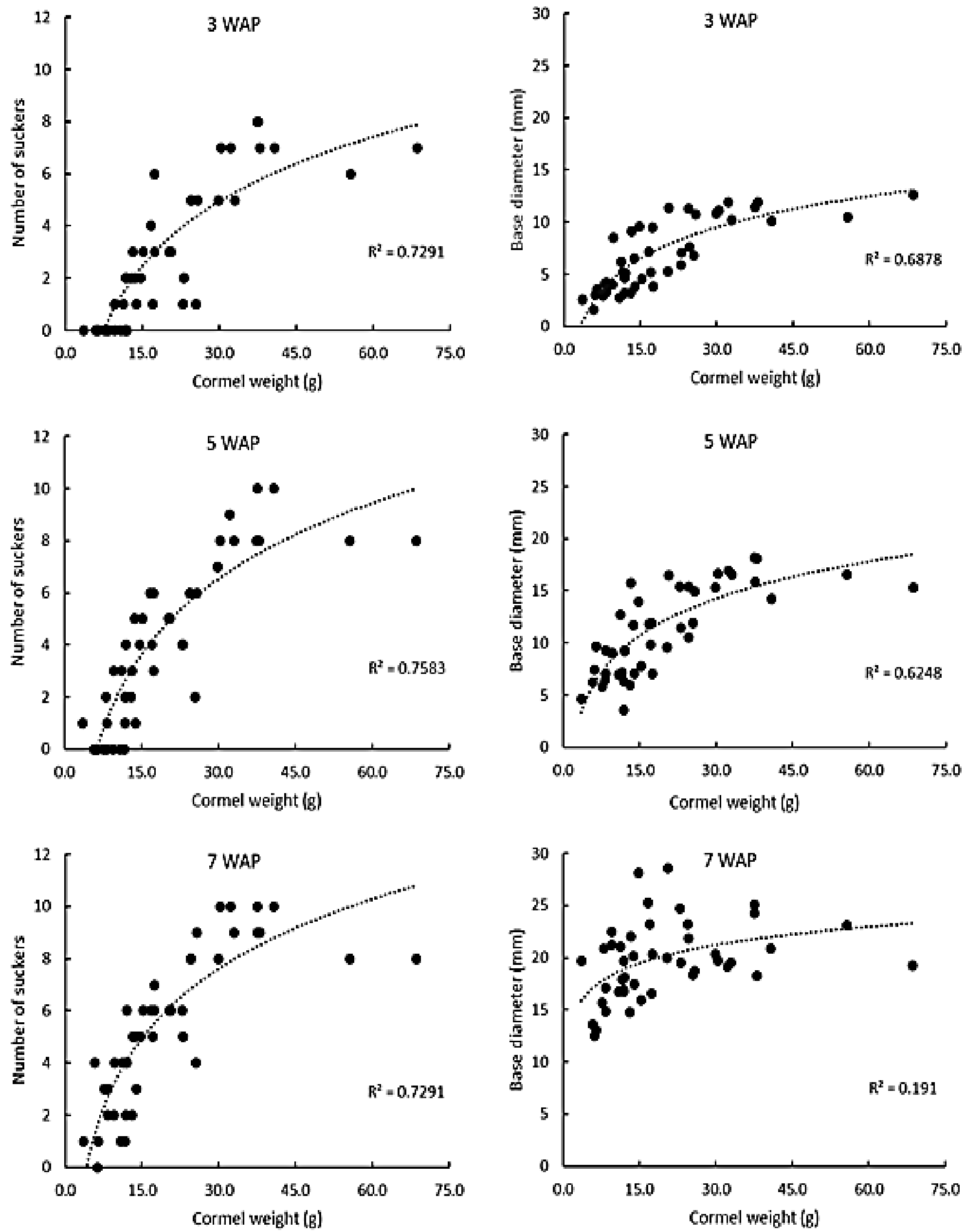

Figure 3. Effects of planted cormel weight on number of suckers and stem base diameter of *Colocasia esculenta* plant, measured at 3, 5, and 7 weeks after planting

