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REGULAR ARTICLE

Comparing growth and physiological responses of *Globba schomburgkii* Hook. f. and *Globba marantina* L. under hydroponic and soil conditions

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ABSTRACT

Globba (*Zingiberaceae*) are attractive herbaceous plants widely used as ornamental plants. However, cultivation is limited because of low propagation rate and depends on the season only. This research aimed to compare growth and physiological responses of *Globba schomburgkii* Hook. f. and *Globba marantina* L. under both soil and hydroponic conditions. *In vitro* plantlets (8 cm in height) were transplanted to a hydroponic culture with the nutrient film technique (NFT). In soil culture, the plantlets were transplanted to small pots containing sand: burned rice husk: peat moss (1:1:1 by volume). Vegetative growth characteristics were measured at 15, 30, 45 and 60 days after transplanting (DAT), whereas reproductive growth and physiological characteristics were measured at 60 DAT. All there was 100% survival in both growth conditions. Plants of both species grown in hydroponic conditions had higher shoot length, leaf area and stem diameter, except number of shoots than when propagated in soil conditions. Moreover, both species grown in hydroponics had earlier inflorescences and more flowers, indicating that they can be flowering out of season. Additionally, in hydroponic conditions both species had significant higher stomatal conductivity, whereas there were no significant differences in photosynthetic rates, transpiration rates and leaf temperature when compared with soil conditions. Therefore, our study provides evidence that *G. schomburgkii* and *G. marantina* are capable of adapting to hydroponic conditions and that hydroponics may be a suitable method for propagating *Globba* and other ginger plant species into cut flower or potted plants all year round.

Keywords: Hydroponics, Nutrient film technique (NFT), Soilless culture, Stomatal conductivity, Zingiberaceae

INTRODUCTION

The genus *Globba* is a perennial herb and it's an ornamental of *Zingiberaceae* family in Thailand with high economic value due to demand for its attractive inflorescence. It is not traded widespread because the commercial varieties have little variation. The conventional propagation of the genus *Globba* uses underground rhizomes, fruits and bulbils (Pimmuen et al., 2014). In addition propagation of this genus seasonally depends.

Hydroponic systems have been suggested as an alternative method for cultivating plants. In recent years, hydroponic systems have became popular in agricultural activities. Hydroponic systems are soilless. The roots are immersed in water or a nutrient solution thus allowing simple control of the nutrient solution by adjusting the concentration of the hydroponic nutrient solution (Libia et al., 2012; Toshiki, 2012). Hydroponic devices have been developed for larger scale commercial use and have been successfully applied for both cut flowers and vegetables. Many crops have been successfully produced by this method including plants such as *Anthurium andreanum* (Dufour and Guérin, 2005), Alpine strawberry (*Fragaria vesca* L.) (Caruso et al., 2011), *Daucus carota* L. (Asaduzzaman et al., 2013), *Cucumis melo* L. cv. Panna (Asao et al., 2013) and Leafy lettuce (Selma et al., 2012). The high yield nutrient film technique (NFT) system can be used for cut flower production and for propagation of many plant species (Monnet et al., 2002; Nosir, 2011). In this system, the plant roots are constantly bathed in thin film solution separate that by thin plastic film which allows the plants to get sufficient oxygen and nutrients (Libia et al., 2012). There are many nutrient formulas of hydroponics and the pH of solution should range from 5.5 to 6.5 (Libia

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et al., 2012; Toshiki, 2012). In order to satisfy the increasing demand for plant material, hydroponic culture has potential to produce plant material year-round under controlled growth conditions. At present, there are few researches about hydroponics on plants of the family *Zingiberaceae*.

