# Genetic Variability for Characters Affecting Stand Establishment in Crested Wheatgrass

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## Abstract

**Experiments were conducted in the laboratory (growth chamber) and field to determine the: (1) magnitude of genetic differences in crested wheatgrass [*Agropyron cristatum* (L.) Gaertn. and *A. desertorum* (Fisch. ex Link) Schult.] for characteristics related to seedling establishment on semiarid range and (2) effectiveness of laboratory procedures to estimate relative performance of breeding lines in the field. Significant differences were found among 175 crested wheatgrass progeny lines for seedling emergence, seedling height, seedling dry weight, and fall stand in the analyses of data combined over 2 field locations. The soil at both study sites was a Xerallic Calciorthids. The genetic variance among progenies comprised over 50% of the total phenotypic variance for most traits in the combined analyses of variance. Seedling emergence in the spring was positively related to fall stands ($r = 0.54^{**}$ to $0.61^{**}$). In growth chamber experiments involving 168 progeny lines, significant genetic variation was detected in seedling recovery after exposure to drought stress in 3 of 4 experiments. The genetic variance comprised over 50% of the total phenotypic variance in 5 of 6 instances in the combined analyses of the field data and in 3 of the 4 laboratory experiments. In general, laboratory determinations of seedling emergence under drought stress and seedling recovery after drought were not significantly related to seedling establishment in the field. A relatively close correlation between seed weight and all plant responses measured in the field ($r = 0.46^{**}$ to $0.57^{**}$ in the pooled data) suggests that preliminary screening on the basis of seed weight appears promising.**


Crested wheatgrass [*Agropyron cristatum* (L.) Gaertn., and *A. desertorum* (Fisch. ex Link) Schult.] has been widely used for revegetating depleted rangelands in Western United States and Canada. The species complex, which was first introduced to North America from Russia in 1898, was particularly instrumental in reclaiming abandoned wheat land during the dry years of the middle 1930's (Dillman 1946, Westover and Rogler 1947). Crested wheatgrass is a good source of early spring forage, although it becomes dormant during hot, dry periods (Rogler 1973).

Failure of seedling establishment especially under conditions of drought stress has been a major deterrent to revegetation programs on western rangelands. The development of crested wheatgrass cultivars with improved seedling vigor has received limited attention (Rogler 1954b). The cultivar 'Nordan' developed at the USDA Northern Great Plains Research Center (Mandan, N. Dak.), represented a significant improvement in seedling performance and has been grown widely in the semiarid rangelands of the West (Rogler 1954a).

Most selection programs aimed at improving the vigor or drought resistance of grass seedlings are based on total plant responses in lieu of specific characteristics. Seedling responses of range grasses to artificially imposed drought stress have been evaluated (Wright 1965, Wright and Jordan 1970). Voigt and Brown (1969) made substantial improvements in the seedling vigor of sideoats grama, *Bouteloua curtipendula* (Michx.) Torr., after 3 cycles of selection in the field. Asay and Johnson (1980) found significant differences among 134 Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski] progeny lines in seedling vigor, seedling recovery after drought stress, and seedling emergence under drought.

A positive correlation between seed size and seedling vigor of forage grasses has been reported by several workers (Asay and Johnson 1980, Lawrence 1963, Kneebone and Cremer 1955, Rogler 1954b, Tossell 1960, Trupp and Carlson 1971). Recurrent selection for seed weight effectively improved the seedling vigor of smooth bromegrass, *Bromus inermis* Leyss. (Trupp and Carlson 1971). In view of the positive relationships observed in his studies, Rogler (1954b) suggested that selection for larger seeds would be a useful criterion for improving seedling vigor in crested wheatgrass.

A major goal of the USDA-ARS plant improvement program at Logan, Utah, is to develop cultivars of grasses that establish readily on semiarid rangelands. Significant genetic differences were found among 120 crested wheatgrass progenies in emergence under drought stress (Johnson and Asay 1978) and among 134 Russian wildrye progenies in seedling emergence and vigor from deep seedings, seedling recovery after drought stress, and seedling emergence during drought (Asay and Johnson 1980). The objectives of this research were to: (1) determine the amount of genetic variation in crested wheatgrass for laboratory determinations of seedling recovery after drought stress and for seedling emergence, seedling vigor, and stand establishment under semiarid conditions in the field and (2) study the relationships between laboratory and field evaluations of characters related to seedling establishment.

