5-1949

Emergence and Survival of Four Introduced Wheatgrasses as Influenced by Rate and Season of Planting on Abandoned Farm Lands of Utah

Donald N. Hyder

EMERGENCE AND SURVIVAL OF FOUR INTRODUCED WHEATGRASSES
AS INFLUENCED BY
RATE AND SEASON OF PLANTING
ON ABANDONED FARM LANDS OF UTAH

by

Donald N. Hyder

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

RANGE MANAGEMENT

1949

UTAH STATE AGRICULTURAL COLLEGE
Logan, Utah

ACKNOWLEDGMENT

For assistance and advice in designing and performing this study, and in the preparation of the thesis, grateful acknowledgment is given to Dr. L. A. Stoddart and Professor C. W. Cook. Acknowledgment is also given to the Utah Agricultural Experiment Station for financial support as a part of Project No. 292; to the Soil Conservation Service for providing the experimental area, labor, machinery, and precipitation records; and to Professor B. H. Crandall for advice in statistical analysis.

TABLE OF CONTENTS

FIGURES AND TABLES

Appendix tables continued: Page

INTRODUCTION

A great deal has been accomplished in developing methods of restoring abused lands through seeding, yet there is much to be desired in refinement of techniques and in substantiation of previous experimental results. Controversial opinions as to the best season of planting indicate that additional trials are needed. New species need to be introduced, developed, and proved. Methods are needed which lead to more efficient utilization of those factors limiting the degree of success in establishment. Since moisture is the most predominant limiting factor throughout the arid and semi-arid range land, special attention is given to more efficient utilization of the precipitation.

There are three fundamental ways of increasing or making the most of the available water supply: (1) increasing the absorption of water by the soil, (2) storing moisture in the soil one year for use the next, and (3) preventing undue withdrawal of water. Tillage and prevention of runoff are means of increasing the absorption of water by the soil, and moisture may be stored in the soil by leaving it fallow during a growing season. Moisture losses from the soil can be partially controlled by reducing evaporation from the soil surface—as by maintaining a soil cover of mulch or stubble, and by reducing transpiration losses—as by killing all weeds.

In reducing competition and transpiration losses, an important aspect is the density of seeded species during the initial stages of establishment. A slight change in the amount of available water, or in the efficiency of its use, can bring about success instead of failure. Easily observed treatment differences are best obtained when the supply of available moisture is near the critical point. During the seasons of plentiful or short supply, differences may not be observed.

Because of the above, a study was made involving 3 recently introduced species of *Agropyron*--intermediate wheatgrass (*Agropyron intermedium*), stiff-hair wheatgrass (*A. trichophorum*), and tall wheatgrass (*A. elongatum*). Performance of each is compared to that of crested wheatgrass (*A. cristatum*). The species were seeded on adjacent plots, measuring 20 by 50 feet, in all combinations of the following: 2 seasons of planting, 3 intensities of seeding, and 3 spacings between drill rows.

REVIEW OF LITERATURE

Increasing the seeding intensity is a costly means of compensating for a low germination percentage and emergence success. The present study has shown an average emergence success of about 11 percent, which is low and points out the extent of seed waste. It seems apparent that the dominant problem is to provide uniform conditions to all seeds. With available moisture being the limiting factor, seedbed preparation should be an attempt to establish uniform distribution of the soil moisture. The moisture problem is involved in the preparation of the seedbed, the date of seeding, the method of seeding, the depth of covering, the intensity of seeding, the spacing of rows, and the use of mulches and nurse crops.

Most literature seems to be general in subject matter and fails to analyze the ecological and physiological factors causing failures in seeding. Hanson and Vorhies (1938) emphasized the need for study of life histories of species; evolution; succession; migration; effects of insects, game, domestic stock; etc. Thatcher, Willard, and Lewis (1937) classified all the primary causes of failure and suggested methods of circumventing the difficulties. The following method of seeding was recommended: " . . . prepare a good seed bed, firm below, with an inch or two of loose soil on top; cultipack; broadcast; and cover lightly with a harrow or weeder crosswise to the cultipacking." (p. 59[3]) Advantages are the firm seedbed and uniform depth of covering. Improvements were made by Duffee (1940) and Beutner and Anderson (1944) by installing Planet Jr. seed hoppers on an eight-foot tandem cultipacker to eliminate the disadvantages of broadcasting.

Most seedbeds for small grains are too loose for seeding grasses or legumes. Experiments by Carnes (1934) have shown that seedlings emerge through a crust better if the soil under them is as firm as the crust. If the soil is firmly packed around and below the seedling, the seedling is prevented from curling under the crust, and may thus exert greater force to break the crust. Mulches and stubble are valuable in preventing the formation of hard crusts.

The advantages and disadvantages of summer fallow have been widely discussed. Its values are conceded, if an extra supply of moisture can be stored in the soil, and if other means of killing weeds are less efficient. In general, however, authors point out the necessity of keeping the soil protected with a stubble or mulch.

To facilitate storing moisture in the soil and preventing rapid evaporation from the soil surface, Friedrich (1945) emphasized the use of a preparatory crop of grain. Grass seed was then drilled in the stubble. Savage (1939) maintains that a high, dense stubble helps to keep the surface soil moist a day or two longer than on bare fallow land. This delay in evaporation often represents the difference between success and failure in obtaining satisfactory initial stands. Close-drilled stubble has other advantages as preparation for grass. The soil is usually firmer, cleaner, and freer of weeds than land without stubble.

Choosing the most favorable date for seeding is an important method of avoiding or reducing freezing injury to the seedlings. (See Thatcher, Willard, and Lewis, 1937.) Fall and early spring seedings often are exposed to the hazard of freezing. Seed can be sown early and endure prolonged sub-zero weather if it has not germinated, but if a warm period intervenes in which the seeds start to grow, followed by low temperatures for a time, the seedlings may be killed. Also the seed may be killed by a lack of oxygen in saturated and frozen soil.

Improper depth of seeding may cause failure, and lack of uniformity in depth of coverage results in waste of seed. Love and Hanson (1932) showed that 3 inches was the maximum depth of penetration for most small seeded grasses, and one half to three fourths inch best under optimum conditions for germination and emergence. Short (1943) reported three fourths to one inch as being the most favorable depth for the seed of most range grasses. Murphy and Arny (1939) found significant correlation between the weight of seed and emergence percentage when planted 2 inches deep or more. While very shallow plantings often attain the best germination, the seedlings that result are usually subject to high mortality from rapid drying of the surface soil. Attention should be given to selecting methods giving uniform coverage at the best depth of planting.

Intensity of seeding is directly related to success. A seeding rate too low results in poor ground cover and consequent failure of the seeding. On the other hand, seeding rates resulting in closely spaced individuals may suffer high mortality because growth is slow and vigor is low when excessive competition exists. The general tendency has been to seed heavy in dry areas in an attempt to overcome the losses and poor response, but the opposite is suggested. Some of the factors that influence the rate of seeding are size and quality of the seed, the number of viable seeds per pound, purity or freedom from inert matter, uniformity of seed distribution, depth and uniformity of coverage, distances between rows, preparation of seedbed, spreading habit of the grass, and climatic conditions. (See Savage, 1939.)

