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Physiological efficiency of succulents under different growing environments in tropical condition

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ABSTRACT : Investigations were undertaken to study the physiological effectiveness of different ornamental succulents under tropical condition. Six species of succulents were evaluated under four different growing environments. Results showed that the performance of succulents grown under conservatory house condition was found to be performed well and ideal with respect to chlorophyll, carotenoids, relative water content and photosynthetic rate than other growing environments. The succulent species *viz.*, *Haworthia limifolia, Monadenium lugardiae* and *Aloe juvenna* were the most suitable species for growing under conservatory house condition due to its high nocturnal CO_2 uptake and cell sap acidification which possess CAM metabolism. CAM involves nocturnal CO_2 uptake and fixation by cytosolic phosphoenolpyruvate carboxylase into malic acid that is stored in the vacuole causing nocturnal cell sap acidification. During the subsequent light period, malic acid is released from the vacuole in the form of malate that is then decarboxylated leading to deacidification of cell sap, formation of pyruvate or phosphoenolpyruvate and liberation of CO_2. Repeated acidification and deacidification cycles represent a characteristic physiological feature of CAM metabolism in succulents which is best suited for xeric environment and possess high photosynthetic efficiency.

KEY WORDS : Succulents, Chlorophyll, Photosynthetic rate, CAM metabolism

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Succulents are forming a large cultural group in a garden with ornamental value and enormously used as indoor as well as outdoor plants. In plains of India, where we get tropical weather throughout the year, succulents play an important role in both indoor and outdoor landscaping. These plants are being used in landscaping, especially in green roofs and vertical gardens and extensively for their specific shape. These plants occupy mostly dry desert localities requires zero maintenance. They are capable of withstanding long spells of drought as they store sufficient moisture in their succulent body parts. Succulents are also grown as single specimen plants in lawns. Many succulent species are also used for hedging, edging and bedding. Bhattacharjee (1978) reported that succulents inhabiting the arid regions will do well in most of the places in India. But the types which are natives of the alpine regions can be cultivated with success only under a sub-tropical climate of medium to high elevation. The succulents do very well in the mild climatic conditions of Bangalore, Kalimpong, Darjeeling and places with a similar climate. The climatic and other requirements of most of the succulents, with a few exceptions, are almost similar and hence these can be grown together under one greenhouse or lath house. So far, research in succulents is very meagre and limited, the experiment was undertaken to study the influence of physiological role under different growing environments in six different succulent plant species.

RESEARCH METHODS

The study was carried out during the period from August 2010 to March 2011 at Horticultural College and Research Institute, Periyakulam, which is situated between 10^0 1' north latitude and 81^0 1' east longitude and at an altitude of 246 meters above mean sea level. Six species of succulents were collected from the foothills of lower palani hills were used in the current study. The experiment was conducted as pot culture study utilizing the accessible different growing environments *viz*., (i) T_1 (Conservatory house), (ii) T_2 (Open condition), (iii) T_3 (Shade net house) and (iv) T_4 (Glass house) and the succulent species *viz.*, S_1-*Aloe juvenna*, S_2- *Haworthia limifolia*, S_3-*Monadenium lugardiae*, S_4 -*Haworthia cuspidata*, S_5 - *Echeveria* sp., S_6-*Echeveria prolifica*. Planting was done in a pots with a standard pot mixture of garden loam, coarse sand, soil, leaf mould, and crushed brick in the ratio of 2:2:2:2:1 was ideal compost used for all the treatments.

The physiological parameters *viz.,* total chlorophyll (Bruinsma, 1961), total carotenoids (Bruinsma, 1961), relative water content (Koide and Mosse, 2004) and photosynthetic rate were recorded and the data on weather parameters *viz*., temperature, relative humidity, light intensity and rainfall were recorded separately for each growing environment during the entire growing period. The experimental results were statistically scrutinized as suggested by Panse and Sukhatme (1985). The critical difference was worked out at 5 per cent (0.05) probability.

