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EFFECT OF HYPERTHERMIA ON THE ECOPHYSIOLOGY OF FERNS IN THE CONTEXT OF CLIMATE CHANGE

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Abstract:

Drought is a major abiotic stress that affects plant growth and productivity. In this study, we investigated the ecophysiological responses of two fern taxa, *Dryopteris cochleata* and *Hypodematium crenatum*, to drought stress. We evaluated the photosynthetic pigments and cell membrane permeability, and examined their stability under hyperthermia stress. Our results showed that both fern taxa were able to maintain their photosynthetic pigments under hyperthermia stress. However, their cell membrane permeability increased significantly under drought stress, with a greater increase observed in *Dryopteris cochleata* compared to *Hypodematium crenatum*. These findings suggest that *Hypodematium crenatum* may have a better ability to cope with drought stress compared to *Dryopteris cochleata*. Hyperthermia, or high temperature stress, can have negative effects on the ecophysiology of ferns, including a decrease in photosynthetic pigments and membrane stability. These findings are particularly important in the context of climate change, as rising temperatures are expected to become more frequent and intense in many regions of the world. These studies emphasize the importance of mitigating the effects of climate change in order to preserve the ecological roles and functions of ferns and other plant species.

Key words: *Dryopteris cochleata*, *Hypodematium crenatum*, Fern, Hyperthermia, Climate change, Cell membrane stability.

Introduction:

Drought is a major abiotic stress that affects plant growth and productivity. Ferns are an important group of plants that are adapted to various environmental conditions, including drought stress. The ecophysiological responses of ferns to drought stress are not well understood. In this study, we investigated the photosynthetic pigments and cell membrane permeability of two fern taxa, *Dryopteris cochleata* and *Hypodematium crenaturn*, under drought stress.

Higher plants are known to manifest a wide spectrum of thermal tolerance. Many of the metabolic changes triggered are concerned with heat injury while a few are associated with heat tolerance. Ecological studies of pterdophytes in India were initiated by Bir (1963) who gave the altitudinal distribution of the pteridophytic flora of hills in N.W. Himalayas. Panigrahi & Patnaik (1968) in their studies of the polypodiaceae of eastern India investigated ecological aspects of pteridophytes of this region.

Ferns in general require low temperature for their optimum growth. In spite of xeric and hostile climate, a good number of ferns are occurring in various parts of Rajasthan.Sharma & Bohra (1977) were the first to study this aspect of the pteridophytic flora of Rajasthan when they carried out a survey of the year-round growth of pteridophytes at Mt. Abu. They also suggested possible modes of perennation during severe period of drought conditions of this region. Sharma et al. (1977) have investigated the possible mechanism of heat and drought resistance of *Actiniopteris* and *Adiantum* the two widely distributed ferns of Rajasthan. These authors suggested that both the ferns are able to resist heat and drought conditions because of the high quantity of bound water.

Kaur & Yadav (1985) worked out mechanism of drought endurance of some homosporous ferns of Rajasthan. Malik & Bhardwaja (1986), Yadav & Bhardwaja (1983) in their investigation of fern genus Athyrium recorded variations in drought resistance of three species of this genus occurring at Mt. Abu, Rajasthan. These authors concluded that drought resistance in plants is directly dependent on pigment stability and cell membrane permeability.

Bhardwaja (1988) has discussed stress response in Marsileaceae in relation to its evolutionary perspective. Sharma & Rathore (1988) investigated proline contents during stress and non-stress conditions in 11 species of ferns of Rajasthan. These authors confirmed that drought resistant ferns posses more amount of proline than the aquatic or moisture loving plants. They further concluded that proline influences stress tolerance in ferns probably through its effect on the degradation of chlorophylls and accumulation of carotenoids.

Cell membrane stability under the increasing temperature in Rajasthan species of Ophioglossum has been worked out by Yadav & Bhardwaja (1994). The role of some xerophytic ferns in soil conservation in Rajasthan has been reported by Yadav (1997). Tripathi (2002) has investigated this aspect for some ferns and fern allies of Rajasthan. He concluded that heat and drought resistance in these ferns of Rajasthan is associated with the stability of cell membrane, higher vacuolar water and higher proline content. Kothari & Yadav (2003) studied cell membrane stability of some ferns of Rajasthan.

