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Effects of Substrate Volumetric Water Content, Nutrient Solution Concentration, and Irrigation Method on Growth and Photosynthesis of *Alocasia*

Chih-Wei Hsieh and Der-Ming Yeh
Department of Horticulture and Landscape Architecture, National Taiwan University, No. 1, Roosevelt Road Section 4, Taipei 106216, Taiwan

Keywords. foliage plants, Johnson's solution, sub-irrigation, substrate electrical conductivity

Abstract. **Alocasias, known for their diverse foliage shapes and variegations, are popular as landscape ornamentals in subtropical and tropical regions and for indoor decoration. However, information on their water management and fertilization is limited. *Alocasia* 'Bambino' was subjected to four substrate volumetric water content (VWC) treatments: 20% VWC (dry), 25%/55% VWC (dry/wet cycle), 40% VWC (even moisture), and 70% VWC (constant sub-irrigation). Results showed the following ranking for growth parameters, including number of new-grown leaves, leaf area, plant dry weight, and net photosynthetic rate: 70% VWC > 40% VWC > 25%/55% VWC > 20% VWC. Plants at 20% VWC exhibited the lowest maximum quantum efficiency of photosystem II (Fv/Fm) and the highest intercellular CO_2 concentration. In addition, plants were supplied with 0% to 150% Johnson's solution once per week, using top- or sub-irrigation. Growth was optimal with 25% to 50% Johnson's solution (0.58–1.10 dS·m^{-1}); beyond this, growth plateaued or declined. Root dry weight was consistently higher under sub-irrigation across all nutrient concentrations. Substrate electrical conductivity (EC) increased with nutrient concentration, but total plant dry weight peaked at 0.4 dS·m^{-1} with a 1 water:2 substrate extraction. Above this EC, top-irrigation caused decreased growth, whereas sub-irrigated plants maintained stable performance.**

Water requirements and optimum substrate water content of foliage plants vary considerably. *Aphelandra* and some fern species require more irrigation than golden pothos (*Epipremnum aureum*) and dracaenas (Henley and Poole 1981). China Doll (*Radermachera sinica*) demands higher irrigation amounts compared with other foliage plants such as Norfolk Island pine (*Araucaria heterophylla*), golden pothos, dumb cane (*Dieffenbachia seguine*), and Ming aralia (*Polyscias fruticosas*) (Poole and Conover 1992). Klock-Moore and Broschat (2001) reported that shoot dry weights of areca palm (*Chrysalidocarpus lutescens*) and *Philodendron* 'Hope' grown with sub-irrigation were reduced by 57% and 32%, respectively, when watered every 2 days instead of daily. The poorest growth of *Radermachera hainanensis* and *R. sinica* was observed with 20% VWC treatment, compared with the 40% VWC treatment (Wang et al. 2024).

Depending on the plant species or cultivar, substrate water content can affect leaf water status, photosystem II (PS II), and net photosynthetic rate (Pn) through stomatal and/or nonstomatal limitations. For example, a 20% VWC treatment resulted in both the lowest *Pn* and the maximal efficiency of PSII photochemistry (Fv/Fm) in two *Radermachera* species: stomatal limitation in *R. hainanensis* and both stomatal and nonstomatal limitations in *R. sinica* (Wang et al. 2024). Stomatal limitation is considered the primary cause of reduced photosynthesis under drought stress, as plants close their stomata to minimize water loss via transpiration, which in turn decreases stomatal conductance (g_s) and transpiration rate (E). Nonstomatal limitations arise from reduced carboxylation efficiency or decreased Rubisco activity (Flexas and Medrano 2002; Zlatev and Lidon 2012).

Nutrient or nitrogen solution concentration and irrigation method greatly affect growth and photosynthesis of Araceae plants. The dry matter and leaf area of taro (*Colocasia esculenta* 'Bun Long') increased as N concentration rose from 0 to 2 mM but declined at 4 or higher mM N (Osorio et al. 2003). *Spathiphyllum* 'Petite' showed increased shoot and root dry weights as N concentration rose from 0 to 8 mM, but root dry weight declined sharply when N exceeded 10 mM (Kent and Reed 1996). Nitrogen deficiency significantly reduced leaf number, leaf area, plant dry weight, stomatal conductance, and chlorophyll content in *Spathiphyllum* 'Sensation', with optimal growth occurring at 8 to 10 mM N. However, excessive nitrogen (16 or 32 mM) led to growth inhibition and marginal leaf necrosis (Mak and Yeh 2001; Yeh et al. 2000). Chang et al. (2012) reported that 7.5 to 11.3 mM N promoted dry weight, leaf area, and flower number of *Anthurium andraeanum*, whereas 5.6 mM N reduced carbon assimilation, and 15 mM N reduced growth. Sub-irrigation requires lower fertilizer concentrations than top-irrigation due to improved nutrient absorption (Ferrarezi et al. 2015), making it advantageous for commercial production. Kent and Reed (1996) found that the optimal N concentration for *Spathiphyllum*

