Germination of Range Plant Seeds at Fixed Temperatures[1]

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Highlight

Low temperatures in the 4-10C (39-50F) range were found in the laboratory to delay germination of pasture plants, especially of perennial grasses. Analysis of meteorological data showed temperatures in this range to be prevalent during rainfall periods in the winter (sowing) season in Israel's semi-arid South, and they are considered a critical factor in seeding perennial grasses on arid range. Germination may be improved by agronomic measures, such as plant selection and breeding for cold resistance and seedling vigour, timing of seeding operations, and soil surface treatments to increase soil temperature.

In an arid environment, the establishment of plants otherwise adapted to climatic extremes often presents additional difficulties. The soil surface is wetted only infrequently, and the germinating seed as well as the developing seedling must compete for the rapidly diminishing moisture of the seedbed. Seedlings may be regarded as established only after their roots have reached the moist deeper soil layers. Where rainfall comes in the cool season (winter rainfall), low temperatures may further retard and adversely affect germination and seedling growth. This may have been the cause of frequent past failures in range seeding operations (Tadmor and Hillel, 1956; Negbi, 1957; Arnon, 1958).

There have been many studies on the temperature dependence of germination (reviewed amongst others by Lehmann and Aichele, 1931; Koller, 1955; Mayer and Poljakoff-Mayber, 1961). However, few were found relevant to the species studied in this work or to semi-arid environments (Koller and Negbi 1955; Koller, 1957). Most of the more relevant recent work has been reviewed by Dubetz, et al. (1962), who studied emergence from soil. The work of Went (1949) and of Jühren, Hiesey and Went (1953) was based on parallel field trials and controlled environment facilities designed to reproduce field conditions as far as possible. McGinnies (1960) studied the interaction of temperature and moisture stress as affecting germination of grasses.

The present paper summarizes data on the temperature dependence of germination for ten cool-season range plants and is part of a more general investigation of environmental factors bearing on establishment of these plants in semi-arid winter rainfall regions (Tadmor et al., 1964, 1965).

Materials and Methods

Soil temperatures were measured by the Israel Meteorological Service at Beersheba (long. 34° 48′ E; lat. 31° 15′ N; alt. 280m) in undisturbed soil at 2 and 5 cm depths, with Amarel bent-step mercury-in-glass thermometers at 3-hr intervals throughout the year since 1956. Data for the rainy (sowing) season were analyzed to determine temperatures employed in this study: 4, 10, 15, 20, 25 and 30C.

The seeds used were those of ten range plants suited to a semi-arid winter rainfall environment with wheat and barley for comparison: the perennial grasses *Agropyron elongatum* Host. P.B. (tall wheatgrass); *Agropyron desertorum* (Fisch.) Schult. (crested wheatgrass, vars. Fairway and Nordan); *Phalaris bulbosa* L. (hardinggrass, local ecotype); *Oryzopsis holciformis* (M.B.) Hack. (hairy ricegrass); and *Hordeum bulbosum* L. (bulbous barley); the annuals wheat (*Triticum aestivum* L. var. Florence Aurore), barley (*Hordeum vulgare* L. var. Beecher) and *Avena sterilis* L. (animated oats); and the annual legumes *Medicago hispida* Gaertn. (bur medic), *M. truncatula* Gaertn. (barrel medic) and *Trifolium purpureum* Loisel (purple clover). While no attempt was made at grading the seed, light or off-color seeds or empty glumes were eliminated as far as possible. Of *Avena sterilis*, only the two lowermost seeds of the spikelet were used after separation from each other and removal of the awns. Seeds were stored in the laboratory at room temperature prior to the experiment.

Seeds were germinated in 9-cm petri dishes, on one layer of filter paper equivalent to Whatman No. 3. 3 ml of tap water were added on zero day and 2 ml more on zero + 2 day. There were 50 seeds in each dish, with 4 replicates, except for the larger-seeded *Avena sterilis*, of which 25 seeds were placed in each dish, with 8 replicates.

Germination was carried out in humidified incubators at temperatures held constant to within ± 0.8C, in the dark except for daily germination counts made in daylight. Counts were terminated on the 30th day or after no further germination had occurred for 7 days. Two parameters were used for analysis: days to "onset" of germination, defined as the day on which 10% of final (30-day) germination was reached; and days to "full" germination defined as the day on which 80% of final germination was reached at any one temperature. In addition, mean days to germination (M.D.G.) were calculated, following Gassner as cited by Lehmann and Aichele (1931, p. 306). This is, in fact, the reciprocal of Kotowski's (1926) coefficient of velocity, and calculated as $\frac{\Sigma(n.Dn)}{\Sigma n}$, where Σn is the total

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number of seeds germinated, n the number of seeds germinated on any one day, and Dn the number of days elapsed on that day since zero day (of wetting).

