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Research Article

Growth and production of beneng taro genotypes (*Xanthosoma undipes* K. Koch) on different soil organic carbon

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ABSTRACT

Beneng taro is a perennial of Araceae and becomes a new commodity in Indonesia. The research aimed to evaluate the growth and yield of beneng taro on various statuses of soil organic carbon (SOC). Three genotypes of taro, i.e., beneng Banten, beneng Bondowoso, and East Nusa Tenggara (NTT) fodder taro were planted in three SOC levels, i.e., 1.79, 2.94, and 4.09% in a randomized split block design in the Leuwikopo Experimental Station, IPB from April to December 2021. SOC was designed by adding cow manure. The results showed that there was no interaction between genotypes and SOC. The increase in SOC from 1.79 to 4.09% did not significantly affect growth but significantly affected the diameter and yield of beneng and NTT fodder taro. An increase in SOC above 1.79% markedly decreased tuber diameter, but conversely increased fresh tuber weight. Tuber weight increased by 5.6% and 12.1% with an increase in SOC from control to 2.94% and 4.09%, respectively. The increase in tuber weight was supported by the trend of increasing biomass weight and the number of roots. SOC source in the present study was cow manure which may also contribute some nutrients, therefore, further research is needed using neutral organic carbon sources to determine the effect solely.

Keywords: Araceae; SOC; growth; manure; NTT taro; talas beneng Banten

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INTRODUCTION

Beneng taro (*Xanthosoma undipes* K. Koch) is a member of Araceae and is a new commodity in Indonesia. The term *beneng* comes from the abbreviation *besar* and *koneng* (*Sundanese* for big and yellow flesh, respectively). The tuber is used to produce flour and the leaves as a substitute for tobacco leaves; and the export volume is increasing in form of fresh tubers, dry leaves, and dried tuber chips (Susilawati et al. (2021). Beneng taro flour contains 8.8-9.3% protein, 26.6% carbohydrates, 0.8% fat, 16.0-18.0% starch, and 0.5-0.7% amylose (Bintanah et al., 2021).

The cultivation of beneng taro in Indonesia adds the list of commercial taro, i.e., bentul taro (*Colocasia esculenta* var *esculenta*), Japanese taro (*C. esculenta* var *antiquorum*), kimpul (*Xanthosoma sagittifolium* (L.) Schott), and sente taro (*C. gigantea*) (Andarini and Risliawati, 2018; Silaban et al., 2019; Maretta et al., 2020; Cahyanti et al., 2022). In general, the taro family is an amphibian crop that can live in both lowland and upland, therefore its cultivation is a part of the climate change adaptation strategy (Hidayatullah et al., 2020; Cahyanti et al., 2022).

As a new commercial crop, the area of beneng taro cultivation continues to increase steadily. For example, according to Susilawati et al. (2021) cultivation area in Pandeglang District, Banten Province of Indonesia increases from 42 ha in 2015 to 88 ha in 2019.

Beneng taro is a perennial, therefore, to support the expansion of the cultivation area, long-term soil fertility management is important.

Soil fertility, namely physics, chemistry, and biology, is closely related to soil organic carbon (SOC) (Bouaravong et al., 2017; Zhu et al., 2022). According to Grilli et al. (2021), the critical level of soil organic-C is 2% or 20 g kg^{-1} soil. Soils with high organic-C content are generally more fertile, have high N availability and cation exchange capacity (CEC), and have a higher water-holding capacity (Machmuller et al., 2015; Grilli et al., 2021).

In the field, soil organic-C content could be increased by planting legume cover crops, incorporating crop residues, and doing crop rotation (Plaza-Bonila et al., 2015). The application of cow manure increases soil organic-C and provides nutrients (Roidah, 2013). According to Sari et al. (2019) adding 0.5 kg of cow manure per plant increases the height, number of leaves, and the leaves width of *Amorphophallus muelleri*. Although the recommendation for beneng taro cultivation has been established by Susilawati et al. (2021), however, the recommendation has not considered soil organic-C yet. Present study aimed to determine the growth and yield of beneng taro on various soil organic-C levels.