Short (1943) pointed out that very light intensities of about 2 pounds per acre would be adequate if the seed could be made to feed through the drill steadily at such low rates. Lemmon and Hafenrichter (1947) used a dilution method to overcome that difficulty.

Schwendiman, Sackman, and Hafenrichter (1940) have discussed the methods used to remove awns and separate the florets to obtain uniformity of seed distribution.

Sprague and Farris (1931) have shown that production is related to the regularity of spacing seeds, as well as to the intensity of seeding, in drill-planted small grains.

Engledow and associates (1924 and 1925) studied the effect of intensity of seeding upon forage and seed yields in England. They concluded that the average number of plants per foot of drill row is a valueless abstraction, and that yields per acre are determined to a large extent by the uniformity with which the seed is spaced in the row.

Closely associated with the distribution of seed in the row is the spacing of the drill rows. Many investigators have shown that 6 inch spacing of the drill rows meets with less success than wider spacing. At Miles City (Short 1943) an experiment with 6, 12, and 30 inch spacings between drill rows showed that after the stand was well established, total yields were about the same for all spacings. Mortality from drought was greatest for the 6 inch spacing and least for the 30 inch.

It is believed that the most desirable intensity and spacing is that which results in equal distances between plants in all directions. Some overlap of, and competition among, root systems is necessary in attaining optimum soil stability and forage production. Another phase of study to determine the optimum degree of competition is suggested. Love and Hanson (1932) found that a crested wheatgrass root system grown under favorable conditions spread to a diameter of 2 feet. Spacing of 18 inches under those conditions would permit a six-inch overlap of the adjacent root systems.

The best season for planting is not always the same for any given region. At best, a great number of trials would only indicate for the seasons of planting used, the number of successes and the number of failures that would be obtained at a given probability over a long period of time with plantings being made every year. In many cases, the chances for success are only slightly greater than the chances for failure. Therefore, all available information should be used in adopting seeding plans.

DESCRIPTION OF THE AREA

Description of the Soil

The Benmore Soil Conservation Service experimental area in Tooele County, Utah, lies, in part, within a shallow arm of the former Lake Bonneville. The remainder consists of alluvial outwash plain and an extent of low mountains, with an average elevation of about 5,500 feet. The area used for this study was dry-farmed to small grains during and for a few years following the World War I period. Uncertain moisture conditions and low grain prices led to abandonment and subsequent purchase by the Federal Government.

In the vicinity of the plots, the lake bottom sediments pass under an overburden of alluvial and colluvial outwash. The mantle of shallow outwash (when the transported material is less than 6 feet deep) was designated as the "Benmore" series. The lake sediments series was designated as the "Grantsville (unconsolidated)." (See Nelson, 1939.) Distinction between the shallow transported materials and the underlying lake sediments is difficult. Recent sheet erosion, the formation of a drainage pattern, land use, and reworking of the surface materials by a fluctuating water level of the arm of the lake has brought about soil changes in color, texture, structure, and gravel content, sometimes within short distances. Consequently, it is not well suited to a plot type of study.

> All are calcareous in the surface soil, have undergone some concentration of free lime in the subsoil and apparent accumulations of fine textures in the B horizon. Surface soils are loose, friable and light brown to grayish brown and calcareous. There is commonly a soft, platy crust about 2 inches thick, then a soft very finely granular (almost floury) mulch. This is underlain by a moderately hard,

> massive light brown to grayish brown calcareous subsoil which crushes easily to a very fine cloddy and granular condition. This has been observed to vary from less than 12 inches to as much as 18 inches, when it grades into either similar material containing many soft lime segregations or into a light gray heavy textured hard strata which breaks very easily into a mass of small cubical fragments at variable depths below an average depth of about 24 inches. (Nelson, 1939.)

Organic matter determination, using the oxidation-reduction method, from a composite soil sample, showed a low average value of 1.61 percent with the difference between two replications being 0.11 percent. A corresponding low moisture equivalent of 17.94 percent was determined. A "glass electrode" reading of the soil pH showed a value of 7.95 in the paste and a value of 8.60 for a 10:1 dilution. The large difference between the two pH readings is in itself a good indication of a highly calcareous soil. The soil slopes gently to the north at an angle of 0° to 5°.

Since all four of the species used in this study are well established upon an adjacent area, it will be well to consider the soil as an agent determining the effectiveness of the precipitation. On March 14, 1948, a rapid rate of drying of the soil following a rain was observed. Although the soil was muddy on the surface and moist to a depth of about 3 inches at 9:00 a.m., the soil appeared to be dry in the top 2 inches by 4:00 p.m. the same day. If the observation was of a normal rate of evaporation from the unprotected soil surface, then germination of grass seed drilled into the soil could be expected to remain low unless special treatment was applied. Because of the above observation, a brief study of evaporation was conducted. Artificial precipitation was applied at 3 intensity levels to 1-foot by 10-foot plots on October 19, 1948. The precipitation was applied at 10:45 a.m. at levels of 0.06, 0.11 and 0.28 inch. During the study, the sky was partly cloudy, wind velocity varied from calm to a mild breeze, and air temperature varied between 62 and 64°F. Soil samples were taken before the water was applied, 45 minutes after, and 4 hours after, at the following depths: 0 to 1 inch, 1 to 1½ inches, and 1½ to 3 inches.

It was interesting to note that the penetration of moisture was very shallow. Only with the 0.28 inch level was there an apparent increase in moisture in the 1 to 1½ inch zone. The rapid rate of evaporation indicates a probable limiting factor in making the most of the precipitation. There is need for more information concerning the characteristics of the soil, and efficiency of methods used to reduce losses of soil moisture.

Moisture determinations were made and those values at the 3 precipitation levels for the surface inch of soil were plotted and integrated into a continuous curve as shown in figure 1. The slope of the curve indicates the relative rate of evaporation. When superimposed on the abscissa "time (in hours)," the rate of evaporation curve following artificial precipitation of 0.28 inch indicates the short period of time during which soil moisture is favorable to germination.