The effect of ageing of seeds and after-ripening on germination was not studied in this work. Seeds were normally tested one year, and at the least several months, after harvesting. While Harper (1964) has drawn attention to the significance of seed polymorphism in relation to bulking seed lots for germination experiments, this problem has not been dealt with.

Results

The analysis of rainfall and soil temperature data obtained for the rainy season at 2-5cm depths (Tadmor et al., 1964) showed daily mean temperatures to be often in the 8-20C range. Daily maxima in dry periods reached 30-35C and on clouded or rainy days dropped to 10-12C or less. Daily minimum temperatures were mostly in the 4-10C range and minima of 2-4C were by no means rare. Monthly means for minima ranged from 5-10C, for maxima from 15-30C and for daily means from 10-20C. These data guided the selection of temperatures employed in germination.

Days to onset of germination.—The data for onset of germination are presented in Fig. 1 and 2. The perennial grasses except for *Hordeum bulbosum* and the annual *Avena sterilis* were retarded by low temperature (4-10C). The majority of the annuals and the perennial grass *Hordeum bulbosum* were, on the contrary, hardly retarded by these temperatures; and while *Hordeum bulbosum* was retarded by high temperature (25-30C), wheat, barley, the *Medicago* spp. and *Trifolium purpureum* were relatively unaffected by temperature extremes.

Full germination.—Fig. 3 and 4 show that as in onset the perennial grasses were retarded by the low temperatures (4-10C). *Avena* and *Hordeum bulbosum* were highly sensitive, being retarded by both the high (25-30C) and the low temperatures. The two *Medicago* spp. were retarded by the high temperatures. Wheat, barley and *Trifolium purpureum* were less sensitive.

Mean days to germination (M.D.G.).—As might have been expected, the data for M.D.G. (Fig. 5 and 6) agree well with those for onset and full germination. The behavior of species is practically identical for full germination and M.D.G.

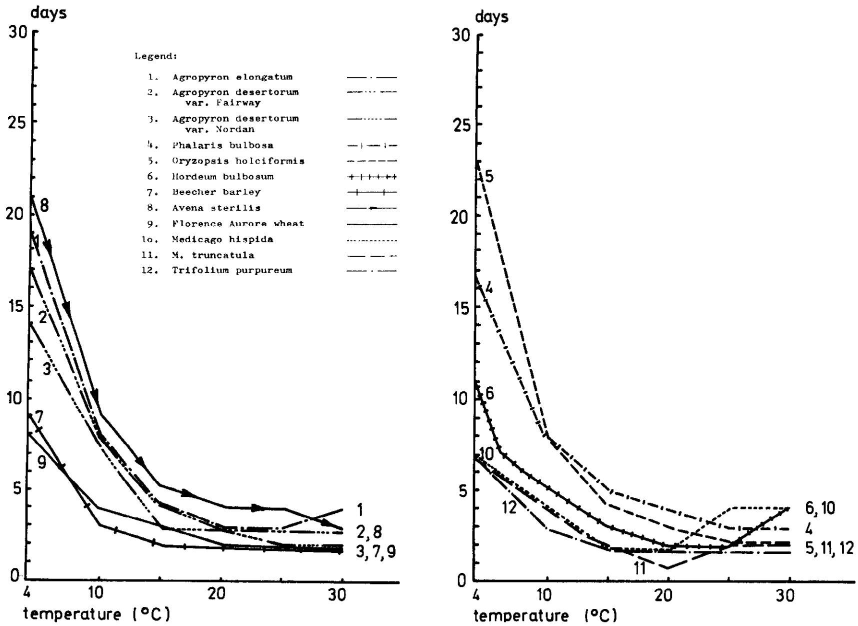

FIG. 1 (left) and 2 (right). Days to onset of germination (10% of final germination) as a function of temperature.

