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# Epiphytic Plants Responses to Light and Water Stress

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**Abstract:** Epiphytes are plants susceptible to the current climate change due to continuous exposure of environmental changes. In this study, we review the epiphytes responses to fluctuations in their surrounding environments. Abiotic factors such as light and water are the important contributors towards the epiphytes growth. Epiphytes might suffer from environmental stresses namely high light intensity and water deficit, affecting its growth and physiological attributes. Epiphytes use several mechanisms to counter aforementioned problems and one of it is through changes of physiological pathways. Some of the epiphytes use Crassulacean Acid Metabolism (CAM) as protection system for survival in severe environments. Future studies should include more approaches used by this plant as defense mechanisms to such stresses and more studies on leaf anatomy, leaf structure and variations in biochemical components for further understanding of the mechanisms involved.

**Key words:** Epiphytes, high light intensity, drought, physiological pathway, crassulacean acid metabolism (CAM)

## INTRODUCTION

International community is widely concerned about climate change as one of the most critical environmental issues faced by mankind (Black *et al*., 2011). $CO_2$ elevation and temperature rise has its impacts on plants' growth, development and its physiological functions (Centritto, 2002) and the earth in general. Forest growth, survival and structure are some of the major concerns from climate change as an output from the interaction between forests and the environment (Chmura *et al*., 2011). An understanding of forest canopy is important where it operated as a medium for the energy, mass and momentum exchanges between environment and the ecosystem of the forest (Song *et al*., 2010). It contains myriads of plant populations and this includes the parasites, hemi-epiphytes, vascular and non-vascular epiphytes (Benzing, 1990; Nadkarni *et al*., 2004). In tropical forest, vascular epiphytes are included as a vital component of the forests biological diversity (Wester *et al*., 2011). Existence of epiphytes at plants and atmosphere interface made them vulnerable to climate change thus, other components of the forest consequently will almost directly affected from any negative impact occur to the epiphytes (Zotz and Bader, 2009). There are also increases in awareness to the view that the survival and continuation of the epiphytes community are gradually at risk (Nadkarni, 1992). Besides, excessive logging and land use to the tropical rain forests especially in the mountain rain forest are harmful and have a dangerous effect to the epiphytes community (Barthlott *et al*., 2001). Plants in this natural environment have higher risks to be affected by several damages in relation to environmental stresses (Huang, 2006). Moreover, epiphytes are subjected to multiple abiotic and biotic stresses of varying intensities and durations. The location of canopy dwelling plants like epiphytes make it sensitive to environmental stress (Oberbauer *et al*., 1996). Where, epiphytes are mainly habituated in a complex light atmosphere (Martin *et al*., 2001) where the main abiotic limitation in epiphytic habitat is the insufficiency of water (Zotz and Hietz, 2001).

When the environment of epiphytes is affected by its climate, automatically the plant's physiological responses will be directly influenced. According to Schurr *et al*. (2006), at any state of environmental change, photosynthesis and growth processes are likely be affected. Climate change affects the overall functions and operations of physiological processes such as growth, transpiration and respiration (Brouder and Volenec, 2008).

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In addition, the growth of plants is mainly influenced by genetic traits or its surroundings (Kramer and Kozlowski, 1979). In fact, plants will respond to environmental stresses through their physiological features such as modification organs's growth, or by using various types of ways to prevail against the stresses (Schurr *et al.*, 2006).

Therefore, it is necessary to discover how environmental factors especially light and water affect the epiphytes as they are mostly threatened by those two types of stresses. Their responses are vital to understand the epiphytes performances in fluctuating environments. This review will focus on the nature, contribution and response of epiphytic plants to light and water stress. Even though this paper touches on the entire globe, there is a clear focus on the growth and physiological responses of epiphytes to light and water stress. These observations also supplemented with reviews on epiphytic adaptive strategies through Crassulacean Acid Metabolism (CAM) in resistance against such stresses.

