IECAG 2021

Proceedings

Response of Hardy Ferns to Drought Stress †

Piotr Salachna *, Iga Siemińska, Anna Pietrak, Agnieszka Zawadzińska, Rafał Piechocki and Roksana Dymek

Department of Horticulture, West Pomeranian University of Technology, 3 Papieża Pawła VI Str., 71-459 Szczecin, Poland; si42992@zut.edu.pl (I.S.); pa37778@zut.edu.pl (A.P.); agnieszka.zawadzinska@zut.edu.pl (A.Z.); rafal.piechocki@zut.edu.pl (R.P.); dr42675@zut.edu.pl (R.D.)

* Correspondence: piotr.salachna@zut.edu.pl; Tel.: +48-91-4496-35

† Presented at the 1st International Electronic Conference on Agronomy, 3–17 May 2021; Available online: https://sciforum.net/conference/IECAG2021

Abstract: Drought-tolerant perennials are intensively sought after plants for decorative purposes. Perennial ferns are cold hardy cultivars that are great for shady to partially shaded areas of the garden but their response to drought stress is unknown. In this study, we examined how reduced watering altered growth of *Athyrium niponicum* 'Red Beauty', *Cyrtomium fortunei* 'Clivicola', *Dryopteris atrata*, *Dryopteris erythrosora*, *Dryoperis filix-mas*, *Dryoperis filix-mas* 'Linearis Polydactylon', and *Polystichum setiferum* 'Proliferum' in comparison with optimal watering conditions. From among the seven fern taxa, *Athyrium niponicum* 'Red Beauty' and *Dryoperis filix-mas* turned out the most sensitive to reduced watering and they demonstrated leaf browning and drying. Little visual leaf damage was observed in *Cyrtomium fortunei* 'Clivicola', *Dryopteris erythrosora*, and *Polystichum setiferum* 'Proliferum'.

Keywords: garden ferns; perennials; drought tolerance; vascular plants

Citation: Salachna, P.; Siemińska, I.; Pietrak, A.; Zawadzińska, A.; Piechocki, R.; Dymek, R. Response of Hardy Ferns to Drought Stress. *Proceedings* **2021**, *68*, x. https://doi.org/10.3390/xxxxx

Published: date

1. Introduction

Despite taking up the least space, growing ornamental plants is the most profitable branch of plant production [1]. Thanks to rising financial capability of buyers and increasing popularity of urban gardening, the sectors of bedding plants and perennials are developing particularly quickly [2,3]. Unfortunately, the market of ornamental plants deteriorated because of global pandemic and related restrictions [4,5]. The crisis spurred a search for new ways of increasing demand, and one of them is introducing new plants that may seem interesting to the customers. The species and cultivars of hardy garden ferns are still relatively poorly known but they can be attractive ornamental plants grown on balconies, in parks and green areas [6]. They comprise numerous taxa differing in height, habit, and leaf shape and color. Additionally, many garden ferns retain their decorative foliage in the winter. Apart from their decorative value, many fern species are edible and medicinal plants [7].

The global climate change that is taking place today often results in water shortages and droughts [8]. Water becomes an increasingly scarce resource, especially in large urban agglomerations, and this requires changes in the care of urban green areas [9]. For this reason, attention is paid to the criteria of selecting ornamental plants that retain their decorative value despite drought stress [10]. Plant response to water shortage varies between species and even cultivars and depends on the intensity and duration of the stress [11]. Therefore, many experiments are carried out to identify ornamental plants featuring increased resistance to unfavorable urban conditions [11,12].

In general, ferns grown in the soil as ornamental plants thrive in shaded and moist sites. However, some species and cultivars seem tolerant to water shortage and are capable of adapting to adverse environmental conditions [13]. This makes studies on sensitivity of different hardy garden fern genotypes to abiotic stress highly justified, as they should allow for pinpointing the most tolerant species and cultivars. The aim of this study was to compare the growth and decorative value of seven taxa of ground ferns cultivated under optimal conditions and under drought stress. We also determined the long term effect of drought on plant quality by assessing their condition after winter.