MATERIALS AND METHODS

Experimental site

The research was carried out at the Leuwikopo Experimental Station IPB (-6.549398, 106.71615; 218 m above sea level) from April to December 2021. During the study, the average monthly rainfall was 318.6 mm (the highest was October 566.4 mm, and the lowest was July 115.6 mm). Daily relative air humidity (RH) was 83.2% (highest June 86.1%, lowest July 79.8%). The average daily temperature was 26.2 ^{o}C. The climate during the study was optimal for beneng taro cultivation according to Susilawati et al. (2021), the temperature ranged from 27.0 to 30.7 ^{o}C and RH was 60-80%.

The soil in the research location is Latosol Darmaga type. Soil nutrient analysis before treatment had pH of 4.84, organic-C content 1.79% (low), total N 0.22% (very low), Bray-available P 0.53 ppm (very low), total P 69.71 ppm, total K 13.94 ppm, Mg-exc 1.47 cmol kg^{-1} (moderate), Ca-exc 3.46 cmol kg^{-1} (low), K-exc 0.38 cmol kg^{-1} (very low), Na- exc 0.37 cmol kg^{-1} (very low), Al- exc 0.21 cmol kg^{-1} and cation exchange capacity (CEC) 14.41 cmol kg^{-1} (low). The cow manure had a pH of 7.62, organic-C 37.64%, total N 2.77%, total P 0.95%, total K 0.34%, Mg 0.53%, and S 0.09%.

Research design

The study used a randomized complete block design (RCBD) split plot with the main plot being taro genotype (3 levels) and subplots being soil organic-C status (3 levels), and the combination was repeated three times. Each experimental unit consisted of 15 plants, and the observational sample used 10 plants selected randomly.

Taro genotype consisted of beneng taro from Banten and Bondowoso, and fodder taro from East Nusa Tenggara (NTT). The NTT taro is identified as *Xanthosoma sagittifolium* (L.) Schott), it was used as a control. Organic-C level was designed as 1.79% (control), 2.94%, and 4.09%. Soil organic-C level was designed by adding 3.06 kg of cow manure for 2.94% organic-C and 6.11 kg per plant for 4.09% organic- C, which represented moderate and high SOC, respectively. See Table 1 for further explanation. Soil organic-C level is classified based on Balitan (2009), i.e., <1% as very low, 1-2% as low, 2-3% as moderate, 3-5% as high, and >5% as very high.

Cultivation method

The land was plowed twice using a 35 HP tractor. The land was cleared of weeds and twigs, then raised beds were constructed. The size of the beds was 0.7 m x 10 m and the distance between the beds was 30 cm. Limestone ($CaCO_3$) was applied at a dose of 1.0 tons ha^{-1} one week before planting. In a bed, 15 plants were maintained with a spacing of 50 cm. Thus, the planting distance was 1 m x 0.5 m.

Table 1. Organic manure (OM) calculation to increase soil organic-C.

Organic-C (%)				OM per plant (kg)	OM ha^{-1} (ton)^Y
Treatment	Original	Increase	OM^Z		
1.79		0	-	-	-
2.94	1.79	1.15	37.64	3.06	61.11
4.09		2.30	37.64	6.11	122.21

Note: ^{Z}OM-organic manure; ^{Y}Soil weight for one hectare is assumed 2 Mkg (100 m x 100 m x 0.2 m x 1,000 kg m^{-3}), population =20,000 plants ha^{-1}.

Before planting, tubers were grouped based on diameter as replicates, namely diameters of 40-70 mm (replication 1), 25-39 mm (replication 2), and 10-24 mm (replication 3). The tubers were dipped into fungicide Dithane M-45 5 g L^{-1} (a.i. mancozeb 80%), then were planted in the middle of beds with the buds facing upwards and covered with cow manure with the amount corresponding to the treatment. Each plant was given 2 g of pesticide Furadan 3G (a.i. carbofuran 3%) to prevent pest infection.

Cow manure was applied twice, i.e., at planting (0 weeks after planting- WAP) and at 18 WAP. The manure application was divided because follow farmer practice for beneng taro cultivation. According to farmers, manure could be applied twice because taro beneng is an annual plant. At planting, the amount of cow manure applied was 0, 0.5, and 1.0 kg per plant, while the second application was 0, 2.56, and 5.11 kg per plant corresponding to soil organic-C treatment of 1.79, 2.94, and 4.09%, respectively. The second manure was given on the soil surface in a circle application method about 10 cm from the taro pseudostem.

