———. 1937b. Charles Thomas Bowen, 1803-1828, first Professor of Chemistry in the University of Nashville. Unpubl. ms., Tennessee State Library. 14 pp.

Kain, John H. 1819a. Remarks on the mineralogy and geology of the north-western part of the State of Virginia, and the eastern part of the State of Tennessee. Amer. Jour. Sci., vol. 1, p. 60-67.

———. 1819b. An account of several ancient mounds and of two caves in Tennessee. Amer. Jour. Sci., vol. 1, p. 428-430.

———. 1831. On medical emulation. Med. Soc. Tennessee. 29 pp.

Lea, A. M. 1837. Report of the Chief Engineer of the State of Tennessee on the surveys and examinations for the Central Railroad and for the Central Turnpike. S. Nye State Printer, Nashville. 81 pp.

Long, S. H. 1832. Fossil remains of mastodon found in Tennessee. Monthly Amer. Jour. Geol. Nat. Sci., vol. 1, p. 565-566.

———. 1875. The improvement of navigation on the Holston and Tennessee Rivers. U.S. House Rep., 43rd Cong. 1st Sess. House Exec. Doc. 167. 51 pp. (Serial No. 1648).

Long, S. H., et al. 1846. Surveys of the Tennessee River. U.S. House Rep., 29th Cong., House Exec. Doc. 95 pp. (Serial No. 485).

McBride, Robert M., and Owen Meredith. 1971. Eastin Morris' *Tennessee Gazetteer* 1834 and Mathew Rhea's *Map of The State of Tennessee* 1832. The Gazetteer Press, Nashville. 325 pp. plus map.

Nance, C. W. 1837. A counter report on the Central Rail Road. S. Nye, State Printer, Nashville. 12 pp.

Platt, Samuel J., and Mary L. Ogden. 1969. Medical men and institutions of Knox County, Tennessee: 1789-1957. S. B. Newman Printing Co., Knoxville. 427 pp.

Rhea, M. 1832. Some antiquities of Tennessee. Atlantic Journal and Friend of Knowledge, vol. 1, p. 80-81.

Rooker, Henry G. 1933. A sketch of the life and works of Dr. Gerard Troost. Tennessee Historical Mag., ser. 2, vol. 3, p. 3-19.

Stewart, Alexander P. 1851-1853. Meteorological observations made at Lebanon, Wilson Co., Tennessee. Nashville Jour. Med. Surgery, vol. 1 (1851), p. 383; vol. 2 (1852), p. 63, 64, 192, 319, 320; vol. 3 (1853), p. 264, 329, 390.

White, Robert H. 1967. A sketch of the life and contributions of Francis Haynes Gordon, M.D. Unpubl. ms., Tennessee State Library. 251 pp.

Wilburn, James R. 1969. The hazard of the die: Tolbert Fanning and the Restoration Movement. Sweet Publ. Co., Austin, Texas. 288 pp.

Wingfield, Marshall. 1954. General A. P. Stewart, his life and letters. West Tennessee Hist. Soc. 259 pp.

Wood, Richard G. 1966. Stephen Harriman Long, 1789-1864; Army engineer, explorer, inventor. Arthur H. Clark Co., Glendale, California. 292 pp.

JOURNAL OF THE TENNESSEE ACADEMY OF SCIENCE

VOLUME 53, NUMBER 1, JANUARY, 1978

OPTIMUM CONDITIONS FOR THE GERMINATION OF SEEDS OF CEDAR GLADE PLANTS: A REVIEW

THOMAS E. HEMMERLY
Middle Tennessee State University
Murfreesboro, Tennessee 37132

AND

ELSIE QUARTERMAN
Vanderbilt University
Nashville, Tennessee 37325

ABSTRACT

Conditions necessary for obtaining maximum germination in certain cedar glade plants, including fourteen perennials, seven spring annuals and sixteen winter annuals, are summarized. Data are obtained principally from published papers. Whereas seeds of spring-germinating species require special pre-treatments, seeds of fall-germinating species require no such pretreatments. Also, maximum germination of seeds of the former category occurs at somewhat higher temperatures than does that of seeds of the latter.

Compared with seeds of cultivated plants which have been selected for high, rapid, and simultaneous germination, those of wild, native plants often do not attain a high percentage of germination at any single combination of environmental conditions or at any one time. On the contrary, such seeds may possess some means by which germination can be delayed, occurring either gradually over a considerable time span, or at higher percentages following an extended pretreatment period.