Very few efforts have been made to Investigate the variability in thermal tolerance of these hygrophyllous fern species (Kaur & Yadav 1985, Malik & Bhardwaja 1986, Sharma et, al. 1977, Bohra, et al. 1979, Yadav and Bhardwaja 1983, 1994). Factors responsible for heat sensitivity and tolerance in ferns cannot be identified in absence of such studies. Present communication embodies the results of effect of hyperthermia (40°C and 50°C) on stability of photosynthetic pigments in two ferns of Rajasthan.

Material and method:

Fresh leaves of *Dryopteris cochleat* and *Hypodematium crenaturn* were taken as experimental material. Thermal treatments of 40°C and 50°C were given according to Sullivan (1967) Observations were made for membrane permeability after an interval of 1h, 2h, & 4h temperature treatments, photosynthetic pigments (total chlorophyll and caretenoids) were measured according to Robbielen's method (1957).Efflux of soluble sugars and proteins was taken as the criterion of membrane permeability (Kalayears 1958) Sugars and proteins were measured according to Yem & Willis (1954) and Lowry, *et al*. (1952) respectively.

Observation:

We evaluated the photosynthetic pigments and cell membrane permeability of *Dryopteris cochleata* and *Hypodematium crenatum* under drought stress. Among various metabolic changes underlying the mechanism of heat and drought tolerance of two taxa, mentioned are made for the effect of hyperthermia on total chlorophylls and carotenoids of these two taxa of Rajasthan. The data have been presented in Table -1-4 and Text Fig -1-5.

A perusal of Table -3 and text figures 3-4 reveals that both species exhibit significant variations in thermal stability of their photosynthetic pigments. Thus, an hour's treatment at 40°C led to more chlorophyll degradation (11.5%) in *Hypodematium crenatum* than *Dryopteris cochleata* (10.48 %) . 4 hour's treatment at 40°C also showed more chlorophyll degradation (25.18%) in *Hypodematium crenatum* than *Dryopteris cochleata* (25.07%) .A temperature treatment of 50°C for four hours led to further loss of total chlorophyll content which was comparatively more in *Dryopteris cochleata* (50.18%) compared to *Hypodematium crenatum* (45.79 %).

Data pertaining to carotenoid contents in response to specified periods of temperature treatment are presented in Table -4and figures 3 and 4. It may be observed from these data that Actinopteris radiata (11.22%), *Hypodematium crenatum* (9.98%) and *Dryopteris cochleata* (9.29%) show significant degradation in their carotenoid contents after 1 hour treatment at 40°C temperature. Almost similar pattern of carotenoid degradation has been observed at different time periods of 50°C temperature treatment. An inverse relationship in the degradation pattern of the two photosynthetic pigments was evident in both taxa.

Leaves of mature plants of both the selected ferns of Rajasthan were treated at different temperatures for specific periods. The data relating to efflux of soluble sugars, proteins as criteria of membrane permeability (Kaloyears, 1958) are presented in Table-4. Cell membrane permeability increased significantly under drought stress, with a greater increase observed in *Dryopteris cochleata* compared to Hypodematium crenatum. This indicates that *Hypodematium crenatum* may have a better ability to cope with drought stress compared to *Dryopteris cochleata*.

