Research article

Response of *Cryptocoryne zaidiana* Ipor & Tawan (Araceae) to shading and water depth

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ABSTRACT. Study on the responses of *Cryptocoryne zaidiana* Ipor & Tawan (Araceae) to shading and water depth was conducted. Vegetative characteristics and biomass partitioning (plant height, total leaf number and total dry weight), leaf weight ratio (LWR), petiole weight ratio (PWR), root weight ratio (RWR), rhizome weight ratio (RhWR), leaf area ratio (LAR) and specific leaf area (SLA)) of *C. zaidiana* grown in natural habitat at Sg. Mering varied between quadrates. Plants under 50% shading produced significantly more leaves, RWR and RhWR than those at 75% shading and under tree canopy. Plants under 75% shading produce the least number leaves. Plants placed at 10 cm water depth showed significantly higher values of LWR, PWR, RWR, LAR and SLA as compared to plants at 0 cm water depth. However, at 30 cm water depth, plants significantly increased their height as compared to the other two water depth regimes. Plants being placed under 75% shading and 10 cm water depth had the highest dry matter production (DMP) while highest NAR was recorded by plants cultivated under 50% shading and 0 cm water depth. Satisfactory sprouting of rhizome-cutting was recorded by 5-node cuttings viz. 38 plants out of 50 rhizomes. The lowest maximal quantum yield was recorded at 50% shading and it was significantly different between both tree canopy shading and 75% shading. Plants grown under 50% shading regime and 0 cm water depth resulted in higher electron transport rate (ETR) value at 640 µmol quanta $m\text{-}^{2}s_{-1}$.

Keywords: *Cryptocoryne*, biomass allocation, light intensity, water depth, photosynthesis

INTRODUCTION

Cryptocoryne (Araceae) is a popular aquarium plant which gained much attention from the aquarium industry worldwide (Rataj & Horeman, 1977). They are heavily exploited for aquarium plants and apparently fetch high prices in the international aquarium market (Mansor, 1991). Ipor *et al*. (2007a & b) and Ipor *et al*. (2008a & b) reported that there were 14 species of *Cryptocoryne* found in Sarawak. The species were *C. auriculata* Engler, *C. bullosa* Engler, *C. ciliata* (Roxburgh) Schott, *C. ferruginea* Engler, *C. grabowskii* Engler, *C. keei* Jacobsen, *C. lingua* Engler, *C. longicauda* Engler, *C. pallidinervia* Engler, *C. striolata* Engler and *C. zonata* De Wit. Another three new species of *Cryptocoryne* found in Sarawak were *C. uenoi* Y. Sasaki (Sasaki, 2002), *C. yujii* Bastmeijer (Bastmeijer & Bogner, 2002) and *C. zaidiana* Ipor & Tawan (Ipor *et al*., 2005). *Cryptocoryne zaidiana* was recently discovered from Long Tran, Tinjar, Miri Division, Sarawak. *Cryptocoryne fusca* Engler was a new record that was found at Lubok Antu (Ipor *et al*., 2006a). The suspected hybrid of *C. purpurea* that is endemic to Tasek Bera was also spotted and presently under intensive study for taxonomic clarification.

Jacobsen (1985) reported most *Cryptocoryne* species found in Borneo could possibly face the danger of local extinction due to the rapid exploitation and demolishment of the forest. These destructive activities might cause fragmentation to their habitats, uncontrolled sedimentation in the river system and poor water quality. So far, *C. zaidiana* was only spotted at Sg. Mering, Tinjar, Miri Division in Sarawak. This species may face permanent disappearance as its only existing locality is part of the proposed oil palm plantation. The present study encompassed the effect of different light intensity, water depth, rhizome cuttings, biomass allocation, and photosynthesis to gather more information and understand *ex-situ* conservation of the species.

MATERIALS AND METHODS

Sampling of *C. zaidiana* was carried out at Sg. Mering, Tinjar, Miri Division, Sarawak and cultivated at the greenhouse at Universiti Malaysia Sarawak (UNIMAS) to obtain sufficient number of lateral shoots for transplanting. The desirable stage of lateral shoots were transplanted in plastic pots (15 cm x 15 cm) containing a mixture of clay and peat soil (1:1).

Biomass allocation (quadrates)

Quadrate of 1.0 m x 1.0 m was used for sampling of the natural population of *C. zaidiana*. All plants in the quadrates were counted. Total leaves and leaf area of each quadrate were also determined. The leaves, roots and petioles were dried at 60°C for seven days to determine the total dry weight, leaf weight ratio (LWR), root weight ratio (RWR), petiole weight ratio (PWR), specific leaf area (SLA), leaf area ratio (LAR) of the individual plant, according to the method described by Patterson & Flint (1983).

Light intensity

The plants were exposed to three different light regimes viz. under tree canopy shading condition, 50% shading condition and 75% shading condition at 0 cm water depth (water level from the soil surface). Each light regime comprised of 20 plants. All plants were labeled before commencing the growth measurement for every two weeks. The measurement included plant height and number of leaf. Ten plants (each harvest comprised of five plants) were selected randomly from each light regimes and harvested after 50 and 80 days of transplanting. Leaf area measurement of individual plant were done before the leaves, roots, petioles and rhizomes were dried in the oven at 60°C for seven days.

Water depth

Three different water levels, 0 cm, 10 cm and 30 cm were used in this project. The depth of the water level was measured from media surface to the water surface. Twenty plants were required for each water depth regime. All treatments were placed under tree canopy shading condition. Growth measurement and biomass allocation were conducted similar to those carried out after light response study.

Photosynthesis

Photosynthesis measurement was done on both light intensity and water depth study. “WALZ Diving - PAM Flourometer” equipment was used to measure the photosynthetic rate of the plants.

Rhizome cuttings

Three types of rhizome cuttings were prepared based on total number of nodes in each cutting. The cuttings were transplanted in medium consisted of sand. Each rhizome cutting type length comprised of 50 rhizome cuttings. Successful sprouting or emerging of shoots was recorded weekly.