Plant maintenance consisted of hilling every 3 weeks, watering once every 3 days if there was no rain, and weeding every 2 weeks. NPK fertilizer 'Mutiara' (16-16-16) was given twice at 4 and 8 WAP at a dose of 5 and 10 g per plant, equivalent to 100 and 200 kg ha^{-1}, respectively. All plants were maintained under a shading net with reduced sunshine intensity by about 20%. The use of shading net was to coop with farmer practice that growing beneng taro in an agroforestry system.

Statistical analysis

Observations on tuber growth were carried out 1-3 WAP and 18 WAP, by calculating the percentage of tubers that produced leaves. Growth variables observed from 4-24 WAP included plant height, petiole length, tuber diameter, and the number of leaves. Plant height was measured from the maximum vertical distance reached by leaves relative to the soil level. The number of suckers was observed at 10 and 20 WAP. At harvest (25 WAP) the fresh and dry weight of stover, number, length of roots, and yield of tuber were observed.

Data were analyzed by ANOVA using the STAR 2013 application. For the ANOVA results that had a significant effect, then the data were evaluated using the Duncan Multiple Range Test (DMRT) at α 5% (level of confidence 95%).

RESULTS AND DISCUSSION

Analysis of variance

The results of the analysis of variance (ANOVA) showed that there was no interaction between the genotype treatments and the soil organic-C status (data not shown). Genotypes expressed differences in plant height, petiole length, and tuber diameter at 12-24 WAP. The number of leaves between genotypes differed at 16-24 WAP and the number of suckers at 10 WAP. At 25 WAP (harvesting time), genotypes showed variations in fresh and dry weight of biomass, number and length of roots, and tuber yield.

Soil organic-C status showed a significant effect on the variables of plant height and petiole length at 8 WAP, corm diameter at 4 WAP and 20 WAP, and the number of leaves at 4-16 WAP (data not shown). However, organic-C treatment had no significant effect on the yield variables.

Growth and number of sucker

More than 90% of tubers propagules had produced the first leaf at 3 WAP, irrespective of genotypes (Table 2). There was a tendency that the plants in the 1.79 and 2.94% soil organic-C to germinate faster than those in the 4.09% organic-C. The reason for the trend is still unknown. But at 18 WAP, all tubers had germinated. At planting, the planting propagule of beneng taro came from a tuber section that had active bud at planting, while NTT fodder taro used whole cormel (daughter corm) with the main bud remaining dormant. It needs further evaluation whether the form of planting propagules affects subsequent growth.

Table 2. Percentage of first leaf emergence of genotypes from different status soil organic-C treatments.

Genotype	Status soil organic-C (%)	First leaf emergence (%)			
		1 WAP	2 WAP	3 WAP	18 WAP
Beneng Banten	1.79	11	62	98	100
	2.94	11	67	96	100
	4.09	7	51	98	100
Beneng Bondowoso	1.79	31	71	98	100
	2.94	29	80	100	100
	4.09	18	73	96	100
NTT fodder	1.79	11	71	91	100
	2.94	27	82	93	100
	4.09	9	73	91	100

Note: Data was counted from total of three replications, therefore it was not suitable for statistical analysis.

Genotypes had different abilities to produce the number of shoots (Table 3). Treatment of soil organic-C did not show a significant effect on the number of suckers (direct shoot growing from mother tuber) at 3 WAP, namely 0.9-1.1 units. Beneng Bondowoso genotype had significantly more shoots than the other genotypes, i.e., 1.0 and 1.6 shoots at 2 and 3 WAP, respectively.

Table 3. Number of buds develop into the shoot of beneng and NTT fodder taro.

Genotype	Number of developed shoot		
	1 WAP	2 WAP	3 WAP
Beneng Banten	0.1b	0.6b	1.1b
Beneng Bondowoso	0.3a	1.0a	1.6a
NTT fodder	0.2ab	0.8b	0.9b

Note: Values in a column followed by different alphabets are significantly different after DMRT test α 5%.

