Slender lespedeza *(Lespedeza virginica* (L.) Britton).

Photo by Thomas G Barnes

Effects of Temperature on Germination of 10 Native

legume species

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ABSTRACT

Seeds of 10 species of legumes native to Missouri germinated poorly when the temperature was lower than 15 °C (59 °F). The fastest time to first germinated seed occurred at 20 °C (68 °F) for all species except purple and white prairie clover, which germinated first at 25 °C (77 °F). The fastest germination rate was first reached at 20 °C (68 °F) for hoary tick clover, sessile tick clover, and slender lespedeza, at 25 °C (77 °F) for white prairie clover, purple prairie clover, panicled tick clover, hairy lespedeza, and tall lespedeza, and at 30 °C (86 °F) for Illinois bundleflower and roundhead lespedeza. Maximum total germination percentage also varied among species. For both the prairie clovers and roundhead lespedeza, hairy lespedeza, and slender lespedeza, the lowest temperature at which maximum total germination percentage occurred was 15 °C (59 °F). For Illinois bundleflower and the 3 tick clovers, the lowest temperature at which maximum total germination percentage occurred was 20 °C (68 °F). For most species, the fastest germination rate occurred at a higher temperature than the maximum germination percentage. Many species attained maximum germination percentage and fastest germination rate across a range of temperatures rather than at a single optimal temperature. Species that rapidly and completely germinate across a wide range of temperatures should germinate more reliably under variable soil conditions than species that exhibit a narrow range.

KEY WORDS

germination rate index, seed, *Dalea candida*, *Dalea purpurea*, *Desmanthus illinoensis*, *Desmodium canescens*, *Desmodium paniculatum*, *Desmodium sessilifolium*, *Lespedeza capitata*, *Lespedeza hirta*, *Lespedeza stuevei*, *Lespedeza virginica*

NOMENCLATURE

Yatskievych and Turner (1990)

Interest in restoring native grasslands has led to increased interest in native legumes. These plants are an important component of grassland ecosystems because they can fix atmospheric nitrogen in association with rhizobia bacteria and can be an excellent food source for both wildlife and domestic livestock. Incorporating native legumes with native, warm-season grasses can increase forage yield and quality in pasture and hay plantings (Posler and others 1993). Temperature is often the main environmental factor affecting seed germination when moisture is not limiting. Good seedling vigor and stand establishment is favored by prompt germination and rapid seedling development (Hur and Nelson 1985). Knowing the optimal temperatures for seed germination is necessary to develop management strategies for successful stand establishment.

The effects of temperature on germination have been determined for many temperate introduced forage legumes. Hill and Luck (1991) studied the effects of temperature on the germination of 10 perennial pasture legumes. They found differences among species for time to first germination, maximum germination percentage, and rate of germination. Brar and others (1991) studied the germination of 20 forage legumes. They found that the legumes differed in temperature range for maximum germination and a majority of the entries tested exhibited a range in temperature for maximum germination between 10 and 25 °C (50 and 77 °C). Townsend and McGinnies (1972) studied the germination of 17 legume species and found that most species germinated successfully over a wide range of temperatures. Species adapted to a wide range of temperatures should be easier to establish than those with highly specific temperature requirements (Townsend and McGinnies 1972; Brar and others 1991).

Little is known about the effects of temperature on germination of native herbaceous legumes. Our objective was to determine the effects of temperature on the time to first germinated seed, total germination, and germination rate index for 10 native legumes.

MATERIALS AND METHODS

Seeds from 1 entry of white prairie clover (*Dalea candida* Michaux ex Willd.), 1 entry of purple prairie clover (*Dalea purpurea* Vent.), 3 entries of Illinois bundleflower (*Desmanthus illinoensis* [Michaux] MacMillan ex Robinson & Fern.), 1 entry of hoary tick clover (*Desmodium canescens* [L.] DC.), 3 entries of panicled tick clover (*Desmodium paniculatum* [L.] DC.), 1 entry of sessile tick clover (*Desmodium sessilifolium* [Torrey] Torrey and A. Gray), 4 entries of roundhead lespedeza (*Lespedeza capitata* Michaux), 1 entry of hairy lespedeza (*Lespedeza hirta* [L.] Hornem.), 2 entries of tall lespedeza (*Lespedeza stuevei* Nutt.), and 4 entries of slender lespedeza (*Lespedeza virginica* [L.] Britton) were collected from various sites across the state of Missouri in late 1992 and 1993 (Table 1).

