GERMINATION OF CALIFORNIA ANNUAL RANGE PLANTS IN RESPONSE TO A SUMMER RAIN[1]

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ABSTRACT

During the period 7 to 9 July, 1974 the northern half of California experienced an unusual summer rain of 40 to 150 mm. This once-in-a-century occurrence provided an opportunity to observe germination responses of resistant annual grasses, legumes, and forbs. Annual plants which have evolved in a Mediterranean climate generally are assumed to have acquired mechanisms for resistance to summer germination, which ordinarily would result in catastrophic losses of seedlings.

Growth of resident and introduced annual range plants in response to the July rain was observed on grazed ranges at the University of California's Sierra Foothill Range Field Station, Browns Valley, Yuba Co. Transects were located on north- and south-facing slopes consisting entirely of herbaceous vegetation. Square-decimeter quadrats were sampled along the transects on 19 July, 30 August, and 18 October, and the seedlings found were counted and identified.

Seeds of only a few annual species germinated and few plants were established in response to the summer rain. Species found were principally *Bromus mollis* L. (soft chess), *Erodium botrys* (Cav.) Bertol. (broadleaf filaree), *Trifolium hirtum* L. (rose clover), and *T. subterraneum* L. (subterranean clover). Seedling densities were low compared with emergence under normal fall rainfall. Moderation of the Mediterranean climate summer temperature regime by soil surface irregularities or by litter cover favored germination and emergence. Emergence also was better on north-facing aspects than on south-facing aspects.

The data indicate that one characteristic of the many herbaceous annual species which have successfully invaded California since Gold Rush times is effective seed dormancy during summer. It is possible that this trait could prove useful in plant introduction screening.

Additional index words: Microtopography, Plant litter, Mediterranean climate, *Bromus mollis* L., *Erodium botrys* (Cav.) Bertol., *Trifolium hirtum* L., *T. subterraneum* L.

THE herbaceous annual vegetation of California's foothill rangelands is generally considered to be well adapted to the Mediterranean climate, a prominent feature of which is a hot, dry summer, essentially rain-free for at least a 100-day period, alternating with a cool wet fall-winter-spring period. Adaptation to this climate includes both anatomical and physiological mechanisms which ensure optimum germination only with low to moderate temperatures that normally occur with autumn rainfall.

In the period 7 to 9 July 1974, the northern half of California experienced an unusual weather event (1). In a latitudinal zone roughly between 38° and 40°, 15 to 40 mm of rainfall occurred at valley locations, and 40 to 150 mm in the foothill and higher elevations, in a pattern associated with normally increasing isohyetal distribution. The University of California's Sierra Foothill Range Field Station, Browns Valley, Yuba Co., at an average elevation of 350 m at approximately 39° latitude, received 57 mm of rainfall during this period.

Table 1. Seedling densities 10 days after a germinating rain.

Species	Seedling density, means Aspect North	South	
Eordium botrys	3.1 ± 2.3	2.0 ± 2.7	NS*
E. cicutarium	0.9 ± 1.3	0.3 ± 0.8	NS
Bromus spp.	42.2 ± 57.1	1.4 ± 6.0	NS†
Hordeum spp.	1.2 ± 3.0	0.8 ± 2.8	NS
Trifolium spp.	0.5 ± 0.9	1.4 ± 2.6	-
Other spp.	0.4	0	NS

* When data for *Erodium botrys* and *E. cicutarium* are combined the means for north and south aspects are significantly different ("t" test, 0.05 level).
† Individual sample values of this species on the north-facing site. NS = Not significant.

On 19 July seedling plants were counted in dm^2 quadrats located along two transects in two grassland areas. The two areas are at an elevation of approximately 300 m and are 1 km apart. One site has a generally northernly aspect, and the other is southerly. Slopes were of the order of 10 to 25%. Soils were of the Sobrante-Las Posas association, which are members of the fine-loamy or fine mixed thermic family of mollic haploxeralfs. Both areas had been cleared of trees and brush by 1968, and reseeded to a mixture of Subterranean clover (*Trifolium subterraneum,* L.) and rose clover (*T. hirtum* All.) in 1971 and 1972, but the herbaceous vegetation still consisted largely of resident annual grasses and forbs.

The samples consisted of a series of 22 quadrats, each one dm^2, taken at 5-m intervals, along two transects representative of the north-facing and south-facing aspects. Seedlings found in each quadrat were removed, counted, and identified, from vegetative characteristics of the shoot and morphological and anatomical characteristics of the attached seed.

Two additional samplings were made, one 30 August and the other on 18 Oct. 1974. During this period no additional rain fell. Samples on these two dates consisted of a series of 66 dm^2 quadrats, taken at 5-m intervals, within 2 m of the 19 July transects. Plants found were identified and counted, but not removed.