We were interested in investigating the growth of the plant in family *Zingiberaceae* using a hydroponic system to find the possibility of a new way to support and production the genus *Globba* species and other related plants to cut flowers economically in the near future. We hypothesized that both *G. schomburgkii* and *G. marantina* grow faster and would start early flowering in hydroponic culture than in soil culture. The main objective of this study was to compare the growth and physiological characters of two *Globba* species between soil and hydroponic conditions. So we compared growth parameters of the surviving plantlets, number of shoots, height of shoots, stem diameter, number of leaves, length of leaves and reproductive parameters, and physiological parameters of photosynthetic rate, transpiration rate, and stomatal conductivity between *G. schomburgkii* and *G. marantina* grown in a soil condition and in a hydroponic condition. We predict that hydroponic grown plants will have growth rate greater parameters.

MATERIALS AND METHODS

Plant materials and preparation

Two *Globba* species were used in the experiments including *G. schomburgkii* and *G. marantina* for multiple shoot proliferation. The microshoots of two *Globba* species were cultured for 60 days on Murashige and Skoog (MS) (Murashige and Skoog, 1962) medium supplemented with 3% (w/v) sucrose, 3 mg/L Benzyladenine (BA) and 0.7% (w/v) agar adjusting the pH to 5.7-5.8 (Pimmuen et al., 2014). Cultures were maintained at 25±2 °C, 16 h photoperiod at the tissue culture laboratory of the equipment building F2 at Suranaree University of Technology.

Acclimatization

After culturing for 2 months *in vitro* plantlets were then moved outside tissue culture room for a 3 weeks acclimatization period. The *in vitro* plantlets of about 8 cm with 3–4 leaves and which had both roots and shoots were thoroughly washed with tap water to remove residual agar from roots and then transplanted to a hydroponic system using the nutrient film technique (NFT) and to small pots containing sand: burned rice husk: peat moss (1:1:1 by volume). The plants were maintained under greenhouse conditions with the evaporative cooling system and closing of roof window of the experimental research at Suranaree University of Technology farm (SUT farm).

Nutrient solution

SUT nutrient solution (Damna et. al., 2017) was applied to the *G. schomburgkii* and *G. marantina* in hydroponic and soil conditions. The nutrient solution contains the following amounts of $Ca(NO_3)_2 4H_2O$ 2.2 kg/10 L, Fe-EDTA (12% Fe) 0.08 kg/10 L, KNO_3 1.18 kg/10 L, $MgSO_4$ 1.18 kg/10 L, KH_2PO_4 0.53 kg/10 L, Fe-EDDHA (6% Fe) 0.004 kg/10 L and Nicsprey 0.05 kg/10 L.

Hydroponic conditions

The plantlets were transplanted to the NFT hydroponic system (50×150×50 cm) during September –November 2016 and grown in small plastic cups (4×4.5 cm.) containing perlites for 60 days. All experiments had three replicates. Each plant was irrigated with SUT nutrient solution at electrical conductivity (EC) of nutrient solution between 1.6- 2.4 mS/cm and pH was maintained at 5.5-6.5. The EC and pH of the nutrient solution were checked daily with manual digital conductivity and pH meters. The plants were maintained under greenhouse conditions by closing the roof windows at the SUT farm.

Soil conditions

The *in vitro* plantlets were transplanted to small pots (14×12 cm) containing sand: burned rice husk: peat moss (1:1:1 by volume) and then covered with polythene wrap and watered on every alternate day to maintain humidity. All the experiments had three replicates and kept at greenhouse conditions with the closing of roof window at SUT farm. Each plant was irrigated with 200 ml of the same nutrients solution as used in hydroponics once daily in the morning. The transplantation dates for soil conditions were identical to the experimental dates for the hydroponic system.

Measurements

Growth parameters

Final measurements were collected on November 2016. The percentage of the surviving plantlets, number of shoots, shoot heights, stem diameter, number of leaves and length of leaves were recorded every 15 days after transplanting (DAT) until the completion of the study. In this study, the height of plants was measured from the base up to the shoot tip. The leaves at the first, second and third from the shoot tip were selected as a representative leaf length measurement because lower leaves often withered. Leaf length was measured along the axis of the midrib to the base and the width was measured at right-angles to left-angles of the axis, at the point of the greatest width of each leaf. The height, length and width were recorded in centimeter (cm). Reproductive growth parameters including the number of inflorescences, length of inflorescences and number of flowers were determined at 60 DAT. Inflorescence length was measured at the first inflorescence of the shoot tip and recorded in centimeter (cm).

