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BIOCHEMICAL AND PHYSIOLOGICAL CHANGES OF DIFFERENT PLANTS SPECIES IN RESPONSE TO HEAT AND COLD STRESS

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ABSTRACT

The present study was conducted to determine the accumulation of proline and sugar in seven different plant species i.e. *Euphorbia resinifera*, *Echinocactus grusonii*, Aloe vera, *Crassula lacteal*, *Bryophyllum pinnatum*, *Yuca aloifolia* and *Sansevieria trifasciata*. Keeping in view the importance of environmental abiotic factors (heat, cold, salinity, dehydration, excessive osmotic pressure etc) on growth and performance of the plant, these species were subjected to heat and cold stress for 72 hours. The temperature was raised to 40ºC and maintained at 8ºC for heat and cold stress respectively. Water content decreased in all 7 species under heat and cold stress. Prominent increase in proline was recorded in *Yuca aloifolia* (10.17852µmolg^{-1}), Aloe vera (4.70448 µmolg^{-1}) followed by *Echinocactus grusonii* (1.51008µmolg^{-}1) when subjected to heat stress. Under cold stress low proline was observed in all plants except *Bryophyllum pinnatum* (0.29766 µmolg^{-1}). Prominent increase in sugar content under cold stress was recorded in *Euphorbia resinifera* (84.71645 µmolg^{-1}) followed by *Yuca aloifolia* (48.51765 µmolg^{-1}) under heat stress. Maximum decrease in sugar content was found in *Crassula lacteal* (4.61145 µmolg^{-1}) when subjected to heat stress. Maximum increase in proline and sugar content was noted when subjected to heat and cold stress, respectively.

Keywords: stress, accumulation, cytosolutes, proline, plants, sugar.

INTRODUCTION

Plants can be affected in many ways by a multitude of different factors that cause stress. Heat can cause shock and drastic cooling can cause plans to freeze and become too cold when they may be adapted to heat. Climate change in agriculture is interrelated processes. Sudden environmental changes including temperature have a great effect on quality, efficiency and productivity of plants. High temperatures can affect phenology, leaf expansion, internodes elongation and flower bud abortion (Trolinder and Shang, 1991). Low temperature limits the survival, productivity and geographical distribution of plants in different area of the world (Boyer, 1982).

Plants resort many adaptive environmental stresses such as dehydration, excessive osmotic pressure, heat and cold. These adaptive mechanisms include changes in the physiological and biochemical processes. Among them, the accumulation of compatible solutes according to the metabolic responses has drawn much attention. Adaptation to all these stresses is associated with metabolic adjustments that lead to the accumulation of several organic solutes like sugar, polyols, betaines and proline (Yancey *et al*. 1982).

There are a number of herbs and plants that have therapeutic and nutritional value. Aloe vera (medicinal aloe) is used in herbal medicine and its extracts may be useful in the treatment of wound and burn healing, minor skin infections, sebaceous cyst, diabetes and elevated blood lipids in humans (Wang and Wang, 2004) *Crassula lactea* is native to Africa. It becomes semi-postrate with time and can be used as a hanging basket (Court and Doreen, 1981). *Yuca aloifolia* is a drought tolerant plant and used as an accent behind beds and borders. *Sansevieria trifasciata* leaves are used to treat Herpes zoster. The warm juice of *S. trifasciata* leaves is used as a treatment for earache, pharyngitis and hoarsene. It is tolerant to salt and saline soil. This plant can inflict painful puncture wounds even through heavy clothing (Adams *et al*. 1968). *Euphorbia resinifera* contains a high concentration of resiniferatoxin and is used to develop a novel and powerful class of analgesics (Huxley *et al*. 1992). *Echinocactus grusonii* also known as Golden barrel cactus is one of the most recognizable cacti in the world. *Bryophyllum pinnatum* also known as *Kalanchoe pinnata* is a succulent plant. In traditional medicine, it has been used to treat ailments such as infections, rheumatism and inflammation. *Kalanchoe* extracts also have immuno suppressive effects. It is used as a traditional treatment for hypertention and kidney stones. Some of its spp. also showed insecticidal properties (Huxley, 1992).

Proline is a proteinogenic amino acid and plays an important role in the plants. It has an exceptional conformational rigidity and is essential for primary metabolism (Kemble and Macpherson, 1954). Observations in several plants indicate that free proline may protect the plants from stress (Van Swaaj *et al*. 1985). Proline protects membranes and proteins against the adverse effects of high concentrations of inorganic ions and temperatures extremes (Pollard and Jones, 1979). Sugars play a central role in plant life: they are produced by photosynthesis, transported to sink tissues, channeled to respiration or converted into storage compounds (lipids, starch, sucrose, fructans) which are eventually broken down into their constituent carbohydrates. It is conceivable that regulation of the metabolic processes involved is dependent upon the concentration of sugars (Elena *et al*. 2005).