2. Materials and Methods

The study was carried out in a plastic tunnel set up by the Department of Horticulture at the premises of the West Pomeranian University of Technology in Szczecin, and it involved the following taxa of hardy ferns from Dryopteridaceae family: *Athyrium niponicum* 'Red Beauty', *Cyrtomium fortunei* 'Clivicola', *Dryopteris atrata*, *Dryopteris erythrosora*, *Dryoperis filix-mas*, *Dryoperis filix-mas* 'Linearis Polydactylon' and *Polystichum setiferum* 'Proliferum'. The plants were propagated in vitro. The plants grew in pots of 1.7 L capacity filled with peat substrate TS1 (pH 6.0) supplemented with PG Mix fertilizer at a dose of 1.0 kg m^{-3}. For 30 days the plants were cultivated in the substrate of variable soil water content (SWC): 80% SWC (control) and 30% SWC (drought). On the last day of drought we measured plant height from the ground level to its highest point, plant width at its widest point, and leaf greenness index in SPAD (Soil Plant Analysis Development) units with the Chlorophyll Meter SPAD-502 optical apparatus (Minolta, Japan). After the drought period ended, all plants were watered in the same way (80% SWC). Long-term impact of drought on plant quality was assessed 181 days after the stress cessation. The bonitation score from 1 to 5 was assigned by three independent researchers. Each variant comprised a total of four plants and four repetitions.

3. Results and Discussion

We found that plant response to drought stress largely depended on the species and cultivar. All plants exposed to drought were lower than those growing under optimal conditions. The greatest growth reduction caused by water shortage was noted in *Dryoperis filix-mas* (48%), and the smallest in *Dryopteris erythrosora* (25%). The order of the response intensity was as follows: *Dryoperis filix-mas* > *Athyrium niponicum* 'Red Beauty' > *Dryopteris filix-mas* 'Linearis Polydactylon' > *Polystichum setiferum* 'Proliferum' > *Cyrtomium fortunei* 'Clivicola' > *Dryopteris atrata* > *Dryopteris erythrosora.* The plants exposed to drought had a smaller diameter than those grown under optimal conditions (80% SWC). The difference in comparison with control was the greatest (37%) for *Dryoperis filix-mas*, and the smallest (11%) for *Polystichum setiferum* 'Proliferum'. The order of plant width differences from control was as follows: *Dryoperis filix-mas* > *Dryopteris atrata* > *Athyrium niponicum* 'Red Beauty' > *Dryopteris erythrosora* > *Cyrtomium fortunei* 'Clivicola' > *Dryopteris filix-mas* 'Linearis Polydactylon' > *Polystichum setiferum* 'Proliferum'. Drought stress clearly decreased leaf greenness index, and the drop was the greatest (82%) in *Dryopteris filix-mas* 'Linearis Polydactylon', and the smallest (51%) in *Polystichum setiferum* 'Proliferum'. For all investigated plants the order leaf greenness drop was as follows: *Dryopteris filix-mas* 'Linearis Polydactylon' > *Athyrium niponicum* 'Red Beauty' > *Dryoperis filix-mas* >*Dryopteris* erythrosora > *Dryopteris atrata* > *Cyrtomium fortunei* 'Clivicola' > *Polystichum setiferum* 'Proliferum'.

Of the examined fern taxa, the one most sensitive to drought was *Dryoperis filix-mas*. Two taxa, *Cyrtomium fortunei* 'Clivicola' and *Dryopteris erythrosora* demonstrated relative tolerance to water scarcity, as despite limited watering they retained their turgor and did not dry. *Cyrtomium fortunei* 'Clivicola' and *Dryopteris erythrosora* may be better adapted to drought stress due to delayed action of the stress factor in the cells and/or tolerance to the stress factor [14]. Drought tolerance consisting in avoidance of dehydration may result from specific adaptations of their leaves, which show succulent traits [15]. Leaf blades of *Cyrtomium fortunei* 'Clivicola' and *Dryopteris erythrosora* are stiffer and thicker than those of the other investigated plants. More extensive research on water storage capacity in fern rhizomes and leaves and the assessment of their gas exchange parameters may allow for better understanding of the resistance and tolerance mechanisms the ferns employ when challenged with water stress [7,13,16].

