Germination Characteristics of Range Legumes

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Highlight

The germination of seeds of 19 legumes planted in range seeding exhibited considerable variability in initiation and total germination in relation to constant and alternating temperatures (0.5 to 30 C) and germination at 15 C and osmotic pressures of 0 to 16 bars. The rate of elongation of juvenile seedlings of most of the legumes was at a competitive disadvantage with weedy annual grasses.

A highly successful range improvement practice in cismontane California and western Oregon is the seeding of annual clovers to provide an abundance of nutritious forage during the spring and higher-quality dry forage during the summer and fall (Williams et al., 1957). These introduced legumes, of Mediterranean origin, represent a desirable counterpart to the many undesirable annual weeds which have colonized range habitats, many of the clovers and the weeds were never abundant or dominant, but the inherent characteristics of the weedy species permitted them to exploit heavily grazed rangelands and come to dominate millions of acres. The inherent characteristics of the legumes, on the other hand, are used by land managers in an attempt to cope with the severe competition from resident weedy annual grasses and forbs (Kay and McKell, 1963; Kay, 1964, 1968). The germination of a number of weedy annual grasses of rangelands in relation to temperature and osmotic stress was reported by Young et al. (1968a,b). The present investigation was made to provide comparable information on the germination of legumes to guide practices in range weed control and improved seeding and management.

Methods

The selections investigated were subclover (Trifolium subterraneum subsp. subterraneum L. var. Tallarook, Mt. Barker, Bacchus Marsh, Woogenellup, Diminup, Duralaganup, and Geraldton; subsp. brachycalyximum Katznelson and Morley var. Clare; subsp. yamminicum Katznelson and Morley, var. Varloop); rose clover (T. hirtum All. var. Wilton, Kondinin Hykon, and Sirint); cup clover (T. cherleri L. var. Cranford); bur clover (Medicago hispida Gaertn.); barrel medic (M. sativa L. var. Cyprus and 173); alfalfa (M. sativa L. var. Rambler); woollypod vetch (Vicia dasycarpa Ten. var. Lana); milkvetch (Astragalus cicer L. var. Cicer), and sainfoin (Onobrychis vicicifolia Scop. var. Onar). Species means and groups of species were compared, rather than individual varieties.

Four replications of 25 seeds of each selection were placed on germination pads in 1-cm-deep petri dishes and kept moist with tap water containing 0.1% by volume 2,6-dichloro-4-nitroaniline. Each legume selection was tested in continuous darkness at 0.5, 5, 10, 15, 20, or 30 C. Germinated seeds were counted at 7-day intervals through 28 days.

Selections of subterranean clover, cup clover, woollypod vetch, and sainfoin were germinated in continuous darkness at alternating temperatures of 16 hr at -20 C and 8 hr at 0.5, 5, 10, 15, or 20 C. After 14 days these seeds were switched to a constant 20 C treatment for 28 days. Seeds of the same legumes were also incubated at a constant -20 C. Aqueous solutions having osmotic pressures of 0, 4, 6, 8, 12, and 16 bars were prepared by dissolving, respectively, 11.6, 15.4, 18.0, 22.5, and 25.8 g of polyethylene glycol 1540 in 100 ml of distilled water, a procedure developed by Parmer & Moore (1966) and modified by Young et al. (1968b). Osmotic pressures of solutions were checked with a vapor-pressure osmometer, and concentrations were adjusted to within 0.1 bar. Four replications of 25 seeds of each legume selection were placed in plastic boxes with 5 g of ground polyethylene plastic and 50 ml of polyethylene glycol solution and germination tests were conducted in darkness at 15 C for 14 days. Seedling length was recorded as an indication of juvenile seedling vigor.

Results

Germination in Relation to Constant Temperatures.

