Germination Requirements of Green Needlegrass (*Stipa viridula* Trin.)

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Abstract

Germination requirements of green needlegrass (*Stipa viridula* Trin.) were studied because of its potential for use in revegetation of disturbed lands. The effects of temperature, light, physiological, and mechanical treatments on germination of green needlegrass seed from 4 sources were examined to determine requirements for maximum germination and possible causes of dormancy. Optimum temperatures for germination were 20°C (constant) and 20–15°C (16 hr-8 hr alternation). Germination was highest in constant darkness. Greatest germination of the most dormant source occurred when seeds were either prechilled or treated with gibberellic acid and the lemma and palea was clipped with a razor blade. The results indicated that dormancy of green needlegrass seeds was associated with a deficiency of endogenous gibberellins and with mechanical and permeability restrictions imposed by the lemma and palea.

Green needlegrass (*Stipa viridula* Trin.) is a native, cool-season perennial bunchgrass common in the northern Great Plains. Several researchers have reported that it has potential for use in revegetation of disturbed lands (Rogler 1960, Frank and Larson 1970, Larson and Carter 1970, Sims and Redente 1974).

Dormancy of green needlegrass seeds often causes problems in stand establishment (Kinch and Wiesner 1963, Fendall and Carter 1965, Frank and Larson 1970). Rogler (1960) found that an average after-ripening period of 7 years was required for seeds of this species to exhibit maximum germination. Researchers have reported that prechilling imbibed green needlegrass seeds at 2 to 4°C for 3 weeks (Dawson and Heinrichs 1952; Niffenegger and Schneiter 1963), 8.6 weeks (Rogler 1960), and 12 weeks (Wiesner and Kinch 1964) reduced or broke dormancy.

Grabe (1963) broke dormancy of green needlegrass seeds by removing a portion of the lemma and pricking the pericarp. Dawson and Heinrichs (1952) found that dormancy was broken by a 3-week prechill at 4°C combined with either lemma and palea removal or scarification in 95% sulfuric acid. They concluded that two kinds of dormancy exist in green needlegrass seed: physiological dormancy that can be overcome by prechilling imbibed seed prior to germination and mechanical dormancy caused by the lemma and palea.

Fendall and Carter (1965) examined the influence of the lemma and palea on germination of green needlegrass seeds. Water uptake during the first 10 hours of germination was limited by the lemma and palea, but this was not a factor influencing total germination. Oxygen uptake was limited by the lemma and palea. Frank and Larson (1970) concluded that presence of an oxidizable inhibitor, impermeability of the lemma and palea to oxygen, prevention of coleoptile and radicle emergence by the lemma and palea, and low seed vigor are among the possible factors involved in dormancy of green needlegrass seeds.

The present study was initiated to provide information concerning germination requirements of green needlegrass as an aid to its use in revegetation. Objectives were to (1) examine the influence of temperature, light, and prechilling on germination and (2) identify possible causes of dormancy by comparing the effects of prechilling, clipping the lemma and palea, and treatment with gibberellic acid (GA) on green needlegrass germination.

Materials and Methods

General Methods

Green needlegrass seeds were obtained from 2 commercial sources, one harvested in South Dakota and one in Montana, and two USDA Soil Conservation Service Plant Materials Centers. Seeds of accession SD-93 were obtained from the Bismarck, N. Dak., Plant Materials Center. Seeds of accession P-15605 were obtained from the Bridger, Mont., Plant Materials Center.

Seeds in all experiments were germinated on standard blue blotter paper underlain by a layer of creped cellulose (Kimpack) placed in plastic boxes measuring 13.0 × 13.5 × 3.5 cm with tightly fitting lids. The substrata were moistened with 100 ml of tap water and remoistened when necessary. Four replications of 100 seeds each were used in all experiments except as noted for pilot experiments. Seeds were treated with thiram, bis (dimethylthiocarbamoyl) disulfide, to minimize fungal growth.

