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Effects of Season, Spacing and Intensity of Seeding on Emergence and Survival of Four Wheatgrass Species in Central Utah

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EFFECTS OF SEASON, SPACING AND INTENSITY OF SEEDING ON EMERGENCE AND SURVIVAL OF FOUR WHEATGRASS SPECIES IN CENTRAL UTAH

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INTRODUCTION

Rehabilitation of deteriorated and abused range lands is being accomplished with greater success each year by the aid of better methods of seeding which include seedbed preparation, intensities of seeding, implements for planting and improved methods of eliminating competition. Much more information is needed, however, in order to recommend suitable methods and species for seeding various vegetation types and zones with reasonable reliability. Throughout the arid and semi-arid range lands, moisture is the principal factor limiting satisfactory seedling establishment. Special attention should therefore be given to more efficient utilization of the moisture supply. Closely related species or species with similar growth characteristics are said to compete more for water, for space and for nutrients; therefore, studies dealing with the effect of spacing and intensity of seeding upon seedling establishment are of paramount importance.

Available water supply can be most effectively used by increasing water absorption of the soil, storing moisture in the soil one year for use the next and preventing soil moisture loss. Increased water absorption of the soil can be accomplished by tillage of the soil and preventing run-off losses. Summer-fallowing is a means of storing water and preventing moisture losses through evaporation and transpiration.

Slight changes in the amount of available water, or in the efficiency of its use, may bring about success instead of failure in the arid regions of the West. Thus, an important aspect is the density of the seeded species during the initial stages of establishment since spacing and intensity of seeding are principal factors determining competition of subsequent stands. Treatment differences are best observed when the supply of available moisture is near the critical point, otherwise, when the supply of moisture is plentiful or short, differences are not apparent and appear unimportant.

Because of the limited knowledge dealing with effect of intensity of seeding and drill row spacing upon subsequent grass stands, a study was conducted during the years 1950-52 on foothill range land in central Utah. For species of wheatgrass (Agropyron) were used in the study. The three recently introduced species, intermediate wheatgrass (Agropyron intermedium), stiffhair wheatgrass (A. trichophorum), and tall wheatgrass (A. elongatum), were compared to the performance of crested wheatgrass (A. cristatum). The species were seeded in a randomized block in all combinations of the following treatments: spring and fall seeding, 3 intensities of seeding, and 3 different spacings between drill rows.

REVIEW OF LITERATURE

Most of the literature before 1935 covered range seeding only in a broad sense, and much of the subject matter to date is only general in scope. The problems of seedbed preparation, date of seeding, method of seeding, depth of seeding, and use of mulches and nurse crops have been studied by many investigators, but the effect of intensity of seeding and drill row spacing has received little attention.

The importance of the ecological and physiological factors that contribute to failure of seedings are today being realized. Pertinent among these are the factors influencing emergence and survival of seedlings. Hanson and Vorhies (1938) emphasized the need for study of the phases of life histories of forage species, processes of biotic association and succession, relation of climate to vegetation and animals, and inter-relations of vegetation with insects, game and domestic stock.

One of the most important factors determining success of range seeding is general weather conditions, and the foremost of these is precipitation. Precipitation affects not only the method of seeding but also the season to seed. According to Stoddart (1946), areas receiving above 6 inches of precipitation during the growing season generally are good prospects for grass seeding. In judging areas suitable for seeding, Stewart, et al. (1951), recommended only areas where the annual precipitation was 12 inches or more.

Since available moisture has been shown to be a limiting factor in seedling emergence and survival, seedbed preparation is very important in conserving moisture. Important considerations of alleviating the primary causes of seeding failure suggested by Thatcher, Willard and Lewis (1937) are: "....prepare a good seedbed, firm below, with an inch or two of loose soil on top; cultipack; broadcast the seed; and cover lightly with a harrow or weeder crosswise to the cultipacking" (p. 53). Colbert (1950) showed that the effects of firming the seedbed favored seedling survival but to a lesser degree than seedling emergence.

Summer fallow is used widely to conserve an extra supply of moisture and to decrease the weed competition. Most authors, however, suggested keeping the soil protected with stubble or mulch. This is especially true in light soils that are likely to blow. Stoddart (1949) found that thorough, deep plowing with a one-way disk was superior to lighter plowing and railing, but that burning followed by drilling was frequently preferable. Stark, Toevs, and Hafenrichter (1946) found that when grass was planted on summer fallow, development was advanced at least one year over grass planted directly into cheatgrass.

In order to reduce competition and conserve soil moisture, brush, cheatgrass and other competitive species must be reduced on seeding areas. About 95 percent eradication of sagebrush can be obtained by use of a 20-inch-disk wheatland plow with the disks set at about a 30 degree angle to give deep plowing action (Stoddart 1948). Past experience has clearly shown that dense cheatgrass (Bromus tectorum) must be eliminated or greatly reduced if reseeding is to be successful. The preparatory crop method not only eliminates cheatgrass by thorough plowing, but it also leaves a firm, stubble-protected seedbed in which to drill the perennial grass seed (Heik 1950). According to Short (1943), late-developing annuals, such as Russian-thistle, seldom compete severely with grass seedlings from fall or early spring plantings, and Savage (1939) found that for drilling grass seed, stubble about 8 inches to 12 inches high produced soil usually firmer, cleaner and freer of weeds than on land without stubble.

Soil crust is another problem determining the success of seedling emergence. Carnes (1934) has shown that seedlings emerge through a crust better if the soil under them is as firm as the surface crust above. Frischknecht (1949) observed crusting of the soil surface in some years and not in others which resulted from frozen subsoil thereby causing puddling on the surface following snow melt in the spring. Carnes (1934) showed that mulches and stubble were valuable in preventing the formation of hard crust.

Adaptability of species to site was found to be of utmost importance in successful range reseeding (Hull, 1944; Pearse, 1947). The final choice of a grass species or strain will depend upon adaptation to climatic conditions, adaptation to land capability and production of forage.

In addition to species adaptability, season of seeding is a very important consideration for insuring seedling survival. Frischknecht (1949) stated that mortality as the result of wintering had 3 main causes (1) heaving of seedlings due to alternate freezing and thawing of the very wet soil surfaces (2) breaking of the primary leaf near the ground level and (3) unseen internal injury as a result of cold temperatures. Pearse (1947) suggested that planting should be done at a time when the soil of the root zone would remain reasonably moist, and temperatures would favor germination and growth for a considerable length of time, or until seedlings were established. Stewart (1947) suggested fall as normally being the best time for seeding because this season was generally most dependable for moisture and establishment of plants. Cook and Stoddart (1947) found that in all cases when drilling, spring seeding was superior to seeding at any other season; however, when broadcasting the seed, fall seeding was better than spring seeding.

In many cases improper depth of seeding has been observed as the cause for failures and in close association is the lack of uniformity of depth of coverage which results in seed wastage. Murphy and Arny (1939) found that the larger the seed the greater the depth from which small-seeded grasses could be expected to emerge was 3 inches, but they considered one-fourth to one-half inch the optimum, varying with the dryness of the surface soil and soil texture. However, Short (1943) considered three-fourths inch to one inch as the most favorable depth for the seed of most range grasses.

Intensity of seeding is also considered important in establishing a successful stand of grass. On poor soils and poor sites increased intensity may be undesirable in attempting to obtain satisfactory seedling establishment. When grass stands are seeded to produce dense stands, excess competition may prevail. Frenske and Hume (1942) stated that, "The rate of seeding depends upon the size of seed, purity, relative freedom from inert matter, germination, method and time of seeding, condition of seedbed, cost of seed, growth habit of the grass whether spreading or bunch, whether cool-season or warm-season type. Warm-season grasses usually require a heavier rate of seeding than cool-season grasses" (p.34).

Bridges (1941, 1942) found that laboratory germination of grass seeds was not in all cases a reliable guide by which to estimate the rate of seeding. Subsequent failure of the viable seeds to produce stands in the field was not due to their inability to germinate but to the lack of proper conditions for germination.

Bleak (1950) suggested for range conditions that intermediate wheatgrass should be drilled at 6 to 8 pounds per acre in rows 8 to 12 inches apart and when drilling is not practical, seed should be broadcast at a total of 10 to 12 pounds per acre and covered by a harrow or similar means. However, Hubbard (1949) found that if the seedbed were suitable, there was no significant difference after a 10-year period in density of stand or yield of crested wheatgrass when seeded at rates varying from 1 to 12 pounds per acre. Short (1943) pointed out that 2 to 3 pounds of crested wheatgrass per acre would be sufficient under optimum conditions if the seed could be made to feed through the drill steadily at such low rates.

Closely associated with intensity of seeding is row spacing. Several writers recommend a width of row spacing, but few point out any relationship of spacing to seedling emergence and survival. Engledow (1925) acknowledged an intimate connection between spacing, plant development and yield. Stewart, et al. (1951) recommended 6 inches to 12 inches for row spacing for average range seeding for most species. Hull (1948) maintained that row spacings of 6 inches were better for weed control, soil protection and grazing than were wider spacing when using crested wheatgrass. However Nelson and Shepherd (1940) found that row spacings from 14 to 35 inches usually gave higher yields of forage and seed than did closer spaced rows.

Sprague and Farris (1931) found that yield of forage was related to the root and top ratio of the plant. The roots were in turn affected by the regularity of spacing of seeds, as well as the intensity of seeding.

In order to insure soil stability and optimum forage production, there should be some overlap and competition of root systems. Therefore, the most desirable intensity and spacing would be one which results in equal distances between all plants. Love and Hanson (1932) described crested wheatgrass, under normal range conditions, as having a root system with a lateral spread of 2 feet and a working level of 3.3 feet. With a spacing of 21 inches, this would allow an overlap of 3 inches between competing root systems.

Hyder (1949) reported that survival was found to be in direct relation to both row spacing and intensity of seeding. Row spacing, however, had more influence upon survival than did intensity of seeding.

In many areas the chances for success are no greater than the chances for failure, therefore, season of planting, depth of planting, species planted, intensity of planting and spacing of rows may all determine the difference between success or failure. For these reasons, all available information should be gathered and properly weighed before wide-scale seeding can be accomplished with any great degree of success.

