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RESEARCH ARTICLE

Are *Tacca leontopetaloides* (Linn.) O. Kuntze Mini Tuber Growth Affected by Media Composition and Tuber Size?

Sandra Arifin Aziz*[A], Rendy Susanto

[A]Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University
Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, Indonesia

*Corresponding author; email: sandraaziz@yahoo.com

Abstract

Tacca (*Tacca leontopetaloides* (Linn.) O. Kuntze) is a tropical plant that is widely used for its starch in some countries as well as medicinal plant. Tacca has advantages as it can grow on sand in tropical seashore areas and rain forests. Farmers in Madura Island Indonesia cultivated tacca by using mother tubers as propagules and harvest the daughter tubers, but no studies have been conducted on the growth of mini-tubers and their cultivation. The purpose of this study was to find the best combination of planting media and the size of mini tuber for growing tacca. The experiment was set in a completely randomized block design with two factors and three replications. The planting media are sand : rice-hull charcoal : cow manure (1:1:1 v/v), soil : sand : cow manure (1:1:1 v/v), soil : rice-hull charcoal : cow manure (1:1:1 v/v), and soil : cow manure (1:1 v/v);mini-tuber weight are1-5 and 5.1-20 g. The result showed Polynesian arrowroot grow best on sand : rice hull charcoal : cow manure (1:1:1 v/v) and rice hull charcoal : cow manure (1:1 v/v) media. Both propagules sizes can be used, but plants from large mini tuber had better growth and produced larger mother and daughter tubers.

Key words: mini tuber, parent tuber, Polynesian arrowroot, organic media planting, secondary tuber

Introduction

Polynesian arrowroot or *Tacca leontopetaloides* (Linn.) O. Kuntze isfrom Taccaceae family (Heyne, 1987; Meena and Yadav, 2010), is an annual tuber (Spenneman, 1994; Wilkin et al., 2005), hermaphrodite dioecious (Wilkin et al., 2005) and an underutilized source of starch in Indonesia.This plant is herbaceous (Abdullah et al., 2014; Booth et al., 2004) plant other than grass or sedges, leaves compound or lobed, stem with longitudinal ridges and hollow (Booth et al., 2004). Abdullah et al. (2014) stated that Polynesian arrowroot possess the most stunning inflorescence with whisker-like filiform bracteoles and the colour of the two conspicuous inner involucral bracts range from white, green, purple, brown to near black colour. The true flowers of *T. leontopetaloides* are dark purple, brown, or near black in colour and they are actinomorphic and hermaphroditic with six stamens.*T. integrifolia* as potted plants and exterior landscaping need 30% shade level for the longest flower stalk, whereas shade level of 70% is most suitable to produce a good quality potted plant with intense flower colour and suitable flower stalk length in Malaysia. Full sunlight will delay and slow down the growth of plants and cause death of plants.

In India *T. leontopetaloides* tubers are usually cooked, boiled with leaves of guava or tamarind to avoid the irritating property of the tubers, or roasted as vegetables (Misra and Misra, 2014). In Hawaii the tubers are used as famine food (Bevacqua, 1994), and it is a staple food in Mozambique (Bruschi et al. 2014). Ndouyang et al. (2014) stated that the Tacca genus has toxic alkaloid taccalonolid E and A. Furthermore Ukpabi et al. (2009) stated that the bitterness in *T. leontopetaloides* comes from taccalin (3,5,7,4'-tetrahydroxy-flavylium-3-xyloside), a phenolic compound, that should be processed before eaten by livestock (Ubwa et al., 2011).

Some medicinal uses of this plant has been documented, such as to reduce chest pain and to cure rashes on newborn baby (Nandwani et al., 2008), to relieve pain of the body and stomach, and it is considered as antidote of food poisoning, and possesses analgesic, antipyretic and anti-inflammatory activities (Jiang et al., 2014).