<u>Preparation of the Soil</u>

The area involved had previously been tilled (1946) and planted to domestic rye. As a result, the area supported a voluntary stand of rye, which was plowed under in early June 1947 when only a small percentage of the rye had reached anthesis--none was judged to have reached the

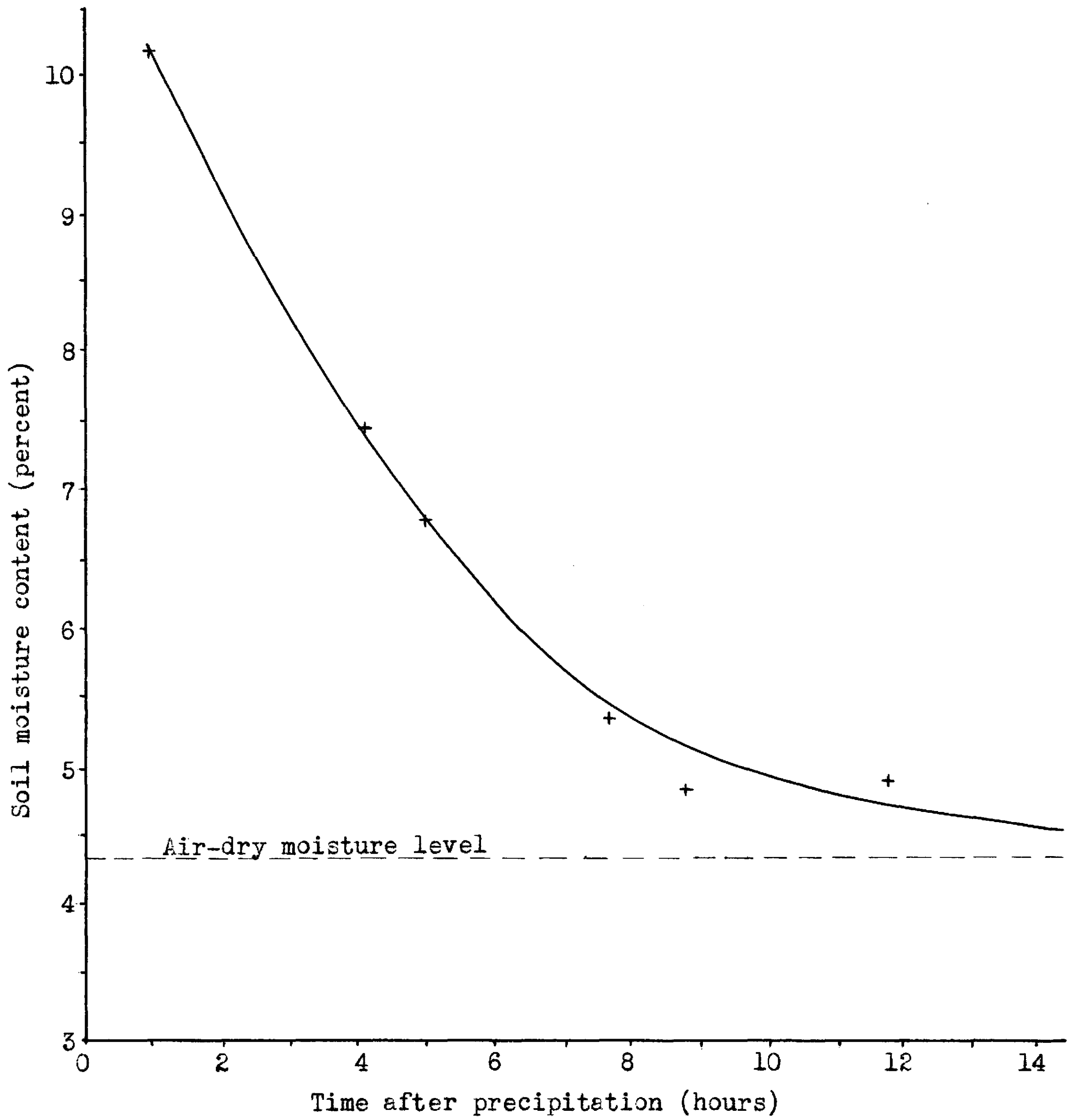

Figure 1. Rate of evaporation losses from the surface inch of soil following artificial precipitation of 0.28 inch

seed stage. Consequently, very little voluntary rye persisted on the plots. Drilling was accomplished during September 1947 and April 1948 without further soil preparation following fallow.

Summary of Precipitation Records

The precipitation in semi-arid regions is characterized by frequent and large variations in amount. Normally in Utah the precipitation occurs largely during the fall, winter, and early spring, with most of this falling in the form of snow. The summers are usually dry except in high mountains. Often at lower elevations one or more of the months of June, July or August is lacking of any precipitation. The variability in itself is a problem in reseeding. As pointed out by Stoddart (1946, p. 7-8), the precipitation which falls in the growing season is a much better index to successful seeding than the total annual amount. For success in seeding, the high rate of evaporation from the soil surface shown in figure 1 indicates the importance of frequent rain storms during the period of germination and emergence. Without a frequent supply of moisture to the surface soil, seeds are subjected to one or more periods of drying out. A high mortality of seeds and seedlings must be expected in that case. Therefore, the critical months are during the winter and spring--winter snows to provide a good supply of moisture to the sub-soil, and the spring rains to replenish the supply of moisture in the surface soil.

The mean annual precipitation at Benmore (Stoddart, 1946, p. 18) based on 32 years of record is 12.82 inches, with 3.38 inches falling during the months of December, January, and February, and 3.86 inches falling during the months of March, April, and May. From 1943 to 1947 inclusive, the mean annual precipitation was 11.77 inches. The infrequency and variability of rain periods during the early spring, as shown in table 1, bears out the importance of storing moisture in the soil and reducing the rate of evaporation.

The average length of time between rain periods during the spring months obtained by dividing the number of rain periods per month into 30 days, as taken from table 1, varies from month to month. The extremes are 3 and 30 days; however, the greater frequency of short periods reduces the average for the totals of March, April, and May to 4½ days.

The longest period of favorable conditions appears to be during the early spring. If it were possible to plant during the late fall and have the seed lie over winter without loss of viability or loss of potential development, most complete utilization of the favorable period would thus be attained. Spring planting often may be delayed until the winter accumulation of moisture is depleted, and seedings be required to depend upon adequate spring precipitation. It seems evident that the most desirable time to have the seed germinate is the early spring--late March or early April. It is believed that adverse temperatures and soil heaving are less often limiting factors to success than soil moisture.

Table 1. Monthly precipitation and number of precipitation periods during March, April, and May at Benmore, Utah*

Year	1943	1944	1945	1946	1947	Average
March:						
Precipitation	0.69	1.72	1.99	1.64	0.37	1.28
No. of ppt. periods	6	7	9	11	2	7
April:						
Precipitation	0.55	1.39	1.77	0.00	2.18	1.18
No. of ppt. periods	5	13	10	0	4	6
May:						
Precipitation	0.51	2.09	1.11	1.93	0.58	1.24
No. of ppt. periods	6	10	11	3	1	6
Total:						
Precipitation	1.75	5.20	4.87	3.57	1.13	3.70
No. of ppt. periods	17	30	30	14	7	20

*Data compiled from reports of the Soil Conservation Service

METHOD OF PROCEDURE

Seed Analysis

The seed was obtained from the Soil Conservation Service nursery near Albuquerque, New Mexico. Analysis and testing by the author was in accordance with the rules for seed testing as listed in Rules and Recommendations for Testing Seeds, 1938. A summary of the results of the seed analysis and testing is shown in Tables I and II.

Seed was separated into 4 components: (1) desired grass seed, (2) other crop seed, (3) weed seed, and (4) inert matter.

