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Review

Supplementary Materials: Survival below Zero: Overlooked Aspects of Freezing-Tolerance in Photosynthetic Fern Tissues

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Table S1. Compilation of fern species from which the tolerance to subzero temperature has already been tested in the literature in green tissues (either sporophyte, gametophyte or chlorophyllous spore). The parameter/approach used to estimate tolerance to subzero temperature, as well as the country and the original reference are specified.

Species	Tissue (Spore, Gametophyte or Leaf)	Below-Zero Temperature Tested (°C)	Measured Parameters	Country	Reference
Adiantum capillus-veneris (Pteridaceae)	Sporophyte	−7	Freezing tolerance, ice nucleation temperature and ice expansion pattern "Measuring chlorophyll fluorescence and pigment compositions (F_V/F_M)"	Austria	Fernández-Marín et al., 2021
Adiantum pedatum (Pteridaceae)	Gametophyte Sporophyte	−40 −10	Frost resistance "Regreening of the whole leaf, 3 weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Alsophila smithii (Cyatheaceae)	Sporophyte	−4.2	Frost tolerance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Alsophila smithii (Cyatheaceae)	Sporophyte	−4.2	Frost tolerance "Evaluation of leaf damage after 4 weeks of exposure to frost"	New Zealand	Warrington & Stanley, 1987
Angiopteris helferiana (Marattiaceae)	Gametophyte Sporophyte	−3 −3	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Arachniodes mutica (Dryopteridaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Arachniodes standishii (Dryopteridaceae)	Gametophyte Sporophyte	−20 −7 to −12.5	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Asplenium ceterach (Aspleniaceae)	Sporophyte	−7	Freezing tolerance, ice nucleation temperature and ice expansion pattern "Measuring chlorophyll fluorescence and pigment compositions (F_V/F_M)"	Austria	Fernández-Marín et al., 2021

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Asplenium laciniatum (Aspleniaceae)	Gametophyte Sporophyte	−20 −12.5	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Asplenium incisum (Aspleniaceae)	Gametophyte Sporophyte	−5 to−20	Freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Asplenium incisum (Aspleniaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Asplenium septentrionale (Aspleniaceae)	Gametophyte	−10	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen,1964
Asplenium septentrionale (Aspleniaceae)	Sporophyte	−23	frost damage, survival "Through linear regression analysis, calculation of total leaf area"	Netherlands	Bremer & Jongejans, 2010
Asplenium septentrionale (Aspleniaceae)	Sporophyte	−10	frost resistance "Through the extraction of fatty acids (FAs) from lipids in the leaves."	Russia	Voronkov & Ivanova, 2022
Asplenium septentrionale (Aspleniaceae)	Sporophyte	−7	Freezing tolerance, ice nucleation temperature and ice expansion pattern "Measuring chlorophyll fluorescence and pigment compositions (F_V/F_M)"	Austria	Fernández-Marín et al., 2021
Asplenium scolopendrium (Aspleniaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Asplenium scolopendrium (Aspleniaceae)	Sporophyte	−14.8	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen, 1964
Asplenium trichomanes (Aspleniaceae)	Sporophyte	−7	Freezing tolerance, ice nucleation temperature and ice expansion pattern "Measuring chlorophyll fluorescence and pigment compositions (F_V/F_M)"	Austria	Fernández-Marín et al., 2021
Asplenium trichomanes (Aspleniaceae)	Sporophyte	−11	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen,1964
Asplenium trichomanes (Aspleniaceae)	Gametophyte	−10 to −21	Frost resistance "Survival, estimated as gametophyte's capacity to grow"	Germany	Kappen,1965
Asplenium ruta-muraria (Aspleniaceae)	Sporophyte	−10	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen,1964
Asplenium platyneuron (Aspleniaceae)	Gametophyte	−12 to −23	Frost resistance "Survival through experimental cultures of prothalli"	USA	Pickett, 1914
Asplenium bulbiferum (Aspleniaceae)	Sporophyte	−6	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003