Physiological parameters

Physiological parameters including photosynthetic rate, transpiration rate, and stomatal conductivity were measured with LCi-SD portable photosynthesis (ADC Bio Scientific Ltd., Country) at 60 DAT. Data collection occurred between 9 and 12 AM on windless and sunny days as described by Syros et al. (2004). To measure the photosynthetic rate, the second and third leaves (fully expanded and healthy) from five plants were selected through stratified standard sampling from both conditions. The first leaf was avoided because it was newly emergent and would not be representative of the plant.

Statistical analysis

This study used a completely randomized design (CRD) to research. The mean values were compared for each variable by applying generalized linear models, using number of days as an independent and number of shoots, the height of shoots, stem diameter, number of leaves, length of leaves, number of inflorescence, inflorescence length and number of flowers as response variables. We tested each variable for normality and homoscedasticity. All models were validated using standardized residuals. To test for physiological difference between plants grown in soil and hydroponic condition, we conducted T-tests. We determined if significant differences between soil and hydroponic conditions as well as the number of days existed with a two way ANOVA. We then performed a post-hoc Duncan's multiple range test (DMRT) to identify specific group differences. All tests were considered significant at P= 0.05 and analyses were done using the SPSS package version 16. We reported all descriptive statistics as means ± standard error.

RESULTS

Growth responses of G. schomburgkii and G. marantina

All plantlets survived until termination of the experiment. Results of all data are presented in Table 1. *G. schomburgkii* plants grown in both conditions had growth rate increases with increasing number of days. We detected significant differences between soil and hydroponic conditions as well as the number of days with ANOVA. For *G. schomburgkii* at 60 DAT, shoot length (20.42±0.27 cm, $P < 0.05$; Table 1), leaf area (5.91±0.10 cm^2, $P < 0.05$; Table 1) and stem diameter (0.46±0.00 cm, $P < 0.05$; Table 1) were significantly higher in hydroponic culture. However, number of shoots (16.00±0.31 cm, $P < 0.05$; Table 1) was significantly lower in hydroponic culture and number of leaves was not significantly different. In addition, it was also observed that plants grown in hydroponics had earlier inflorescent emergence than those grown in soil (32 DAT in comparison to 34 DAT). They had more inflorescences, longer inflorescences and more flowers than in soil conditions (Fig. 1A, C; Table 3). In hydroponics, *G. schomburgkii* bulbils had long white papaya seed-like appearance and new plantlets regenerated from bulbils (Fig. 1E).

Plantlets survived in both growth conditions with 100% survival rate. For *G. marantina* at 60 DAT, a number of shoots (7.63±0.43, $P < 0.05$; Table 1) was lower in hydroponics, However, shoot length (16.06±0.15 cm, $P < 0.05$; Table 1), leaf area (4.93±0.05 cm^2, $P < 0.05$; Table 1), stem diameter (0.46±0.01 cm, $P < 0.05$; Table 1) were significantly higher in hydroponics and a number of leaves (3.72±0.09, P □ 0.05; Table 1) was no significant difference. In addition, plants grown in hydroponics had earlier inflorescences than those grown in soil (34 DAT in comparison to 36 DAT). They had fewer inflorescences and shorter inflorescences than in soil conditions (Fig. 1B, D), however hydroponic plants had more flowers (Table 3). Similarly, bulbils of *G. marantina* regenerated into new plantlets (Fig. 1F).