DESCRIPTION OF THE AREA

The Soil

The experimental area is located at Benmore, Utah, in Tooele County, on foothill lands administered by the Soil Conservation Service. The area lies, in part, within a shallow arm of the former Lake Bonneville with the remainder of the area being made up of an alluvial outwash plain. The average elevation is about 5,500 feet with low mountains surrounding most of the area. During and after World War I, the area had been dry-farmed in growing small grains. Low grain prices and uncertainty of adequate moisture for even moderate yields led to the abandonment of the land after which it was reclaimed by the Federal Government for rehabilitation.

The soil in the vicinity of the plots is residual and designated as the "Grantsville (unconsolidated) Clay Loam" of the Bonneville Lake sediment series (Nelson, 1939). A short distance to the south, the lake sediment passes under an overburden of alluvial and colluvial outwash (when the transported material is less than 6 feet deep) which was designated as the "Benmore Series". Recent sheet erosion has been rather severe throughout the area. Nelson (1939) in his work on soil survey and classification stated:

"The arm of Lake Bonneville was shallow, with a fluctuating level, probably dry at times, and the sediments variously affected by reworking, by local additions of outwash materials and by difference in drainage. As a result the soils differ in color, texture, structure, and gravel content, frequently within short distances. 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 crushed 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 aggregations or into a light gray heavy textured hard strata which breaks very easily into a mass of small cubical fragments of seldom as much as one-half inch across. Beds of waterworn gravel are at variable depths below an average depth of about 24 inches. Gravels may be present on the surface over considerable areas."

Generally the penetration of moisture from light precipitation is very shallow. Hyder (1949) in a previous study on the area found that only when there was 0.28 inch of precipitation or more was there an apparent increase in moisture in the 1 to 1½ inch zone and after 14 hours the surface inch of soil was back to nearly the air-dry moisture level. This rapid rate of evaporation and short period of time during which there was favorable soil moisture was believed the limiting factor to seed germination.

Vegetation

Previous to the initiation of the study the area was covered by big sagebrush (*Artemesia tridentata*), wheatgrasses (*Agropyron spp.*), and rabbit-brush (*Chrysothamnus spp.*). However, most of the area has either been heavily grazed or plowed and at the time of the initiation of the study, the area was primarily covered with annuals and sagebrush.

Precipitation

The variability of monthly rainfall and annual rainfall, as shown in table 1, indicates the wide variations in precipitation that can be expected on foothill areas in central Utah. The infrequency of rain periods during the early spring, table 2, adds significance to 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 varies from as

Table 1. Monthly precipitation for Benmore, Utah, 1948 to 1951 1/

Month	1948	1949 2/	1950	1951	Average
Jan.	.36	1.50	3.43	1.23	1.63
Feb.	.49	.47	.85	.62	.61
Mar.	1.99	1.59	.74	1.37	1.42
Apr.	.75	.65	.37	2.20	.99
May	.09	1.64	1.12	1.98	1.21
Jun.	1.48	.52	.42	.64	.76
Jul.	.07	.26	.60	1.50	.61
Aug.	1.01	.27	.03	.87	.54
Sep.	.35	.39	.80	.13	.42
Oct.	.81	1.47	.55	1.16	1.00
Nov.	.79	.46	1.31	1.85	1.08
Dec.	2.04	.56	.54	3.66	1.70
Total	10.14	9.78	10.76	17.21	11.97

1/ Data compiled from reports of U. S. Weather Bureau.
2/ Data taken at Vernon, Utah five miles from Benmore, Utah by Mr. Durrant. Benmore record is not complete.

Table 2. Monthly precipitation and number of precipitation periods during March, April and May at Benmore, Utah[1]

Year	1943	1944	1945	1946	1947	1951	Average
March:							
Precipitation	0.69	1.72	1.99	1.64	0.37	1.37	1.30
No. of ppt. periods	6	7	9	11	2	6	7
April:							
Precipitation	0.55	1.39	1.77	0.00	2.18	2.20	1.34
No. of ppt. periods	5	13	10	0	4	12	7
May:							
Precipitation	0.51	2.09	1.11	1.93	0.58	1.98	1.37
No. of ppt. periods	6	10	11	3	1	9	7
Total:							
Precipitation	1.75	5.20	4.87	3.57	3.13	5.55	4.01
No. of ppt. periods	17	30	30	14	7	27	21

1/ Data compiled from reports of the Soil Conservation Service and U.S. Weather Bureau. Data for 1948, 1949, and 1950 for number of precipitation periods during month were not complete.

few as 2½ days to as many as 30 days.

The mean annual precipitation at Benmore, over a period of 32 years, beginning with 1912 to 1943 inclusive, was 12.82 inches. Seasonally, 30.11 percent of the precipitation fell in the spring, 20.75 percent in the summer, 22.77 percent in the fall, and 26.37 percent in the winter. The total amount received during the growing season, April 1 to October 1, was 45.50 percent (table 3). From 1943 to 1951 inclusive, the mean annual precipitation was 11.86 inches.

The average annual precipitation for 1950-51 was 12.94 inches of which 42.89 percent fell in the spring, 23.26 percent in the summer, 15.38 percent in the fall and 18.47 percent in the winter. The amount received during the 1951 growing season was 7.8 inches or 56.57 percent of the annual total (table 3).

As show in table 1, the precipitation for the growing season of 1951 was well above average. However, during fall and winter, moisture was considerably below the average (table 3). If the winter accumulation of moisture is low, spring seedings must depend upon spring precipitation alone. The longest period of favorable growing conditions for the Benmore area is during the early spring. Therefore, it would be most desirable to have the seed germinate in the early spring.

Foothill regions of Utah are characterized by large variations in amount, distribution, and frequency of precipitation. High rates of evaporation from the surface soil stress the importance of frequent rain storms during the period of germination and emergence. Seeds may be subjected to one or more period of drying out if the surface soil does not have a frequent supply of moisture. If this is the case, high mortality of

Table 3. Monthly precipitation for water year of 1950-51 at Benmore, Utah compared to average (1912-1943)[1/]

Month	1950-51[2/]	1912-1943[3/]
October	.55	1.22
November	1.31	.90
December	.54	1.01
January	1.23	1.03
February	.62	1.34
March	1.37	1.49
April	2.20	1.17
May	1.98	1.20
June	.64	.74
July	1.50	.94
August	.87	.98
September	.13	.80
Total	12.94	12.82

1/ Water year is designated as that period of time in which the soil mantle is first recharged in October of one year until its initial recharge in October of the subsequent year.

2/ Data from U. S. Weather Bureau reports.

3/ Data from Stoddart (1946).

seeds and seedlings is to be expected. Therefore, winter snows must be relied upon to provide a good supply of moisture to the sub-soil, and spring rains are needed to replenish the supply of moisture in the surface soil. On areas where soil crusting is a problem, spring rains are important in order to keep the soil surface soft so seedlings can emerge.

METHOD OF PROCEDURE

Preparation of the soil

The brush on the area was eradicated during the first week of April in 1948. Three implements (wheatland plow, tumbling log-harrow, rail) were used in the process of eradication. Each implement cleared about one-third of the area.

This area was again cultivated during the last week in August of 1949. The entire area was plowed with a wheatland plow. During the second week in July of 1950, the area was again cultivated so as to summer fallow and destroy weeds on the area. At this time there was a sparse stand of Russian thistle (*Salsola pestifer*) and cheatgrass (*Bromus tectorum*). However, it was noted during the summer of 1951 that this summer fallow preparation was rather poor since the area had a moderate stand of cheatgrass and Russian thistle on it even after two cultivations. Perhaps an earlier date of summer fallowing should have been used before the seed on the cheatgrass had matured.

Seed Analysis

The seed which was used for the fall and spring seedings of experimental planting was obtained from the Utah State Agricultural Experiment Station harvest of 1949. Analysis and testing was in accordance with the rules for seed testing as listed in *Rules and Recommendations for Testing Seeds*, U. S. D. A. Circ. 480, 1938. A summary of the results of the seed analysis and testing is shown in appendix tables 20 and 21.

The seed to be tested was separated into 4 components: (1) filled grass seed of the species to be tested, (2) other crop seed, (3) weed seed, and (4) inert matter. Since the amounts of other crop seeds and weed seeds were negligible, they were included with inert matter in order to weigh them.

Four samples of each grass species were separated into groups of 100 filled seeds per sample for the germination period, the germination oven was washed with a solution of formaldehyde consisting of 1 part formaldehyde to 100 parts of distilled water. This was allowed to stand for 1 hour and then the oven was rinsed with distilled water. All petri dishes were similarly treated. Each sample of seed was allowed to stand in a solution of 1 part formaldehyde to 320 parts water for a period of 10 minutes then taken out and allowed to dry on blotters. The seeds were then spread on moist blotters in the treated petri dishes and covered with a damp blotter and placed in the germination oven at a constant temperature of 68° F. Seeds were considered as germinated upon the extrusion of the radicle and coleoptile. 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 period were counted and recorded as hard seeds.

Storage treatment of the seed prior to testing and drilling consisted of dry storage at room temperature. The species tested were well within the tolerance limits (appendix table 21).

The purity and germination percentages of each species were used to calculate the bulk seed containing the same number of viable seeds contained in one pound of crested wheatgrass (appendix table 22). The number of viable seeds per unit length of drill row could then be used to compute the emergence success from the normal seedling count.