Phytochemical screening of *T. leontopetaloides* showed that their leaves contain alkaloids, saponins and tannins whereas the tuber only contains alkaloids (Borokini and Ayodele, 2012).The tuber also contains flavonoid (Ukpabi et al., 2009), and this finding is differed from Habila et al. (2011) that reported no flavonoids in *T. leontopetaloides*. Habila et al. (2011), however, reported that *T. leontopetaloides* has antioxidant activities of 86% at 125 µg.mL^{-1}, reducing potential and total phenolic content express in terms of Gallic acid equivalent (GAE) 0.217nm, 6.90 mg, compared with Gallic acid standard (1.268nm). Jiang et al. (2014) stated that 120 constituents have been isolated from *T. leontopetaloides*, including steroidals, phenolics, flavonoids, sesquiterpenoids, triterpenoids and starch. Steroidals and diarylheptanoids showed potent bioactivities, such as cytotoxic, microtubule-stabilizing, NF-kB activation and PPAR transcriptional and insecticidal activities. The starch from *T. leontopetaloides* has high amylase content and showed potential uses in food and drug system. Huang et al. (2002) stated that leaf extract from *T. leontopetaloides* can be used against slugs and snails.

Evaluation of the physicochemical properties of fresh and stored (4 months) Tacca tubers showed that the bitter brown skinned tuber had 28.25-29.00% dry matter, 25.00-27.25% starch 40-43 mg/100 g ascorbic acid, 3.15-3.58% crude flavonoid extract,and a density of 1.67 g.mL^{-1} density (Ukpabi et al., 2009). The proximate composition of the tuber flesh was 1.10-1.50% protein, 2.70-2.73% ash, 0.28-0.68% fiber, 0.08-0.10% fat and 95.02-95.42% total carbohydrate on dry matter basis (Ukpabi et al., 2009), and Marcel et al. (2012) reported that the tubers have 35% starch content.

People still use starch from Tacca tubers as staple food in Madura Island, East Java, Indonesia. Tacca has many benefits, one of them is that it grows on sand in tropical seashore areas, rain forest and subtropical rain forest (Heyne, 1987; Meena and Yadav, 2010). The vast idle tropical seashore areas in Indonesia can be made more productive by producing starch from *T. leontopetaloides*. Spennemann (1994) stated that *T. leontopetaloides* was found to grow on very fine to medium soil with low to medium humus content. *T. leontopetaloides* height of leaves and flowercan reach 0.2-1.2 m and 0.8-1.8 m, respectively, when grown understory of coconut tree, *Artocarpus altilis* or *Pandanus tectorius*. Pate et al. (2014) study in Nigeria reported that intra-row spacing of 20 and 25 cm, application of NPK and poultry manure produced higher tuber production of Polynesian arrowroot than using cow manures. Media used in this research should resemble the media where Polynesian arrowroot was found in nature, media combination that have high porosity i.e. sand and rice hull charcoal for porosity, soil and cow manure as clay source, binding agent, as well as nutrient source. Mualim (2009) reported that cow manure application increased soil pH, P_2O_5, K_2O, decreased C-organic, and change the soil texture from clay to dusty clay in *Talinum triangulare* cultivation.

Farmers in Madura Island cultivated tacca by using mother tubers as propagules and harvest the daughter tubers, but there has no report on using mini tuber produced from seedlings and their cultivation.This cultivation tradition decreases the harvest because the use of big tuber as propagule. Mini tubers can befound on land cultivated with *T. leontopetaloides*, but they are usually lay idle, or disturb the planting distance needed for producing big tuber, and were treated as weeds. Spennemann (1994) stated that in Marshall Islands traditional and modern cultivation of Polynesian arrowroot only harvest the big tubers, while the small tubers are left behind in the holes. A new tuber formed close to the one of the previous year. Although the tubers are generally described as small, there are reports of larger tubers, weighing over 500 g. The number of tubers of each mature plant can range from one to well over thirty, with numbers between ten and twenty being the most common. The plants tend to show preponderance for small tubers, with a few big ones added. In onion cultivation in Nigeria, large onion bulb (*Allium cepa*) can be used for growth, high yield and better quality of onion seeds (Ashagrie et al., 2014). Hussain et al. (2001) reported that medium size bulbs had greater leaf production than small and large bulbs.