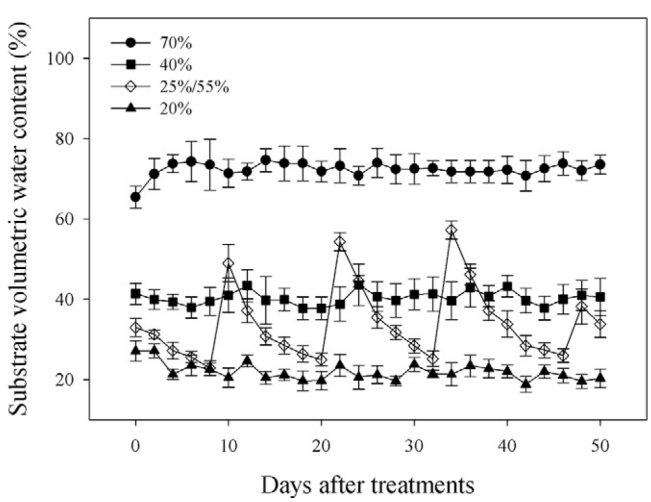

Fig. 1. Changes in volumetric water content over time for each irrigation treatment (n = 8, means ± standard error).

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Current address for C.-W.H.: Department of Industrial Application, Floricultural Experiment Branch, Taiwan Agriculture Research Institute, Ministry of Agriculture, Yunlin County 646004, Taiwan.
D.-M.Y. is the corresponding author. E-mail: dmyeh@ntu.edu.tw.

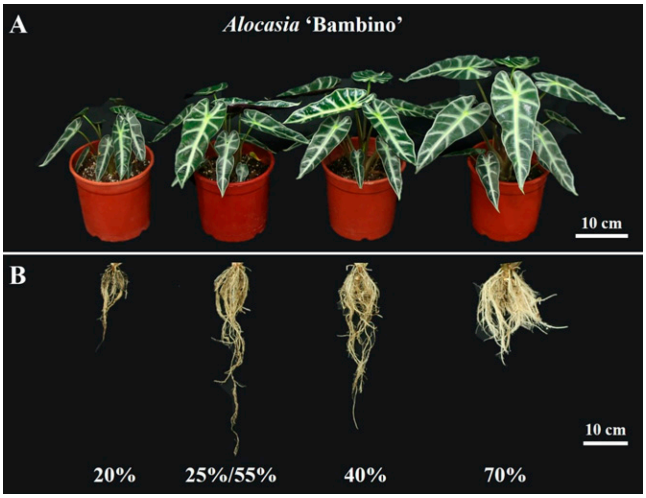

Fig. 2. Potted plant (**A**) and root (**B**) appearance of *Alocasia* 'Bambino' after various irrigation treatments.

Table 1. Effects of volumetric water content (VWC) on number of new-grown leaves, leaf area, leaf SPAD-502 value, shoot and root dry weight, and root-to-shoot ratio of *Alocasia* 'Bambino'.

		Leaf				
Mean VWC (%)	Number of new-grown leaves	Area (cm^2)	SPAD-502 value	Shoot dry wt (g)	Root dry wt (g)	Root-to-shoot ratio
20	3.3 d[i]	195.9 d	69.8 c	1.7 d	0.4 d	0.23 b
25/55	4.9 c	407.1 c	74.7 bc	3.1 c	1.0 c	0.31 a
40	5.7 b	475.4 b	79.5 b	4.5 b	1.3 b	0.29 a
70	6.7 a	707.8 a	85.5 a	6.9 a	1.6 a	0.23 b

[i]Mean separation within columns by least significant difference test at $P < 0.05$.

'Petite' was 8 to 10 mM under an ebb-and-flow system, lower than the 7.5 to 30 mM N as reported by Campos and Reed (1993) for conventional top-irrigation. *Spathiphyllum* 'Sensation' required 8 mM N to achieve the maximum shoot dry weight under sub-irrigation, significantly lower than 16 mM N under top-irrigation (Mak and Yeh 2001).

Alocasia (Araceae) has gained significant popularity in recent years due to its diverse leaf shapes, colors, textures, and venation patterns. Most *Alocasia* species grow in the humid understory of lowland forests, suggesting a preference for moist environments (Burnett 1984). However, some commercial growers suggest, based on production experience, that *Alocasia* benefits from distinct dry/wet cycles, while excessive irrigation should be avoided to prevent root rot. The capacitance soil moisture sensor, such as the WET sensor, employs frequency domain reflectometry to measure VWC in the soil or substrate by assessing dielectric permittivity and bulk EC. This instrument provides several advantages, including low regular maintenance, easy calibration, and low susceptibility to reading errors (Burnett and van Iersel 2008).