Drill Calibration

The drill used for the seeding was a 6 foot single-disc type drill with ten spout openings 7 inches apart. It was necessary to calibrate both sides of the drill since the left and right sides of the drill were controlled by separate seeding intensity governors. For each intensity of each species, the number of grams of seed to be dropped from 5 holes in 20 wheel revolutions was computed in the following manner:

$$I = \frac{1}{2} (G/R \times 20)$$

When:

I = grams desired per 5 drill openings in 20 wheel revolutions
G = grams to be seeded per acre
R = Wheel revolutions per acre (605) = 43,560 (sq. ft. per acre)/CxW
C = wheel circumference = 12 feet
W = width of the drill = 6 feet

Therefore: $I = \frac{1}{2} (G/30.25)$

Drill calibrations for the various intensities and species were accomplished by: (1) propping 1 wheel off the ground for turning (2) filling the hopper with seed (3) starting at small openings and successively increasing the opening until the proper openings were determined. The seed dropped during 20 wheel revolutions was caught on a canvas and weighed for recording each drill setting. The weights per drill settings were compared with the desired amount and the setting closest to the desired amount was used as shown in appendix table 23. With all species, the amount of seed dropped in the actual seeding operation differed from the desired amount. The greatest variation was found in the fall seeding because time did not permit drill calibrations for the different seed sources in some cases. Therefore, new calibrations were made and used for the spring seeding and also the rates of seeding for the fall were rechecked.

Design of Experiment

Two blocks measuring 1340 by 130 feet each were laid out side by side with a driveway 20 feet wide between them. The seedbeds were divided into 72 plots each and each plot measured 18½ by 130 feet (figure 1). The blocks were lettered A and B from east to west making two replications of completely randomized plots within each bed. All possible combinations of spacing, intensity, and season for each of the four species were planted in two replications.

The 4 species of wheatgrasses were drilled at spacings of 7, 14, and 21 inches. Intensities of filled seed used for each species were comparable to 2.5, 5.0 and 7.5 pounds to the acre of Agropyron cristatum (appendix table 22) and are referred to as low, medium, or high rates. Spacing was accomplished by using all drill spouts for the 7 inch spacing, every other spout for the 14 inch spacing, and by stopping up every second and third spout for a spacing of 21 inches. Spouts not used were placed in seed bags and the seed caught. Failure of the species to perform the same way may be 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 in soils and among species.

Seedings were made during the fall on September 19, 1950, and during the early spring, April 4, 1951, making a total of 144 plots in the entire study.

Drilling the Seed

All plots were drilled in the same manner (figure 1). The seeding

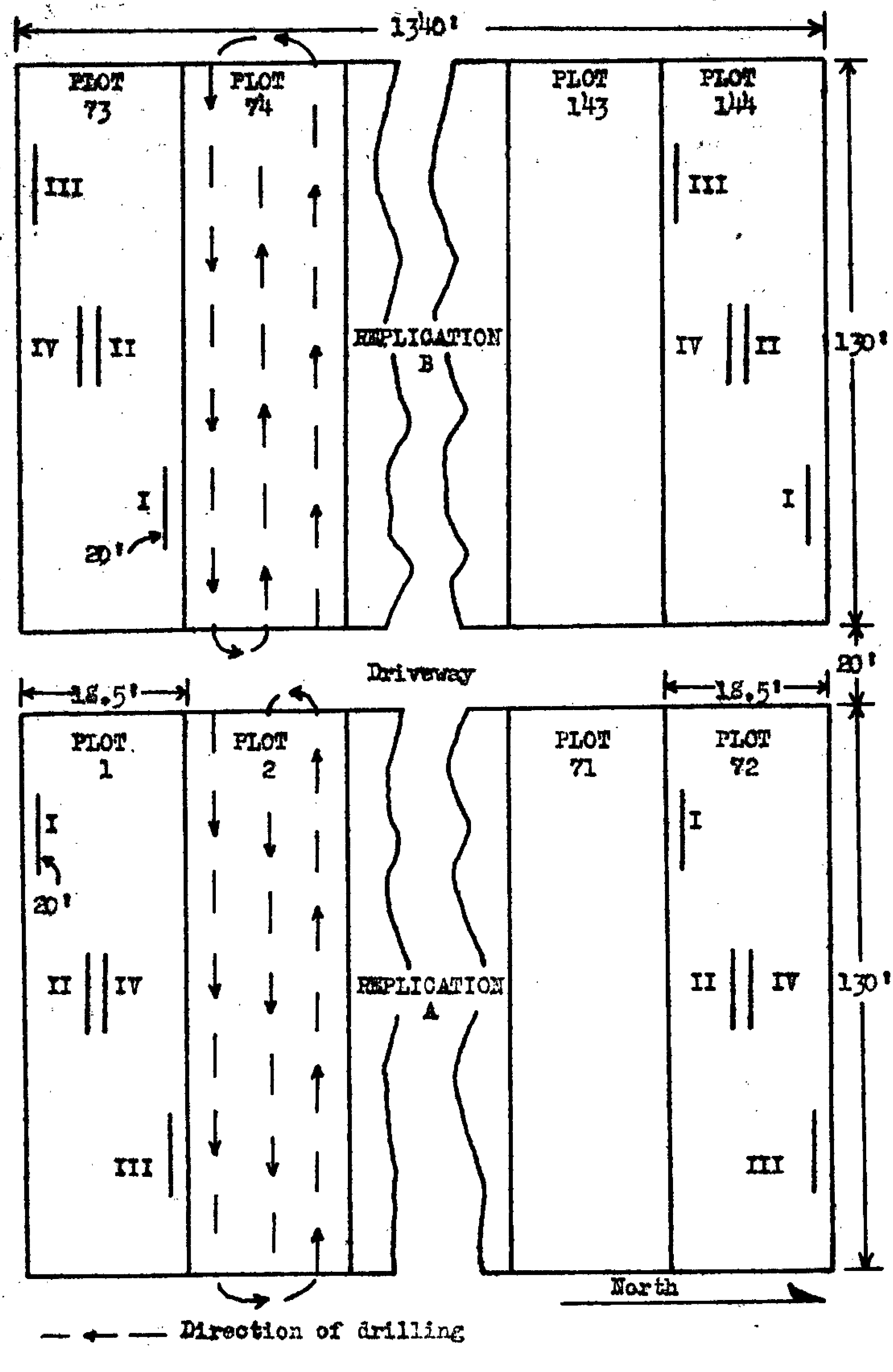

Figure 1. Diagram of experimental area including replications, plot locations, and location of sampling units within the plots

depth was very difficult to regulate due to the unevenness of the soil surface. This resulted in varying the seeding depth from ½ inches with an average depth about 1 inch.

For the purpose of sampling drill rows, openings in the drill were numbered consecutively from left to right when facing the back of the drill. Drill spout number one was always functioning as was drill spout number seven. All drill spouts were used for the 7 inch spacing; spout numbers 1, 3, 5, 7 and 9 were used for the 14 inch spacing; and spout numbers 1, 4, 7 and 10 were used for the 21 inch spacing.

<u>Method of Sampling and Analysis of Data</u>

No emergence data for fall seeding could be taken before winter snows because less than 5 percent of the seedlings had emerged due to lack of fall moisture. This observation was made on December 10, 1950.

After seedlings had sufficient opportunity to emerge in the spring of 1951, three sampling plots or units consisting of 20 linear feet of drill row were established in each plot. The outer drill rows consisting of 1 and 2, and 9 and 10 were often overlapped in drilling and could not be used for sampling. Therefore, drill row number seven, common to all three spacings, was used. The sampling units were located by pacing 7 steps from a corner along drill row number seven and measuring a 20-foot linear unit and then pacing 7 steps to the next sampling unit being sure to locate drill row number seven in the center set of drill rows, etc., (figures 1 and 2). These sampling units were established and seedling emergence counts made from June 8 to 15, 1951.

It was believed that restricting sampling to the same drill row or

Figure 2. A plot area showing drill rows with a sampling unit located in the foreground, June 8, 1951

rows would be a means of reducing experimental error by eliminating much of the variance caused by differences among drill openings. To determine whether this was a significant factor, another sample unit was taken exactly opposite number 2 but on a different drill row (figure 1). This drill row was number 3 for spacings of 7 inches and 14 inches, and drill row number 4 for the 21 inch spacing. Each 20 feet of linear drill row sampled constituted 15 percent of its individual drill row and the four samples per plot sampled 2 percent of the total linear feet of drill row per plot.

Because of the time involved in making counts of the linear drill row samples, the vertical point method of sampling described by Levy and Madden (1933) was used on the same linear drill row sample as used on actual seedling counts in drill row number seven (figure 3). Sample unit number 3 was randomly selected from the four sampling units within the plot. The vertical point method apparatus was moved along the entire 20-foot sampling unit recording all strikes of the pin-points upon seedlings. Two pin-points striking the same seedling were recorded as two hits. The total hits from the vertical point method for 20 feet was then compared with the 20-foot linear sample count in order to determine whether or not the pin-point method could be used with reasonable accuracy and with a saving of time.

Survival counts could not be made during the fall of 1951. The summer drought and lack of early fall precipitation extended the summer dormancy of the seedlings into late winter and snow fall. Jack rabbits also had grazed much of the forage produced and would make counting of the survived plants difficult. Practically no fall regrowth occurred. These factors delayed survival counts on the established sampling units until April 25 and 26, 1952. Evaluation of survival was accomplished by expressing the

Figure 3. The vertical point method apparatus located over a portion of a linear drill row sampling unit

survived individuals as a percent of the emerged seedlings originally counted per plot. 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

Comparison of Sampling Methods

Variability among drill rows. In order to determine whether there was any difference between drill rows, drill row number 3 and drill row number 7 for the 7 inch spacings and 14 inch spacings was selected for study. A paired comparison was made between sampling units 3 and 4 (table 4). In testing the hypothesis that there was no difference between drill rows, the calculated "t" value was 0.673. The probability of a larger "t" value was greater than a 19 to 1 chance. Therefore, the two drill rows, numbers 3 and 7, did not vary significantly (Snedecor, 1946, p. 84).

The comparison for the 21 inch spacing was similarly made (table 5). The calculated "t" value in this case was 0.790 which likewise showed no significant difference between drill rows number 4 and number 7.

The lack of significance between drill rows indicates that for all practical purposes any drill row that was seeded could have been selected at random for sampling purposes. This, of course, applies only to the drill used for this experiment which gave rather even distribution of seed for any drill spout that was seeding.