Germination counts were made daily for a period of 28 days after planting. Seeds were considered to have germinated when the coleoptile and radicle had extended one-half the length of the seed. Percent germination was calculated on the basis of the percent live seed in each source, i.e.,

$$(1) \quad \text{\% germination adjusted for live seed} = \frac{\text{\% germination of source} \times}{\text{\% live seed of source} \times} 100$$

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to adjust for differences in viability among sources. Percent live seed in each source was determined in standard germination and viability tests. Rate of germination was calculated by the equation of Kotowski (1926) for coefficient of velocity of germination (CVG) where:

$$\text{CVG} = \frac{N100}{\Sigma(ND)} \qquad (2)$$

in which N = number of seeds germinated and D = number of days corresponding to each N.

Influence of Temperature, Light, and Prechilling on Germination

Effects of temperature, light, and prechilling on germination of green needlegrass were examined by germinating prechilled and unchilled seed under dark and light conditions in growth chambers adjusted for constant temperatures of 5, 10, 15, 20, 25, and 30° C and alternating temperatures of 15-20, 15-25, 20-15, 20-25, 25-15, and 25-20° C. The prechill treatment consisted of exposing imbibed seeds to a temperature of 2 to 4° C for 1 month. The light treatment consisted of 400 μE m^{-2} sec^{-1} of photosynthetically active radiation for 8 hours daily. Alternating temperatures consisted of 16 hours at the first temperature and 8 hours at the second temperature daily.

Comparative Effects of Prechilling, Clipping, and Gibberellic Acid on Germination

Germination of caryopses with the lemma and palea removed, seeds with the lemma and palea clipped, and intact seeds were compared in a pilot experiment. Seeds were clipped with a razor blade by cutting both ends of the lemma and palea which cover the caryopsis. Care was taken to avoid damage to the caryopsis. Four replications of 25 seeds each were germinated in the dark in a seed germinator adjusted for a constant temperature of 25° C.

Following the pilot experiment, the effects of clipping and physiological treatments on germination were compared. The physiological treatments consisted of a 1-month prechill at 2 to 4° C and moistening of the substrata with 100 μg ml^{-1} GA (gibberellic acid). This concentration of GA was selected because a previous experiment had demonstrated that clipped seeds of the South Dakota and Montana sources germinated equally well when treated with *100, 500, 1000*, and *1500* μg ml^{-1} GA. Seeds were germinated in the dark in a seed germinator adjusted for 20-15° C (16 hours-8 hours).

Statistical Analyses

A split-split-plot experimental design was used for constant and alternating temperature experiments in the temperature, light, and prechilling study. In the study of the effects of prechilling, clipping, and GA on germination a completely random experimental design was used for pilot experiments and a randomized complete-block design was used in the final experiment. Data were analyzed by analysis of variance. Duncan's multiple range test was used at the 0.05 level of probability to identify significantly different means when *F* values were found significant.

Results

Influence of Temperature, Light, and Prechilling on Germination

Constant Temperatures

Significant differences in percent germination and rate of germination existed among seed sources at constant temperatures. Seeds of accession P-15605 exhibited the highest percent germination averaged over all treatments. The South Dakota source exhibited the highest rate of germination. The Montana source had the lowest germination rate and percentage.

Differences in germination percentages and rates among sources resulted from differences in level of dormancy among sources. Accession P-15605 and the South Dakota source were the least dormant sources, while accession SD-93 and the Montana source were the most dormant sources. Diffrences in seed age and harvest date are among the possible factors responsible for differing levels of dormancy among the 4 seed sources.