Braun (1950) considered the cedar glades the most distinctive feature of the Central Basin of Tennessee. The unique flora was described by Gattinger (1901), Harper (1926), Freeman (1933) and Quaterman (1950a,b). Rocky, barren flats containing deep, vertical cracks are formed on Lebanon (Ordovician) limestone. As used by Quarterman (1950b), the term "cedar glade" is properly applied to the open spaces consisting of exposed rock and thin soil surrounded by woods typically including red cedar. Plants growing in cedar glades, as well as the seeds of such plants, are subjected to hot, dry summers which alternate with cool, moist winters.

Only in recent years has seed germination in cedar glade plants been investigated. Autecological investigators of cedar glade species have used controlled laboratory conditions to determine optimum or near-optimum conditions for germination. Such information has a two-fold use: 1) it can be related to the conditions under which germination occurs in the field and 2) it has practical value in experiments in which the laboratory germination of seeds of cedar glade plants is required.

The present review was compiled using principally results of published papers on seed germination in cedar glade plants, those items of unpublished data obtained by one of the authors being included only when germination results for a given species have not been previously published, or when such germination percentages exceeded those of previously published data. All species in this study were among those included in a check-list of glade plants by Baskin, Caudle and Quarterman (1968). Although a few introduced species are included, most are either endemic to or characteristic of cedar glades.

Conditions necessary for obtaining maximum germination are indicated in Tables 1-3, in which fourteen perennials, seven spring annuals and sixteen winter annuals, respectively, are listed. Final germination counts were made at the end of a four-week or thirty-day period, although most of the germination typically occurred during the first week or two. In those instances in which germination was considerably less than 100%, it can be assumed that combinations of pre-treatment and germination regimen not yet attempted might result in higher germination figures or that only a fraction of a given seed crop germinates during a given year.

The seeds of perennials (Table 1) that germinate in the spring (all except *Delphinium*) require either scarification or an extended stratification period in order to achieve maximum germination. Seeds of all spring annuals (Table 2) required ten to twenty-eight weeks of stratification. In contrast, seeds of winter annuals (Table 3) never require stratification, high germination percentages being attained at maturity or following periods of from four to twenty-six weeks of dry storage. Pre-treatment requirements in *Delphinium* compare well with those of winter annuals.

TABLE 1: *Conditions necessary for maximum germination of seeds of cedar glade perennials.*

Species	Pre-treatment	Germination °C	Germination %	Reference
Astragalus tennesseensis Gray (Leguminosae)	scarification scarification & leaching	25 25	90 100	Baskin and Quarterman, 1969
Agave virginica L. (Amaryllidacea)	8 weeks stratification	18 28 18/28	100 100 100	Baskin and Baskin, 1971a
Delphinium virescens Nutt.[a] (Ranunculaceae)	3.5 mo. dry storage	15	100	Baskin and Baskin, 1974c
Desmanthus illinoensis (Michx.) Macm. (Leguminosae)	scarification	room temp.	100	Latting, 1961
Dodecatheon meadia L. var. *meadia* (Primulaceae)	8 weeks stratification	10	85	Turner and Quarterman, 1968
Echinacea pallida Nutt. (Compositae)	16 weeks stratification	10/25 (dark)	66	Hemmerly, unpublished data
Echinacea tennesseensis (Beadle) Small (Compositae)	16 weeks stratification	15	67	Hemmerly, unpublished data
Eragrostis spectabilis (Pursh) Steud. (Gramineae)	10 weeks stratification	10/25	100	Hemmerly, unpublished data
Petalostemon gattingeri Heller (Leguminosae)	scarification	25	88	Breeden, 1968

Petalostemon purpureum (Vent.) Rydb. (Leguminosae)	scarification	25	97	Breeden, 1968
Psoralea subacaulis T. and G. (Leguminosae)	scarification & leaching	30	100	Baskin and Quarterman, 1970
Ruellia humilis Nutt. (Acanthaceae)	14 weeks stratification 1,000 mg/1 GA_3 for	30 25	76 99	Baskin and Baskin, 1970b
Talinum calcaricum Ware (Portulacaceae)	6 weeks stratification	7/27	98	Ware and Quarterman, 1969
Viola egglestonii Brainerd (Violaceae)	16 weeks stratification (cold greenhouse)	10/20	95	Baskin and Baskin, 1975d

[a] Field germination occurs in the fall; for other species listed, germination occurs in the spring.