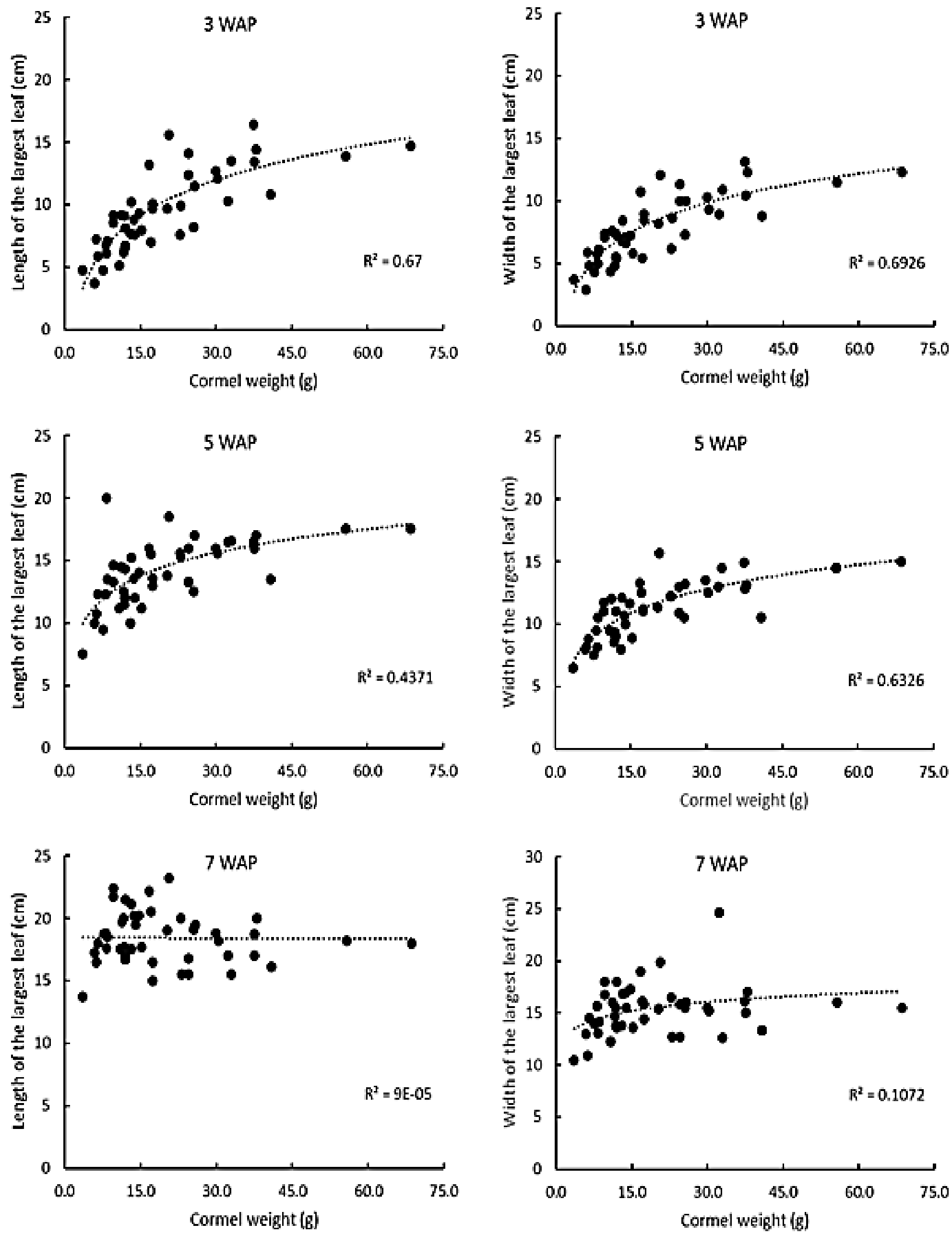

Figure 4. Effects of planted cormel weight on length and width of the largest leaf in *Colocasia esculenta* plant, measured at 3, 5, and 7 weeks after planting