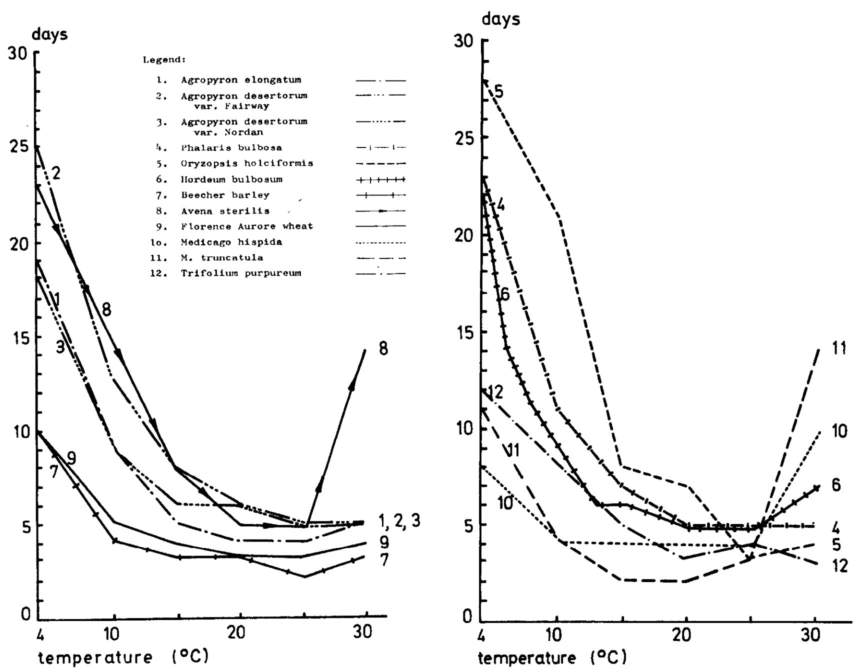

FIG. 3 (left) and 4 (right). Days of full germination (80% of final germination) as a function of temperature.

Final germination.—There was no clear optimum temperature range for final germination (at 30 days) in six of the species studied once the time factor was eliminated (Fig. 7). This agrees with Harrington (1963). Nevertheless, final germination percentage shows clearly the unfavorable effect of 4C and especially of 30C on the germination percentage of some of the species, including *Trifolium purpureum,* which was so consistent in its relative indifference to temperature extremes regarding its time to germination.

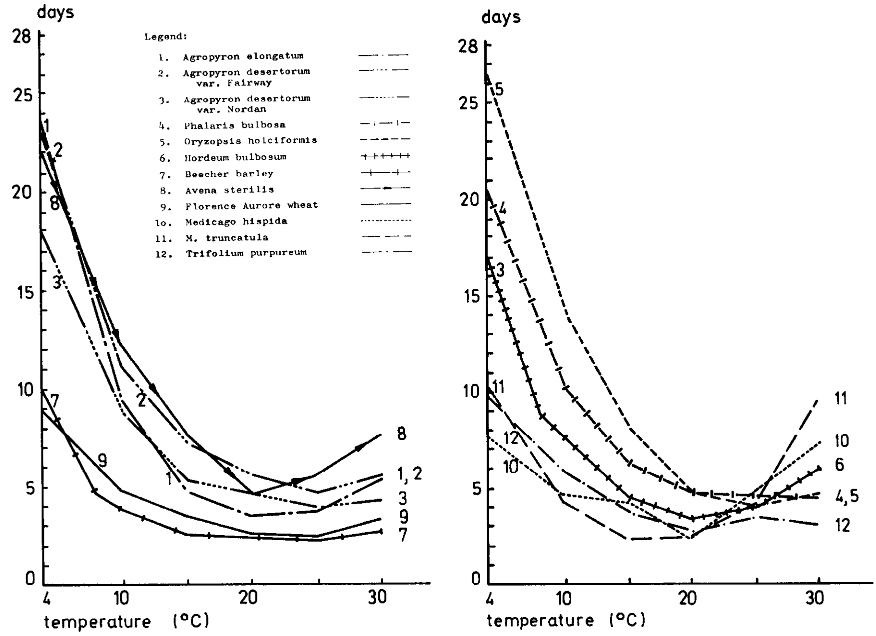

FIG. 5 (left) and 6 (right). Mean days to germination (M.D.G.) as a function of temperature.

Discussion

The speed with which range plants germinate may be the critical factor in establishment under the seedbed conditions prevailing in a semi-arid environment. Low temperatures in the 4-10C range, which are of frequent occurrence during the rainy (sowing) season in the Negev markedly retarded onset and full germination of all the perennial grasses investigated, except onset of *Hordeum bulbosum.* The annuals, both gramineae (except *Avena)* and legumes were less adversely affected by low temperatures. Past failures of the cold-sensitive species in seeding operations may be explained by this germination behavior. Low temperatures may have slowed germination to such an extent that the seedbed dried out and the seeds lost their viability prior to emergence. Possible causes of failure to emerge are discussed by Leslie (1965). This contrasts with the germination behavior of the crop plants such as barley and wheat, which were not markedly retarded by low temperatures.