Planting propagule of beneng taro of Banten and NTT fodder taro visually had many dormant buds, but the buds that developed into the shoot were limited. The fact indicates that the growing shoot of both genotypes had strong apical dominance. The phenomenon of strong apical dominance is also noted in *Amorphophallus* tuber (Araceae) as stated by Tajuddin et al. (2020).

Number of leaves

The leaf number of Banten and Bondowoso taro was not significantly different, but both genotypes were significantly different from NTT fodder taro starting from 16 WAP (Table 4). At the end of the experiment, beneng taro of Banten dan Bondowoso had three leaves on average, while NTT fodder taro had 1.7 leaves. According to Zelin and Setyawan (2019) the number of taro leaves is influenced by planting material and genotype. Unexpectedly, the leaf number of NTT fodder taro continued to decline from 12 to 24 WAP. Based on leaf anatomy, NTT fodder taro seems like *Xanthosoma sagittifolium*, unlike beneng taro. These different genotypes could be the explanation for different apical dominance among used genotypes.

Table 4. Leaves number of beneng and NTT taro, and soil organic-C treatments.

Treatment		Number of leaves					
		4 WAP	8 WAP	12 WAP	16 WAP	20 WAP	24 WAP
Genotype	Beneng Banten	2.3	3.3	3.5	3.2a	3.0a	3.0a
	Beneng Bondowoso	2.8	3.7	3.9	3.2a	2.8a	3.0a
	NTT fodder	2.5	3.3	2.8	1.8b	1.8b	1.7b
Organic -C	1.79%	2.4b	3.5a	3.6a	2.9a	2.7	2.6
	2.94%	2.6a	3.4ab	3.3b	2.7b	2.5	2.5
	4.09%	2.6a	3.3a	3.3b	2.7b	2.4	2.6

Note: Values in a column of accessions or soil organic-C followed by different alphabets are significantly different after DMRT test α 5%.

It is important to note that the increase in leaves number at 4 WAP but the decrease in the number at 12 and 16 WAP as in Table 4 is unlikely to reflect the actual plant response to 2.94% soil organic-C. The argument was due to the plants just receiving 0.5 kg at 0 WAP and the completed treatment started at 18 WAP. This means that up to 0.5 kg per plant application, organic-C added to soil was equal to 0.19%. Therefore, for all accessions, soil organic-C 1.79% (control) + 0.19% (supplement manure at 0 WAP) equal to 1.98% seemed sufficient for the plant to produce the optimum number of leaves. In all accessions, the number of leaves generally decreased since 16 WAP from the previous age. These results contradict data obtained by Talkah (2015) and Nagano et al. (2016), where the application of organic fertilizer or compost significantly increase the number of taro leaf.

Plant height and petiol size

NTT fodder taro had shorter plant architecture as compared to Banten and Bondowoso genotypes starting from 12 WAP (Table 5). Plant height was supported by the height of pseudostem and length of petioles. At 12 WAP, NTT fodder taro produced new leaves with short petioles and mild elongation of pseudostem. Genotypes likely have different strategies to allocate assimilates. In *Xanthosoma sagittifolium,* as stated by Maghfirah et al. (2022), the plant that produces more cormel tends to reduce height. There is a possibility that the assimilates produced by beneng taro are allocated to enlarge the pseudostems, while the assimilate of NTT fodder taro is used to enlarge the pseudostems and also to produce cormel.

Regardless of accessions, treatment of 4.06% soil organic-C significantly increased plant height at 8 WAP and did not affect plant height on the other weeks (Table 5). At 8 WAP, the soil organic-C status was not yet 4.06% or 4.09% because only the first part of cow manure was added. However, the importance of soil organic-C is evident in the present experiment.

Banten and Bondowoso genotypes of beneng taro statistically had similar petiole lengths, while NTT fodder taro significantly had a shorter size from 12 WAP (Table 5). The petiole of Banten and Bondowoso taro increased on average 3-7 cm every four weeks starting from 4 WAP. At 24 WAP, the petiole of beneng taro from Banten and Bondowoso reached maximum, i.e., 40.22 cm and 35.31 cm, respectively. On the other side, the petiole of NTT fodder taro increased on average 4.5 cm from 4 to 8 WAP and decreased thereafter. In the field, NTT taro was susceptible to pests and diseases especially at petiole, unlike beneng taro. To some extent, pests and diseases could contribute to the performance of NTT fodder taro in the present experiment. The decreasing soil organic-C at a certain time after application as stated by Gu et al. (2016), was also considered.