Under stress condition changes occur in plant physiology and biochemical process to adapt it. The present study was conducted keeping in view the importance and effect of environmental abiotic factors on organic cytosolutes (proline and sugar) under stress conditions.

MATERIALS AND METHODS

Sample collection

The present study was conducted to investigate the effect of heat and cold stress on accumulation of proline and sugar in different plants. Seven different plant species i.e. *Euphorbia resinifera, Echinocactus grusonii*, Aloe vera, *Crassula lacteal, Bryophyllum pinnatum, Yuca aloifolia* and *Sansevieria trifasciata* were selected. The plants were collected from Nowshera, Professor Colony and Nursery of Horticulture Department, The University of Agriculture Peshawar.

Stress

After the identification of plants, they were brought to lab for In vitro studies. They were subjected to three treatments i.e. control, heat stress (40^0C) and cold stress (8^0C) for 72 hours.

Each specimen was placed in separate Petri dish and was tagged according to the name of plant, stress, time, temperature and date of collection. Following parameters were studied:

- Dry weight
- Water content
- Proline detection
- Sugar detection

METHODOLOGY

For proline and sugar extraction and qualification Singh *et al*. 1973 method was used.

RESULTS AND DISCUSSIONS

Apparent changes in samples under heat and cold stress

Tables 1 and 2 shows the apparent changes occurred in plant samples after giving the heat (40^0C) and cold (8^0C) stress for 72 hours. After 72 hours of temperature stress, apparent changes were observed. *Euphorbia resinifera, Echinocactus grusonii,* Aloe vera and *Yuca aloifolia* showed complete dryness under heat stress while *Crassula lacteal, Bryophyllum pinnatum* and *Sansevieria trifasciata* did not show significant dryness. Under cold stress only *Sansevieria trifasciata* showed prominent dryness.

These results indicated that plants with prominent dryness have less resistance to heat and cold stress with respect to those plants with no or less dryness. This may relate to the heat and drought stress on plants. Plants that are in hot and dry climate may have adaptations to deal with drought and heat better than a plant in a more temperate region (Fitter and Hay, 1987).

Table-1. Apparent changes in different plants under heat stress.

S. No.	Plant name	Apparent change
1	*Euphorbia resinifera*	+++
2	*Echinocactus grusonii*	+++
3	*Aloe vera*	+++
4	*Crassula lacteal*	-
5	*Bryophyllum pinnatum*	-
6	*Yucca aloifolia*	+++
7	*Sansevieria trifasciata*	-

(+)Sign shows apparent change while (–) sign shows no apparent change.

Table-2. Apparent changes in different plants under cold stress.

S. No.	Plant name	Apparent change
1	*Euphorbia resinifera*	-
2	*Echinocactus grusonii*	-
3	*Aloe vera*	-
4	*Crassula lacteal*	-
5	*Bryophyllum pinnatum*	-
6	*Yucca aloifolia*	-
7	*Sansevieria trifasciata*	+++

(+)Sign shows apparent change while (–) sign shows no apparent change.

Loss of water and dry weight

Water content was more reduced in plants under heat stress as compared to that under cold stress due to decrease in fresh weight as expressed by percent loss of water. The loss in water was calculated as given in Table-3. Maximum loss of water was recorded in Aloe vera (97.5%) due to The dry weight for each sample under heat and cold stress was also estimated (Table-3).

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Table-3. Loss of water content and dry weight of plants under Heat and Cold stress.

S. No.	Plant name	Heat stress		Cold stress	
		Dry weight (gm)	**% loss of water**	**Dry weight** (gm)	**% loss of water**
1	*Euphorbia resinifera*	0.32	92	2.23	44.3
2	*Echinocactus grusonii*	0.40	90	2.05	48.8
3	*Aloe vera*	0.10	97.5	1.29	67.8
4	*Crassula lacteal*	0.13	96.8	3.00	25
5	*Bryophyllum pinnatum*	0.39	90.25	2.81	29.8
6	*Yucca aloifolia*	0.81	79.8	2.50	37.5
7	*Sansevieria trifasciata*	0.33	91.8	3.39	15.25

Standard weight considered for all samples was 4 gm.