Application of the point method for measuring emergence. Seedling emergence as determined by actual count of 20 linear drill row feet and by the pin-point method are shown in table 6. From these data correlation squared or "r^2" was found to equal 0.4070. This can be interpreted as meaning that 40.70 percent of the variability of the actual population variability can be accounted for by the pin-point (point) method, or that a sample 100.0 percent larger is required by the pin-point method compared to the actual

Table 4. Sampling data for testing variability among drill-rows between drill-rows 7 and 3 for seedling emergence in 96 observations

Sample No. 2 Drill-row 7 X_1	Sample No. 4 Drill-row 3 X_2	Difference $X = X_1 - X_2$
14	19	-5
9	13	-4
15	19	-4
25	27	-2
19	30	-11
9	12	-3
23	70	-47
40	29	11
5	17	-12
27	21	6
54	30	24
29	25	4
2	8	-6
5	4	1
35	82	-47
57	15	42
26	46	-20
32	27	5
102	20	82
38	34	4
20	35	-15
48	52	-4
46	38	8
62	99	-37
28	40	-12
13	18	-5
43	16	27
34	75	-41
18	31	-13
14	20	-6
95	89	6
49	153	-104
35	62	-27
43	21	22
66	35	31
89	72	17
33	71	-38
68	44	24
109	151	-42
115	99	16
60	60	0
36	42	-6
49	116	-67
25	47	-22
18	45	-27
39	27	12
101	53	48
108	109	-1

Table 4. (Continued)

Sample No. 2 Drill-row 7	Sample No. 4 Drill-row 3	Difference
X_1	X_2	$X-X_1-X_2$
16	18	-2
16	11	5
32	13	19
84	29	55
7	12	-5
13	11	2
7	26	-19
13	26	-13
5	4-	1
6	11	-5
17	20	-3
68	64	4
15	24	-9
11	8	3
56	20	36
78	36	42
31	15	16
23	8	15
87	19	68
101	60	41
28	26	2
38	41	-3
88	38	50
27	48	-21
48	41	7
28	25	3
100	115	-15
56	71	-15
14	14	0
19	8	11
75	32	43
114	48	66
53	33	20
60	29	31
30	18	12
106	67	39
47	90	-43
79	105	-26
59	68	-9
93	57	36
57	37	20
25	31	-6
50	34	16
159	106	53
10	23	-13
21	19	2
116	43	73
75	158	-83
TOTAL 4391	4128	263

Table 5. Sampling data for comparison of drill-row variability between drill-rows 7 and 4 for seedling emergence in 48 observations

Sample No. 2 Drill-row 7 X_1	Sample No. 4 Drill-row 4 X_2	Difference $X = X_1 - X_2$
20	16	4
6	5	1
13	8	5
38	14	24
11	13	-2
4	6	-2
8	10	-2
12	13	-1
1	18	-17
2	1	1
14	10	4
25	14	11
23	11	12
12	10	2
12	22	-10
61	6	55
34	38	-4
33	29	4
45	52	-7
21	2	19
17	41	-24
12	2	10
91	30	61
79	78	1
23	1	22
1	9	-8
36	35	1
35	43	-8
28	22	6
32	15	17
47	38	9
95	137	-42
6	2	4
18	27	-9
32	27	5
172	86	86
28	14	14
31	28	3
10	68	-58
92	83	9
1	30	-29
5	1	4
54	55	-1
75	104	-29
32	32	0
28	40	-12
102	86	16
93	117	-24
TOTAL 1670	1549	121

Table 6. Seedling emergence as determined by actual count of 20 linear drill-row feet compared to determinations made by number of hits with the point method on the same drill row distance

Plot Number	Sample No. 3 Actual Count X	Sample No. 3 Point Method Y	Ratio of X to Y
1	24	3	8
2	8	1	8
3	53	6	8.8
4	33	0	0
5	26	8	3.2
6	57	5	11.4
7	15	1	15
8	65	10	6.5
9	7	0	0
10	19	2	9.5
11	24	3	8
12	52	16	32
13	93	4	23.2
14	18	2	9
15	49	17	2.9
16	17	3	5.7
17	31	7	4.4
18	21	6	3.5
19	14	3	4.7
20	36	9	4
21	102	7	14.6
22	68	3	22.7
23	57	15	3.8
24	12	0	0
25	57	7	8.1
26	78	10	7.8
27	46	3	15.3
28	22	12	1.8
29	37	3	12.3
30	61	9	6.8
31	29	8	3.6
32	23	1	23
33	21	6	3.5
34	108	16	6.8
35	53	16	3.3
36	33	8	4.1
37	66	24	2.8
38	94	21	4.5
39	1	0	0
40	33	12	2.8
41	13	5	2.6
42	0	0	0
43	152	19	8
44	28	8	3.5
45	97	8	12.1

Table 6. (Continued)

Plot Number	Sample No. 3 Actual Count X	Sample No. 3 Point Method Y	Ratio of X to Y
46	45	17	2.6
47	26	11	2.4
48	26	3	8.7
49	73	29	2.5
50	39	2	19.5
51	98	23	4.3
52	28	1	28
53	13	2	7.5
54	38	7	5.4
55	33	5	6.6
56	34	0	0
57	39	6	6.5
58	44	12	3.7
59	12	0	0
60	9	0	0
61	23	4	5.8
62	43	4	10.8
63	1	0	0
64	46	11	4.2
65	42	4	10.5
66	60	2	30
67	19	1	19
68	19	1	19
69	67	9	7.4
70	75	4	18.8
71	61	5	12.2
72	64	11	5.8
73	114	31	3.7
74	97	13	7.5
75	77	12	6.4
76	78	18	4.3
77	10	4	2.5
78	4	1	4
79	63	9	7
80	47	11	4.3
81	73	7	10.4
82	26	1	26
83	34	6	5.7
84	4	1	4
85	9	6	1.5
86	28	6	4.7
87	30	1	30
88	17	5	3.4
89	39	5	7.8
90	112	22	5.1
91	45	7	6.4
92	94	37	2.5

Table 6. (Continued)

Plot Number	Sample No. 3 Actual Count X	Sample No. 3 Point Method Y	Ratio of X to Y
93	14	6	2.3
94	54	15	3.6
95	15	5	3
96	40	19	2.1
97	14	6	2.3
98	52	15	3.5
99	16	5	3.2
100	34	7	4.9
101	33	9	3.7
102	179	20	9
103	68	5	13.6
104	23	7	3.3
105	11	4	2.8
106	68	18	3.8
107	70	12	5.8
108	84	16	5.2
109	81	7	11.6
110	8	6	1.3
111	78	14	5.6
112	1	0	0
113	53	7	7.6
114	2	0	0
115	135	27	5
116	89	30	3
117	10	5	2
118	119	15	7.9
119	113	7	16.1
120	95	25	3.8
121	27	10	2.7
122	45	7	4.4
123	59	9	6.6
124	23	6	3.8
125	21	4	5.2
126	57	6	9.5
127	37	5	7.4
128	78	24	3.2
129	11	3	3.7
130	23	5	4.6
131	25	10	2.5
132	25	11	2.3
133	19	11	1.7
134	30	3	10
135	16	4	4
136	29	4	7.2
137	17	2	8.5
138	79	5	15.8
139	6	0	0
140	33	9	3.7

Table 6. (Continued)

Plot Number	Sample No. 3 Actual Count X	Sample No. 3 Point Method Y	Ratio of X to Y
141	24	3	8
142	36	3	12
143	19	2	9.5
144	89	8	11.1
TOTAL	6418	1170	984.6
MEAN	44.69	8.12	6.84

seedling count per linear drill row foot to obtain the same degree of accuracy for both methods.

There was a highly significant[1] difference in the variability accounted for by the actual seedling count per linear drill row as compared to the pin-point method. The total sum of squares due to regression of the pin-point method on actual seedling counts was highly significant (table 7). Of the variation in the seedling population, only about 47 percent was accounted for by the pin-point method. This is shown by the proportion of the total sum of squares accounted for by regression and by the value of "r^2" (table 7). The regression value was 0.1495 which means that the pin-point apparatus actually hit and accounted for only about 15 percent of the total seedling population.

As previously stated, it requires 2.14 times the size of sample (linear drill row feet) by the pin-point method compared to the actual linear drill row count in order to measure the differences between treatments equally as well by both methods, even though the pin-point method accounts for only about 15 percent of the total population of seedlings. However, the pin-point method requires only about three-fourths as much time as actual drill row counts for the same linear distance.

<u>Factors Influencing Germination and Emergence</u>

<u>Season of Planting.</u> The effect of season of planting upon germination and emergence and the subsequent normal seedling[2] count was not found to be

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).
"Highly significant" will indicate values larger than the corresponding tabular value at a probability of 0.01 (99 to 1).

2/ Normal seedlings are the actual drill row emergence count corrected and adjusted for the variation in actual drill rate of seeding to the desired rate of seeding. Hereafter the term "normal seedling" will refer to this.