Although it may sound odd, range plant improvement for successful establishment should aim at plants able to germinate and develop rapidly at low temperatures in order to withstand a hot dry climate. A parallel exists in recent work attempting to incorporate the low temperature growth ability of Mediterranean into British grass strains for "early bite" (Morgan, 1964).

Another, more short-term approach to ensuring establishment may be to alter seedbed temperatures by soil surface treatments and other agrotechnical means (Bement et al. 1961). This seems to be a prerequisite to successful seeding under present conditions. Work on this point is in progress and preliminary results are promising (Cohen et al. 1965).

Eight of the species were sensitive to the high temperatures normally encountered in the seedbed only in early and late winter (November and March). High temperatures should therefore not be limiting if sowing is suitably timed. While both the low (4-10C) and the high (25-30C) temperatures adversely affected germination, the low temperatures delayed germination rather than depressing germination percentage. Thus, even at 4C *Oryzopsis holciformis* germinated, but only reached "onset" on the 23rd and "full" germination on the 28th day (Fig. 2 and 4). While by the 30th day "final" germination percentage was below 20% at 4C as compared with over 60% at 10C (Fig. 7), even at 4C, germination eventually reached 60% if counts were continued beyond the 30th day.

The high temperatures, on the other hand, depressed germination rather than delaying it. They hastened or did not delay onset of germination (Fig. 1 and 2). Full germination of species sensitive to the high temperatures such as *Medicago* was much less delayed by the high temperatures (25-30C) than full germination of the cold-sensitive perennial grasses by the low temperatures (Fig. 3 and 4). The adverse effect of high temperature (30C) was most marked in depressing final germination percentage of *Hordeum bulbosum* and *Trifolium purpureum* to well below 10%. This difference between the effect on germination of low and of high temperature, noted also by McGinnies (1960), does not seem to have received sufficient attention. Otherwise, our data are in general agreement with previous studies (Lehmann and Aichele, 1931; Dubetz et al. 1962; Harrington, 1963). Low germination of *Avena sterilis* may have been due to dormancy. As reported elsewhere (Tadmor et al. 1965), piercing the seedcoat of ungerminated grains remaining on the 30th day, as described by Thurston (1957) resulted in almost all tests in additional germination by the 50th day.

The concepts of time to "onset" and "full" germination were employed in analysis of the data, since the time factor seemed of overriding importance in discussion of temperature dependence of germination in a semi-arid environment. The method was adapted from Koller (1957) and compares well with other forms of presentation. The choice of 10% of final germination for onset and 80% for full germination is arbitrary. 10% rather than 20% of final germination was chosen for onset because of the positive skewness of the daily germination curve (Hepton, 1957). It is important to distinguish here between "time to germination" and total or "final" germination percentage. Time to germination is the more important in this context. As shown by the low final germination percentage of *Hordeum bulbosum* and *Trifolium purpureum* at 30 C (Fig. 7) and as stated by Heydecker (1960), speedy germination does not necessarily coincide with high germination percentage. Mean days to germination (M.D.G.) were calculated for the analysis of our data following Harrington (1963). This parameter was more comparable to days to onset and full germination than Kotowski's (1926) coefficient of velocity used by Heydecker (1960) and Dubetz et al. (1962). M.D.G. has the advantage over onset and full germination of one single parameter integrating the time and quantity components of germination and