Environmental conditions that permit germination are often of short duration on rangelands. An inherent facility for rapid germination at a wide range of temperatures should be of advantage in establishing a legume on rangelands. The subterranean clovers, alfalfa, and cup clover germinated in 7 days at all temperatures from 0.5 through 30 C (Fig. 1). The rose clovers and medics required at least 5 C for germination in 7 days. Germination of all the legumes was depressed markedly at 30 C, though the rose clovers and cup clover retained some germinability. The woollypod vetch and sainfoin selections tested germinated in 7 days only within a restricted range of temperatures; and cicer milkvetch selections did not germinate in 7 days at any temperature.

Total germination.—Total germination is difficult to establish for legumes that have a high percentage of hard seeds, such as cicer milkvetch and rose clover. Even so, the percentage germination of such legumes at 28 days of incubation generally followed the trends among selections incubated 7 days (Fig. 1 and Table 1). A notable exception were the sainfoin selections, whose germination pattern in relation to temperature was not the same at 28 days as at 7 days. No legume had a marked difference in

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2 In this study, osmotic pressure is assumed to be equivalent in effect to matric suction or soil-water tension. One bar equals 1 atm within 1%.
Fig. 1. Germination of legumes incubated for 7 days at 0.5 to 30 C.

Table 1. Percentage germination of legumes in relation to constant temperatures (28 day incubation period).*

<table>
<thead>
<tr>
<th>Legumes</th>
<th>Selections</th>
<th>0.5 C</th>
<th>5 C</th>
<th>10 C</th>
<th>15 C</th>
<th>20 C</th>
<th>30 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subterranean clovers</td>
<td>9</td>
<td>28b w</td>
<td>59ab v</td>
<td>71b u</td>
<td>76ab u</td>
<td>59ab v</td>
<td>1x</td>
</tr>
<tr>
<td>Medics</td>
<td>3</td>
<td>5c w</td>
<td>54b uv</td>
<td>66b u</td>
<td>63c u</td>
<td>54b uv</td>
<td>4w</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>1</td>
<td>5c w</td>
<td>68a v</td>
<td>81a u</td>
<td>88a u</td>
<td>73a uv</td>
<td>5w</td>
</tr>
<tr>
<td>Rose clovers</td>
<td>4</td>
<td>8c v</td>
<td>54b u</td>
<td>55c u</td>
<td>55cd u</td>
<td>51b u</td>
<td>12v</td>
</tr>
<tr>
<td>Cup clovers</td>
<td>1</td>
<td>51a v</td>
<td>70a u</td>
<td>65b u</td>
<td>61c u</td>
<td>60ab uv</td>
<td>2w</td>
</tr>
<tr>
<td>Woollypod vetch</td>
<td>1</td>
<td>20b x</td>
<td>50b w</td>
<td>67b v</td>
<td>81a u</td>
<td>61ab vv</td>
<td>5y</td>
</tr>
<tr>
<td>Sainfoin</td>
<td>1</td>
<td>50a vv</td>
<td>61ab uv</td>
<td>70b u</td>
<td>41e w</td>
<td>29c x</td>
<td>0y</td>
</tr>
<tr>
<td>Cicer milkvetch</td>
<td>2</td>
<td>0c v</td>
<td>0c v</td>
<td>3d v</td>
<td>18f v</td>
<td>90c uv</td>
<td>1v</td>
</tr>
</tbody>
</table>

Mean 21v 52u 60u 59u 58u 4w

*Means are compared within and among temperatures. Means followed by the same letters (a through e) in vertical sequence or by the same letters (u through w) in horizontal sequence are not significantly different at the .01 probability as determined by Duncan's Range Test.

Table 2. Percentage germination of subterranean clovers, cup clovers, woollypod vetch, and sainfoin after pretreatment with temperatures alternating with -20 C and constant -20 C incubation followed by 28 days at 20 C.