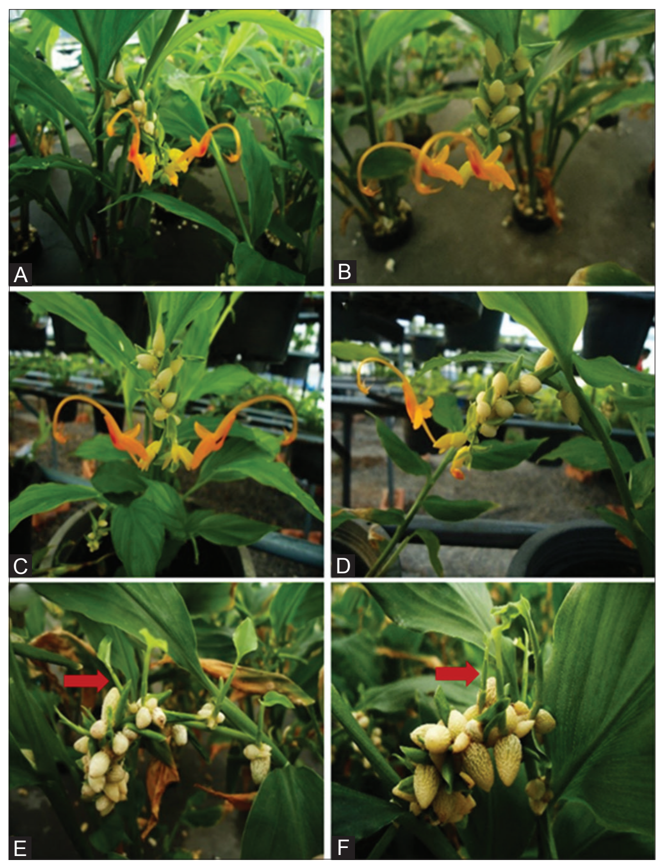

Fig 1. Growth characteristics; (A) The inflorescence of G. schomburgkii grown in hydroponic condition at 38 DAT, (B) The inflorescence of G. marantina grown in hydroponic condition at 41 DAT, (C) The inflorescence of G. schomburgkii grown in soil condition at 41 DAT, (D) The inflorescence of G. marantina grown in soil condition at 47 DAT, (E) New plantlets regenerated from bulbils of G. schomburgkii grown in hydroponic condition (red arrow) and (F) New plantlets regenerated from bulbils of G. marantina grown in hydroponic condition (red arrow).

We performed linear regression with days and condition as predictors for number of shoots, shoot length, number of leaves, leaf area and stem diameter. We found that days was a strongly significant predictor for all response variables except number of leaves in the hydroponic *G. schombergii* treatment (Fig. 2) and *G. marantina* (Fig. 3). In general, biweekly most growth measurements indicated a consistently higher growth pattern for hydroponics compared to soil conditions.

Furthermore, it was observed that the roots of plants grown in soil conditions were short and large, tuberous roots. While, the plant roots grown in hydroponics were longer and had more branched, fibrous roots, than those grown in soil conditions (Fig. 4).

Physiological responses of *G. schomburgkii* and *G. marantina*

In both species, there were no significant differences in the physiological responses except for stomatal conductivity between soil and hydroponic cultures (Table 2). Plants grown in the hydroponic conditions had higher stomatal conductivity, 0.22 μmol CO_2/mol$^-$ for *G. schomburgkii* and 0.11 μmol CO_2/mol$^-$ for *G. marantina* when compared with soil conditions.

DISCUSSIONS

Growth responses in hydroponic and soil conditions

This is the first report on the ornamental plants of ginger family plants grown in hydroponic conditions. Two months

Table 1: Growth indices of *G. schomburgkii* and *G. marantina*.