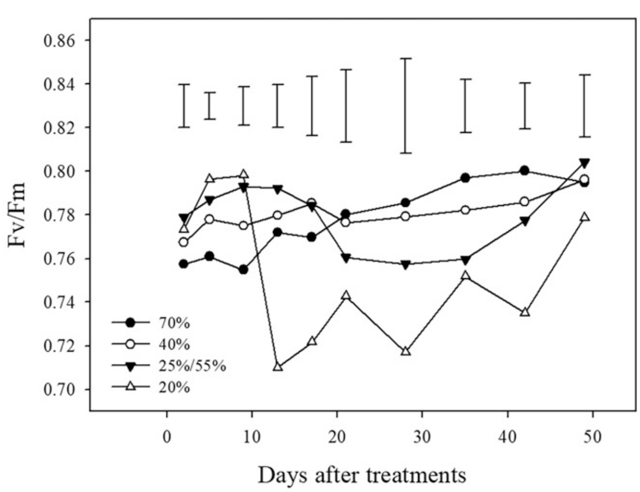

Fig. 3. Changes in leaf Fv/Fm of *Alocasia* 'Bambino' during various volumetric water content treatments. Vertical bars represent least significant difference ($LSD_{0.05}$) among treatments on the same day (n = 5).

Currently, research on substrate water content, nutrition concentration, and irrigation method of *Alocasia* remains lacking. This study aimed to evaluate the effects of VWC and compare top- and sub-irrigation under various nutrient solution concentrations on the growth and photosynthesis of *Alocasia* 'Bambino'.

Materials and Methods

Plant materials. Tissue-cultured plants of *Alocasia* 'Bambino' at the 7 to 8 macroscopic leaf stage were planted in 1.4-L plastic pots containing a mixture of 1 peatmoss (Fafard No. 1, Conrad Fafard, Agawam, MA, USA):1 perlite (No. 2, Nanhai Vermiculite Industrial Co., New Taipei City, Taiwan) by volume.

Expt. 1. Effects of VWC. Plants were cultivated in a 50% shaded Venlo-typed greenhouse covered with polyvinyl films. The average noontime photosynthetic photon flux density (PPFD; 400–700 nm, photosynthetically active radiation) ranged from 800 to 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$, and the average temperature during the experimental period was 28.9 °C. Environmental parameters, including temperature and light intensity, were measured using data loggers (HOBO UA-002-64 Pendant Temp/Light, Onset Computer Co., Cape Cod, MA, USA). Each plant was supplemented with 5 g of controlled release fertilizer 13N–4.3P–9.1K (Hi-Control, S101, 13-11-10-2TE, Type 100; Asahi Kasei, Tokyo, Japan), which was incorporated into the substrate.

There were four irrigation treatments, as follows:

1. Dry condition: Each plant was manually top-irrigated with 50 mL of tap water whenever the VWC dropped below 20%.
2. Dry/wet cycle: A dry/wet cycle was established by thoroughly manually top-irrigating with tap water until full capacity whenever the VWC was lower than 25%.
3. Even moisture: Each plant was manually top-irrigated with 100 mL of tap water whenever the VWC fell below 40%.
4. Constant sub-irrigation: Potted plants were placed into plastic buckets filled constantly with tap water up to 3 to 4 cm above the bottoms of the pots.

VWCs at 10 cm below the substrate surface were measured during 0800 to 1100 HR with WET sensor (Type HH2; Delta-T Devices, Cambridge, UK) before irrigation. There were eight plants for each irrigation treatment.

The recently fully expanded leaves from each plant were sampled at 4- to 7-d intervals during the experiment to measure Fv/Fm values using a portable chlorophyll fluorometer Mini-Pam (Heinz Walz GmbH, Effeltrich, Germany) after the leaves had been dark-adapted for 30 min at 30 °C.

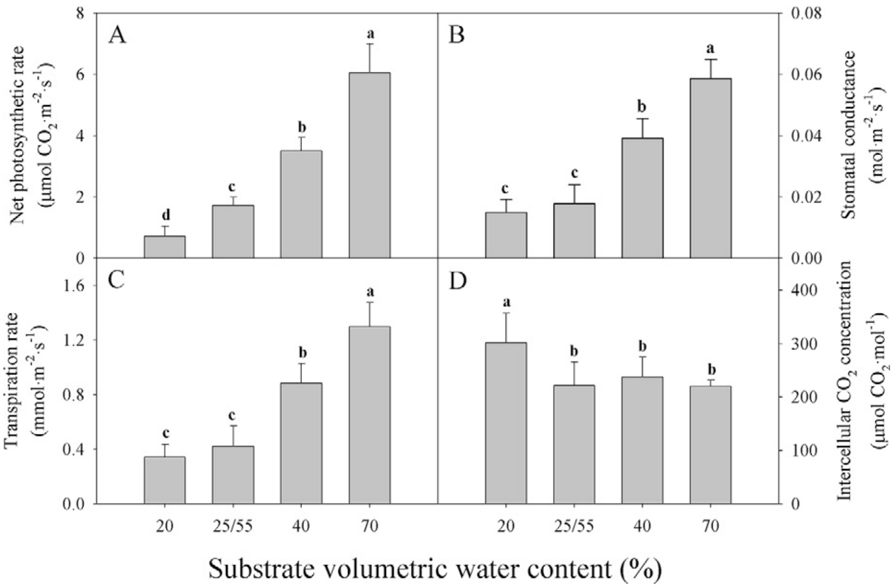

Fig. 4. Effects of volumetric water content on net photosynthetic rate (**A**), stomatal conductance (**B**), transpiration rate (**C**), and intercellular CO_2 concentration (**D**) of the recently fully unfolded leaves of *Alocasia* 'Bambino'. Vertical bars represent standard errors of the means. Mean separation by least significant difference at $P < 0.05$.