Table 5. Plant height and petiole length of taro genotype and soil organic-C treatments.

Treatment		4 WAP	8 WAP	12 WAP	16 WAP	20 WAP	24 WAP
		Plant height (cm)					
Genotype	Beneng Banten	26.92	43.71	59.64a	67.12a	74.25a	80.03a
	Beneng Bondowoso	25.91	41.03	58.94a	68.42a	73.23a	73.37a
	NTT fodder	19.88	32.97	33.60b	27.71b	24.16b	24.85b
Organic- C	1.79%	21.62	37.45b	49.52	54.76	58.16	59.47
	2.94%	24.09	38.83b	49.94	53.35	56.82	59.92
	4.09%	26.99	41.42a	52.72	55.15	56.66	58.85
		Petiole length (cm)					
Genotype	Beneng Banten	15.77	22.28	28.77a	33.70a	36.98a	40.22a
	Beneng Bondowoso	13.22	18.92	27.02a	31.78a	34.82a	35.31b
	NTT fodder	10.27	14.67	14.59b	11.62b	9.93b	11.08c
Organic- C	1.79%	11.78	18.19b	22.96	25.61	27.21	28.56
	2.94%	13.21	18.11b	23.31	25.44	27.40	29.51
	4.09%	14.27	19.57a	24.11	26.06	27.12	28.54

Note: Values in a column of accessions or soil organic-C followed by different alphabets are significantly different after DMRT test α 5%.

Tuber diameter

In general, beneng taro of Banten and Bondowoso had larger tuber diameters than NTT fodder taro (Table 6). After 12 WAP, NTT fodder taro had the smallest tuber diameter than other accessions. Weekly rainfall during 12 to 14 WAP (on June-July 2021) was low as compared to previous weeks (data not shown). It is speculated that limited precipitation could inhibit taro growth, especially for NTT fodder taro. Hidayatullah et al. (2020) stated that tuber diameter is affected by the availability of water, where water shortage for 7-15 days reduced the tuber diameter by more than 20%. NTT fodder taro was obtained from Eban Village of NTT, which is an area of drought-prone, see Kefi et al. (2020) for the description of the site. Nevertheless, visual evaluation of NTT fodder taro in the present experiment showed very responsive to water shortages as indicated by curling leaf blades after no rain for one week. There is a possibility that NTT fodder taro has a high evapotranspiration rate, but this assumption needs further study.

Increasing soil organic-C to 2.94% significantly increased tuber diameter at 4 WAP but significantly decreased tuber diameter at 20 WAP (Table 6). The increase in tuber diameter at 4 WAP (Table 6) as well as the plant height and petiole length (Table 5) could be understood as the effect of the first application of manure at 0 WAP. However, the decrease in diameter at 20 WAP was relatively difficult to explain, because at 18 WAP soil organic-C level was by the treatment. Manure application at 18 WAP coincided with July-August 2021 when rain was very limited. So, there is a possibility that increasing soil organic-C is less effective when soil moisture is limited. This is in line with the opinion of Plaza-Bonilla et al. (2015).

Table 6. Tuber diameter of taro genotype and soil organic-C treatments.

Treatment		Tuber diameter at different ages (mm)					
		4 WAP	8 WAP	12 WAP	16 WAP	20 WAP	24 WAP
Genotype	Beneng Banten	21.06	39.12	47.74a	48.45a	48.79a	51.04a
	Beneng Bondowoso	21.48	34.33	45.94a	42.34a	40.91a	43.10b
	NTT fodder	16.55	25.25	27.99b	19.92b	15.94b	17.48c
Organic- C	1.79%	16.77b	30.47	38.78	36.75	36.42a	37.28
	2.94%	20.58a	33.77	41.14	36.07	34.92b	36.83
	4.09%	21.74a	34.47	41.75	37.90	34.30c	37.51

Note: Values in a column of accessions or soil organic-C followed by different alphabets are significantly different after DMRT test α 5%.