TABLE 2: *Conditions necessary for maximum germination of seeds of cedar glade spring annuals.*

Species	Pre-treatment	Germination °C	Germination %	Reference
Ambrosia artemisiifolia L.[a] (Compositae)	12 weeks stratification	15/25	72	Willemsen, 1975
Aristida longespica Poir (Gramineae)	10 weeks stratification	10/25	100	Hemmerly, unpublished data
Cyperus aristatus Rottb. (Cyperaceae)	18 weeks stratification	18/28	95	Baskin and Baskin, 1971e
Isanthus brachiatus (L.) BSP (Labiatae)	14 weeks stratification	25	43	Baskin and Baskin, 1969
	1,000 mg/ GA_3 for 24 hours	15	71	Baskin and Baskin, 1974a
	3 separated 14-week stratification periods	15/30	97	Baskin and Baskin, 1975e
Lobelia gattingeri A. Gray (Campanulaceae)	16 weeks stratification	25	67	Caudle and Baskin, 1968a
Panicum capillare L. (Gramineae)	28 weeks stratification	25	92	Baskin and Baskin, 1969
Sporobolus vaginiflorus (Torr.) wood (Gramineae)	6 weeks stratification	25	100	Quarterman, unpublished data

[a] Introduced species.

TABLE 3: *Conditions necessary for maximum germination of seeds of cedar glade winter annuals.*

Species	Pre-treatment	Germination °C	Germination %	Reference
Arabidopsis thaliana [a] (L.) Heyn. (Cruciferae)	1 mo. dry storage	10	100	Baskin and Baskin, 1972b
Arenaria patula (Michx. (Caryophyllaceae)	none	15	73	Caudle and Baskin, 1968b,
Bupleurum rotundifolium L. (Umbelliferae)	2 mo. dry storage	15/6 (dark)	81	Baskin and Baskin, 1974b
[a] *Draba verna* L. (Cruciferae)	5 mo. dry storage	15	100	Baskin and Baskin, 1970a
Geranium carolinianum (L. (Geraniaceae)	1.5 dry storage and scarification	5, 10, 15, 20, 25	100	Baskin and Baskin, 1974d
		15/6, 20/10, 30/15	100	Baskin and Baskin, 1974d
	3 mo. dry storage	35/20	100	Baskin and Baskin, 1974d
Helenium amarum (Raf.)[a,b] H. Rock (Compositae)	none	15 10/25	100 100	Baskin and Baskin, 1973a
Holosteum umbellatum [a] L. (Caryophyllaceae)	26 weeks dry storage	10	70	Baskin and Baskin, 1973b
Leavenworthia crassa Rollins (Cruciferae)	4 mo. dry storage	10	87	Caudle and Baskin, 1968b
Leavenworthia exigua Rollins var. *exigua* (Cruciferae)	4-5 mo. dry storage	15	72	Baskin and Baskin, 1972c
Leavenworthia stylosa Gray (Cruciferae)	5 mo. dry storage + 5 days moisture + 25-day dry period	22/26	84	Zager, Quarterman. and Waits, 1971
Leavenworthia torulosa Gray (Cruciferae)	5 mo. dry storage	15	58	Baskin and Baskin, 1971b
Leavenworthia uniflora (Michx.) Britt. (Cruciferae)	5 mo. dry storage	12/23 20	95 95	Baskin and Baskin, 1971b
Phacelia dubia L. var. *dubia* (Hydrophyllaceae)	2 mo. dry storage	15	90	Baskin and Baskin, 1971c
Sedum pulchellum Michx. (Crassulaceae)	4 mo. dry storage	10	85	Caudle and Baskin, 1968b
Torilis japonica (Houtt.)[a] DC. (Umbelliferac)	none	20/10	95	Baskin and Baskin, 1975c
Valerianella umbilicata (Sull.) Wood. (Valerianaceae)				
f. *patellaria*	4 mo. dry storage	30/16	86	Baskin and Baskin, 1976
f. *intermedia*	3 mo. dry storage	30/16	94	Baskin and Baskin, 1976

[a] Introduced species.
[b] Also considered a spring annual.