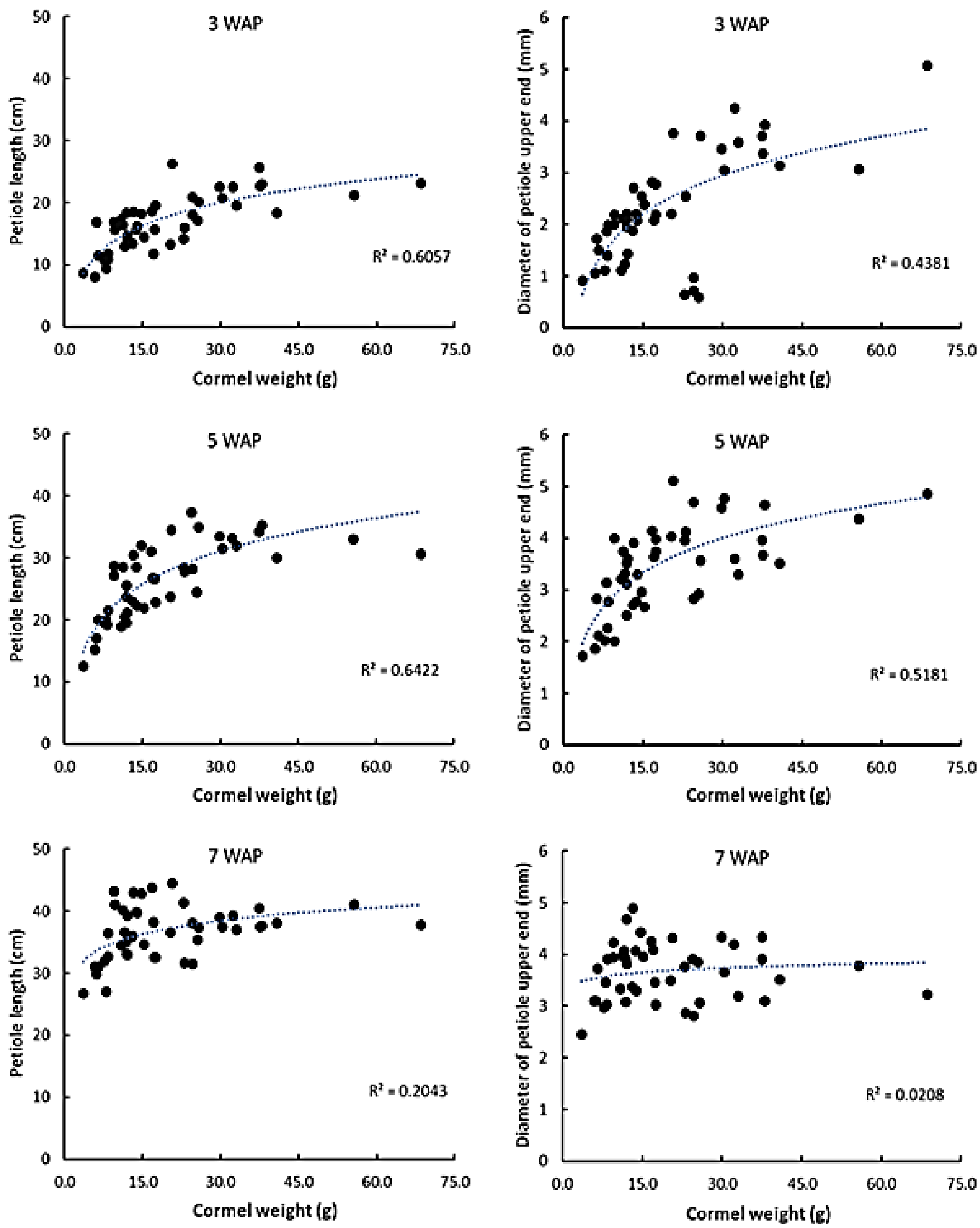

Figure 5. Effects of planted cormel weight on length of the longest petiole and diameter of upper end petiole in *Colocasia esculenta* plant, measured at 3, 5, and 7 weeks after planting