RESULTS

Biomass allocation (Quadrate)

The highest total leaf (TL) was in quadrate 1 followed by quadrate 3 and 2, respectively (Figure 1). The highest total plant dry weight (TPDW) was also recorded in quadrate 3, while the lowest value was recorded in quadrate 2. Plants in quadrate 3 showed the highest value for leaf dry weight (LDW), while the lowest value was recorded in quadrate 2. The highest value of petiole dry weight (PDW) was from the quadrate 3. Plants in quadrate 2 gave the lowest value of PDW. Plants in quadrate 3 showed the highest rhizome dry weight (RhDW) followed

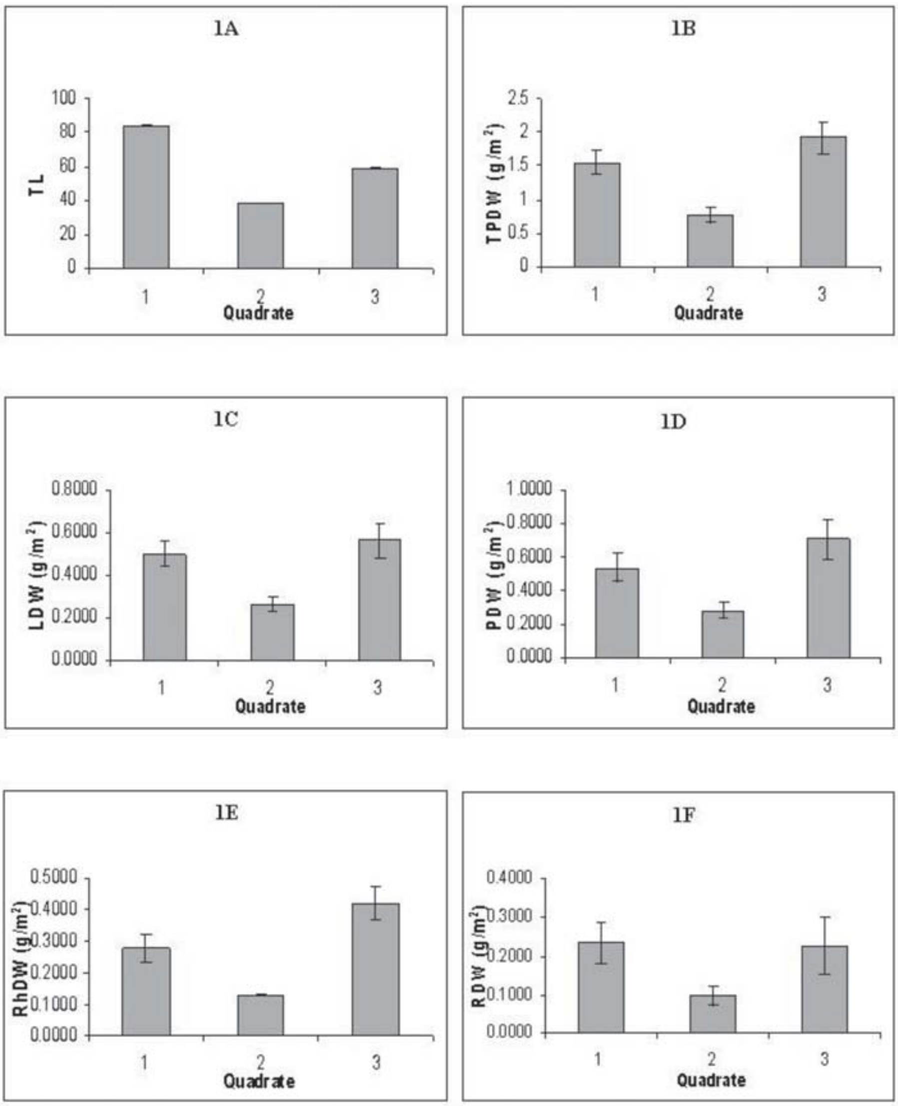

Figure 1. The vegetative characteristics of *Cryptocoryne zaidiana* sampled in 1m x 1m quadrate at Sg. Mering, Tinjar, Miri. [1A = Total leaves (TL), 1B= Total plant dry weight/m^2 (TPDW) (g/m^2), 1C = Leaf dry weight (LDW) (g/m^2), 1D = Petiole dry weight (PDW) (g/m^2), 1E = Rhizome dry weight (RhDW) (g/m^2), 1F = Root dry weight (RDW) (g/m^2)]. Vertical bars are values of standard error.

by plants in quadrate 1 and 2. All values were significantly different. Plants in quadrate 1 showed the highest value of root dry weight (RDW), however, it was not significant compared to plants in quadrate 3. The lowest value of RDW was recorded in quadrate 2 and it was significantly different in both quadrate 1 and 3.

The highest leaf weight ratio (LWR) was obtained by plants in quadrate 2 (Figure 2). However, the value was not significantly different from plants in quadrates 1 and 3. Plants in quadrate 3 showed the highest value of biomass partitioning to petiole (PWR). However, the value was not significant from plants in quadrates 1 and 2. The highest value of root weight ratio (RWR) was shown by plants in quadrate 1 and the lowest was shown by plants in quadrate 3. However, the value was not significant from each other. The highest value of rhizome weight ratio (RhWR) was obtained from plants in quadrate 3. This value was not significantly different from plants in quadrates