This research aims to find media composition and tuber sizes that can be used to cultivate Polynesian arrowroot.

Materials and Methods

Treatments

The experiment was conducted in Bogor, Indonesia from October 2013 to May 2014 and laid out in completely randomized block design with twofactors, compositionof planting media and mini tuber weight, with three replications. The composition of planting media tested are sand : rice hull charcoal : cow manure (1:1:1 v/v), soil : sand : cow manure (1:1:1 v/v), soil : rice hull charcoal : cow manure (1:1:1 v/v), and soil : cow manure (1:1 v/v).

The tuber propagules are grouped into 1-5 (small tubers) and 5.1-20 g (large tubers). The propagules came from Sumenep, Madura Island. The shade percentage was 35%. Duncan Multiple Range Test was used on variables that were significantly different ($P<0.05$).

Results and Discussion

Composition of Planting Media and Polynesian arrowroot growth

Plants grown on soil : cow manure (1:1 v/v) media had the lowest values on all growth variables observed (Figure 1 and 2). Plants on sand : rice-hull charcoal : cow manure (1:1:1 v/v) media were 36.90-47.98% taller those on soil : cow manure (1:1 v/v), and those grown in soil : rice hull charcoal : cow manure (1:1:1 v/v) were 31.13-37.34% taller than those grown in soil : cow manure (1:1 v/v) (data not shown).

Leaf emerged on 6 WAT (weeks after planting) in soil : rice-hull charcoal : cow manure media (1:1:1 v/v). Leaf number wasaffected by media combination at 16-18 WAP. Leaf number of the plants grown on sand : rice hull charcoal : cow manure (1:1:1 v/v) was 58.8-62.5% greater than that in soil : sand : cow manure (1:1:1 v/v). The plants did not form new leaves between 19-22 WAP, but leaf number on sand : rice hull charcoal : cow manure media (1:1:1 v/v) was 31.5-44.5% greater than that in soil : cow manure (1:1 v/v).

In addition, individual leaf area of the plants grown in sand: rice hull charcoal : cow manure media (1:1:1 v/v) was larger and the plants grew faster. Shoot diameter was affected by media composition on 15-22 WAT. Shoot diameter of the plants grown in sand: rice hull charcoal : cow manure (1:1:1 v/v) was 51.38-71.17% greater than that inthose in soil : cow manure (1:1 v/v), likely due to a larger leaf area.

Relative growth rate was not affected by media composition. Tacca grown on sand : rice hull charcoal : cow manure (1:1:1 v/v) had 22.98% higher RGR than those grown on soil : cow manure (1:1 v/v), likely due to greater leaves, petiole, tuber, and root dry weight.

Net assimilation rate was affected by how much the leaves shaded each other. Tacca grown on sand : rice hull charcoal : cow manure (1:1:1 v/v) had 104.7% higher NAR than those grown on soil : cow manure (1:1 v/v), likely due to greater leaf area.