Seeds were collected by hand at each location from several randomly selected plants representative of the local population. During winter 1994, seeds of each entry were germinated in the greenhouse. In spring 1994, 30 seedlings of each entry were transplanted in 3 replicates (10 plants per replicate) to a field nursery located at Bradford Farm near Columbia, Missouri, in a spaced-plant arrangement with 1 m (3 ft) between plants and 1 m (3 ft) between rows. In fall 1995, pods were hand harvested from each of the 30 plants of each entry. Thus, seeds of each entry were produced under similar environmental conditions, even though all were originally collected from different locations in Missouri. Seeds were threshed by hand using a rubboard and stored in a standard refrigerator at 4 °C (39 °F) until the germination tests were conducted in 1996. Just prior to initiating each germination test, seeds were removed from the refrigerator and handscarified by rubbing with sandpaper. *Desmodium* seeds were not scarified because tests showed that scarification did not improve their germination (data not shown). Immediately following scarification, seeds were surface sterilized with 95% ethyl alcohol for 3 min to reduce fungal growth during germination. Then, 3 sets of 100 seeds of each entry were placed on germination paper wetted with distilled water in a dark growth chamber for 28 d. Germination papers were rolled and placed in an open plastic bag to help retain moisture.

The growth chamber was set at 10, 15, 20, 25, or 30 °C (50, 59, 68, 77, or 86 °F, respectively). The experiment was conducted twice using 2 growth chambers. Each growth chamber was used for a complete set of temperature treatments. Germination counts were taken daily for 28 d. Seeds were considered germinated upon emergence of the radicle through the seed coat in accordance with the Association of Official Seed Analysts (AOSA 1965).

The time to first germinated seed was recorded for each entry. Total germination percentage and germination rate index were calculated for each species. Total germination at each temperature was calculated from the total number of seeds germinated divided by the total number of seeds. The mean germination rate index was calculated using the method described by Maguire (1962) as:

$$\text{Germination Rate Index} = (N_i \,/\, D_i)$$

where N_i is the number of seeds germinated out of 100 on the *i*th day and D_i is the number of days from the start of the germination test to the *i*th day.

Data were analyzed using the Statistical Analysis System (SAS) (SAS Institute 1985) to perform analysis of variance (ANOVA, PROC GLM; SAS Institute 1985) in a completely randomized design in which the treatments were arranged in a 10 x 5 factorial (10 species x 5 temperature treatments). The linear statistical model included the effects of replication, temperature, and the interaction of replicate and temperature. The effect of temperature represented the main plot and was tested using the interaction of replicate and temperature as the denominator of F. All other effects used the residual error for the denominator of F. Preliminary ANOVAs showed no significant interaction between entry and temperature, so all entries were pooled within each species for final analysis. Fisher's Least Significant Difference (LSD) tests were performed to test for significant differences between temperature treatments within each species (Steel and Torrie 1960). All differences were reported as significant at $P \leq 0.05$. Because of the heterogeneous variance and relatively large ranges encountered with total germination percentage, that data were transformed using arcsine square root transformation to stabilize the variance (Snedecor and Cochran 1989). Significant differences in germination percentage were based on the transformed data, but untransformed data were used in the tables.

RESULTS

Warmer temperatures tended to reduce the time to first germinated seed (Table 2). At the coolest temperature tested, 10 °C, hoary tick clover, panicled tick clover, and sessile tick clover failed to germinate and the other 7 species averaged 26 d for time to first germinated seed. At 15 °C, the average time to first germinated seed for all species decreased to 11 d. For all species except white and purple prairie clover, the fastest time to first germinated seed occurred at 20 °C and did not differ significantly for the 20, 25, and 30 °C treatments. The fastest time to first germinated seed for white and purple prairie clover occurred at 25 °C, which did not differ significantly from 30 °C. Thus, use of time to first germinated seed for analysis separated the 10 species into 2 groups: species that germinated fastest at either 20 or 25 °C.

When germination rate index was used to analyze the effect of temperature on germination, different patterns emerged for some species when compared to using time to first germinated seed. Germination rate index is the summation of the daily germination rate and takes into account the rate at which seeds germinate across time. The germination rate index can range from a minimum of 0 to a maximum of 100, with larger numbers representing faster germination rates. Because it measures time to germination of all seeds and not just the first seed to germinate, it is probably a better predictor of the effects of temperature on germination rate.