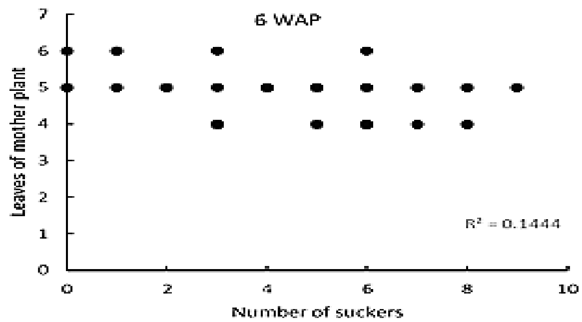

Figure 6. Correlation between number of suckers and number of leaves in mother plant of *Colocasia esculenta*, measured at 6 weeks after planting

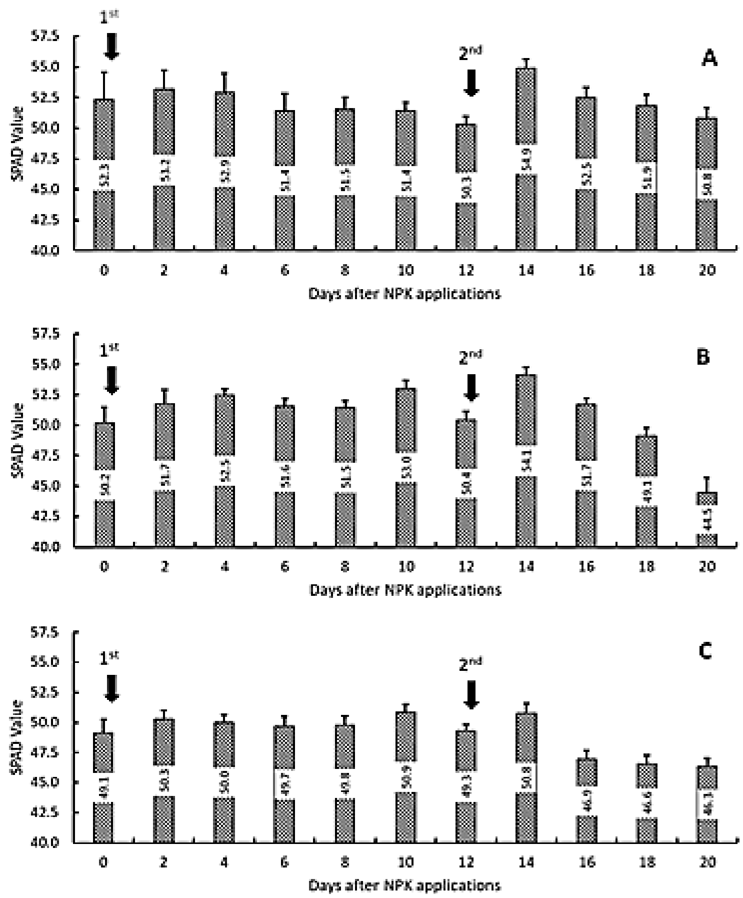

Figure 7. Response of green taro plants to twice NPK fertilizer applications starting at 4 WAP, monitored based on dynamic of SPAD value for time span of 20 days. A = large, B = medium, and C = small planted cormel

Response of green taro to NPK fertilizer application

The response of green taro plants to NPK fertilizer applications was evaluated. It started at 4 WAP, for time span of 20 days, it was monitored based on dynamic SPAD value measured every two days. At 4 WAP, the taro plant used was at the late slow growth phase within the prefigured S-curve growth. After 12 days on the first NPK application, a drop in SPAD value was significant; thus, the second NPK application was executed at 12 WAP. After an immediate increase in SPAD value at 2 days after second application, the following SPAD measurements exhibited sharper and continue decline of SPAD value, reached the lowest value only within 8 days after the second NPK application (Figure 7). This rapid decline of SPAD value after the second application was associated with exponential growth phase of the taro plants. Lesson learned from the results of SPAD monitoring is taro plants needs to be fertilized with NPK at a beginning of the exponential growth phase in taro plants.