Percent and rate of germination differed significantly among

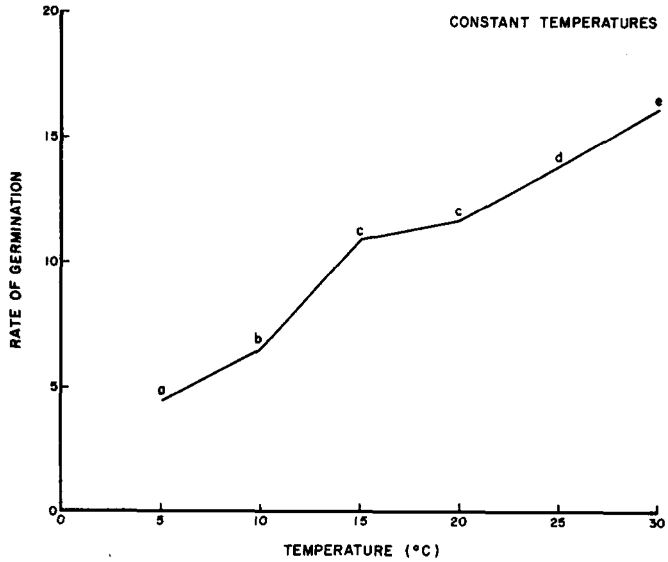

Fig. 1. *Effects of constant temperatures on germination rate of green needlegrass seeds. Means associated with the same letter are not significantly different at the 0.05 level of probability.*

constant temperatures. Averaged over all seed sources and treatments, percent germination was highest at 20° C. Rate of germination increased with increasing temperature (Fig. 1). There was an interaction of seed source with constant temperatures for percent germination. Percent germination of P-15605 and SD-93 averaged

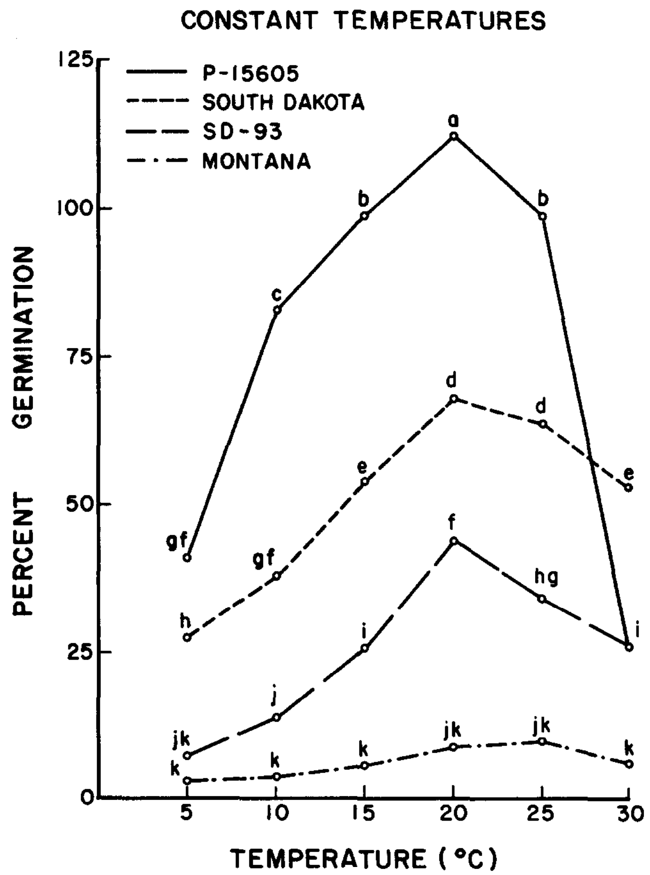

Fig. 2. *Effects of constant temperatures on percent germination (adjusted for live seed) of green needlegrass seed from 4 sources. Means followed by the same letter are not significantly different at the 0.05 level of probability. Since percent germination was adjusted for live seed, it sometimes exceeds 100% because of random variation.*

Table 1. Effects of alternating temperatures (° C) on percent germination (adjusted for live seed) of green needlegrass seed from 4 sources.