Asplenium flaccidum (Aspleniaceae)	Sporophyte	−6.5	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Asplenium radicans (Aspleniaceae)	Gametophyte	−12 to −23	Frost resistance "Survival through experimental cultures of prothalli"	USA	Pickett, 1914
Athyrium vidalii (Athyriaceae)	Gametophyte Sporophyte	−40 −5 to −20	freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Athyrium filix-femina (Athyriaceae)	Sporophyte	−2 to −3	Frost Resistance "Through observations"	UK	Bannister, 1973
Athyrium filix-femina (Athyriaceae)	Gametophyte	−10 to −21	Frost resistance "Survival, estimated as gametophyte's capacity to grow"	Germany	Kappen,1965
Athyrium yokoscense (Athyriaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Athyrium yokoscense (Athyriaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Athyrium niponicum (Athyriaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Athyrium vidalii (Athyriaceae)	Gametophyte	−30	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Blechnum spicant (Blechnaceae)	Sporophyte	−5 to −8.7	Frost Resistance "Through observations"	UK	Bannister, 1973
Blechnum spicant (Blechnaceae)	Sporophyte	−25	Frost resistance "Through saturated humidity"	Germany	Kappen,1966
Blechnum spicant (Blechnaceae)	Sporophyte	−19.5	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen,1964
Blechnum chambersii (Blechnaceae)	Sporophyte	−3.2	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Blechnum discolor (Blechnaceae)	Sporophyte	−8.6	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Blechnum penna-marina (Blechnaceae)	Sporophyte	−5 to −7 −20	Frost Resistance "Through short-term exposure to low and high temperatures"	New Zealand	Bannister & Fagan, 1989
Blechnum penna-marina (Blechnaceae)	Sporophyte	−5 to −7 −20	Frost Resistance "Quantification of the relationship between damage and exposure temperature to cold using probit analysis"	New Zealand	Bannister, 1984a
Blechnum procerum (Blechnaceae)	Sporophyte	−5.8	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Cyrtomium falcatum (Dryopteridaceae)	Gametophyte Sporophyte	−30 −15	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982

Cystopteris fragilis (Cystopteridaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Cystopteris fragilis (Cystopteridaceae)	Gametophyte	−10 to −21	Frost resistance "Survival, estimated as gametophyte's capacity to grow"	Germany	Kappen,1965
Davallia tasmanii (Davalliaceae)	Sporophyte	−5	Frost Resistance "Quantification of the relationship between damage and exposure temperature to cold using probit analysis	New Zealand	Bannister, 1984b
Deparia pterorachis (Athyriaceae)	Gametophyte Sporophyte	−40 −5 to −20	freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Deparia pterorachis (Athyriaceae)	Gametophyte	−30	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Dicksonia fibrosa (Dicksoniaceae)	Sporophyte	−8 to −11	Frost tolerance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Dicksonia fibrosa (Dicksoniaceae)	Sporophyte	−8 to −11	Frost tolerance "Evaluation of leaf damage after 4 weeks of exposure to frost"	New Zealand	Warrington and Stanley, 1987
Dicksonia squarrosa (Dicksoniaceae)	Sporophyte	−6.5	Frost tolerance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister 2003
Diplazium squamigerum (Athyriaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Dryopteri samurensis (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance "Regreening of the whole leaf, 3 weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Dryopteris amurensis (Dryopteridaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Dryopteris laeta (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Dryopteris laeta (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Dryopteris monticola (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Dryopteris intermedia (Dryopteridaceae)	Sporophyte	−10	Photosynthetic Capacity and Leaf Reorientation	USA	Noodén & Wagner, 1997
Dryopteris intermedia (Dryopteridaceae)	Sporophyte	−3 to −7.2	Survival "Investigating the Softening of Stipe for Evolutionary Adaptation"	USA	Tessier, 2018
Dryopteris filix-mas (Dryopteridaceae)	Sporophyte	−5 to −11	Frost Resistance "Quantification of the relationship between damage	New Zealand	Bannister, 1984