Parameters	Treatments	DAT			
		15	30	45	60
No. of shoots±SE	T1	4.60±0.20^a	6.93±0.32^b	12.77±0.42^a	16.00±0.31^a
	T2	4.80±0.15^a	8.03±0.44^a	13.83±0.69^a	14.33±0.73^a
	T3	1.43±0.15^c	3.97±0.18^c	8.77±0.34^b	11.07±0.82^b
	T4	1.93±0.09^b	3.87±0.15^c	6.20±0.23^c	7.63±0.43^c
F-test		**	**	**	**
Shoot length±SE	T1	6.77±0.29^d	8.88±0.20^c	11.10±0.35^c	11.17±0.50^c
	T2	8.48±0.49^c	8.62±0.15^c	8.98±0.25^d	9.22±0.08^d
	T3	11.89±0.16^a	14.04±0.56^a	17.93±0.68^a	20.42±0.27^a
	T4	10.35±0.34^b	12.41±0.20^b	15.68±0.30^b	16.06±0.15^b
F- test		**	**	**	**
No. of leaves±SE	T1	3.66±0.13	3.86±0.08	3.89±0.08	4.01±0.03
	T2	3.78±0.09	3.78±0.14	3.78±0.08	3.84±0.08
	T3	3.40±0.09	3.52±0.04	3.68±0.12	3.80±0.04
	T4	3.68±0.13	3.68±0.06	3.69±0.09	3.72±0.09
F- test		ns	ns	ns	ns
Leaf area±SE	T1	2.48±0.23b	3.54±0.12	4.57±0.13bc	4.83±0.08b
	T2	3.24±0.13a	4.05±0.10	4.12±0.18c	4.27±0.14c
	T3	2.40±0.05b	4.16±0.33	5.45±0.06a	5.91±0.10a
	T4	2.70±0.05b	3.77±0.12	4.92±0.21b	4.93±0.05b
F- test		**	ns	**	**
Stem diameter±SE	T1	0.26±0.01	0.38±0.01b	0.38±0.01c	0.39±0.00b
	T2	0.25±0.02	0.26±0.01c	0.33±0.00d	0.39±0.01b
	T3	0.30±0.00	0.45±0.02a	0.45±0.00a	0.46±0.00a
	T4	0.25±0.02	0.34±0.01b	0.43±0.01b	0.46±0.01a
F- test		ns	**	**	**

Means in the same column followed by different letters a-d are significantly different according to the Duncan's multiple range test (DMRT) at P ≤ 0.05. a, b, c, and d denotes difference between groups soil and hydroponic. T1: *G. schomburgkii* grown in soil condition, T2: *G. marantina* grown in soil condition, T3: *G. schomburgkii* grown in hydroponic condition, T4: *G. marantina* grown in hydroponic condition. (** indicates significant P-value at 0.01 level; ns =not significant)

Table 2: Physiological indices of *G. schomburgkii* and *G. marantina* grown in soil and hydroponic conditions at 60 DAT

Species	Conditions	Photosynthetic rate (A) μmol/(m^2.s)	Transpiration rate (E) mmol H_2O/(m^2.s)	Stomatal conductivity (Gs) μmol CO_2/mol-	Leaf temperature (Tci) (°C)
G. schomburgkii	Soil	7.84±0.66	2.96±0.27	0.13±0.01	36.71±1.23
	Hydroponic	8.38±1.20	3.08±0.37	0.22±0.0**	33.70±1.47
G. marantina	Soil	5.57±0.74	1.96±0.26	0.09±0.01	34.24±1.08
	Hydroponic	6.12±0.04	2.11±0.10	0.11±0.01**	33.87±1.58