At 42 d after treatments, net photosynthetic rate (Pn), stomatal conductance (g_s), transpiration rate (E), and intercellular CO_2 concentration (Ci) of the recently fully expanded leaves were assessed using a portable photosynthesis system (LI-6400; LI-COR, Lincoln, NE, USA). Air was pumped through a desiccant (Drierites; W.A. Hammond Drierite Co., Xenia, OH, USA) and soda lime (LI-COR) to eliminate excess water vapor and CO_2. Light intensity within leaf chamber was set at 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PPFD, and a reference CO_2 concentration of 400 $\mu mol \cdot mol^{-1}$ was provided. The air flow rate was set at 500 $\mu mol \cdot s^{-1}$, and the measurement area was set at 2 cm^2. One leaf per plant was measured as one replicate, and each treatment had three replicates.

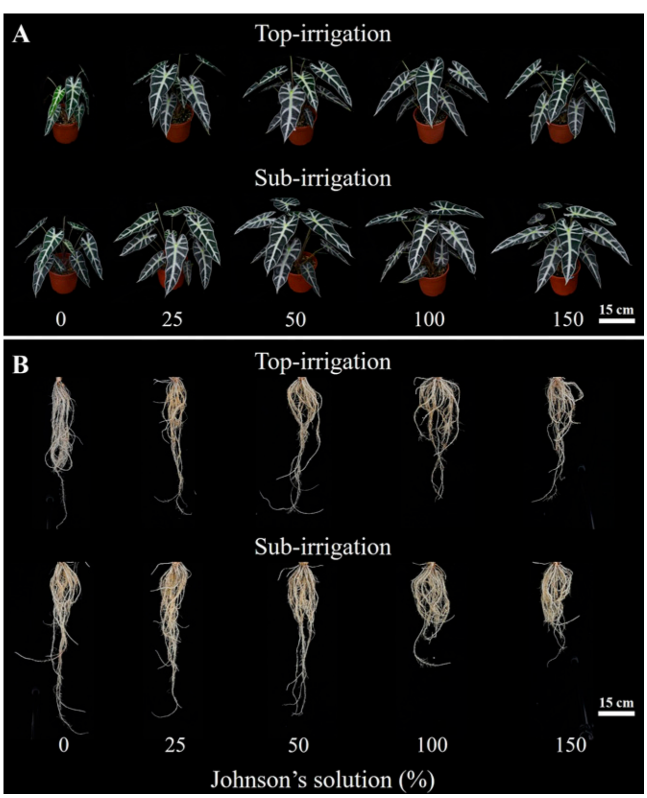

Fig. 5. Effect of nutrient solution concentration and irrigation method on appearance of *Alocasia* 'Bambino' on day 109 after treatments. (**A**) Whole plant and (**B**) root.

At 51 d after treatments being initiated, the number of new-grown leaves was recorded. The relative chlorophyll content of the green portion in the recently fully expanded leaves was measured using a chlorophyll meter (SPAD-502; Minolta Camera Co., Tokyo, Japan). Leaf area of each plant was calculated using Easy Leaf Area software (Easlon and Bloom 2014). Shoots and roots were collected and oven-dried at 70 °C for 72 h to determine dry weights.

This experiment was arranged in a completely randomized design, with eight replicated plants in each treatment. Comparison between different treatment means was made by least significant difference at $P < 0.05$ using CoStat 6.4 (CoHort Software, Monterey, CA, USA).

Expt. 2. Effects of nutrient solution concentration and irrigation method. Plants were grown in a 50% shaded greenhouse with an average noontime PPFD of 500 to 800 $\mu mol \cdot m^{-2} \cdot s^{-1}$, and average temperature of 28.2 °C during the experimental period. Plants were supplied with Johnson's solution (Johnson et al. 1957) at 0% (deionized water), 25%, 50%, 100%, or 150% strength. The full strength (100%) of Johnson's solution contained (mM): 14.0 N, 2.0 P, 6.0 K, 4.0 Ca, and 1.0 Mg, obtained from 6 KNO_3, 2 $NH_4H_2PO_4$, 1 $MgSO_4 \cdot 7H_2O$, and 4 $Ca(NO_3)_2 \cdot 4H_2O$, along with micronutrients in deionized water. The pH levels of all nutrient solutions were measured using a pH meter (SP-2300; Suntex Instruments Co., New Taipei City, Taiwan) and adjusted to 6.4 with 1 N NaOH. The corresponding electrical conductivity (EC) values of each solution, measured with a conductivity meter (Model SC-170; Suntex Instruments Co.), were 0.03, 0.58, 1.10, 1.99, and 2.87 $dS \cdot m^{-1}$, respectively.