## EPIPHYTES

Epiphytes are plants that settle on other plants and their habitats vary from the terrestrial understory to edge of the tree canopy (Zotz and Hietz, 2001). The epiphytic plants use other plants like trees, shrubs and woody vines as host. In contrast with the parasites, they are fully autotrophic (Benzing, 1998) or are considered as true epiphytes (Reinert, 1998). Ferns, orchids and bromeliads are embraces as epiphytes where they have characteristics that include thick and waxy leaves that allow them to require small amount of water (Ainuddin, 2007). There were plenty of epiphytic plants grew in wet tropical countries (Freiberg, 2001: Benzing, 1998, 1990). Besides, the vascular epiphytes are distinct characteristic element of tropical moist forests (Hietz *et al.*, 2002). Additionally, epiphytes are globally known as dominant elements of the tropical rainforest (Fayle *et al.*, 2009) and most of the vascular epiphytes are tropical plants (Zotz and Hietz, 2001). In addition, Benzing (1990) also mentioned that the epiphytes rarely exist in drier places. However, he stated that there are few types of epiphytes that could grow in the arid regions such as the orchids and the bromeliads where they are supported by plants like the Mexican and Peruvian cactus.

According to Diaz *et al.* (2010), administrative practices in Chilean temperate rainforests prominently overlook the epiphytic plants communities. They were removed due to misperception that they are the indicators of deteriorating tree health and reducing production of timber. In fact, epiphytes do act as a source of the tropical rainforest ecology where it contributes to many forests functions such as storing water from rainfall and holding nutrients (Benzing, 2004). In the process of hydrological and nutrient cycles of a forest system, epiphytes are the vital contributor (Benzing, 1998) since they engage and hold nutrients from the surrounding (Benzing, 1990).

Epiphytes play a significant function in influencing their nearby area microclimate particularly the canopy area (Stuntz *et al.*, 2002). Moreover, according to Rosdi and Ainuddin (2004), microclimate of the surroundings area seems to be affected by the existence of plant. For example, the surrounding microclimatic state at the forest floor, does show a balance ecological system contained by much drier and warmer condition of the atmosphere, which is as the reflection of the contribution of canopy epiphytes and their accumulated dead organic matters (Freiberg, 2001; Freiberg and Turton, 2007). The vascular and non-vascular epiphytes contribute to the forest biomass. According to Nadkarni (1984), these epiphytic plants contribute to more than a few tons per hectare of biomass. In addition, these epiphytic plants also elevated the uptake of carbon and productivity of the forest (Diaz *et al.*, 2010). For instance, a study of an epiphyte of *Asplenium nidus* shows that it could accumulate its dry mass up to one tones of per hectare (Ellwood *et al.*, 2002).

In both vascular and non vascular plants there are epiphytisms among them and which comprise of pteridophytes, flowering plants, latter bryophytes, algae and lichens (Reinert, 1998). Generally, vascular epiphytic plants varieties are mostly localized in tropical regions (Dubuisson *et al.*, 2009). Furthermore, Otto *et al.* (2009) reported that plenty of epiphytes that mainly ferns are absolutely acclimatized to the environment that is airy. According to Lorenzo *et al.* (2010), almost 80% species of the epiphytes fit into just four families: Bromeliaceae, Orchidaceae Polypodiaceae and Araceae.

## PLANT STRESS

Climate change is the present issue that manipulates the ecological features of an ecosystem. The changes in the environment have huge effects especially on plants growth and its distribution. Interaction between plants and the environment will influence plants physiological functions thus affecting some ecological processes (Hegland *et al.*, 2009). When the environment of a plant is affected by its climate, the natural processes of this plant will be directly influenced. Plant stress is always influenced by adverse environmental conditions, such as insufficient water supply, diseases, lack of nutrients or insect damage. There are many types of stresses caused by the changes of its surrounding area either in a minor or major way. These abiotic stresses will effect growth and in the long run, it will exterminate the survival of plant.

Canopy act as a filter to plant beneath it and reduce the solar energy received to the ground (Ainuddin and Lili, 2005). Environmental stresses for example water deficit and high light intensity might occur to epiphytes which live beneath the forest canopy. A species of *Platycerium bifurcatum* developed in diverse habitat which always exposed by drought and stress of high irradiance (Rut *et al*., 2008). The surrounding microclimate of the epiphyte area will therefore affect their mortality and as a result, it will affect the distribution of different species (Fayle *et al*., 2009). Epiphytes were also reported as the first population to be declined as their ecosystem was at risk and disturbed (Dubuisson *et al*., 2009).