## Materials and Methods

Plant materials included in the laboratory and field experiments consisted of open-pollinated progenies (entries) of 170 clonal lines of crested wheatgrass. The clones were selected from a 20,000-plant source nursery on the basis of vegetative vigor, leafiness, and resistance to insects and diseases. The parental lines were derived primarily from genetically diverse sources of induced and natural tetraploid forms of crested wheatgrass as well as from hybrids between induced and natural tetraploids. Five seedlots of commercial cultivars were harvested from the same nursery and were included as checks. All seedlots were harvested at the same phenological stage of development and were of uniform quality.

### Laboratory Experiments

Data for seedling emergence under controlled drought stress, which were used in laboratory-field correlations, were determined by Johnson and Asay (1978). Seeds were germinated in soil that was separated from a polyethylene glycol-6,000 osmoticum with a cellulose acetate membrane. The amount of water moving across this semipermeable membrane, and hence the water potential of the soil, was controlled by the water potential of the osmotic solution. Two levels of soil water potential (–3.5 and –5.5 bars)

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were employed.

The procedures used to screen the crested wheatgrass progenies for seedling recovery after drought stress were similar to those described by Asay and Johnson (1980). Three seedlings were started in each of 28 plastic containers per entry. The cone-shaped containers were 3.8 cm in diameter at the top and tapered over the 21-cm length to a 2.5-cm diameter at the bottom. After 3 weeks in the greenhouse, the plants were transferred to a growth chamber programmed for 12-hr daylength, 30/10°C day/night temperatures, 20/60% day/night relative humidity, and 900 $\mu E/m^2/sec$ quantum flux density between 400 and 700 nm. Trays with containers were arranged in the chamber as a randomized complete block with 7 containers per entry-replication combination and 4 replications. After a 1-week equilibration period in the growth chamber, water was withheld from the plants for 17 days. The trays were then returned to the greenhouse and watered daily for 3 weeks. Each group of 7 containers was then rated for degree of recovery by 3 independent observers using a scale of 1 to 9 (1 = no living plants and 9 = maximum recovery based on number of living tillers and amount of green leaf area). Four experiments, each comprising 42 entries, were conducted. Two check seedlots were included in each trial.

Two 100-seed samples of each entry were used to estimate seed weight.

### Field Experiments

Characters associated with seedling establishment were evaluated on 2 representative rangeland areas near Park Valley, Utah, (site 1) and near Malta, Idaho (site 2). Site 1 receives an average annual precipitation of 24.4 cm and site 2 receives an average of 28.5 cm. The soil in both areas was a Xerallic Calciorthids. Plots were seeded 9 November and 10 November 1976 on sites 1 and 2, respectively, and germination did not occur until the following spring. Each plot consisted of a 3-m row in which 500 seeds were planted 3.5 cm deep with a cone seeder equipped with a double-disc furrow opener. Data were taken from the center 1.8-m section of the plot to allow for border effects. Plots were arranged as randomized complete blocks with 3 replications at site 1 and 2 replications at site 2. Although 336 entries were included in the trials on site 1 and 175 at site 2, data are presented only for those 175 entries seeded at both locations.

Emergence and seedling height were recorded during mid-May.

**Table 1. Seedling recovery of crested wheatgrass progeny lines after exposure to drought stress in the growth chamber.**

| Parameter | Experiment[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| | | Ratings[2] | | |
| Min. | 1.0 | 0.8 | 0.2 | 0 |
| Max. | 7.2 | 7.2 | 7.2 | 6.3 |
| $S_{\bar{x}}$ | 0.88 | 1.00 | 1.41 | 1.05 |
| F (prog) | 2.94** | 2.16** | 1.14 | 2.41** |
| Gen. Var. (%) | 66 | 54 | 12 | 59 |

[1]Each trial included 42 lines and was replicated 3 times.
[2]Ratings were made by 3 observers on a 1 to 9 scale.
(1 = complete mortality, 9 = maximum recovery based on number of living tillers and amount of green leaf area).
**Significant at the 0.01 level of probability.

The second emergence and seedling height data were obtained during the third week of June. Shoot dry weight of the seedlings in the 1.8 m of row was determined at the 2 locations during the last week of July and stand percentage during the last week in October. Percentage stand was computed as the ratio of the number of 10 cm sections with plant cover to the total number of 10 cm sections in the 1.8 m row.

### Statistical Analyses

All data were subjected to analyses of variance. Percent genetic variability was computed on a phenotypic mean basis as the ratio of $\sigma^2_p/\sigma^2_{\bar{ph}}$, where $\sigma^2_p$ was the variance component due to differences among progenies and $\sigma^2_{\bar{ph}}$ was the total phenotypic variance among progeny lines or the variance of a progeny mean. In the computation of the variance components, progenies were considered as random variables and locations (sites) as fixed. Simple correlations were computed to study the relationship between laboratory and field data. Only 118 entries were in common in all laboratory and field studies. Consequently, the correlation matrix was restricted to these lines (116 df).