This experiment was arranged in a split-plot factorial design, with irrigation method as the main plot and nutrient solution concentration as the subplot. There were six plants in each treatment. All plants in each treatment received nutrient solution once per week, without additional watering. For the top-irrigation treatments, each pot was hand-watered with 300 mL of nutrient solution. For the sub-irrigation treatments, each sub-irrigation tray was manually filled with nutrient solution to a depth of 3 to 4 cm for 1 to 2 h at each irrigation and then the solutions were recycled to the reservoirs.

At 109 d after treatments, the number of new-grown leaves, SPAD-502, and Fv/Fm values of the green portion of the recently fully expanded leaf were recorded or measured as previously described. Five plants of each treatment were sampled, and the whole plant leaf area and dry weights of shoots and roots were determined as mentioned previously. The growing substrate and roots of each plant were divided into top, middle, and bottom zones, each ~3 to 4 cm thick. Discs were pulverized, and substrate samples from the zones were collected for 1 substrate:2 water (by volume) extracts, followed by EC measurement (Scoggins et al. 2002). Regression analyses were performed and presented

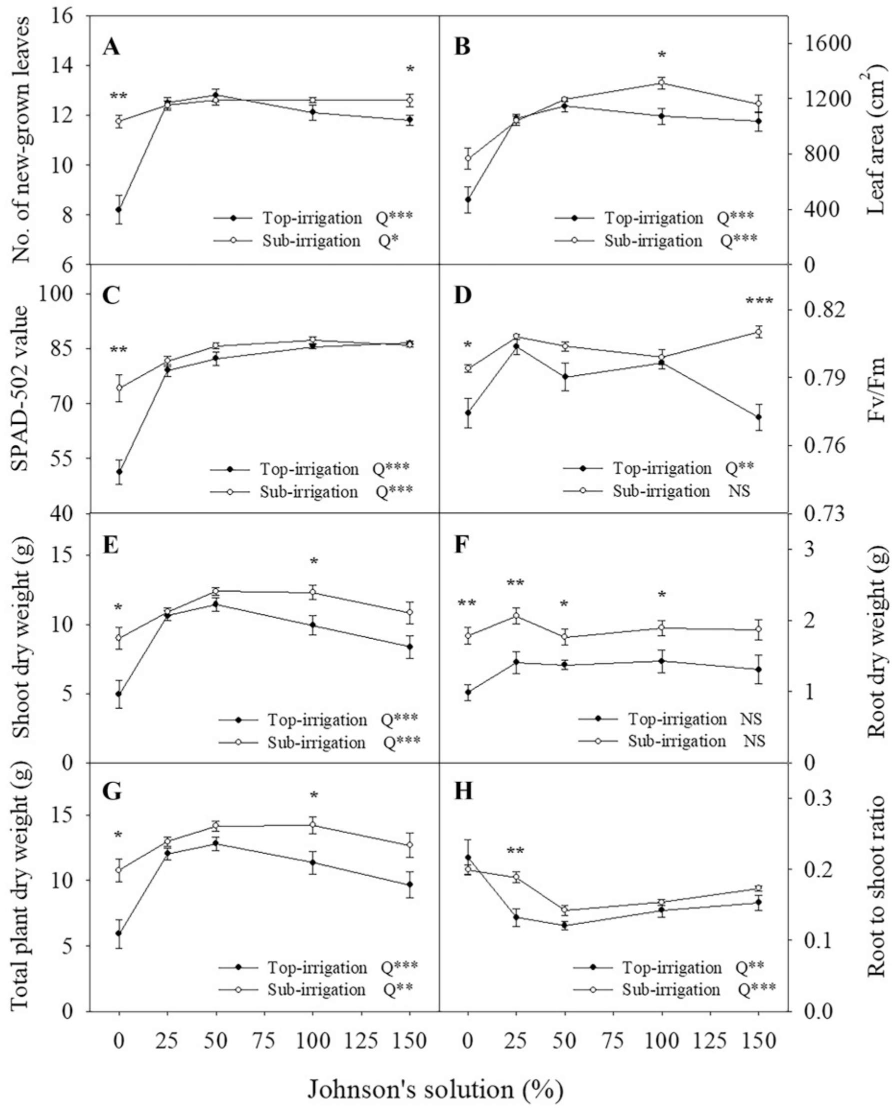

Fig. 6. Effects of nutrient solution concentration and irrigation method on number of new-grown leaves (**A**), leaf area (**B**), leaf SPAD-502 value (**C**), Fv/Fm (**D**), shoot dry weight (**E**), root dry weight (**F**), total plant dry weight (**G**), and root-to-shoot ratio (**H**) of *Alocasia* 'Bambino'. Bars represent standard error of the mean (n = 6). Mean separation within the same nutrient solution concentration by *t* test. NS, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively. Q = quadratic responses.

using SigmaPlot 10.0 (Systat Software Inc., Palo Alto, CA, USA). The treatment means of top- and sub-irrigation were separated by *t* test. Regression analysis was used to describe the relationships between nutrient solution concentration and EC of various substrate layers and between the whole substrate EC and total plant dry weight.