**p<0.01 statistically significant difference from soil condition

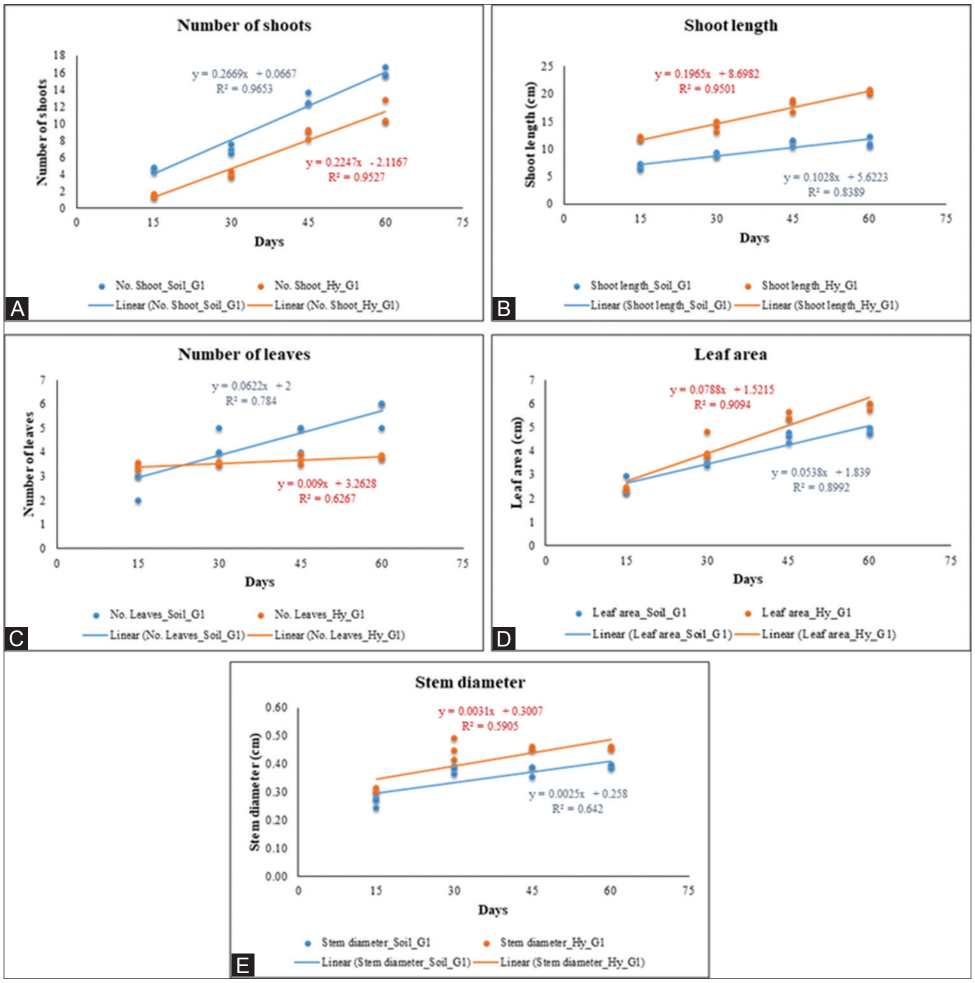

Fig 2. The relationship between *G. schomburgkii* grown in soil and hydroponic conditions; (A) days and number of shoots, (B) days and shoot length, (C) days and number of leaves, (D) days and leaf area and (E) days and stem diameter. Linear regression fits and associated R^2 values are displayed in each figure.

Table 3: Reproductive growth indices of *G. schomburgkii* and *G. marantina* at 60 DAT.

Treatments	Parameters		
	No. of inflorescence±SE	Inflorescence length±SE	No. of flowers±SE
T1	4.633±0.07^{b}	4.89±0.05^{b}	4.05±0.11^{bc}
T2	3.43±0.05^{c}	4.47±0.13^{b}	3.79±0.14^{c}
T3	5.90±0.17^{a}	5.41±0.27^{a}	4.74±0.13^{a}
T4	3.00±0.20^{c}	3.90±0.02^{c}	4.22±0.06^{b}
F-test	**	**	**

Means in the same column followed by different letters a-d are significantly different according to the Duncan's multiple range test (DMRT) at P ≤ 0.05. a, b, c, and d denote difference between groups soil and hydroponic. T1: *G. schomburgkii* grown in soil conditions, T2: *G. marantina* grown in soil condition, T3: *G. schomburgkii* grown in hydroponic condition, T4: *G. marantina* grown in hydroponic condition. (** indicates significant P-values at 0.01 level)

after transplanting from *in vitro* culture into hydroponic conditions, plantlets of *G. schomburgkii* and *G. marantina* can adapt to the *ex vitro* conditions and root structure supported the hypothesis that both species can be successfully reared in hydroponic culture. These results were similar to other authors who successfully produced several ornamental plants to increase productivity by this method such as: *Anthurium andreanum* (Dufour and Guérin, 2005), *Althaea rosea*, *Calendula officinalis* and *Impatiens balsamina* (Liu et al., 2008), Gerbera (Khalaj et al., 2011; Karras et al., 2007), *Gladiolus* (Milandri et al., 2008; Nosir, 2011) and *Iris* (Chang et al., 2010).