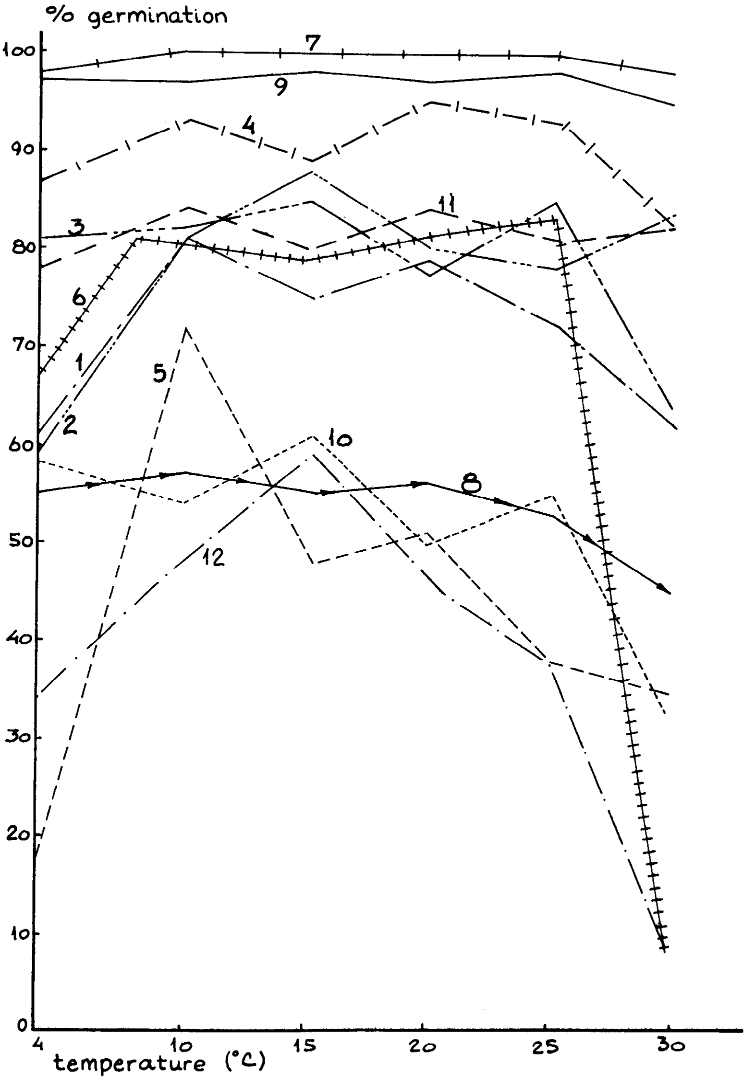

FIG. 7. Final percent germination as a function of temperature.

hence giving smoother graphs. On the other hand, the problem referred to by Heydecker is not resolved. Final germination percentage in our data is not at all consistent with the time-dependent parameters (onset, full, M.D.G.) and there may be no alternative to using both together in evaluating germination (Dubetz et al. 1962).

Summary and Conclusions

Ten range plants, with wheat and barley for comparison, were germinated at fixed temperatures of 4, 10, 15, 20, 25 and 30 C. The germination of the perennial grasses was markedly retarded by low (4-10 C) temperatures, whereas the annuals (except *Avena sterilis*) were much less sensitive to temperature extremes. As low temperatures frequently prevail during the sowing season in semi-arid winter rainfall regions, this is a critical factor in seeding operations. Plant breeding and selection as well as agronomic measures, such as adjusting seedtime and especially soil surface treatments to raise seedbed temperatures, are necessary to hasten germination and establishment of perennial grasses during the wet and cold winter months.

High temperatures (25-30C) had a less adverse effect on germination although they affected eight of the species. They should not adversely affect suitably timed seeding operations.

The usefulness of parameters other than final percent germination is discussed in evaluating germination data for semi-arid range plants.

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Cassady to FAO Assignment in Kenya

John T. Cassady left the Southeastern Forest Experiment Station and the Forest Service on August 1 to accept an assignment with the Food and Agriculture Organization of the United Nations in Kenya.

John is a charter member of the American Society of Range Management and is truly the "Father of the Southern Section." He organized the Section in 1951 and was elected as its first Chairman in 1952. He wrote the guidelines for our first constitution and bylaws and also wrote the Section history in 1957. He nursed the Section along through the critical early years and has always given a helping hand year after year. Happily he will continue as a Section member while in his new job.

John wrote this about his new assignment: "I am being appointed as Agricultural Officer (Range Management and Ecology). My work will be in the Plant Production and Protection Division, Food and Agriculture Organization of the United Nations. I will be conducting research as a member of a research team made up of a Wildlife Biologist, Plant Physiologist, Bush Control Specialist, and a Livestock Specialist. I will hold down the Range Management spot.

"The team will undertake studies of grazing management that involve rotational systems of grazing, stocking rates, joint use between cattle, sheep, goats, as well as wild ungulates, range improvement, bush control, and the use of fire in grazing management.

"The assignment is expected to last about three years. We will work with local specialists, training them to take over the work when we leave."

John is seriously interested in forming a Society Section in Kenya. His new address is: c/o UNDP, P.O. Box 30218 Nairobi, Kenya.