None of the species had their largest germination rate index at 10 or 15 °C (Table 3). For 3 species, hoary tick clover, sessile

TABLE 1

Collection information for native legumes (Fabaceae) tested for germination at various temperatures.

Scientific Name	Common Name	Entry	Collection Site [a]	Collection Date
Dalea candida	White prairie clover	59	St Clair , Dade	19 to 20 Sep 1993
Dalea purpurea	Purple praire clover	71	Laclede	29 Jul 1993
Desmanthus illinoensis	Illinois bundleflower	15	Pike	12 Aug 1993
		61	St Clair	19 Aug 1993
		72	Texas	29 Jul 1993
Desmodium canescens	Hoary tick clover	25	Boone	8 Sep 1993
Desmodium paniculatum	Panicled tick clover	8	Adair	8 Sep 1993
		29	Boone	6 Sep 1993
		76	Texas	29 Jul 1993
Desmodium sessilifolium	Sessile tick clover	63	St Clair , Dade	19 to 20 Sep 1993
Lespedeza capitata	Roundhead lespedeza	4	Atchison , Holt	26 to 27 Aug 1993
		10	Adair	14 Aug 1993
		31	Boone	8 Sep 1993
		78	Texas	12 Nov 1992
Lespedeza hirta	Hairy lespedeza	43	Cole , Osage	21 and 28 Jul 1993
Lespedeza stuevei	Tall lespedeza	45	Cole , Osage	21 and 28 Jul 1993
		99	Barry	19 Aug 1993
Lespedeza virginica	Slender lespedeza	11	Adair	14 Aug 1993
		46	Cole , Osage	21 and 28 Jul 1993
		80	Texas	4 Dec 1992
		89	Oregon	29 Jul 1993

[a] All collection sites are counties within the State of Missouri.

TABLE 2

Days to first germinated seed of native legumes as influenced by temperature. Lower numbers indicate faster overall emergence for each temperature treatment.

Species	Temperature (°C) 10	15	20	25	30
	d				
White prairie clover	27 c [a]	8 b	5 b	2 a	2 a
Purple prairie clover	27 c	9 b	5 b	2 a	2 a
Illinois bundleflower	26 c	10 b	4 a	3 a	2 a
Hoary tick clover	NG [b]	17 b	6 a	5 a	5 a
Panicled tick clover	NG	18 b	8 a	6 a	4 a
Sessile tick clover	NG	17 b	6 a	5 a	6 a
Roundhead lespedeza	26 c	9 b	4 a	3 a	2 a
Hairy lespedeza	27 c	8 b	4 a	3 a	2 a
Tall lespedeza	28 c	14 b	6 a	3 a	3 a
Slender lespedeza	26 c	7 b	4 a	3 a	3 a
Mean	26 c	11 b	5 a	4 a	3 a

[a] Means within a species followed by the same letter are not significantly different at the 0.05 level.
[b] NG = no germination.

TABLE 3

Germination rate index [a] of native legumes as influenced by temperature. Higher numbers indicate faster overall emergence for each temperature treatment.

Species	Temperature (°C) 10	15	20	25	30
White prairie clover	1 c [b]	5 b	10 b	18 a	17 a
Purple prairie clover	1 d	5 c	10 b	23 a	19 a
Illinois bundleflower	<1 d	3 d	8 c	16 b	28 a
Hoary tick clover	0 b	1 b	6 a	7 a	8 a
Panicled tick clover	0 c	1 c	7 b	9 ab	10 a
Sessile tick clover	0 c	2 bc	8 a	9 a	6 ab
Roundhead lespedeza	<1 e	4 d	12 c	15 b	24 a
Hairy lespedeza	0 d	5 c	10 b	18 a	14 ab
Tall lespedeza	0 c	2 c	6 b	10 a	7 b
Slender lespedeza	<1 c	6 b	10 a	8 a	5 b
Mean	<1 c	4 b	9 a	12 a	15 a

[a] Calculated as the daily germination percentage divided by the day number summed for all days.
[b] Means within a species followed by the same letter are not significantly different at the 0.05 level.

tick clover, and slender lespedeza, the largest germination rate index first occurred at 20 °C. Germination rate index of hoary tick clover and sessile tick clover did not differ at 20, 25, and 30 °C. Germination rate index for slender lespedeza did not differ between 20 and 25 °C, but decreased at 30 °C. For 5 species, white prairie clover, purple prairie clover, panicled tick clover, hairy lespedeza, and tall lespedeza, the largest germination rate index first occurred at 25 °C. Germination rate index did not differ between 25 and 30 °C, except for tall lespedeza. The largest germination rate index for Illinois bundleflower and roundhead lespedeza occurred at 30 °C.