<table>
<thead>
<tr>
<th>Species</th>
<th>Pretreatment of 14 days incubation at alternating temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 hr 16 hr</td>
</tr>
<tr>
<td>Subterranean clovers</td>
<td>3</td>
</tr>
<tr>
<td>Cup clovers</td>
<td>7</td>
</tr>
<tr>
<td>Woollypod vetch</td>
<td>0</td>
</tr>
<tr>
<td>Sainfoin</td>
<td>0</td>
</tr>
</tbody>
</table>

Total germination between 5 and 20 C (Table 1). However, germination at 0.5 and 30 C was considerably lower. Sainfoin seeds are normally covered with a pod whose presence markedly affects the rate of germination (Fig. 2). The pod greatly retarded germination at the lower incubation temperatures. Total germination at 28 days of incubation was essentially equal between selections with or without pods.

Variability within species.—A number of selections of subterranean and rose clover were investigated. The variability in germination in response to temperature of each species is compared by superimposing the means and standard deviations of both species in the same diagram (Fig. 3). At 28 days of incubation, little variability was shown at the extreme temperatures (0.5 and 30 C). The subterranean clovers exceeded the rose clovers in total germination by one standard deviation range at 0.5 C, whereas the reverse was true at 30 C. From 5 through 20 C, the selections of both species expressed a great deal of overlapping variability.

Germination in Relation to Alternating Temperatures.

Four of the legumes tested—subterranean clovers, cup clover, woollypod vetch, and sainfoin—produced considerable germination when incubated at 0.5 C for 7 days through 28 days. Selections of the four legumes that germinated appreciably at 0.5 C failed to germinate under an alternating cycle with 16 hr of -20 C. The higher the temperature of the 8-hr portion of the alternating cycle, the lower and more erratic was the germination when these seeds were switched to a constant 20 C.

Germination in Relation to Osmotic Stress.

The legumes tested, except for the rose clovers and alfalfa, showed no
marked differences in germination from 0 through 6 bars of osmotic stress. From 8 to 12 bars, however, percentage germination fell sharply, terminating at 16 bars. Seeds of many selections appeared to imbibes moisture at 16 bars of osmotic stress, but no roots or shoots emerged within the 14-day incubation period. There was still considerable germination of subterranean clovers, cup clover, and sainfoin selections at 8 and 12 bars of osmotic stress.

At 0 bars of osmotic stress, total percentage germination was lower than with the petri dish method with all selections except cicer milkvetch, which doubled. The environment of the closed boxes and the matrix of polystyrene plastic apparently was not as favorable for germination as the petri dishes and moist blotter-paper technique. However, the plastic-box method did not selectively depress germination among legumes except cicer milkvetch.

Elongation.—The seedlings of all legumes tested except woolypod vetch had a very low rate of root and shoot elongation for 14 days of incubation, in comparison with elongation figures given by Young et al. (1968b) for the weedy annual grass medusahead (Trianthema asperum (Sim.) Nevski) (Fig. 4). Woolypod vetch compares favorably with medusahead in juvenile root and shoot elongation at low osmotic stress, and exceeds medusahead at moderate to high osmotic stress.

Discussion

It is difficult to apply the classical concept of cardinal temperatures to the germination and establishment of legumes on arid rangelands. Arid rangelands in temperate portions of the world that receive winter precipitation and summer drought usually have two periods when environmental conditions permit germination.

The first germination period begins in the autumn, following sufficient precipitation to bring soil moisture within the requirements of the individual species. In cismontane California, this is in the period October through December. Environmental conditions, particularly temperature and moisture at the time of germination, largely determine which plant species will be dominant in this annual community during the ensuing growing season. Early seasons (i.e., warmer germination period) are generally referred to as “clover years,” while late initial rains result in a cold germination period and a “poor clover year”—conversely, a good grass year. Any germination in the spring will bring plants into a closed community, with little likelihood of becoming established.