Four hundred seeds of each grass species were separated into groups of 100 each for the germination test. The seeds were spread on blotters in dishes and placed in an oven maintained at a constant temperature of 68°F. Seeds were considered as germinated upon extrusion of the radical. Cumulative germination of each species was recorded daily for a period of 14 days. Seeds which absorbed water slowly, and remained hard at the end of the test were counted and reported as hard seeds.

Treatment of the seed prior to testing and drilling consisted of dry storage at room temperature.

A high percentage of empty lemmas and other inert matter in the crested wheatgrass seed introduced inaccuracy into the purity analysis, and a low germination percentage with excessive variation for that species. The other species tested were well within the tolerance limits (table II).

The purity percentage of each species was used to calculate the weight of bulk seed containing the same number of seeds as one pound of crested wheatgrass (table III). Germination percentages were used to determine the approximate number of viable seeds drilled per unit length of drill row. The number of viable seeds per unit length of drill row was then used in computing the emergence success from the normal seedling count.

<u>Drill Calibration</u>

It was necessary to calibrate both sides of the drill for 3 intensities for each species. A sixteen-hole drill having drill openings 6 inches apart and wheels with a circumference of 11.8 feet was used. For each intensity of each species, the number of grams of seed to be dropped from 8 holes in 20 wheel revolutions was computed in the following manner:

$$I = G \times C \times W \times 20/2F = G \times C \times W \times 10/F$$

when:

I = grams desired per 8 drill openings in 20 wheel revolutions
G = grams to be seeded per acre
F = square feet per acre = 43,560
C = wheel circumference = 11.8 feet
W = width of the drill = 8.5 feet

therefore:

$$I = G/43.43$$

Drill calibration for the different intensities was accomplished by propping one wheel off the ground, filling the hopper with seed, then, by trial and error, adjusting to the proper drill opening. The seed dropped during 20 wheel revolutions was caught on a canvas and weighed. The weight was then compared with the desired amount as shown in table IV. In each case the drill-intensity setting giving the closest result was selected to be used for that species and intensity. With all species the amount of seed dropped in the actual seeding operation differed slightly from the desired amount, and those differences were considered in comparing species and seeding intensities (table 4, p. 25).

Design of Experiment

Four seedbeds measuring 740 by 50 feet each were laid out side by side with a driveway 20 feet wide between each pair. Each bed was divided into 36 plots measuring 20 by 50 feet. Beds A and C, when lettered consecutively from west to east, were a series of twice-replicated plots, selected at random within each block, drilled in the fall (September 25, 1947). Beds B and D were drilled during the following spring (April 13, 1948).

Agropyron cristatum, *A. intermedium*, *A. trichophorum*, and *A. elongatum* were drilled separately on randomly selected plots. The seeding intensity (table III) was varied in two different ways: by drill-setting, and drill row spacing. Three drill-settings for rate of seeding in all combinations with 3 row spacings were used. The rows were spaced by placing certain drill tubes in seed bags, to obtain spacings of 6, 12 and 18 inches. The intensities obtained by drill calibration are referred to as low, medium, or high in reference to the rate of seeding in a single row. These intensity classifications represent the same number of seeds for all species, and were determined by the number of seeds of crested wheatgrass in 2.5, 5.0 and 7.5 pounds of bulk seed. The corresponding weights become pounds per acre when drill rows are 6 inches apart. It follows that failure of the species to perform the same results are from: (1) difference in germination capacity among the species, for which the data can be corrected; (2) inaccuracy in drill calibration, for which the data can be partially corrected; and (3) the natural or inherent differences of species and soil.

Two replications of each combination of the 4 species, 3 intensities, and 3 drill row spacings were drilled on September 25, 1947, and 2 replications during the early spring, April 13, 1948, making a total of 144 plots.

Drilling the Seed

Drilling was accomplished with an $8\frac{1}{2}$-foot surface drill. Drag chains were removed to prevent covering the seed too deeply. Even so, the uneven surface of the soil resulted in a depth of seeding varying from 0 to nearly 3 inches, with an average depth of 1 to $1\frac{1}{2}$ inches.

The plots were all entered at the northeast and southeast corners. Consequently the left side of the drill was always at the edge of the plot.

For determining the open drill-holes at the various spacings, the drill openings were numbered consecutively from left to right. Drill tube number one was always functioning. For the 12-inch row spacing, the even-numbered drill-opening tubes were placed in bags to catch the seed. A similar procedure was followed in spacing the drill rows 18 inches apart.

Method of Sampling and Analysis of Data

After seedlings were established, plots were sampled by establishing permanent list quadrats measuring 3 feet wide by 5 feet long. Where drill rows could be distinguished the quadrats were placed on rows numbered 6, 7, 8, 9, 10, and 11 from the outside of the plot. Thus, for the 6 inch spacing six rows were sampled, for the 12 inch spacing three rows were sampled, and for the 18 inch spacing two rows were sampled, for a distance of 5 feet.

The quadrats were located by pacing 16 feet from a corner along one side. Quadrats were established in the northeast and southwest corners. It was necessary to further sample many of the plots, and quadrats were then established in the remaining 2 corners. Four quadrats sampled 6 percent of the area of the plot. However, if the 6 drill rows referred to in the previous paragraph are considered as the sampled populations, then 4 quadrats would sample 20 percent of the area. More complete sampling would have resulted in reducing interaction and sampling error in analysis of variance.

Restricting sampling to the same drill rows throughout the experiment was a means of reducing experimental error by eliminating much of the variance caused by differences among drill openings. The variance due to season, species, intensity, and spacing was thus more accurately estimated. Rows near the edge of all plots were judged to be atypical in that competition and other habitat factors were not the same.

A normal seedling count was taken on the established quadrats June 2, 1948. The number on each quadrat was recorded, and the total for all quadrats converted to the number of seedlings per 100 feet of drill row.

In evaluating emergence success, spacing of the rows can, theoretically, have no effect. Therefore, the 3 variations in row spacing serve as replicates within each block and provide 6 replications of each treatment for evaluating treatment effects and experimental error.

Analysis of variance indicates the statistical significance of differences between seasons, species, and intensities. Those differences showing a probability of 19 or more to 1 are considered significant.

List counts of survived individuals could not be made during the fall of 1948. Jackrabbits grazed most of the forage produced, and the summer drought period caused early and extended summer dormancy. Very little fall growth occurred. Survival counts were made on the established quadrats April 2 and 3, 1949. Difficulty was encountered in selecting only those survived individuals previously counted as normal seedlings, since new seedlings were present on the plots. Evaluation of survival was accomplished by converting the survival counts to an area containing 100 square feet. The figure was then expressed as a percent of the normal seedlings originally counted. For the purpose of statistical analysis the percentages were transformed to angles (Snedecor, 1946. p. 449) which were used in computing an analysis of variance.

RESULTS AND DISCUSSION

Factors Influencing Germination and Emergence

Season of planting. The effect of season of planting upon germination and emergence and the subsequent normal seedling count was significant[1] as shown by analysis of variance (table 2). However, season did not affect all species to the same degree. The high degree of significance of interaction between season and species shown in table 2 indicates that the species must be known before the best season of planting can be designated. Actually, the performance for all species was best for the spring season of planting, but only slightly so for crested wheatgrass. Small differences are more likely to have been the result of a sampling mis-chance.