In summarizing optimum temperatures for germination, the following patterns emerge: seeds of spring-germinating perennials and spring annuals require, in most instances, somewhat higher temperatures (commonly 25 C) than do those of winter annuals, which usually germinate best at 10 or 15 C. Alternating temperatures (most often 10/25 C) provided maximum results only in approximately one-fourth of the species tested.

Comparisons were made with respect to required pre-treatment, germination temperature and maximum germination obtained on the bases of annual vs. perennial habit, indigenous vs. introduced species and time of field germination. The only consistent relationship was that between seeds of spring-germinating species which required, in all cases, special pre-treatment in contrast to seeds of fall-germinating species which required no such pre-treatment, being capable of germinating at high percentages at maturity or following dry storage. It is obvious that in the field pre-treatment requirements postpone germination until the following spring, thus avoiding the subjection of seedlings to winter conditions. In species lacking such requirements, the seedlings which result from fall germination have adaptations which enable at least some of them to survive the winter.

Acknowledgment

This paper was supported in part by a Faculty Research Grant from Middle Tennessee State University.

Literature Cited

Baskin, Carol C. and Jerry M. Baskin. 1969. Germination and dormancy in cedar glade plants. IV. *Isanthus brachiatus, Panicum capillare, Cyperus inflexus, Eragrostis spectabilis* and *Rueliia humilis*. J. Tenn. Acad. Sci. 44: 69-70.

Baskin, Carol C. and Elsie Quarterman. 1969. Germination requirements of seeds of *Astragalus tennesseensis*. Bull. Torrey Bot. Club 96: 315-321.

Baskin, Jerry M. and Carol C. Baskin. 1970a. Germination eco-physiology of *Draba verna*. Bull. Torrey Bot. Club 97: 209-216.

Baskin, Jerry M. and Carol C. Baskin. 1970b. Replacement of chilling requirement in seeds of *Ruellia humilis* by gibberellic acid. Planta 94: 250-252.

Baskin, Jerry M. and Carold C. Baskin. 1971a. The ecological life history of *Agave virginica* L. in Tennessee cedar glades. Amer. Midl. Nat. 86: 449-462.

Baskin, Jerry M. and Carol C. Buskin, 1971b. Germination ecology and adaptation to habitat in *Leavenworthia* spp. (Cruciferae). Amer. Midl. Nat. 85: 22-35.

Baskin, Jerry M. and Carol C. Baskin. 1971c. Germination ecology of *Phacelia dubia* var. *dubia* in Tennessee glades. Amer. J. Bot. 58: 98-104.

Baskin, Jerry M. and Carol C. Baskin, 1971d. Germination of *Cyperus inflexus* Muhl. Bot. Gaz. 132: 3-9.

Baskin, Jerry M. and Carol C. Baskin. 1971e. The possible ecological significance of the light requirement for germination in *Cyperus inflexus*. Bull. Torrey Bot. Club 98: 25-33.

Baskin, Jerry M. and Carol C. Baskin. 1972a. A contribution to the ecological life cycle of *Leavenworthia stylosa*. J. Tenn. Acad. Sci. 47: 91-93.

Baskin, Jerry M. and Carol C. Baskin. 1972b. Ecological life cycle and physiological ecology of seed germination of *Arabidopsis thaliana*. Can. J. Bot. 50: 353-360.

Baskin, Jerry M. and Carol C. Baskin. 1972c. The ecological life cycle of the cedar glade endemic *Leavenworthia exigua* var. *exigua*. Can. J. Bot. 50: 1711-1723.

Baskin, Jerry M. and Carol C. Baskin. 1973a. Ecological life cycle of *Helenium amarum* in central Tennessee. Bull. Torrey Bot. Club 100: 117-124.

Baskin, Jerry M. and Carol C. Baskin. 1973b. Studies on the ecological life cycle of *Holsteum embellatum*. Bull. Torrey Bot. Club 100: 110-116.

Baskin, Jerry M. and Carol C. Baskin. 1974a. Breaking dormancy in seeds of *Isanthus brachiatus* (Labiatae) with gibberellic acid. Phyton 32: 159-165.

Baskin, Jerry M. and Carol C. Baskin. 1974b. Some aspects of the autecology of *Bupleurum rotundifolium* in Tennessee cedar glades. J. Tenn. Acad. Sci. 49: 21-24.