In transmontane California and Nevada, precipitation may not become sufficient until temperatures are too low to permit germination, or a germination period may begin for weedy grasses such as downy brome (Bromus tectorum L.) in late summer following thunder showers (Piemeisel, 1938). Fall germination of downy brome in Ne-
vada occurs in 1 out of 5 years. For species with an after-ripening requirement, such as medusahead, the requirement must be satisfied before fall germination (Young, 1968a). The fall germination period is followed by a winter period of cold and moisture stress. Seedbed environmental conditions during the winter months do not permit germination; but studies by Young et al. (1968c) have shown that overwintering in the seedbed can have a dramatic effect on germination characteristics.

The second germination period begins in early spring, when soil moisture conditions are ideal but seedbed temperatures are very low, especially at night. As seedbed temperatures rise to the optimum for germination of desirable forage species, soil moisture is depleted by resident weedy species. The soil moisture regime may be temporarily recharged by spring precipitation, but seeded species must have enough time to become well established if they are to withstand the long summer drought. Ellern and Tadmor (1966) characterized an ideal plant for establishment on arid rangelands as one with inherent ability to germinate and develop rapidly at low temperatures, so as to withstand an early change to a hot dry climate.

The subterranean clovers, cup clover, woolypod vetch, and sainfoin selections tested showed a remarkable rate and amount of germination at 5 and 0.5 C. The rate of germination at very low temperatures greatly exceeded the inherent capabilities of most desirable or weedy range grasses (Ellern and Tadmor, 1967; Young et al., 1968a). These legumes appear to be highly adaptable to germination in late fall and early spring in cold seedbeds of arid rangelands. Although subterranean clover is well adapted to annual ranges of California, it is very difficult to establish in years with below-average temperatures during the germination period.

The low rate of elongation of juvenile seedlings of most legumes may be a disadvantage in competition with weedy grasses. The legumes have the same relative reduction of elongation in relation to osmotic stress that is found in range grasses (Young et al., 1968b). Their rate of elongation at 0 bars of tension, however, is much less than that of many grasses, especially medusahead.

A notable exception among the legumes is woolypod vetch. This species compares favorably with medusahead in rate of juvenile seedling elongation in relation to osmotic stress, which helps explain why this legume is proposed as a smother crop for medusahead.

Information on seedbed temperature on rangelands is rather limited. In the semiarid Negev region of Israel, diurnal temperature fluctuations in the seedbed zone of shallow-seeded range plants normally reach an amplitude of 20 C on bright days and about 10 C during cloudy and rainy periods (Tadmor et al., 1964). In Nevada, the daily range of air temperature may be 30 to 40 C in extreme instances (U.S.D.A., 1941).

There is little possibility of selecting strains of legumes with increased capabilities for germination at very low temperatures. The reason is that variability in germination is greatly reduced with extreme incubation temperatures, as the subterranean and rose clover selections used in this investigation show. McGinnies (1960) and Ellern and Tadmor (1966) suggested physical modification of range-land seedbeds to provide a temperature regime more favorable to the establishment of desirable species that cannot germinate at low temperatures.

### Table 3. Percentage germination of legumes in relation to osmotic stress (14 days of incubation at 15 C).

<table>
<thead>
<tr>
<th>Species</th>
<th>Bars osmotic stress</th>
<th>0</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subterranean clovers</td>
<td>59ab</td>
<td>68a</td>
<td>59ab</td>
<td>50b</td>
<td>24c</td>
<td></td>
</tr>
<tr>
<td>Rose clovers</td>
<td>33a</td>
<td>27ab</td>
<td>21b</td>
<td>6c</td>
<td>0c</td>
<td></td>
</tr>
<tr>
<td>Alfalfa</td>
<td>75a</td>
<td>60a</td>
<td>25b</td>
<td>20b</td>
<td>0c</td>
<td></td>
</tr>
<tr>
<td>Cup clovers</td>
<td>55a</td>
<td>55a</td>
<td>60a</td>
<td>25b</td>
<td>11c</td>
<td></td>
</tr>
<tr>
<td>Medics</td>
<td>40a</td>
<td>37a</td>
<td>32a</td>
<td>15b</td>
<td>3c</td>
<td></td>
</tr>
<tr>
<td>Sainfoin</td>
<td>39a</td>
<td>42a</td>
<td>36ab</td>
<td>27b</td>
<td>11c</td>
<td></td>
</tr>
<tr>
<td>Woolypod vetch</td>
<td>79a</td>
<td>74a</td>
<td>72a</td>
<td>54b</td>
<td>5c</td>
<td></td>
</tr>
<tr>
<td>Cicer milkvetch</td>
<td>25a</td>
<td>20a</td>
<td>19a</td>
<td>5b</td>
<td>0b</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>51a</td>
<td>48a</td>
<td>41a</td>
<td>25b</td>
<td>10c</td>
<td></td>
</tr>
</tbody>
</table>