Results

VWC treatments. The VWC for the dry treatment throughout the experiment ranged from 18% to 25% (Fig. 1), with a mean of 20% (hereafter shown as 20% VWC). In the dry/wet cycle treatment, the VWC during dry and wet periods was 25% and 55%, respectively (shown as 25%/55% VWC, with a mean of 34% VWC). The VWC for the even moisture treatment ranged from 35% to 46%, with a mean of 40% (shown as 40% VWC). In the constant sub-irrigation treatment, the VWC remained ∼70% throughout the experiment (shown as 70% VWC).

Growth responses to VWC treatments. Plants subjected to the 20% VWC treatment exhibited the poorest growth performance (Fig. 2A), and the lowest number of new-grown leaves, leaf area, leaf SPAD-502 value, and shoot and root dry weights (Table 1). In comparison with plants with the 20% VWC treatment, the 25%/55% and 40% VWC treatments resulted in increased number of new-grown leaves, leaf area, and shoot dry weight (Fig. 2A and Table 1). Higher root-to-shoot ratio was recorded in the 25%/55% and 40% VWC treatment (Table 1), suggesting a relatively greater allocation of biomass to roots at moderate moisture levels. Plants exposed to the 70% VWC treatment exhibited the best plant performance (Fig. 2A) and showed enhanced development of primary and lateral roots (Fig. 2B), with the maximum new-grown leaves, leaf area, leaf SPAD-502 value, and plant dry weights (Table 1).

Fv/Fm and photosynthetic responses to VWC treatments. Leaf Fv/Fm value in plants with the 20% VWC treatment decreased to 0.71 at day 13 after treatment and exhibited significant fluctuations throughout the experiment (Fig. 3). In contrast, leaf Fv/Fm value in plants with the 70%, 40%, and 25%/55% VWC treatments remained stable, consistently ranging between 0.75 and 0.80.

The photosynthetic parameters aligned with plant appearance and overall growth performance. The Pn of the most recently fully expanded leaf was the highest with the 70% VWC treatment, followed by the 40%, 25%/55%, and/or 20% VWC treatments (Fig. 4A). Stomatal conductance and transpiration rate exhibited a similar trend, except that no significant difference was observed between the 25%/55% and 20% VWC treatments (Fig. 4B and 4C). The intercellular CO_2 concentration was significantly higher in the 20% VWC treatment than other VWC treatments (Fig. 4D).

Growth responses to nutrient solution concentration and irrigation method. Plants under top-irrigation without nutrient solution exhibited the poorest growth, showing the fewest new-grown leaves, as well as the lowest leaf area, SPAD-502 value, Fv/Fm, and total plant dry weight (Figs. 5A and 6A–6G). As the nutrient solution concentration increased up to 25% to 50% of Johnson's solution, the number of new-grown leaves, leaf area, SPAD-502 value, Fv/Fm, and both shoot and root dry weights increased. However, these parameters plateaued or gradually declined with higher concentrations (Figs. 6A–G). Regardless of nutrient solution concentration, sub-irrigation consistently resulted in more root growth and higher root dry weight compared with top-irrigation (Figs. 5B and 6F). The root-to-shoot ratio decreased as nutrient solution concentration increased up to 25% to 50% of Johnson's solution, after which the ratio remained relatively unchanged (Fig. 6H).

Growing substrate EC and growth. The EC in the growth substrate increased with increasing nutrient solution concentration (Fig. 7). Under sub-irrigation, the EC values of the upper substrate layer in the 100% to 150% Johnson's nutrient solution treatments were ∼2.2 times higher than that in the top-irrigation treatments. However, in the middle and lower substrate layers, EC values were higher under top-irrigation than sub-irrigation (Fig. 7). Regardless of irrigation method, total plant dry weight increased as the whole substrate EC increased up to 0.4 $dS \cdot m^{-1}$, above which the plant dry weight did not alter dramatically with sub-irrigation while dry weight decreased with top-irrigation (Fig. 8).