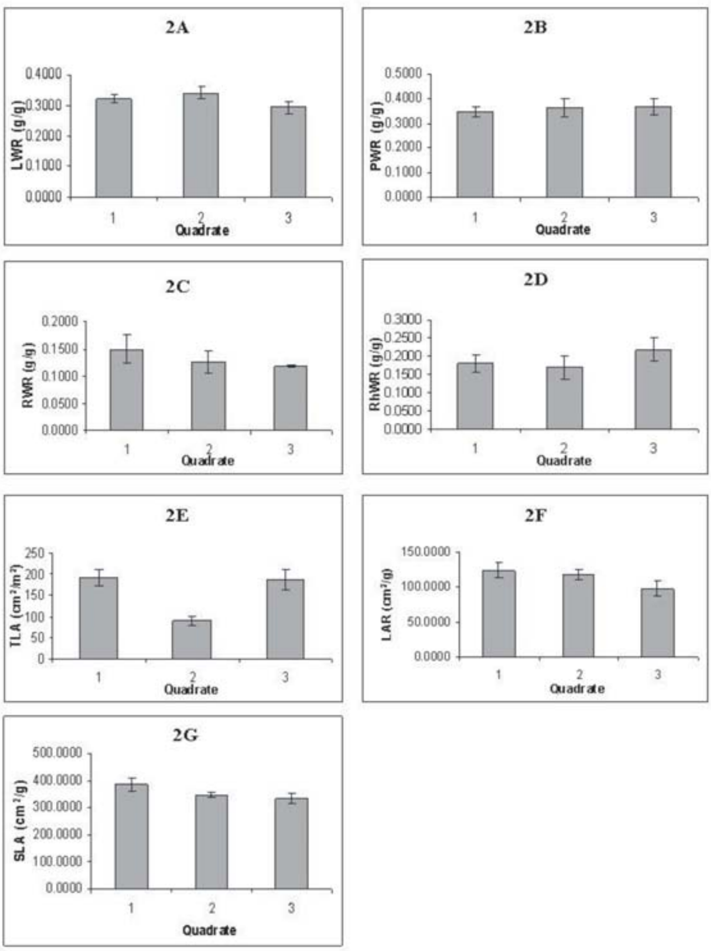

Figure 2. The vegetative characteristics of *Cryptocroyne zaidiana* sampled in 1m x 1m quadrate at Sg. Mering, Tinjar, Miri. [2A = Leaf weight ratio (LWR) (g/g), 2B = Petiole weight ratio (PWR) (g/g), 2C = Root weight ratio (RWR) (g/g), 2D = Rhizome weight ratio (RhWR) (g/g), 2E = Total leaf area (TLA) (cm^2/m^2), 2F = Leaf area ratio (LAR) (cm^2/g), 2G = Specific leaf area (SLA)(cm^2/g)]. Vertical bars are values of standard error.

1 and 2. Plants in quadrate 1 showed the highest value of total leaf area (TLA) and the lowest value was shown by plants in quadrate 2. The value was significantly different from each other. The highest leaf area ratio (LAR) was shown by plants in quadrate 1 and the lowest was shown by plants in quadrate 3. However, there were no significant difference in those three quadrates. Plants in quadrate 1 also showed the highest value of specific leaf area (SLA) and there were no significant difference between those three quadrates.

Light intensity response

Exposing of plants to different shade conditions such as under 50% shading, 75% shading and tree canopy had no significant effect on plant height (Figure 3). Plants under 75% shading were higher than those under the 50% shading and vice versa for tree canopy shading at 10th week after transplanting. However, increment of plant height was significantly influenced by duration after transplanting.

Plants under 50% shading produced significantly more leaves than those from 75% shading and under tree canopy (Figure 4). Plants at 75% shading produced the least number of leaf. However, there was no significant difference on number of leaves produced by plants between 75% shading and tree canopy shading from 2nd week to 6th week. At week 4, 8 and 10, plants under 50% shading had significantly more leaves as compared to those under 75% shading and tree canopy shading. At 4th and 8th week, plants under 75% shading and tree canopy had the same number of leaves.

Biomass allocation

The patterns of biomass allocation of *C. zaidiana* grown under tree canopy shading, 50% and 75% shading is shown in Figure 5. The highest number of leaves was produced by plants under 75% shading and 50% shading.

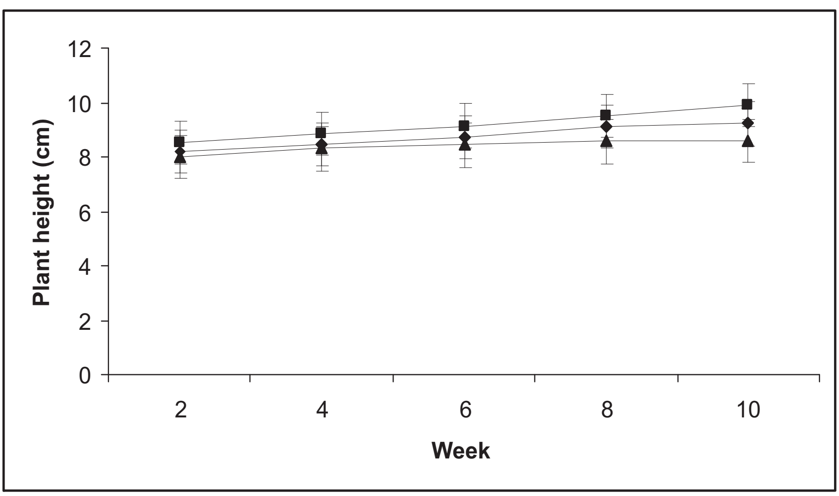

Figure 3. Effect of shading on height of *Cryptocoryne zaidiana*. Tree canopy shading (--♦--), 50% shading (--Δ--) and 75% shading (--€--). Vertical bars are values of LSD= 0.05.

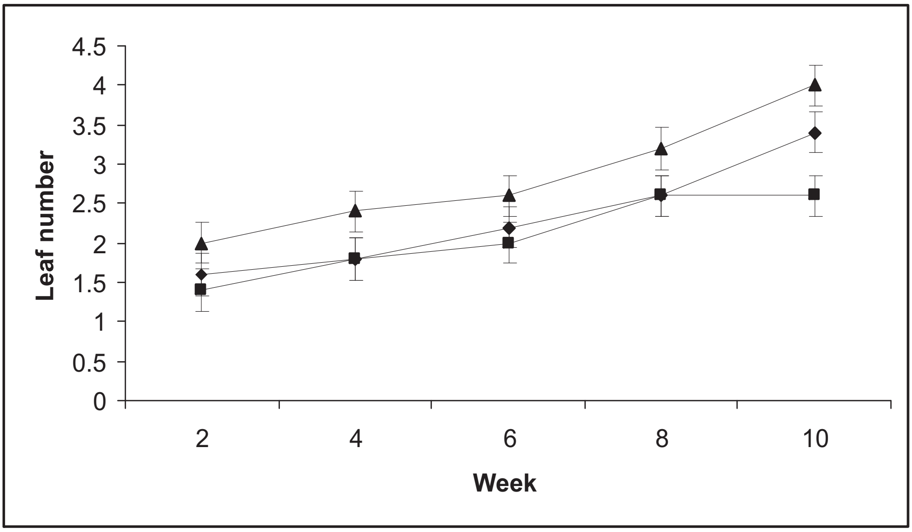

Figure 4. Effect of shading on leaf number of *Cryptocoryne zaidiana*. Tree canopy shading (--♦--), 50% shading (--Δ--) and 75% shading (--€--). Vertical bars are values of LSD= 0.05.