However, epiphytes also exhibit ecophysiological, morphological and anatomical adaptation to survive under these harsh canopy conditions (Lorenzo *et al*., 2010). According to Suzuki *et al*. (2005), a complex system of transcription factors and other rigid genes will control the multiple defenses of enzymes, proteins and specific pathways if any plant is acclimatize to those abiotic stresses. Each plant will use different mechanism dealing with abiotic stress. For instance in *Mimosa strigillosa*, under environmental stress of soil pH, more growth is distributed to shoot under optimum condition, while under stress, it allow more growth to the roots (Nuruddin and Chang, 1999). This reflects that plant use different approach as an adjustment to environmental stress.

## LIGHT STRESS

Light is one of the stress factors that have a huge influence on plant. The energy source for photosynthesis in plants is light and it is the vital requirement for plant life (Long *et al*., 1994). Light intensity and light quality fluctuation definitely have its effects on biochemical, physiological and plants developmental processes where under the low light level, growth and development are disturbed due to insufficient energy and under high light intensity, photodamaged may occur due to overload of the plant's system (Humby and Durnford, 2006). Epiphytes can grow under different light condition ranging from the nearly full sun which is out in the open branches to the deep shade on base of the stem (Hietz and Briones, 2001). Epiphytes environment is always exposed to such stress and the regulation of plant growth and development are affected by the changes of the environmental conditions. Epiphytes that live under plant canopy are typically exposed to the elements of harsh atmosphere where light stress may arise among the epiphytic plants.

Light stress is when an excess light is absorbed greater than what is needed during the process of photosynthesis, where the excess of light is defined as when the ratio of Photon Flux Density (PFD) and photosynthesis is high (Demmig-Adams and Adams, 1992). High light intensity will lead to high temperature which will influence the plant growth due to hotter and drier surrounding microclimate. Different mechanisms shield the photosynthetic apparatus from over-energization under the overload light but, if the mechanisms of photoprotective of plant are insufficient, photoinhibition process will be turned on (He *et al*., 1996). The trigger to photoinhibition occurs due to the overexposure of plant to irradiance which it is higher than the irradiance usually obtained by plant (Stancato *et al*., 2002). The photochemical inactivation mostly of Photosystem II (PS II) is involved in photoinhibition (Sarvikas *et al*., 2006). Therefore, every organism that conducts photosynthesis is probably vulnerable to injury due to radiation influences, but the level of susceptibility depends on factors such as environmental, genotype, phenotype and physiological (Alves *et al*., 2002).

The growth of plants is closely related to photosynthesis and without light, photosynthesis will not occur and the growth of plants will be retarded. According to Winter *et al*. (1983), many CAM plants are not only could survive in the area with high light intensity but also under shaded condition. Capability of some species to survive under certain light range is probably dependent on how far they can adapt to new levels of light by changing their photosynthetic response (Heschel *et al*., 2004).

## WATER STRESS

Meteorological term for drought is implied as restriction of water for a long period of time while water stress is likely to signify the complex progression of the effect of drought which is triggered by drought (Lombardini, 2006). Drought stress also has become more severe in some area due to the global climate change (Elsheery and Cao, 2008). Living in the canopy environments, water limitation is likely to occur among epiphytes. Extensive environmental conditions of drought and salinity converge to lower water accessibility of plants lead to the limitation of photosynthesis (Flexas *et al*., 2004), growth and worldwide yield (Chaves *et al*., 2003). The rate of $CO_2$ assimilation of plants may be reduced under the condition of water insufficiency (Stancato *et al*., 2001). Closure of stomata and photosynthetic rates reduction are also stimulated by the limitation of water availability (Angelopoulos *et al*., 1996). For instance, in *Mimosa strigillosa,* the stomata are closed and leaves are folded to reduce loss of water (Chang *et al*., 1997). In addition, both stomatal closure and inhibition of leaf growth are among the earliest reactions towards drought to defend the plants from excessive water loss where it might lead to leaf cell dehydration and runaway xylem cavitations thus, bring towards the mortality (Chaves *et al*., 2003).

