Temperature Requirements for Germination in Relation to Wild-Land Seeding[1]

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In California there is considerable interest in improving the quality of range forage and in producing a protective cover on watersheds denuded by fire. This has led to the sowing of grasses and forbs on large wild-land acreages. Selecting desirable species is one of the first problems encountered in a seeding program. The selection has to consider the ability of a species to germinate satisfactorily under the environmental conditions of the area to be sown. It has been known for many years that germination is markedly influenced by temperature and moisture.

A second problem in wild-land seeding is that of choosing favorable sowing dates. Availability of soil moisture poses no problem to seeding in regions of year-round precipitation or where land can be irrigated. Under these conditions, any season of favorable temperatures may be chosen for sowing. Where there are seasonal droughts, however, and the land can not be irrigated, the choice of sowing times is limited. Species are eliminated that require germination temperatures not attained during seasons when the soil is moist. In the southern California mountains, moisture for germination is available in the soil only during a 5- to 6-month rainy season in the cool part of the year.

The objectives of the present study were: first, to determine the relation of temperature to germination for a number of grasses and forbs that are considered promising for seeding of wild lands in southern California; and second, to correlate the germination responses of these species with the local seasonal precipitation and temperature patterns, in order to select the most promising species for sowing.

The influence of temperature upon the germination of a wide range of agricultural plants is discussed in literature reviews by Harrington (1923) and Edwards (1932). In general each species has an optimal range of temperature. Germination is diminished under temperatures higher or lower than the optimal range. Sprague (1944) studied the effects of controlled air temperature, soil temperature and length of day upon the germination of several forage grasses and legumes. He found that high day and night temperatures (100° F. and 85° F. respectively) seriously reduced the seedling emergence of several species.

The influence of temperature on germination was recognized in the Federal Seed Act (USDA 1950, 1952). This Act set temperature standards for seed germination tests. For each species the standard test is conducted under optimal temperature conditions. Commercial seed lots are labeled with the germination percentage obtained at optimal temperatures; however, these temperatures are not shown on the label. The label, therefore, provides information about the viability of the seed, but not all of the information needed by the person planning the sowing. The information needed is the germination rate for the seed under the seasonal field temperatures where sowing is to be done.

Materials and Methods

Day and night temperatures representative of each of the four seasons of the year were determined from records taken for nine years at an elevation of 2,800 feet in the San Gabriel Mountains of southern California (Sinclair and Hamilton, 1953). The temperatures selected were: summer, 86° F. day and 62° F. night; spring and fall, 74° day and 50° night; and winter, 62° day and 39° night. Germination tests were made under these day and night temperatures in the Earhart Plant Research Laboratory at the California Institute of Technology (Went, 1950). Each germination test consisted of planting 100 seeds in vermiculite, watering with Hoagland's nutrient solution (Hoagland and Arnon, 1950), and placing the germinator in a temperature-controlled greenhouse. Emerged seedlings were counted at weekly intervals. Under each set of temperatures, quadruplicate germination tests were made for each accession of Italian ryegrass (*Lolium multiflorum*) and of smilo (*Oryzopsis miliacea*). Single germination tests were made under each set of temperatures for 18 other species.[2] All tests were conducted under an 8-hour day with natural light, and a 16-hour night.

Results

Italian ryegrass germinated well under laboratory temperatures representing all four seasons of the year (Table 1). Smilo, in contrast, germinated well only under summer temperatures. Smilo also showed a greater seasonal temperature response than ryegrass when rates of

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Table 1. Two-week germination of Italian ryegrass and smilo accessions under temperatures representative of the four seasons in a southern California mountain area

Species and Accession	Age of Seed	Germination		
		Summer	Spring-fall	Winter
	Years	*Percent*		
Italian ryegrass				
Acc. a[1]	—	80	76	71
Acc. b	2	50	52	94
Acc. c	—	96	91	86
Acc. d	—	89	88	76
Smilo				
Acc. a[1]	7	52	4	0
Acc. b	6	13	0	0
Acc. c	4	45	13	0

[1] Accession from seed used in a field sowing.

germination were compared (Table 2). Smilo germinated three times as fast under summer as under winter temperatures, Italian ryegrass only twice as rapidly. In addition, Italian ryegrass, under all temperatures studied, germinated as fast as or faster than smilo at the latter's most rapid rate, which was under summer temperatures. Italian ryegrass, under summer temperatures, attained 80 percent germination in 14 days whereas smilo required 42 days.