Plants under 75% shading also produced the highest total plant dry weight. Leaf weight ratio (LWR) of plants under 50% shading was significantly lower than those under both tree canopy and 75% shading. Petiole weight ratio (PWR) of plants under all light regimes had no significant difference. However, plants under 75% shading showed highest value of PWR. Root weight ratio (RWR) of plant under tree canopy shading showed the lowest value of RWR than that under the other light regimes. Plants under 75% shading recorded significantly lower value of rhizome weight ratio (RhWR) than those under tree canopy shading and 50% shading. Plants under 50% shading recorded highest value of RhWR but it has no significant difference when compared as compare to those under tree canopy. Leaf area ratio (LAR) of plants under 50% shading recorded significantly higher than that under the other light regimes, but there were no significant difference between plant under tree canopy and 75% shading on leaf area ratio (LAR). Specific leaf area (SLA) of plants under 50% shading was significantly higher than those under tree canopy and 75% shading. However, there was no significant difference between tree canopy and 75% shading for specific leaf area (SLA).

There was a significant difference on dry matter production (DMP) of plants under 50% shading as compare to those under tree canopy and 75% shading (Table 1). However, DMP was not significantly different between those under tree canopy and 75% shading. Net assimilation rate (NAR) was significantly different among the three different light regimes. Plants under 50% shading recorded the highest value of NAR whilst lower value of NAR under tree canopy shading. Plants under 75% shading regime showed significantly higher value of leaf area duration (LAD) than that under the other two light regimes.

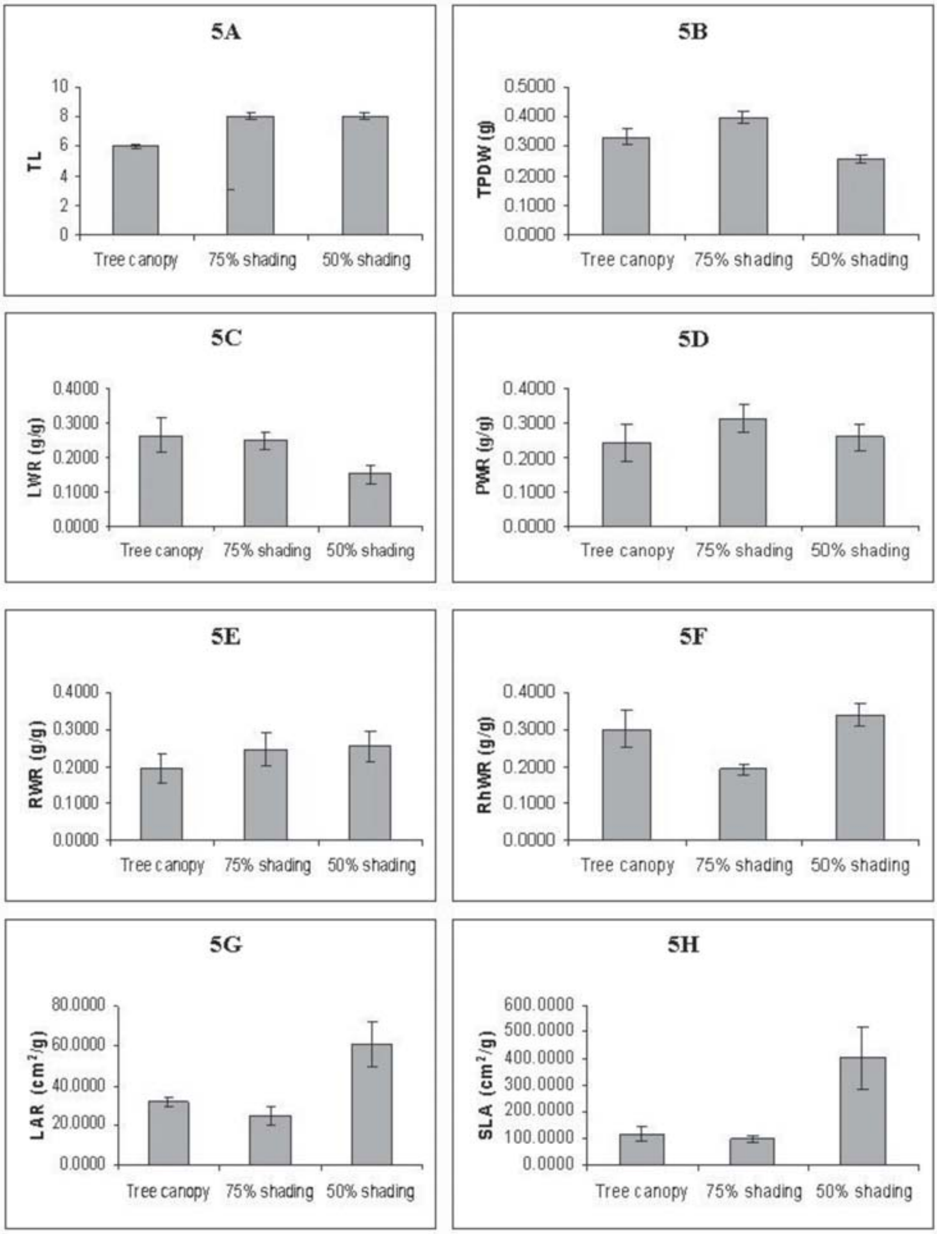

Figure 5. The vegetative characteristics of *Cryptocoryne zaidiana* under different shade conditions. [5A = Total leaves (TL) 5B = Total plant dry weight (TPDW) (g) 5C = Leaf weight ratio (LWR) (g/g), 5D = Petiole weight ratio (PWR) (g/g), 5E = Root weight ratio (RWR) (g/g), 5F = Rhizome weight ratio (RhWR) (g/g), 5G = Leaf area ratio (LAR) (cm2/g), 5H = Specific leaf area (SLA)(cm2/g)]. Vertical bars are values of standard error.