Table 1photosynthetic pigments (mg/gfw) in leaves of 2 fern taxa of Rajasthan

Sr.no.	Taxa	Chl a	Chl b	Total chl	Carotenoids
1	*Dryopteris cochleata*	1.106	0.86	2.02	0.443
2	*Hypodematium crenatum*	1.162	2.136	2.366	0.445

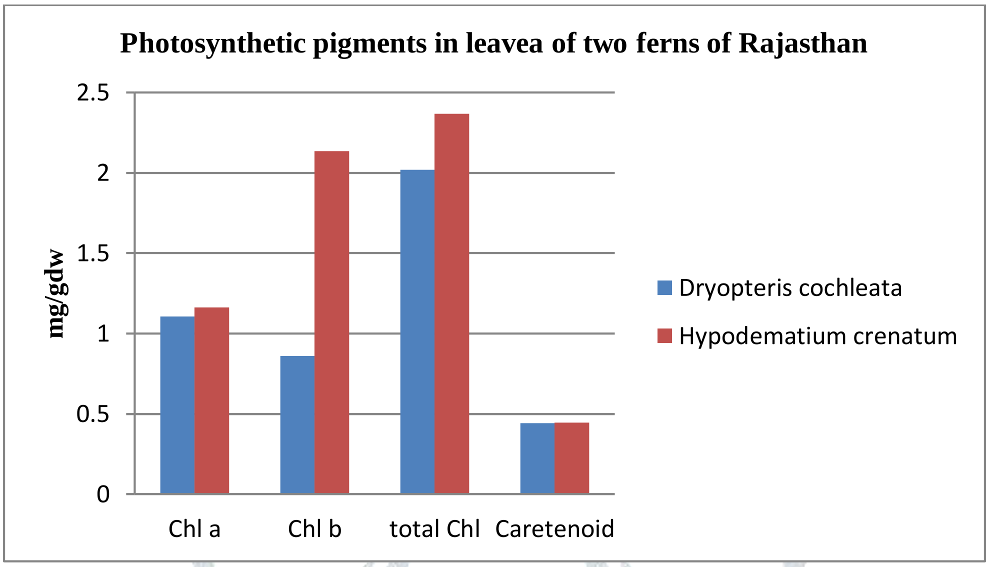

Figure 1 photosynthetic pigments in leavea of two ferns of Rajasthan

Table 2 Stability of photosynthetic pigments (total chlorophyll) in leaves of some fern taxa of Rajasthan at various temperature regimes for a specified period of time (values represented as % degradation)

Sr no.	Species	40°C			50°C		
		1h	2h	4h	1h	2h	4h
1	*Dryopteris cochleata*	11.15	21.86	25.18	16.82	4.18	50.18
2	*Hypodematium crenatum*	10.48	19.07	24.77	12.06	35.779	45.79

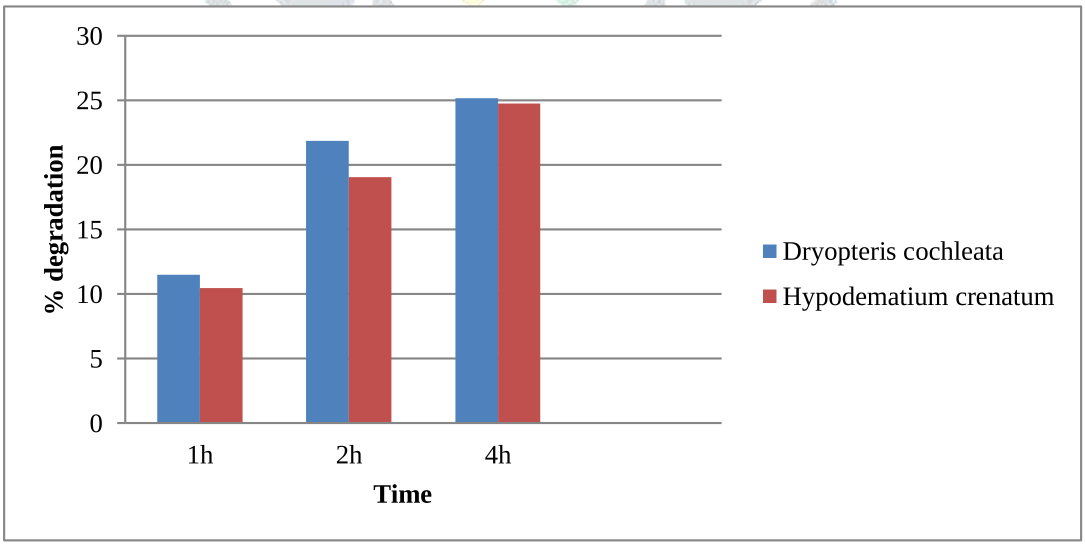

Figure 2 Stability of photosynthetic pigments (total chlorophylls) in leaves of two fern taxa of Rajasthan at 40°c temperature regimes for a specified period of time (values represented as % degradation)