Leaf damage in taro plant due to aphid's attack

Some of the green taro plants used in this study were attacked by leaf aphids (*Aphis gossypii*), causing damage to leaf. Matured leaves were more significantly damaged while newly produced young leaves have not shown any damage, indicating slow inter-leaf mobility of the aphids. However, the aphids caused damages in both smaller-thinner and larger-thicker leaves in green taro (Figure 8). Nymphs and adult aphids feed on plant juices, sucking liquid in epidermal cells at lower surface of the taro leaves.

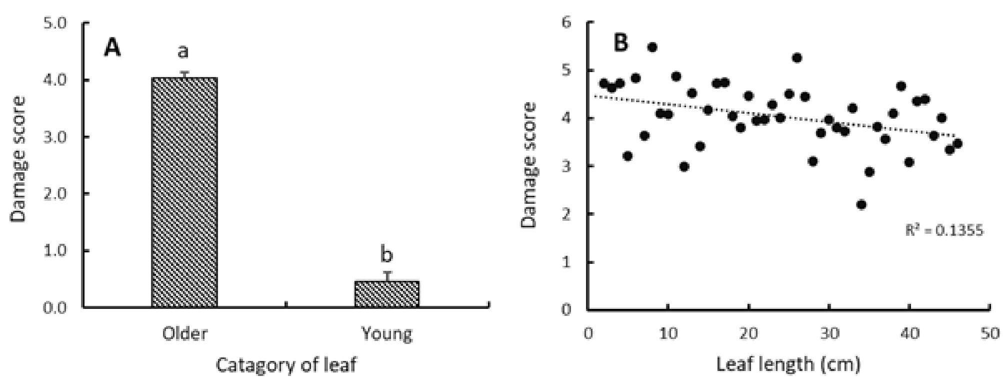

Figure 8. The newest fully open young leaf was less attacked by aphids (A), but aphids attack both small and large leaves (B) in *Colocasia esculenta* plant