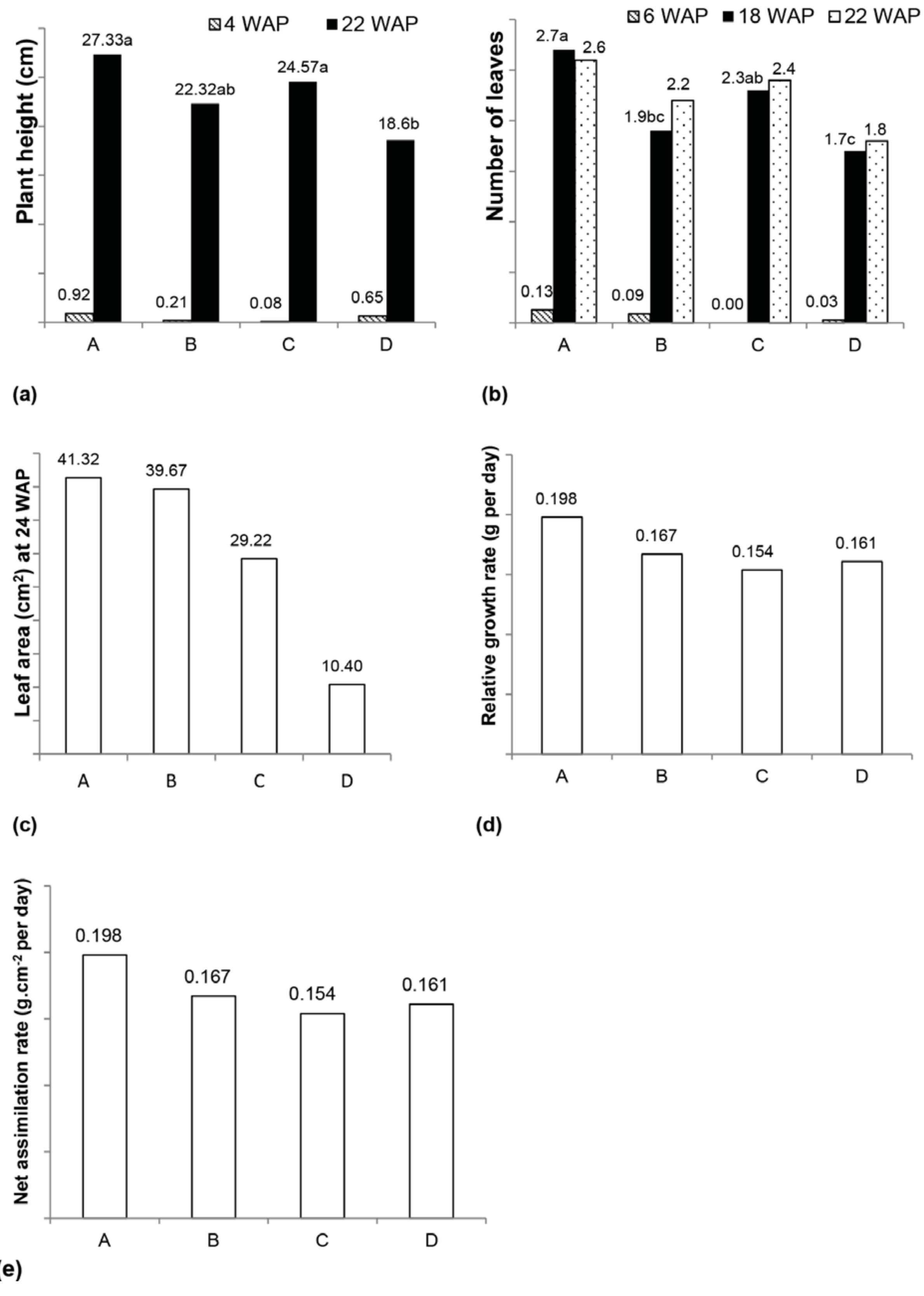

Figure 1. Growth variables of *T. leontopetaloides* at different media combination (A-D): (a) plant height (cm) at 4 and 22 WAP; (b) number of leaves at 6, 18, 22 WAP; (c) leaf area (cm^2) at 22 WAP; (d) relative growth rate (g per day) at 18-24 WAP; and (e) net assimilation rate ($g.cm^{-2}$ per day) at 18-24 WAP where A = sand : rice hull charcoal : cow manure; B = soil : sand : cow manure; C = soil : rice hull charcoal : cow manure; D = soil : cow manure.

Weight difference between total tuber produced to initial mini tuber was affected significantly by media combination on 1-24 WAP (data not shown).The weight of daughter tubers on sand : rice-hull charcoal : cow manure (1:1:1 v/v) was 216.54% than that on soil : cow manure (1:1 v/v), whereas on sand : rice hull charcoal : cow manure (1:1:1 v/v) was 401.80% greater than that on soil : cow manure (1:1 v/v) (Figure 2).