Of the 18 additional species studied, approximately half showed marked differences in germination under the several temperature conditions employed. Four species germinated best under summer temperature conditions; three species germinated best under spring-fall conditions; three germinated best under winter temperatures (Table 3).

Table 2. Number of weeks to attain 50-percent germination

Species and accession	Germination period		
	Summer	Spring-fall	Winter
	Weeks		
Italian ryegrass			
Acc. a[1]	1	1	2
Acc. b	1	2	2
Smilo			
Acc. a[1]	2	4	6
Acc. b	3	3	(more than 6)

[1] Accession from seed used in a field sowing.

Seed lots representing different strains of two of the species showed different germination responses to temperature. Examples are orchard grass (*Dactylis glomerata*) represented by a "common" and a "very late" strain, and pine bluegrass (*Poa scabrella*) represented by two seed lots of this highly variable species (Jepson, 1925).

Assignment of a species to one of the seasonal classes (Table 3) was based on the differences in germination percentage attained under the seasonal conditions employed. Twenty percent more germination at one seasonal condition than at both of the other conditions was considered evidence of a significant seasonal response. Species showing this difference or more were placed in the seasonal class in which the higher germination was obtained.

Discussion

Knowledge of the temperature requirements for germination serves two needs in seeding work. First, species can be selected that have a good chance of germinating under the temperature-moisture regime of a particular region. Second, the best time of year for sowing particular species can be determined, based upon seasonal temperature data for the sowing site and knowledge about seasonal availability of soil moisture. With this knowledge, funds and effort in wild-land seeding can be used most effectively.

Table 3. Germination response of grasses and forbs to southern California seasonal temperature conditions[1]

Germinated uniformly well at all seasonal temperatures:

Crested wheatgrass (*Agropyron cristatum*
Black mustard (*Brassica nigra*)
Soft chess (*Bromus mollis*)
Ripgut grass (*Bromus rigidus*)
Harlan brome (*Bromus stamineus*)
Orchard grass (*Dactylis glomerata*)[2]
Russian wild-rye (*Elymus junceus*)
Italian ryegrass (*Lolium multiflorum*)
Perennial ryegrass (*Lolium perenne*)
California common alfalfa (*Medicago sativa*)
Rose clover (*Trifolium hirtum*)

Germinated best at high (summer) temperatures:

Orchard grass (very late strain) (*Dactylis glomerata*)[2]
Beardless wild-rye (*Elymus triticoides*)
Bush muhly (*Muhlenbergia porteri*)
Smilo (*Oryzopsis miliacea*)
Mediterraneangrass (*Schismus barbatus*)

Germinated best at moderate (spring-fall) temperatures:

Perennial veldtgrass (*Ehrharta calycina*)
Small-flowered melicgrass (*Melica imperfecta*)
Pine bluegrass (*Poa scabrella*)[2]

Germinated best at low (winter) temperatures:

Mountain brome (*Bromus marginatus*)
Red bromegrass (*Bromus rubens*)
Pine bluegrass (*Poa scabrella*)[2]

[1] Germination during 4 weeks (6 weeks for smilo) based upon 100 seeds per test.
[2] Different seed accessions.

The germination percentages carried on the label of commercial seed lots are inadequate. This point is exemplified by germination results obtained with Italian ryegrass and smilo. The seed bag labels for two of the seed lots used in this study indicated germination of 90.00 percent for ryegrass and 76.55 percent for smilo. No indication was made of the fact that both species were tested under temperatures that correspond to southern California summer conditions. Furthermore, the germination test of ryegrass is completed in 14 days while smilo requires 42 days.