The main limitation of plant survival and growth is water stress and during acclimatization of plants to water stress, it involves several physiological and anti-oxidative apparatus (Upadhyaya *et al*., 2008). Therefore, stress tolerance indicates the capability of plants to survive in adverse environment through the adaptation and acclimatization from the state of stress (Lombardini, 2006). Epiphytes must tolerate the stress to survive in the harsh environment. Therefore, there were many defenses applicable to epiphytic plants (Benzing, 1990). For instance, the adjustment of conductance can defend a plant itself to drought or water stress. Moreover, Benzing (1990) also stated that osmotic adjustment and carbon dioxide fixation are other ways that can be used by plants to overcome this situation. According to Luvaha *et al*. (2008), in changing of environmental climate, it is beneficial for species to apply avoidance of drought mechanisms and adaptation through active osmoregulation. In addition, plants tolerate drought by avoiding tissue dryness and at the same time sustaining water potential or enduring the low water potential (Chaves *et al*., 2003). Generally, thick cuticles, succulence, sunken stomata and a thicker layer of boundary on the leaf surface are some of the adaptations applied by plants to conserve their water status (Hsu *et al*., 2006). For C4 or CAM plants, they use other methods of to cope with stress through carbon dioxide fixation for production of sugar with a minimum water loss (Xoconostle-Cazares *et al*., 2010). Water insufficiency in soil and plant tissue during drought leads to the adjustment in the processes of plant photosynthesis and has its effect on plant growth, development and survival in harsh environment (Lombardini, 2006).

## GROWTH RESPONSE TO LIGHT AND WATER STRESS

Growth is a mechanism achieved by division of cell, cell enlargement and differentiation and it is associated with the physiological, ecological, genetic and morphological measures and their complex interactions (Farooq *et al*., 2009). One of the important elements for plant growth and development is light (Saifuddin *et al*., 2010). Nearly all plants use solar radiation not only source of energy for photosynthesis, but also to regulate their processes of growth and development (Lombardini, 2006). Cervantes *et al*. (2005) theorized that individual epiphytes under extreme light intensity microhabitats within the canopy in a tropical dry forest of Yucatan, Mexico may have a restriction in their growth and reproduction. A study by Singh and Srivastava (1985) conformed to this finding where the fern of *Azolla pinnata* R. Brown recorded has the lowest value of mean leaf area in both of under the shade and highest light intensity treatments (Table 1).

In terms of biomass, unlike $C_3$ plants that grow in high light area, plants that grown under shade would distribute more biomass to their photosynthetic tissues, creating thin, horizontally oriented foliages with little intra-canopy shadings thus, they have relatively higher concentrations of chlorophyll and higher coefficients of light absorption, however, these shaded plants have smaller value in root biomass indicating low rates of transpiration and low light saturated rates of photosynthesis (Skillman *et al*., 2005).

Decline in the vegetative growth of plants are one of the initial consequences of drought where water deficit will stimulate changes in terms of cell structure of plants and its metabolism (Khaled, 2010). Another consequence of water stress is turgor loss which reduces the size of cells leading to reductions in leaf expansion and shoot extension plus the leaf area reduction will definitely lessen the surface area for transpiration and thus, smaller leaves will decrease the light absorption and photosynthesis (Lombardini, 2006). In a study by Ainuddin and Nur

Table 1: Growth of fern and epiphytes species grown under different light treatment

| Species | Duration of study | Growth area | Dry weight | References |
|---|---|---|---|---|
| *Azolla pinnata* R. Brown | Four months | Mean frond area ($cm^2$):<br>Shade: 22.4<br>Light intensity 35%: 142.2<br>Light intensity 50%: 219.4<br>Light intensity 70%: 130.6<br>Light intensity 100%: 86.4<br>Light intensity 70%: 0.643 | Mean dry weight (g):<br>Shade: 0.015<br>Light intensity 35%: 0.382<br>Light intensity 50%: 0.653<br>Light intensity 100%: 1.563 | Singh and Srivastava (1985) |
| *Epidendrum secundum* Jacq. | 1 day | Shaded plants: Leaf area per individual ($cm^2$): 364.9±96.2 | - | Moreira *et al.* (2009) |
| *Dichaea cogniauxiana* Shltr. | 1 day | Shaded plants: Leaf area per individual ($cm^2$): 78.2±16.7 | - | |