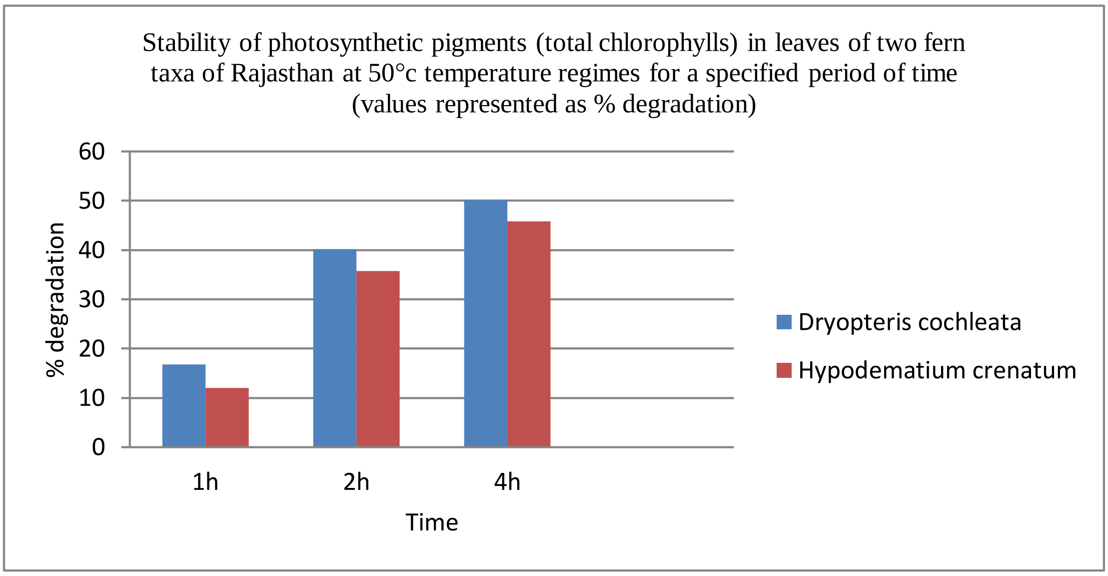

Figure 3 stability of photosynthetic pigments (total carotenoid) in leaves of two fern taxa of Rajasthan at 50°c temperature regimes for a specified period of time (values represented as % degradation)

Table3 stability of photosynthetic pigments (total carotenoid) in leaves of 2 fern taxa of Rajasthan at various temperature regimes for a specified period of time (values represented as % degradation)

Sr no.	Species	40°C			50°C		
		1h	2h	4h	1h	2h	4h
1	*Dryopteris cochleata*	9.29	12.91	20.35	17.60	32.56	38.83
2	*Hypodematium crenatum*	9.98	14.14	25.07	18.06	35.79	50.79