Plant biomass, roots, and tubers yield

Genotype had significantly different roots and biomass weights, and these differences were not affected by soil organic-C status (Table 7). There was no interaction between genotype and soil organic-C for those variables. Beneng taro from Banten and Bondowoso statistically produced similar fresh and dry biomass weights, but they differed from NTT fodder taro. The NTT fodder taro had the smallest weight of plant biomass, length, and number of roots as shown in Table 7.

Table 7. Plant biomass and roots of taro genotypes and soil organic-C treatments.

Treatment	Plant biomass (g)^{Z}		Roots	
	Fresh	Dry	Length (cm)^{Y}	Number
Beneng Banten	968.74a	151.63a	46.65a	38.5a
Beneng Bondowoso	1,086.40a	179.19a	53.09a	45.8a
NTT fodder	188.21b	40.48b	14.26b	5.2b
Organic-C 1.79%	684.76	118.76	38.66	27.4
Organic-C 2.94%	758.22	123.64	37.53	28.7
Organic-C 4.09%	800.37	128.91	37.81	33.4

Note: Values in a column of accessions or soil organic-C followed by different alphabets are significantly different after DMRT test α 5%; ^{Z}Include leaves and petiole; ^{Y}Longest root.

Table 7 shows that soil organic-C treatment had no significant effect on plant biomass weight, length, and the number of roots (Table 7). The conclusion was supported by the P-value of ANOVA test for the fresh weight of plant biomass (P=0.3002), dry weight of plant biomass (P=0.0719), root length (P=0.9835), and the number of roots (P= 0.3415).

Genotypes had different abilities to produce suckers (Table 8). Beneng taro of Bondowoso had the highest number of suckers, i.e., 1.5 at 10 WAP and 1.1 at 20 WAP, while NTT fodder taro did not produce any suckers. Moreover, soil organic-C treatment did not affect the ability of taro to produce sucker (Table 8). The finding is in line with Kartina et al. (2017) where manure application does not affect the number of suckers of beneng taro. Many authors concluded that the number of taro suckers is determined by genotype, planting material, spacing, and water availability (Zelin and Setyawan, 2019; Hidayatullah et al., 2020; Maghfirah et al., 2022).

The tuber yield differed among genotypes; there was no interaction between genotypes and soil organic-C status (Table 8). Beneng taro of Bondowoso tended to have higher productivity than other genotypes, i.e., 532.2 g per plant or 10.64 tons ha^{-1}. Nevertheless, tuber yield in the present study was lower than that reported by Susilawati (2021), i.e., 2.4-15.0 kg per plant at 8-12 months after planting.

Increasing soil organic-C levels significantly increased the weight of fresh tubers (Table 8). There was an increase in tuber weight of 5.6% and 12.1% with an increase in organic-C from control to 2.94% and 4.09%, respectively. Increasing tuber weight is in line with increases in the weight of plant biomass and the number of roots as shown in Table 7. Tubers of NTT fodder taro tended to be more susceptible to disease than other genotypes as indicated by the percentage of the healthy tuber of 74.4% while beneng taro from Banten had 97.8% healthy tubers (Table 8). However, there was no consistent effect of the percentage of healthy tubers based on the organic-C treatment.

Table 8. Number of suckers and yield of taro genotype and soil organic-C treatments.

Treatment	Number of suckers		Average yield at 25 WAP^Z		
	10 WAP	20 WAP	Individual (g)	Hectare (ton)^Y	Healthy tuber (%)^X
Beneng Banten	0.1b	0.3b	412.4	8.25	97.8
Beneng Bondowoso	1.5a	1.1a	532.2	10.64	95.6
NTT fodder	0.0c	0.0c	190.0	3.80	74.4
Organic-C 1.79%	0.4	0.4	339.1c	6.78c	90.0
Organic-C 2.94%	0.5	0.5	358.1b	7.16b	85.6
Organic-C 4.09%	0.6	0.5	380.2a	7.60a	92.2

Note: Values in a column of accessions or soil organic-C followed by different alphabets are significantly different after DMRT test α 5%; ^{Z}Fresh tuber; ^{Y}Population 20,000 ha^{-1}, not included damage tuber by diseases; ^{X}Healthy tuber from total therefore not suitable for statistical analysis.