Table 7. Analysis of variance of data shown in table 6

Source	Degrees of Freedom	Sums of Squares	Variance
Total	143	7,609.75	
Due to regression	1	3,557.10	3,557.10**
Deviation from regression	142	4,052.65	28.54

$$r^2 = \frac{(Sxy)^2}{(Sx^2)\,(Sy^2)} = .4674$$

$b_{y.x} = .1495$

$Sx^2 = 159,145.31$

$Sy^2 = 7,609.75$

$r = .6837$

$n = 144$

$Sxy = 23,792.75$

** Highly significant

Table 8. Analysis of variance of the number of normal seedlings emerged of four species of Agropyron presented in table 9

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square
Between seasons	1	485,228	485,228
Between replications	1	17,755	17,755
Error (a)	1	34,565	34,565**
Between species	3	48,855	16,285**
Between intensities	2	516,252	258,126**
Between spacings	2	57,323	28,662**
Interaction:			
Season by species	3	58,384	19,461**
Season by intensity	2	67,600	33,800**
Season by spacing	2	1,140	570
Species by intensity	6	28,496	4,749
Species by spacing	6	46,662	7,777
Intensity by spacing	4	7,272	1,818
Season by species by intensity	6	7,142	1,190
Season by species by spacing	6	27,301	4,550
Season by intensity by spacing	4	19,932	4,983
Species by intensity by spacing	12	34,233	2,853
Season by spacing by intensity by species	12	36,697	3,058
Error (b)	70	251,327	3,590
Total	143	1,746,164	12,211

* Significant
** Highly significant

Table 9. Normal seedling emergence from four Agropyron species seeded at three intensities and at three spacings during the fall and spring[1/]

FALL

Species	7" Spacing Low	7" Spacing Medium	7" Spacing High	14" Spacing Low	14" Spacing Medium	14" Spacing High	21" Spacing Low	21" Spacing Medium	21" Spacing High	TOTAL
Agropyron cristatum	114	215	284	139	142	324	77	223	149	1667
Agropyron intermedium	126	247	431	103	356	560	78	158	155	2294
Agropyron trichophorum	133	202	369	69	229	355	52	87	91	1587
Agropyron elongatum	41	169	269	119	156	168	113	190	251	1476
SUBTOTAL	414	933	1353	430	883	1407	320	638	646	
TOTAL			2700			2720			1604	
GRAND TOTAL										7024

SPRING

Species	7" Spacing Low	7" Spacing Medium	7" Spacing High	14" Spacing Low	14" Spacing Medium	14" Spacing High	21" Spacing Low	21" Spacing Medium	21" Spacing High	TOTAL
Agropyron cristatum	163	347	454	247	49[illegible]	444	125	240	520	3031
Agropyron intermedium	243	543	943	162	429	587	108	498	445	3958
Agropyron trichophorum	226	391	583	275	515	635	176	261	586	3648
Agropyron elongatum	[illegible]	674	682	303	572	659	234	556	767	4746
SUBTOTAL	931	1955	2662	987	2007	2325	643	1555	2318	
TOTAL			5548			5319			4516	
GRAND TOTAL										15383

1/ Individual figures represent seedlings per 180 feet of linear drill row.

significant as shown by the analysis of variance (table 8). However, it is felt that lack of sufficient replication failed to bring out significance of the difference between seasons of planting. The spring planting had 2.2 times more emerged seedlings than did the fall planting (table 9). Other research workers in similar studies in the same locality (Hyder, 1949; Cook and Stoddart, 1951) found significantly better emergence from spring seedings. A high degree of significance for interaction was found between season and species as shown in table 8 which indicates that species react differently from spring and fall planting. Intermediate wheatgrass had the highest emergence from fall planting, but ranked second highest from the spring planting; whereas, tall wheatgrass was the lowest in emergence from the fall planting, but was highest from the spring planting. However, spring planting resulted in the best performance for all species.

These results pertain only to the two seasons involved in the study (fall, 1950 and spring, 1951). The years may be judged to have been selected at random, but the difference between seasons applies only to a given pair of seasons.

Two sources of variation complicate the selection of the best season of planting or evaluating species or intensities based upon the numbers of normal seedlings emerged. Both are involved in the numbers of viable seed planted. The two sources of variation are as follows:

1. Drill openings 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, however, the errors involved in some cases were large. In all cases the ratio of low to medium and high intensities was not 1 to 2 and 3 respectively. Thus, the drill did not deliver the same number of seeds for each species at a given intensity.

2. Germination of the species varied from 88 percent for tall wheatgrass to 93 percent for crested wheatgrass. Equal numbers of seeds for all four species would be expected to germinate in direct proportion to their germination capacity.

Because of these sources of variation, the number of seedlings emerged was not readily suited to direct comparison between species. Therefore, correction of the data for irregularities in drill calibration provided a more correct means of making comparisons between methods and species (table 10). The corrections were made by expressing the number of normal seedlings in terms of percent of viable seeds drilled or "emergence success". However, there was only slight variation in germination capacity of the filled seed among species. Therefore, data can be expressed either on the basis of filled seed or viable seed without affecting the interpretation.

The average emergence success from spring seeding was 2.2 times higher than that from fall seeding. The emergence success from the spring seeding for tall wheatgrass was 3.2 times greater than that from fall seeding; whereas, intermediate wheatgrass was only 1.8 times higher from spring than from fall seeding (table 10).

Species. A highly significant difference was found in emergence among species (table 8).

By the aid of least significant differences (table 11), it is shown that for the fall seeding intermediate wheatgrass produced significantly higher seedling emergence than the other three species; however, for the spring seeding tall wheatgrass produced significantly greater emergence than the other species. This is also borne out by evaluating the species by use of relative emergence success (table 12).

Table 10. Number of normal seedlings emerged and success in percent of viable seeds drilled per 100 feet of row for four species of *Agropyron* at three seeding intensities and three drill row spacings

				Season of Planting				
				Spring		Fall		
Species	Seeding intensity	Desired rate of seeding (full seeds)	Viable seeds	Aver. no. seedlings	Percent success	Aver. no. seedlings	Percent success	Average percent success
Agropyron cristatum	Low	562	523	111	21.3	69	13.2	17.2
	Medium	1124	1045	225	21.5	121	11.6	16.6
	High	1686	1568	295	18.8	158	10.1	14.5
		3372	3136	631	20.1	348	11.1	15.6
Agropyron intermedium	Low	562	523	107	20.4	64	12.2	16.3
	Medium	1124	1045	306	29.3	175	16.7	23.0
	High	1686	1568	411	26.2	239	15.2	20.7
		3372	3136	824	26.7	478	15.2	21.0
Agropyron trichophorum	Low	562	517	141	27.3	53	10.3	18.8
	Medium	1124	1034	243	23.5	108	10.4	17.0
	High	1686	1551	376	24.2	170	11.0	17.6
		3372	3102	760	24.5	331	10.7	17.6
Agropyron elongatum	Low	562	495	174	35.2	57	11.5	23.4
	Medium	1124	989	375	37.9	107	10.8	24.4
	High	1686	1484	439	29.6	143	9.6	19.6
		3372	2968	988	33.3	307	10.3	21.8
TOTALS	Low	2248	2058	533	25.9	243	11.8	18.9
	Medium	4496	4113	1149	27.9	511	12.4	20.2
	High	6744	6171	1521	24.6	710	11.5	18.0
	Total	13488	12342	3203	26.0	1464	11.9	18.9

Table 11. Average number of normal seedlings emerged per 100 feet of drill row for four *Agropyron* species during fall and spring planting

Species	Season: Fall	Season: Spring	Average
Agropyron cristatum	116	210	163
Agropyron intermedium	159	275	217
Agropyron trichophorum	110	253	182
Agropyron elongatum	103	330	216
Average	122	267	195
L.S.D.* between species within season	40	40	28

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

Table 12. Emergence success in percent of viable seeds per 100 feet of drill row planted for four species of *Agropyron* during fall and spring

Species	Season of Planting		Average
	Fall	Spring	
Agropyron cristatum	11.1	20.1	15.6
Agropyron intermedium	15.2	26.7	21.0
Agropyron tricophorum	10.7	24.5	17.6
Agropyron elongatum	10.3	33.3	21.8
Average	11.9	26.0	18.9

For the average of both seasons tall wheatgrass and intermediate wheatgrass gave significantly better seedling emergence than did either stiffhair wheatgrass or crested wheatgrass.

The same relationship in emergence success for these same species for the spring seeding was found also by Hyder (1949); however, for the fall seeding crested wheatgrass gave the highest emergence success followed by tall wheatgrass, stiffhair wheatgrass, and intermediate wheatgrass respectively.

Intensity of seeding. The intensity of seeding should theoretically have no affect upon the number of seedlings emerged except in direct proportion to the number of viable seeds planted. The average emergence successes of 18.9, 20.2 and 18.0 percent (table 10) for low, medium and high respectively, support that assumption. Therefore, it seems unlikely that a real biological difference should exist between season and intensity in emergence of seedlings; yet, table 8 shows a highly significant interaction. Interaction between season and intensity was largely the result of actual differences between the intensities caused by the increase in number of viable seeds planted at the low, medium and high intensities. This is substantiated by table 13 which shows that there is no true significance between intensity and season when put on the basis of percent emergence success. Differences between intensities were also nonsignificant when based upon numbers of viable seed planted.

As shown in table 14, the three intensities gave approximately the expected results in seedling emergence with a 1 to 2 and 3 ratio in re-

lation to intensity of seeding.

Table 13. Analysis of variance of emergence success in percent of viable seeds drilled per 100 feet of drill row at each season, intensity and replication

Intensity	Spring					
	Rep. A	Rep. B	Total	Rep. A	Rep. B	Total
Low	88.7	119.8	208.5	53.2	41.0	94.2
Med.	108.0	116.5	224.5	52.2	46.9	99.1
High	80.9	117.0	197.9	46.4	45.3	91.7
Total Rep.	277.6	353.3		151.8	133.2	
Total			630.9			285.0

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
Between Intensities	2	147.12	73.56
Between Seasons	1	9,970.65	9,970.65**
Between Replications	1	271.78	271.78
Intensity by Seasons	2	46.37	23.18
Error	5	988.63	197.73
Total	11	11,424.55	

** Highly significant

Table 14. Average number of normal seedlings of four species of Agropyron emerged per 100 feet of drill row for each intensity and season of planting.

Season of planting	Rate of seeding 1/ Low	Medium	High	Average	L.S.D.** between intensities within seasons
Fall	61	128	177	122	34
Spring	133	287	380	267	34
Average	97	208	279	195	24

1/ 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 intensities respectively.

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

__Spacing of drill rows.__ Theoretically spacing should have no effect upon emergence although table 8 shows it to be highly significant. There is no apparent explanation for this unless it is the 1 in 20 chance in sampling.

__Recovery of seeds planted.__ In order to determine what happens to seeds after they are planted and whether ungerminated seeds retain viability, 200 seeds were recovered from a drill row of each species from the spring seeding. In fall seeded drill rows, it was impossible to recover seeds due to advanced decomposition. Although all seed sown in a drill row could not be recovered, all seeds encountered were counted until 200 seeds had been found.