RESEARCH FINDINGS AND DISCUSSION

The growing environments significantly influenced the total chlorophyll content, total carotenoids, relative water content and photosynthetic rate (Table 1 and 2). The higher chlorophyll content was recorded in conservatory house (T_1) (0.501 mg g^{-1}) and lower was recorded in open condition (T_2) (0.514 mg g^{-1}). The chlorophyll content was found to be maximum in *Monadenium lugardiae* (S_3) (0.571mg g^{-1}) and minimum in *Haworthia cuspidata* (S_4) (0.488 mg g^{-1}). The interaction effect on chlorophyll content was maximum in T_1 in *Monadenium lugardiae* (S_3) (0.677 mg g^{-1}) and minimum (0.364 mg g^{-1}) in open condition (T_2) in *Haworthia cuspidata* (S_4). The carotenoid content was higher in the treatment T_1 (conservatory house) (0.184 mg g^{-1}), followed by glass house condition (T_4) which recorded carotenoid content of (0.166 mg g^{-1}). The treatment open condition (T_2) recorded lowest carotenoid content of (0.140 mg g^{-1}). The carotenoid content was found to be maximum in *Echeveria prolifica* (S_6) (0.178 mg g^{-1}) and minimum in *Aloe juvenna* (S_1) (0.157 mg g^{-1}). The interaction effect on carotenoid content was maximum in T_1 in *Echeveria prolifica* (S_6) (0.224 mg g^{-1}) and minimum (0.133 mg g^{-1}) in open condition (T_2) in *Aloe juvenna.* (S_1). Data showed that there were some variations between different succulent species and between the environments. Total carotenoids were considered as assessor photosynthetic pigments, and play an important role as protective agent against the degradation of chlorophyll under full sunshine. Chlorophyll analysis showed only minimal differences between the treatments (Osmond, 1978).

Accordingly, the ratio between carotenoids concentration and total chlorophyll is very important in such xerophytic plant species (Gad Mariam, 2004). Das and Mukhopadhyay (1976) reported that for the life of plants, light is important as it is responsible for most of their processes. It is the source of energy, affecting the shape of organs, periodicity of growth and reproduction. In poor light, growth slows down, the plants become starved and flower poorly; their typical natural colouration changes. Many genera are well adapted to thrive in conditions of great light intensity and summer heat. Lee *et al*. (2006) reported that the CO_2 assimilation rate of *Crassula* hybrid 'Himaturi', a succulent ornamental species with the crassulacean acid metabolism (CAM) photosynthetic pathway, was affected by light intensity. Some succulents have a unique capacity to shift their photosynthetic mode between the C_3 type and CAM, depending on environment and age. In both chlorophyll and carotenoids, the drop in concentration occurred immediately after the initiation of the drought period.

The relative water content recorded higher in the treatment T_1 (conservatory house) (91.72 %), followed by shadenet house condition (T_3) which recorded carotenoid content of (88.66 %). The treatment open condition (T_2) recorded lowest carotenoid content of (79.6 %). The relative water content found to be maximum in *Haworthia limifolia* (S_2) (92.20 %) and minimum in *Aloe juvenna* (S_1) (86.81 %). The interaction effect on relative water content was maximum in T_1 in *Haworthia limifolia* (S_2) (92.34 %) and minimum value (81.48 %) in open condition (T_2) in *Aloe juvenna* (S_1). As per the findings of Larcher (1995) tolerance may be interpreted as the ability of the cells of both chlorenchyma and pith lose up to 50 per cent of their water during drought. In this regard, approximately 80 per cent of the water loss comes from the water storage parenchyma (Barcikowski and Nobel, 1984 and Goldstein *et al*., 1991). It could be interpreted as the ability of the pith parenchyma to lose up to 50 per cent of its water content during the dry period while the chlorenchyma remained turgid and photosynthetically active (Goldstein *et al*., 1991). On the other hand, when the environmental conditions were favorable, the daily net CO_2 fixation rate increased three–fold in the driest month compared to the most humid (Pimienta–Barrios *et al*., 2002).

