J. Agron. Indonesia 38 (3) : 238 - 242 (2010)

The Effects of Pot Sizes and Number of Plants per Pot on the Growth of *Amorphophallus muelleri* Blume

Yoko Mine[1], Edi Santosa[2]*, Wakanori Amaki[1], and Nobuo Sugiyama[1]

[1]Faculty of Agriculture, Tokyo University of Agriculture, Funako, Atsugi, Kanagawa 243-0034, Japan
[2]Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, Jl. Meranti Kampus IPB Darmaga 16680, Indonesia

Received 16 August 2010/Accepted 11 November 2010

ABSTRACT

To determine the effects of pot sizes and the number of plants per pot on the growth of *Amorphophallus muelleri*, seed corms weighing 100-125 g were planted in polyethylene pots. In the first experiment, a corm was planted in pots containing various amounts of growth media: i.e., 0.25, 0.40, 0.50, 1.00, 1.33, 2.00 and 4.00 kg. In the second experiment, different numbers of plant, i.e., 1, 2, 3, 4 and 5, were grown in pots containing 4.00 kg of growth media. When plants were grown in pots containing a small amount of media (1.33 kg pot^{-1} or less), they produced small daughter corms and entered dormancy earlier than usual. The number of plants per pot had little effect on corm weight if the amount of growth media per plant was 0.80 kg or greater. As a result, corm yield increased with an increase in the number of plants per pot. The period from corm planting to harvest was slightly longer when only one plant was grown in a pot than when 2–5 plants were grown in the same-sized pot. This study suggested that the low productivity of *A. muelleri* in shallow soil was associated not only with a small amount of soil per plant but also with limited rooting volume.

Keywords: available water, competition, dormancy, plant density, soil depth

INTRODUCTION

The corm of *Amorphophallus muelleri* Blume is a source of glucomannan, a long carbohydrate chain composed of glucose and mannose (Ohtsuki, 1968; Jansen *et al*., 1996). In Japan, glucomannan is an important raw material of *konnyaku*, a Japanese traditional cooking ingredient. In Indonesia and other Asian countries, *A. muelleri* as well as *A. konjac* K. Koch, *A. bulbifer* (Roxb.) Blume and *A. paeoniifolius* (Dennst.) Nicolson have been used as traditional foods or medicines (Sugiyama and Santosa, 2008).

Hetterscheid and Ittenbatch (1996) and Jansen *et al*. (1996) described *A. muelleri* as a perennial *Araceae* plant that has a single smooth tuber and tripartite solitary leaf with cylindrical and solid petiole. *A. muelleri* is a shade-loving plant and enters dormancy in the dry season (Jansen *et al*., 1996; Santosa *et al*., 2006; Sugiyama and Santosa, 2008). Cultivation of *A. muelleri* (locally called *iles-iles*) in agroforests in East Java has been studied by Santosa *et al*. (2003). They reported that its cultivation under timber tree canopies has been introduced into villages near timber plantations in Java as social programmes aiming to increase farmers' income. Most farmers grow *A. muelleri* in agroforests under teak trees, with little regard for cultivation practices; they only remove weeds 2–3 times a year, while some farmers adjust the planting density by transplanting plants from high-density areas to low-density areas after emergence (Santosa *et al*., 2003). According to our observations, agroforests in which *A. muelleri* plants are cultivated are distributed in some areas with hardpans, or shallow soils, in South Sulawesi, Lombok and Java, although *A. muelleri* productivity in such shallow soils is generally low (unpublished report). Shallow soil means a limited volume of soil from which plants can extract nutrients and water (Hartmann *et al*., 1981), leading to low productivity. It is possible, however, that plant roots experience a mechanical stress that might also limit the productivity of *A. muelleri* in shallow soil. Therefore, the effect of limited soil depth on *A. muelleri* yield needs to be studied in relation to both the amount of growth media per plant and rooting volume. The aim of this study is to determine the effect of the amount of growth media per plant on the growth and yield of *A. muelleri*.

MATERIALS AND METHODS

Two experiments were conducted in Bogor, West Java, Indonesia (248 m above sea level), in the rainy season from December 2007 to June 2008. During the experiments, daily maximum and minimum temperatures were 30 °C and 27 °C, respectively (average 28.5 °C), and the relative humidity was 85%. Plants were placed under a canopy of rose apple trees (*Syzygium samarangense* (Blume) Merr. and Perry) in which the solar radiation at midday was approximately reduced by 50%.

* Corresponding author. e-mail: edisang@gmail.com

Planting materials used in both experiments were 1-season corms, 100–125 g in fresh weight and 5.0–5.4 cm in diameter. These seed corms were harvested in July 2007 and stored at room temperature until planting time (30 December 2007). At planting, all corms had already sprouted, and the buds were 1.0–1.5 cm in height. Uniform seed corms were planted in plastic pots.