	Seed Source[1]			
Temperature	P-15605	South Dakota	SD-93	Montana
15-20	79fg	74efg	66de	16ab
15-25	84gh	66de	50c	14ab
20-15	83gh	77fg	79fg	22b
20-25	59cd	73ef	53c	12a
25-15	90h	78fg	59cd	14ab
25-20	59cd	72ef	58cd	14ab

[1]Means followed by the same letter are not significantly different at the 0.05 level of probability. Means represent averages over light and prechill treatments.

over light and prechill treatments was higher at 20° C than at other temperatures (Fig. 2). Percent germination of the South Dakota source did not differ between 20° C and 25° C. For the Montana source, percent germination did not differ significantly among constant temperatures.

Averaged over all seed sources, constant temperatures, and prechill treatments, percent germination and rate of germination were significantly higher in the dark than in the light. There was an interaction of light with constant temperatures. Percent germination was higher in the dark than in the light at temperatures below 20° C but not at temperatures of 20° C or higher (Fig. 3). Prechilled seeds exhibited higher percent (Fig. 4) and rate of germination than unchilled seeds.

Alternating Temperatures

Significant differences in percent germination and rate of germination existed among seed sources at alternating temperatures. Seeds of accession P-15605 and the South Dakota source exhibited the highest rate of germination. The Montana source had the lowest germination rate and percentage at alternating temperatures.

Percent and rate of germination differed significantly among alternating temperatures. Percent germination averaged over all seed sources and treatments was highest at 20-15° C. Rate of germination tended to increase with increasing mean temperature. There was an interaction of seed source with alternating temperatures. Percent germination of the Montana source and the South Dakota source did not differ among the 5 alternating temperatures most favorable to germination of each (Table 1). P-15605 germinated

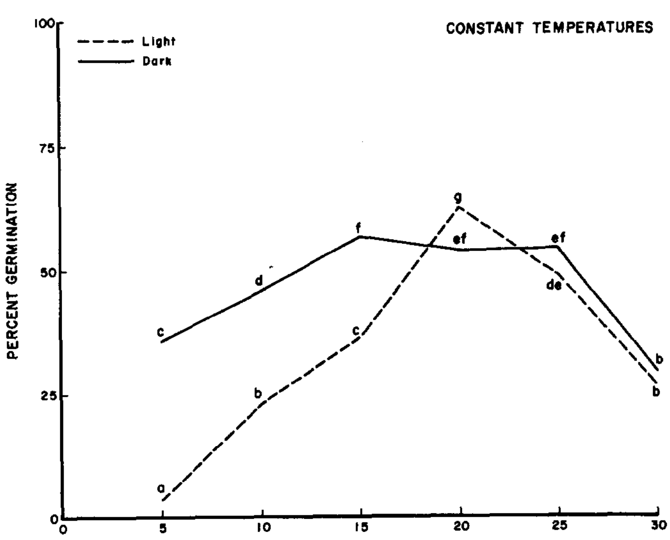

Fig. 3. *Percent germination (adjusted for live seed) of green needlegrass seeds as affected by interaction of light with constant temperatures. Means associated with the same letter are not significantly different at the 0.05 level of probability.*