Table 1. Effect of shading on dry matter production (DMP), net assimilation rate (NAR) and leaf area duration (LAD) of *C. zaidiana* during the 50th to 80th day after transplanting. Within each column, values sharing the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Shading	DMP (g)	NAR (cm2/g)	LAD (cm2/g)
Tree canopy	0.0493b	0.00012c	413.1b
50%	0.4578a	0.00081a	558.46b
75%	0.0567b	0.00031b	1982.77a

Water depth response

Plants in the water depth of 30 cm were significantly higher than those from other water depths at the 8th and 10th week after transplanting (Figure 6). Plants at 0 cm and 10 cm water depth were not significantly different in the plant height from 2nd week until the 10th week after transplanting. Plants from 0 cm and 10 cm water depth were also not significantly different with those from 30 cm water depth particularly from 2nd to 6th week after transplanting.

Plants in the water depth of 30 cm had the least leaves compared to plants under 0 cm and 10 cm water depth regimes (Figure 7). Plants in the water depth of 0 cm and 10 cm shared the same number of leaves since the 2nd week after transplanting until the 4th week. However, plants in the water depth regimes of 10 cm produced more leaves than those plants at 30 cm after the 6th week till the 8th week. Plants at water depth of 30 cm had the least leaf number compared to those from 10 cm water depth from the 8th to 10th week after transplanting. On the

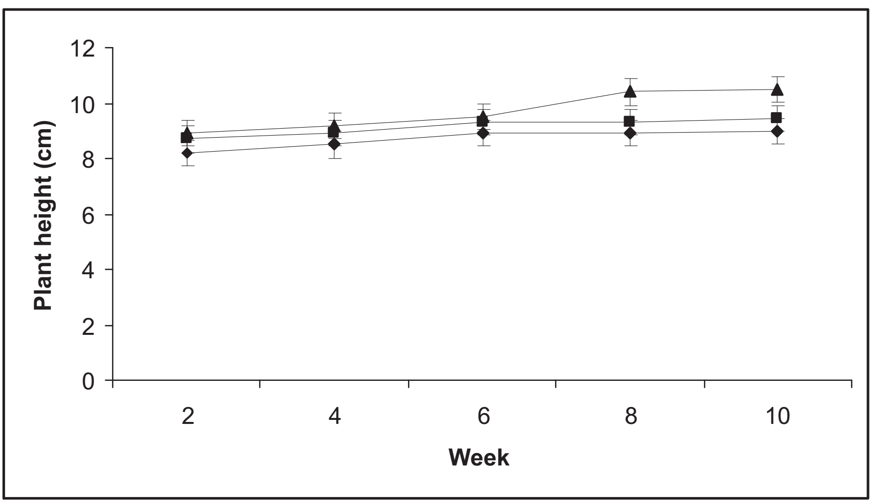

Figure 6. Effect of water depths on plant height of *Cryptocoryne zaidiana*. 0 cm depth (--♦--), 10 cm water depth (--Δ--) and 30 cm water depth (--€--). Vertical bars are values of LSD= 0.05.

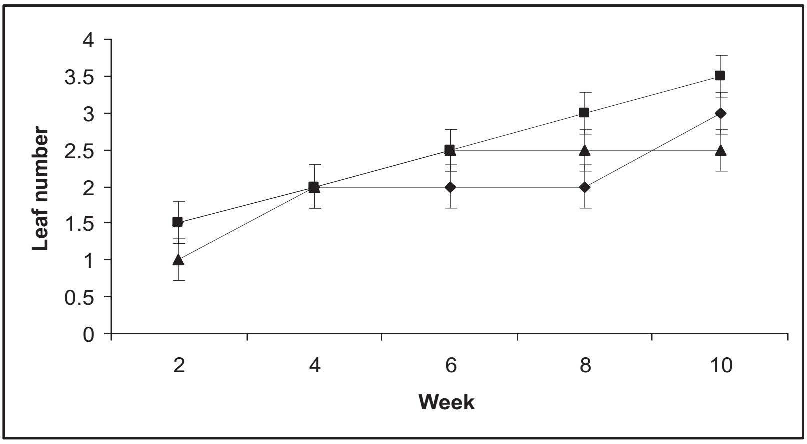

Figure 7. Effect of water depth on number of leaf of *Cryptocoryne zaidiana*. 0 cm depth (—♦—), 10 cm water depth (—€—) and 30 cm water depth(—Δ—). Vertical bars are values of LSD= 0.05.

10th week of transplanting, plants in water depth of 10 cm produced significantly highest number of leaves compared to plants in water depth of 30 cm. However, it had no significant difference by comparing it with the plants in water depth of 0 cm.

Biomass allocation

Harvesting 80 days after transplanting from different water depth was significantly different in the number of leaves (TL) of plants (Figure 8). Plants under 10 cm water depth had higher leaf number. However, plants under 0 cm water depth had higher total plant dry weight (TPDW).There were no significant difference on leaf weight ratio (LWR) of plants under water depth of 0 cm and 10 cm. Value of LWR of plants under water depth of 10 cm was higher than those from 0 cm water depth. This phenomenon was also observed in petiole weight ratio (PWR) as plants under water depth of 10 cm were higher than those from 0 cm water depth. Plants under water depth of 0 cm tend to decrease its root weight ratio (RWR). However, plants grown under 0 cm water depth had higher rhizome weight ratio (RhWR) than those under 10 cm water depth. Leaf area ratio (LAR) and specific leaf area (SLA) at 0 cm water depth were significantly lower than those from 10 cm water depth.

The dry matter production (DMP) was significantly different among the two different water depths (Table 2). The DMP of plants in the water depth of 0 cm was higher than those from 10 cm water depth. However, the net assimilation rate (NAR) of plants in both water depth regimes did not show any significant difference although the highest NAR value was recorded from 0 cm water depth. Plants at water depth of 10 cm recorded significantly higher value of LAD than those from 0 cm water depth regimes.