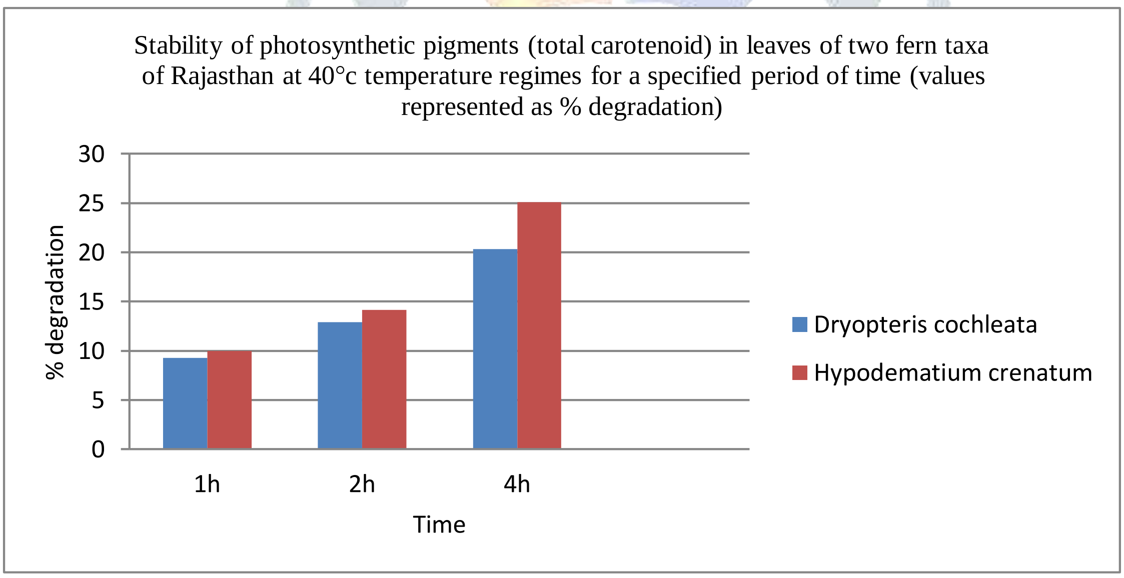

Figure 4 Stability of photosynthetic pigments (total carotenoid) in leaves of two fern taxa of Rajasthan at 40°c temperature regimes for a specified period of time (values represented as % degradation)

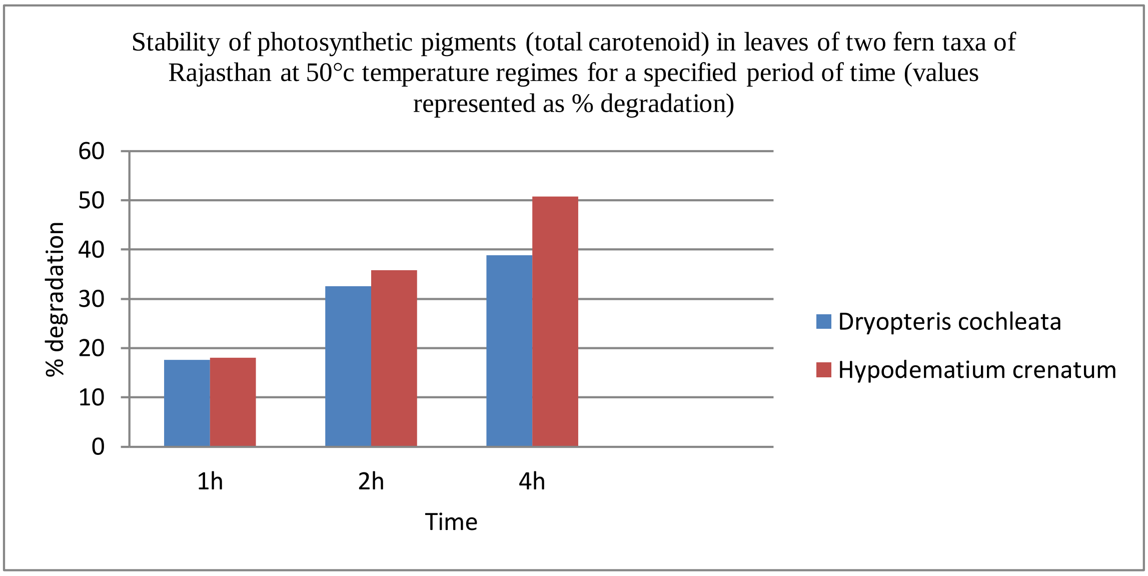

Figure 5 Stability of photosynthetic pigments (total carotenoid) in leaves of two fern taxa of Rajasthan at 50°c temperature regimes for a specified period of time (values represented as % degradation)

Table 4 Effect of hyperthermia on cell membrane permeability in leaves of two fern taxa of Rajasthan for a specified period of time (values represented as % of control) soluble proteins and sugars in leachates