In experiment I, commercial plastic pots with diameters ranging from 12.5 to 30.0 cm were used. Commercial fine compost at rates of 0.25, 0.40, 0.50, 1.00, 1.33, 2.00 and 4.00 kg was used to fill pots with diameter 12.5, 15.0, 16.5, 19.0, 23.5, 23.5 and 30.0 cm, respectively. In experiment II, 30.0 cm pots were filled with 4.00 kg of the same growth media used in experiment I. In both experiments, pots were laid out at distances of 50 cm □ 50 cm. The compost (pH 7.1) contained 1.44% of total N, 2.38% of P_2O_5, 3.03% of K_2O, 1.70% of CaO, 1.70% of MgO, 26.6% of organic C, 45.9% of organic matter and 76.3 me $(100\ g)^{-1}$ of total exchangeable cations (Green Valley; LHM Research Station, Solo, Indonesia). The compost also contained some trace elements such as Mn, Cu, Zn, Co and Fe at levels of 1.56, 0.17, 2.51, 0.50 and 27.5 ppm, respectively. At the time of application, the moisture content of the compost was 15%. No additional fertilizer or chemical pesticide was applied in both experiments.

Corms were planted 4 cm below the soil surface. Irrigation was performed every day until a small amount of water came out from the drainage hole of the pots. The experiments were designed in a randomized complete block design with 3 replications. Five pots were used in each replication. Plant growth, i.e., petiole length and diameter, and rachis width, were monitored monthly, and yield was determined at the end of the experiment when plants entered dormancy. Dormancy was judged by senescent withering of the leaf. The water-holding capacity of the growth media in each pot was measured 1 h after watering at the end of the experiments by weighing the growth media before and after drying for more than 24 h at 70 °C.

RESULTS AND DISCUSSION

Results

During the experiments, all treatments produced single leaf per corm (data not shown). The amount of growth media significantly affected the petiole length of *A. muelleri*; it increased gradually with the increase in the amount of growth media up to 2.00 kg (Table 1). On the other hand, there were no difference in petiole diameter and rachis width among treatments (Table 1).

A new corm (daughter corm) was formed between the petiole and decomposing seed corm. When the seed corm depleted its dry mass, a new corm had already reached a particular size, and thereafter it continued to enlarge until dormancy. The largest corm diameters were obtained with 0.40-1.00 kg of growth media, while corm weight increased with an increase in growth media from 2.00-4.00 kg (Table 2). Along with an increase in corm weight, corm height increased and harvesting time was delayed.

Leaf wilting was observed for all plants in small pots, even if plants were watered every day to maintain the soil moisture content at about 25% (v/v). *A. muelleri* plants had a smaller number of roots when grown in 0.25–0.50 kg of growth media than when grown in 1.00–4.00 kg of media (data not shown). Maximum root length was also restricted in pots with a small amount of growth media (30.1 cm vs. 74.5 cm for 0.25 kg vs. 2.00 kg media treatments, respectively).

An increase in the number of plants from 1 to 2, 3, 4 and 5 per pot resulted in a decrease in growth media from 4.00 to 2.00, 1.33, 1.00 and 0.80 kg per plant, respectively. No trend was detectable regarding the effect of the number of plants per pot on plant growth although there were significant differences in rachis width among treatments (Table 3).

The number of plants per pot did not significantly affect corm size and corm fresh weight although variations

Table 1. Effect of the amount of growth media on vegetative growth of *Amorphophallus muelleri*

Amount of growth media (kg)	Petiole length (cm)	Petiole diameter (cm)	Rachis width (cm)
0.25	58.7 ± 0.3[y]a[z]	1.7 ± 0.0a	25.3 ± 0.3a
0.40	55.0 ± 1.7a	1.8 ± 0.0a	25.3 ± 2.2a
0.50	66.0 ± 0.6b	1.8 ± 0.0a	26.3 ± 0.3a
1.00	65.7 ± 0.7b	1.8 ± 0.0a	26.3 ± 0.3a
1.33	67.0 ± 1.0b	1.7 ± 0.0a	27.0 ± 0.0a
2.00	72.0 ± 0.6c	1.7 ± 0.1a	27.7 ± 0.3a
4.00	69.0 ± 2.1bc	1.7 ± 0.0a	29.3 ± 1.9a

Note: y Mean ± SE. n = 5
z Means followed by the same letter within a same column were not significantly different by Tukey test at $P < 0.05$

in corm size (standard error, SE) became significantly larger (Table 4). On the other hand, days to harvest were slightly longer when only 1 plant was grown in a pot than when 2–5 plants were grown in a pot. The average corm size was not affected by the number of plants per pot.