Najwa (2009), water restriction lowered length and area of *Asplenium nidus*. According to Vurayai *et al.* (2011), decline in leaf area is the initial defense of plants to drought as in their study, water stress reduces area of the leaf to transpires less water. In addition, the reductions of leaf water potential and stomatal closure are the instantaneous reaction to water insufficiency, which point towards to decline in $CO_2$ uptake and photosynthesis (Li *et al.*, 2008). The reduction in photosynthesis results in a slower growth and lower plant biomass (Du *et al.*, 2010) because plants need water to create biomass (Benzing, 1990). Furthermore, stomata closure and slower plant growth are desirable approaches to decrease further water loss (Sinclair and Purcell, 2005). However, only a few studies were done on the direct and long term observation as in concern of the growth of epiphytic plants (Hietz *et al.*, 2002).

## PHYSIOLOGICAL RESPONSE TO LIGHT AND WATER STRESS

Generally, the function of physiology of plant explains the growth of plants and its respond to the surrounding factors and cultural treatments (Kramer and Kozlowski, 1979). In extreme environments especially in high light intensity and water stress condition, plants will respond to changes through their physiological processes, such as the rate of photosynthesis, transpiration and stomatal conductance. In plant's leaves, the factors from plant nutrition, light regime, leaf age, water stress and other physiological parameters can affect the photosynthetic $CO_2$ assimilation (Von Caemmerer and Farquhar, 1981).

Although light is essential for photosynthesis, the light intensity whether it is low or high can affect plant growth (Valladares and Niinemets, 2008). Light intensity determines the degree of opening of the stomata and the guard cell, controlling water balance and influencing the photosynthesis rate of a plant via the light receptors that drive fixation of $CO_2$ and reduced intercellular $CO_2$ concentration (Yu *et al.*, 2004). In addition, the environment plays an important role in determining the photosynthesis efficiency, for example, plants that grow in a low light regime, their leaves absorb lower photon energy and they are depending on photon supplies for their photosynthesis rate (Miyake *et al.*, 2009). Moreover, in a tropical dry forest of Yucatan, Mexico, plants that grow in the lower level of the canopy would have a lower photosynthetic rate while and plants that grow in the higher level of the canopy would experience photoinhibition (Cervantes *et al.*, 2005). Roberts *et al.* (1998) found similar results where maximum rates of photosynthesis in shaded leaves are lower than the exposed ones while Schafer and Luttge (1988) found the opposite findings (Table 2). Epiphytes usually lived in a place that receives variability in light and is high in PFD since their photosynthetic apparatus will be affected, resulting in high evaporation rate which affects the plant water relations (Schafer and Luttge, 1988).

Moreover, physiological and biochemical processes of photosynthesis were affected by water stress (Ramanjulu *et al.*, 1998). According to Chang *et al.* (1995), in adjustment to water stress condition, two physiological characteristics vital to plants are water transport system efficiency and regulatory system for water loss. In declining water availability, stomata closure has been noted as the earliest response of plants physiological attributes towards drought (Flexas and Medrano, 2002). Since there is known close correlation between stomatal conductance ($g_s$) and net $CO_2$ assimilation ($A_{net}$), it has been classified that in drought condition, stomatal closure has an influence in limiting the $CO_2$ uptake in the leaves (Flexas *et al.*, 2004). In the limitation of net photosynthesis rate, stomatal or non-stomatal factors were involved in this situation but the limitation was also dependable on the harshness and persistence of stress and also genetic reaction of the plant species (Ramanjulu *et al.*, 1998). The survival capability of plant

Table 2: Photosynthesis rate of epiphytes species grown under different light treatment