An average of 12 percent of the seed recovered rotted in the ground, 28 percent germinated but did not emerge, 57 percent emerged, and 3 percent remained in the ground as filled seed (table 15). Almost all the seed that remained in the ground which was considered filled seed and still ungerminated was crested wheatgrass seed. Of the 23 hard crested wheatgrass seed recovered or 11.5 percent, 47.8 percent germinated when tested in the laboratory. This amounted to a total of 5.6 percent of the 200 crested wheatgrass seed recovered that was still viable. Therefore, crested wheatgrass may have had seedling emergence after the emergence data for this study was collected and actually affect later survival counts. Upon taking survival counts one year after emergence data had been taken, there were apparently no new seedlings of crested wheatgrass. Frischknecht (1959) found that seed of some species could remain viable after long periods (15 months) in the ground and would germinate and emerge when conditions were satisfactory.

Table 15. Analysis of 200 seeds recovered from drill rows, July 13, 1951, from spring seeding of April 4, 1951

Species	No. of seeds rotted	Per-cent	Number of seeds germinated: Did not emerge	Per cent	Emerged	Per-cent	No. of seeds not germi-nated1/	Per-
Agropyron cristatum	29	14.5	64	32	84	42	23	11.5
Agropyron elongatum	29	14.5	48	24	122	61	1	0.5
Agropyron trichophorum	18	9	54	27	128	64	0	0
Agropyron intermedium	19	9.5	58	29	123	61.5	0	0
Average	24	12	56	28	114	57	6	3

1/ These are hard full seeds that had not yet germinated. Upon laboratory germination test, 11 seeds germinated of the *Agropyron cristatum* and none for the *Agropyron elongatum*.

Factors Influencing Survival

Season of planting. Survival success is defined as the number of emerged seedlings surviving the following year after planting, expressed in percent of the number of normal seedlings emerged.

Analysis of variance (table 16) shows a highly significant difference between seasons and also a highly significant interaction between season and species. The fall seeding had an average survival of 53.3 percent (table 17); whereas, the spring seeding had an average survival of only 12.7 percent. Earlier germination for the fall seeding permitted the development of larger individuals prior to the summer drought, thus suggesting that survival is influenced directly by the size and vigor of plants at the beginning of a summer drought period.

The spring seeding gave more than twice the number of emerged seedlings compared to fall seeding, 26 and 11.9 percent respectively. However, the high mortality among spring seedlings of 87.3 percent resulted in fewer established plants for spring seeding compared to fall seeding. Fall seeding produced an average of 6.3 plants for every 100 viable seed planted compared to 3.3 percent for spring seeding.

Species. There was a highly significant difference in the survival of seedlings for the different species. Stiffhair wheatgrass and crested wheatgrass produced 37.9 and 35.1 percent survival respectively compared to intermediate wheatgrass with 30.3 percent and tall wheatgrass with 28.6 percent (table 17). The interaction between season and species was highly significant. Tall wheatgrass showed the least difference between fall and spring survival; whereas, the greatest difference was produced by stiffhair wheatgrass. Tall wheatgrass had 41.1 percent survival from fall seeding

Table 16. Analysis of variance of angles corresponding to survival percentages for four species of Agropyron presented in table 17

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
Between seasons	1	26,994	26,994**
Between replications	1	58	58
Error (a)	1	1	1
Between species	3	609	203**
Between intensities	2	479	239**
Between row spacings	2	34	17
Interaction:			
Season by species	3	2,154	718**
Season by intensity	2	108	54
Season by spacing	2	81	41
Species by intensity	6	224	37
Species by spacing	6	121	20
Intensity by spacing	4	97	24
Season by species by intensity	6	272	45
Season by species by spacing	6	264	44
Season by intensity by spacing	4	178	44
Species by intensity by spacing	12	524	44
Season by species by intensity by spacing	12	306	26
Error (b)	70	2,420	35
Total	143	34,924	244

1/ Angles by Arc sine transformation. See Snedecor, 1946, p. 447

* Significant
** Highly significant

Table 17. Average percent of normal seedlings surviving at the end of one year for four species of *Agropyron* planted at three intensities and three drill row spacings during the fall and spring[1]

Species	Drilling intensity[2]	Season of Planting								All Season
		Fall				Spring				
		Row Spacing				Row Spacing				
		7"	14"	21"	Average	7"	14"	21"	Average	Average
Agropyron cristatum	Low	51.2	54.0	56.8	54.0	15.7	12.0	16.1	14.6	34.3
	Medium	56.9	58.2	46.9	54.0	16.4	18.9	20.6	18.6	36.3
	High	56.7	52.9	49.4	53.0	18.7	14.4	16.2	16.4	34.7
	Average	54.9	55.0	51.0	53.6	16.9	15.1	17.6	16.5	35.1
Agropyron intermedium	Low	46.0	66.0	55.1	55.7	11.1	11.1	13.9	12.0	33.9
	Medium	53.5	37.5	65.6	52.2	7.5	8.8	6.3	7.5	29.9
	High	45.6	58.4	41.4	48.5	7.9	6.6	3.0	5.8	27.1
	Average	48.4	54.0	54.0	52.1	8.8	8.8	7.7	8.4	30.3
Agropyron trichophorum	Low	65.5	75.3	66.7	69.2	5.8	9.8	14.8	10.1	39.7
	Medium	77.9	70.9	80.0	76.3	6.9	13.4	8.8	9.7	43.0
	High	49.4	46.4	63.1	53.0	8.7	8.3	10.3	9.1	31.1
	Average	64.2	64.2	69.9	66.1	7.1	10.5	11.3	9.6	37.9
Agropyron elongatum	Low	38.8	39.4	36.4	36.9	22.9	19.4	12.9	18.4	27.7
	Medium	50.8	52.7	44.4	49.3	20.4	13.4	17.4	17.1	33.2
	High	29.3	36.9	45.2	37.1	17.2	5.7	15.9	12.9	25.0
	Average	38.3	43.0	42.0	41.1	20.2	12.8	15.4	16.1	28.6
AVERAGE	Low	49.4	58.7	53.8	54.0	13.9	13.1	14.4	13.8	33.9
	Medium	59.8	54.8	59.2	57.9	12.8	13.6	13.3	13.2	35.6
	High	45.3	48.7	49.8	47.9	13.1	8.7	11.3	11.1	29.5
	Average	51.5	54.1	54.2	53.3	13.3	11.8	13.0	12.7	33.0

1/ Survival was recorded April 25 and 26, 1952, and was expressed in terms of percent of seedlings counted June 8 to 15, 1948, which still survived.

2/ 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 18. Success of seeding in percent of relative numbers of survived plants for 4 species of Agropyron per number of viable seeds planted per 100 feet of drill row

Species	Drilling Intensity	Season of Planting: Fall — Percent viable seed established	Season of Planting: Spring — Percent viable seed established	All Seasons — Percent viable seed established
Agropyron cristatum	Low	7.1	3.1	5.9
	Medium	6.3	4.0	6.0
	High	5.4	3.1	5.0
	Average	6.3	3.4	5.6
Agropyron intermedium	Low	6.8	2.4	5.5
	Medium	8.7	2.2	6.9
	High	7.4	1.5	5.6
	Average	7.6	2.0	6.0
Agropyron trichophorum	Low	7.1	2.8	7.5
	Medium	7.9	2.3	7.3
	High	5.8	2.2	5.5
	Average	6.9	2.4	6.8
Agropyron elongatum	Low	4.2	6.5	6.5
	Medium	5.3	6.5	8.1
	High	3.6	3.8	4.9
	Average	4.4	5.6	6.5
AVERAGE	Low	6.3	3.7	6.3
	Medium	7.1	3.7	7.1
	High	5.6	2.7	5.2
	Average	6.3	3.4	6.2

1/ 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.

and 16.1 percent in the spring; whereas, stiffhair wheatgrass had 66.1 percent survival from fall seeding compared to only 9.6 percent in the spring.

When the species were compared on the basis of percent viable seeds established (table 18), it was found that stiffhair wheatgrass gave the best overall results of 6.8 percent of the viable seeds planted surviving, followed by tall wheatgrass with 6.5 percent, intermediate wheatgrass with 6.[illegible] percent, and crested wheatgrass with only 5.6 percent. From the data presented in table 18, it appeared that somewhat better seedling establishment could be expected from intermediate and stiffhair wheatgrass seeded in the fall; whereas, tall wheatgrass and crested wheatgrass appeared to be considerably better for spring seeding. The only species giving a better success of seeding for the spring than for the fall was tall wheatgrass. The percent of viable seed established in this case for fall was 4.4 percent compared to 5.6 percent for spring seeding.

Intensity of seeding. Intensity of seeding produced a highly significant effect upon seedling survival. The highest average percent survival, 35.6 percent, was produced by the medium intensity with the low intensity giving only 33.9 percent survival and the high intensity giving still lower survival of 29.5 percent (table 17). The same relationship was found with respect to percent viable seed established (table 18).

In order to determine whether or not there was a significant downward linear trend in survival as the intensity increased, the sums of squares for intensity with two degrees of freedom were broken down into individual degrees of freedom, one for linear and one for quadratic (Snedecor, 1946, p. 403). Of the total sums of squares, 479 for intensity, the linear relationship was highly significant and accounted for 310 of the total sums of squares. The quadratic relationship was also significant and accounted for 169 of the total sums of squares. Therefore, there was a definite downward trend from low intensity to the high intensity in percent survival, but of greater importance was the quadratic relationship which indicated that intensity at the medium rate had reached the peak of diminishing returns. This suggested that the medium rate produced greatest returns from number of viable seed planted.

The number of seedlings established on a given unit area was as would be expected, progressively greater for the low, medium, and high seeding intensities. As shown in table 19, medium intensity resulted in 2.24 times more established plants than the low intensity, and high intensity was only 1.15 times higher than medium intensity. Therefore, as previously stated, intensity did not give the expected increase in relation to viable seed planted. This indicates that competition among seedlings was a significant factor in survival of seedlings.

Drill row spacing. The effect of drill row spacing was not found to be significant as indicated by analysis of variance (table 16). The averages for percent survival for the two seasons are 32.4, 33.0 and 33.6 percent respectively for 7 inch, 14 inch and 21 inch spacings. It is possible that the effect will have a greater influence in future years.