The seasonal temperature and moisture patterns over most of the southern California wild-land areas greatly restrict the period during which seeds can germinate. The surface soil in these areas is moist enough for germination and seedling growth only during late fall, winter and early spring. Even during these seasons rainless periods of 10 days' to 6 weeks' duration occasionally dry the surface soil. Smilo, in spite of its high potential germination under standard conditions, can not be expected to germinate well in the field in these areas because the times when moisture is available do not coincide with the times when satisfactory germination temperatures prevail (Table 1). Further, the rainless periods that occur in the rainy season frequently dry the surface soil before the slowly germinating smilo seeds have time to germinate. On the other hand, Italian ryegrass is capable of rapid germination even under the cooler winter temperatures of this region. Thus it germinates during the short periods when mosture is available.

A chance to compare the laboratory findings for Italian ryegrass and smilo with a field sowing in southern California presented itself in the spring of 1952. During the previous summer a brush fire (the Cherry Canyon fire) had swept through about 8,000 acres of the Angeles National Forest. The burned area was sown by airplane in January 1952 to a mixture of grass and legume species to obtain a quick soil-protecting cover. (This seed was drawn upon for one accession each of Italian ryegrass and smilo seed used in the tests already described.) During the succeeding month the sown area received about 10 inches of rain. At the end of the month a check of the area showed excellent germination of Italian ryegrass, but no germination of smilo. Later in the summer, a few smilo plants were found, confined to depressions and channels where moisture remained in the surface layer of the soil long enough to permit germination of this slow-germinating species.

Both the laboratory and field results show that lack of summer rains in southern California rules out those species requiring high temperatures for rapid germination. The irregularity of the annual rainfall pattern in fall, winter and spring creates a high risk for the sowing of species favored by temperatures of any one of these seasons. Only by sowing those species that germinate well under all seasonal temperatures is it possible to be assured of good germination.

The differences in germination between two accessions each of pine bluegrass and orchard grass emphasize the fact that different seed lots or strains of the same species may respond differently to temperature. This indicates the necessity of knowing the location where the seed was grown and the strain of the species. It also indicates the advisability of testing each seed lot of any variable species to be used in a sowing.

The results of this study show that information can be rapidly obtained on the germination capabilities of grasses and forbs. Once the effect of temperature upon the rate of germination is known, this information can be correlated with the climatic conditions of the area to be sown, and the most desirable species can be selected. Variability may occur between strains of the same species, which means that extension of germination data from one seed lot to another may not be justified. While the response of germination to temperature is known for crops in common use, it frequently is not known for plants newly introduced or for native plants which are being used agriculturally for the first time. Knowledge about the germination requirements for such species may be gained readily in the laboratory and may save years of costly trial and error in the field.

Summary

This study was designed to determine the relationship of temperature to germination of various grasses and forbs that are considered promising for seeding of wild lands in southern California.

Twenty species were classified on the basis of laboratory tests of germination under local summer, spring-fall and winter temperatures. Italian ryegrass and ten other species germinated equally well over the entire range of seasonal temperature conditions used. Smilo and four other species germinated best at summer temperatures. Three species germinated best at spring-fall temperatures, and three others germinated best at winter temperatures. For two species, seed lots and strains differed in their germination under the same seasonal temperatures.

The laboratory findings served to explain observed differences in field germination of Italian ryegrass and of smilo in southern California wild-land sowings.

The germination percentage obtained in field sowings may be much lower than the potential germination percentage reported on seed bag labels. This lower germination in the field may be due to unfavorable temperature conditions at the time of expected germination, or unfavorable moisture conditions at times when temperatures are optimum for germination.

To achieve a successful field sowing it is necessary to make a careful choice of species, using only those that will germinate under the field temperature conditions that will prevail when there is adequate

soil moisture. Laboratory tests have shown that temperature limitations can be rapidly and economically determined. This information can then be correlated with local field temperature and moisture conditions for use in selecting species and in choosing sowing dates.

LITERATURE CITED

Edwards, T. I. 1932. Temperature relations of seed germination. Quart. Rev. Biol. 7: 428–443.

Harrington, C. T. 1923. Use of alternating temperatures in the germination of seeds. Jour. Agr. Res. 23: 295–332.

Hoagland, D. R. and D. I. Arnon. 1950. The water-culture method for growing plants without soil. Calif. Agr. Expt. Sta. Circ. 347. 32 pp.

Jepson, W. L. 1925. A manual of the flowering plants of California. Berkeley, Calif. 1238 pp.