| Species | Duration of study (days) | Photosynthesis rate | References |
|---|---|---|---|
| *Kalanchoe uniflora* | 60 | Light saturated photosynthetic rate:<br>1. With shading (LL light): 2.5± 0.4 µmol $CO_2$ $m^{-2}$ $sec^{-1}$<br>2. Without shading (HL light): 2.2 ± 0.1 µmol $CO_2$ $m^{-2}$ $sec^{-1}$ | Schafer and Luttge (1988) |
| *Clusia minor* L. | 1 | Maximum rates of photosynthesis:<br>1. Exposed leaves: 5.75 µmol $CO_2$ $m^{-2}$ $sec^{-1}$<br>2. Shaded leaves: 2.0 µmol $CO_2$ $m^{-2}$ $sec^{-1}$ ), | Roberts *et al.* (1998) |
| *Asplenium cuspidatum* | 1 | Net $CO_2$ uptake rates at light intensities $^3$ 1000 mmol:<br>2.6 µmol $CO_2$ $m^{-2}$ $sec^{-1}$ | Hietz and Briones (2001) |
| *Polypodium puberulum* | 1 | Net $CO_2$ uptake rates at light intensities $^3$ 1000 mmol:<br>2.5 µmol $CO_2$ $m^{-2}$ $sec^{-1}$ | |
| *Platycerium bifurcatum* | 5 | Net photosynthetic rate:<br>1. High irradiance at 300 and 400 µmol m–$^2$ $sec^{-1}$:<br>< 3 µmol $CO_2$ $m^{-2}$ $sec^{-1}$ | Rut *et al.* (2008) |

in severe drought is based on water loss limitation through minimum opening of stomata (Sanusan *et al*., 2010). Although the closure of stomata helps in sustaining high leaf water content and its water potential however is also responsible for the decline in photosynthesis (Ohashi *et al*., 2006). Moreover, in water deficit condition, the decline in $CO_2$ assimilation rate is due to electron transfer in the Photosystem II was reduced, thus affecting the quantum yield in its photochemical apparatus (Stancato *et al*., 2001). In a study of drought tolerance in cereal species, it was found that the value of the quantum yield of PS II in water deficit condition was reduced with the increment in the stress level (Flagella *et al*., 1998).

Compared to other climatic elements in nature, light varies through its amplitude and radiation quantity and quality obtained by plants (Alves *et al*., 2002). When plants are subjected to strong light, their physiological features will respond. The declines in capability for photosynthesis were stimulated by exposing photosynthetic organisms, structures or organelles to visible light which has been denoted in various terms such as photoinhibition, photooxidation, photoinactivation, photolability, solarization and photodynamic reactions (Powles, 1984). Photoinhibition were used to explain the inhibition of photosynthetic capacity (Demmig-Adams and Adams, 1992) and the independence of gross adjustment in pigment concentration caused by excessive light (Powles, 1984). Long *et al*. (1994) also supported that photoinhibition was considered as light dependent and a gradual reduction of photosynthetic rate (Demmig-Adams and Adams, 1992) which was independent of any developmental change.

Furthermore, it is known that exposing green plants to excessive light has caused damages to photosynthetic apparatus (Powles, 1984). Moreover, tremendously too much light obtained by plants possibly will damage photosynthetic pigments (Powles, 1984) and the structure of plants which leading to photodamage (Larcher, 2003). In tropical region, high irradiance and high temperature arise concurrently with drought will direct the plants towards increasing their photon energy in chloroplast, which also decreases photochemical efficiency, thus leading to photosynthetic apparatus damages (Elsheery and Cao, 2008).

Chlorophyll fluorescence technique is a good indicator in determining the response from stresses. Whereby, in understanding adaptation system of plant and resistance to stress from the environment, chlorophyll fluorescence act as an assistant regards to this matter (Siam *et al*., 2008). This technique is handy and be used broadly by plant physiologists and ecophysiologists (Maxwell and Johnson, 2000). Chlorophyll fluorescence measuring techniques has currently improved and therefore is a vital instrument in the basic and applied physiology of plant (Krause and Weis, 1991). Using this technique, it calculates the modifications in photosystem II (PS II) action through the Chlorophyll a fluorescence changes which stimulated by the stress (Percival, 2005). There have been plenty of evidences associated with PS II acting as the main site of lesion in photoinhibition (Powles, 1984). The apparatus of photosynthesis in plants could possibly be affected provisionally by environmental stresses prior to the permanent morphological injury (Naumann *et al*., 2008; Percival and Sheriffs, 2002). Under various conditions and at various times, this technique of chlorophyll fluorescence measurement can estimate the parameters of the actual photosynthetic efficiency of the leaf (Maxwell and Johnson, 2000). It also measures the potential maximum of the quantum efficiency of $F_v/F_m$ (Duraes *et al*., 2001).

Plant responses to stress conditions in this technique can be quantified through the measurement of fluorescence sign from dark adapting leaves of a plant for a certain period of time. As reported by Baker and Rosenqvist (2004), when the leaf was subjected to immediate light, fluorescence increases to a level of minimal fluorescence ($F_0$) which at this state the reaction centre of PS II.