			and exposure temperature to cold using probit analysis		
Dryopteris filix-mas (Dryopteridaceae)	Sporophyte	−5 to −8.7	Frost Resistance “Through observations”	UK	Bannister, 1973
Dryopteris filix-mas (Dryopteridaceae)	Sporophyte	−13.8	Frost resistance “Survival, estimated through plasma resistance in sporophytes”	Germany	Kappen,1964
Dryopteris filix-mas (Dryopteridaceae)	Sporophyte	−18	Frost resistance “Through saturated humidity”	Germany	Kappen,1966
Dryopteris dilatata (Dryopteridaceae)	Sporophyte	−5 to −7.7	Frost Resistance “Through observations”	UK	Bannister, 1973
Dryopteris sp. (Dryopteridaceae)	Sporophyte	−15.5	Frost resistance “Survival, estimated through plasma resistance in sporophytes”	Germany	Kappen,1964
Dryopteris crassirhizoma (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Frost resistance “Regreening of the whole leaf, 3weeks after thawing” for the sporophyte	Japan	Sato & Sakai, 1981
Dryopteris crassirhizoma (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris monticola (Dryopteridaceae)	Gametophyte Sporophyte	−40 −10	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris austriaca (Dryopteridaceae)	Gametophyte	−40	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris sabaei (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance “Regreening of the whole leaf, 3 weeks after thawing” for the sporophyte	Japan	Sato & Sakai, 1981
Dryopteris sabaei (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris sichotensis (Dryopteridaceae)	Gametophyte	−40	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris fragrans (Dryopteridaceae)	Gametophyte	−40	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris erythrosora (Dryopteridaceae)	Gametophyte Sporophyte	−12.5 to −15 −7	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris lacera Kuntze. (Dryopteridaceae)	Gametophyte Sporophyte	−20 −12.5	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Dryopteris dilatata (Dryopteridaceae)	Sporophyte	−10.3	Frost resistance “Survival, estimated through plasma resistance in sporophytes”	Germany	(Kappen,1964)
Dryopteris dilatata (Dryopteridaceae)	Gametophyte	−10 to −21	Frost resistance “Survival, estimated as gametophyte’s capacity to grow”	Germany	Kappen,1965
Dryopteris dilatata (Dryopteridaceae)	Sporophyte	−20	Frost resistance “Through saturated humidity”	Germany	Kappen,1966
Equisetum arvense (Equisetaceae)	Spore	−20	Survival “Calculation of spores Germination Percentage After Treatment”	Japan	Kato, 1976

Equisetum hyemale (Equisetaceae)	Spore	−70	Survival “Assessment of spores Germination Rate After Thawing”	US	Whittier, 1996
Equisetum ramosissimum (Equisetaceae)	Spore	−25 to −196	Survival “Evaluation of Spore Germination Percentage after 24 Months of Dry Storage at Different Temperatures”	UK Spain	Ballesteros et al., 2011
Equisetum variegatum (Equisetaceae)	Sporophyte	−46.7	Frost tolerance “Analysis of Lipid Composition and Fatty Acids During the Cold Period”	Russia	Nokhsorov et al., 2021
Equisetum variegatum (Equisetaceae)	Sporophyte	−18.3 to −46.7	Frost tolerance “Qualitative and quantitative analysis and the ratio of photosynthetic pigments in sporophytes during winter.”	Russia	Petrov et al., 2010
Equisetum scirpoides (Equisetaceae)	Sporophyte	−42.2	Frost tolerance “Qualitative and quantitative analysis and the ratio of photosynthetic pigments in sporophytes during winter.”	Russia	Petrov et al., 2010
Equisetum scirpoides (Equisetaceae)	Sporophyte	−46.7	Frost tolerance “Analysis of Lipid Composition and Fatty Acids During the Cold Period”	Russia	Nokhsorov et al., 2021
Gymnocarpium dryopteris (Cystopteridaceae)	Gametophyte	−10 to −21	Frost resistance “Survival, estimated as gametophyte’s capacity to grow”	Germany	Kappen,1965
Histiopteris incisa (Dennstaedtiaceae)	Gametophyte Sporophyte	−3 −3	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Histiopteris incisa (Dennstaedtiaceae)	Sporophyte	−6.6	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Lepisorus thunbergianus (Polypodiaceae)	Gametophyte Sporophyte	−30 −20	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Odontosoria chinensis (Lindsaeaceae)	Gametophyte	−20	Frost resistance “Survival, estimated as capacity to grow”	Japan	Sato, 1982
Osmunda regalis (Osmundaceae)	Spore	−20	Survival “Investigating the germination percentage of chlorophyllous spores after one month of storage”	Italy	Magrini S & Scoppola A, 2012
Osmunda regalis (Osmundaceae)	Spore	−25 to −196	Survival “Evaluation of Spore Germination Percentage after 24 Months of Dry Storage at Different Temperatures”	UK Spain	Ballesteros et al., 2011
Osmunda japonica (Osmundaceae)	Spore	−18	Survival “Determination of spore germination percentage after each storage period”	China	Li & Shi, 2014
Phegopteris connectilis (Thelypteridaceae)	Sporophyte	−3.7 to −6	Frost Resistance “Through observations”	UK	Bannister, 1973
Phymatosorus pustulatus	Sporophyte	−5 to −8	Frost Resistance	New Zealand	Bannister, 1984a