Table 19. Success of seeding in relative numbers of survived plants per 100 feet of drill row for 4 species of Agropyron planted for three seeding intensities

Intensity of seeding	Average number of viable seeds	Average percent emergence	Average percent survival	Average no. of survived individuals
Low	514	18.9	33.9	33
Medium	1028	20.2	35.6	74
High	1543	18.0	29.5	85
Average	1028	18.9	33.0	64

CONCLUSIONS

Excessive losses of soil moisture by evaporation caused rapid drying of the surface soil resulting in relatively low germination and emergence. Soil crusting was also a factor in reducing emergence as indicated by the recovery of seed which showed that 28 percent of the seed germinated and did not emerge; however, causes other than crusting may be partially responsible for this reduced emergence. Drilling in stubble, stubble mulch, or adding humus to the surface soil may be a method of preventing severe crusting while also conserving moisture.

Early and prolonged summer drought along with the grazing by jack rabbits greatly influenced and restricted the growth of the seeded species. Some badly damaged plants, because of jack rabbits, had already died and others were severely weakened.

No significant difference in the quantity of seed planted, as determined by seedling emergence, was found to occur between drill seeding spouts. Therefore, when subsequent seedings are made with the same drill, drill rows may be selected randomly for measuring results.

The pin-point or vertical point method of sampling was not found to be as accurate as actual counts of seedlings in drill rows based upon the same linear feet. However, when the drill row feet sampled by the pin-point method is increased 2.14 times that sampled by the actual count method, both methods could be used with the same efficiency. By actual linear seedling count, it requires about one-third more time than by the pin-point method tosample the same linear distance. Thus, the actual count method requires less time for the same degree of accuracy. However, as plants increase in size, the point method may become more accurate.

Observations made in December of 1950 indicated that very few seed emerged during the fall and that most of the emergence was in the early spring of 1951. Winter killing and alternate freezing and thawing during the early spring may have been the contributing factor to the lower emergence from fall seeding. Some seeds lost their viability over the winter period and others apparently rotted. Soil crusting and rapid drying of the surface soil were apparently the limiting factors in emergence success from spring planting.

Depth of seeding due to uneveness of the soil surface was also a factor contributing to the emergence success. Seeds planted too near the surface may not have germinated due to rapid drying of the surface soil and resulting desiccation of the seed; whereas, those seeds planted too deep may have lacked vigor for emergence.

Season of planting was found to have no significant difference in emergence success; however, the spring seeding in all cases was considerably better than fall seeding, averaging 2.2 times higher in emergence. Increased replication probably would have made these differences in emergence success statistically significant.

About 57 percent of all viable seed planted in the spring germinated and produced normal seedlings, 28 percent germinated but did not emerge, 12 percent rotted and the remaining 3 percent were hard seed. Crested wheatgrass had considerably more hard seed than the other wheatgrass species; however, 48 percent of these hard seed were still viable.

The medium intensity of seeding gave a significantly greater number of established seedlings per viable seeds planted followed by the low intensity and the high intensity in that order. This indicates that the high intensity was affected more by competition than the other intensities.

The differences between the survival percentages of 32.4 for the 7 inch spacings, 33.0 for the 14 inch spacings, and 33.6 for the 21 inch spacings were small and not statistically significant; however, it is believed that possibly, as the plants increase in size and compete for space and moisture, spacing will become a more significant factor.

Under the conditions of this experiment, intermediate wheatgrass and stiffhair wheatgrass seeded in the fall, at the medium intensity, produced the best results based upon viable seed becoming established. However, tall wheatgrass gave the best results when seeded in the spring at the medium intensity. It is concluded that seeding in 7 inch drill row spacings at the medium intensity will produce the greatest number of plants per unit area and the best returns from amount of seed drilled.

Only 18.9 percent of the viable seed planted produced normal seedlings and only 33.0 percent of these seedlings had become established a year later. Thus, 6.2 percent of the viable seed planted actually became established plants.

For experimental seedings, the drill to be used should be calibrated for each individual seed source so as to limit the error involved in seeding intensities. This is due to the differences between seed sources in size of seed, purity of seed, and number of viable seed per pound.

SUMMARY

A study dealing with intensity and spacing and using four wheatgrass species, Agropyron cristatum, A. intermedium, A. trichophorum and A. elongatum, was made on summer fallowed soil near Benmore, Utah during the years 1950-52. These species were seeded by drill on adjacent randomized plots measuring 18.5 by 130 feet in 2 replications using all combinations of the following: 2 seasons—fall and spring, 3 intensities, and 3 drill row spacings.

The pin-point or vertical point method was checked against actual seedling count in 20-foot linear drill row samples and was found to require 2.14 times the size of linear drill row feet in order to measure the differences between treatments equally as well as actual seedling counts. Even though the pin-point method accounted for only about 15 percent of the total population of seedlings, it can be used to compare treatments when the results are based upon seedling emergence.

Season of planting was not found to have a significant effect upon emergence, even though spring planting was 2.2 times higher in emergence success than fall planting. All species were considerably higher in emergence success from spring seedings than from fall seedings, but the differences were not sufficiently large to be statistically significant.

Survival of seedlings was four times greater from fall seeding than from spring seeding which was statistically significant. Although the emergence from spring seeding was greater, the higher survival from fall seeding resulted in a greater number of established plants per unit area.

The four wheatgrass species responded differently to season of planting with respect to both emergence and survival of seedlings. Of the species

tested, intermediate wheatgrass had the highest emergence success for the fall season of planting followed by crested wheatgrass, stiffhair wheatgrass, and tall wheatgrass in order of decreasing emergence success. However, emergence success from spring seeding was somewhat different. Tall wheatgrass had the highest emergence success from spring seeding followed by intermediate wheatgrass, stiffhair wheatgrass, and crested wheatgrass. Season and species, likewise, displayed a significant interaction when based upon normal seedling survival. Intermediate wheatgrass and stiffhair wheatgrass had the highest percent viable seed established from fall seeding; whereas, tall wheatgrass and crested wheatgrass were highest from spring seeding. Tall wheatgrass was the only speciesto give higher success of seedling establishment when seeded in the spring than when seeded in the fall.

Among the four wheatgrasses studied, highly significant differences were found among the species in responses based upon emergence of seedlings, survival of seedlings, and establishment of seedlings per viable seed planted. Tall wheatgrass produced the greatest number of normal seedlings expressed as percent viable seed planted and crested wheatgrass produced the smallest number. However, tall wheatgrass had the lowest survival percentage of normal seedlings and crested wheatgrass and stiffhair wheatgrass had the highes. When results were based upon percent of viable seed planted producing established plants, stiffhair wheatgrass and tall wheatgrass were highest and crested wheatgrass the lowest. Thus, when all treatments were considered, stiffhair and tall wheatgrass produced the greatest number of established plants from an equal number of viable seed planted.

Intensity of seeding had no significant effect upon seedling emergence except in direct relation to the number of viable seed planted. However, survival was significantly affected by intensity of seeding. The highest average percent survival, 35.6 percent, was produced by the medium intensity with the low intensity giving only 33.9 percent survival and the high intensity giving still a lower survival of only 29.5 percent. There was a definite downward trend from the low intensity to the high intensity in percent survival, but of greater importance was the quadratic relationship which indicated that intensity at the medium rate had reached the peak of diminishing returns and produced the greatest number of established plants based upon viable seed planted.

Distance between drill rows or spacing was not found to be a significant factor affecting survival; however, survival increased somewhat as drill row spacing increased. The average percent survival was 32.4 percent for 7 inch spacing, 33.0 percent for 14 inch spacing, and 33.6 percent for 21 inch spacing.

It was concluded that medium rate of seeding and 7 inch drill row spacing was the best seeding combination since this gave the largest number of plants per unit area and best returns from amount of seed drilled.

The number of viable seeds that actually became established plants was very small compared to the total number of viable seeds planted. It was found that only 18.9 percent of the viable seeds planted produced normal seedlings and only 33.0 percent of these seedlings became established a year later. Thus, 6.2 percent of the viable seed planted actually became established plants.

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APPENDIX

Table 20. Purity analysis of four species of *Agropyron* used for seeding

	A. cristatum	*A. intermedium*	*A. tricophorum*	*A. elongatum*
Weight of sample	2.830	3.214	3.02	6.980
Inert matter	.444	.389	.55	.800
Hard Seed weight	2.386	2.825	2.47	6.180
Purity percent	84.3	87.9	81.8	85.5
Average weight of 100 seed (grams)	0.234	0.443	0.473	0.464
No. of hard seeds per 100 grams	42,735	22,573	21,142	21,552
Grams of hard seed per lb. bulk seed	382.38	398.71	371.04	387.83
No. of hard seed per lb. bulk seed	163,410	90,001	78,445	83,585
No. hard seed per gram bulk seed	360	198	173	184

Table 21. Germination percentages for four species of Agropyron used for seeding

Species	Samples (100 seeds each)	Accumulated germination at 14 days	Variation* percent of mean	No. of hard seed Remaining
Agropyron cristatum	1	89	4.3	11
	2	96	3.2	4
	3	92	1.1	8
	4	96	3.2	4
	Total	373		27
	Average	93		7
Agropyron intermedium	1	88	5.7	12
	2	96	3.2	4
	3	98	5.7	2
	4	91	2.2	9
	Total	373		27
	Average	93		7
Agropyron trichophorum	1	91	1.1	9
	2	95	3.3	5
	3	94	2.2	6
	4	89	3.3	11
	Total	369		31
	Average	92		8
Agropyron elongatum	1	88	0.0	12
	2	92	4.5	8
	3	89	1.2	11
	4	83	5.7	17
	Total	352		48
	Average	88		12

* Tolerance for variability in variation as follows: Agropyron cristatum 6 percent, Agropyron intermedium 6 percent, Agropyron trichophorum 6 percent, Agropyron elongatum 7 percent. Limits as listed in Rules and Recommendations for Testing Seeds. U.S.D.A. Cir. 480. 1938.