Discussion

Alocasia 'Bambino' subjected to the 20% VWC treatment exhibited the lowest leaf number, leaf area, and plant dry weights (Fig. 2A and Table 1). Drought stress reduces cellular turgor pressure, thereby inhibiting cell expansion and division, which leads to a reduction in

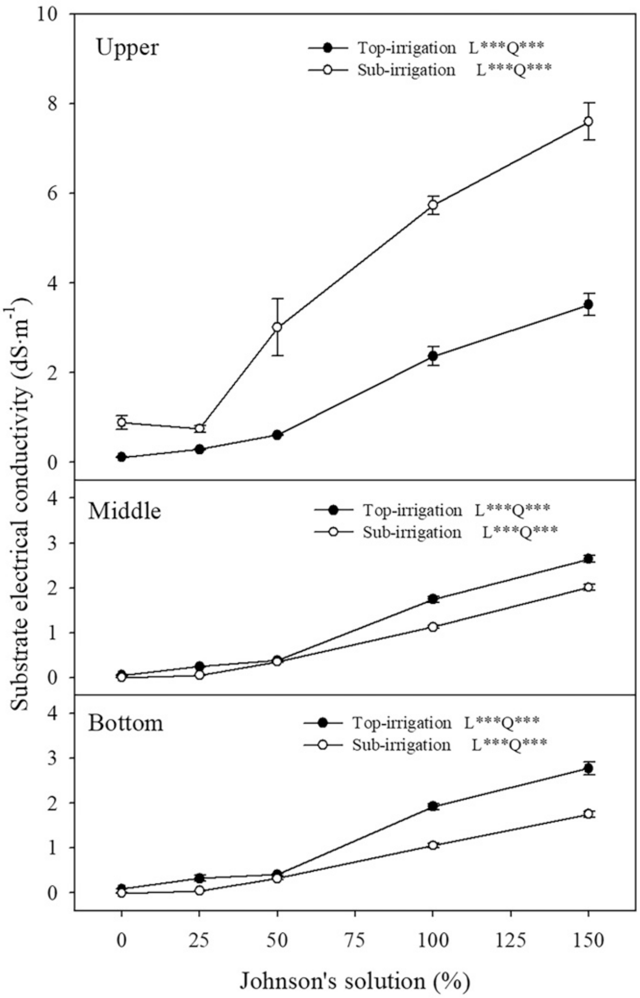

Fig. 7. Effect of nutrient solution concentration and irrigation method on electrical conductivity of extracts from the upper, middle, and bottom zones of the substrate. Bars represent standard error of the mean (n = 4). ***Significant at $P < 0.001$; linear = L, quadratic = Q.

leaf number, leaf area, and diminished photosynthetic capacities and assimilate production (Burnett and van Iersel 2008; Garland et al. 2012; Wang et al. 2024; Zhen and Burnett 2015; Zhen et al. 2014). The 20% VWC treatment also resulted in decreased leaf SPAD-502 value in *Alocasia* 'Bambino' (Table 1), suggesting the absence of a compensatory response often observed in other plants, where reduced leaf area under drought conditions corresponds with an increase in chlorophyll concentration per unit leaf area (Nezami et al. 2008; Wang et al. 2024). The lowest root-to-shoot ratio was recorded in plants under the 20% VWC treatment (Table 1). This contrasts with many other species, where drought stress increases the root-to-shoot ratio as plants allocate more carbohydrates to roots to maintain root surface area for improved water uptake (Sánchez-Blanco et al. 2009; Taiz and Zeiger 2010). These results indicate that *Alocasia* does not tolerate drought well, similar to other foliage plants such as *Aphelandra* (Henley and Poole 1981), *Nephrolepis* (McConnell 1990), and *Radermachera* (Wang et al. 2024).

Plants subjected to the 25%/55% VWC treatment exhibited increased leaf number, leaf area, and plant dry weights compared with the 20% VWC treatment (Fig. 2A and Table 1). The 40% VWC treatment promoted greater growth than the 25%/55% treatment (average of 34% VWC), suggesting that *Alocasia* 'Bambino' not only requires higher watering levels but also prefers consistently moist conditions over periodic watering. The maximum leaf number, leaf area, and plant dry weight were observed in plants under the 70% VWC treatment (Fig. 2A and Table 1). Plants subjected to the 70% VWC exhibited the highest root dry weight (Table 1) and showed enhanced development of primary and lateral roots (Fig. 2B); however, root distribution was restricted in the lower, water-saturated layers of the growth substrate (Fig. 2). This suggests a preference for moist conditions but an intolerance to prolonged flooding. This aligns with its natural habitat, where warm and moist environments support rapid growth (Burnett 1984; Reark 1953). A closely related genus, *Colocasia*, exhibited enhanced growth under moist or flooded conditions (Caesar 1980; Ikezawa et al. 2014).

Chlorophyll fluorescence is a key physiological indicator for evaluating plant responses to water stress, with Fv/Fm being the most representative parameter (Maxwell and Johnson 2000). The Fv/Fm values in the 70%, 40%, and 25%/55% VWC treatments ranged between 0.75 and 0.80 (Fig. 3), which is within the normal range (0.75–0.85) reported for healthy plants (Bolhar-Nordenkampf et al. 1989). In contrast, the Fv/Fm value in plants under the 20% VWC treatment declined to 0.71 and exhibited significant fluctuations throughout the experiment (Fig. 3), suggesting that *Alocasia* 'Bambino' experienced PSII damage under water deficit and exhibited slower recovery. A similar decline in Fv/Fm was reported for two *Radermachera* species under drought stress (Wang et al. 2024).