(Polypodiaceae)			"Quantification of the relationship between damage and exposure temperature to cold using probit analysis"		
Polypodium vulgare (Polypodiaceae)	Sporophyte	−7	Freezing tolerance, ice nucleation temperature and ice expansion pattern "Measuring chlorophyll fluorescence and pigment compositions (F_V/F_M)"	Austria	Fernández-Marín et al., 2021
Polypodium vulgare (Polypodiaceae)	Sporophyte	−18	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen, 1964
Polypodium vulgare (Polypodiaceae)	Gametophyte	−10	Frost resistance "Survival, estimated as gametophyte's capacity to grow"	Germany	Kappen, 1965
Polypodium vulgare (Polypodiaceae)	Sporophyte	−18	Frost resistance (Saturated humidity)	Germany	Kappen, 1966
Polypodium vulgare (Polypodiaceae)	Sporophyte	nd	Freezing resistance "By examining the abundance and seasonal growth patterns"	Ireland, France, Germany	Klinghardt & Zotz, 2021
Polypodium interjectum (Polypodiaceae)	Sporophyte	nd	Freezing resistance "By examining the abundance and seasonal growth patterns"	Ireland, France, Germany	Klinghardt & Zotz, 2021
Polypodium cambricum (Polypodiaceae)	Sporophyte	nd	Freezing resistance "By examining the abundance and seasonal growth patterns"	Ireland, France, Germany	Klinghardt & Zotz, 2021
Polypodium cambricum (Polypodiaceae)	Sporophyte	−7	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen, 1964
Polystichum vestitum (Dryopteridaceae)	Sporophyte	−5 to −7	Frost resistance "Quantification of the relationship between damage and exposure temperature to cold using probit analysis	New Zealand	Bannister, 1984a
Polystichum neozelandicum (Dryopteridaceae)	Sporophyte	−6	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Polystichum acrostichoides (Dryopteridaceae)	Sporophyte	−10	Photosynthetic Capacity and Leaf Reorientation	USA	Noodén & Wagner, 1997
Polystichum retrosopaleaceum (Dryopteridaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Polystichum tripteron (Dryopteridaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Polystichum braunii (Dryopteridaceae)	Gametophyte	−40	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Polystichum retrosopaleaceum (Dryopteridaceae)	Gametophyte Sporophyte	−40 −5 to −20	Freezing resistance "Regreening of the whole leaf, 3weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1981
Polystichum retrosopaleaceum (Dryopteridaceae)	Gametophyte Sporophyte	−70 to −196 −15 to −20	Freezing resistance "Regreening of the whole leaf, 3 weeks after thawing" for the sporophyte	Japan	Sato & Sakai, 1980
Polystichum braunii	Gametophyte	−40	Freezing resistance	Japan	Sato & Sakai, 1981