## Results and Discussion

### Laboratory Experiments

In earlier studies (Johnson and Asay 1978), significant differences were found among the crested wheatgrass progenies for

**Table 2. Seedling vigor and stand establishment of 175 crested wheatgrass progeny lines on two rangeland areas.**

| Location | Parameter | Emergence (No.) May | Emergence (No.) June | Height (cm) May | Height (cm) June | DM Yield (g/plot) | Stand (%) |
|---|---|---|---|---|---|---|---|
| 1 | Max. | 82 | 68 | 5.0 | 12.3 | 7.6 | 88 |
| | Min. | 13 | 9 | 1.7 | 4.3 | 0.1 | 41 |
| | $\bar{x}$ | 43 | 38 | 3.6 | 9.1 | 2.0 | 72 |
| | $S_{\bar{x}}$ | 9.0 | 8.2 | 0.39 | 1.16 | 1.06 | 6.5 |
| | *F* (prog.) | 1.85** | 1.70** | 2.62** | 1.51** | 1.91** | 1.58** |
| | Gen. Var. (%) | 46 | 41 | 62 | 34 | 48 | 37 |
| 2 | Max. | 70 | 123 | 10.0 | 23.0 | 31.3 | 95 |
| | Min. | 9 | 15 | 2.0 | 6.0 | 1.3 | 44 |
| | $\bar{x}$ | 33 | 59 | 5.6 | 13.2 | 10.7 | 70 |
| | $S_{\bar{x}}$ | 8.9 | 17.9 | 1.03 | 2.33 | 4.28 | 8.2 |
| | *F* (prog.) | 1.56** | 1.34* | 1.97** | 1.47* | 1.36* | 1.19 |
| | Gen. var. (%) | 36 | 25 | 49 | 32 | 27 | 16 |
| Pooled Data | Max. | 66 | 84 | 6.6 | 15.8 | 14.8 | 87 |
| | Min. | 12 | 18 | 1.8 | 6.0 | 0.5 | 44 |
| | $\bar{x}$ | 39 | 46 | 4.4 | 10.7 | 5.5 | 71 |
| | $S_{\bar{x}}$ | 6.5 | 8.3 | 0.45 | 1.12 | 1.70 | 5.1 |
| | *F* Prog (P) | 2.10** | 2.06** | 3.31** | 2.18** | 2.13** | 1.79** |
| | Loc (L) | 108** | 271** | 800** | 562** | 1102** | 8.73** |
| | PxL | 1.14 | 1.38* | 2.01** | 1.32* | 1.76** | 1.01 |
| | Gen. Var. (%) | 52 | 52 | 70 | 54 | 53 | 44 |

*,** Significant at 0.05 and 0.01 probability level, respectively.

seedling emergence under 2 levels of controlled drought stress. Although a significant progeny × stress level interaction was encountered, ample genetic variation was available to facilitate selection for this component of stand establishment.

The entries also differed significantly ($P<0.01$) in seedling recovery after exposure to drought in 3 of the 4 experiments conducted (Table 1). The genetic variance comprised over 50% of the total phenotypic variance in the 3 experiments where significant differences were obtained. It is evident that laboratory procedures can detect differences in seedling recovery and that sufficient genetic variability is available for selection. The duration of the stress period imposed on the seedlings has a profound effect on the results. A difference of just a few hours in which the trays are removed from the chamber can mean the difference between complete seedling recovery to complete mortality. Also, to compensate for temperature variation within the chamber, trays of seedlings should be removed individually over a period of a day or more. A check entry probably should be included in each tray and removal of the tray then should be based on the appearance of the check. The containers in our experiments may have limited root growth and therefore may not have adequately evaluated the effect of the root system on seedling survival. For determinations of drought avoidance capacity afforded by early and extensive root development at the seedling stage, a less restrictive soil environment would have to be used.

**Field Experiments**

Significant differences were found among the progeny lines for all traits measured at field location 1 and for all but percentage stand at location 2 (Table 2). In the analyses of the data pooled over locations, differences among the progenies were significant ($P<0.01$) for all traits evaluated. This range in phenotypic variation along with the relative magnitudes of the genetic variances offers considerable promise to the breeder working to improve stand establishment characteristics in crested wheatgrass. The genetic variability for seedling emergence and fall stand is especially encouraging. Seedling emergence averaged over locations ranged from 18 to 84% in June and the mean percentage stand ranged from 44 to 87%. The genetic variance comprised 52 and 44% of the phenotypic variance for emergence and stand, respectively, in the combined analyses. A positive relationship was also found between seedling emergence and fall stand, suggesting that seedling survival and possibly rate of tillering of the progenies was relatively consistent during the summer. Correlation coefficients between emergence 1 and 2 and fall stand were 0.54 and 0.59 at location 1 and 0.64 and 0.61 at location 2 (critical *r*, $P<0.01$, 116 df, = 0.24).