Sinclair, J. D. and E. L. Hamilton. 1953. A guide to the San Dimas Experimental Forest. Calif. Forest and Range Expt. Sta., Berkeley, Calif. 19 pp., mimeo.

Sprague, V. G. 1944. The effects of temperature and day length on seedling emergence and early growth of several pasture species. Soil Sci. Soc. Amer. Proc. 8: 287–294.

U. S. Dept. Agr. 1952. Testing agricultural and vegetable seeds. Agric. Handbook No. 30, Supt. Doc., Gov. Printing Office, Wash. D. C.

——, Production and Marketing Administration. 1950. Rules and regulations under the federal seed act. Service and Regulatory Announcements No. 156.

Went, F. W. 1950. The Earhart plant research laboratory. Chronica Botanica 12: 89–108.

AN ECOLOGICAL AND RANGE VEGETATION ANALYSIS OF THE UPLAND SITES OF THE SOUTHERN EXTENSION OF THE OAK-HICKORY FOREST REGION IN TEXAS

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The southern extension of the oak-hickory forest region in Texas was studied in an ecological and vegetational survey made during 1952 and 1953 to determine the following: (1) the relation of soil to the eastern, southern and western boundaries of the region; (2) the relation of temperature, rainfall and evaporation to the composition and distribution of the vegetation in the study area; (3) the development of a range condition guide from ecological and grazing data obtained in wooded and open pastures and relict areas throughout the area; and (4) the relation of time and intensity of grazing by livestock to present and potential usage on a condition class basis. Sites representing different stages of ecological development were selected for vegetational analysis. Line-interception and belt-transect measurements were made to determine relative composition and density of the vegetation and the effect of different stockng rates in open and wooded sites.

The closest correlation of the soils and vegetation occurred on the western boundary. However, the vegetational boundaries generally coincided with the soil type limits. The ecotones between the forest and the surrounding vegetational regions in the east and southeast regions were broader and had a great intermingling of plant species of the areas which were represented in the site.

Climate has played an important role in the composition and distribution of the vegetation of the region. The limits of the southern and eastern sectors of the region were largely determined by the total yearly rainfall in the south and southwest. The oak-hickory forest did not penetrate to any extent into areas in which yearly rainfall exceeded evaporation. Mesquite and eastern redcedar were frequent components in the drier western and southwestern regions. Winged elm occurred with the greatest frequency in the wetter northern portions of the region.

Two species of grass were selected from each group of decreaser, increaser and invader forage plants to determine the effects of climate on their distribution. Analysis showed that the distribution and composition of the herbaceous plants varied in the four sectors. Little bluestem had approximately the same composition in all regions. Panicums and paspalums were more abundant in the northeast and southeast; Texas winter grass was confined primarily to the wooded sites; curly mesquite was recorded only in the southwest portion. Climatic and soil factors apparently were equally effective in determining the composition and distribution of the vegetation in all sectors, except in the northeast, where climate was the decisive factor.

A range condition guide was developed for the region. Indicator grasses were selected from the decreaser, increaser and invader classes. Comparisons of the relative density and species composition of these indicator plants were made in sites subjected to different treatments such as: (1) number of acres per animal unit year; (2) summer deferment; (3) total deferment; and (4) relict sites or areas which were apparently undisturbed. The range condition guide shows that little bluestem was a good indicator of sites in excellent and high-good condition. Brownseed paspalum and silver bluestem were the best indicators of a fair and good condition range; three-awns and panicums were indicators of areas in poor condition. The number of woody stems per acre and the percentage composition of the woody plants were of little or no value in the development of the range condition guide for this area.

The data pertaining to the length of time the various sites have been grazed were inconclusive due to the many recent changes in management plans and/or owners in the recent past. All areas sampled had been subjected to the present stocking rate for periods in excess of three years. The study indicated that the stocking rate must provide more than 15 acres per animal unit on a yearlong basis to prevent the destruction of the decreaser plants in the upland sites. Brownseed paspalum and silver bluestem grass were the dominant plants in the 10–15 acres-per-animal-unit group, indicating that the site was not producing the forage that it would yield if a sound management program were effected in the area.—
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