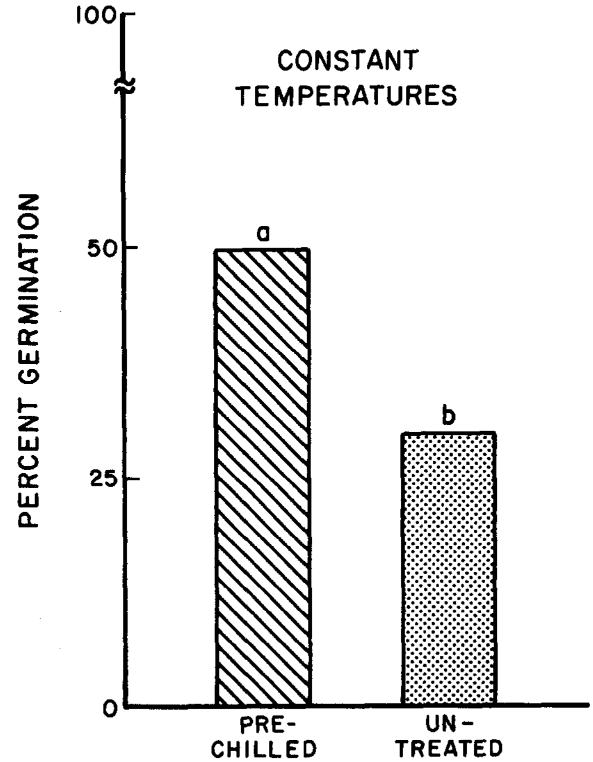

Fig. 4. *Effects of prechilling on percent germination (adjusted for live seed) of green needlegrass seeds averaged over sources, light treatments, and constant temperatures. Means associated with the same letter are not significantly different at the 0.5 level of probability.*

significantly better at 25-15, 15-25, 20-15, and 15-20° C. Seeds of accession SD-93 exhibited higher percent germination at 20-15° C than at other alternating temperatures.

Differences among the 4 sources in the effect of temperature on germination were related to differences in level of dormancy. As a result of relatively lower dormancy, seeds of accession P-15605 and the South Dakota source germinated equally well over a wider range of temperatures than seeds of accession SD-93. Germination of the Montana source did not differ over a wide range of constant and alternating temperatures because it was the most dormant source and the germination was relatively low at all temperatures.

Averaged over all seed sources, alternating temperatures, and prechill treatments, percent germination and rate of germination was higher in the dark than in the light. There was an interaction of light with alternating temperatures. Percent germination was not higher in the dark at alternating temperatures with a 16-hour period at 25° C, but it was higher in the dark at all other alternating temperatures.

Prechilled seeds exhibited significantly higher percent and rate of germination than unchilled seeds at alternating temperatures. There was an interaction of prechill treatment with seed source. Prechilled seeds of the South Dakota source, Montana source, and SD-93 all exhibited higher percent germination, while that of prechilled P-15605 seeds did not differ from percent germination of unchilled seeds.

Comparative Effects of Prechilling, Clipping, and Gibberellic Acid on Germination

Clipped seeds and seeds with the lemma and palea removed exhibited significantly higher germination than the intact seeds in the pilot experiment (Table 2). Percent germination of seeds with the lemma and palea removed was not different from clipped seed.

Significant differences in percent germination existed among physiological treatments and among seed sources in the final experiment (Table 3). There was an interaction of physiological

Table 2. Effects of lemma and palea removal and clipping on percent germination (adjusted for live seed) of 4 sources of green needlegrass in the dark at 25° C.

	Seed treatment			
Seed source	Control	Lemma and palea removed	Clipped	Source means
P-15605	78	130	92	100a[1]
South Dakota	65	94	100	87a
SD-93	33	39	46	40b
Montana	9	19	24	18c
Treatment means	47a	71b	66b	

[1]Means followed by the same letter are not significantly different at the 0.05 level of probability. The interaction between source and seed treatment was not significant at the 0.05 level.

Table 3. Effects of prechilling, clipping, and 100 $\mu g\ ml^{-1}$ gibberellic acid (GA) on percent germination (adjusted for live seed) of 4 sources of green needlegrass after 28 days in darkness at 20-15° C (16 hours-8 hours).

	Seed source			
Seed treatment	P-15605	South Dakota	SD-93	Montana
Control				
Not clipped	89cdef[1]	81defgh	94cde	28l
Clipped	115b [2]	87cdef	76efghi	65hij
Prechilled				
Not clipped	93cdef	77efghi	96cd	47k
Clipped[3]	84defg	62ijk	27l	68ghi
GA				
Not clipped	102bc	87cdef	96cd	49jk
Clipped	137a	79defgh	81efgh	75fghi

[1]Means followed by the same letter are not significantly different at the 0.05 level of probability.
[2]Since percent germination was adjusted for live seed, it sometimes exceeded 100% because of random variation.
[3]Fungal growth tended to depress germination percentages of prechilled clipped seed.

treatments with seed sources and of mechanical treatments with seed sources. Treatment with GA and clipping resulted in higher percent germination of the Montana source and P-15605 but not of the South Dakota source and SD-93. Prechilling increased percent germination of the Montana source over that of untreated controls, but it did not increase percent germination of P-15605, the South Dakota source, and SD-93. This was a result of the relatively greater dormancy of the Montana source. There was no difference between percent germination of Montana seeds treated with GA and those that were prechilled. Germination of clipped seeds of the Montana source was greater than that of prechilled intact seeds. There was no significant difference in percent germination among clipped control, clipped prechilled, or clipped GA treated seeds of the Montana source, although there was a trend for highest germination with the combination of clipping and treatment with GA.