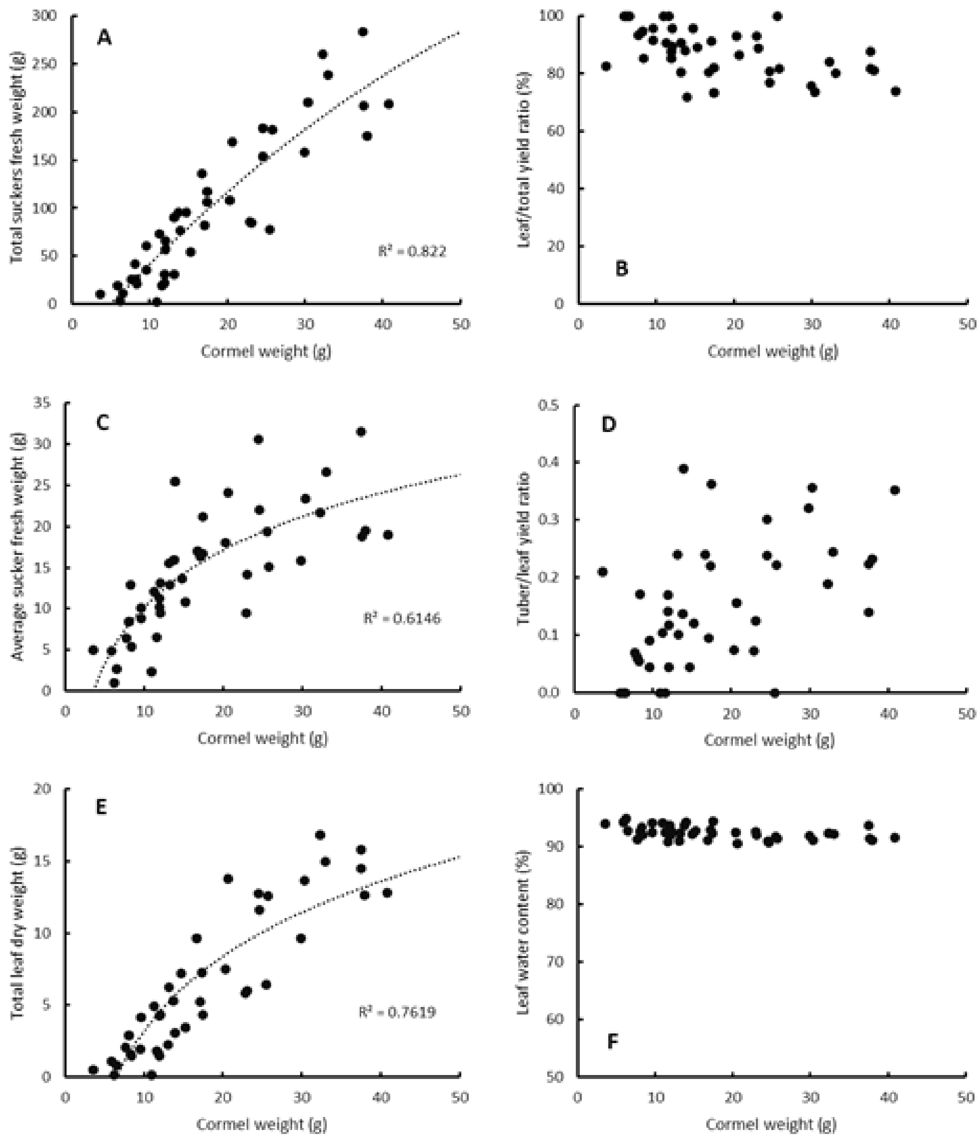

Figure 9. Effect of planted cormel weight on some yield characteristics in *Colocasia esculenta* plant at 9 weeks after planting

Growth at early vegetative stage

Except for number of leaves, all other parameters measured using non-destructive procedure at 3 and 6 WAP were significantly favoring large planted cormel. Green taro plant planted using larger cormel produced a smaller number of leaves, but larger leaf size compared to that planted using smaller cormel which produced slightly more but smaller leaves. Furthermore, results of destructive sampling indicated that green taro grown using larger cormel exhibited highest values in all other directly measured and calculated parameters; however, exhibited lower values on leaf/total fresh weight ratio and leaf water content (Table 1).

Low ratio of leaf/total fresh weight is due to larger planted cormel plant produced larger tuber. Meanwhile, low leaf water content is more likely be associated with higher water loss due to transpiration in larger plants. These results were also supported by other facts that weight of planted cormel was strongly related to total and average fresh weight of suckers and total leaf dry weight; reversely, weight of planted cormel exhibited weak association with leaf/total yield ratio, tuber/leaf fresh weight ratio, and leaf water content (Figure 9).

Table 1. Effects of planted cormel size on selected traits during vegetative growth and at harvest