Leaf wilting was observed when more than 4 plants were grown in a 4.00 kg pot. Based on our observations, when several plants were grown together, roots occupied all available space and twisted around each other. The water-holding capacity of the growth media did not differ among treatments, ranging from 23 to 25% (v/v) (data not shown).

Discussion

Rooting volume determines the capacity of media to provide water and nutrients for plant growth (Hartmann *et al*., 1981). The results of experiment I indicated that limited rooting volume significantly reduced plant growth

Table 2. Effect of the amount of growth media on daughter corm size and harvesting time of *Amorphophallus muelleri*

Amount of growth media (kg)	Corm diameter (cm)	Corm height (cm)	Corm weight (g)	Harvesting time (days)[x]
0.25	5.0 ± 0.0[y]a[z]	3.3 ± 0.2a	47.6 ± 1.1a	64.0 ± 1.7a
0.40	6.7 ± 0.3c	5.3 ± 0.2bc	121.3 ± 0.6b	110.7 ± 0.7b
0.50	6.7 ± 0.3c	5.0 ± 0.0b	164.5 ± 3.0c	112.3 ± 1.5b
1.00	6.6 ± 0.0c	5.0 ± 0.0b	162.7 ± 5.6c	111.3 ± 0.7b
1.33	6.1 ± 0.2bc	5.0 ± 0.0b	180.3 ± 0.5d	134.0 ± 3.1c
2.00	6.0 ± 0.1b	5.1 ± 0.1b	192.7 ± 1.6e	148.7 ± 0.7d
4.00	6.4 ± 0.3bc	5.8 ± 0.2c	194.7 ± 4.8e	149.3 ± 0.3d

Note: x Days after planting (30 December 2007)
y Mean ± SE. n = 5
z Means followed by the same letter within a column were not significantly different by Tukey test at $P < 0.05$

Table 3. Effect of the number of plants per pot on vegetative growth of *Amorphophallus muelleri*

Number of plants per pot	Petiole length (cm)	Petiole diameter (cm)	Rachis width (cm)
1	69.0 ± 2.1[y]a[z]	1.7 ± 0.0a	29.3 ± 1.9ab
2	54.5 ± 1.9a	1.7 ± 0.0a	24.0 ± 2.0a
3	68.7 ± 2.3a	1.5 ± 0.0a	32.0 ± 0.6b
4	69.0 ± 9.9a	1.6 ± 0.2a	26.0 ± 2.4ab
5	60.0 ± 4.1a	1.8 ± 0.1a	23.8 ± 1.5a

Note: y Mean ± SE. n = 5
z Means followed by the same letter within a column were not significantly different by Tukey test at $P < 0.05$

Table 4. Effect of the number of plants per pot on average daughter corm size and harvesting time of *Amorphophallus muelleri*

Number of plants per pot	Corm diameter (cm)	Corm height (cm)	Corm weight (g)	Harvesting time (days)[x]
1	6.4 ± 0.3[y]a[z]	5.8 ± 0.2a	194.7 ± 4.8a	149.3 ± 0.3b
2	6.2 ± 0.0a	5.9 ± 0.0a	136.6 ± 3.9a	132.0 ± 1.7a
3	6.1 ± 0.1	5.6 ± 0.3a	146.2 ± 17.6a	138.0 ± 5.7ab
4	6.4 ± 0.4a	5.4 ± 0.4a	164.3 ± 39.4a	133.3 ± 5.3a
5	5.4 ± 1.5a	5.9 ± 0.7a	231.2 ± 72.8a	131.8 ± 1.3a

Note: x Days after planting (30 December 2007)
y Mean ± SE. n = 5
z Means followed by the same letter within a column were not significantly different by Tukey test at $P < 0.05$

and yield of *A. muelleri*. The water-holding capacity of the growth media measured 1 h after watering at the end of the experiment did not differ among treatments. This suggests that the total amount of available water is proportional to the amount of the media in the pot, and a small amount of growth media creates limited moisture reservoirs. Thus, it is possible that the small amount of growth media dry quickly after watering, restricting petiole extension growth and corm development. Furthermore, a small amount of growth media (less than 2.00 kg) shortened the period from planting to harvest, suggesting that plants entered dormancy because of a water shortage in these treatments. In *Amorphophallus*, water scarcity is responsible for early dormancy. Santosa *et al*. (2004) stated that *A. paeoniifolius* growing in a greenhouse entered dormancy earlier under limited water supply than under sufficient water supply. Jansen *et al.* (1996) also stated that dry seasons induced dormancy in *Amorphophallus*. Hetterscheid and Ittenbatch (1996) classified *Amorphophallus* species into two groups based on ecological characteristics; *Amorphophallus* species originating from Java such as *A. muelleri* and *A. paeoniifolius* show a strong tendency to enter dormancy during cultivation under drought conditions, whereas other species originating from Sumatra, Borneo and West Malaysia occasionally skip dormancy.