As would be expected, location effects were highly significant for all plant responses measured. The progeny X location interaction was significant in most instances; however, the correlations between locations were positive and significant in all cases ($r = 0.24$ to 0.44). Differences among progenies in emergence and fall stand were relatively consistent over locations, as was indicated by the nonsignificant progeny X location interactions.

**Field-laboratory Relationships**

In most instances, correlations between laboratory determinations of emergence under stress and seedling recovery after stress were not significantly correlated with plant responses measured in the field (Table 3). The poor relationship between seedling emergence under drought stress in the laboratory and field emergence was particularly disappointing. However, the field plantings were made in the late fall and soil moisture was not a major limiting factor until after emergence had occurred the following spring. Apparently emergence from a deep seeding with no attempt to impose drought stress may give a more realistic prediction of field emergence in the early spring. Earlier work with Russian wildrye (Asay and Johnson 1980, Lawrence 1963) would support this approach.

After emergence, stand establishment depends largely on the complex factors influencing seedling survival and tillering under extended or intermittent stress. Seedling recovery after drought stress measured in the laboratory failed to provide a consistent estimate of seedling establishment in the field, although a significant but low correlation ($r = 0.22$) with stand was detected in the pooled field data. However, the significant correlation between emergence and stand observed in our field trials would indicate that differences in seedling recovery after drought were not determinant factors of fall stand.

Seed size was significantly ($P<0.01$) and positively correlated with all characters evaluated in the field. Correlation coefficients between seed size and field data averaged over the 2 locations ranged from 0.46 to 0.57. This represents a significant relationship considering the complex interactions of environmental and genetic factors involved in the establishment of stands on semiarid range. In addition, seed weight was significantly correlated ($P<0.05$) with

**Table 3. Correlations *(r)* of data from laboratory and field evaluations of seedling vigor in 118 crested wheatgrass progeny lines.**

| Laboratory criteria | Field criteria: Emergence May | Emergence June | Height May | Height June | D.M. yield | Stand |
|---|---|---|---|---|---|---|
| | | | Location 1 | | | |
| Emergence: | | | | | | |
| −3.5 bars | −.09 | −.17 | −.03 | .07 | .09 | −.08 |
| −5.5 bars | −.11 | −.12 | −.09 | .09 | .12 | −.09 |
| Seedling recovery | .10 | .18* | .15 | .09 | .17 | .17 |
| Seed wt. | .45** | .45** | .59** | .36** | .45** | .45** |
| | | | Location 2 | | | |
| Emergence: | | | | | | |
| −3.5 bars | .07 | .19* | .06 | .13 | .24** | .10 |
| −5.5 bars | −.04 | .08 | .01 | .08 | .08 | .02 |
| Seedling recovery | −.11 | −.03 | −.10 | .08 | .10 | .14 |
| Seed wt. | .27** | .33** | .43** | .43** | .39** | .37** |
| | | | Field Data Pool | | | |
| Emergence: | | | | | | |
| −3.5 bars | −.02 | .02 | .03 | .12 | .23 | −.01 |
| −5.5 bars | −.08 | −.01 | −.03 | .11 | .12 | −.04 |
| Seedling recovery | .05 | .10 | .01 | .09 | .15 | .22* |
| Seed wt. | .48** | .49** | .57** | .46** | .49** | .51** |

*,**Significant at 0.05 and 0.01 probability level, respectively (116 df).

recovery after drought ($r$ = 0.19). No correlation was found between seed weight and germination under controlled drought stress in the laboratory.

## Summary

Our data confirmed earlier findings that seed weight was a useful criterion in a crested wheatgrass breeding program to develop germplasm with improved stand establishment characteristics. Screening in the laboratory for emergence under drought stress and seedling recovery after exposure to drought would be less likely to lead to enhanced stand establishment. Seedling emergence in the field was indicative of ultimate stand establishment. Seedling emergence from deep seedings in the laboratory has demonstrated promise as a selection criterion in Russian wildrye and should be evaluated in crested wheatgrass. Until a better understanding of plant responses to environmental stresses during stand establishment are developed, preliminary screening on the basis of seed weight appears most promising. This should be followed by evaluation of stand estabishment under semiarid conditions in the field.

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