Rhizome growth development

After one week of placing the rhizomes in the sprouting medium, five cuttings of 5-node rhizome cutting were started to sprout (Figure 9). The 3- and 1-node of rhizome cuttings started to sprout on the 2nd week and the 4th week, respectively. There was a drastic increment in number of plants produced from the 5-node cuttings of rhizomes between the 3rd and 4th week of sprouting period. Sprouting of the 3-node

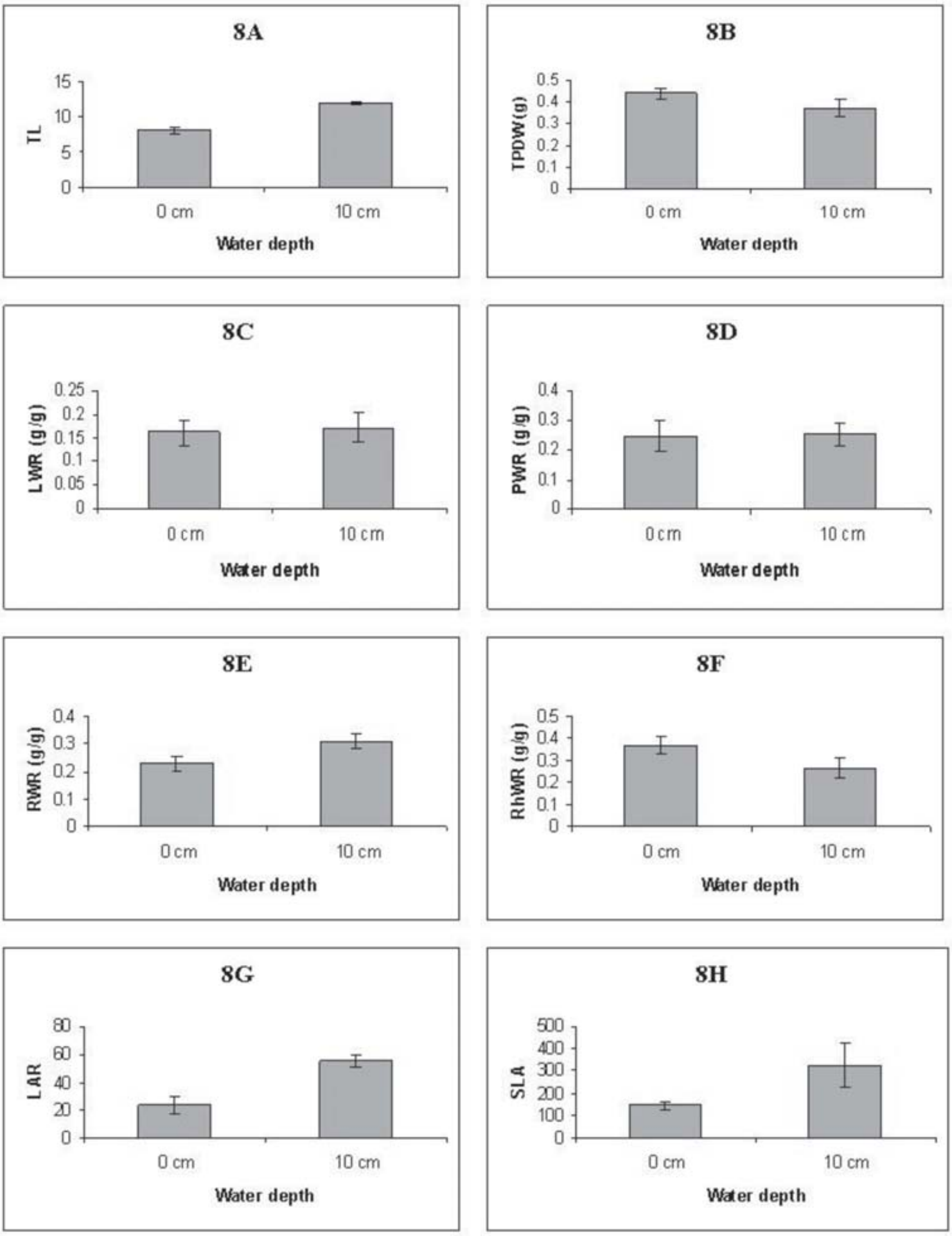

Figure 8. The vegetative characteristics of *Cryptocoryne zaidiana* under different water depth conditions. [8A = Total leaves (TL) 8B = Total plant dry weight (TPDW) (g) 8C = Leaf weight ratio (LWR) (g/g), 8D = Petiole weight ratio (PWR) (g/g), 8E = Root weight ratio (RWR) (g/g), 8F = Rhizome weight ratio (RhWR) (g/g), 8G = Leaf area ratio (LAR) (cm^2/g), 8H = Specific leaf area (SLA)(cm^2/g)]. Vertical bars are values of standard error.

Table 2. Effect of water depth on dry matter production (DMP), net assimilation rate (NAR) and leaf area duration (LAD) of *Cryptocoryne zaidiana* during the 50th to 80th day after transplanting. Within each column, values sharing the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Water depth	DMP (g)	NAR (cm^2/g)	LAD (cm^2/g)
0 cm	0.3194a	0.00086a	86.97b
10 cm	0.1942b	0.00038a	501.43a