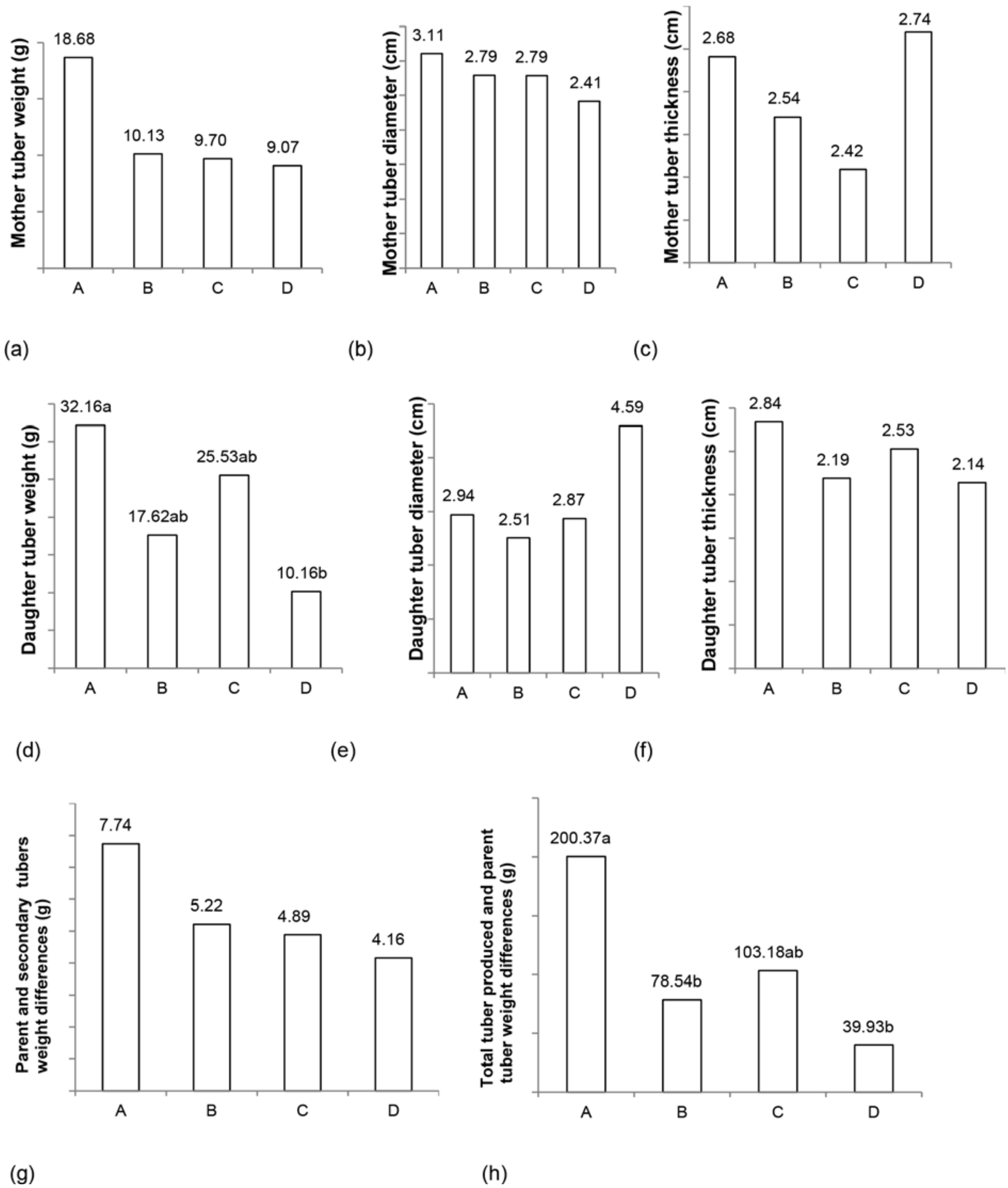

Figure 2. *T. leontopetaloides* tuber production at different media combination (A-D) at 24 WAP: (a) mother tuber weight (g); (b) mother tuber diameter (cm); (c) mother tuber thickness (cm); (d) daughter tuber weight (g); (e) daughter tuber diameter (cm); (f) daughter tuber thickness (cm); (g) weight differences between parent and secondary tubers (g); (h) weight differences between total tuber produced and parent tubers (g), where A = sand : rice hull charcoal : cow manure; B = soil : sand : cow manure; C = soil : rice hull charcoal : cow manure; D = soil : cow manure.