3 Evans, R. A. and J. A. Young. 1968. Effects of plant litter on establishment of introduced annual species in big sagebrush communities. Meeting of Western Section of the Ecology Society of America, Logan, Utah.

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\(\text{Mean followed by the same letter are not significantly different at the .01 probability level as determined by Duncan's Range Test. All comparisons are made horizontally.}^{a}\)

\(\text{Sainfoin selections with remnant of pod removed.}^{b}\)
Recent investigations by Evans et al. (1967) and Eckert and Evans (1967) indicated that furrowing or herbicide-furrowing combinations greatly enhanced wheatgrass seedling establishment on arid rangelands. These treatments may benefit legumes also. Kay (1966) described the use of paraquat to control resident annual vegetation during the establishment of seeded legumes, and pointed out that seeding into the old sod provided an improved environment for germinating seedlings. The mulch of dead vegetation helps retain moisture and reduces temperature variation and the hazard of frost heaving.

The seeds of a number of plant species have been shown to respond to temperature fluctuations, germinating better (sometimes only) at alternating temperatures (Morinage, 1926; Lehmann and Aichele, 1931; Stotzky and Cox, 1962). Ellern and Tadmor (1967) reported that alternating temperatures did not stimulate the germination of species (including alfalfa, burclover, and barrel medic) suitable for seeding semiarid rangelands. Alternation cycles with temperatures unfavorable for germination retarded germination more than would be expected from their relative influence on the weighted mean. In this investigation, alternation between temperatures favorable for germination and -20 C inhibited the germination of legumes whose seeds would have germinated at a constant 0.5 C. The germination of subterranean clovers, cup clover, woolypod vetch, and sainfoin at an optimum temperature was greatly reduced by pretreatment at alternating temperatures with an unfavorable alternate of -20 C. The higher the favorable temperature in the alternation cycle with -20 C, the greater the reduction in posttreatment germination at constant temperatures. Freezing of wet seeds at a constant -20 C for 28 days did not harm germination under incubation at a constant 20 C.

The germination of the legumes in relation to osmotic stress generally followed patterns reported by Uhvits (1946) for alfalfa germination in relation to osmotic stress induced by mannitol solutions. Using the same experimental procedure as in this investigation, Young et al. (1968b) reported similar germination responses for range grasses in relation to osmotic stress. Percentage germination of most of the grasses was higher at all levels of stress, however, the subclovers maintained considerable germination at 12.0 bars of osmotic stress, while the rose clovers ceased germination at 8 bars. McGinnies (1960) and Chippendale (1949) pointed out that species that germinate well under a high osmotic stress are not necessarily those that survive and reproduce under severe drought conditions. They cite examples where the reverse has been true. Repeated examples of this inverse relation suggest an inherent linkage in the physiologic systems of the contrasting species. Seeds with the ability to germinate under high osmotic stress may actually be less adaptable to an arid climate since they would be more likely to sprout and die under false starts engendered by early rainfall of low volume not followed by additional moisture in time to keep the seedling alive. Such sequences are found in cismontane California in freak summer storms and early fall rains.