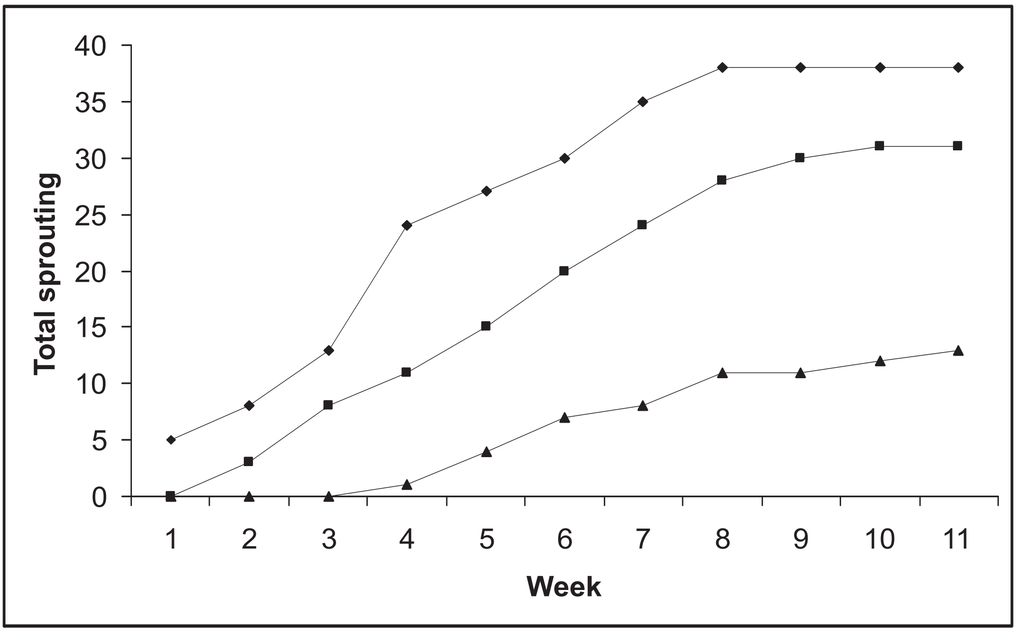

Figure 9. Sprouting of rhizome cuttings of *Cryptocoryne zaidiana.* 1 node (—Δ—), 3 nodes (—€—) and 5 nodes (—♦—).

cuttings increased consistently the 2nd week to the 9th week of sprouting period. The 1-node cutting recorded the lowest number of sprouting.

Photosynthesis

Plants grown under the tree canopy revealed a higher quantum yield compared to the plants grown under 50% and 75% light intensity (Figure 10). Plants grown under 50% shading however had shown significantly lower yield than those from 75% shading and tree canopy shading.

Plants grown in the water depth of 30 cm produced higher maximum quantum yield than those plants under 10 cm of water depth regime (Figure 11). However, quantum yield from different water depths was not significantly different.

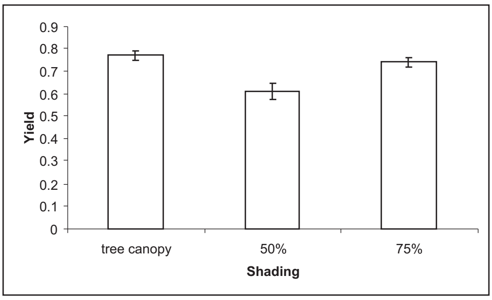

Figure 10. Effect of shading on maximal quantum yield in *Cryptocoryne zaidiana.* Vertical bars are values of standard error.

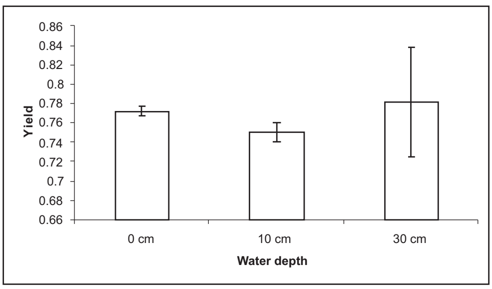

Figure 11. Effect of water depth on maximal quantum yield in *Cryptocoryne zaidiana.* Vertical bars are values of standard error.

Figure 12 showed the relation of electron transport rate with the increasing photosynthetic active radiation of plants grown under different light regimes. Samples grown under 50% shading have higher photosynthetic production at 640 ìmol quanta $m^{-2} s^{-1}$ than which grown under 75% shading and under tree canopy.

Figure 13 showed the relation of electron transport rate with the increasing photosynthetic active radiation of plants grown in different water depth regimes. Plants grown in the water depth of 0 cm recorded higher photosynthetic production at 640 ìmol quanta $m^{-2} s^{-1}$ than that grown under 30 cm and 10 cm water depth regimes.

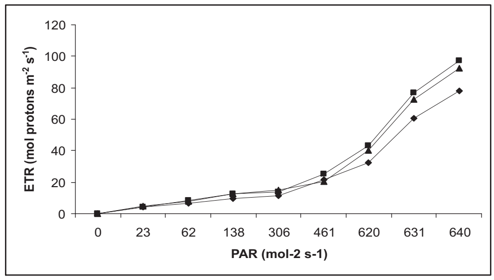

Figure 12. Effect of shading on light curve (electron transfer rate (ETR) vs. photosynthetic active radiation (PAR) in *Cryptocoryne zaidiana*. Tree canopy shading (—♦—), 75% shading (——) and 50% shading (—€—).

DISCUSSION

Vegetative characteristics and biomass partitioning of *C. zaidiana* grown in natural habitat at Sg. Mering varied between quadrates. Plants in the 1st quadrate showed the highest value in the root weight ratio (RWR), leaf area ratio (LAR) and specific leaf area (SLA). It can be concluded that plants responded towards low light availability. Leaf area ratio (LAR) and specific leaf area (SLA) can be expected to decrease as light availability increase. Plants in the 2nd quadrate showed the lowest value of root dry weight (RWR) and leaf weight ratio (LWR). This might happen due to low light availability that reduced biomass allocation to root and increasing the leaf weight ratio (LWR).

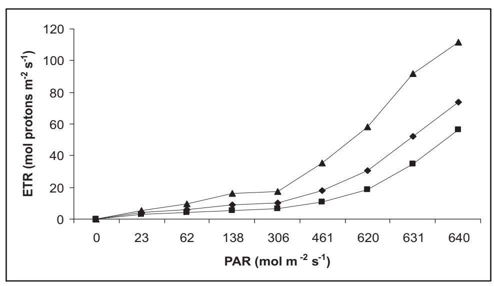

Figure 13. Effect of water depth on light curve (electron transfer rate (ETR) vs. photosynthetic active radiation (PAR)) in *Cryptocoryne zaidiana*. 30 cm depth (—♦—), 0 cm depth (—Δ—) and 10 cm depth (—€—).

Ipor *et al.* (2006b) also observed similar trend for *C. ferruginea*. Plants in the 3rd quadrate had a high value of leaf dry weight (DWL), dry weight of petiole (DWP) and dry weight of rhizome (DWRh). Plants under 75% shading were significantly higher than that under the 50%. This might be due to the intensity of light received by the plants under 75% shading and under the tree canopy were lower than the 50% shading as revealed in Figure 3. Phototropism may occur as plant did elongate itself to receive more light for its requirement to grow. Furthermore, *Cryptocoryne* species is capable of growing well under thick canopy (Jacobsen, 1985).