Tuber Sizes and Polynesian arrowroot growth

Plant height was affected by tuber size at 13-22 WAT (data not shown). The plants from larger tubers (5.1-20 g) were 65.09-81.73 % taller than those from the smaller tubers (1-5 g). Leaf number was affected by tuber size at 19-20 WAP. Plants from small tubers (1-5 g) had 20.4-5.0% more leaves than those from large tubers (5.1-20 g). However, the leaf area was 47.13% smaller.

Shoot diameter of the plants from 5.1-20 g tubers was significantly larger than the plants from 1-5 g tubers. No significant effect of tuber size on RGR and NAR (Figure 3).

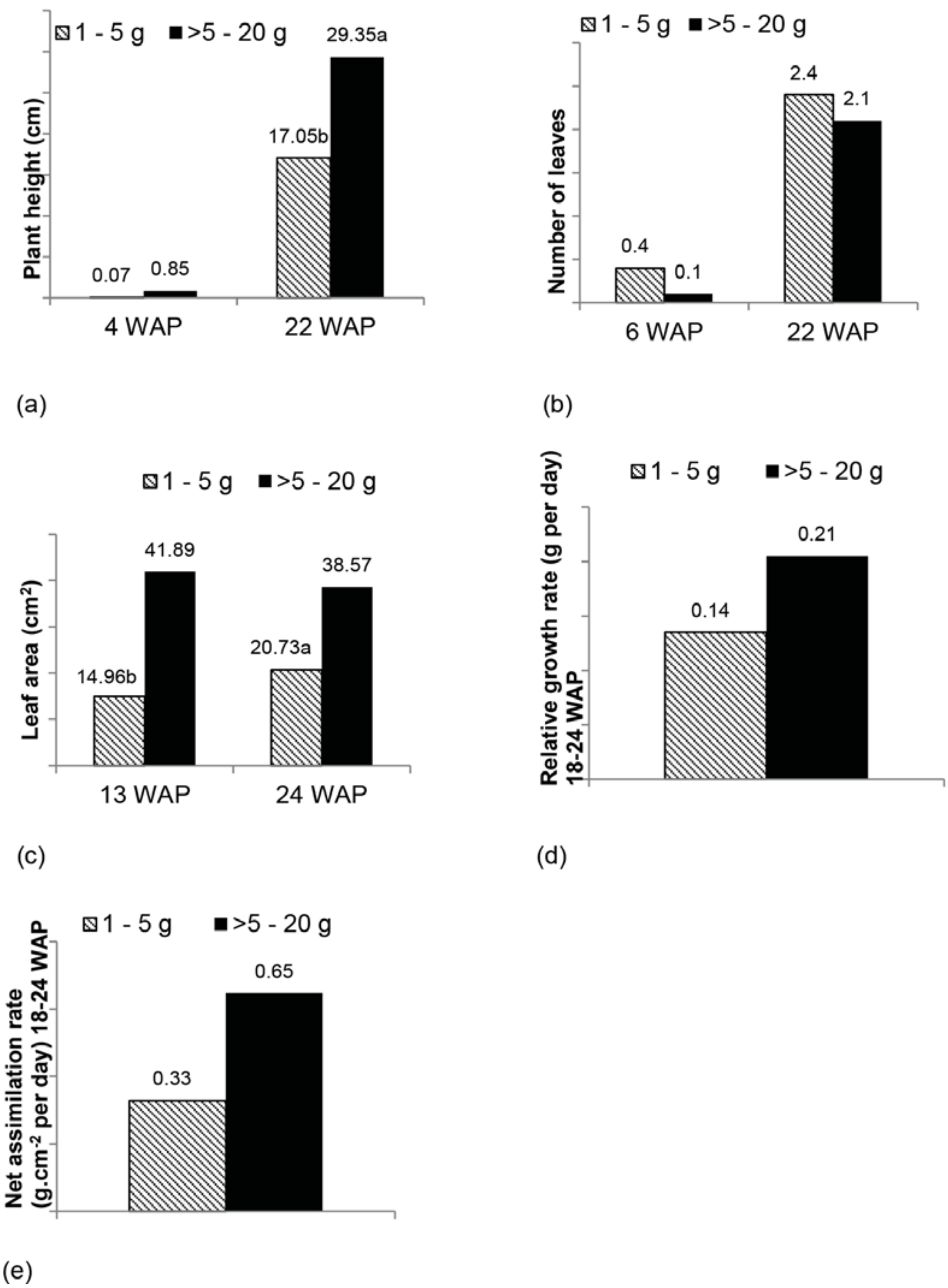

Figure 3. Growth variables of *T. leontopetaloides* small (1-5 g) and large (>5-20 g) tubers: (a) plant height at 4 and 22 WAP; (b) number of leaves at 6 and 22 WAP; (c) leaf area (cm^2) at 13 and 24 WAP; (d) relative growth rate (g per day) at 18-24 WAP; (e) net assimilation rate ($g.cm^{-2}$ per day) at 18-24 WAP.

The tuber size significantly affected the sizes of the daughter tuber harvested, mother tuber diameter, mother and daughter tuber thickness (Figure 4, data not shown). Large tubers (5.1-20 g) had significantly greater mother and daughter tuber weight, mother and daughter tuber thickness than small tubers (1-5 g), i.e. 166.52, 54.61, 29.86, and 59.93%, respectively. Large propagules (5.1-20 g) produced 166.52 and 54.61 % larger mother and daughter tubers, respectively, than small propagules (1-5 g), and the mother and daughter tubers produced were 29.86 and 59.93% thicker than the initial mini-tuber propagules.