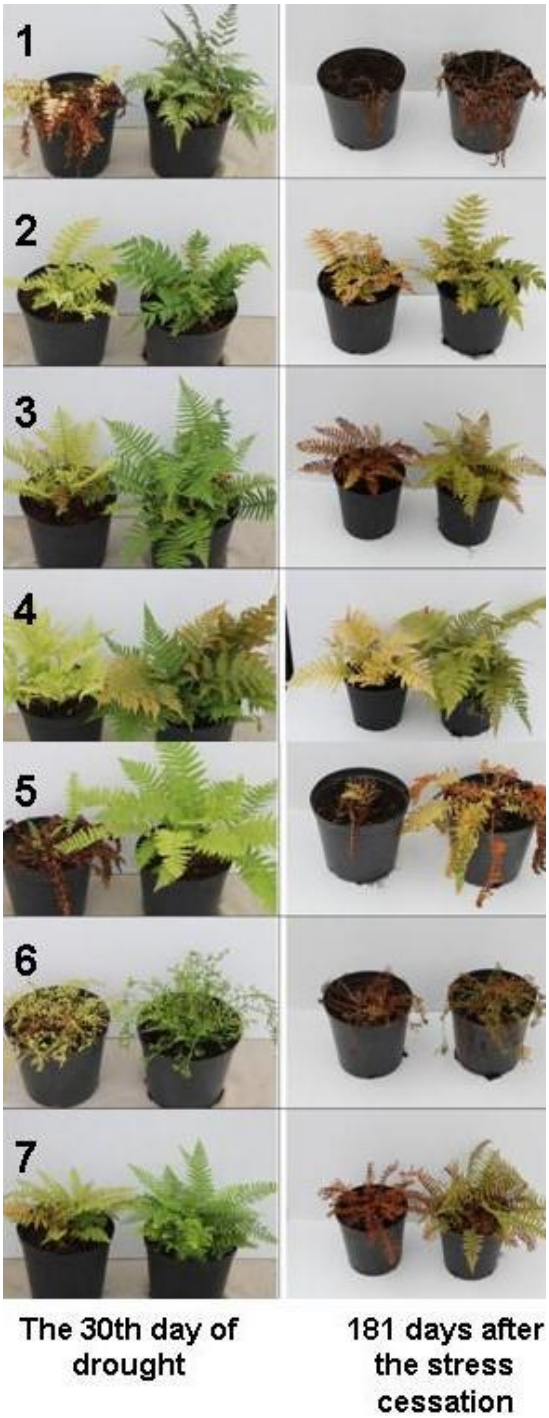

Figure 1. External appearance of the investigated fern taxa on the 30th day of drought and 181 days after the stress cessation. 1. *Athyrium niponicum* 'Red Beauty'; 2. *Cyrtomium fortunei* 'Clivicola'; 3. *Dryopteris atrata*; 4. *Dryopteris erythrosora*; 5. *Dryoperis filix-mas*; 6. *Dryoperis filix-mas* 'Linearis Polydactylon'; 7. *Polystichum setiferum* 'Proliferum'. Left: stress; Right: control.

The visual score assessment after winter revealed that even 181 days after treatment, the ferns still showed visible signs of summer drought. Among ferns experiencing water shortage the lowest bonitation score (2.0) was reached by *Dryoperis filix-mas*, and the highest (4.3) by *Polystichum setiferum* 'Proliferum'. The bonitation score was increasing in the following order: *Dryoperis filix-mas* > *Dryopteris filix-mas* 'Linearis Polydactylon' > *Dryopteris atrata* > *Athyrium niponicum* 'Red Beauty' > *Dryopteris erythrosora* > *Cyrtomium fortunei* 'Clivicola' > *Polystichum setiferum* 'Proliferum'.

Table 1. Long-term effects of drought (assessed 181 days after the stress cessation) on visual score of seven fern taxa.

Fern taxa	Visual Score
Athyrium niponicum 'Red Beauty'	3.7
Cyrtomium fortunei 'Clivicola'	4.0
Dryopteris atrata	3.5
Dryopteris erythrosora	3.8
Dryoperis filix-mas	2.0
Dryoperis filix-mas 'Linearis Polydactylon'	3.3
Polystichum setiferum 'Proliferum'	4.3

4. Conclusions

We demonstrated different responses of individual hardy fern taxa to water shortage. The stress negatively affected plant height and width, the leaf greening index, and decorative value after winter as assessed with the bonitation scale. *Athyrium niponicum* 'Red Beauty' and *Dryopteris filix-mas* were found the most sensitive to drought, while *Cyrtomium fortunei* 'Clivicola', *Dryopteris erythrosora*, and *Polystichum setiferum* 'Proliferum' showed moderate resistance to this stress. The results of our study may be helpful in selecting hardy fern showing tolerance or resistance to drought.