The amount of available water per plant also decreases with increasing number of plants per pot. Although 4.00 kg of growth media per 5 plants corresponded to 0.80 kg of growth media per plant, corm weight and days to harvest among treatments in experiment II were similar, which was different from the results of experiment I. Therefore, it is likely that a small amount of growth media itself does not cause yield reduction and early induction of dormancy if the rooting volume is quite large. However, it is not clear why root mechanical stress stimulates leaf wilting and dormancy. Considering the results of both experiments I and II, it is likely that low yield and early induction of dormancy in small pots was derived from not only a limited water supply but also from mechanical stress caused by a limited rooting volume.

It is probable that subsoil allows deeper rooting and increases plant productivity in shallow soils possibly because roots that extend deeply can make use of water in the subsoil. However, this study suggested that the beneficial effect of subsoil on plant growth was also associated with the relief of mechanical stress to plant roots.

In experiment II, corm size and weight was independent of the number of plants per pot. This suggested that yield could be increased with an increase in plant density if plants were well watered, as in this study. Sumarwoto (2005) recommended planting density of *A. muelleri* of 37.5 cm × 37.5 cm in the first year, 57.5 cm × 57.5 cm in the second year and 100 cm × 100 cm in the third year. However, no experimental results were provided to support their recommendation. In a rainy season experiment, Bhagavan *et al*. (2008) stated that corms of *A. paeoniifolius* were larger with a wide plant spacing (60 cm × 60 cm) than with a narrow plant spacing (45 cm × 45 cm), but total yield was lower with a wide spacing than with a narrow spacing (41 ton ha^{-1} vs. 63 ton ha^{-1}). Plant density changes not only the amount of growth media per plant, but also light conditions. Although the effect of intraspecific competition for light on plant growth was not included in this study, it is well known that *A. muelleri* is a shade-loving plant (Santosa *et al*., 2006). Thus, it is possible that competition for light did not result in detrimental effects on plant growth in *A. muelleri*. If this is the case, plant spacing should be narrower than that recommended by Sumarwoto (2005) in order to increase the yield potential of *A. muelleri* in deep soils or well-watered conditions.

CONCLUSION

In conclusion, the productivity of *A. muelleri* was dependent on rooting volume; a small rooting volume may limit the available amount of water and cause mechanical stress to roots. The results of this study suggested the importance of subsoil for increasing the productivity of *A. muelleri* in shallow soil.

ACKNOWLEDGEMENT

The authors gratefully thank Dr Fred Rumawas for providing planting material.

REFERENCES

Bhagavan, B.V.K., R. Chandrashekar, P.V. Rao, K.S. Raju, T.Y. Madhulety, K.V. Rao. 2008. Effect of seed corm weight, spacing and time of harvest for raising quality seed planting material of elephant foot yam. p. 107-110. *In* Proceeding National seminar on *Amorphophallus*: Innovative technologies. Indian Council of Agriculture Research, New Delhi.

Hartmann, H.T., W.J. Flocker, A.M. Kofranek. 1981. Plant Science. Growth, Development, and Utilization of Cultivated Plants. Prentice-Hall, New Jersey.

Hetterscheid, W.L.A., S. Ittenbatch. 1996. Everything you always wanted to know about *Amorphophallus*, but were afraid to stick your nose into. Aroideana 19:7-131.

Jansen, P.C.M., C. van der Wilk, W.L.A. Hetterscheid. 1996. *Amorphophallus* Blume ex Decaisne. p. 45-50. *In* M. Flach, F. Rumawas (*Eds.*) PROSEA 9: Plant Yielding Non-seed Carbohydrates. Backhuys Publ., Leiden.

Ohtsuki, T. 1968. Studies on reserve carbohydrates of four *Amorphophallus* species with special reference to mannan. Bot. Mag. Tokyo 81:119-126.

Santosa, E., N. Sugiyama, S. Hikosaka, S. Kawabata. 2003. Cultivation of *Amorphophallus muelleri* Blume in timber forests of East Java, Indonesia. Jpn. J. Trop. Agric. 47:190-197.

Santosa, E., N. Sugiyama, E. Sulistyono D. Sopandie. 2004. Effects of watering frequency on the growth of elephant foot yams. Jpn. J. Trop. Agric. 48:235-239.

Santosa, E., N. Sugiyama, M. Nakata, O.N. Lee. 2006. Growth and corm production of *Amorphophallus* at different shading levels in Indonesia. Jpn. J. Trop. Agric. 50:87-91.

Sugiyama, N., E. Santosa. 2008. Edible *Amorphophallus* in Indonesia-Potential Crops in Agroforestry. Gadjah Mada University Press, Yogyakarta.

Sumarwoto. 2005. Iles-iles (*Amorphophallus muelleri* Blume); deskripsi dan karakteristiknya. Biodivertas 6:185-190.