Two weeks after transplanting into soil, plantlets of *G. schomburgkii* and *G. marantina* well adapted to the condition with new leaves and after two months, all plantlets survived. Modern growing media provide aeration and water absorption, oxygen and other nutrients that affect growth and development (Verdonck et al., 1982; El-Sayed et al., 2015). Different materials may impact the plants

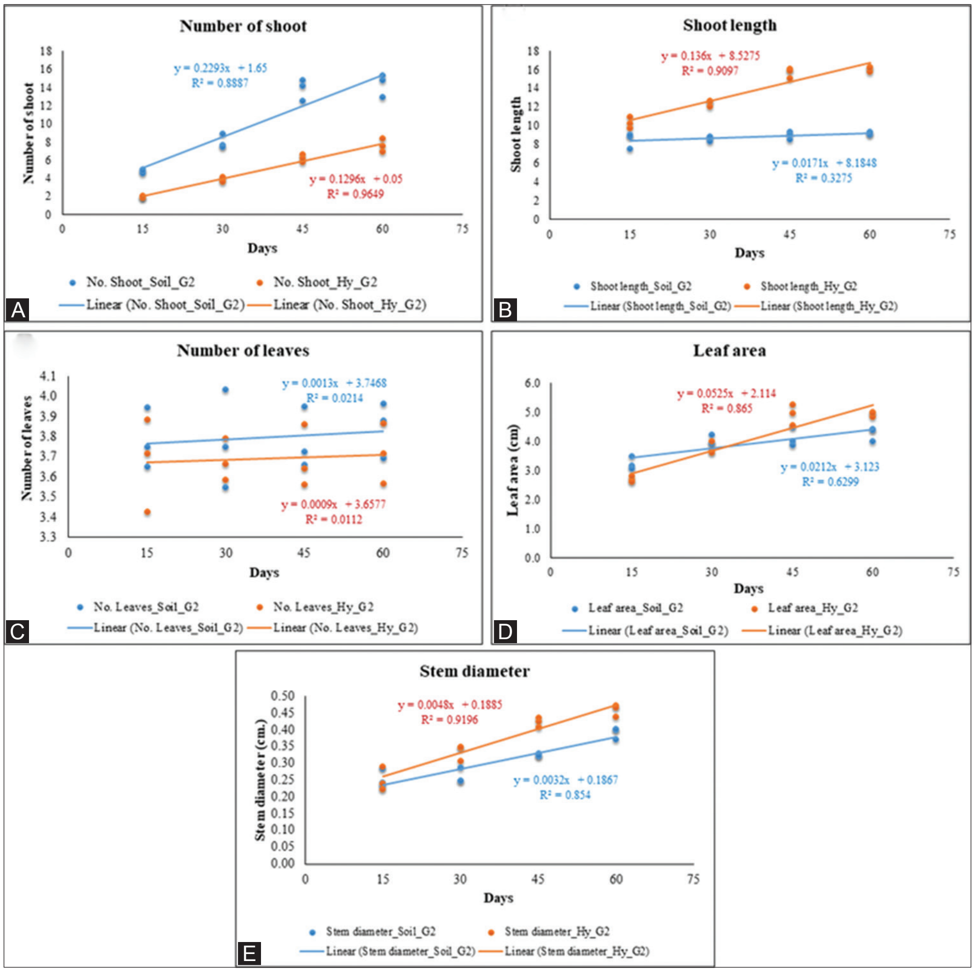

Fig 3. The relationship between *G. marantina* grown in soil and hydroponic conditions; (A.) days and number of shoots, (B.) days and shoot length, (C.) days and number of leaves, (D.) days and leaf area and (E.) days and stem diameter. Linear regression fits and associated R^2 values are displayed in each figure.