Proline content in different plants under heat and cold stress

Proline level increased in *Echinocactus grusonii*, Aloe vera, *Bryophyllum pinnatum*, *Yuca aloifolia* and *Sansevieria trifasciata* upon incubation at 40^0 C; however the increase in concentration was different for different plants. The highest level was recorded for *Yuca aloifolia* (32.8 folds) followed by Aloe vera (12.7 folds), *Echinocactus grusonii* (4.05 folds) *Sansevieria trifasciata* (2.57 folds) and *Bryophyllum pinnatum* (1.30 folds) respectively. While minimum increase was observed in *Bryophyllum pinnatum*. In contrast no increase in proline level was found in *Euphorbia resinifera* and *Crassula lacteal* with respect to control. Decrease in proline level was recorded in all plants except *Bryophyllum pinnatum* (0.29766 $\mu molg^{-1}$) under cold stress. From the context it can be speculated that *Euphorbia resinifera, Echinocactus grusonii*, Aloe vera, *Bryophyllum pinnatum, Yuca aloifolia* and *Sansevieria trifasciata* are tolerant to heat as compared to plants that produce little or no proline under heat stress.

The role of proline under various abiotic stresses has been reviewed by Kavi *et al*. 2005, who reported the dramatic accumulation of proline due to increase synthesis and decrease degradation under a variety of stress condition such as salt and drought in many plants. Proline accumulates in higher plants in response to abiotic and biotic stresses such as water stress and chilling stress (Taylor, 1996).

Table-4. Proline detection ($\mu molg^{-1}$) in different plants under heat and cold stress on fresh weight basis.

S. No.	Species	Sample control	Sample cold	Sample heat
1	*Euphorbia resinifera*	0.5445	0.000	0.53724
2	*Echinocactus grusonii*	0.37752	0.15972	1.51008
3	*Aloe vera*	0.37752	0.15972	4.70448
4	*Crassula lacteal*	0.22506	0.1815	0.17424
5	*Bryophyllum pinnatum*	0.13068	0.29766	0.17424
6	*Yucca aloifolia*	0.31218	0.16698	10.17852
7	*Sansevieria trifasciata*	0.27588	0.26136	0.71874

Sugar content in different plants under heat and cold stress

In *Euphorbia resinifera, Echinocactus grusonii, Crassula lacteal, Bryophyllum pinnatum, Yuca aloifolia* and *Sansevieria trifasciata* sugar concentration increased under cold stress (8^0 C), however increase in sugar level was different for different plants. The prominent increase was observed in *Crassula lacteal* (6 folds) followed by *Sansevieria trifasciata* (4 folds), *Bryophyllum pinnatum* (2.5 folds), *Euphorbia resinifera* (2.4 folds), *Echinocactus grusonii* (1.6 folds) and *Yuca aloifolia* (1.2 folds) respectively. On other hand decrease in sugar level was observed in Aloe vera with reference to control. Sugar level was decreased in *Sansevieria trifasciata* and *Euphorbia resinifera* under heat stress. It is concluded from the results that *Euphorbia resinifera, Echinocactus grusonii, Crassula lacteal, Bryophyllum pinnatum, Yuca aloifolia* and *Sansevieria trifasciata* are tolerant to cold stress as compared to the plants that produce little or no sugar under cold stress.

These results support the findings of Sasaki *et al*. 1996 (Sasaki *et al*. 1996), who reported that under natural conditions, soluble sugars increase during the onset of winter when plants are subjected to low temperatures. He further observed that sugars content also increase during cold acclimation under artificial conditions.

Table-5. Sugar detection (μmolg^{-1}) in different plants under heat and cold stress on fresh weight basis.

S. No.	Species	Sample control	Sample cold	Sample heat
1	*Euphorbia resinifera*	25.7635	84.71645	19.0953
2	*Echinocactus grusonii*	5.04445	8.29195	8.1404
3	*Aloe vera*	9.24455	9.0497	16.2375
4	*Crassula lacteal*	3.897	23.18715	4.61145
5	*Bryophyllum pinnatum*	7.90225	19.4417	8.59505
6	*Yucca aloifolia*	23.53355	29.03265	48.51765
7	*Sansevieria trifasciata*	9.89405	39.7927	9.4394

CONCLUSIONS

The plants under study showed different response when kept under heat or cold stress. It was concluded that maximum increase in proline content occurs when subjected to heat stress, while maximum increase in sugar content occurs if subjected to cold stress. Plants with increased sugar level showed more tolerance to cold as compared to plants having little or no sugar while plants showed more tolerance to heat due to increase in proline level.

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