The data presented in table 3 indicate those differences between seasons which were significant. Season averages for each species must differ by the least significant difference (L. S. D.) of 66 to justify the statement that the difference in performance would occur not greater than 1 in 20 trials by mis-chance in random sampling. Crested wheatgrass was the only species that did not show significantly better germination and emergence for the spring season of planting than for fall. As measured by a least significant difference of 51, the difference between season averages was well above the 19 to 1 probability; thus indicating that as a group these species did respond differently when planted during fall and spring.

1. "Significant" is interpreted to mean that the calculated value of F is larger than the corresponding tabular value at a probability of 0.05 (19 to 1).
   "Very significant" will indicate values larger than the corresponding tabular value at a probability of 0.01 (99 to 1).

Table 2. Analysis of variance of the number of normal seedlings of four species of *Agropyron* seeded at Benmore, Utah

Source of variation	Degrees of freedom	Mean square
Between seasons	1	388,024*
Between replications	1	21,437
Error (a)	1	1,175
Between species	3	41,558**
Between intensities	2	85,796**
Interaction:		
Season by species	3	44,530**
Season by intensity	2	52,225**
Species by intensity	6	9,834*
Season by species by intensity	6	11,175*
Error (b)	118	4,479
Total	143	

*Significant
**Very significant

Table 3. Average number of normal seedlings emerged per 100 feet of row

Species	Season: Fall	Season: Spring	Average	L.S.D.* between seasons
Crested wheatgrass	39	41	40	66
Intermediate wheatgrass	15	156	86	66
Stiffhair wheatgrass	53	138	96	66
Tall wheatgrass	86	203	145	66
Average	48	135	92	51
L.S.D.* between species	44	44	31	

*Least significant difference at a probability of 19 to 1.

Comparison between species also may be made from the data and least significant differences in table 3. Those differences will be discussed further in the following section.

It is necessary to understand that results pertain only to the 2 seasons involved in the study (fall, 1947 and spring, 1948). Even though the years may be judged to have been selected at random, the difference between the seasons was an unvariable sum applying only to the given pair of seasons.

Selecting the best season of planting, (or evaluating species or intensities) from the numbers of normal seedlings emerged, was complicated by 2 sources of variation. Both were involved in the number of viable seed planted. Those sources of variation are as follows:

1. Drill openings used did not give the exact rate of seeding as planned. The drill was calibrated to deliver the same number of seeds at a given intensity for each species, but the errors involved were large. The ratio of low to medium and high intensities was not 1 to 2 and 3 respectively. Further, at a given intensity, the drill did not deliver the same number of seeds for each species.

2. Germination of the species varied from 59 percent for crested wheatgrass to 98 percent for tall wheatgrass. Equal numbers of seeds for all four species would be expected to germinate in direct proportion to their germination capacity.

Because of those sources of variation listed above, the number of seedlings emerged on each plot was not suited to direct comparison with that on other plots. When corrected for species differences in germination capacity and irregularities in drill calibration (table 4), the data provided a more correct means of making direct comparisons between methods and species. Those corrections were made by expressing the number of normal seedlings in terms of percent of the number of viable seeds drilled (table 4). During further discussion the term "emergence success" will be used in reference to those percentages. (See table 8.)

The average emergence success for spring was 4.3 times higher than that for fall; however, there was little difference between the seasons for crested wheatgrass. For intermediate wheatgrass the success for the plots seeded during the spring was nearly 10 times greater than that for fall (table 5).

Species. Variation in emergence between species (table 2) was very significant. However, the success of the various species in germination and seedling emergence was not consistent, as indicated by very significant interaction between species and season and a significant interaction between species and intensity.

After learning where real differences probably occurred (least significant differences shown in table 3), the best evaluations can be made of relative emergence success of different species (table 5). The emergence success of 7.1 percent for crested wheatgrass planted in the fall was higher than that for the other species.

On the plots seeded during the fall, tall wheatgrass was second high in emergence with 5.3 percent success, and intermediate wheatgrass was low with only 2.0 percent. Tall wheatgrass was high for the spring season of planting with 25.1 percent success, and crested wheatgrass was low with 9.1 percent. Stiffhair wheatgrass was third high each season.

For the spring season of planting and for the average of both seasons there was an insignificant difference between intermediate wheatgrass and stiffhair wheatgrass.

Table 4. Rates of seeding in number of seeds per 100 feet of a single row*

Species	Seeding intensity	Desired rate of seeding (full seeds)	Actual rate of seeding Full seeds	Actual rate of seeding Viable seeds
Crested wheatgrass	Low	438	488	288
	Medium	876	940	555
	High	1314	1330	785
Intermediate wheatgrass	Low	438	446	393
	Medium	876	923	812
	High	1314	1234	1086
Stiffhair wheatgrass	Low	438	432	385
	Medium	876	801	713
	High	1314	1330	1184
Tall wheatgrass	Low	438	380	372
	Medium	876	875	857
	High	1314	1240	1225

*The differences between desired rate of seeding and actual rate of seeding in number of full seeds show the errors involved in drill calibration.

Table 5. Emergence success in percent of viable seeds planted for four species of *Agropyron*

Species	Season of planting: Fall	Season of planting: Spring	Average
Crested wheatgrass	7.1	9.1	8.1
Intermediate wheatgrass	2.0	19.5	10.7
Stiffhair wheatgrass	3.5	17.0	10.3
Tall wheatgrass	5.3	25.1	15.2
Average	4.3	18.3	11.4

Emergence success was in direct proportion to the size of seed. As indicated by the number of seeds per pound (table III), the species in order of decreasing size of seed are: Agropyron elongatum, A. trichophorum, A. intermedium, and A. cristatum. There was little difference in size of seed between intermediate wheatgrass and stiffhair wheatgrass.

Intensity of seeding. The intensity of seeding could hardly have an affect upon the number of seedlings emerged except in direct proportion to the number of viable seeds planted. The average emergence successes of 11.0, 12.0 and 11.1 percent for low, medium and high intensities respectively, support that assumption. Consequently, it is hardly conceivable that a real biological interaction could exist between species and intensity, or season and intensity. Nevertheless, table 2 shows significance of both those interactions. The causes for discrepancy between species and intensity were the differences in germination capacity and drill calibration. Interaction between season and intensity is the result of actual differences between the intensities, and there is indication that occasional extreme variation in suitability of the soil as a seedbed has made a contribution to interaction. In table 6 the failure of the differences between pairs 20 and 55, 34 and 144, and 39 and 205 to be the same is attributed directly to the differences between intensities of seeding. This failure of the differences between pairs to be the same is an indication of interaction by statistical computation.

A difference was known to exist among the rates of seeding at the three intensity levels. Nevertheless, a lack of significant difference in emergence between some pairs of intensities was obvious, as shown in tables 6 and 7. For emergence success in percent refer to table 8.