No significant difference on height between plants under the 75% shading regimes and under the tree canopy. It may happen because of light penetration under the tree canopy is able to be sometimes higher or lower than 75% shading condition (Figure 3). According to Bjorkman (1968) and Ishmine *et al.* (1985), reduced light to a certain degree would result in increased stem extension of *Solidago virgaurea* L. and height of *Paspalum urvillei* Steud. However, further reduction of light suppressed plant growth.

Plants under 50% shading produced significantly more leaves than the 75% shading and tree canopy. Plants under 75% shading produce least leaves. Ipor *et. al* (2003) reported that higher light intensity promoted more leaves production by a plant, and under lower light condition, less number of leaf was produced but the individual leaf area tends to be broader. In comparing to the colour of leaves in the different shading, leaves being produced under 50% shading are yellowish green in colour and thicker while under the 75% shading regime were dark green in colour. Kramer & Kozlowski (1979) reported that leaves do turn yellow as they reflect on loosing of chlorophyll and unmasking of carotenoid pigments.

Plants in the water depth of 30 cm were higher than in the other two water depth regimes. This also may be due to the phototropism of the plants, which grew taller to reach sufficient light source on the water. Ipor *et al.* (2007c) also observed that *C. pallidinervia* grew in 15 cm of water depth were significantly higher than that in the 0 cm and 7 cm depth regimes. Ipor *et al.* (2003) also reported that *C. striolata* grew in deeper water had longer leaves with taller plants. In this study, it was also observed that the water in the 30 cm had the highest value of turbidity which was 750 NTU and significantly differed compared to other regimes. The dark water condition also influenced the height of the plant as it had to elongate itself to reach for the light source as dark water might reduce the intensity of light penetrated through the water surface. Water absorbed light in increasing amounts with greater depth and as turbidity from organic and inorganic suspended particles increase (Kirk, 1983). Plants under 10 cm water depth had received enough light as the water depth regime did not really influence the plants to elongate themselves.

Plants in the water depth of 30 cm had significantly lesser leaf number than those plants under 0 cm and 10 cm water depth. Placement of plants at deeper level usually reduced the availability of light or reduction of light penetrated from the water surface.

The highest leaf weight ratio (LWR) recorded was by plants under tree canopy shading. This might be due to the response of plants towards the light limitation. Light limitation led to slight drop in internal carbohydrate concentration. Plants responds to this by producing more leaves of a reduced specific weight and by reducing root growth, thereby bringing the ratio back to the point (Mooney & Winner, 1991). Plants under 75% shading showed the highest value of petiole weight ratio (PWR). Plants required a longer petiole in order to reach for sufficient light intensity. Plants under 50%

shading show the highest value of root weight ratio (RWR) and rhizome weight ratio (RhWR). Active photosynthesis rate in those plants under 50% shading might led the plants to produce more biomass partitioning to roots and rhizomes. Low light availability will reduce biomass allocation to root (RWR) and increasing the leaf weight ratio (LWR) (Wein *et al.*, 1988).

Plants under 10 cm water depth showed higher value of leaf weight ratio (LWR), petiole weight ratio (PWR), root weight ratio (RWR), leaf area ratio (LAR) and specific leaf area (SLA) compared to plants under 0 cm water depth. Partitioning to leaves was enhanced by reduction in light intensity (Jablonski & Geiger, 1987).

Plants placed under 75% shading and 10 cm water depth had the highest dry matter production (DMP). The highest NAR was recorded by plants cultivated under 50% shading and 0 cm water depth. The NAR is the amount of dry matter produced by the plant per unit of leaf area and is most logically related to the amount of light energy intercepted by plant (Charles-Edward & Ludwig, 1974). Logically, it means that plants under 50% shading and 0 cm water depth intercepted the highest amount of light energy. The highest leaf area duration (LAD) value was recorded by plants under 75% shading regime and 10 cm water depth. Plants in these conditions tended to produce larger leaves.

The highest sprouting of rhizome cutting was recorded by 5-node cuttings viz. 38 plants out of 50 rhizomes. Besides through seeds, *C. zaidiana* could be vegetatively propagated by means of rhizome. Naturally, spreading through rhizomes tended to be more efficient as compared to the seed dispersion. Production of seeds could be irregular and seasonal whereas rhizome production occurred through out the year.

Plants in the 50% shading produced lowest value of the maximal quantum yield and were significantly different between both tree canopy shading and 75% shading. However, study by Charles-Edward (1981) showed that leaves of plants grown under high light levels have faster rates of photosynthesis compared to leaves of plants grown under low light level. The highest maximal quantum yield was recorded by plants in the water depth of 30 cm, followed by plants in the water depth of 0 cm and 10 cm. Higher value of maximal quantum yield concluded that plants have higher photochemical efficiency of photosystem II (PSII) primary reaction center (Krause & Weis, 1991).

Plants grown under 50% shading regime and 0 cm water depth resulted higher electron transport rate (ETR) value at 640 µmol quanta m^{-2} s^{-1}. Both samples indicated higher photosynthetic production rate. Exposure to high light intensity would exhibit higher rates of photosynthesis than under low light intensity. It was observed that plant under the 50% shading regime initiated flowering. This might be due to the response of plants towards the light. It was discovered that growth pattern of *C. zaidiana* as dependant on the light intensity of the environment. Different water depth also contributed to different growth pattern. However, both studies (experiments) only showed significant effect on the number of leaves being developed. The study also showed that the plants do respond better towards different light intensity effect as they produce much taller leaves compared to different water depth even though did not show a clear significant among the plants.

CONCLUSION

Shading and water depth significantly influenced the growth, biomass allocation, growth pattern, maturity and photosynthetic rate of *C. zaidiana*. *Cryptocryne zaidiana* tended to grow well under heavy shading (under thick tree canopy and 75% shading) and shallow water. Similar observation on the growth pattern and physiological response of *C. zaidiana* in natural conditions was conducted. The plants hardly survived in shallow part of the river as the species appeared to amphibious group. *Cryptocryne zaidiana* had a great potential for mass production of planting materials through rhizome cutting.

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