(Dryopteridaceae)	Sporophyte	−5 to −20	"Regreening of the whole leaf, 3 weeks after thawing" for the sporophyte		
Polystichum aculeatum (Dryopteridaceae)	Sporophyte	−13.6	Frost resistance "Survival, estimated through plasma resistance in sporophytes"	Germany	Kappen, 1964
Pteridium aquilinum (Dennstaedtiaceae)	Sporophyte	−3.5 to −4	Frost Resistance "Through observations"	UK	Bannister, 1973
Pteridium aquilinum (Dennstaedtiaceae)	Sporophyte	−2 to −5	Frost resistance "Through saturated humidity"	Germany	Kappen, 1966
Pteridium esculentum (Dennstaedtiaceae)	Sporophyte	−6	Frost resistance Experimental Methods and Assessment of Damage Severity	New Zealand	Bannister, 2003
Pteris cretica (Pteridaceae)	Gametophyte	−15	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Pteris multifida (Pteridaceae)	Gametophyte Sporophyte	−7 −5	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Pteris dispar (Pteridaceae)	Gametophyte Sporophyte	−7 −5	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Pteris vittata (Pteridaceae)	Gametophyte Sporophyte	−5 −3	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Struthiopteris niponica (Blechnaceae)	Sporophyte	−20	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Thelypteris pozoi (Thelypteridaceae)	Gametophyte	−20	Frost resistance "Survival, estimated as capacity to grow"	Japan	Sato, 1982
Thelypteris limbosperma (Thelypteridaceae)	Sporophyte	−2.5 to −3	Frost Resistance "Through observations"	UK	Bannister, 1973
Vittaria lineata (Pteridaceae)	Gametophyte Sporophyte	−10	Frost tolerance, Survival "Habitat and Distribution Analysis with Morphological and Physiological Assessment"	USA	Farrar, 1978

References

Bannister P. (1973). A note on some observations on frost damage in the field, with particular reference to various ferns. *Transactions of the Botanical Society of Edinburgh*, *42*(1), 111–113. https://doi.org/10.1080/03746607308685266.

Bannister P. (1984). The seasonal course of frost resistance in some New Zealand pteridophytes. *New Zealand Journal of Botany*, *22*(4), 557–563. https://doi.org/10.1080/0028825X.1984.10425290.

Bannister P. (2003). Are frost hardiness ratings useful predictors of frost damage in the field? A test using damage records from the severe frost in South Otago and Southland, New Zealand, July 1996. *New Zealand Journal of Botany*, *41*(3), 555–569. https://doi.org/10.1080/0028825X.2003.9512869.

Bannister P, & Fagan B. (1989). The frost resistance of fronds of *Blechnum penna-marina* in relation to season, altitude, and short-term hardening and dehardening. *New Zealand Journal of Botany*, *27*(3), 471–476. https://doi.org/10.1080/0028825X.1989.10414127.

Bremer P, & Jongejans E. (2010). Frost and forest stand effects on the population dynamics of *Asplenium scolopendrium*. *Population Ecology*, *52*(1), 211–222. https://doi.org/10.1007/s10144-009-0143-7.

Farrar DR. (1978). Problems in the identity and origin of the appalachian vittaria gametophyte, a sporophyteless fern of the eastern united states. *American Journal of Botany*, *65*(1), 1–12. https://doi.org/10.1002/j.1537-2197.1978.tb10828.x.

Fernández-Marín B, Arzac MI, López-Pozo M, Laza JM, Roach T, Stegner M, & García-Plazaola JI. (2021). Frozen in the dark: Interplay of night-time activity of xanthophyll cycle, xylem attributes, and desiccation tolerance in fern resistance to winter. *Journal of Experimental Botany*, *72*(8), 3168–3184. https://doi.org/10.1093/jxb/erab071.

Hutchinson JT, & Langeland KA. (2014). Tolerance of *Lygodium microphyllum* and *L. japonicum* spores and gametophytes to freezing temperature. *Invasive Plant Science and Management*, *7*(2), 328–335.

Kappen L. (1964). Untersuchungen über den Jahreslauf der Frost-, Hitze-und Austrocknungsresistenz von Sporophyten einheimischer Polypodiaceen (Filicinae). *Flora oder Allgemeine Botanische Zeitung*, *155*(1), 123–166. https://doi.org/10.1016/S0367-1615(17)33347-5.