Baskin, Jerry M. and Carol C. Baskin. 1974c. Some aspects of prairie larkspur (*Delphinium virescens*) in Tennessee cedar glades. Amer. Midl. Nat. 92: 58-71.

Baskin, Jerry M. and Carol C. Baskin. 1074d. Some ecophysiological aspects of seed dormancy in *Geranium carolinianum* L. from central Tennessee. Oecologia 16: 209-219.

Baskin, Jerry M. and Carol C. Baskin. 1975a. Additions to the herbaceous flora of the middle Tennessee cedar glades. J. Tenn. Acad. Sci. 50: 25-26.

Baskin, Jerry M. and Carol C. Baskin. 1975b. Do seeds of *Helenium amarum* have a light requirement for germination? Bull. Torrey Bot. Club 102: 73-75.

Baskin, Jerry M. and Carol C. Baskin. 1975c. Ecophysiology of seed dormancy and germination in *Torilis japonica* in relation to its life cycle strategy. Bull. Torrey Bot. Club 102: 67-72.

Baskin, Jerry M. and Carol C. Baskin. 1975d. Observations on the ecology of the cedar glade endemic *Viola egglestonii*. Amer. Midl. Nat. 93: 320-329.

Baskin, Jerry M. and Carol C. Baskin. 1975e. Seed dormancy in *Isanthus brachiatus* (Labiatae) Amer. J. Bot. 62: 623-627.

Baskin, Jerry M. and Carol C. Baskin. 1976. Germination ecology of winter annuals: *Valerianella umbilicata*, f. *pattellaria* and f. *intermedia*. J. Tenn. Acad. 51: 138-141.

Baskin, Jerry M. and Elsie Quarterman. 1970. Autecological studies of *Psoralea subacaulis*. Amer. Midl. Nat. 84: 376-397.

Baskin, Jerry M., Elsie Quarterman, and Carol Caudle. 1968. Preliminary checklist of the herbaceous vascular plants of cedar glades. J. Tenn. Acad. Sci. 43: 65-71.

Braun, E. Lucy. 1950. Deciduous forests of eastern North America. Hafner Publishing Company, New York and London, 533 p.

Breeden, Johnnie E. 1968. Ecological tolerances in the seeds and seedling stages of two species of *Petalostemon* (Leguminosae). Ph.D. Thesis Vanderbilt Univ., Nashville, Tennessee, 198 p.

Caudle, Carol and Jerry M. Baskin. 1968a. Germination and dormancy in cedar glade plants III, *Lobelia gattingeri*. J. Tenn. Acad. Sci. 43: 116-117.

Caudle, Carol and Jerry M. Baskin. 1968b. The germination pattern of three winter annuals. Bull. Torrey Bot. Club 95: 331-335.

Freeman, C. P. 1933. Ecology of cedar glade vegetation near Nashville, Tennessee. J. Tenn. Acad. Sci. 8: 143-228.

Gattinger, A. 1901. Flora of Tennessee. Gospel Advocate Publishing Company, Nashville, Tennessee. 296 p.

Harper, R. M. 1926. The cedar glades of Middle Tennessee. Ecol. 7: 48-54.

Latting, June. 1961. The biology of *Desmanthus illinoensis*. Ecol. 42: 487-493.

Quarterman, Elsie. 1950a. Ecology of cedar glades I. Distribution of glade flora in Tennessee. Bull. Torrey Bot. Club 77: 1-9.

———. 1950b. Major plant communities of Tennessee cedar glades. Ecol. 31: 234-254.

Turner, Barbara Holman and Elsie Quarterman. 1968. Ecology of *Dodecatheon meadia* L. (Primulaceae) in Tennessee glades and woodland. Ecol. 49: 909-915.

Ware, Stewart A. and Elsie Quarterman. 1969. Seed germination in cedar glade *Talinum* Ecol. 50: 137-140.

Willemsen, Roger W. 1975. Effect of stratification, temperature and germination temperature on germination and the induction of secondary dormancy in common ragweed seeds. Am. J. Bot. 62: 1-5.

Zager, Rhona D., Elsie Quarterman and E. Douglas Waits. 1971. Seed dormancy and germination in *Leavenworthia stylosa* (Cruciferae). J. Tenn. Acad. Sci. 46: 98-101.