The photosynthetic rate was significantly higher in the treatment T_1 (conservatory house) (0.071 g), followed by shadenet house condition (T_3) which recorded photosynthetic rate of (0.067 g). The treatment open condition (T_2) recorded lowest photosynthetic rate of (0.060 g). The photosynthetic rate found to be maximum in *Monadenium lugardiae* (S_3) (0.0693 g) and minimum in *Haworthia cuspidata* (S_4) (0.0381 g). The interaction effect on photosynthetic rate was maximum in T_1 in *Monadenium lugardiae* (S_3) (0.074 g) and minimum value (0.030 g) in open condition (T_2) in *Haworthia cuspidata*. (S_4). The results are interpreted with the findings of Goldstein *et al.* (1991) who reported that the thickness of parenchyma tissue, where most of the water accumulated in the cladodes is stored, was notably reduced as the drought conditions progressed, especially in *Opuntia* mother cladodes exposed to full sunlight and with daughter cladodes. Barcikowski and Nobel (1984) reported that the lateral movement of water from the parenchyma tissue during the dry period would sustain stomatal opening keeping the photosynthetic tissue active at least during the initial period of drought. These traits

Table 1 : Influence of different growing environments on total chlorophyll (mg g^{-1}), carotenoid (mg g^{-1}) and chlorophyll stability index in different succulent species

Treatments	Total chlorophyll (mg g^{-1})						Total carotenoid (mg g^{-1})					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
T_1	0.576	0.726	0.677	0.564	0.549	0.574	0.181	0.191	0.181	0.191	0.171	0.224
T_2	0.460	0.437	0.450	0.364	0.538	0.424	0.133	0.133	0.124	0.147	0.162	0.141
T_3	0.545	0.519	0.577	0.491	0.538	0.522	0.154	0.175	0.177	0.165	0.165	0.157
T_4	0.531	0.560	0.580	0.533	0.546	0.442	0.159	0.156	0.146	0.151	0.157	0.192
Mean	0.528	0.511	0.571	0.488	0.543	0.490	0.157	0.164	0.157	0.164	0.164	0.178
		S.E.±			C.D. (P=0.05)			S.E.±			C.D. (P=0.05)	
T		0.00006			0.00012			0.00005			0.00011	
S		0.00007			0.00014			0.00007			0.00014	
T x S		0.00014			0.00029			0.00013			0.00028	

T_1 – Conservatory; T_2 –Open Condition ; T_3 – Shade net; T_4 - Glasshouse; S_1 – *Aloe juvenna*; S_2 –*Haworthia limifolia*; S_3 – *Monadenium lugardiae. ;* S_4 – *Haworthia cuspidata;* S_5 –*Echeveria* sp. S_6. *Echeveria prolifica*; T-Treatments; S- Succulent species

Table 2 : Influence of different growing environments on relative water content and photosynthetic efficiency (g) in different succulent species

Treatments	Relative water content (%)						Photosynthetic efficiency (g)					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
T_1	87.37	92.34	92.53	92.84	93.22	92.05	0.071	0.119	0.074	0.042	0.071	0.052
T_2	81.48	70.66	77.80	84.21	76.89	85.76	0.060	0.104	0.065	0.030	0.063	0.040
T_3	87.01	86.61	89.69	88.85	90.99	88.86	0.068	0.114	0.069	0.039	0.068	0.049
T_4	87.36	92.21	87.18	90.69	83.79	89.49	0.065	0.108	0.068	0.033	0.065	0.043
Mean	87.30	92.20	89.05	89.14	87.34	89.04	0.066	0.1113	0.069	0.0381	0.067	0.045
		S.E.±			C.D. (P=0.05)			S.E.±			C.D. (P=0.05)	
T		0.532			1.097			0.00058			0.00120	
S		0.651			1.343			0.00071			0.00147	
T x S		1.302			2.687			0.00143			0.00295	

T_1 – Conservatory; T_2 –Open Condition ; T_3 – Shade net; T_4 - Glasshouse; S_1 – *Aloe juvenna*; S_2 –*Haworthia limifolia*; S_3 – *Monadenium lugardiae. ;* S_4 – *Haworthia cuspidata;* S_5 –*Echeveria* sp. S_6. *Echeveria prolifica*;
T-Treatments; S- Succulent species

become significant for *Opuntias* and other succulent plants. Hence, the present study found that the succulent species *viz.*, *Haworthia limifolia*, *Monadenium lugardiae* and *Aloe juvenna* were the most suitable species for growing under conservatory house condition due to its high nocturnal CO_2 uptake and cell sap acidification which possess CAM metabolism.

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