Author Contributions: Conceptualization, P.S.; methodology, P.S. and A.Z.; formal analysis, P.S.; A.P., R.D. and I.S.; investigation, P.S.; I.S. and R.P.; writing, P.S.; A.Z.; A.P. and R.P.; project administration, P.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hovhannisyan, V.; Khachatryan, H. Ornamental Plants in the United States: An Econometric Analysis of a Household-Level Demand System. *Agribusiness* **2017**, *33*, 226–241.
2. Chakrapani, K.; Balraj, G.; Thiyagarajan, T.M. Urban Gardening for the Pandemic. *Agrosci. Today* **2020**, *1*, 17–20.
3. Zawadzińska, A.; Salachna, P.; Nowak, J.S.; Kowalczyk, W. Response of Interspecific Geraniums to Waste Wood Fiber Substrates and Additional Fertilization. *Agriculture* **2021**, *11*, 119.
4. Anacleto, A.; de Araújo Bornancin, A.P.; Mendes, S.H.C.; Scheuer, L. Between Flowers and Fears: The New Coronavirus Pandemic (COVID-19) and the Flower Retail Trade. *Ornam. Hortic.* **2021**, *27*, 26–32.
5. Beckmann-Cavalcante, M.Z. Floriculture and Covid-19. *Ornam. Hortic.* **2021**, *27*, 6–7.
6. Salachna, P.; Piechocki, R. Salinity Tolerance of Four Hardy Ferns from the Genus Dryopteris Adans. Grown under Different Light Conditions. *Agronomy* **2021**, *11*, 49.
7. Wang, Y.; Gao, S.; He, X.; Li, Y.; Zhang, Y.; Chen, W. Response of Total Phenols, Flavonoids, Minerals, and Amino Acids of Four Edible Fern Species to Four Shading Treatments. *PeerJ* **2020**, *8*, e8354.
8. Mukherjee, S.; Mishra, A.; Trenberth, K.E. Climate Change and Drought: A Perspective on Drought Indices. *Curr. Clim. Chang. Rep.* **2018**, *4*, 145–163.
9. Pauleit, S.; Zölch, T.; Hansen, R.; Randrup, T.B.; van den Bosch, C.K. Nature-Based Solutions and Climate Change–Four Shades of Green. In *Nature-Based Solutions to Climate Change Adaptation in Urban Areas*; Springer: Cham, Switzerland, 2017; pp. 29–49.
10. Kazemi, F.; Safari, N. Effect of Mulches on Some Characteristics of a Drought Tolerant Flowering Plant for Urban Landscaping. *Desert* **2018**, *23*, 75–84.
11. Rafi, Z.N.; Kazemi, F.; Tehranifar, A. Effects of Various Irrigation Regimes on Water Use Efficiency and Visual Quality of Some Ornamental Herbaceous Plants in the Field. *Agric. Water Manag.* **2019**, *212*, 78–87.
12. Rafi, Z.N.; Kazemi, F.; Tehranifar, A. Morpho-Physiological and Biochemical Responses of Four Ornamental Herbaceous Species to Water Stress. *Acta Physiol. Plant.* **2019**, *41*, 1–13.
13. Wang, Y.; Gao, S.; He, X.; Li, Y.; Li, P.; Zhang, Y.; Chen, W. Growth, Secondary Metabolites and Enzyme Activity Responses of Two Edible Fern Species to Drought Stress and Rehydration in Northeast China. *Agronomy* **2019**, *9*, 137.

14. John, S.P.; Hasenstein, K.H. Biochemical Responses of the Desiccation-Tolerant Resurrection Fern Pleopeltis Polypodioides to Dehydration and Rehydration. *J. Plant Physiol.* **2018**, *228*, 12–18.
15. John, S.P.; Hasenstein, K.H. Desiccation Mitigates Heat Stress in the Resurrection Fern, Pleopeltis polypodioides. *Front. Plant Sci.* **2020**, *11*, 597731.
16. Nishida, K.; Hanba, Y.T. Photosynthetic Response of Four Fern Species from Different Habitats to Drought Stress: Relationship between Morpho-Anatomical and Physiological Traits. *Photosynthetica* **2017**, *55*, 689–697.