Table 6. Average numbers of seedlings of four species of *Agropyron* emerged for each intensity and season of planting

Season of planting	Rate of seeding* Low	Medium	High	Average	L.S.D.** between intensities
Fall	20	34	39	31	38
Spring	55	144	205	135	38
Average	38	89	122	83	27
L.S.D.**between seasons	53	53	53	51	

*Drilling intensity was based on the number of seeds in 2.5, 5.0 and 7.5 pounds of *Agropyron cristatum* for all species at low, medium and high respectively.
**Least significant difference at a probability of 19 to 1.

Table 7. Average numbers of seedlings emerged for three intensities of seeding

Species	Rate of seeding* Low	Medium	High	Average	L.S.D.** between intensities
Crested wheatgrass	26	31	62	40	54
Intermediate wheatgrass	37	76	143	86	54
Stiffhair wheatgrass	35	117	95	82	54
Tall wheatgrass	53	129	187	123	54
Average	38	88	122	83	27
L.S.D.** between species	54	54	54	51	

*Drilling intensity was based on the number of seeds in 2.5, 5.0 and 7.5 pounds of *Agropyron cristatum* for all species at low, medium and high respectively.
**Least significant difference at a probability of 19 to 1.

Table 8. Number of seedlings emerged and success in percent of viable seeds drilled per 100 feet of row for four species of *Agropyron* planted at Benmore, Utah

Species	Relative seeding intensity*	Viable seeds per 100 feet	Season of planting: Spring, Avg. No. seedlings	Spring, Percent success	Fall, Avg. No. seedlings	Fall, Percent success	Average percent success
Agropyron cristatum	low	288	34	11.8	21	7.3	9.6
	medium	555	38	6.8	32	5.8	6.3
	high	785	76	9.7	63	8.0	8.9
	total	1625 8	148	9.1	116	7.1	8.1
Agropyron intermedium	low	393	69	17.6	9	2.3	10.0
	medium	812	126	15.5	15	1.8	8.7
	high	1086	251	23.1	21	1.9	12.5
	total	2291	446	19.5	45	2.0	10.7
Agropyron trichophorum	low	385	52	13.5	21	5.5	9.5
	medium	713	192	26.9	35	4.9	15.9
	high	1184	145	12.1	24	2.0	7.1
	total	2282	389	17.0	80	3.5	10.3
Agropyron elongatum	low	372	79	21.2	31	8.3	14.8
	medium	857	216	25.2	52	6.1	15.7
	high	1215	319	26.3	46	3.8	15.1
	total	2444	614	25.1	129	5.3	15.2
TOTALS	low	1438	234	16.3	82	5.7	11.0
	medium	2937	572	19.5	134	4.6	12.0
	high	4270	791	18.5	154	3.6	11.1
	total	8642	1597	18.5	370	4.3	11.4

*Drilling intensity was calculated to give for each species an identical number of full seeds as occurred in 2.5, 5.0 and 7.5 pounds of *Agropyron cristatum*.

Factors Influencing Survival

Survival success is defined as being the number of survived individuals expressed in percent of the number of normal seedlings emerged.

A primary phase of the study was to determine the influence of rate of seeding (by both row spacing and drilling intensity) upon survival. Therefore, an early consideration is: To what degree did competition determine mortality? A test of that can be made by computing the correlation coefficient of the number of normal seedlings on each plot with the corresponding survival percentage. If the survival percentage was influenced by competition, a negative correlation would exist; thus showing that the percentage survival decreases with increasing numbers of plants per unit area.

The correlation coefficient for the fall season of planting was 0.046. The small and positive value indicates that a correlation did not exist. Consequently, species differences, natural variation, and experimental error are the factors contributing to variation in survival percentages for the fall season of planting.

Plots drilled during the spring showed a correlation coefficient of -0.265 between the numbers of emerged plants and the numbers of those survived. Although the coefficient value is not significant at a probability of 0.05, the author believes that competition was present as a factor of mortality. The probability of a correlation value equal to -0.265, with 34 degrees of freedom, occurring due to chance alone is slightly greater than 0.10 or about 1 in 9.

The greater emergence for the spring plots apparently increased the density of individuals to a state of critical competition.

Season of planting. There is further explanation for the difference in survival success between seasons. Earlier germination for the fall seeding permitted the development of larger individuals previous to the summer drought than occurred on the spring seeded plots. Survival is influenced directly by the size and vigor of plants at the beginning of a dormancy period.

Average survival for the fall seeding was 40 percent (table 9); whereas, the spring seeding showed a survival of 26 percent. When those percentages are superimposed upon emergence percentages of 4.5 and 18.5 for fall and spring seedings respectively, the spring seeding still shows the best results. Analysis of variance (table 10) did not show a significant mean square between seasons; nevertheless, the author believes that a difference in survival did exist.

Species. There was little difference in survival percentages among the species. Intermediate wheatgrass was high with 31 percent survival, followed closely by tall wheatgrass with 29 percent. Stiffhair wheatgrass and crested wheatgrass averaged 25 and 20 percent respectively. The greatest difference between seasons (42 percent) was present in intermediate wheatgrass. Crested wheatgrass had the least difference between season averages in both the normal seedling and survival data. It was interesting to observe that for both seasons the species with the lowest emergence success had the highest survival rate--intermediate wheatgrass for the fall planting and crested wheatgrass for the spring planting. Perhaps that is further indication that competition was a factor influencing mortality.

Table 9. Survival of normal seedlings in percent for four species of *Agropyron**

Species	Drilling intensity**	Season of planting: Fall, Row spacing (inches) 6	12	18	Average	Spring, Row spacing (inches) 6	12	18	Average	All season average
Agropyron cristatum	low	31	28	16	25	14	47	26	29	27
	medium	31	36	25	31	3	8	41	17	24
	high	25	24	35	28	3	3	8	5	17
	average	29	29	25	28	7	19	25	17	23
Agropyron intermedium	low	70	57	59	62	9	33	16	19	41
	medium	32	60	19	37	3	3	7	4	21
	high	43	100	29	57	7	8	3	6	32
	average	48	72	36	52	6	15	9	10	31
Agropyron trichophorum	low	21	37	11	23	8	0	11	6	15
	medium	48	38	15	34	7	15	12	11	23
	high	41	30	34	35	3	7	11	7	21
	average	37	35	20	31	6	7	11	8	20
Agropyron elongatum	low	34	49	0	28	17	19	3	13	21
	medium	48	62	84	65	10	1	12	8	37
	high	61	58	33	51	8	5	10	8	30
	average	48	56	39	48	12	8	8	9	29
AVERAGE	low				35				17	26
	medium				42				10	26
	high				43				7	25
	average	41	48	30	40	8	12	13	11	26

*Survival was recorded April 2 and 3, 1949, and was expressed in terms of percent of seedlings counted June 2 and 3, 1948, which still survived.

**Drilling intensity was calculated to give for each species an identical number of full seeds as occurred in 2.5, 5.0 and 7.5 pounds of *A. cristatum*.