Three conclusions were drawn from the 19 July sampling (Table 1) and corollary field observations. First, plant densities were higher (although not significantly) on the north-facing site. This was expected because previous experience has shown that the combination of physiographic and edaphic factors associated with north- vs. south-facing slopes frequently results in a more favorable germination environment on the northernly slopes. Secondly, the genera most responsive to the summer rainfall were *Bromus, Erodium,* and *Trifolium,* principally the species soft chess (*B. mollis* L.), broadleaf filaree [*E. botrys* (Cav.) Bertol.], rose clover and subterranean clover respectively. Third, occurrence of seedlings in densities greater than 100 per dm^2 was always associated with physical disturbance of the site. The most prominent example was "pugging", i.e., cattle hoofmarks or pits made in

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wet soil the previous winter (Fig. 1), especially when these were at least 5 cm deep. Evidence for microenvironmental changes resulting from microsite manipulation (2, 4, 6) suggests that seed accumulation, catchment of water, and changes in temperature and relative humidity in these pits would favor both higher plant densities and greater survival under the high temperatures and atmospheric aridity of midsummer. Intermediate densities (20 to 100/dm^2) were most frequently found for soft chess in microsites with a relatively large accumulation of litter from the previous season. It was previously shown (5 that litter accumulation acts as a layer of insulation, moderating temperature and moisture, and creating favorable microsites for germination and establishment of invading grasses. Broadleaf species other than filaree and clovers were so infrequent that no attempt was made to identify them.

Plants found on the 30 August and 18 October sampling dates were almost entirely filaree. Data from both sampling dates were combined for broadleaf and cutleaf filaree [*E. botrys* and *E. cicutarium* (L.) L'Her.], giving means of 3.7 and 2.6 plants/dm^2 for the north-aspect site on 30 August and 18 October, respectively. For the south aspect, the means were 1.5 and 1.1 plants/dm^2. On each sampling date the difference in plant densities between aspects was statistically significant ("t" test, 0.01 level). The most likely explanation for the difference between aspects for these sampling dates is differential survival.

Except for the rose subterranean clovers, which are used in range re-seeding, the species identified consisted of resident (but not native) annuals. Their rapid spread geographically and their ubiquity indicate the strong colonizing ability and successful adaptation of these species. The densities observed in this study were generally low compared with normal seed populations, for example, Sumner reported seed densities of approximately 100 to 300/dm^2 (7). The sole exception was emergence of soft chess in hoofmarks on the north aspect site, where approximately 30% of normal fall emergence occurred. While not measured, there is little doubt that the hoofmarks 4 to 10 cm deep served to collect water and to maintain a relatively cool, moist, and shaded microenvironment for at least a week or more. Germination differences on north- and south-facing aspects, the relatively few seedlings that emerged, and the few species responding to the summer rain compared with the normal flora, all reflect the unusual interaction of high day temperatures [35 or 40 C and above and normal for summer (3)] and moderate night temperatures [10 to 20 C normal for summer (3)] with adequate soil moisture for germination. Further, germination differences of annual species in relation to temperature are also emphasized by this unusual rainfall event. Broadleaf filaree dominated the stand that resulted from the summer rain and apparently required the least seedbed modification for germination, and survival, as indicated by its persistence in the more rigorous environment of the south-facing slope. Germination of this species is 40 to 50% at 40 C alternating with 10 or 15 C, about half of maximum which occurs at 20 C days with 10 C nights (8). Soft chess, with most other annual grasses of this community, does not germinate

Fig. 1. Example of germination response to site disturbance. Dark patches are dense clusters of soft chess growing in "pits" resulting from cattle hoofmarks made the previous winter.

with 40 C day temperatures regardless of night temperatures (9). This species established in the field only with drastic microsite modification and on north-aspect sites, conditions reflecting lower temperatures in the seedbed. Nonscarified rose clover seed exhibited very low germination at 40 C days alternating with 10 or 15 C nights with no germination under any other 40 C alternating regime (9). This is reflected in very low establishment in the field.

Summer rainfall is very unusual in this climate and the conditions for germination that it creates are at the extreme edge of adaptation of some of the species in the community and beyond that of others. Microsite modification by either alteration of the microtopography or plant litter coverage of the soil surface lowers the temperature enough to increase germination.

These, plus previously reported results suggest that selection for site specific adaptation in areas with complex climatic and topographic patterns can be aided by appropriate screening for germination responses to temperature regimes, especially those representing unfavorable parts of the season.

LITERATURE CITED

1. California Crop-Weather. 1974. California Crop and Livestock Reporting Service, California Dep. of Food and Agric., Bur. Agric. Stat., Sacramento, Calif.

2. Evans, R. A., J. R. Holbo, R. E. Eckert, Jr., and J A. Young. 1970. Functional environment of downy brome communities in relation to weed control and revegetation. Weed Sci. 13:159-162.

3. ———, B. L. Kay, and J. A. Young. 1975. The microenvironment of a dynamic annual community in relation to range improvement. Hilgardia. 43:79-102.
4. ——— and J. A. Young. 1972. Microsite requirements for establishment of annual rangeland weeds. Weed Sci. 20:350-356.
5. ——— and ———. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Sci. 18:697-703.
6. Raguse, C. A. and R. A. Evans. 1977. Growth of subclover (*Trifolium subterraneum* L.) in a range soil as affected by microclimate and phosphorus avilability. I. Field Studies. Agron. J. 69:21-25.
7. Sumner, D. C. and R. M. Love. 1961. Seedling competition from resident range cover. Calif. Agric. 15:6.
8. Young, J. A., R. A. Evans, and B. L. Kay. 1975. Dispersal and germination dynamics of broadleaf filaree. *Erodium botrys* (Cav.) Bertol. Agron. J. 67:54-57.
9. Young, J. A., R. A. Evans, and B. L. Kay. 1973. Temperature requirements for seed germinating in an annual-type rangeland community, Agron. J. 65:656-659.