Discussion

Successful revegetation of disturbed lands is more likely to be achieved if those involved in revegetation projects select planting dates based on knowledge of the temperature requirements for germination of the species to be planted and knowledge of the seasonal temperature and moisture conditions of the area to be seeded (Ashby and Hellmers 1955). The temperature optima (20 and 20-15° C) for germination of green needlegrass seed may represent an adaptation for germination under environmental conditions characteristic of spring. In the northern Great Plains, 50% of the annual precipitation is received from April to July (Sindelar and Plantenberg 1978). Planting of green needlegrass in the northern Great Plains should be timed so that germination will take place during the spring when temperature and moisture conditions are most favorable for germination and seedling growth.

Seed dormancy is recognized as an important adaptation of plants that enables them to survive during seasons of adverse environmental conditions (Nikolaeva 1977). The prechill requirement of green needlegrass may be an adaptation that prevents germination when seeds are disseminated in the summer but allows germination to proceed in the spring after seeds have overwintered in the soil. Environmental conditions would expectedly be more favorable for germination and seedling growth in the spring than in the summer. Green needlegrass is often planted in late fall so that dormancy will be reduced the following spring when environmental conditions are favorable for germination (Schaaf and Rogler 1960, Larson and Carter 1970).

Germination of green needlegrass seeds was inhibited by light, particularly at temperatures which were suboptimal for germination. Possible inhibition of green needlegrass seed germination by light was also noted by Niffenegger and Schneiter (1963). The effects of light on germination in relation to the factors responsible for inhibition and their ecological significance need further study.

Dormancy of green needlegrass seeds is not caused by an inhibitor in the lemma and palea since clipped seeds and seeds with the lemma and palea completely removed germinated equally well. Treatment with GA eliminated the prechill requirement of seeds from the Montana source. According to Mayer and Poljakoff-Mayber (1975), seeds of some plant species appear to synthesize gibberellins during prechill treatments. Apparently, dormancy of green needlegrass seeds is associated with a deficiency of endogenous gibberellins and with mechanical and permeability restrictions caused by the lemma and palea. Dormancy of Indian ricegrass (*Oryzopsis hymenoides* (Roem. & Schult) Ricker), a species with which green needlegrass occasionally hybridizes in nature (Johnson and Rogler 1943), has also been attributed to a possible inherent deficiency of endogenous gibberellins (McDonald and Khan 1977). Findings of the present study substantiate earlier reports (Dawson and Heinrichs 1952, Fendall and Carter 1965) that dormancy of green needlegrass is caused by physiological and mechanical mechanisms.

Rapid establishment of artificially seeded stands of green needlegrass can be enhanced by planting nondormant seeds. One way this can be accomplished is to plant Lodorm green needlegrass, a variety with reduced seed dormancy that was released in 1969 (Schaaf and Rogler 1970a, 1970b). However, seed dormancy may be desirable for stand longevity since it is an important adaptation for seed and seedling survival. Also, much of the green needlegrass seed sold commercially originates from native stands. Thus, development of an economical means of breaking dormancy of seeds from native sources would be desirable. The beneficial effects of clipping on germination indicate that a method of scarifying the lemma and palea without damage to the caryopsis could prove helpful in stand establishment. Another method of promoting germination of green needlegrass that needs to be researched is penetration of seeds with gibberellic acid applied in acetone (Khan et al. 1973, Tao and Khan 1974).

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