Kappen L. (1965). Untersuchungen über die Widerstandsfähigkeit der Gametophyten einheimischer Polypodiaceen gegenüber Frost, Hitze und Trockenheit. *Flora oder Allgemeine Botanische Zeitung. Abt. B, Morphologie und Geobotanik*, *156*(1), 101–115. https://doi.org/10.1016/S0367-1801(17)30007-8.

Kappen L. (1966). Der Einfluß des Wassergehalts auf die Widerstandsfähigkeit von Pflanzen gegenüber hohen und tiefen Temperaturen, untersucht an Blättern einiger Farne und von *Ramonda myconi*. *Flora oder Allgemeine Botanische Zeitung. Abt. A, Physiologie und Biochemie*, *156*(4), 427–445. https://doi.org/10.1016/S0367-1836(17)30278-1.

Kato Y. (1976). The effect of freezing and organic solvents on viability of chlorophyllous fern spores. *Cytologia*, *41*(2), 387–393. https://doi.org/10.1508/cytologia.41.387.

Klinghardt M, & Zotz G. (2021). Abundance and seasonal growth of epiphytic ferns at three sites along a rainfall gradient in Western Europe. *Flora*, *274*, 151749. https://doi.org/10.1016/j.flora.2020.151749.

Nokhsorov VV, Dudareva LV, Senik SV, Chirikova NK, & Petrov KA. (2021). Influence of Extremely Low Temperatures of the Pole of Cold on the Lipid and Fatty-Acid Composition of Aerial Parts of the Horsetail Family (Equisetaceae). *Plants*, *10*(5), 996. https://doi.org/10.3390/plants10050996.

Noodén LD, & Wagner Jr WH. (1997). Photosynthetic capacity and leaf reorientation in two wintergreen ferns, *Polystichum acrostichoides* and *Dryopteris intermedia*. *American Fern Journal*, *87*(4), 143–149. https://doi.org/10.2307/1547836.

Pence VC. (2000). Survival of chlorophyllous and nonchlorophyllous fern spores through exposure to liquid nitrogen. *American Fern Journal*, *90*(4), 119–126. https://doi.org/10.2307/1547488.

Petrov KA, Sofronova VE, Chepalov VA, Perk AA, & Maksimov TK. (2010). Seasonal changes in the content of photosynthetic pigments in perennial grasses of cryolithic zone. *Russian Journal of Plant Physiology*, *57*, 181–188. https://doi.org/10.1134/S1021443710020044.

Pickett FL. (1914). Some ecological adaptations of certain fern prothallia-Camptosorus rhizophyllus Link., Asplenium platyneuron Oakes. *American Journal of Botany*, *1*, 477–498.

Sato T. (1982). Phenology and wintering capacity of sporophytes and gametophytes of ferns native to northern Japan. *Oecologia*, *55*, 53–61

Sato T, & Sakai A. (1980). Freezing resistance of gametophytes of the temperate fern, *Polystichum retrosopaleaceum*. *Canadian Journal of Botany*, *58*, 1144–1148. https://doi.org/10.1139/b80-141.

Sato T, & Sakai A. (1981). Cold tolerance of gametophytes and sporophytes of some cool temperate ferns native to Hokkaido. *Canadian Journal of Botany*, *59*, 604–608. https://doi.org/10.1139/b81-085.

Tessier JT. (2018). Upright fronds of *Dryopteris intermedia* suffer frost damage and breakage during winter. *American Fern Journal*, *108*, 19–26.

Voronkov A, & Ivanova T. (2022). Significance of lipid fatty acid composition for resistance to winter conditions in *Asplenium scolopendrium*. *Biology*, *11*(4), 507. https://doi.org/10.3390/biology11040507.

Warrington IJ, & Stanley CJ. (1987). Seasonal frost tolerance of some ornamental, indigenous New Zealand plant species in the genera Astelia, Dicksonia, Leptospermum, Metrosideros, Phormium, Pittosporum, and Sophora. *New Zealand Journal of Experimental Agriculture*, *15*(3), 357–365. https://doi.org/10.1080/03015521.1987.10425582.

Whittier P. (1996). Extending the viability of *Equisetum hyemale* spores. *American Fern Journal*, *86*(4), 114–118. https://doi.org/10.2307/1547150.