This investigation made no measure of the after-ripening requirement of the various legumes, for none of the seeds were freshly harvested. The after-ripening requirements and other germination characteristics of individual varieties of the legumes are being investigated with seeds obtained from common gardens.

**Literature Cited**


**Young, J. A., R. A. Evans, and R. E. Eckert, Jr.** 1969. Population dy-
Influence of Spring, Fall, and Spring-Fall Grazing on Crested Wheatgrass Range

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Highlight

Grazing crested wheatgrass during spring only, fall only, and spring and fall to a 1-inch stubble height for 10 years had little effect on vegetative characteristics of the seeded stands. Invasion of the stands by other species was greater with spring or spring-fall use than with fall use. Litter decreased with all seasonal treatments, but decreased most under spring-fall use. Drought and growing-season moisture were the critical factors in determining forage yields. The spring-fall pastures produced more forage, provided more days of grazing, and gave the highest average beef production, 177 lb/season. Spring grazing was next and fall grazing the least productive for animal weight gains.

Crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) is undoubtedly the most common and widely used introduced grass for range seedings in the western United States and parts of southern Canada. Its earliest record of introduction into the United States dates back to 1898. In 1915 it was found to be particularly adapted in the northern Great Plains (Westover and Rogler, 1934; Weintraub, 1953, p. 3). Since that time, crested wheatgrass has been used extensively for seedings both west and south of the Plains area. Large areas are commonly seeded and it was estimated as early as 1951 that, of the 8 million acres seeded in the western United States since the mid-thirties, a majority was planted to crested wheatgrass (Woolfolk, 1951).

With this long history, literature is extensive pertaining to adaptability, response to fertilization, clipping, morphological attributes, and economics of seeding crested wheatgrass. Also, its grazing value has been widely investigated throughout the entire western region. Most of the grazing reports, however, have dealt with livestock gains and/or changes in vegetative cover as a result of grazing intensities during one particular season of use: spring grazing, season-long grazing, or a combination of spring grazing plus later use of the regrowth forage. Essentially no research has been done on how long-term grazing influences crested wheatgrass when comparing specific grazing seasons. Therefore, it was the purpose of the research reported here to find out what happens to crested wheatgrass when it is grazed only in the spring, the fall, or both spring and fall over an extended period of years.

Study Area and Methods

The research was conducted at the Manitou Experimental Forest, 28 miles northwest of Colorado Springs, Colorado. The study site is situated at an elevation of approximately 7,800 ft. Annual precipitation has averaged 15.7 inches during the past 25 years. For the 10-year period of study 1957-1966, annual moisture averaged 16.1 inches, with approximately two-thirds of this amount or 10.7 inches being received during the growing season from April through August.

Because of the elevation and weather patterns along the Front Range, winters are open but cold, with temperatures occasionally as low as -40 F. The growing season is short, and only during July and August do overnight temperatures usually stay above freezing. Daytime temperatures during this period seldom exceed 90 F.

Soils on the site are alluvial, derived primarily from outwash materials of Pikes Peak granite. They are generally of low to moderate fertility, have a moderate amount of organic matter, and are quite porous. Classification is a sandy loam.

The study pastures were located on a large alluvial fan within a natural grassland opening of the ponderosa pine type. Years back, many of these open areas were cultivated; this particular one was last cultivated in 1934. Both during and after cultivation, considerable sheet and gully erosion occurred on its westerly facing, 6 to 10% slopes. At the time of seeding in 1946, the area was occupied by a dense cover of low-value forbs typical of abandoned fields in the pine-bunchgrass type.

In preparation for seeding, the area was moldboard plowed, disked, and cultipacked in the fall of 1945. It was then planted in the spring of 1946 at the rate of 5 lb/acre of crested wheatgrass seed, using a single-disc grain drill with a 7-inch row spacing. An excellent stand developed in the next 2 years, and...