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Levels of purple pigments in leaves of some weeds under natural high irradiance

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Abstract

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The amounts of purple pigments including anthocyanins and betalains in leaves of some local weed species growing under natural habitat were studied and higher levels were found in C_4 plants than in C_3 plants. The higher levels in C_4 plants may be due to their higher photosynthetic efficiency. The possible involvement of photosynthesis in high irradiance reaction (HIR) response of purple pigment synthesis is discussed.

Introduction

Purple pigmentation has been reported as a light dependent process and as a response of HIR in plants (Piattelli 1976, Wong 1976, Mancinelli and Rabino 1978, Mancinelli 1983). The HIR responses have been shown to be mediated by phytochrome (Hartmann 1966, Lange et al. 1971, Smith 1970). It has also been suggested that HIR responses may involve an interaction between photosynthesis and phytochrome (Schneider and Stimson 1971, 1972). However, this involvement of photosynthesis in HIR responses has been considered negligible by some researchers (Mancinelli et al. 1975). Thus the involvement of photosynthesis in HIR responses has become a question of debate. The observations made in the present study on purple pigmentation in leaves under natural habitat, it is felt, may be helpful in the progress of understanding the HIR responses.

Materials and methods

Leaves of the annual herbal species including *Portulaca oleracea* L., *Alternanthera sessilis* R. Br., *A. pungens* H. B. K., *Gomphrena decumbens* Jacq., *Euphorbia hirta* L., *E. hypercifolia* L., *E. thymifolia* L., *Mollugo lotoides* O. Kze., *M. oppositifolia* L., and *Lippia nodiflora* Mich., growing under natural habitat in the University of Hyderabad campus, exhibited either green (normal) or varying degrees of purple pigmentation during summer months of March to May. The purple pigmented plants grew on red soils with low moisture levels and were exposed to high natural irradiance (950 W m^{-2}, Li-Cor Light meter). Pigmentation was greater in the mature and fully expanded leaves than in young leaves of the plant. The purple pigments were extracted from fully expanded leaves with 15 ml of 1% (V/V) HCl in methanol and estimated according to Mancinelli et al. (1975). Chlorophylls were estimated according to Arnon (1949). Soil moisture and leaf moisture levels were determined after drying at 120 °C and 80 °C respectively. The values reported are mean of five replications.

Results and discussion

Various densities of purple pigmentation were observed in some local dicotyledonous weed species subjected to high natural irradiance under natural habitat. Although these species have diverse taxonomy, physiologically they can be grouped as C_3 and C_4 plants with respect to their mode of photosynthetic carboxylations. In C_3 plants pigmentation was very low and was confined mostly to the basal leaves, even though these were growing under similar environmental conditions. The densities were very high in the C_4 species (Table 1). An inverse correlation between soil, plant water status and purple pigmentation was also observed.

Table 1. Moisture and pigment levels in leaves of the weeds growing on soils with different moisture levels.

Plant species		Soil moisture content (%)	Leaf moisture content (%)	Leaf Ψ (– bars)	Chlorophyll content (mg g^{-1} (fresh wt.)	Anthocyanins (A_{530}–0.33 A_{657})
C_4 Plants						
Portulaca oleracea	green	12.52	92.4	– 4.50	1.19±0.09	0.44±0.02
	purple	4.26	83.7	– 7.42	0.72±0.06	1.56±0.16
Alternanthera pungens	green	8.82	79.8	– 6.16	2.22±0.20	–
	purple	4.26	72.8	–10.80	1.26±0.40	1.05±0.07
Gomphrena decumbens	green	9.20	89.1	– 4.81	1.60±0.08	–
	purple	5.40	62.1	– 9.46	1.20±0.07	0.71±0.08
Euphorbia hypercifolia	green	8.82	68.0	– 6.62	2.15±0.06	–
	purple	4.26	63.0	–10.75	1.53±0.12	0.85±0.06
E. thymifolia	green	8.82	73.5	– 6.42	1.80±0.09	–
	purple	6.41	63.2	– 8.82	1.56±0.15	0.98±0.02
Mollugo lotoides	green	9.20	88.1	– 5.46	1.54±0.12	–
	purple	5.40	69.7	– 8.92	1.32±0.09	0.65±0.03
C_3 Plants						
Mollugo oppositifolia	green	9.20	86.7	– 5.68	1.21±0.08	–
	purple	4.26	65.4	– 9.45	1.05±0.06	0.42±0.01
Lippia nodiflora	green	16.86	90.3	– 4.80	1.43±0.03	–
	purple	5.94	79.5	– 8.64	1.02±0.08	0.24±0.02
Alternanthera sessilis	green	9.20	87.4	– 5.32	1.38±0.10	–
	purple	5.40	72.3	– 9.46	1.14±0.05	0.21±0.06

The nature and operational state of photoreceptor pigments of HIR responses of plant photomorphogenesis have been a subject of much recent speculation. Although several models have been proposed to explain the HIR responses, none of the current hypotheses has reached the point of providing a reasonable, coherent and unified interpretation of HIR phenomena (Mancinelli and Rabino 1978). The irradiations required to elicit full expression of the HIR responses have been reported to be within the spectral range of those effective in photosynthesis. Hence it is speculated that photosynthesis may contribute substrates and sources of energy required for the expression of HIR responses (Siegelman and Hendricks 1958, Creasy 1968, and Schneider and Stimson 1971, 1972). Evidence showed the utility of photosynthetic reductant power NADPH and reduced ferredoxin on the P_{fr}/P_{tot} ratio of seedlings under continuous irradiation. From the observations made at the field level, it is clear that the high levels of anthocyanins were observed in C_4 plants, possessing the C_4 dicarboxylic acid pathway of carbon fixation. Photochemically the C_4 plants are characterised by higher levels of P_{700}, chlorophyll *a* and high rates of cyclic photophosphorylation; and their light saturation point is also very high being near to full day sunlight when compared to C_3 plants (Black and Mayne 1970). Since PSI and cyclic photophosphorylation are known to be resistant to severe water stress condition (Hsiao 1973), the observed high anthocyanin levels in plants on soils with low moisture content may evidence the involvement of photosynthesis in the synthesis of anthocyanins. The involvement of cyclic photophosphorylation in the HIR response of anthocyanin synthesis was demonstrated with inhibitor studies (Schneider and Stimson 1971). However, the role of these inhibitors in other metabolic pathways was also critically discussed (Mancinelli et al. 1975). Thus, the observations made at the field level on anthocyanin pigmentation mostly in some C_4 weeds may provide evidence for the involvement of photosynthesis in HIR responses of photomorphogenesis.

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