The response of net photosynthetic rate to VWC (Fig. 4) followed a pattern similar to that of overall plant growth (Table 1). Plants subjected to the 20% VWC treatment exhibited the lowest Pn, g_s, and E, indicating that the reduction in Pn was due to stomatal limitations. Under drought conditions, plants typically close their stomata to minimize water loss through transpiration, which also restricts CO_2 influx necessary for carboxylation, thereby reducing photosynthetic activity (Kramer and Boyer 1995; Zhen and Burnett 2015). However, the highest intercellular CO_2 concentration (*Ci*) was observed under the 20% VWC treatment (Fig. 4), indicating also the involvement of nonstomatal limitations. A similar reduction in Pn, attributed to both stomatal and nonstomatal limitations, was reported for *R. sinica* under drought stress (Wang et al. 2024).

Alocasia 'Bambino' grown without a nutrient solution exhibited greater growth under sub-irrigation than top-irrigation (Figs. 5A and 6), likely due to reduced nutrient leaching, increased water availability, and enhanced uptake of residual nutrients under sub-irrigation (Ferrarezi et al. 2015). Growth parameters measured under sub-irrigation were generally higher than those under top-irrigation (Fig. 6), particularly root dry weight, which was consistently greater with sub-irrigation regardless of nutrient solution concentration (Fig. 6F). This is consistent with *Alocasia*'s preference for moist conditions, as shown in Expt. 1 (Figs. 2–4). Growth plateaued in plants supplied with 25% to 50% Johnson's solution (EC of 0.58–1.10 $dS{\cdot}m^{-1}$) applied once per week (Figs. 5 and 6), supporting Burnett's (1984) observation that *Alocasia* is not a heavy feeder.

The EC values of the upper substrate layer in the 100% to 150% Johnson's nutrient solution treatments were significantly higher under sub-irrigation than under top-irrigation (Fig. 7), likely due to the absence of leaching and evaporation-driven salt accumulation (Argo and Biernbaum 1995). However, because the primary nutrient-absorbing roots of many ornamental crops are concentrated in the middle and lower layers, the elevated EC in the upper layer is unlikely to significantly affect plant growth (Kent and Reed 1996; Mak and Yeh 2001). Previous studies have reported higher EC values in the middle and lower layers under sub-irrigation compared with top-irrigation (Mak and Yeh 2001; Yeh et al. 2004). In contrast, this study showed that under the

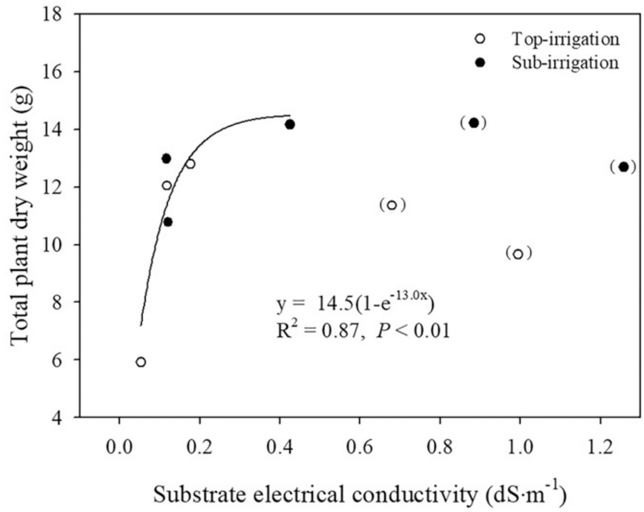

Fig. 8. The relationship between electrical conductivity of the whole substrate and total plant dry weight of *Alocasia* 'Bambino'. Points (open or close) in the parenthesis were omitted when fitting the regression.

100% and 150% Johnson's nutrient solution treatments, EC in the middle and lower substrate layers was higher in top-irrigation than in sub-irrigation treatments (Fig. 7), likely due to greater root biomass in sub-irrigated plants, which enhanced nutrient uptake and thereby reduced substrate EC.

Regression analysis revealed that total plant dry weight increased as the whole substrate EC rose to 0.4 $dS \cdot m^{-1}$ (Fig. 8), but declined at higher EC levels, particularly under top-irrigation. A substrate EC range of 0.25 to 0.75 $dS \cdot m^{-1}$ (based on a 1 water:2 substrate extraction) is considered suitable for salt-sensitive plants (Warncke and Krauskopf 1983). These results suggest that *Alocasia* is salt-sensitive.

In summary, *Alocasia* 'Bambino' exhibited the most pronounced growth responses under high moisture conditions (70% VWC), low nutrient levels (25% to 50% Johnson's solution), and sub-irrigation, particularly when exposed to elevated temperatures. Sub-irrigation consistently promoted enhanced plant growth, whereas top-irrigation resulted in poorer performance, particularly in nutrient-deficient or high nutrient environments. Total plant dry weight peaked at a whole substrate EC of 0.4 $dS \cdot m^{-1}$, suggesting that *Alocasia* is sensitive to salt and prefers moist, low-nutrient conditions.

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