Measured trait	Planted cormel size: Large		Medium		Small		LSD.05
3 WAP							
Number of suckers	5.67	a[1]	2.40	b	0.26	c	1.01
Number of leaves	1.67	a	2.00	a	2.40	a	0.38
Stem base diameter (mm)	10.36	a	6.33	b	4.01	c	1.51
Length of petiole (cm)	20.78	a	16.30	b	13.25	c	2.30
Upper-end petiole diameter (mm)	3.01	a	2.07	b	1.62	b	0.60
Length of largest leaf (cm)	12.55	a	9.28	b	6.68	c	1.44
Width of largest leaf (cm)	10.33	a	7.63	b	5.50	c	1.12
6 WAP							
Number of suckers	6.86	a	4.20	b	1.73	c	0.94
Number of leaves	4.67	a	4.93	ab	5.13	b	0.39
Stem base diameter (mm)	21.25	a	16.57	b	13.85	c	2.43
Length of petiole (cm)	35.13	a	32.06	b	29.92	c	2.75
Upper-end petiole diameter (mm)	3.60	a	3.06	b	2.53	c	0.49
Length of largest leaf (cm)	16.74	a	17.20	a	15.00	b	1.15
Width of largest leaf (cm)	13.80	a	14.00	a	11.02	b	1.45
9 WAP[2]							
Number of suckers	8.80	a	5.86	b	3.53	c	1.49
Total weight of suckers (g)	186.43	a	91.23	b	26.76	c	26.90
Average weight of suckers (g)	21.45	a	15.98	b	7.19	c	3.21
Leaf fresh weight (g)	151.02	a	78.88	b	24.70	c	22.79
Tuber fresh weight (g)	35.41	a	12.35	b	2.05	c	7.10
Leaf/total fresh weight ratio (%)	81.76	a	86.77	a	93.44	b	5.12
Tuber weight ratio	0.23	a	0.16	a	0.07	b	0.07
Leaf dry weight (g)	12.37	a	5.98	b	1.77	c	1.83
Leaf water content (%)	91.69	a	92.53	ab	93.07	b	0.86

1/ Means followed by similar word within each row are not significantly different based on LSD.05.
2/ Destructive measurements.

Discussion

Planted cormel size and morphological growth in taro

Larger cormel contains higher amount of nutrient reserve for supporting early growth in all plants. In taro plant, larger cormel was also associated with higher number of buds which, in turn, can develop into next generation plants. In this study, larger cormel size used as planting material produced more suckers. Similar result was reported by Gebre *et al.* (2015). Besides producing a greater number of suckers, Tsedalu *et al.* (2014) also reported that taro plants cultivated using larger cormel exhibited earlier seedling emergence and higher plant height, leaf number, leaf area, tuber weight and diameter at plant base as well as higher total and marketable yield. Gerrano *et al.* (2019) observed that significant variation was observed among accessions for most of the traits except number of leaves. In this study, the number of leaves in the mother plant was unexpectedly lower in plant grown using larger cormel. Meanwhile, Muinat *et al*. (2017) argued that the differences in growth and yield observed among the accessions may be attributed to non-uniformity in the size of the propagules used. Manyatsi *et al.* (2011) found that taro plants grown in irrigated flat plots consistently exhibited the highest number of leaves compared to other cultivation systems. The number of leaves seems to be affected by cultural practices and/or environmental conditions.

The effect of cormel size on stem diameter of green taro mother plant was significant during early growth phase but the plausible effect of larger cormel diminished during later growth phase, perhaps due to competition between mother plant with its suckers for soil water and nutrients. The decrease in plant water content directly causes decline in internal hydraulic pressure, which in turn, cause stem shrinkage. Low internal hydraulic pressure also limits leaf expansion rate (Widuri *et al*., 2017). Maximum daily shrinkage (MDS) or stem diameter variations (SDV) in tomatoes plant has been used for diagnosing water stress in a timely manner. The MDS had the advantages of sensitivity and signal intensity while the others were lacking (Wang *et al*., 2017). This SDV indicators can be used for determining plant water status and for scheduling irrigation at different growth/developmental stages (Meng *et al.*, 2017). Halted enlargement proses in stem of mother plant at 7 WAP was assumed to be allied with massive growth of its suckers. Leaf blade and petiole followed similar trends.