Table 10. Analysis of variance of angles[1] corresponding to survival percentages for four species of Agropyron seeded at Benmore, Utah

Source of variation	Degrees of freedom	Mean square
Between seasons	1	15,090
Between replications	1	636
Error (a)	1	462
Between species	3	389
Between intensities	2	100
Between row spacings	2	937
Interactions:		
Season by species	3	719
Season by intensity	2	2,052*
Season by spacing	2	403
Species by intensity	6	768
Species by spacing	6	728
Intensity by spacing	4	385
Season by species by intensity	6	33
Season by species by spacing	6	230
Season by intensity by spacing	4	224
Species by intensity by spacing	12	169
Season by species by intensity by spacing	12	389
Error (b)	70	505
Total	143	570

[1]Angles by Arc sine transformation. See Snedecor, 1946, p. 447.
*Significant

<u>Intensity of seeding</u>. As shown in analysis of variance (table 10), no significant differences in survival were found between different seeding intensities. Nevertheless, it is believed that the rate of seeding did influence survival on the spring seeded plots. The average survival percentages for all species planted in spring according to intensity of seeding were as follows:

Low intensity	17 percent
Medium intensity	10 percent
High intensity	7 percent
Average	11 percent

Even though the low intensity showed the highest survival percentage, success as measured by the number of survived individuals on a given unit area was greater for the medium and high intensities. The data shown in table 11 reveal that the high intensity resulted in 1.6 times more survived plants than the low intensity, but slightly less than that of medium intensity.

<u>Drill row spacing</u>. Row spacing influenced the numbers of normal seedlings per unit area. As indicated in analysis of variance (table 10), row spacing contributed more to variation in survival percentages than did intensity of seeding. Corresponding mean squares for intensities and row spacings were 100 and 937 respectively. A lack of significant variation caused by either factor, however, makes segregation of the 2 effects unreliable. If the 2 sources of variation were combined in analysis of variance, the resulting mean square would approach the 5 percent probability level. An indication of the influence of row spacing upon survival for the spring seeded plots is shown in table 9. The average survival percentages for the 6, 12 and 18 inch row spacings were 8, 12 and 13 percent respectively.

Table 11. Success of seeding intensities in relative numbers of survived plants for 4 species of Agropyron planted during the spring, 1948

Intensity of seeding	Number of viable seeds	Percent emergence	Survival percent	Avg. No. of survived individuals
Low	234	16.3	17	6.48
Medium	572	19.5	10	11.15
High	791	18.5	7	10.24
Average	532	18.5	11	10.83

CONCLUSIONS

From these results it appears that bare, fallow soil was not suitable for seeding the species planted. There was indication that the limiting factor to seeding success on the fallow soil was inefficient use of the precipitation. Excessive losses of soil moisture by evaporation caused rapid drying of the surface soil, and, consequently, low germination and emergence. Drilling in stubble of a grain is suggested as a method of increasing the efficiency of conservation of the precipitation.

Emergence success was low for both seasons of planting. Nevertheless, there were differences between seasons and species, and less apparent ones among seeding intensities and row spacings.

Planting in the spring proved to be more successful than fall planting. Emergence on the spring plots was 4.3 times more than on the fall plots, as indicated by a count of normal seedlings on June 2 and 3, 1948.

Most of the seed planted during the fall apparently remained dormant in the soil until the following spring. Observations indicated that very little emergence occurred during the fall of 1947. Lower emergence for the fall planting may be primarily attributed to winter kill and alternate freezing and thawing during the early spring when germination was occurring.

Because of delayed spring planting (April 13), emergence occurred at a later date on the spring plots. Consequently, rapid drying and crusting of the surface soil between rain periods, while germination was occurring, were apparently the factors limiting the emergence success on spring plots.

Lack of uniformity in depth of seeding on the uneven soil surface contributed to lower germination because of rapid drying of the surface soil with consequent desiccation of seed planted too shallow. Emergence of germinated seed was restricted for those planted too deep.

Among other things, emergence success was in direct proportion to the size of seed. The largest seeded species, tall wheatgrass, showed the highest emergence success and the smallest seeded species, crested wheatgrass, was lowest.

The affect of season of planting was unequal among the species. Crested wheatgrass was apparently more resistant to winter kill and alternate freezing and thawing. Emergence success was higher on the fall seeded plots for crested wheatgrass than for the other species. On the spring seeded plots the emergence success for crested wheatgrass was only slightly higher than that on the fall plots, whereas other species were much higher.

Survival was somewhat in direct relation to the number of individuals on a unit area. Although survival of individuals was higher on the plots planted during the fall, the larger number of seedlings on the spring plots more than compensated for the higher losses.

The number of seedlings per unit area on the fall planted plots was too low to introduce competition as a factor contributing to mortality.

Survival was in direct proportion to both row spacing and intensity of seeding on the spring plots. Row spacing had more influence upon survival than intensity of seeding. A lack of uniformity in seed distribution contributed to a less accurate estimate of the influence of rate of seeding than that of row spacing, which was uniform throughout the seeding. Future experimentation might well incorporate the advantage of of seed dilution to obtain more uniformity in seed distribution at low intensities of planting.

Evaluation of species, seasons, and methods of planting in terms of numbers of individuals emerging and surviving was inadequate, hence the results have no practical significance. Future comparisons on forage production by clipping, rate of survival and reproduction during designated periods, and size of individual plants (especially of root systems) may more adequately evaluate the species, seasons, and methods of planting.

A lack of definite correlation between the number of viable seeds planted and the number of emerged stiffhair wheatgrass seedlings on the fall seeded plots introduced a perplexing problem. That failure was apparently due to an extreme deviation in the suitability of the soil as a seedbed. Origin of the soil, as explained previously, indicates that abrupt changes are probable. Therefore, the area is not well suited to a plot type of study.

SUMMARY

A seeding study was made on abandoned fallow soil near Benmore, Utah, in the years 1947-49, involving *Agropyron cristatum*, *A. intermedium*, *A. trichophorum*, and *A. elongatum*. The species were seeded by surface drill on adjacent plots measuring 20 by 50 feet in all combinations of the following: 2 replications, 2 seasons, 3 intensities of seeding, and distances of 6, 12 and 18 inches between rows.

The influence of grazing by jackrabbits and early summer drought severly restricted growth of the seeded species. The differences among seasons, species, and rates of seeding were often less than the differences caused by natural variation of soil and species and errors involved in controlling the experiment.

Planting in the early spring proved to be more successful than fall planting. Although survival of individuals was greater on the plots planted during the fall, higher emergence on the spring plots more than compensated for the higher losses.

Both emergence and survival were low for both seasons of planting.

Factors influencing germination, emergence, and survival did not equally affect the four species planted. For the fall season of planting crested wheatgrass showed the highest emergence success, followed by tall wheatgrass, stiffhair wheatgrass, and intermediate wheatgrass in order of decreasing emergence success. Intermediate wheatgrass showed the highest survival rate on the fall plots.