Total germination percentage was also affected by temperature for all species (Table 4). For most species, the maximum total germination percentage tended to occur at lower temperatures than germination rate index. Maximum total germination percentage did not occur at 10 °C for any species. For both the prairie clovers and roundhead lespedeza, hairy lespedeza, and slender lespedeza, the lowest temperature at which maximum total germination percentage occurred was 15 °C. For Illinois bundleflower, tall lespedeza, and the 3 tick clovers, the lowest temperature at which maximum total germination percentage occurred was 20 °C.

Maximum total germination percentage was not significantly different over a wide range of temperatures for most of the species. Total germination percentages for the prairie clovers, roundhead lespedeza, and hairy lespedeza, did not differ significantly from 15 through 30 °C.

DISCUSSION

For all 10 of the native legumes we studied, the fastest germination rate occurred at or above 20 °C, and the lowest temperature at which maximum total germination percentage occurred was at or above 15 °C. This differs from results reported for introduced legume species. Brar and others (1991) studied several introduced forage legumes, which included alfalfa, medic, sainfoin, winter pea, 3 species of vetch, and 5 species of clover. They found that the fastest germination rate index occurred at or above 15 °C, and the lowest temperature at which maximum total germination percentage occurred was at or above 10 °C for 19 of the 20 introduced legume entries.

Most of the native legumes in this study germinated well across a wide range of temperatures. Four species, white and purple prairie clover, roundhead lespedeza, and hairy lespedeza, did not differ in germination percentage from 15 through 30 °C. Being able to germinate well across a wide range of temperatures can be an advantage, especially in temperate climates where a wide range of soil temperatures occurs (Townsend and McGinnies 1972; Brar and others 1991).

For 8 of the 10 species, the fastest germination rate, as measured by the germination rate index, occurred at a higher temperature than the maximum total germination percentage. For example, in roundhead lespedeza, the lowest temperature at which maximum total germination percentage occurred was 15 °C, but the fastest rate of germination did not occur until 30 °C. Rapid germination can be critical when competition for resources

TABLE 4

Total germination percentage of native legumes as influenced by temperature at 28 d after planting.

Species	Temperature (°C) 10	15	20	25	30
	%				
White prairie clover	3 b [a]	65 a	62 a	59 a	47 a
Purple prairie clover	3 b	67 a	69 a	73 a	57 a
Illinois bundleflower	3 c	44 b	55 ab	56 a	59 a
Hoary tick clover	0 c	33 b	57 a	52 ab	48 ab
Panicled tick clover	0 c	25 b	78 a	76 a	69 a
Sessile tick clover	0 c	39 b	73 a	66 a	37 b
Roundhead lespedeza	5 b	63 a	69 a	65 a	65 a
Hairy lespedeza	1 b	69 a	65 a	70 a	58 a
Tall lespedeza	<1 c	39 b	47 ab	51 a	39 b
Slender lespedeza	4 d	67 a	60 a	38 a	26 c
Mean	3 c	51 a	64 a	58 a	51 a

[a] Means within a species followed by the same letter are not significantly different at the 0.05 level.

is high and the window of opportunity for growth and development is small. This condition may occur when moisture conditions are variable or when competition from other species is a problem. Seeding species at temperatures below what is required for rapid germination might not be a good strategy for favorable establishment in some environments. Only 2 species, hoary tick clover and sessile tick clover, had their maximum total germination percentage and largest germination rate index both occur at the same temperature (20° C), indicating that this may be close to their optimum temperature for germination.

Successful stand establishment requires more than just assuring good germination when environmental conditions are favorable. Good seedling vigor after germination is necessary to ensure good stands. Little is known about the effects of temperature on seedling growth of native legume species. Research is needed to further our knowledge of the effects of temperature on seedling development of native legumes.

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