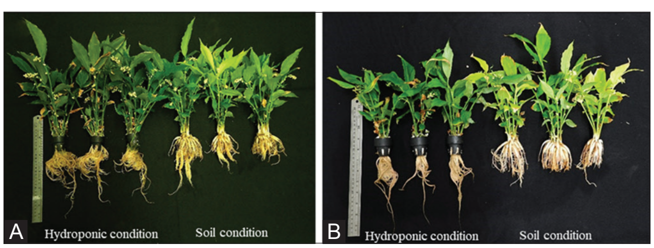

Fig 4. Characteristics of roots; (A) Roots of G. schomburgkii grown in hydroponic and soil conditions after 60 DAT and (B) Roots of G. marantina grown in hydroponic and soil conditions after 60 DAT.

directly. Therefore, suitable material selection is vital in determining productivity increments (Olympious, 1992). After transplantation, plantlets of *G. schomburgkii* and *G. marantina* can adapt to the *ex vitro* conditions as well as adapting to soil conditions. These results were similar to observations from other authors. For example, Chanchula (2012) studied another species of genus *Globba* (*Globba williamsiana*) and found that the highest 94.44% survival rate was in sand: burned rice husk: peat moss (1:1:1 by volume), while in this study both species had 100% survival rate.

Both *G. schomburgkii* and *G. marantina* were reported to have annual inflorescences between June and September (Saensouk et al., 2017). However, this study showed inflorescences of both species from October to November, indicating that they can bloom out of season. Therefore, extending the inflorescence period from nature may have been induced with the hydroponics or continuous watering. Thus hydroponic technique has an advantage to increase flower production as reported in Asiatic hybrid lily cv. "Blackout" (Asker, 2015), gladiolus (Norsir, 2011) and *Anthurium andreanum* (Dufour et al., 2005).

Physiological responses in hydroponic and soil conditions

There were no significant differences in the photosynthetic rate, the transpiration rate and leaf temperature, however stomatal conductance significantly differed between the soil and hydroponic cultures. These results were similar to Zhang et al. (2013) who reported that the net photosynthetic rate, the transpiration rate of lotus were not significantly different between hydroponic and soil culture. From this result, hydroponic plants accumulate CO_2 with higher stomatal conductance and are well adapted to increase photosynthetic rate leading to higher growth. Hydroponic culturing increases leaf area index so as to improve the photosynthetic rate (Qiuying et al., 2005; Gajewska et al., 2006; He and Tan, 2011), which was consistent with that of stomatal conductivity and these results indicate that there was a difference between the two conditions in term of leaf physiological index. Hence, the result showed that *G. schomburgkii* and *G. marantina* are capable of adapting to a water-culture environment.

CONCLUSION

The two *Globba* species can adapt well to the conditions under greenhouse and plantlets showed 100% survival rate after transplanting. *Globba* plants grown in hydroponic system had more leaf area, greater shoot lengths and stem diameter in addition to earlier inflorescences and more flowers than those of soil conditions. Soil conditions provided the most shoots and displayed tuberous roots in response to low water level in soil compared with hydroponics where plant roots were in constant contact with the water. Thus, *Globba* production in hydroponic system can be an alternative way for production of *Globba* into cut flower or pot plants in the future. Moreover, at present these system successful commercial and it's can also control several factors such as mineral nutrient composition, pH and EC of nutrient solution, etc. However, hydroponics would be more fruitful for ginger family plants providing realistic growth conditions, due to the long root systems. In conclusion, the results from this study will provide a useful information for gardener to develop a sustained method for cultivation of agricultural crops and this can solve the problem of an unsuitable planting area.

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Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

P.P. performed the experiments, analyzed the results and prepared the manuscript. T.M. designed the research. P.S. revised the manuscript. N.M. designed the research, analyzed the results and revised the manuscript.

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