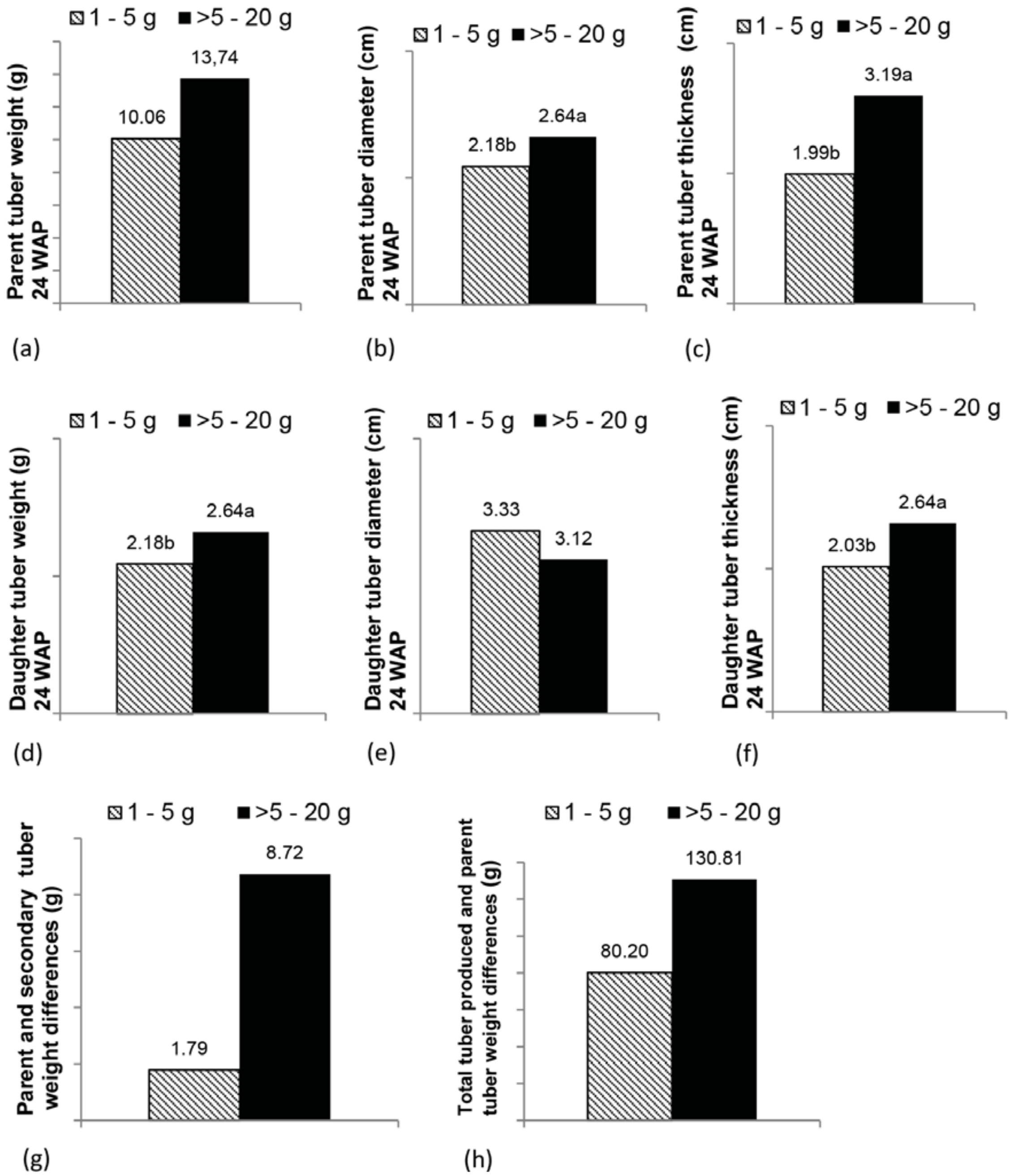

Figure 4. *T. leontopetaloides* small (1-5 g) and large (>5-20 g) tuber production at 24 WAP: (a) mother tuber weight (g); (b) mother tuber diameter (cm); (c) mother tuber thickness (cm); (d) daughter tuber weight (g); (e) daughter tuber diameter (cm); (f) daughter tuber thickness (cm); (g) parent and secondary tubers weight differences (g); (h) weight differences between total tuber produced and parent tuber weight differences (g).

Media composition influenced Tacca growth and tuber production. In Madura Island, Polynesian arrowroot mostly found grow on sand in the seacoast that has good drainage. This condition is similar to rice hull charcoal media in this experiment. Rice hull charcoal (Saleh, 2010) and cow manure (Mualim, 2009) has higher C-organic, N, and K_20 than sand, which resulted in better plant growth and greater tuber weight.

T. leontopetaloides grown on soil : cow manure media (1:1 v/v) had the lowest value on all growth growthvariables due to slow leaf emergence, more leaves of smaller sizes, low RGR and NAR, that was the opposite of *T. leontopetaloides* on sand : rice hull charcoal : cow manure (1:1:1 v/v) media. Media composition with high porosity supported better *T. leontopetaloides* growth. Large tubers associated with high carbohydrate content (source) promoted better growth (sink). Soemonoet et al.(1986) found on *Amorphopallus campanulatus* that plants from large tuber propagules grow faster, had an increased LAI and significantly produced larger tuber weight per plant and per hectare.

Farmers in Madura Island cultivated *T. leontopetaloides* by using mother tubers as propagules and harvest the big daughter tubers. This cultivation tradition decreases the harvest because the large tubers are used as propagule.*T. leontopetaloides* are harvested mostly from the wild, and limited information available on culture and types of propagules used for cultivation.The results of this study showed that mother tuber size became larger when using mini tuber, and produced daughter tubers. Therefore mini tubers can be used as propagules to produce Tacca tubers for consumption in the future.

Conclusion

Polynesian arrowroot grow best on media combination of sand : rice hull charcoal : cow manure (1:1:1 v/v) and rice hull charcoal : cow manure (1:1 v/v). Both mini tuber sizes can be used as propagules, but larger mini tuber size produced better growth and larger mother and daughter tubers.

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