## CRASSULACEAN ACID METABOLISM: AS DEFENSE MECHANISM FROM STRESS FOR EPIPHYTES

Plant reacts to numerous stresses imposed by the climate change such as high and low concentrations of carbon dioxide, high light intensity and high temperature, which all have effects on carbon fixation and anatomical pathway (Holtum and Winter, 1999). There are three types of photosynthesis pathway, C3, C4 and Crassulacean Acid Metabolism (CAM) and many dynamic defense systems exist for epiphytics (Benzing, 1990). In fact, plants that grow in arid land modify their physiological metabolic system via CAM (Grams and Thiel, 2002). CAM is a $CO_2$ concentrating mechanism that activates the Phosphoenolpyruvate Carboxylase (PEPC) enzyme at night for detaining the respiratory and atmospheric $CO_2$. Physiologically, CAM preserves carbon and water in plants that grow in surroundings with limited accessibility those two resources either in short or long term basis (Borland and Taybi, 2004). In CAM photosynthesis, plant use a metabolic strategy in which during the cooler period at night, the stomata of the plants open to allow the nocturnal uptake of carbon dioxide ($CO_2$) and during the day, stomata close to prevent the loss of water (Dodd *et al*., 2002; Rut *et al*., 2008). Thus, by this processes during day and night, it is considered that water stress could be adapted by CAM plants through the reduction of water loss (Luttge, 2004).

There have been many studies on the availability of this pathway on plants especially the epiphytes (Borland *et al*., 1998; Herrera *et al*., 2000; Hsu *et al*., 2006; Rut *et al*., 2008). A study by Holtum and Winter (1999) found that the tropical epiphytic and lithophytic ferns are the common plants that undergo CAM than it is presently investigated. In this study, eventhough the *Polypodium crassifolium* and *Polypodium veitchii* did not showed a strong CAM features, CAM activity still happened and was shown in the increase of titratable acidity. This shows that there is an occurrence of the CAM indirectly.

In a study by Wanek *et al*. (2002), there was an activity of CAM cycle in all stages of development of *Clusia* species which was the *Clusia osaensis* Hammel-ined., *Clusia peninsulae* Hammel-ined. and *Clusia valerii* Standl. This study shows that from the titratable protons and malic and citric acid there was a significant day-night flux cycle. Therefore, they advocate that the accessibility of water and light intensity created the appearance of CAM. Among epiphytes, the broad occasions of CAM are not expected as an outcome from short, but probably frequent phases of drought stress (Hsu *et al*., 2006). According to Rabas and Martin (2003), plants that are succulent will regularly uptake $CO_2$ through CAM and additionally to the mechanism of $C_3$.

Stresses from ecological factors could alter the isotope composition of C13 in many expected ways, ultimately via the effects on the balance among stomatal conductance and carboxylation (Robinson *et al*., 2000). Leavitt and Long (1982) reported that light intensity has an effect on the photosynthesis rate and in turn, it manipulates the composition of the carbon isotopic of plant and stresses from water could also influence stomata conductance and availability of water for photosynthesis. Epiphytes might survive via CAM where this mechanism allows plants to defense themselves through several stresses such as light and drought.

## CONCLUSION

Climate changes have been manipulating the ecological value of an ecosystem. Light and water plays an important role in epiphytes growth and physiological performances. Many of epiphytes growth and physiological parameters are being affected, including the decline in biomass, photochemical efficiency and many more. Plants especially epiphytes have many ways in adapting to stressful conditions, which in such cases, CAM are vital for epiphytes in surviving harsh environment. The fixation of $CO_2$ at night and the closing of stomata during day are the essential mechanisms for the epiphytes. Through these adjustments on their physiological functions, epiphytes certainly have a higher percentage in survivability by preventing themselves from dying water loss and increasing temperature. Other mechanisms encountered by plants to defense themselves from such stresses should be further investigated to get better idea of other stress responses in plants. In order to obtain a larger picture on the underlying explanation on what other parameters that are affected by light and water stress, things such as leaf anatomy, leaf structure and biochemical components variations in epiphytes need to be explored in the future.

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