INFLUENCE OF SEED SIZE AND DENSITY ON GERMINATION, SEEDLING EMERGENCE, AND YIELD OF GRAIN SORGHUM[1]

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ABSTRACT

Seed size is highly influential in determining germinability and seedling vigor of grain sorghum (*Sorghum bicolor* L. Moench), but whether this factor is predominate over seed density (i.e. specific gravity) has not been established. A 2-year study was conducted to determine to what extent seed size and density influence germination and subsequent field performance. Large and small seed lots from the same genotype were compared to "more dense" and "less dense" seed lots which were separated using either urea-phosphate or sucrose solutions. The results indicated that seed lots with larger and denser seeds had a higher percent germination. The data also supported the conclusion that a higher percentage of viable seeds could be selected from seed lots with low average germinability by using specific gravity separations. However, the establishment of seedlings, final stands, and grain yields were not a function of size or density when the same number of viable seeds were planted in the field.

Additional index words: **Seed vigor, Stand establishment, *Sorghum bicolor* (L.) Moench.**

WHILE environmental factors such as moisture and temperature probably exert the greatest influence on seed germination, emergence and early seedling performance, factors such as seed size, weight, and density also have been shown to be highly important. Most research has indicated that the larger the seed, the better germination and subsequent rate of growth (2). Some studies with grain sorghum (*Sorghum bicolor* (L.) Moench) have shown that medium and large size kernels produce better germination percentages and more vigorous seedlings than small,[3] but other work has shown kernel size to have little effect on germination percentage[4] or seedling establishment (7). Grain yields appear to be unaffected by either size or related to source in some studies (1). Kernel density (ie. specific gravity) however, greatly influences the growth of many species (4, 6, 8). High density seeds of grain sorghum have a higher percent and rate of germination and, in general, produce more vigorous seedlings[4]. Research in our laboratory has confirmed the latter observation and one would suspect that this increased vigor would ultimately result in higher grain yield. No concrete evidence for this has been reported. The purpose of the present study was to determine overall field performance, including yield, of several seed lots differing in seed size and density.

MATERIALS AND METHODS

Experiments were conducted over 2 years in both laboratory and field. In 1973, two sorghum cultivars were used. 'TX 414' had 58% germination and variety '7301' had 95% germination. Each original seed lot was separated into two size classes by use of seed sieves. A portion of each was retained to serve as a control. The large fraction (25% of total) would not pass 10/64 hole size and the smaller fraction (70% of total) would pass 10/64 but was retained by 8/64 hole size. Separations into two density classes were made by floating a portion of the original seed lots on a concentrated urea-phosphate solution and then diluting with water until approximately one-half of the seeds (the "more dense") had sunk to the bottom of the container. Densities of the solutions at which this occurred were 1.228 g/ml for TX 414 and 1.267 g/ml for 7301. Each density fraction was thoroughly washed with distilled water and air dried to approximately 8% moisture. Washings with urea-phosphate followed by distilled water were given the large, small and control seed fractions, the control being a sample of the original seed lot. All fractions were retested for percent germination and calculations adjusted to permit planting two populations in the field. The exact number of viable seeds needed to produce 125,000 and 250,000 plants/ha were planted in a complete randomized design with four replications. Plots were four rows in 76 cm spacing and 4.6 m in length. Final stands and grain yields (14% moisture) were taken from an area 3 m in length of the two center rows.

In 1974, three hybrids were used. 'RS 671' and 'NC + 70 X' were obtained from commercial sources as unprocessed seed and 'Martin × SC33' experimental was increased in Puerto Rico. The latter was included in order to have a seed lot with poor germination. Density separations were made as above except a sucrose solution was used and the fractions were segregated at a density of 1.237 g/ml. Seed sizing was accomplished as in the first year. Stand counts were taken from 3 m of the middle two rows at 3-day intervals starting when seedlings began to emerge through the soil surface. Final stands and grain yields were taken from the same area.

RESULTS AND DISCUSSION

The cultivars (1973) and hybrids (1974) responded similarly within the various seed classes so the performance data for each were combined and tabulated. Percent germination was higher for the large size and more dense seed classes than for either the smaller or less dense seed classes for the two cultivars (Table 1). However, only the more dense fraction proved su-

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[2] Associate professors, Dep. of Agronomy, Univ. of Nebraska, Lincoln, NE 68583.

[3] Hanson, N. S. 1942. Factors affecting germination and seedling emergence of sorghum. M.S. thesis, University of Nebraska. 61 p.

[4] Cleveland, D. C. 1970. Determination of base temperature in a heat unit system for predicting grain sorghum emergence. M. S. thesis. Univ. of Nebraska. 93 p.