Response of taro plant to NPK application

The SPAD value dropped at 12 days after the first NPK application at 4 DAP, but it required less than 8 days dropping after the second NPK application at 6 DAP. This difference was associated with different size of the taro plants at time of NPK fertilizer was applied. Larger plants during rapid vegetative growth at 6 DAP used up more nutrients. Ogbonna and Nweze (2012) reported that taro plants require 200 to 250 kg/ha NPK to achieve its highest tuber yield around 20 to 40 ton/ha, depending on varieties used. Meanwhile, Raju and Byju (2019) suggested NPK ratio of 4.7:1.0:6.4 for an efficient fertilizer application. This ratio indicated that the compound NPK fertilizer at equal dose, i.e., at 15:15:15, is not efficient especially for phosphorous nutrient. However, the exact ratio should be varied depending on nutrient availability in soil at specific location (Lakitan *et al*., 2018; 2020). Lee *et al.* (2016) also suggested to apply different rate of N, P, and K for maximum yield in taro plants and reminded that higher NPK rates tend to decrease fertilizer use efficiency.

Leaf damage in taro plant due to aphid attack

Aphids (*Aphis gossypii* Glover) were one of sucking pests on many agriculturally important crops, including taro (Sangeetha *et al.*, 2019). Aphids commonly behaved as specific host races as success rates of colonization after reciprocal host transfers were very poor (Agarwala and Choudhury, 2013). In this study, aphids were observed to suck liquid at lower surface of the taro leaves. Large population of aphids caused serious damage to leaf of taro plants. Since aphids do not have wings, their mobility from one leaf to another was limited. High leaf water content in taro plants may cause the aphid to tend to stay on the same spot. Mutualistic interaction between aphids and small black ant was observed in this study. Blanchard *et al*. (2019) explained that the aphid–ant interaction has been well documented.

Results of destructive sampling

Results of destructive sampling indicated that green taro grown using larger cormel exhibited highest values in total and average weight of suckers, leaf fresh and dry weight, tuber fresh weight, and tuber/total fresh weight ratio. However, leaf/total fresh weight ratio and leaf water content were lower in taro grown using large cormel. The low leaf/total fresh weight ratio was associated with larger petiole and tuber in plants cultivated using large cormel as planting material. Tuber weight is part of the total fresh weight. Gebre *et al.* (2015) reported that the ratio of yield to weight of planting material in taro plant was highest if the corm size used was 51-100 g, but the highest yield was achieved at corm size 151-200 g. Muinat *et al.* (2017) and Pratiwi *et al.* (2014) also found similar results, i.e., the largest corm size used as planting material in their study produced higher tuber yield. Results of some studies had mentioned that photosynthetic allocation to tubers can be enhanced with some different treatments, for example by exposing tuberizing potato plants to red or blue LED lights (He *et al.,* 2020) or application of uniconazole in sweet potato plant (Duan *et al.*, 2019). Lower leaf water content in the taro plant grown with large corm as planting material was more likely be associated with higher water loss due to transpiration. Larger plants have larger total leaf area. Leaf area index was directly related to intercepted radiation which had been used in model for predicting transpiration. Actual transpiration = 0.96 × calculated transpiration using the model (Alam *et al.*, 2021). Transpiration and leaf physical traits provided double assurance for avoiding overheating, particularly for plant from dry habitat. However, transpiration is a more effective way to cool leaves than physical traits when water is sufficient. Physical traits and transpiration regulate leaf temperature, co-evolution of gas exchange and thermal regulation of leaves (Lin *et al*., 2017).

In conclusion, larger cormel size consistently improves almost all morphological traits and yield components in taro plant, except it did not significantly affect number of leaves, slightly lower leaf water content, and lower ratio of leaf to total fresh weight. The number of leaves seems to be genetically controlled. Lower leaf water content did not negatively affect other growth traits. Meanwhile, lower ratio of leaf to total fresh weight was not necessarily disadvantage since the low ratio was associated with less leaf weight but higher tuber yield. Therefore, it is recommended to use large cormel varied from 23.09 g to 68.59 g rather than smaller cormel size as planting material in taro cultivation.

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