Research implications

The present study notes two important things, i.e., taro genotypes showing the diversity in growth and yield, and the genotype responding differently to soil organic-C status. Regarding the first note, it is widely known that the genetic background of taro determines the response to agronomic inputs (Andarini and Risliawati, 2018; Hidayatullah et al., 2020; Maretta et al., 2020; Maghfirah et al., 2022). Beneng taro is a relatively new commodity in terms of the domestication process, therefore, its genetics hasn't been much improved from the wild type. A less substantial response of the beneng taro genotype used in the present experiment to organic-C may be due to genetic background. Kartina et al. (2017) reported that beneng taro has no response to fertilization application.

Related to the second note, environmental factors especially water availability in the present experiment could be a key explanation for why the effect of soil organic-C status is not uniform on Beneng and NTT fodder taro, even though the amount of manure added was very large, e.g., up to 122.21 tons ha^{-1} (Table 1). Hidayatullah et al. (2020) stated that water availability affects the growth of taro. From May to early September 2021, precipitation in the study site was limited which might cause a detrimental effect on the number of leaves, plant height, and tuber diameter at 20 WAP. Thus, second manure application at 18 WAP in concordance with the dry season might determine the effect of increasing soil organic-C status on general soil fertility.

Some weeds, pests, and diseases were still present at the experimental plot although regular control was implemented. Their presence in the field was probable to have a negative contribution to overall plant performance. Especially noxious weeds like *alang-alang* (*Imperata cylindrica*) and *Mimosa sp* should be handled with care. *Mimosa invisa* and *Mimosa pudica* weeds have thorns that tore petioles and leaves when they were pulled. Furthermore, *Aphis gossypii*, mealybugs, armyworms (*Spodoptera litura*), and grasshoppers (*Oxya sp.*) were also found sparsely in the field. According to Hidayatullah et al. (2020) caterpillar attacks might damage taro leaves by up to 40%. Leaf blight (*Phytophtora colocasiae* Rac.) and sooty mildew began to appear at 8 WAP. According to Otieno (2020), *P. colocasiae* mostly attacks plants aged 3-7 months with a severity level of 21-30%. In the future, it is needed to study the effect of different source of organic-C, because manure was suspected of carrying weed seeds and taro disease in the present experiment. Several alternatives of organic-C sources are biochar, water hyacinth, and rice straw (Talkah, 2015; Bouaravong et al., 2017; Zhu et al., 2022).

It should be noted that up to 17 WAP, the soil organic-C treated plants of 2.94 and 4.09% actually only received supplement manure of 0.5 and 1.0 kg per plant. Thus in reality, for example, the plant treated with organic-C at level of 4.09% up to 17 WAP received 1.79% (original soil) + 0.40% (1.0 kg of manure) equal to 2.19%. Technically, the application of 0.5 and 1 kg of manure per plant is equivalent to 10 and 20 tons ha^{-1}. In other words, organic-C up to 17 WAP was considered at a sufficient level for taro plants. According to Diaguna et al. (2022), Sutra taro produces a similar response especially petiole length when manure at the dose of 5-20 tons ha^{-1} is applied.

Finally, organic-C treatment significantly increased tuber weight (Table 8), in contrast to the findings of Diaguna et al. (2022) where tuber yield was not responsive to increasing doses of manure. Taking into account the economic aspect, soil organic-C level of about 2% is considered sufficient to support the cultivation of beneng taro. In the field, it is recommended to apply manure on the active root zone about 15-50 cm from the plant, unlike in the present experiment at 10 cm. Table 7 shows that the root length of beneng taro from Banten and Bondowoso, and NTT fodder taro was 46.65, 53.09, and 14.26 cm, respectively.

CONCLUSIONS

The growth of beneng taro of Banten and Bondowoso, and NTT fodder taro was not significantly affected by soil C-organic status so 1.79% soil organic-C was concluded to be sufficient to support optimum plant growth. Nevertheless, the increase in soil organic-C significantly increased tuber yield, where organic-C 4.09% gave the highest yield as compared to other treatments. But economically, 1.79% organic-C is sufficient in the cultivation of beneng taro at the farmer level.

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