Sr no.	Species		40°C			50°C		
			1h	2h	4h	1h	2h	4h
1	*Dryopteris cochleata*	Proteins	6.92	10.93	25.68	14.98	23.63	37.62
		Sugars	15.42	25.23	44.33	17.24	27.32	47.29
2	Hypodematium crenatum	Proteins	6.89	9.97	20.98	14.68	23.31	32.91
		Sugars	9.89	16.91	20.36	14.74	25.58	33.61

Discussion:

Among various metabolic changes underlying the mechanism of heat and drought tolerance of the selected forms of Rajasthan. Effect of hyperthermia on total chlorophyll, carotenoids and cell membrane permeability has been studied during the present investigations.Thus, inverse relationship in the degradation pattern of the two different types of photosynthetic pigments namely chlorophylls d carotenoids at higher temperatures is evident in ferns of Rajasthan. Thermal decay in photosynthetic pigments is a limiting factor for plant growth and supra optimal condition (Mothos 1964). Bohra et al. (1979) and Yadav & Bhardwaja (1983) concluded that xerophytic species of ferns possess higher carotenoid contents and show leaser degradation chlorophylls.

Membrane damage is regarded to be primary cause of thermal injury in plants (Berry et al 1975). A positive correlation between membrane stability and thermal tolerance has been observed in some Rajasthan ferns (Kaur & Yadav, 1985; Yadav & Bhardwaja, 1994, Kothari & Yadav 2003). Zhang et al. (2017) investigated the response of two fern species to drought stress by analyzing various physiological and biochemical parameters, including photosynthetic pigments, membrane stability, and antioxidant activity. They found that both species exhibited a decrease in photosynthetic pigments and membrane stability, as well as an increase in antioxidant activity, in response to drought stress.

In the present studies under drought stress, of two taxa showed that their cell membrane permeability increased significantly, which may indicate damage to their cell membranes. This damage can lead to leakage of solutes, including soluble proteins and sugars, from the cells. These observations support the view that the survival and growth period of these taxa of ferns of Rajasthan is linked to their differential tolerance to the successively increasing temperatures of the habitat (Yadav & Bhardwaja, 1983). Our findings are consistent with those of Zhang et al. (2017) in terms of the decrease in photosynthetic pigments and membrane stability under drought stress. However, our study focused on the response of ferns to hyperthermia, or high temperature stress, rather than drought stress specifically. Despite the differences in stressors, our results suggest that the two fern species we studied exhibit similar responses to hyperthermia as they do to drought stress. a study done by Wang et al. (2020) investigated the response of another fern species to drought stress by analyzing its leaf water potential, gas exchange, and photosynthetic pigments. They found that the fern species exhibited a decrease in leaf water potential and gas exchange, as well as a decrease in photosynthetic pigments, under drought stress.

Present study results also suggest that *Hypodematium crenatum* may have a better ability to cope with drought stress compared to *Dryopteris cochleata*, as it had a lower increase in cell membrane permeability under drought stress. Present study with respect to previous studies highlight the importance of understanding the ecophysiology of fens under stress conditions, and how they respond to different stressors. Our findings suggest that hyperthermia can have similar effects on ferns as drought stress, which may have implications for the survival and distribution of fern species in the face of global climate change.

Conclusion:

Our study suggests that hyperthermia, or high temperature stress, can have negative effects on the ecophysiology of ferns, including a decrease in photosynthetic pigments and membrane stability. These findings are particularly important in the context of climate change, as rising temperatures are expected to become more frequent and intense in many regions of the world, Ferns play an important role in many ecosystems, and their sensitivity to temperature stress could have significant implications for their distribution and abundance in the future. Furthermore, ferns are often used as indicators of ecosystem health, and changes in their ecophysiology could serve as early warning signs of environmental stress.

Overall, our study highlights the need for further research into the response of ferns to different stressors, including both drought and hyperthermia, in order to better understand their ecophysiology and inform conservation efforts. Additionally, our findings emphasize the importance of mitigating the effects of climate change in order to preserve the ecological roles and functions of ferns and other plant species.

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