Emergence success of tall wheatgrass on the spring plots was higher than that of the other species. Crested wheatgrass was low in emergence on the spring plots, but showed the highest rate of survival.

The species arranged in order of decreasing survival percentages without regard to season of planting were: intermediate wheatgrass, tall wheatgrass, crested wheatgrass, and stiffhair wheatgrass.

The influence of rate of seeding on survival on the spring plots was apparent, however, there was very little, if any, correlation between the two on the fall plots. Survival was in direct relation to both row spacing and intensity of seeding. It appeared that spacing of the rows had more influence on survival success than intensity of seeding.

It was concluded that the medium rate of planting and the 6 inch row spacing gave the highest success as measured by numbers of plants per unit area surviving the first year.

LITERATURE CITED

Beutner, E. L., and Anderson, D. 1944. Method of seedbed preparation and reseeding deteriorated range lands. Am. Soc. Agron. Jour. 36:171-72. Feb.

Carnes, A. 1934. Soil crusts. Agr. Eng. 15:167-69.

Duffee, F. W. 1940. Soil packer grass seeder. Agr. Eng. 21:21-2. Jan.

Engledow, F. L., and Wadham, S. M. 1924. Investigations on yield in the cereals. (I) Jour. Agr. Sci. 14:287-324.

________________ 1925. Investigations on yield in the cereals. (II) A spacing experiment with wheat. Jour. Agr. Sci. 15:125-46.

Frenzke, C. J., and Hume, A. N. 1942. Regrassing areas in South Dakota. South Dakota State College Agr. Exp. Sta. Bul. 361. June.

Friedrich, C. Allan. 1945. Seeding crested wheatgrass on cheatgrass land. Montana Farmer. Mar. 1.

Hanson, H. C., and Vorhies, C. T. 1938. Need for research on grasslands. Sci. Mo. 46:230-41. Mar.

Lemmon, P. E., and Hafenrichter, A. L. 1947. Dilution method for plot or field seeding of grasses and legumes alone or in mixtures. Am. Soc. Agron. Jour. 39:817-21. Sept.

Love, L. D., and Hanson, H. C. 1932. Life history and habits of crested wheatgrass. Jour. Agr. Research 45(6):371-383.

Murphy, R. P., and Arny, A. C. 1939. Emergence of grass and legume seedlings planted at different depths in five soil types. Am. Soc. Agron. Jour. 31:17-28. Jan.

Nelson, Morlan W. 1939. Conservation survey. Benmore range experiment station. Map & soil description. U. S. Dept. Agr. Soil Conservation Service. Mimeo.

Savage, D. A. 1939. Grass culture and range improvement in the central and southern great plains. U. S. Dept. Agr. Circ. 491. Feb.

Schwendiman, J. L., Sackman, R. F., and Hafenrichter, A. L. 1940. Processing seed of grasses and other plants to remove awns and appendages. U. S. Dept. Agr. Circ. 558.

Short, L. R. 1943. Reseeding to increase the yield of Montana range lands. U. S. Dept. Agr. Farmer's Bul. 1924. Feb.

Snedecor, George W. 1946. Statistical methods. Ames, Iowa. The Iowa State College Press. Fourth Edition. 485 pp.

Sprague, H. B., and Farris, N. F. 1931. Effect of uniformity of spacing seeds on the development and yields of barley. Am. Soc. Agron. Jour. 23:516-33. July.

X Stoddart, L. A. 1946. Seeding arid ranges to grass with special reference to precipitation. Logan, Utah. Utah Agr. Exp. Circ. 122: 29pp.

Rules and recommendations for testing seeds. 1938. U. S. Dept. Agr. Circ. 480. July.

Thatcher, L. E., Willard, C. J., and Lewis, R. D. 1937. Better methods of seeding meadows. Ohio Agr. Exp. Sta. Bul. 588. Dec.

APPENDIX

Table I. Purity analysis of four species of *Agropyron*

Species	*Agropyron cristatum*	*Agropyron intermedium*	*Agropyron trichophorum*	*Agropyron elongatum*
Weight of sample (grams)	7.719	41.550	22.570	32.955
Purity percentage	71.47	92.08	84.82	93.08
Other crop seed	None	None	None	None
Weed seed	17 seeds	0.77%	0.78%	17 seeds
Inert matter	28.53%	7.15%	14.40%	6.92%
No. of seeds in sample	2,604	8,090	3,630	5,024
No. of seeds/pound	153,022	88,318	72,954	69,151
Grams per 100 seeds	0.296	0.514	0.622	0.656

Table II. Germination percentages for four species of Agropyron

Species	Groups (100 seeds each)	Accumulated germination at 14 days	Variation* (% of mean)	No. of hard seeds remaining
Agropyron cristatum	1	53	10.2	5
	2	60	1.7	5
	3	66	11.9	3
	4	56	5.1	4
	Total	234		17
	Average	59		4
Agropyron intermedium	1	89	1.1	3
	2	88	0.0	1
	3	88	0.0	6
	4	87	1.1	4
	Total	352		14
	Average	88		3
Agropyron trichophorum	1	90	1.1	1
	2	88	1.1	1
	3	87	2.2	2
	4	92	3.4	1
	Total	357		5
	Average	89		1
Agropyron elongatum	1	98	0.0	0
	2	98	0.0	0
	3	100	2.0	0
	4	98	0.0	1
	Total	394		1
	Average	98		0

*Tolerance for variability in variation as follows: Agropyron cristatum 10%, A. intermedium 7%, A. trichophorum 7%, and A. elongatum 5%. Limits as listed in Rules and Recommendations for Testing Seeds. 1938.

Table III. Comparative seeding intensities in numbers of seeds per pound of four species of *Agropyron*

Species	Number of seeds per pound	Conversion factors	Seeding intensities (lbs.)* Low	Medium	High
Agropyron cristatum	153,022	1.00	2.50	5.00	7.50
Agropyron intermedium	88,318	1.73	4.33	8.66	12.99
Agropyron trichophorum	72,954	2.10	5.25	10.50	15.75
Agropyron elongatum	69,151	2.21	5.53	11.06	16.59

*The seeding intensities become pounds per acre when drilled in rows 6 inches apart.

Table IV. Rates of seeding in grams per 10 wheel revolutions and pounds per acre for four species of *Agropyron* when drilled in rows spaced 6 inches apart

	Desired rate		Actual rate	
Species	Seeding intensity	Grams per 10 wheel revolutions	Grams per 10 wheel revolutions	Pounds per acre
Agropyron cristatum	Low	26.1	29	2.78
	Medium	52.2	56	5.36
	High	78.3	79	7.57
Agropyron intermedium	Low	45.2	46	4.41
	Medium	90.4	95	9.10
	High	135.6	127	12.17
Agropyron trichophorum	Low	54.8	54	5.17
	Medium	109.7	100	9.57
	High	164.5	166	15.89
Agropyron elongatum	Low	57.7	50	4.79
	Medium	115.4	115	11.02
	High	173.1	163	15.62