Table 22. Comparative seeding intensities in numbers of filled seeds per pound of bulk seed

Species	Number of hard seed per pound	Conversion factor	Seeding Low	Intensities Medium	(lbs.)* High
Agropyron cristatum	163,410	1.00	2.50	5.00	7.50
Agropyron intermedium	90,001	1.82	4.55	9.10	13.65
Agropyron trichophorum	78,445	2.08	5.20	10.40	15.60
Agropyron elongatum	83,585	1.96	4.90	9.80	14.70

Table 23. Rate of seeding in grams per 20 wheel revolutions and pounds per acre for four species of Agropyron when drilled in rows 7 inches apart

Species	Seeding Intensity	Desired Rate: Pounds per acre	Desired Rate: Grams per 20 wheel revolutions per drill width	Actual Rate, Fall: Grams per 20 wheel rev. per drill width	Actual Rate, Fall: Pounds per acre	Actual Rate, Spring: Grams per 20 wheel rev. per drill width	Actual Rate, Spring: Pounds per acre
Agropyron cristatum	Low	2.50	37.48	112.2	7.48	65.7	4.38
	Medium	5.00	74.98	183.7	12.25	77.6	5.18
	High	7.50	112.46	262.3	17.49	112.2	7.48
Agropyron intermedium	Low	4.55	68.22	67.7	4.51	67.7	4.51
	Medium	9.10	136.46	88.8	5.92	130.1	8.68
	High	13.65	204.68	130.1	8.68	263.9	17.60
Agropyron trichophorum	Low	5.20	77.98	85.9	5.73	77.8	5.19
	Medium	10.40	155.94	167.7	11.18	156.3	10.42
	High	15.60	233.92	265.0	17.67	235.6	15.71
Agropyron elongatum	Low	4.90	73.48	83.8	5.59	78.7	5.25
	Medium	9.80	146.94	172.8	11.52	147.9	9.86
	High	14.70	220.42	272.7	18.19	222.3	14.82

Table 24. Normal seedling emergence for four species of Agropyron, June 8, 1951[1]

Species	Replication	Fall: 7" spacing Low	Medium	High	14" spacing Low	Medium	High	21" spacing Low	Medium	High	TOTAL
Agropyron cristatum	A	67	112	174	63	72	137	62	132	57	
	B	47	103	110	76	70	187	15	91	92	
Total		114	215	284	139	142	324	77	223	149	1667
Agropyron intermedium	A	92	106	225	45	188	250	59	86	85	
	B	34	241	206	58	168	310	19	52	70	
Total		126	347	431	103	356	560	78	138	155	2294
Agropyron trichophorum	A	47	119	222	24	130	148	29	52	72	
	B	86	83	147	45	99	207	23	35	19	
Total		133	202	369	69	229	355	52	87	91	1587
Agropyron elongatum	A	20	87	132	76	91	86	73	117	133	
	B	21	82	137	43	65	82	40	73	118	
Total		41	169	269	119	156	168	113	190	251	1476
TOTAL INTENSITY		414	933	1353	430	883	1407	320	638	646	
TOTAL SPACING				2700			2720			1604	
TOTAL FALL											7024

1/ Individual figures represent seedlings per 80 ft. of linear drill row.

Table 24. (Continued)

Species	Replication	SPRING 7" spacing Low	Medium	High	14" spacing Low	Medium	High	21" spacing Low	Medium	High	TOTAL
Agropyron cristatum	A	71	202	130	71	263	104	53	150	108	
	B	92	145	324	176	228	340	72	90	412	
Total		163	347	454	247	491	444	125	240	520	3031
Agropyron intermedium	A-	102	258	490	64	274	294	28	221	132	
	B	141	285	453	98	155	293	80	277	313	
Total		243	543	943	162	429	587	108	498	445	3958
Agropyron trichophorum	A	147	161	368	89	314	160	67	145	260	
	B	79	230	215	186	201	475	109	116	326	
Total		226	391	583	275	515	635	176	261	586	3648
Agropyron elongatum	A	171	286	317	115	241	252	111	149	366	
	B	128	388	365	188	331	407	123	407	401	
Total		299	674	682	303	572	659	234	556	767	4746
TOTAL INTENSITY		931	1955	2662	978	2007	2325	643	1555	2318	
TOTAL SPACING				5548			5319			4516	
TOTAL SPRING											15383

Table 25. Number of normal seedlings emerged and success in percent of viable seeds drilled per 100 feet of row for four species of *Agropyron* from three intensities, two replications and two seasons

			SPRING				FALL			
			Replication A		Replication B		Replication A		Replication B	
Species	Intensity	Viable seeds	Avg. no. seedlings	Percent success	Avg. no seedlings	Percent success	Avg. no. seedlings	Percent success	Avg. no. seedlings	Percent success
Agropyron cristatum	Low	523	81	15.5	142	27.2	80	15.3	58	11.1
	Medium	1045	256	24.5	193	18.5	132	12.6	110	10.5
	High	1568	143	9.1	448	28.6	153	9.8	162	10.3
	Total	3136	480	15.3	783	25.0	365	11.6	330	10.5
Agropyron intermedium	Low	523	81	15.5	133	25.4	82	15.7	46	8.8
	Medium	1045	314	30.0	298	28.5	158	15.1	192	18.4
	High	1568	382	24.4	441	28.1	233	14.9	244	15.6
	Total	3136	777	24.8	872	27.8	473	15.1	482	15.4
Agropyron trichophorum	Low	517	126	24.4	156	30.2	42	8.1	64	12.4
	Medium	1034	258	25.0	288	22.1	125	12.1	90	8.7
	High	1551	328	21.1	423	27.3	184	11.9	155	10.0
	Total	3102	712	23.0	807	26.0	351	11.3	309	10.0
Agropyron elongatum	Low	495	165	33.3	183	37.0	70	14.1	43	8.7
	Medium	989	282	28.5	469	47.4	123	12.4	92	9.3
	High	1484	390	26.3	489	33.0	146	9.8	140	9.4
	Total	2968	837	28.2	1141	38.4	339	11.4	275	9.3
TOTALS	Low	2058	453	22.0	614	29.8	274	13.3	211	10.3
	Medium	4113	1110	27.0	1188	28.9	538	13.1	484	11.8
	High	6171	1243	20.1	1801	29.2	716	11.6	701	11.4
	TOTAL	12342	2806	22.7	3603	29.2	1528	12.4	1396	11.3

Table 26. Angles by Arc sine transformation for seedling survival taken April 25 and 26, 1952[1/]

		FALL									
		7" spacing			14" spacing			21" spacing			
Species	Replication	Low	Medium	High	Low	Medium	High	Low	Medium	High	TOTAL
Agropyron cristatum	A	46.8	47.8	50.1	54.5	46.3	51.9	49.6	48.9	32.0	427.9
	B	44.0	50.2	46.9	41.3	53.3	42.8	46.2	35.0	52.3	412.0
		90.8	98.0	97.0	95.8	99.6	94.7	95.8	83.9	84.3	839.9
Agropyron intermedium	A	41.3	58.4	42.8	49.5	38.8	50.2	44.5	52.2	37.5	415.2
	B	46.7	42.2	42.1	58.3	36.6	49.5	59.2	57.2	43.1	434.9
		88.0	100.6	84.9	107.8	75.4	99.7	103.7	109.4	80.6	850.1
Agropyron trichophorum	A	57.9	60.5	45.3	54.8	55.0	50.4	52.2	66.6	50.4	493.1
	B	52.0	64.1	43.6	63.4	60.5	37.6	58.1	59.2	61.6	500.1
		109.9	124.6	88.9	118.2	115.5	88.0	110.3	125.8	112.0	993.2
Agropyron elongatum	A	28.4	38.5	40.6	33.8	48.2	30.3	34.8	42.3	42.9	339.8
	B	42.6	52.8	24.4	47.3	44.4	44.4	41.3	41.0	41.4	379.6
Total		71.0	91.3	65.0	81.1	92.6	74.7	76.1	83.3	84.3	719.4
TOTAL INTENSITY		359.7	414.5	335.8	402.9	383.1	357.1	385.9	402.4	361.2	
TOTAL SPACING				1110.0			1143.1			1149.5	
TOTAL FALL											3402.6

1/ Angles by Arc sine transformation. See Snedecor, 1946. p. 447.

Table 26. (Continued)

Species	Replication	7" spacing Low	7" spacing Medium	7" spacing High	14" spacing Low	14" spacing Medium	14" spacing High	21" spacing Low	21" spacing Medium	21" spacing High	Total
Agropyron	A	22.3	24.4	23.7	16.4	24.0	7.9	25.5	30.1	28.7	203.0
cristatum	B	24.2	23.1	26.4	21.7	27.6	25.2	22.2	21.1	22.2	213.7
Total		46.5	47.5	50.1	38.1	51.6	33.1	47.7	51.2	50.9	416.7
Agropyron	A	15.2	14.8	14.4	25.7	18.4	8.9	25.0	16.5	6.3	145.2
intermedium	B	22.1	17.0	18.2	14.3	15.1	19.2	20.7	12.8	11.1	150.5
Total		37.3	31.8	32.6	40.0	33.5	28.1	45.7	29.3	17.4	295.7
Agropyron	A	12.7	16.5	18.9	15.0	26.6	14.5	22.7	20.6	19.1	166.6
trichophorum	B	16.0	14.3	13.6	19.6	10.0	17.5	22.6	12.0	18.4	144.0
Total		28.7	30.8	32.5	34.6	36.6	32.0	45.3	32.6	37.5	310.6
Agropyron	A	26.8	24.1	21.1	19.1	15.4	8.9	24.2	20.4	20.4	180.4
elongatum	B	30.8	28.7	27.2	29.7	25.1	16.2	17.7	26.1	26.1	227.6
Total		57.6	52.8	48.3	48.8	40.5	25.1	41.9	46.5	46.5	408.0
TOTAL INTENSITY		170.1	162.9	163.5	161.5	162.2	118.3	180.6	159.6	152.3	
TOTAL SPACING				496.5			442.0			492.5	
TOTAL SPRING											1431.0
GRAND TOTAL INTENSITY		529.8	577.4	499.3	564.4	545.3	475.4	566.5	562.0	513.5	
GRAND TOTAL SPACING				1606.5			1585.1			1642.0	
Grand total											4833.6